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EXECUTIVE SUMMARY

Twenty-seven glasses were designed to assess the impacts of both sludge variation (±5 or ±10% for the major sludge components) and waste loading (WL) (50 or 52%) on the Product Consistency Test (PCT) response after two thermal histories (quenching and a modified ccc schedule) within the Frit 202-A11 – Sludge Batch 3 (SB3) system. The PCT results of the quenched glasses (regardless of compositional view) indicate that all Frit 202-A11 – Sludge SB3 (referred to as HTLG) variability study glasses are very acceptable relative to the Environmental Assessment (EA) glass benchmark. More specifically, the normalized boron releases (NL [B] in g/L) range from 0.8 g/L (for HTLG-60VS based on the measured composition) to 1.384 g/L (HTLG-79VS based on the measured bias-corrected (bc) composition). These results can be compared to the NL [B] for the EA benchmark of 16.695 g/L. The PCT results of the quenched glasses are consistent with previous data in the Frit 202-A11 – SB3 system.

The PCT results for the ccc glasses are not as straight forward. The NL [B]s for the slow cooled glasses range from 0.607 g/L (for HTLG-57ccc based on the measured composition) to 9.42 g/L (for HTLG-67ccc based on the measured bc compositional view). Although these glasses would be classified as acceptable relative to the EA glass benchmark, the relatively high release of the slow cooled glasses would be of concern if this system were to be implemented into the Defense Waste Processing Facility (DWPF). The PCT responses for those glasses in which either nepheline or both nepheline and aegirine formed upon slow cooling lead to a significant reduction in PCT response. Although the formation of aegirine has (in general) a slightly negative impact on the PCT response, the formation of nepheline and aegirine is a combination that has a high probability of leading to a significant reduction in durability upon slow cooling.

With respect to the Cold Crucible Induction Melter (CCIM) demonstration, a clear cut delineation of sludge compositions and/or targeted WLs is desirable to avoid the formation of either of these phases. However, based on a statistical assessment of the PCT and X-ray diffraction (XRD) data, this direct relationship does not appear to exist for this sludge/frit system and identifying the nepheline and/or aegirine primary phase field is not readily apparent based on the limited data. In addition, the possibility to target higher WLs (> 50%) to avoid any negative impacts on durability as a result of crystallization, as previously done with the nominal SB3 composition, was dependent upon the sludge component combinations. Moreover, when composition variation is applied to the sludge, multiple sludge and frit combinations fall within the nepheline and/or aegirine phase fields even at 52% WL, which ultimately lead to a negative impact on durability. Nonetheless, the PCT results do suggest that the probability of observing the negative impact is lower at the higher WLs. Only 2 of the inner layer, 52% WL based glasses have NL [B] > 2 g/L after slow cooling as compared to 4 of the 9 inner layer EVs targeted 50% WL.

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LIST OF ABBREVIATIONS

AD	Analytical Development
ARM	Approved Reference Material
ASTM	American Society of Testing and Materials
bc	bias corrected
ccc	Canister Centerline Cooling
CCIM	Cold Crucible Induction Melter
DOE	Department of Energy
DWPF	Defense Waste Processing Facility
EA	Environmental Assessment
EDS	Energy dispersive spectroscopy
HTLG	High temperature liquidus glasses
ICP-AES	Inductively Coupled Plasma-Atomic Emission Spectroscopy
JHM	Joule heated melter
LM	Lithium metaborate
PCT	Product Consistency Test
PF	Peroxide fusion
PSAL	Process Science Analytical Laboratory
SB3	Sludge Batch 3
SEM	Scanning Electron Microscopy
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
T_L	Liquidus temperature
η	viscosity
WAPS	Waste Acceptance Product Specifications
WL	waste loading
XRD	X-ray diffraction

1.0 Introduction

Initial operations at the Defense Waste Processing Facility (DWPF) targeted a nominal waste loading of 28% (on a calcined oxide, mass basis). Based on strategic glass formulation approaches and physical improvements to the Joule Heated Melter (JHM) system, operations with Sludge Batch 3 (SB3) transitioned to a nominal waste loading of 38%. Although this has lead to a significant increase in the waste throughput for the site, additional increases are possible by coupling advanced melter technologies with glass formulation efforts. More specifically, advancements in melter technology have the potential to produce glass faster and at higher waste loadings (the two primary parameters that drive waste throughput) relative to current operations. One of these technologies is the Cold Crucible Induction Melter (CCIM) with bubbler and/or mechanical agitation.

Since any additional (sustained) improvement in waste loading and/or melt rate relative to current operations will help to reduce the life-cycle costs for the Department of Energy (DOE) at the Savannah River Site (SRS), there is interest in demonstrating the viability of CCIM technology to yield such an improvement. An initial CCIM demonstration is currently planned for the fall of 2007 and will be based on a DWPF waste slurry feed surrogate with a nominal operating temperature of approximately 1250°C targeting a 50% waste loading (WL) glass.[1] The waste slurry feed (nominally 40 - 45 weight percent solids) surrogate will be representative of SB3 in order to allow a direct comparison to the DWPF joule heated melter performance during processing of this sludge waste. The pilot scale demonstration is being conducted to evaluate performance and identify potential processing issues with the existing CCIM technology and will include characterization of the resultant glass product to ensure current product performance (durability) specifications are met.

The CCIM glass product will be a borosilicate glass at a high waste loading (nominally at 50%, based on a calcined oxide basis) that must meet current requirements for disposal at a Federal Repository. Specifically, the Waste Acceptance Product Specifications (WAPS Specification 1.3) define acceptance through the use of the American Society of Testing Materials (ASTM) Product Consistency Test (PCT) as the measure of waste form performance or durability (ASTM 2002). Acceptance relies upon the mean leachate concentrations of lithium, sodium and boron (after normalization for the glass composition) being less than those of the Environmental Assessment (EA) benchmark glass (Jantzen et al. 1993).

The CCIM demonstration, which will utilize a "constant" sludge composition (targeting a nominal SB3 composition) coupled with Frit 202-A11 at nominally 50% WL, will theoretically yield a constant glass composition. Although this will support programmatic objectives, there is some need to assess the potential impacts of sludge variation and/or waste loading differences on potential processing and/or product performance properties. More specifically, the vendor will produce a sludge targeting the nominal SB3 composition. Recognizing the low probability of producing the exact targeted sludge composition and/or that actual WL could vary from 50 ± 2% (around the nominal 50% target), leads to questions regarding the impact of these variations on processing properties or perhaps more importantly on the durability of the final waste form. This is of particular importance given the nonlinear behavior previously observed between waste loading and critical processing / performance properties for this glass forming system. The

[1] Although this report is being issued after the CCIM demonstration, the activities documented here were developed to support, and were completed before, that demonstration. This report is being written from that perspective. The data presented in this report were used to support the decision to increase the WL in the CCIM demonstration from 50% to 52%.

results from Peeler et al. (2007) suggested that a balance between WL and processing and product performance issues may be required for this CCIM demonstration. This latter statement is based on the fact that frit development efforts were not necessarily intended to optimize this glass system nor have these efforts accounted for the variation from the intended target that is likely to occur in the composition of the waste slurry feed surrogate that is being used in the study.

Given the identification of Frit 202-A11 as the preferred frit (Peeler et al. 2007), supplemental information was needed to provide a technical basis to facilitate potential decisions regarding the melter demonstration. Peeler et al. (2007) conducted an experimental study to provide technical data, which investigated the impact of WL on critical properties of interest for the Frit 202-A11/SB3 glass system. That report documented the compositional and physical property information associated with two series of Frit 202-A11 based SB3 glasses. The first series (three glasses targeting 45, 50, and 55% WL) was fabricated and characterized as part of the experimental support for the frit down-select process. In the second series (referred to as the "waste loading series"), eight Frit 202-A11 based glasses were produced and characterized targeting WLs from 44 – 58% in 2% increments. The primary intent of the second series was to cover a finer WL grid over which trends in critical properties could be assessed and decisions regarding the targeted WL could be made.

All of the glasses of the Peeler et al. (2007) study, regardless of heat treatment, were acceptable when their durabilities were compared to those of the EA glass. In general, for the nominal Frit 202-A11/SB3 glass system, as WL was increased, the durabilities for the quenched versions of the glasses tended to decrease due to the changing composition of the glass. For the glasses subjected to the canister centerline cooling (ccc) regime, the durability response appeared to be nonlinear as WL was increased. At WLs of 50% or less, X-ray diffraction (XRD) analysis indicated the potential for the presence of aegirine and/or nepheline crystalline phases, and when these phases were present, there was a decrease in the durability of the glass. As WL was increased above 50%, there appeared to be a transition from the aegirine and/or nepheline primary phase fields to the spinel primary phase field leading to more durable ccc glasses.

Thus, the results for durability suggested that WLs of 50% or greater should be targeted for the CCIM demonstration, thus, avoiding the potential for the formation of aegirine and/or nepheline. However, if decisions to target WLs of 50% or greater are made, liquidus temperature (T_L) measurements indicated that there could be some degree of crystallization within the melter if a nominal 1250°C temperature were to be used. The results from that study suggested that increasing WLs leads to higher liquidus temperatures in the glass forming system of interest. To minimize the potential of crystallization during processing, higher melt temperatures could be targeted which not only could allow for higher WLs to be obtained but could also result in a reduction in viscosity, which in itself could pose certain processing issues (e.g., the ability to control the pour and the possibility of increased volatility). The viscosity of the 50% WL glass at 1250 and 1300°C was measured to be 20 and 13 Poise, respectively. Thus, the results from Peeler et al. (2007) suggested that a balance between processing and product performance issues may be required for the initial CCIM demonstration since the frit development efforts to date were not necessarily intended to optimize this glass system nor did they account for the variation from the intended target that is likely to occur in the composition of the waste slurry feed surrogate that is being used in the study.

To address this last issue, an additional experimental study was conducted to investigate the impact of sludge variation on select properties of the Frit 202-A11/SB3 glass system. The purpose of this report is to describe that investigation and to present the results that it generated.

The composition of Frit 202-A11 is provided in Section 2. Section 3 describes the nominal composition of SB3 as well as the way variation in that composition was introduced in order to facilitate the selection of glass compositions for this phase of study. The selected glass compositions are presented in Section 3. Section 4 provides a description of the experimental aspects of this study. Section 5 presents the results of this experimental effort including visual observations of the study glasses, statistical reviews of the chemical composition and PCT measurements of the study glasses, and XRD assessments. Section 6 provides the conclusions that are drawn from these results.

2.0 Candidate Frit Composition

Based on preliminary model assessments as well as initial scoping tests which generated select physical property data, Frit 202-A11 was identified as the primary candidate for processing SB3 through the CCIM technology at an ~ 50% WL (Peeler et al. 2007). Table 2-1 summarizes the nominal composition of Frit 202-A11 (wt%, calcined oxide basis).

Table 2-1. Nominal Composition (wt%) of Frit 202-A11.

Frit ID	B_2O_3	Li_2O	Na_2O	SiO_2
202-A11	9	6	3	82

3.0 Sludge Batch 3 (SB3) Composition

Table 3-1 summarizes the nominal SB3 simulant (non-radioactive) composition being used to support the glass formulation studies. This composition was based on the analytical data reported by the DWPF during processing of SB3 and represents a "running average" (renormalized after removing U_3O_8 and ThO_2).[2] It is recognized that the removal of U_3O_8 from the composition and the renormalization do increase the concentration of the other components. That being said, the primary concern with this renormalization process is the relative increase in the Fe_2O_3, NiO, and Cr_2O_3 values as these components are spinel formers, and it is anticipated (and has been observed in preliminary testing) that spinel formation (or liquidus temperature) could be a significant technical issue for processing of SB3 at WLs of 50% or greater. The artificial increase in these components and the targeting of higher WLs should increase the propensity for spinel formation. It should be noted that the $SO_4^{=}$ concentration was fixed at 0.719 wt% (and was not renormalized).

Table 3-1. Nominal SB3 Simulant Composition.

Oxide	Nominal SB3 Composition
Al_2O_3	16.898
CaO	3.305
Cr_2O_3	0.192
CuO	0.075
Fe_2O_3	37.302
K_2O	0.339

[2] The U_3O_8 concentration in SB3 was approximately 9 wt% (on a calcined oxide basis). ThO_2 was less than 0.5 wt%.

MgO	3.813
MnO	7.085
Na_2O	24.174
NiO	1.921
SiO_2	3.940
TiO_2	0.057
$SO_4^=$	0.719
ZrO_2	0.184
	100.000

Given the nominal SB3 composition, the primary objective of this task was to introduce compositional variation around the sludge and to assess the impact on specific properties of interest at WLs of interest. An interval of possible concentration values for each of the major oxides (Al_2O_3, CaO, Fe_2O_3, MgO, MnO, Na_2O, NiO, and SiO_2) of Table 3-1 is given in Table 3-2 and was determined by introducing variation around the nominal concentration for that oxide in the manner indicated in the latter table. As shown, the variation applied was ±10% of the nominal value for Al_2O_3, Fe_2O_3, MnO, and Na_2O, ±0.5 wt% for CaO, MgO, SiO_2, and "Others," and ±0.25 wt% for NiO. Application of the variation was intended to bound the possible compositional differences between the nominal SB3 composition and that produced by the vendor. For example, the nominal Al_2O_3 content in the sludge was anticipated to be 16.898 wt%. With the applied variation of ±10%, values between 15.21 and 18.59 wt% could be realized in the actual SRAT product produced by the vendor.

Table 3-2. Outer-Layer Intervals for the Major SB3 Oxides and Others

Variation Applied	±10 %	±0.5 wt%	±10 %	±0.5 wt%	±10 wt%	±10 %	±0.25 wt%	±0.5 wt%	±0.5 wt%
Oxide	Al_2O_3	CaO	Fe_2O_3	MgO	MnO	Na_2O	NiO	SiO_2	Others
Min	15.21	2.81	33.57	3.31	6.381	21.75	1.67	3.44	1.070
Max	18.59	3.81	41.03	4.31	7.799	26.59	2.17	4.44	2.070

The "Others" is a grouping of the minor oxides (Cr_2O_3, CuO, K_2O, $SO_4^=$, TiO_2, and Zr_2O) that is shown in Table 3-2. The composition of "Others" is given in Table 3-3.

Table 3-3. Composition (in mass fractions) of Others Grouping

Cr_2O_3	CuO	K_2O	$SO_4^=$	TiO_2	ZrO_2	Others
0.12102	0.05096	0.21656	0.45860	0.03822	0.11465	1.00000

Now, what constitutes a feasible SB3 composition for this variation study? A feasible composition is a combination of the oxides (including "Others") of Table 3-2 at concentrations in mass fractions such that each concentration is within the interval in that table for that oxide and such that the sum of the mass fractions over all of the oxides equals one. The problem of finding these feasible combinations may be considered as a mixture problem (Cornell 2002). Statistical software such as JMP Version 6.0.2 is available to assist in working with such problems (SAS 2006).

One of the tools provided by JMP is its Custom Design routine within its Design of Experiments platform (SAS 2005). This routine allows the user to specify a mixture problem in a framework such as that described above, and with the problem defined in such a manner the user is then allowed to provide JMP with a model of interest, e.g., a model involving linear effects for each of the mixture components such as the one given by Equation 1, which serves as the basis for selecting an optimal set (relative to that model and the chosen optimality criterion) of design points.

Equation 1.

$$y = a_1 \times Al_2O_3 + a_2 \times CaO + a_3 \times Fe_2O_3 + a_4 \times MgO + a_5 \times MnO$$

$$+ a_6 \times Na_2O + a_7 \times NiO + a_8 \times SiO_2 + a_9 \times Others$$

where y represents a "response" variable whose relationship to these sludge oxides is to be investigated as a linear function of their mass-fraction concentrations. While the actual fitting of Equation 1 is of no interest in this study, its use is very beneficial in selecting feasible compositions on the boundary of the region defined by the concentration intervals of Table 3-2.

There are several options available to the user in performing this optimization. One of the options is that the user can specify the target sum for the mixture. In this case, the sum of the concentrations was specified in JMP as 1 on a mass fraction basis. JMP also provides the user with a choice of optimality criteria; for this situation the D-optimality criterion (see SAS (2005) for a description of the available criteria) was selected to serve as the basis for optimizing the test matrix. Ten different starting conditions were also selected to drive the optimization process. Finally, the minimum number (i.e., 9 – one for each of the a_i terms in Equation 1) of points was specified as the desired number for the test matrix. Using this framework and approach led to the test matrix (in mass fractions) that is provided in Table 3-4.

Table 3-4. Outer-Layer Sludge Compositions (as mass fractions).

Al_2O_3	CaO	Fe_2O_3	MgO	MnO	Na_2O	NiO	SiO_2	Others
0.15536	0.0281	0.4103	0.0431	0.06381	0.21753	0.0167	0.0444	0.0207
0.1521	0.0381	0.36022	0.0431	0.06381	0.26587	0.0217	0.0444	0.0107
0.1859	0.0381	0.3357	0.0431	0.06381	0.26159	0.0167	0.0344	0.0207
0.1521	0.0381	0.37522	0.0331	0.06381	0.26587	0.0167	0.0344	0.0207
0.1859	0.0281	0.40476	0.0331	0.06381	0.21753	0.0217	0.0344	0.0107
0.1521	0.0281	0.35604	0.0431	0.07799	0.26587	0.0217	0.0344	0.0207
0.1521	0.0381	0.40938	0.0431	0.07799	0.21753	0.0167	0.0344	0.0107
0.1859	0.0381	0.36058	0.0331	0.07799	0.21753	0.0217	0.0444	0.0207
0.1859	0.0281	0.33724	0.0331	0.07799	0.26587	0.0167	0.0444	0.0107

To provide additional coverage of the sludge region of interest for SB3, further points were selected for experimental testing. These additional sludge compositions were selected from the concentration intervals (i.e., an inner-layer set of intervals) defined by Table 3-5. The information given in that table indicates how variation was introduced to determine each of the intervals: variation was applied as ±5% of the nominal value for Al_2O_3, Fe_2O_3, MnO, and Na_2O while ±0.5 wt% variation was applied for CaO, MgO, SiO_2, and "Others," and ±0.25 wt% for NiO. Thus, while the intervals for CaO, MgO, SiO_2, "Others," and NiO were the same as those of Table 3-2, the intervals for the other major oxides fall within those intervals defined in Table 3-2.

Table 3-5. Inner-Layer Intervals for the Major SB3 Oxides and Others

Variation Applied	±5	±0.5	±5	±0.5	±5	±5	±0.25	±0.5	±0.5
	%	wt%	%	wt%	wt%	%	wt%	wt%	wt%
Oxide	Al_2O_3	CaO	Fe_2O_3	MgO	MnO	Na_2O	NiO	SiO_2	Others
Min	16.055	2.81	35.435	3.31	6.736	22.962	1.67	3.44	1.07
Max	17.745	3.81	39.165	4.31	7.445	25.379	2.17	4.44	2.07

Using JMP's Custom Design routine in a manner similar to that used for the outer-layer, a set of 9 optimal sludge compositions was selected from the region defined by Table 3-5. These compositions are provided in Table 3-6.

Table 3-6. Inner-Layer Sludge Compositions (as mass fractions)

Al_2O_3	CaO	Fe_2O_3	MgO	MnO	Na_2O	NiO	SiO_2	Others
0.16109	0.0281	0.37766	0.0331	0.07445	0.25379	0.0167	0.0344	0.0207
0.17745	0.0281	0.39165	0.0431	0.06736	0.23054	0.0167	0.0344	0.0107
0.16055	0.0381	0.3753	0.0331	0.06736	0.25379	0.0167	0.0444	0.0107
0.17745	0.0372	0.35435	0.0331	0.06736	0.25379	0.0217	0.0344	0.0207
0.16055	0.0281	0.3603	0.0431	0.06736	0.25379	0.0217	0.0444	0.0207
0.17745	0.0381	0.35548	0.0431	0.07445	0.22962	0.0167	0.0444	0.0207
0.17745	0.0281	0.38048	0.0331	0.07445	0.22962	0.0217	0.0444	0.0107
0.16055	0.0381	0.39165	0.0359	0.06736	0.22962	0.0217	0.0344	0.0207
0.16055	0.0381	0.36321	0.0431	0.07445	0.25379	0.0217	0.0344	0.0107

The sludge compositions of Table 3-4 and Table 3-6 were expanded to cover all of the sludge oxides by exploding the mass fraction of "Others" into mass fractions for its components as given by Table 3-3. The resulting outer-layer sludge compositions were combined with Frit 202-A11 at a WL of 50% to generate 9 glass compositions. Each of the resulting inner-layer sludge compositions was combined with Frit 202-A11 at a WL of 50% and 52%, which yielded a total of 18 glass compositions.

The target glass compositions are provided in Table 3-7 and Table A1 of Appendix A. The 9 outer-layer points are labeled with glass identifiers from HTLG-53VS through HTLG-61VS, the 9 inner-layer points at 50% WL are labeled as HTLG-62VS through HTLG-70VS, and the 9 inner-layer points at 52% WL are labeled as HTLG-71VS through HTLG-79VS.

Table 3-7. Target Compositions of the Frit 202-A11 Variability Study Glasses.

Glass ID	EV	WL	Al_2O_3	B_2O_3	CaO	Cr_2O_3	CuO	Fe_2O_3	K_2O	Li_2O	MgO	MnO	Na_2O	NiO	SO_4	SiO_2	TiO_2	ZrO_2	Total
HTLG-53VS	OL	50	7.77	4.50	1.41	0.13	0.05	20.52	0.22	3.00	2.16	3.19	12.38	0.84	0.47	43.22	0.04	0.12	100.00
HTLG-54VS	OL	50	7.61	4.50	1.91	0.06	0.03	18.01	0.12	3.00	2.16	3.19	14.79	1.09	0.25	43.22	0.02	0.06	100.00
HTLG-55VS	OL	50	9.30	4.50	1.91	0.13	0.05	16.79	0.22	3.00	2.16	3.19	14.58	0.84	0.47	42.72	0.04	0.12	100.00
HTLG-56VS	OL	50	7.61	4.50	1.91	0.13	0.05	18.76	0.22	3.00	1.66	3.19	14.79	0.84	0.47	42.72	0.04	0.12	100.00
HTLG-57VS	OL	50	9.30	4.50	1.41	0.06	0.03	20.24	0.12	3.00	1.66	3.19	12.38	1.09	0.25	42.72	0.02	0.06	100.00
HTLG-58VS	OL	50	7.61	4.50	1.41	0.13	0.05	17.80	0.22	3.00	2.16	3.90	14.79	1.09	0.47	42.72	0.04	0.12	100.00
HTLG-59VS	OL	50	7.61	4.50	1.91	0.06	0.03	20.47	0.12	3.00	2.16	3.90	12.38	0.84	0.25	42.72	0.02	0.06	100.00
HTLG-60VS	OL	50	9.30	4.50	1.91	0.13	0.05	18.03	0.22	3.00	1.66	3.90	12.38	1.09	0.47	43.22	0.04	0.12	100.00
HTLG-61VS	OL	50	9.30	4.50	1.41	0.06	0.03	16.86	0.12	3.00	1.66	3.90	14.79	0.84	0.25	43.22	0.02	0.06	100.00
HTLG-62VS	IL	50	8.05	4.50	1.41	0.13	0.05	18.88	0.22	3.00	1.66	3.72	14.19	0.84	0.47	42.72	0.04	0.12	100.00
HTLG-63VS	IL	50	8.87	4.50	1.41	0.06	0.03	19.58	0.12	3.00	2.16	3.37	13.03	0.84	0.25	42.72	0.02	0.06	100.00
HTLG-64VS	IL	50	8.03	4.50	1.91	0.06	0.03	18.77	0.12	3.00	1.66	3.37	14.19	0.84	0.25	43.22	0.02	0.06	100.00
HTLG-65VS	IL	50	8.87	4.50	1.86	0.13	0.05	17.72	0.22	3.00	1.66	3.37	14.19	1.09	0.47	42.72	0.04	0.12	100.00
HTLG-66VS	IL	50	8.03	4.50	1.41	0.13	0.05	18.02	0.22	3.00	2.16	3.37	14.19	1.09	0.47	43.22	0.04	0.12	100.00
HTLG-67VS	IL	50	8.87	4.50	1.91	0.13	0.05	17.77	0.22	3.00	2.16	3.72	12.98	0.84	0.47	43.22	0.04	0.12	100.00
HTLG-68VS	IL	50	8.87	4.50	1.41	0.06	0.03	19.02	0.12	3.00	1.66	3.72	12.98	1.09	0.25	43.22	0.02	0.06	100.00
HTLG-69VS	IL	50	8.03	4.50	1.91	0.13	0.05	19.58	0.22	3.00	1.80	3.37	12.98	1.09	0.47	42.72	0.04	0.12	100.00
HTLG-70VS	IL	50	8.03	4.50	1.91	0.06	0.03	18.16	0.12	3.00	2.16	3.72	14.19	1.09	0.25	42.72	0.02	0.06	100.00
HTLG-71VS	IL	52	8.38	4.32	1.46	0.13	0.05	19.64	0.23	2.88	1.72	3.87	14.64	0.87	0.49	41.15	0.04	0.12	100.00
HTLG-72VS	IL	52	9.23	4.32	1.46	0.07	0.03	20.37	0.12	2.88	2.24	3.50	13.43	0.87	0.26	41.15	0.02	0.06	100.00
HTLG-73VS	IL	52	8.35	4.32	1.98	0.07	0.03	19.52	0.12	2.88	1.72	3.50	14.64	0.87	0.26	41.67	0.02	0.06	100.00
HTLG-74VS	IL	52	9.23	4.32	1.93	0.13	0.05	18.43	0.23	2.88	1.72	3.50	14.64	1.13	0.49	41.15	0.04	0.12	100.00
HTLG-75VS	IL	52	8.35	4.32	1.46	0.13	0.05	18.74	0.23	2.88	2.24	3.50	14.64	1.13	0.49	41.67	0.04	0.12	100.00
HTLG-76VS	IL	52	9.23	4.32	1.98	0.13	0.05	18.48	0.23	2.88	2.24	3.87	13.38	0.87	0.49	41.67	0.04	0.12	100.00
HTLG-77VS	IL	52	9.23	4.32	1.46	0.07	0.03	19.78	0.12	2.88	1.72	3.87	13.38	1.13	0.26	41.67	0.02	0.06	100.00
HTLG-78VS	IL	52	8.35	4.32	1.98	0.13	0.05	20.37	0.23	2.88	1.87	3.50	13.38	1.13	0.49	41.15	0.04	0.12	100.00
HTLG-79VS	IL	52	8.35	4.32	1.98	0.07	0.03	18.89	0.12	2.88	2.24	3.87	14.64	1.13	0.26	41.15	0.02	0.06	100.00

4.0 Experimental Studies

The glass compositions presented in Table 3-7 (and Table A1 of Appendix A) were selected to allow for an assessment of the impact of possible variation in the sludge composition on properties of interest, specifically glass durability. As previously mentioned, the actual CCIM demonstration will utilize a sludge simulant produced by an off-site vendor. Although the vendor targeted the nominal SB3 composition as shown in Table 3-1, some variation from the target should be anticipated. Coupling the compositional uncertainty of the sludge simulant with potential uncertainties in the targeted WL may lead to a compositional region beyond that covered by technical data to date. That being the case, a series of glasses was fabricated and tested with the intent of bounding the compositional variation of the sludge simulant over a WL interval of interest. The glasses are referred to as the "HTLG" glasses indicating that these are high T_L glasses. The numbering of variability study glasses, which began with the number 53, was a continuation of the numbering scheme already established for the CCIM task with the "VS" indicating that these were "variability study" glasses.

4.1 Glass Fabrication

Each HTLG variability glass was prepared from the proper proportions of reagent-grade metal oxides, carbonates, H_3BO_3, and salts in 150 g batches. The raw materials were thoroughly mixed and placed into a 90% platinum / 10% rhodium, 250 mL crucible. The batch was placed in a high-temperature furnace at the target melt temperature of 1250°C. The crucible was removed from the furnace after an isothermal hold at 1250°C for 1 hour. The glass was poured onto a clean, stainless steel plate and allowed to air cool (quench). The glass pour patty was used as a sampling stock for the various property measurements, including chemical composition and durability testing.

Approximately 25 g of each HTLG glass was heat-treated to simulate cooling along the centerline of a DWPF-type canister to gauge the effects of thermal history on product performance. This cooling schedule is referred to as the ccc (canister centerline cooling) curve. It should be noted that the ccc schedule was altered to capture the increased nominal CCIM melt temperature of 1250°C. That is, the nominal DWPF ccc schedule begins at 1150°C and initially ramps down at 8°C/min into the 900°C range. The adjusted cooling schedule was initiated at 1250°C and was ramped down at 10°C/min to 1150°C at which point the normal DWPF ccc schedule was followed. Also note that there was no isothermal hold at 1150°C. This altered cooling curve may be extremely conservative relative to the actual cooling cycle. That is, the CCIM pour cycles may be vastly different than the nominal DWPF pours and could result in much quicker cool down cycle times than those being simulated.

4.2 Compositional Analysis

To confirm that the as-fabricated glasses corresponded to the defined target compositions of Table 3-7, a representative sample from each glass was submitted to the SRNL Process Science Analytical Laboratory (PSAL) for chemical analysis under the auspices of analytical plans[f]. Two dissolution techniques (i.e., sodium peroxide fusion [PF] and lithium-metaborate [LM]) were used. Each glass was prepared in duplicate for each cation dissolution technique (PF and LM). All of the prepared samples were analyzed (twice for each element of interest) by Inductively

[f] There were two analytical plans to guide these measurements as provided by TB Edwards in the memorandum SRNL-SCS-2007-00030, "Analytical Plans for Measuring the Chemical Compositions of the HTL Variability Study Glasses (U)," dated June 18, 2007.

Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES). The measurements generated by these plans are presented and reviewed in the results section.

4.3 Homogeneity

Homogeneity in this report refers to the lack of any crystallization in the glass samples. Although visual observations for crystallization were performed, representative samples of all HTLG VS glasses 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 undissolved solids) were present at 0.5 vol% or greater, the diffractometer was not only capable of detecting the crystals but also allowed for a qualitative determination of the type of crystal(s) present. Otherwise, a characteristically high background devoid of crystalline peaks indicated that the glass product was amorphous, suggesting either a completely amorphous product or that the degree of crystallization was below the detection limit.

4.4 Durability

The ASTM PCT was used as the measure of waste form performance or durability. The PCT was performed in triplicate on each HTLG quenched and ccc glass. The experimental test matrix also included the EA glass, the Approved Reference Material (ARM) glass, and blanks from the sample cleaning batch. Samples were ground, washed, and prepared according to the standard procedure. Fifteen milliliters of Type I ASTM water were added to 1.5 g of glass in stainless steel vessels. The vessels were closed, sealed, and placed in an oven at 90 ± 2°C where the samples were maintained for 7 days. Once cooled, the resulting solutions were sampled (filtered and acidified) and then analyzed by PSAL under the auspices of two analytical plans[f]. These measurements and the corresponding normalized release rates that were calculated from them are presented and discussed in the next section.

[f] There were two analytical plans to guide these measurements as provided by TB Edwards in the memorandum SRNL-SCS-2007-00021, "Analytical Plans for Measuring the PCT Solutions for the HTL Variability Study Glasses (U)," dated May 16, 2007.

5.0 Results

In this section, the results from the variability study are presented and reviewed. Discussions are provided of the visual observations for both the quenched and ccc versions of the study glasses, the measurements of the chemical composition of the glasses, the crystallization of the glasses as assessed by XRD, and the measurements of the PCTs.

5.1 Visual Observations

5.1.1 Quenched Glasses

Prior to discussing the visual observations, a few words regarding the terminology used to describe the appearance of the glasses are warranted. The use of "clean" indicates that the sample was classified as a single-phase system (i.e., no evidence of crystallization either on the surface or within the bulk). The term "surface crystals" implies that the surface of the glass was characterized by the presence of crystallization while the cross-section of bulk glass appeared homogeneous (i.e., single-phase, black and shiny). Surface crystallization in the HTLG glasses was apparent through the presence of a "textured" surface that ranged in appearance from "dull" to "metallic". Most quenched glasses were also characterized by a metallic haze that covered the surface of the glass – indicative of surface crystallization. The haze was very light on some glasses but very extensive (to the point of being "mirror-like") on other glasses. On some pour patty surfaces, swirls or patches of crystallization could also be observed.

Table 5-1 and Table 5-2 summarize the visual observations on the quenched and ccc HTLG VS glasses, respectively. In general, the quenched glasses were characterized by varying degrees of surface crystallization with the pour patty cross-section being single phased or "clean" based on visual observations. With respect to the impact of inner versus outer layer at 50% WL or inner layer at 50 versus 52% WL, there is no clear distinction that can be made based on these visual observations. More specifically, surface crystallization is observed on all of the HTLG VS glasses independent of the WL or sludge layer from which the glass was based.

5.1.2 CCC Glasses

Table 5-2 summarizes the visual observations of the ccc glasses. The results indicate a high degree of devitrification in all 202-A11 based HTLG glasses. All of the pour patty surfaces, as well as the cross sections or bulk, contain extensive devitrification or crystallization. Although visually unappealing, the primary concern to address is the possible impact of the devitrification on durability (i.e., Does the slow cooling promote the formation of a crystalline phase which results in a negative impact on the durability response relative to the equivalent quenched glass?). If there is no impact or the impact does not result in an unacceptable PCT response (as defined by the EA benchmark), the glasses would meet DWPF acceptance criteria. It is known that the formation of spinels has very little if any practical impact on the PCT response of DWPF-type glasses. However, nepheline and/or aegirine formation in these glasses is possible and could lead to a practical and/or significant reduction in durability as measured by the PCT.

Table 5-1. Visual Observations of Quenched HTLG VS Glasses.

Glass	WL	Layer	Quenched
HTLG-53VS	50	Outer	Light haze on pour patty surface; bulk clean
HTLG-54VS	50	Outer	Light haze on pour patty surface; bulk clean
HTLG-55VS	50	Outer	Haze or streaks on pour patty surface; bulk clean
HTLG-56VS	50	Outer	Metallic swirls covering surface; bulk clean
HTLG-57VS	50	Outer	Black shiny glass with a few light swirls on surface; bulk clean
HTLG-58VS	50	Outer	Metallic sheen on surface with some metallic swirls; bulk clean
HTLG-59VS	50	Outer	Dark shiny glass surface; bulk clean
HTLG-60VS	50	Outer	Metallic swirls covering portions of surface; bulk clean
HTLG-61VS	50	Outer	Haze with metallic swirls on surface; bulk clean
HTLG-62VS	50	Inner	Haze with metallic swirls on surface; bulk clean
HTLG-63VS	50	Inner	Dark brown glass with a haze on surface; bulk clean
HTLG-64VS	50	Inner	Dark brown glass with a haze on surface; bulk clean
HTLG-65VS	50	Inner	Dark brown glass with a haze on surface; bulk clean
HTLG-66VS	50	Inner	Dark brown glass with a haze on surface, spots of crystals possible; bulk clean
HTLG-67VS	50	Inner	Metallic/shiny haze on surface with crystals; bulk clean
HTLG-68VS	50	Inner	Dark glass with light swirl haze on surface; bulk clean
HTLG-69VS	50	Inner	Metallic/shiny haze on surface with crystals; bulk clean
HTLG-70VS	50	Inner	Metallic/shiny haze on surface with crystals; bulk clean
HTLG-71VS	52	Inner	Metallic/shiny haze on surface with metallic swirls; bulk clean
HTLG-72VS	52	Inner	Black shiny glass with limited spots of crystals; bulk clean
HTLG-73VS	52	Inner	Metallic/shiny haze on surface with crystals; bulk clean
HTLG-74VS	52	Inner	Bronze with metallic swirls on surface; bulk clean
HTLG-75VS	52	Inner	Bronze with metallic swirls on surface; bulk clean
HTLG-76VS	52	Inner	Bronze with metallic swirls on surface; bulk clean
HTLG-77VS	52	Inner	Metallic haze on surface; bulk clean
HTLG-78VS	52	Inner	Metallic sheen or haze on surface with some metallic swirls, bulk clean
HTLG-79VS	52	Inner	Metallic sheen or haze on surface with some metallic swirls, bulk clean

Table 5-3. Visual Observations of CCC HTLG VS Glasses.

Glass	WL	Layer	CCC
HTLG-53VS	50	Outer	Dull surface with crystals; bulk crystallized
HTLG-54VS	50	Outer	Dull surface with crystals; bulk devitrified
HTLG-55VS	50	Outer	Dull matte surface with crystals; bulk devitrified
HTLG-56VS	50	Outer	Dull matte surface with crystals; bulk crystallized
HTLG-57VS	50	Outer	Shiny/metallic surface with crystals, bulk crystallized
HTLG-58VS	50	Outer	Dull matte, brown crystallized surface; bulk crystallized
HTLG-59VS	50	Outer	Hazy surface with patches of crystals; bulk devitrified
HTLG-60VS	50	Outer	Shiny/metallic surface with crystallization; bulk crystallized
HTLG-61VS	50	Outer	Dull matte surface with crystals; bulk crystallized
HTLG-62VS	50	Inner	Dull matte surface with major crystallization; bulk crystallized
HTLG-63VS	50	Inner	Shiny/metallic surface with crystallization; bulk crystallized
HTLG-64VS	50	Inner	Dull matte surface with crystals, some metallic spots; bulk crystallized
HTLG-65VS	50	Inner	Dull matte surface with crystals; bulk crystallized
HTLG-66VS	50	Inner	Dull matte surface with major crystallization; bulk crystallized
HTLG-67VS	50	Inner	Dull matte surface with crystals; bulk crystallized
HTLG-68VS	50	Inner	Dull matte surface with crystals; bulk crystallized
HTLG-69VS	50	Inner	Dull matte surface with crystals; bulk crystallized
HTLG-70VS	50	Inner	Dull matte surface with crystals; bulk crystallized
HTLG-71VS	52	Inner	Crystallization on surface, bulk devitrified
HTLG-72VS	52	Inner	Dull matte surface with crystals; bulk crystallized
HTLG-73VS	52	Inner	Metallic crystallization on surface; bulk devitrified
HTLG-74VS	52	Inner	Dull matte surface with patches of crystals; bulk crystallized
HTLG-75VS	52	Inner	Dull matte surface with patches of crystals; bulk crystallized
HTLG-76VS	52	Inner	Dull matte surface with crystals; bulk crystallized
HTLG-77VS	52	Inner	Dull matte surface with crystals; bulk crystallized
HTLG-78VS	52	Inner	Dull matte surface; bulk devitrified
HTLG-79VS	52	Inner	Crystals over entire surface; bulk devitrified

5.2 Compositional Analysis

In this section, the measured versus targeted compositions of the 27 study glasses (HTLG-53VS through HTLG-79VS) are presented and compared. As stated earlier, the targeted compositions for these glasses are provided in Table 3-7 and in Table A1 of Appendix A. Chemical composition measurements for these glasses were conducted by the PSAL following two analytical plans, designated as series "P" and series "Q."[f] Two dissolution methods were utilized in measuring these chemical compositions: samples prepared by lithium metaborate (LM) dissolution were used to measure elemental (cation) concentrations of aluminum (Al), calcium (Ca), chromium (Cr), copper (Cu), potassium (K), magnesium (Mg), sodium (Na), nickel (Ni), sulfur (S), silicon (Si) for series "Q" only, titanium (Ti), and zirconium (Zr) concentrations, while samples from glasses prepared by peroxide fusion (PF) dissolution were used to measure elemental concentrations of boron (B), iron (Fe), lithium (Li), and silicon (Si) with Si being measured for both series "P" and series "Q.". All of the glasses were prepared twice by LM and by PF. The prepared samples were analyzed twice by ICP-AES with the instrumentation being re-calibrated between the two readings for each prepared glass.

Table A2 in Appendix A provides the elemental concentration measurements derived from the samples prepared using LM for series "P," Table A3 in Appendix A provides the series "P" measurements derived from the samples prepared using PF, Table A4 in Appendix A provides the elemental concentration measurements derived from the samples prepared using LM for series "Q," and Table A5 in Appendix A provides the series "Q" measurements derived from the samples prepared using PF. Measurements for the Batch 1 standard glass samples that were included in the PSAL analytical plans along with the study glasses are also provided in these tables.

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

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

5.2.1 Measurements in Analytical Sequence

Exhibit A1 in Appendix A provides plots of the measurements generated by the PSAL in Table A2 for samples prepared using the LM method. The plots are in analytical sequence with different symbols and colors being used to represent each of the study and standard glasses. Similar plots for the samples prepared using the PF method (i.e., the data in Table A3) are provided in Exhibit A2 in Appendix A. Exhibits A3 and A4 provide similar plots of the data in Tables A4 and A5 for the "Q" series of glasses. From the limited perspective of these plots, there appear to be no obvious outliers or other problems in these chemical composition measurements.

[f] The two analytical plans were provided by TB Edwards in the memorandum SRNL-SCS-2007-00030, "Analytical Plans for Measuring the Chemical Compositions of the HTL Variability Study Glasses (U)," dated June 18, 2007.

5.2.2 Batch 1 Standard Results

In this section, the PSAL measurements of the chemical compositions of the Batch 1 samples are reviewed. These measurements are investigated across the ICP analytical blocks by series (i.e., “P” and “Q”), and the results are used to bias correct the measurements for the study glasses.

Exhibit A5 in Appendix A provides statistical analyses of the Batch 1 results generated by the LM prep method by block for each oxide of interest in series “P.” The results include analysis of variance (ANOVA) investigations looking for statistically significant differences between the means of these groups for each of the oxides for each of the standards. The results from the statistical tests for the Batch 1 standard may be summarized as follows: Cr_2O_3, MgO, MnO, Na_2O, NiO, and $SO_4^=$ have measurements that indicate a significant ICP-AES calibration effect on the block averages at the 5% significance level for the “P” series. The reference values for the oxide concentrations of the standards are given in the header for each set of measurements in the exhibit.

Exhibit A6 in Appendix A provides a similar set of analyses for the ICP-AES measurements derived from samples prepared via the PF method for the “P” series. There is no indication of a significant ICP-AES calibration effect on the block averages for these measurements at the 5% significance level. The reference values for the oxide concentrations of the standards are given in the header for each set of measurements in the exhibit.

Exhibit A7 in Appendix A provides a similar set of analyses for the ICP-AES measurements derived from samples prepared via the LM method for the “Q” series. The results from the statistical tests for the Batch 1 standard may be summarized as follows: MgO, Na_2O, $SO_4^=$, and ZrO_2 have measurements that indicate a significant ICP-AES calibration effect on the block averages at the 5% significance level for the “Q” series. The reference values for the oxide concentrations of the standards are given in the header for each set of measurements in the exhibit.

Exhibit A8 in Appendix A provides a similar set of analyses for the ICP-AES measurements derived from samples prepared via the PF method for the “Q” series. The results from the statistical tests for the Batch 1 standard may be summarized as follows: Fe_2O_3 and Li_2O have measurements that indicate a significant ICP-AES calibration effect on the block averages at the 5% significance level for the “Q” series. The reference values for the oxide concentrations of the standards are given in the header for each set of measurements in the exhibit.

Thus, some of these results provide incentive for adjusting the measurements by the effects of the ICP-AES calibrations. Bias-correction was conducted for an oxide as long as the reference value for the oxide concentration in the Batch 1 glass was greater than or equal to 0.1 wt%. The basis for the bias correction is presented as part of Exhibits A5 through A8 – the average measurement for Batch 1 for each ICP-AES block for Al_2O_3, B_2O_3, CaO, Cr_2O_3, CuO, Fe_2O_3, K_2O, MgO, Na_2O, NiO, and SiO_2. No bias correction was conducted for $SO_4^=$ and ZrO_2.

The bias correction was conducted as follows. For each oxide, let $\bar{a}_{ij}$ be the average measurement for the i^{th} oxide at analytical block j for Batch 1, and let t_i be the reference value for the i^{th} oxide for Batch 1. (The averages and reference values are provided in Exhibits A5 through and A8.) Let $\bar{c}_{ijk}$ be the average measurement for the i^{th} oxide at analytical block j for the k^{th} glass. The bias adjustment was conducted as follows

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

Bias-corrected measurements are indicated by a "bc" suffix, and such adjustments were performed for all of the analytes of this study except for $SO_4^=$ and ZrO_2. Both measured and measured "bc" values are included in the discussion that follows. In these discussions bias-corrected values for $SO_4^=$ and ZrO_2 are included for completeness (e.g., to allow a sum of oxides to be computed for the bias-corrected results). These bias-corrected values are the same as the original values for $SO_4^=$ and ZrO_2 (i.e., once again, no bias correction was performed for this pair of oxides).

5.2.3 Composition Measurements by Glass Number

Exhibits A9 and A10 in Appendix A provide plots of the oxide concentration measurements for the "P" series by Glass ID (including Batch 1) for the measured and bias-corrected (bc) values for the LM and PF preparation methods, respectively. The measurements are grouped by their Lab IDs for each Glass ID within their targeted concentrations for the indicated oxide. Exhibits A11 and A12 in Appendix A provide similar plots for the "Q" series results. Different symbols and colors are used to represent the different glasses. These plots show the individual measurements across the duplicate measurements of each preparation method. A review of the plots presented in these exhibits reveals the repeatability of the individual values for each analyte for each glass. There is no suggestion of any significant problems in the repeatability of the measurements in these plots. In comparing the measured values to their targeted concentrations, some differences are seen between the measured values and the targeted concentrations for some oxides for some of the glasses.

A review of these comparisons suggests that there is a pattern to the relationship between the targeted and measured concentrations for glasses numbered 65 and 66. It appears that these two glasses may have been switched at some point prior to the time these chemical composition measurements were conducted. A closer look at this possibility is provided in the next section.

5.2.4 Measured versus Targeted Compositions

The duplicate measurements for each oxide for each glass (over all of the preparation methods) were averaged to determine a representative chemical composition for each glass. These determinations were conducted both for the measured and for the bias-corrected data. A sum of oxides was also computed for each glass based upon both the measured and bias-corrected values. Exhibit A13 in Appendix A provides plots showing the results for each glass of series "P" for each oxide to help highlight the comparisons among the measured, bias-corrected, and targeted values. A similar plot for the series "Q" glasses is provided in Exhibit A14 of Appendix A.

Some general and specific observations from the plots of Exhibits A13 and A14 are offered below. In general, the measured and the measured bc compositional views for CaO appear to be higher than their targeted values for all study glasses. The measured and the measured bc compositional views for Fe_2O_3 and MgO appear to be lower than their targeted values for most of the study glasses. The measured Cr_2O_3 values also appear lower than targeted for most study glasses; however, these differences may be within analytical error of the ICP.

Specific observations include the measured Li_2O value for HTLG-56VS which is slightly higher than its targeted value (3.16 versus 3.0 wt% in glass). The measured NiO value for HTLG-71VS is extremely low (0.002 wt% - essentially a detection limit value) as compared to its targeted value (0.87 wt%). A review of the batch sheet suggests that NiO was added to the glass. A comparison of the measured and targeted SO_4 values suggests volatilization for most of the HTLG glasses was minimal (i.e., less then ±10% difference between target and measured values). However, 7 of the 27 HTLG glasses (HTLG-67, -69, -71, 74, -75, -76, and -78) had relatively high differences between the target and measured SO_4 values. The average difference was approximately 15% suggests some degree of volatilization in these seven glasses. Perhaps of some interest is that 5 of these 7 glasses are based on the 52% (higher WL) inner layer EVs.

Perhaps of most significance, are the comparisons of the target and measured values for HTLG-55VS and HTLG-66VS. Comparing the measured Al_2O_3, CaO, and MgO values for these two glasses with their respective target concentrations, these two glasses appear to be switched. It is not known whether the sample switch occurred during the batching or melting processes, or during the labeling of the samples during preparation for compositional analysis. Regardless of where the error may have occurred, the data suggest that these two glasses were indeed switched at some point during the testing program. The sums of oxides for all of the glasses fall within the interval from 95% to 105%.

Table A6 in Appendix A provides a summary of the average compositions as well as the targeted compositions and some associated differences and relative differences. Notice that the targeted sums of oxides for the standard glasses do not sum to 100% due to an incomplete coverage of the oxides in the Batch 1 and LRM glasses. Entries in Table A6 show the relative differences between the measured or bias-correct values and the targeted values. These differences are shaded when they are greater than or equal to 5%.

With the exception of HTLG-65VS and HTLG-66VS, the analytical results suggest that the target compositions of the study glasses were met (at least to the extent of having no significant impact to the objectives of the study). With respect to HTLG-65VS and HTLG-66VS, the XRD and PCT data suggest the conclusions would not be different even if switching had occurred. More specifically, both glasses precipitated only magnetite upon ccc and the PCT responses are essentially identical regardless of the compositional view used to normalize.

5.3 XRD Results

Representative samples of the ccc HTLG glasses were submitted for XRD analysis and Table 5-2 summarizes the results. The formation of magnetite (spinel) in all of the HTLG variability study glasses is consistent with previous research at these higher WLs. Based on previous or historical data, the presence of spinel in the ccc based glasses will have no measurable effect on the durability response of these glasses. The same can not be said for the formation of nepheline and/or aegirine. Formation of these two phases has been linked to a negative impact on the durability of HLW glasses – the magnitude of that impact being dependent on the extent of devitrification (volume %) and the ultimate change to the residual glass matrix.

At 50% WL, the XRD results indicate the presence of nepheline and/or aegirine in 6 of the 9 outer layer glasses and in 7 of the 9 inner layer glasses. These results indicate if the vendor's SRAT product lies within the compositional variation applied and a 50% WL is obtained, there is a high probability that aegirine and/or nepheline will be present in the resulting glass product upon slow cooling. However, as one transitions to higher WLs (52%), only four of the nine inner layer based, HTLG VS glasses have nepheline or aegirine present after slow cooling. Although no outer layer, 52% WL glasses were fabricated, the results appear to be consistent with previous trends indicating that targeting higher WLs (within the Frit 202-A11 – SB3 system) lowers the possibility of the formation of these two phases. However, the fact that both phases exist in some of the 52% WL glasses suggests that there are sludge oxide combinations that could still lead to their formation and a possible negative impact on durability. From a demonstration perspective, the questions at hand are: "What is the composition of the SRAT product produced by the vendor? and How does it compare to the EVs (inner or outer) being evaluated in the variability study"? If the actual SRAT product is compositionally similar to one of the EVs in which nepheline and/or aegirine formed, then targeting higher WLs (at least up to 52%) may not be sufficient to avoid a negative response in durability space. However, it appears that one could lower (but not eliminate) the possibility of forming nepheline and/or aegirine in the slow cooled glasses (within the compositional region tested) by targeting higher WLs. Again, this is consistent with the observations of Peeler et al. (2007) in the Frit 202-A11 – nominal SB3 study in which as WL was increased above 50%, there appeared to be a transition from the aegirine and/or nepheline primary phase fields to the spinel primary phase field, leading to more durable ccc glasses.

Table 5-2. XRD Results for the CCC Glasses.

Glass	WL	Outer/Inner Layer	XRD Results
HTLG-53VS	50	Outer	Magnetite, aegirine
HTLG-54VS	50	Outer	Magnetite, aegirine, nepheline
HTLG-55VS	50	Outer	Magnetite, aegirine, hematite, nepheline
HTLG-56VS	50	Outer	Magnetite, aegirine, hematite, nepheline
HTLG-57VS	50	Outer	Magnetite
HTLG-58VS	50	Outer	Magnetite
HTLG-59VS	50	Outer	Magnetite, aegirine
HTLG-60VS	50	Outer	Magnetite, aegirine
HTLG-61VS	50	Outer	Magnetite
HTLG-62VS	50	Inner	Magnetite, nepheline
HTLG-63VS	50	Inner	Magnetite, aegirine
HTLG-64VS	50	Inner	Magnetite, aegirine
HTLG-65VS	50	Inner	Magnetite
HTLG-66VS	50	Inner	Magnetite
HTLG-67VS	50	Inner	Magnetite, aegirine, nepheline, lithium silicate
HTLG-68VS	50	Inner	Magnetite, aegirine
HTLG-69VS	50	Inner	Magnetite, aegirine
HTLG-70VS	50	Inner	Magnetite, aegirine
HTLG-71VS	52	Inner	Magnetite, aegirine, nepheline
HTLG-72VS	52	Inner	Magnetite
HTLG-73VS	52	Inner	Magnetite, nepheline
HTLG-74VS	52	Inner	Magnetite
HTLG-75VS	52	Inner	Magnetite
HTLG-76VS	52	Inner	Magnetite, aegirine
HTLG-77VS	52	Inner	Magnetite
HTLG-78VS	52	Inner	Magnetite, aegirine
HTLG-79VS	52	Inner	Magnetite

5.4 PCT Testing

The study glasses, after being batched and fabricated, were subjected to the 7-day PCT to assess their durabilities. More specifically, Method A of the PCT (ASTM C-1285-2002 [see ASTM

(2002)]) was used for these measurements. Durability is the critical product quality metric for DWPF glass studies. Two heat treatments (quenching and a modified ccc schedule) were used during the fabrication of each of the study glasses. Both heat treatments for each study glass were subjected to the PCT (in triplicate). PCTs were also conducted in triplicate for samples of the EA glass and for samples of the ARM glass as part of each PCT plan. Blanks (samples consisting only of ASTM Type I water) were also submitted as part of each PCT plan. Two plans were provided to PSAL to support the evaluation of the compositions of the solutions resulting from the PCTs[f]. Samples of a multi-element, standard solution were also included in each analytical plan (as a check on the accuracy of the ICP-AES used for the measurements). In this and the following sections, the measurements generated by the PSAL for these PCTs are presented and reviewed.

Table B1 in Appendix B provides the elemental leachate concentration measurements determined by the PSAL for the solution samples generated by the PCTs by set. Since there were two cleaning batches that supported the first set of PCTs (with a pair of blanks in each batch), the first set of PCTs contained 4 blanks while the second series contained the usual two. One of the quality control checkpoints for the PCT procedure is solution-weight loss over the course of the 7-day test. None of the PCT results for either set indicated a solution-weight loss problem. Any measurement in Table B1 below the detection limit of the analytical procedure (indicated by a "<") was replaced by ½ of the detection limit in subsequent analyses. In addition to adjustments for detection limits, the values were adjusted for the dilution factors: the values for the study glasses, the blanks, and the ARM glass in Table B1 were multiplied by 1.6667 to determine the values in parts per million (ppm) and the values for EA were multiplied by 16.6667. The last five columns of Table B1 provide the measurements resulting from these adjustments.

In the sub-sections that follow, the analytical sequence of the measurements is explored for each set of PCTs, the measurements of the standards are investigated and used to assess the overall accuracy of the ICP measurement process for each set, the measurements for each glass are reviewed, and plots are provided that explore the effects of heat treatment on the PCTs for these glasses.

5.4.1 PCT Measurements in Analytical Sequence

Exhibit B1 in Appendix B provides plots of the leachate (ppm) concentrations in analytical sequence as generated by the PSAL for all of the data by PCT set. Exhibit B2 in Appendix B provides plots of the leachate (ppm) concentrations in analytical sequence by set for only the study glasses (i.e., measurements for EA, ARM, blanks, and the solution standards are excluded). From the limited perspective provided by these plots, no problems are seen. More detailed investigations into these results are provided below.

5.4.2 Repeatability of the PCT Measurements for a Glass/Heat Treatment Combination

Exhibit B3 in Appendix B provides a closer look at the repeatability of the triplicate PCTs for each study glass and heat treatment combination. While there are some differences in the measurements for the two heat treatments for some of these glasses, there does appear to be good repeatability for the triplicates for each treatment for each of the glasses. A closer look at the differences between the heat treatments for each of the study glasses is provided in the discussions that follow.

[f] The two analytical plans were provided by TB Edwards in the memorandum SRNL-SCS-2007-00021, "Analytical Plans for Measuring the PCT Solutions for the HTL Variability Study Glasses (U)," dated May 16, 2007.

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

Exhibit B4 in Appendix B provides analyses of the PSAL measurements of the samples of the multi-element solution standard by ICP-AES analytical (or calibration) block for each PCT set. An ANOVA investigating for statistically significant differences among the block averages for these samples for each element of interest is included in these exhibits. For the first set of PCTs, there is a statistically significant (at approximately a 5% level) difference among the Al average measurements, the Fe average measurements, the Li average measurements, and the Na average measurements over the calibration blocks. For the second set of PCTs, there is a statistically significant (at approximately a 5% level) difference among the Fe average measurements and the Si average measurements over the calibration blocks. However, no bias correction of the PCT results for the study glasses was conducted. This approach was taken since the triplicate PCTs for a single study glass were placed in different ICP-AES blocks. Averaging the ppm values for each set of triplicates helps to minimize the impact of the ICP-AES effects for both sets of PCTs.

Table 5-3 summarizes the average measurements and the reference values for the 3 primary elements present in the multi-element solution. The results indicate consistent and accurate measurements from the PSAL processes used to conduct these analyses.

Table 5-3. Results from Samples of the Multi-Element Solution Standard by PCT Set

Set 1					Set 2				
Block	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)	Block	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
1	19.9	10.0	83.9	50.1	1	21.3	10.3	81.4	51.9
2	20.2	9.7	78.8	49.0	2	20.5	10.2	84.3	48.9
3	20.1	9.8	82.1	49.1	3	20.3	10.1	82.8	49.6
4	20.4	9.8	82.0	50.3	4	19.9	10.2	81.3	50.3
5	20.0	9.7	84.9	48.8	5	20.2	10.1	83.1	48.8
6	19.8	9.6	79.9	49.4	6	20.9	10.3	82.4	50.4
Grand Average	20.1	9.8	81.9	49.4	Grand Average	20.5	10.2	82.6	50.0
Reference Value	20	10	81	50	Reference Value	20	10	81	50
% difference	0.39%	-2.41%	1.13%	-1.96%	% difference	2.58%	1.96%	1.93%	-0.07%

5.4.4 Normalized PCT Results

PCT leachate concentrations are typically normalized using the cation composition (expressed as a weight percent) in the glass to obtain a grams-per-liter (g/L) leachate concentration. The normalization of the PCTs is usually conducted using the measured compositions of the glasses. This is the preferred normalization process for the PCTs. For completeness, the targeted cation and the bias-corrected cation compositions were also used to conduct this normalization.

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

1. Determine the common logarithm of the elemental parts per million (ppm) leachate concentration for each of the triplicates and each of the elements of interest (these values are provided in Table B2 of Appendix B),

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

Normalizing Using Measured Composition (preferred method)

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

Or Normalizing Using Target Composition

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

Or Normalizing Using Measured Bias-Corrected Composition

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

Exhibit B5 in Appendix B provides scatter plots for these results and offers an opportunity to investigate the consistency in the leaching across the elements for the glasses of this study. All combinations of the normalizations of the PCTs (i.e., those generated using the targeted, measured, and bias-corrected compositional views) and both heat treatments are represented in a pair of scatter plot matrices: one matrix for each set of PCTs. Consistency in the leaching across the elements for a set of PCTs is typically demonstrated by a high degree of linear correlation among the values for pairs of these elements. The smallest correlation seen over both sets of PCTs is that for Li and Na in the first set, with a value of ~94%.

Table 5-4 and Table 5-5 summarize the normalized PCTs for the quenched and ccc glasses, respectively. The glasses are listed by glass identifier with normalized PCT data being presented for targeted, measured, and measured bc compositional views. The PCT results of the quenched glasses (regardless of compositional view) indicate that all HTLG variability study glasses are very acceptable relative to the EA glass benchmark. More specifically, the normalized boron releases (NL [B] in g/L) range from 0.8 g/L (for HTLG-60VS based on the measured composition) to 1.384 g/L (HTLG-79VS based on the measured bc composition). These results can be compared to the NL [B] for the EA benchmark of 16.695 g/L. Again, the PCT results of the quenched glasses are consistent with previous data in the Frit 202-A11 – SB3 system.

The PCT results for the ccc glasses are not as straight forward. The NL [B]s for the slow cooled glasses range from 0.607 g/L (for HTLG-57ccc based on the measured composition) to 9.42 g/L (for HTLG-67ccc based on the measured bc compositional view). Although these glasses would be classified as acceptable relative to the EA glass benchmark, the relatively high release of the slow cooled glasses would be of concern if this system were to be implemented into DWPF. This latter statement should be tempered with the fact that Frit 202-A11 was not optimized for the SB3 system but was simply developed within the time constraints to meet programmatic objectives. If the CCIM technology were to be implemented into DWPF, more detailed glass formulation studies would be performed leading to a frit recommendation that would address this concern.

Table 5-4. Normalized PCTs for Quenched Glasses by Compositional View.

Glass ID	Composition	NL [B (g/L)]	NL [Li (g/L)]	NL [Na (g/L)]	NL [Si (g/L)]
ARM	reference	0.487	0.572	0.525	0.277
EA	reference	17.602	9.546	13.774	3.953
ARM	reference	0.500	0.583	0.509	0.274
EA	reference	18.262	10.023	13.728	4.004
HTLG-53VS	targeted	1.074	0.925	0.976	0.489
HTLG-54VS	targeted	1.259	0.998	1.200	0.578
HTLG-55VS	targeted	0.985	0.854	1.025	0.482
HTLG-56VS	targeted	1.272	1.132	1.245	0.599
HTLG-57VS	targeted	0.815	0.834	0.846	0.468
HTLG-58VS	targeted	1.236	0.984	1.217	0.579
HTLG-59VS	targeted	1.151	0.993	1.093	0.517
HTLG-60VS	targeted	0.826	0.823	0.869	0.440
HTLG-61VS	targeted	0.980	0.863	0.996	0.503
HTLG-62VS	targeted	1.108	0.934	1.061	0.534
HTLG-63VS	targeted	0.974	0.872	0.936	0.487
HTLG-64VS	targeted	1.142	0.995	1.109	0.544
HTLG-65VS	targeted	1.107	0.946	1.092	0.541
HTLG-66VS	targeted	0.971	0.848	1.007	0.476
HTLG-67VS	targeted	0.944	0.848	0.904	0.431
HTLG-68VS	targeted	0.942	0.844	0.882	0.463
HTLG-69VS	targeted	0.980	0.898	0.987	0.464
HTLG-70VS	targeted	1.276	1.041	1.216	0.557
HTLG-71VS	targeted	1.222	1.010	1.134	0.544
HTLG-72VS	targeted	1.044	0.903	0.984	0.504
HTLG-73VS	targeted	1.291	1.031	1.169	0.537
HTLG-74VS	targeted	1.069	0.915	1.076	0.495
HTLG-75VS	targeted	1.196	0.956	1.136	0.530
HTLG-76VS	targeted	0.997	0.893	1.023	0.462
HTLG-77VS	targeted	0.991	0.895	0.988	0.496
HTLG-78VS	targeted	1.081	0.962	1.080	0.506
HTLG-79VS	targeted	1.362	1.087	1.267	0.573
HTLG-53VS	measured	1.080	0.946	0.994	0.483
HTLG-54VS	measured	1.266	1.019	1.237	0.585
HTLG-55VS	measured	0.984	0.870	1.064	0.476
HTLG-56VS	measured	1.293	1.075	1.277	0.608
HTLG-57VS	measured	0.812	0.842	0.835	0.463
HTLG-58VS	measured	1.230	1.014	1.254	0.576
HTLG-59VS	measured	1.168	1.015	1.101	0.515
HTLG-60VS	measured	0.803	0.828	0.830	0.439
HTLG-61VS	measured	0.995	0.881	1.000	0.509
HTLG-62VS	measured	1.100	0.943	1.074	0.538
HTLG-63VS	measured	0.979	0.884	0.917	0.493
HTLG-64VS	measured	1.172	1.006	1.106	0.540
HTLG-65VS	measured	1.123	0.947	1.095	0.541
HTLG-66VS	measured	0.971	0.872	1.000	0.484
HTLG-67VS	measured	0.965	0.847	0.907	0.441
HTLG-68VS	measured	0.956	0.842	0.895	0.477
HTLG-69VS	measured	0.973	0.898	0.983	0.468
HTLG-70VS	measured	1.281	1.063	1.225	0.578
HTLG-71VS	measured	1.204	0.994	1.135	0.547
HTLG-72VS	measured	1.061	0.903	0.986	0.516
HTLG-73VS	measured	1.332	1.037	1.178	0.555
HTLG-74VS	measured	1.127	0.931	1.075	0.514
HTLG-75VS	measured	1.228	0.956	1.145	0.544
HTLG-76VS	measured	0.998	0.903	1.017	0.472
HTLG-77VS	measured	1.002	0.895	0.976	0.504
HTLG-78VS	measured	1.071	0.966	1.080	0.512

Glass ID	Composition	NL [B (g/L)]	NL [Li (g/L)]	NL [Na (g/L)]	NL [Si (g/L)]
HTLG-79VS	measured	1.353	1.102	1.265	0.585
HTLG-53VS	measured bc	1.103	0.941	1.055	0.473
HTLG-54VS	measured bc	1.284	1.015	1.313	0.561
HTLG-55VS	measured bc	1.005	0.866	1.129	0.467
HTLG-56VS	measured bc	1.312	1.071	1.355	0.583
HTLG-57VS	measured bc	0.830	0.838	0.911	0.454
HTLG-58VS	measured bc	1.256	1.009	1.331	0.564
HTLG-59VS	measured bc	1.193	1.011	1.169	0.505
HTLG-60VS	measured bc	0.814	0.825	0.905	0.421
HTLG-61VS	measured bc	1.009	0.878	1.090	0.488
HTLG-62VS	measured bc	1.116	0.940	1.140	0.516
HTLG-63VS	measured bc	0.993	0.881	1.000	0.473
HTLG-64VS	measured bc	1.197	1.002	1.206	0.530
HTLG-65VS	measured bc	1.140	0.943	1.194	0.519
HTLG-66VS	measured bc	0.991	0.868	1.091	0.474
HTLG-67VS	measured bc	0.987	0.853	0.969	0.426
HTLG-68VS	measured bc	0.947	0.838	0.955	0.456
HTLG-69VS	measured bc	0.995	0.904	1.049	0.454
HTLG-70VS	measured bc	1.269	1.057	1.309	0.550
HTLG-71VS	measured bc	1.231	1.000	1.213	0.529
HTLG-72VS	measured bc	1.052	0.898	1.052	0.492
HTLG-73VS	measured bc	1.320	1.032	1.257	0.529
HTLG-74VS	measured bc	1.117	0.927	1.148	0.488
HTLG-75VS	measured bc	1.216	0.951	1.224	0.517
HTLG-76VS	measured bc	1.021	0.909	1.087	0.456
HTLG-77VS	measured bc	0.993	0.891	1.041	0.481
HTLG-78VS	measured bc	1.095	0.972	1.152	0.497
HTLG-79VS	measured bc	1.384	1.109	1.350	0.568

Table 5-5. Normalized PCTs for CCC Glasses by Compositional View.

Glass ID	Composition	NL [B (g/L)]	NL [Li (g/L)]	NL [Na (g/L)]	NL [Si (g/L)]
ARM	reference	0.487	0.572	0.525	0.277
EA	reference	17.602	9.546	13.774	3.953
ARM	reference	0.500	0.583	0.509	0.274
EA	reference	18.262	10.023	13.728	4.004
HTLG-53VS	targeted	0.826	0.916	0.915	0.500
HTLG-54VS	targeted	4.102	2.576	2.106	0.919
HTLG-55VS	targeted	6.657	5.274	3.061	1.357
HTLG-56VS	targeted	2.599	2.615	1.817	0.968
HTLG-57VS	targeted	0.609	0.677	0.716	0.413
HTLG-58VS	targeted	0.865	0.890	1.040	0.548
HTLG-59VS	targeted	1.805	1.965	1.356	0.677
HTLG-60VS	targeted	0.643	0.769	0.763	0.431
HTLG-61VS	targeted	0.896	0.918	0.948	0.531
HTLG-62VS	targeted	2.347	2.049	1.596	0.836
HTLG-63VS	targeted	0.726	0.768	0.891	0.467
HTLG-64VS	targeted	6.717	5.625	3.135	1.400
HTLG-65VS	targeted	0.945	1.070	1.023	0.551
HTLG-66VS	targeted	0.875	1.036	0.966	0.501
HTLG-67VS	targeted	9.013	7.403	4.217	1.663
HTLG-68VS	targeted	0.666	0.683	0.744	0.424
HTLG-69VS	targeted	0.705	0.725	0.804	0.429
HTLG-70VS	targeted	2.977	2.273	1.689	0.833
HTLG-71VS	targeted	8.287	6.163	4.751	1.877
HTLG-72VS	targeted	0.730	0.703	0.792	0.434
HTLG-73VS	targeted	3.888	3.924	2.244	1.215
HTLG-74VS	targeted	0.903	0.882	0.937	0.489
HTLG-75VS	targeted	0.832	0.805	0.971	0.497
HTLG-76VS	targeted	1.556	1.153	1.109	0.529
HTLG-77VS	targeted	0.685	0.706	0.758	0.418
HTLG-78VS	targeted	0.723	0.838	0.892	0.448
HTLG-79VS	targeted	1.387	1.354	1.199	0.607
HTLG-53VS	measured	0.831	0.937	0.932	0.493
HTLG-54VS	measured	4.125	2.629	2.170	0.929
HTLG-55VS	measured	6.645	5.375	3.176	1.342
HTLG-56VS	measured	2.641	2.483	1.863	0.982
HTLG-57VS	measured	0.607	0.684	0.707	0.409
HTLG-58VS	measured	0.861	0.917	1.072	0.544
HTLG-59VS	measured	1.831	2.010	1.366	0.675
HTLG-60VS	measured	0.625	0.774	0.729	0.430
HTLG-61VS	measured	0.909	0.938	0.952	0.537
HTLG-62VS	measured	2.330	2.069	1.615	0.842
HTLG-63VS	measured	0.730	0.778	0.873	0.473
HTLG-64VS	measured	6.889	5.690	3.128	1.391
HTLG-65VS	measured	0.959	1.071	1.026	0.551
HTLG-66VS	measured	0.875	1.065	0.959	0.509
HTLG-67VS	measured	9.211	7.395	4.231	1.704
HTLG-68VS	measured	0.676	0.681	0.754	0.438
HTLG-69VS	measured	0.700	0.725	0.802	0.432
HTLG-70VS	measured	2.988	2.320	1.701	0.866
HTLG-71VS	measured	8.160	6.062	4.756	1.885
HTLG-72VS	measured	0.742	0.703	0.794	0.444
HTLG-73VS	measured	4.013	3.947	2.262	1.255
HTLG-74VS	measured	0.952	0.898	0.936	0.508
HTLG-75VS	measured	0.853	0.806	0.978	0.510
HTLG-76VS	measured	1.558	1.166	1.103	0.539
HTLG-77VS	measured	0.692	0.706	0.749	0.425
HTLG-78VS	measured	0.715	0.841	0.892	0.453

Glass ID	Composition	NL [B (g/L)]	NL [Li (g/L)]	NL [Na (g/L)]	NL [Si (g/L)]
HTLG-79VS	measured	1.378	1.372	1.198	0.619
HTLG-53VS	measured bc	0.848	0.933	0.989	0.484
HTLG-54VS	measured bc	4.184	2.620	2.304	0.891
HTLG-55VS	measured bc	6.787	5.351	3.372	1.316
HTLG-56VS	measured bc	2.679	2.474	1.978	0.942
HTLG-57VS	measured bc	0.620	0.681	0.771	0.401
HTLG-58VS	measured bc	0.879	0.913	1.138	0.533
HTLG-59VS	measured bc	1.870	2.001	1.450	0.662
HTLG-60VS	measured bc	0.634	0.771	0.795	0.412
HTLG-61VS	measured bc	0.923	0.934	1.038	0.515
HTLG-62VS	measured bc	2.364	2.062	1.715	0.808
HTLG-63VS	measured bc	0.740	0.776	0.952	0.453
HTLG-64VS	measured bc	7.036	5.666	3.411	1.364
HTLG-65VS	measured bc	0.973	1.067	1.118	0.529
HTLG-66VS	measured bc	0.893	1.061	1.046	0.499
HTLG-67VS	measured bc	9.420	7.441	4.522	1.648
HTLG-68VS	measured bc	0.669	0.677	0.805	0.418
HTLG-69VS	measured bc	0.716	0.730	0.856	0.420
HTLG-70VS	measured bc	2.961	2.308	1.818	0.823
HTLG-71VS	measured bc	8.345	6.100	5.083	1.824
HTLG-72VS	measured bc	0.736	0.699	0.847	0.423
HTLG-73VS	measured bc	3.976	3.928	2.414	1.198
HTLG-74VS	measured bc	0.943	0.893	1.000	0.483
HTLG-75VS	measured bc	0.846	0.802	1.046	0.485
HTLG-76VS	measured bc	1.593	1.174	1.179	0.522
HTLG-77VS	measured bc	0.685	0.703	0.799	0.405
HTLG-78VS	measured bc	0.732	0.846	0.952	0.440
HTLG-79VS	measured bc	1.410	1.381	1.278	0.601

Table 5-6 provides a summary of the XRD results for the ccc glasses and the PCT responses for the quenched and ccc glasses (normalized based on the targeted glass composition). The information is presented in this manner to provide insight into the effect of the various crystalline phases that formed upon slow cooling on the PCT response. A comparison of the quenched and ccc PCT response provides insight into the magnitude of the crystallization effect (assuming that the quenched glasses contained only magnetite which should have no impact on the PCT response).

Consider the ccc glasses which precipitated magnetite as the only crystalline phase upon slow cooling (i.e., HLTG-57, -58, 65, -66, -72, -74, -75, -77, and -79). There is very little, if any, practical difference in PCT response between the quenched and ccc versions of these glasses. The NL [B]s are all below ~1.4 g/L. Next consider the formation of aegirine upon slow cooling (i.e., HTLG-53, -59, -60, -63, -64, -68, -69, -70, -76, and -78) and its impact on the PCT response. With the exception of HTLG-64ccc (an inner layer, 50% WL based glass), all of the NL [B]s are less than 3 g/L. The NL [B] of HTLG-64ccc is reported to be 6.7 g/L. For those glasses precipitating only aegirine after slow cooling, the PCT data are mixed which is related to the effect of this crystalline phase on the response. More specifically, in some glasses (HTLG-53, -60, -63, -68, -69, and -78), the formation of this phase appears to have no practical impact on the PCT response. Aegirine formation in the slowly cooled versions of HTLG-59, -70, and -76 appears to have a measurable, negative impact on the PCT response – but the glasses still have very acceptable NL [B] values as compared to the EA benchmark. The troubling data point for aegirine formation is HTLG-64 (an inner layer, EV targeted 50% WL). The formation of aegirine in this glass has a significant, negative impact on the PCT response (~ 6x decrease in durability). Although this is still “acceptable”, it would be of concern with respect to DWPF operations. The aegirine based data suggest that the impact of its formation within the composition region studied is rather unpredictable.

Next consider those glasses which formed either nepheline or both nepheline and aegirine upon slow cooling (i.e., HTLG-54, -55, -56, -67, and -71). The NL [B]s for these ccc based glasses range from ~2.3 g/L (HTLG-62) to ~9.1 g/L (HTLG-67). Although the formation of aegirine has (in general) a slightly negative impact on the PCT response (as previously discussed), the formation of nepheline and aegirine is a combination that has a high probability of leading to a significant reduction in durability upon slow cooling.

With respect to the CCIM demonstration, one would hope that there is a clear cut delineation of sludge compositions and/or targeted WLs that could avoid the formation of either of these phases within the sludge composition region being evaluated. However, based on a statistical assessment of the PCT and XRD data, there does not appear to be a direct relationship among the sludge components and their combinations that can be used to identify a nepheline and/or aegirine primary phase field. In addition, the ability to avoid the formation of these phases within the sludge compositional region and WL interval used is not available. More specifically, based on previous data, the possibility to target higher WLs (> 50%) to avoid any negative impacts on durability as a result of crystallization was observed when the nominal SB3 composition was utilized. However, when composition variation is applied to the sludge, there are multiple combinations of sludge components that fall within the nepheline and/or aegirine phase fields even at 52% WL which ultimately lead to a negative impact on durability. Having said that, the PCT results do suggest that the probability of observing that negative impact is lower at the higher WLs (only 2 of the inner layer, 52% WL based glasses have NL [B] > 2 g/L after slow cooling as compared to 4 of the 9 inner layer EVs targeted 50% WL).

Table 5-6. XRD and PCT results for the HTLG Variability Study Glasses.
(PCT normalized to target compositions).

Glass	WL	Outer/Inner Layer	XRD Results for CCC	NL [B] (g/L) for Quenched	NL [B] (g/L) for CCC
HTLG-53VS	50	Outer	Magnetite, aegirine	1.074	0.826
HTLG-54VS	50	Outer	Magnetite, aegirine, nepheline	1.259	4.102
HTLG-55VS	50	Outer	Magnetite, aegirine, hematite, nepheline	0.985	6.657
HTLG-56VS	50	Outer	Magnetite, aegirine, hematite, nepheline	1.272	2.599
HTLG-57VS	50	Outer	Magnetite	0.815	0.609
HTLG-58VS	50	Outer	Magnetite	1.236	0.865
HTLG-59VS	50	Outer	Magnetite, aegirine	1.151	1.805
HTLG-60VS	50	Outer	Magnetite, aegirine	0.826	0.643
HTLG-61VS	50	Outer	Magnetite	0.980	0.896
HTLG-62VS	50	Inner	Magnetite, nepheline	1.108	2.347
HTLG-63VS	50	Inner	Magnetite, aegirine	0.974	0.726
HTLG-64VS	50	Inner	Magnetite, aegirine	1.142	6.717
HTLG-65VS	50	Inner	Magnetite	1.107	0.945
HTLG-66VS	50	Inner	Magnetite	0.971	0.875
HTLG-67VS	50	Inner	Magnetite, aegirine, nepheline, lithium silicate	0.944	9.013
HTLG-68VS	50	Inner	Magnetite, aegirine	0.942	0.666
HTLG-69VS	50	Inner	Magnetite, aegirine	0.980	0.705
HTLG-70VS	50	Inner	Magnetite, aegirine	1.276	2.977
HTLG-71VS	52	Inner	Magnetite, aegirine, nepheline	1.222	8.287
HTLG-72VS	52	Inner	Magnetite	1.044	0.730
HTLG-73VS	52	Inner	Magnetite, nepheline	1.291	3.888
HTLG-74VS	52	Inner	Magnetite	1.069	0.903
HTLG-75VS	52	Inner	Magnetite	1.196	0.832
HTLG-76VS	52	Inner	Magnetite, aegirine	0.997	1.556
HTLG-77VS	52	Inner	Magnetite	0.991	0.685
HTLG-78VS	52	Inner	Magnetite, aegirine	1.081	0.723
HTLG-79VS	52	Inner	Magnetite	1.362	1.387

5.5 Glasses Fabricated Using Nominal SB3 Compositions

As this variability study was being completed, measurements on the composition of the SB3 sludge simulant that was prepared by the vendor became available. Three glasses were made based upon these measurements targeting WLs of 45, 50, and 55%; the glasses were designated as HTLG-100, HTLG-101, and HTLG-102, respectively. The targeted compositions of these glasses are provided in Table 5-7. Glasses were prepared from the proper proportions of reagent-grade metal oxides, carbonates, H_3BO_3, and salts in 150 g batches as described in Section 4.1.

Table 5-7. Targeted Compositions of Glasses at 45, 50, and 55 %WL Based Upon Vendor's Measured Composition of SB3

	HTLG-100	HTLG-101	HTLG-102
WL	45	50	55
Al_2O_3	7.83	8.70	9.56
B_2O_3	4.95	4.50	4.05
CaO	1.26	1.40	1.53
Cr_2O_3	0.09	0.10	0.11
CuO	0.00	0.00	0.00
Fe_2O_3	15.77	17.52	19.27
K_2O	0.33	0.37	0.41
Li_2O	3.30	3.00	2.70
MgO	1.86	2.04	2.24
MnO	4.07	4.53	4.98
Na_2O	11.80	12.78	13.75
NiO	0.58	0.65	0.71
SO_4	0.40	0.44	0.49
SiO_2	46.88	42.98	39.07
TiO_2	0.00	0.00	0.00
ZrO_2	0.08	0.09	0.09
Total	99.19	99.07	98.98

The XRD assessments of the ccc versions of these glasses indicated magnetite, aegirine, nepheline, and lithium silicate for HTLG-100 but only magnetite for HTLG-101 and HTLG-102. These data suggest that targeting higher WLs (between 50 and 55%) should result in very acceptable glasses regardless of thermal heat treatment (quenched or ccc).

PCTs were conducted for these glasses and the resulting solutions were submitted to PSAL for measurement. The PCTs were conducted in triplicate for both quenched and ccc versions of these three glasses along with a blank and with triplicate EA and triplicate ARM samples. The raw data from these analyses are provided in Table 5-8 for documentation purposes.

Table 5-8. PCT Results for HTLG-100, HTLG-101, and HTLG-102

Glass ID	SRTC-ML ID	Al ar	B ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
Blank-1	07-2935	<0.100	<0.100	<0.100	<1.00	<1.00	<0.100	0.083	0.083	0.083	0.833	0.833	0.083
Blank-2	07-2936	<0.100	<0.100	<0.100	<1.00	<1.00	<0.100	0.083	0.083	0.083	0.833	0.833	0.083
ARM-1	07-2937	2.98	9.93	0.329	8.5	21.8	36.8	4.967	16.550	0.548	14.167	36.334	61.335
ARM-2	07-2938	2.95	10	<0.100	8.53	22.6	36.9	4.917	16.667	0.083	14.217	37.667	61.501
ARM-3	07-2939	3.19	9.77	<0.100	8.41	21.5	36.8	5.317	16.284	0.083	14.017	35.834	61.335
EA-1	07-2940	0.279	38.6	<0.100	11.9	104	56	4.650	643.335	0.833	198.334	1733.337	933.335
EA-2	07-2941	0.276	39.3	<0.100	11.9	104	56.3	4.600	655.001	0.833	198.334	1733.337	938.335
EA-3	07-2942	0.3	39.8	<0.100	11.9	104	56.9	5.000	663.335	0.833	198.334	1733.337	948.335
HTLG-100-1	07-2943	8.76	7.64	2.72	7.34	40	59.8	14.600	12.734	4.533	12.234	66.668	99.669
HTLG-100-2	07-2944	8.45	6.58	3.25	7.07	38.5	57.6	14.084	10.967	5.417	11.784	64.168	96.002
HTLG-100-3	07-2945	8.47	6.56	3.22	7	39	58.1	14.117	10.934	5.367	11.667	65.001	96.835
HTLG-100-ccc-1	07-2946	10.8	50.1	12.6	42	116	152	18.000	83.502	21.000	70.001	193.337	253.338
HTLG-100-ccc-2	07-2947	10.7	50.8	12.7	42.4	115	161	17.834	84.668	21.167	70.668	191.671	268.339
HTLG-100-ccc-3	07-2948	10.4	49.6	11.8	41.7	114	154	17.334	82.668	19.667	69.501	190.004	256.672
HTLG-101-1	07-2949	10.7	7.79	3.15	7.13	52.8	56	17.834	12.984	5.250	11.884	88.002	93.335
HTLG-101-2	07-2950	10.9	8.06	2.3	7.53	54.4	58.8	18.167	13.434	3.833	12.550	90.668	98.002
HTLG-101-3	07-2951	11	7.89	2.38	7.59	56.1	59.1	18.334	13.150	3.967	12.650	93.502	98.502
HTLG-101-ccc-1	07-2952	10.5	14.7	2.81	15.1	72.3	82.6	17.500	24.500	4.683	25.167	120.502	137.669
HTLG-101-ccc-2	07-2953	10.1	14.4	2.99	15	70.8	82.6	16.834	24.000	4.983	25.001	118.002	137.669
HTLG-101-ccc-3	07-2954	9.81	14	3.2	14.5	68.4	79.1	16.350	23.334	5.333	24.167	114.002	131.836
HTLG-102-1	07-2955	15.1	8.27	7.46	7.45	70.8	61.4	25.167	13.784	12.434	12.417	118.002	102.335
HTLG-102-2	07-2956	15	8.13	6.8	7.43	71.2	59.8	25.001	13.550	11.334	12.384	118.669	99.669
HTLG-102-3	07-2957	15	8.07	6.63	7.51	72.2	60	25.001	13.450	11.050	12.517	120.336	100.002
HTLG-102-ccc-1	07-2958	11.9	4.97	1.83	6.06	56.3	51.3	19.834	8.283	3.050	10.100	93.835	85.502
HTLG-102-ccc-2	07-2959	12.1	5.03	1.86	6.2	58.1	52	20.167	8.384	3.100	10.334	96.835	86.668
HTLG-102-ccc-3	07-2960	12.3	5.07	1.95	6.23	58.4	53.1	20.500	8.450	3.250	10.384	97.335	88.502

Using the targeted compositions for these three glasses, the PCT responses were normalized as in the earlier discussion. This yielded the results presented in Table 5-9. The trends in the quenched glasses indicate that the durability does gradually decrease as WL increases. Assuming the formation of magnetite in these glasses, this trend is consistent with previous data and reflects a changing durability response as a function of a changing glass composition. With respect to the ccc based glasses, the durability trend is opposite to that of their quenched counterparts. As WL increases for the ccc glasses, the durability increases. This is primarily a function of the transition from the nepheline, aegirine, lithium silicate phase fields experienced at 45% WL to a magnetite only phase field at 50% WL and higher as determined by XRD analyses. The results indicate that glasses based on the measured composition of the vendor's sludge simulant, which target 50% WL or higher, produce very acceptable glasses – regardless of thermal history.

Table 5-9. Normalized PCT Response Based upon Targeted Compositions for HTLG-100, HTLG-101, and HTLG-102

WL	Glass ID	Heat Treatment	NL B (g/L)	NL Li (g/L)	NL Na (g/L)	NL Si (g/L)
	ARM		0.47	0.60	0.51	0.28
	EA	ref	18.63	10.02	13.91	4.13
45	HTLG-100	ccc	5.44	4.57	2.19	1.18
50	HTLG-101	ccc	1.71	1.78	1.24	0.68
55	HTLG-102	ccc	0.67	0.82	0.94	0.48
45	HTLG-100	quenched	0.75	0.78	0.75	0.44
50	HTLG-101	quenched	0.94	0.89	0.96	0.48
55	HTLG-102	quenched	1.08	0.99	1.17	0.55

6.0 Summary

Strategic glass formulation approaches and physical improvements to DWPF's existing Joule Heated Melter (JHM) have lead to a significant increase in the waste throughput for the Savannah River Site. Although WLs have transitioned from a nominal 28% to ~ 38% WL with SB3 while maintaining melt rate, additional increases are possible by coupling advanced melter technologies with glass formulation efforts. More specifically, advancements in melter technology have the potential to produce glass faster and at higher waste loadings (the two primary parameters that drive waste throughput) relative to current operations. One of these technologies is the Cold Crucible Induction Melter (CCIM) with bubbler and/or mechanical agitation.

Since any additional (sustained) improvement in waste loading and/or melt rate relative to current operations will help to reduce the life-cycle costs for the Department of Energy (DOE) at the Savannah River Site (SRS), there is interest in demonstrating the viability of CCIM technology to yield such an improvement. A demonstration is currently planned for the fall of 2007 and will be based on a DWPF waste slurry feed surrogate with a nominal operating temperature of approximately 1250°C. The CCIM glass product will be a borosilicate glass at a high waste loading (about 50%, based on a calcined oxide basis) that must meet current requirements for disposal at a Federal Repository.

Given the identification of Frit 202-A11 as the preferred frit (Peeler et al. 2007), supplemental information was needed to provide a technical basis to facilitate decisions regarding the melter demonstration. More specifically, initial testing to identify the candidate frit was based on a nominal sludge composition without accounting for variation that could result based on the vendor's ability to produce the targeted composition. The CCIM demonstration, which will utilize a "constant" sludge composition (targeting a nominal SB3 composition) coupled with Frit 202-A11 at ~50% waste loading (WL), will theoretically yield a constant glass composition. Although this will support programmatic objectives, there is some need to assess the potential impacts of sludge variation and/or waste loading differences on potential processing and/or product performance properties. Recognizing the low probability of producing the exact targeted nominal sludge composition and/or that targeted WL could vary from 50 ± 2% (around the nominal 50%), the impact of these variations must be considered on processing properties or perhaps, more importantly, on the durability of the final waste form. This is of particular importance given the nonlinear behavior previously observed between waste loading and critical processing / performance properties for this glass forming system. The results from Peeler et al. (2007) suggested that a balance between WL and processing and product performance issues may be required for this CCIM demonstration. This latter statement is based on the fact that frit development efforts were not necessarily intended to optimize this glass system nor have these efforts accounted for the variation from the intended target that is likely to occur in the composition of the waste slurry feed surrogate that is being used in the study.

Twenty-seven glasses were designed to assess the impacts of both sludge variation (±5 or ±10% for the major sludge components) and WL (50 or 52%) on the PCT response after two thermal histories (quenching and a modified ccc schedule). The PCT results of the quenched glasses (regardless of compositional view) indicate that all HTLG variability study glasses are very acceptable relative to the EA glass benchmark. More specifically, the normalized boron releases (NL [B] in g/L) range from 0.8 g/L (for HTLG-60VS based on the measured composition) to 1.384 g/L (HTLG-79VS based on the measured bc composition). These results can be compared to the NL [B] for the EA benchmark of 16.695 g/L. Again, the PCT results of the quenched glasses are consistent with previous data in the Frit 202-A11 – SB3 system.

The PCT results for the ccc glasses are not as straight forward. The NL [B]s for the slow cooled glasses range from 0.607 g/L (for HTLG-57ccc based on the measured composition) to 9.42 g/L (for HTLG-67ccc based on the measured bc compositional view). Although these glasses would be classified as acceptable relative to the EA glass benchmark, the relatively high release of the slow cooled glasses would be of concern if this system were to be implemented into DWPF. The PCT responses for those glasses in which either nepheline or both nepheline and aegirine formed upon slow cooling lead to a significant reduction in PCT response. Although the formation of aegirine has (in general) a slightly negative impact on the PCT response (as previously discussed), the formation of nepheline and aegirine is a combination that has a high probability of leading to a significant reduction in durability upon slow cooling.

With respect to the CCIM demonstration, a clear cut delineation of sludge compositions and/or targeted WLs is desirable to avoid the formation of either of these phases within the sludge composition region being evaluated. However, based on a statistical assessment of the PCT and XRD data, there does not appear to be a direct relationship among the sludge components and their combinations that can be used to identify a nepheline and/or aegirine primary phase field. In addition, the ability to avoid the formation of these phases within the sludge compositional region and WL interval used is not available. More specifically, based on previous data, the possibility to target higher WLs (> 50%) to avoid any negative impacts on durability as a result of crystallization was observed when the nominal SB3 composition was utilized. However, when composition variation is applied to the sludge, there are multiple combinations of sludge components that fall within the nepheline and/or aegirine phase fields even at 52% WL, which ultimately lead to a negative impact on the durability. Nevertheless, the PCT results do suggest that the probability of observing the negative impact is lower at the higher WLs (only 2 of the inner layer, 52% WL based glasses have NL [B] > 2 g/L after slow cooling as compared to 4 of the 9 inner layer EVs that targeted 50% WL).

7.0 Path Forward

(1) Future glass formulation studies should utilize alternative process control models (even if preliminary) which may be more applicable to the higher WL regions of interest to the CCIM technology. This is not a critical statement against the current DWPF process control models (which have been very successful in controlling the DWPF process) but an acknowledgement that the compositional region of interest for these higher WL glasses may stretch the applicability of the current models.
(2) Perform specific studies to identify the compositional regions in which nepheline and/or aegirine develop and methods which frit development efforts can implement to avoid their formation.
(3) Optimize the frit selection process for the systems of interest. Although the current study did identify Frit 202-A11 as a candidate for the SB3 system, the formation of nepheline and/or aegirine in the slowly cooled glasses would be a concern for DWPF implementation. More specifically, having a system that is sensitive to sludge variation with respect to durability is a positioning which DWPF may wish to avoid. Development of more robust frits capable of handling anticipated variation would be desired – even more so, if the limiting parameter was associated with a processing constraint (i.e., T_L or viscosity) and not a durability related issue.

8.0 References

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Appendix A

Tables and Exhibits Supporting the Review of the Chemical Composition Measurements

Table A1. Targeted Oxide Concentrations (as wt%'s) for the HTL Study Glasses

Glass ID	WL	Al2O3	B2O3	CaO	Cr2O3	CuO	Fe2O3	K2O	Li2O	MgO	MnO	Na2O	NiO	SO4	SiO2	TiO2	ZrO2	Total
HTLG-53	50	7.77	4.50	1.41	0.13	0.05	20.52	0.22	3.00	2.16	3.19	12.38	0.84	0.47	43.22	0.04	0.12	100.00
HTLG-54	50	7.61	4.50	1.91	0.06	0.03	18.01	0.12	3.00	2.16	3.19	14.79	1.09	0.25	43.22	0.02	0.06	100.00
HTLG-55	50	9.30	4.50	1.91	0.13	0.05	16.79	0.22	3.00	2.16	3.19	14.58	0.84	0.47	42.72	0.04	0.12	100.00
HTLG-56	50	7.61	4.50	1.91	0.13	0.05	18.76	0.22	3.00	1.66	3.19	14.79	0.84	0.47	42.72	0.04	0.12	100.00
HTLG-57	50	9.30	4.50	1.41	0.06	0.03	20.24	0.12	3.00	1.66	3.19	12.38	1.09	0.25	42.72	0.02	0.06	100.00
HTLG-58	50	7.61	4.50	1.41	0.13	0.05	17.80	0.22	3.00	2.16	3.90	14.79	1.09	0.47	42.72	0.04	0.12	100.00
HTLG-59	50	7.61	4.50	1.91	0.06	0.03	20.47	0.12	3.00	2.16	3.90	12.38	0.84	0.25	42.72	0.02	0.06	100.00
HTLG-60	50	9.30	4.50	1.91	0.13	0.05	18.03	0.22	3.00	1.66	3.90	12.38	1.09	0.47	43.22	0.04	0.12	100.00
HTLG-61	50	9.30	4.50	1.41	0.06	0.03	16.86	0.12	3.00	1.66	3.90	14.79	0.84	0.25	43.22	0.02	0.06	100.00
HTLG-62	50	8.05	4.50	1.41	0.13	0.05	18.88	0.22	3.00	1.66	3.72	14.19	0.84	0.47	42.72	0.04	0.12	100.00
HTLG-63	50	8.87	4.50	1.41	0.06	0.03	19.58	0.12	3.00	2.16	3.37	13.03	0.84	0.25	42.72	0.02	0.06	100.00
HTLG-64	50	8.03	4.50	1.91	0.06	0.03	18.77	0.12	3.00	1.66	3.37	14.19	0.84	0.25	43.22	0.02	0.06	100.00
HTLG-65	50	8.87	4.50	1.86	0.13	0.05	17.72	0.22	3.00	1.66	3.37	14.19	1.09	0.47	42.72	0.04	0.12	100.00
HTLG-66	50	8.03	4.50	1.41	0.13	0.05	18.02	0.22	3.00	2.16	3.37	14.19	1.09	0.47	43.22	0.04	0.12	100.00
HTLG-67	50	8.87	4.50	1.91	0.13	0.05	17.77	0.22	3.00	2.16	3.72	12.98	0.84	0.47	43.22	0.04	0.12	100.00
HTLG-68	50	8.87	4.50	1.41	0.06	0.03	19.02	0.12	3.00	1.66	3.72	12.98	1.09	0.25	43.22	0.02	0.06	100.00
HTLG-69	50	8.03	4.50	1.91	0.13	0.05	19.58	0.22	3.00	1.80	3.37	12.98	1.09	0.47	42.72	0.04	0.12	100.00
HTLG-70	50	8.03	4.50	1.91	0.06	0.03	18.16	0.12	3.00	2.16	3.72	14.19	1.09	0.25	42.72	0.02	0.06	100.00
HTLG-71	52	8.38	4.32	1.46	0.13	0.05	19.64	0.23	2.88	1.72	3.87	14.64	0.87	0.49	41.15	0.04	0.12	100.00
HTLG-72	52	9.23	4.32	1.46	0.07	0.03	20.37	0.12	2.88	2.24	3.50	13.43	0.87	0.26	41.15	0.02	0.06	100.00
HTLG-73	52	8.35	4.32	1.98	0.07	0.03	19.52	0.12	2.88	1.72	3.50	14.64	0.87	0.26	41.67	0.02	0.06	100.00
HTLG-74	52	9.23	4.32	1.93	0.13	0.05	18.43	0.23	2.88	1.72	3.50	14.64	1.13	0.49	41.15	0.04	0.12	100.00
HTLG-75	52	8.35	4.32	1.46	0.13	0.05	18.74	0.23	2.88	2.24	3.50	14.64	1.13	0.49	41.67	0.04	0.12	100.00
HTLG-76	52	9.23	4.32	1.98	0.13	0.05	18.48	0.23	2.88	2.24	3.87	13.38	0.87	0.49	41.67	0.04	0.12	100.00
HTLG-77	52	9.23	4.32	1.46	0.07	0.03	19.78	0.12	2.88	1.72	3.87	13.38	1.13	0.26	41.67	0.02	0.06	100.00
HTLG-78	52	8.35	4.32	1.98	0.13	0.05	20.37	0.23	2.88	1.87	3.50	13.38	1.13	0.49	41.15	0.04	0.12	100.00
HTLG-79	52	8.35	4.32	1.98	0.07	0.03	18.89	0.12	2.88	2.24	3.87	14.64	1.13	0.26	41.15	0.02	0.06	100.00

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

Glass ID	Block	Sub-Block	Sequence	Lab ID	Al (wt%)	Ca (wt%)	Cr (wt%)	Cu (wt%)	K (wt%)	Mg (wt%)	Mn (wt%)	Na (wt%)	Ni (wt%)	S (wt%)	Ti (wt%)	Zr (wt%)
Batch 1	1	1	1	BCHLM1111	2.65	0.873	0.079	0.314	2.54	0.830	1.40	7.24	0.529	0.022	0.372	0.066
HTLG-57VS	1	1	2	P06LM21	5.02	1.04	0.039	0.024	0.088	0.941	2.52	9.27	0.717	0.085	0.017	0.049
HTLG-66VS	1	1	3	P11LM11	4.77	1.42	0.073	0.042	0.207	0.916	2.62	10.5	0.749	0.147	0.027	0.079
HTLG-65VS	1	1	4	P08LM21	4.35	1.05	0.076	0.042	0.179	1.22	2.71	10.5	0.773	0.146	0.029	0.087
HTLG-64VS	1	1	5	P05LM11	4.35	1.47	0.047	0.024	0.097	0.934	2.65	10.6	0.597	0.088	0.016	0.054
HTLG-60VS	1	1	6	P01LM21	5.06	1.48	0.079	0.047	0.205	0.953	3.03	9.42	0.803	0.149	0.027	0.086
HTLG-61VS	1	1	7	P03LM21	5.04	1.07	0.045	0.023	0.093	0.942	3.06	11.0	0.606	0.089	0.015	0.049
HTLG-61VS	1	1	8	P03LM11	5.02	1.07	0.044	0.022	0.094	0.927	3.00	11.0	0.601	0.087	0.015	0.046
Batch 1	1	1	9	BCHLM1112	2.69	0.867	0.080	0.313	2.53	0.833	1.39	7.39	0.529	0.026	0.369	0.065
HTLG-64VS	1	1	10	P05LM21	4.37	1.48	0.046	0.023	0.098	0.915	2.52	10.7	0.579	0.089	0.016	0.049
HTLG-63VS	1	1	11	P13LM21	4.85	1.09	0.038	0.023	0.098	1.17	2.54	9.93	0.543	0.088	0.016	0.052
HTLG-60VS	1	1	12	P01LM11	5.18	1.53	0.078	0.042	0.199	0.934	3.02	10.2	0.755	0.154	0.026	0.083
HTLG-57VS	1	1	13	P06LM11	5.08	1.08	0.041	0.023	0.093	0.941	2.37	9.53	0.725	0.090	0.016	0.049
HTLG-66VS	1	1	14	P11LM21	4.94	1.49	0.072	0.041	0.207	0.903	2.49	11.0	0.735	0.147	0.027	0.077
HTLG-65VS	1	1	15	P08LM11	4.41	1.09	0.074	0.042	0.185	1.21	2.52	10.7	0.744	0.155	0.028	0.086
HTLG-63VS	1	1	16	P13LM11	4.82	1.08	0.039	0.022	0.089	1.19	2.50	10.1	0.570	0.086	0.016	0.048
Batch 1	1	1	17	BCHLM1113	2.69	0.851	0.081	0.310	2.50	0.852	1.32	7.51	0.541	0.024	0.371	0.065
Batch 1	1	2	1	BCHLM1121	2.63	0.865	0.077	0.310	2.50	0.845	1.35	7.18	0.535	0.022	0.369	0.064
HTLG-66VS	1	2	2	P11LM22	4.76	1.41	0.070	0.040	0.211	0.908	2.67	10.3	0.744	0.147	0.025	0.076
HTLG-64VS	1	2	3	P05LM22	4.35	1.47	0.043	0.022	0.103	0.925	2.64	10.4	0.589	0.088	0.013	0.048
HTLG-65VS	1	2	4	P08LM22	4.31	1.05	0.073	0.041	0.182	1.23	2.66	10.3	0.781	0.154	0.026	0.086
HTLG-57VS	1	2	5	P06LM12	4.98	1.06	0.037	0.022	0.099	0.927	2.49	9.13	0.719	0.089	0.014	0.047
HTLG-61VS	1	2	6	P03LM12	4.98	1.07	0.042	0.022	0.101	0.941	3.06	10.9	0.611	0.092	0.013	0.045
HTLG-57VS	1	2	7	P06LM22	5.04	1.08	0.036	0.023	0.092	0.951	2.45	9.29	0.725	0.088	0.014	0.047
HTLG-61VS	1	2	8	P03LM22	4.96	1.06	0.043	0.022	0.096	0.952	3.06	10.8	0.617	0.090	0.013	0.047
Batch 1	1	2	9	BCHLM1123	2.62	0.866	0.079	0.313	2.52	0.861	1.31	7.09	0.548	0.024	0.374	0.064
HTLG-63VS	1	2	10	P13LM22	4.81	1.07	0.036	0.022	0.101	1.20	2.68	9.75	0.559	0.093	0.015	0.051
HTLG-60VS	1	2	11	P01LM12	4.97	1.47	0.075	0.041	0.201	0.937	3.02	9.67	0.751	0.147	0.024	0.081
HTLG-64VS	1	2	12	P05LM12	4.30	1.46	0.044	0.023	0.099	0.941	2.65	10.5	0.597	0.091	0.014	0.053
HTLG-60VS	1	2	13	P01LM22	4.95	1.44	0.078	0.047	0.212	0.967	3.12	9.18	0.813	0.151	0.025	0.084
HTLG-63VS	1	2	14	P13LM12	4.72	1.05	0.037	0.022	0.094	1.22	2.66	9.68	0.577	0.092	0.014	0.047
HTLG-65VS	1	2	15	P08LM12	4.35	1.07	0.072	0.042	0.189	1.23	2.61	10.5	0.751	0.151	0.026	0.085
HTLG-66VS	1	2	16	P11LM12	4.80	1.45	0.071	0.042	0.212	0.934	2.51	10.6	0.759	0.149	0.025	0.079
Batch 1	1	2	17	BCHLM1123	2.64	0.887	0.079	0.324	2.54	0.857	1.30	7.29	0.543	0.023	0.380	0.065
Batch 1	2	1	1	BCHLM1211	2.63	0.855	0.077	0.310	2.45	0.828	1.29	7.17	0.526	0.024	0.368	0.064
HTLG-62VS	2	1	2	P07LM21	4.29	1.06	0.075	0.043	0.189	0.942	2.82	10.2	0.604	0.149	0.025	0.085
HTLG-59VS	2	1	3	P14LM21	4.09	1.46	0.038	0.025	0.102	1.15	2.93	8.96	0.558	0.090	0.014	0.051
HTLG-58VS	2	1	4	P09LM21	4.08	1.06	0.076	0.044	0.179	1.24	2.93	10.5	0.797	0.166	0.026	0.082
HTLG-56VS	2	1	5	P12LM11	4.07	1.46	0.077	0.044	0.197	0.932	2.33	10.6	0.589	0.153	0.026	0.085
HTLG-55VS	2	1	6	P04LN11	5.01	1.46	0.097	0.046	0.191	1.15	2.36	10.3	0.589	0.147	0.025	0.090
HTLG-53VS	2	1	7	P02LM11	4.11	1.05	0.062	0.146	0.179	1.19	2.40	8.78	0.575	0.144	0.027	0.089
HTLG-56VS	2	1	8	P12LM21	4.09	1.46	0.076	0.043	0.213	0.903	2.37	10.6	0.561	0.147	0.024	0.084
Batch 1	2	1	9	BCHLM1212	2.61	0.858	0.077	0.314	2.48	0.840	1.29	7.00	0.526	0.019	0.369	0.065
HTLG-54VS	2	1	10	P10LM21	4.06	1.45	0.040	0.036	0.103	1.15	2.34	10.5	0.739	0.087	0.017	0.046
HTLG-54VS	2	1	11	P10LM11	4.04	1.43	0.042	0.036	0.091	1.20	2.43	10.4	0.776	0.085	0.018	0.047
HTLG-59VS	2	1	12	P14LM11	4.12	1.47	0.038	0.025	0.102	1.17	3.02	8.97	0.570	0.084	0.015	0.046

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

Glass ID	Block	Sub-Block	Sequence	Lab ID	Al (wt%)	Ca (wt%)	Cr (wt%)	Cu (wt%)	K (wt%)	Mg (wt%)	Mn (wt%)	Na (wt%)	Ni (wt%)	S (wt%)	Ti (wt%)	Zr (wt%)
HTLG-55VS	2	1	13	P04LM21	5.00	1.45	0.092	0.045	0.199	1.14	2.49	10.3	0.564	0.149	0.026	0.086
HTLG-62VS	2	1	14	P07LM11	4.39	1.05	0.075	0.047	0.230	0.923	3.00	10.3	0.643	0.148	0.024	0.086
HTLG-58VS	2	1	15	P09LM11	4.10	1.05	0.073	0.044	0.208	1.15	3.09	10.5	0.739	0.143	0.025	0.080
HTLG-53VS	2	1	16	P02LM21	4.13	1.04	0.060	0.147	0.197	1.15	2.52	8.85	0.551	0.144	0.027	0.090
Batch 1	2	1	17	BCHLM1213	2.61	0.884	0.073	0.310	2.52	0.821	1.34	6.96	0.508	0.025	0.369	0.065
Batch 1	2	2	1	BCHLM1221	2.61	0.882	0.076	0.318	2.51	0.824	1.38	7.07	0.522	0.016	0.370	0.065
HTLG-62VS	2	2	2	P07LM22	4.33	1.06	0.071	0.041	0.193	0.925	2.98	10.4	0.588	0.141	0.025	0.084
HTLG-58VS	2	2	3	P09LM22	4.11	1.06	0.076	0.043	0.185	1.21	3.20	10.7	0.787	0.163	0.027	0.082
HTLG-58VS	2	2	4	P09LM12	4.14	1.06	0.072	0.042	0.207	1.14	3.17	10.9	0.739	0.142	0.025	0.079
HTLG-56VS	2	2	5	P12LM12	4.09	1.44	0.076	0.043	0.205	0.923	2.66	10.7	0.586	0.150	0.026	0.085
HTLG-55VS	2	2	6	P04LM22	5.04	1.44	0.092	0.044	0.200	1.14	2.70	10.5	0.563	0.143	0.026	0.086
HTLG-59VS	2	2	7	P14LM12	4.18	1.48	0.037	0.024	0.105	1.15	3.25	9.28	0.566	0.088	0.015	0.046
HTLG-54VS	2	2	8	P10LM22	4.14	1.46	0.039	0.036	0.108	1.12	2.60	10.8	0.725	0.082	0.017	0.045
Batch 1	2	2	9	BCHLM1222	2.65	0.874	0.075	0.310	2.50	0.805	1.41	7.15	0.513	0.017	0.366	0.063
HTLG-53VS	2	2	10	P02LM22	4.22	1.06	0.059	0.145	0.199	1.15	2.64	9.22	0.553	0.140	0.027	0.090
HTLG-56VS	2	2	11	P12LM22	4.14	1.45	0.075	0.042	0.220	0.878	2.71	10.9	0.553	0.138	0.025	0.083
HTLG-55VS	2	2	12	P04LM12	5.11	1.45	0.096	0.045	0.199	1.13	2.79	10.6	0.583	0.139	0.026	0.091
HTLG-59VS	2	2	13	P14LM22	4.15	1.46	0.037	0.024	0.105	1.13	3.31	9.27	0.546	0.080	0.014	0.051
HTLG-54VS	2	2	14	P10LM12	4.17	1.46	0.041	0.035	0.092	1.18	2.71	10.9	0.765	0.083	0.018	0.047
HTLG-53VS	2	2	15	P02LM12	4.21	1.06	0.061	0.145	0.181	1.17	2.74	9.21	0.563	0.138	0.027	0.087
HTLG-62VS	2	2	16	P07LM12	4.46	1.06	0.074	0.045	0.227	0.918	3.23	10.7	0.637	0.139	0.024	0.085
Batch 1	2	2	17	BCHLM1223	2.68	0.865	0.075	0.310	2.47	0.827	1.48	7.19	0.519	0.018	0.368	0.064

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

Glass ID	Block	Sub-Block	Sequence	Lab ID	B (wt%)	Fe (wt%)	Li (wt%)	Si (wt%)
Batch 1	1	1	1	BCHPF1111	2.54	8.96	2.06	22.3
HTLG-65VS	1	1	2	P08PF11	1.37	11.6	1.39	19.8
HTLG-62VS	1	1	3	P07PF11	1.37	12.2	1.38	19.6
HTLG-63VS	1	1	4	P13PF21	1.38	12.9	1.35	19.4
HTLG-65VS	1	1	5	P08PF21	1.35	11.3	1.38	19.6
HTLG-54VS	1	1	6	P10PF11	1.35	11.4	1.35	19.5
HTLG-61VS	1	1	7	P03PF11	1.35	10.7	1.36	19.5
HTLG-56VS	1	1	8	P12PF11	1.34	11.9	1.45	19.2
Batch 1	1	1	9	BCHPF1112	2.37	8.56	2.04	22.1
HTLG-62VS	1	1	10	P07PF21	1.42	12.1	1.38	19.5
HTLG-60VS	1	1	11	P01PF21	1.43	11.8	1.38	19.9
HTLG-60VS	1	1	12	P01PF11	1.41	11.7	1.37	19.8
HTLG-56VS	1	1	13	P12PF21	1.37	11.9	1.48	19.5
HTLG-63VS	1	1	14	P13PF11	1.37	12.4	1.39	19.5
HTLG-54VS	1	1	15	P10PF21	1.4	11.9	1.38	20.1
HTLG-61VS	1	1	16	P03PF21	1.4	11.3	1.37	20
Batch 1	1	1	17	BCHPF1113	2.39	8.54	2.05	22.3
Batch 1	1	2	1	BCHPF1121	2.56	9.31	2.05	23
HTLG-62VS	1	2	2	P07PF12	1.44	12.7	1.38	20.1
HTLG-54VS	1	2	3	P10PF22	1.42	12.4	1.36	20.2
HTLG-56VS	1	2	4	P12PF12	1.41	12.7	1.46	19.9
HTLG-54VS	1	2	5	P10PF12	1.39	12.3	1.37	20.1
HTLG-65VS	1	2	6	P08PF12	1.39	11.9	1.4	20.2
HTLG-60VS	1	2	7	P01PF22	1.46	12.9	1.4	20.7
HTLG-63VS	1	2	8	P13PF22	1.41	13.7	1.37	20.1
Batch 1	1	2	9	BCHPF1123	2.45	9.16	2.05	23
HTLG-63VS	1	2	10	P13PF12	1.4	12.5	1.39	19.9
HTLG-65VS	1	2	11	P08PF22	1.4	11.9	1.4	20.2
HTLG-60VS	1	2	12	P01PF12	1.45	12.6	1.39	20.6
HTLG-56VS	1	2	13	P12PF22	1.38	12.5	1.48	20.1
HTLG-62VS	1	2	14	P07PF22	1.4	12.9	1.38	20.1
HTLG-61VS	1	2	15	P03PF22	1.39	11.7	1.36	20.3
HTLG-61VS	1	2	16	P03PF12	1.37	11.3	1.37	20.1
Batch 1	1	2	17	BCHPF1123	2.39	8.86	2.05	22.4
Batch 1	2	1	1	BCHPF1211	2.56	8.98	2.05	23
HTLG-66VS	2	1	2	P11PF21	1.45	12.1	1.35	19.9
HTLG-66VS	2	1	3	P11PF11	1.38	11.6	1.35	19.6
HTLG-59VS	2	1	4	P14PF21	1.4	13.8	1.37	20
HTLG-57VS	2	1	5	P06PF11	1.4	13.4	1.38	20
HTLG-64VS	2	1	6	P05PF11	1.39	12.8	1.37	20.3
HTLG-59VS	2	1	7	P14PF11	1.4	14.1	1.36	20.1
HTLG-58VS	2	1	8	P09PF11	1.39	12.1	1.35	20.1
Batch 1	2	1	9	BCHPF1212	2.44	9.09	2.05	22.8
HTLG-64VS	2	1	10	P05PF21	1.36	12	1.37	20.1
HTLG-55VS	2	1	11	P04PF21	1.42	11.9	1.36	20.1
HTLG-53VS	2	1	12	P02PF21	1.41	14.4	1.36	20.4
HTLG-57VS	2	1	13	P06PF21	1.37	13.4	1.38	20.1
HTLG-58VS	2	1	14	P09PF21	1.4	12.3	1.35	20
HTLG-53VS	2	1	15	P02PF11	1.4	14.3	1.36	20.4
HTLG-55VS	2	1	16	P04PF11	1.39	11.7	1.37	20.1
Batch 1	2	1	17	BCHPF1213	2.43	9.12	2.03	22.9
Batch 1	2	2	1	BCHPF1221	2.71	9.95	2.22	24.8
HTLG-57VS	2	2	2	P06PF22	1.45	13.8	1.38	20.4
HTLG-58VS	2	2	3	P09PF22	1.44	12.6	1.35	20.2
HTLG-64VS	2	2	4	P05PF22	1.35	12.3	1.39	20.4
HTLG-57VS	2	2	5	P06PF12	1.39	13.7	1.38	20.2
HTLG-58VS	2	2	6	P09PF12	1.39	12.2	1.36	20.1
HTLG-55VS	2	2	7	P04PF22	1.39	11.9	1.37	20.2

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

Glass ID	Block	Sub-Block	Sequence	Lab ID	B (wt%)	Fe (wt%)	Li (wt%)	Si (wt%)
HTLG-53VS	2	2	8	P02PF22	1.39	14.5	1.37	20.8
Batch 1	2	2	9	BCHPF1222	2.43	9.26	2.06	23.2
HTLG-66VS	2	2	10	P11PF12	1.38	11.9	1.35	19.9
HTLG-59VS	2	2	11	P14PF12	1.37	14	1.35	20
HTLG-66VS	2	2	12	P11PF22	1.38	12.3	1.37	20.2
HTLG-64VS	2	2	13	P05PF12	1.35	12.7	1.38	20.5
HTLG-55VS	2	2	14	P04PF12	1.4	12.1	1.37	20.4
HTLG-53VS	2	2	15	P02PF12	1.36	14.3	1.36	20.3
HTLG-59VS	2	2	16	P14PF22	1.34	13.5	1.37	20
Batch 1	2	2	17	BCHPF1223	2.23	8.69	1.88	21.4

Table A4. Measured Elemental Concentrations (wt%) for Series "Q" Samples Prepared Using Lithium Metaborate

Glass ID	Block Sub-Blk	Sequence	Lab ID	Al (wt%)	Ca (wt%)	Cr (wt%)	Cu (wt%)	K (wt%)	Mg (wt%)	Mn (wt%)	Na (wt%)	Ni (wt%)	S (wt%)	Si (wt%)	Ti (wt%)	Zr (wt%)
Batch 1	1-1	1	BCHLM1111	2.64	0.885	0.078	0.315	2.54	0.871	1.33	7.13	0.544	0.015	22.4	0.380	0.063
HTLG-72VS	1-1	2	Q02LM11	4.95	1.10	0.042	0.025	0.098	1.28	2.90	9.83	0.581	0.087	18.9	0.014	0.047
HTLG-77VS	1-1	3	Q09LM21	5.00	1.11	0.037	0.024	0.105	0.963	3.22	10.0	0.750	0.091	19.3	0.015	0.052
HTLG-73VS	1-1	4	Q05LM11	4.46	1.52	0.041	0.024	0.112	0.944	2.82	10.8	0.599	0.084	18.8	0.014	0.044
HTLG-69VS	1-1	5	Q10LM21	4.34	1.48	0.067	0.043	0.197	1.02	2.73	9.65	0.751	0.137	19.5	0.024	0.083
HTLG-69VS	1-1	6	Q10LM11	4.34	1.47	0.066	0.041	0.195	1.02	2.72	9.67	0.741	0.136	19.5	0.024	0.083
HTLG-72VS	1-1	7	Q02LM21	4.91	1.09	0.041	0.026	0.102	1.25	2.81	9.96	0.579	0.086	18.6	0.014	0.047
HTLG-77VS	1-1	8	Q09LM11	5.00	1.12	0.038	0.027	0.115	0.964	3.10	10.0	0.794	0.086	18.9	0.014	0.045
Batch 1	1-1	9	BCHLM1112	2.64	0.875	0.075	0.308	2.47	0.852	1.34	7.15	0.528	0.013	22.6	0.374	0.061
HTLG-68VS	1-1	10	Q04LM21	4.70	1.04	0.037	0.028	0.093	0.941	2.87	9.46	0.740	0.081	19.0	0.014	0.044
HTLG-78VS	1-1	11	Q08LM21	4.47	1.51	0.070	0.045	0.205	1.02	2.77	9.76	0.764	0.137	18.4	0.025	0.083
HTLG-73VS	1-1	12	Q05LM21	4.43	1.51	0.042	0.023	0.099	0.983	2.72	10.7	0.607	0.087	18.4	0.014	0.047
HTLG-68VS	1-1	13	Q04LM11	4.72	1.06	0.039	0.023	0.093	0.953	2.89	9.53	0.757	0.088	18.9	0.013	0.045
HTLG-79VS	1-1	14	Q13LM11	4.55	1.56	0.040	0.029	0.113	1.22	2.97	11.1	0.751	0.084	18.3	0.014	0.042
HTLG-79VS	1-1	15	Q13LM21	4.47	1.51	0.039	0.027	0.114	1.22	3.07	10.6	0.751	0.088	18.3	0.014	0.044
HTLG-78VS	1-1	16	Q08LM11	4.44	1.48	0.071	0.046	0.202	1.04	2.78	9.85	0.769	0.133	18.3	0.025	0.086
Batch 1	1-1	17	BCHLM1113	2.60	0.875	0.076	0.310	2.47	0.847	1.35	7.06	0.526	0.018	22.2	0.370	0.062
Batch 1	1-2	1	BCHLM1121	2.62	0.868	0.077	0.309	2.48	0.836	1.36	7.07	0.522	0.020	22.2	0.366	0.065
HTLG-68VS	1-2	2	Q04LM22	4.71	1.04	0.039	0.028	0.092	0.939	2.87	9.41	0.735	0.085	19.0	0.014	0.048
HTLG-69VS	1-2	3	Q10LM12	4.33	1.46	0.066	0.040	0.193	0.985	2.59	9.61	0.723	0.137	18.8	0.023	0.086
HTLG-73VS	1-2	4	Q05LM12	4.46	1.51	0.042	0.023	0.106	0.942	2.68	10.7	0.590	0.088	18.3	0.014	0.049
HTLG-72VS	1-2	5	Q02LM22	4.94	1.10	0.041	0.024	0.096	1.22	2.66	10.0	0.565	0.084	18.1	0.014	0.050
HTLG-79VS	1-2	6	Q13LM22	4.50	1.53	0.039	0.027	0.111	1.19	3.04	10.7	0.736	0.085	18.2	0.014	0.047
HTLG-77VS	1-2	7	Q09LM12	5.05	1.12	0.039	0.026	0.111	0.955	3.08	10.1	0.783	0.088	18.8	0.014	0.049
HTLG-78VS	1-2	8	Q08LM22	4.51	1.52	0.071	0.044	0.203	1.02	2.77	9.89	0.753	0.133	18.5	0.025	0.088
Batch 1	1-2	9	BCHLM1123	2.62	0.875	0.075	0.310	2.49	0.819	1.35	7.17	0.515	0.015	22.2	0.368	0.067
HTLG-68VS	1-2	10	Q04LM12	4.74	1.05	0.040	0.022	0.094	0.933	2.91	9.57	0.738	0.082	19.0	0.014	0.047
HTLG-79VS	1-2	11	Q13LM12	4.57	1.57	0.039	0.028	0.115	1.18	2.95	11.1	0.731	0.086	18.4	0.014	0.045
HTLG-72VS	1-2	12	Q02LM12	4.95	1.11	0.040	0.025	0.099	1.21	2.67	9.98	0.552	0.084	18.1	0.014	0.051
HTLG-69VS	1-2	13	Q10LM22	4.35	1.48	0.066	0.042	0.196	0.993	2.63	9.71	0.730	0.135	19.0	0.024	0.087
HTLG-73VS	1-2	14	Q05LM22	4.49	1.53	0.042	0.023	0.104	0.948	2.67	10.9	0.591	0.089	18.3	0.014	0.049
HTLG-78VS	1-2	15	Q08LM12	4.53	1.53	0.070	0.046	0.205	1.02	2.70	10.2	0.752	0.133	18.2	0.025	0.089
HTLG-77VS	1-2	16	Q09LM22	4.98	1.10	0.038	0.024	0.105	0.938	2.97	10.1	0.729	0.084	18.4	0.014	0.057
Batch 1	1-2	17	BCHLM1123	2.63	0.879	0.075	0.308	2.50	0.826	1.28	7.18	0.511	0.019	21.8	0.368	0.065
Batch 1	2-1	1	BCHLM1211	2.64	0.868	0.077	0.312	2.47	0.838	1.33	7.18	0.522	0.024	22.1	0.368	0.068
HTLG-71VS	2-1	2	Q11LM21	4.54	1.10	0.086	0.050	0.216	0.980	3.08	10.8	0.002	0.142	18.3	0.027	0.091
HTLG-70VS	2-1	3	Q06LM11	4.26	1.43	0.038	0.025	0.102	1.19	2.91	10.5	0.746	0.083	18.7	0.015	0.050
HTLG-67VS	2-1	4	Q12LM11	4.79	1.46	0.069	0.046	0.205	1.17	2.97	9.64	0.558	0.140	19.3	0.025	0.088
HTLG-67VS	2-1	5	Q12LM21	4.76	1.44	0.069	0.046	0.207	1.16	2.97	9.60	0.565	0.141	19.2	0.025	0.088
HTLG-75VS	2-1	6	Q03LM11	4.54	1.11	0.072	0.046	0.203	1.23	2.84	10.8	0.758	0.129	18.7	0.027	0.088
HTLG-71VS	2-1	7	Q11LM11	4.59	1.12	0.087	0.049	0.208	0.974	3.14	11.1	0.002	0.148	18.5	0.027	0.090
HTLG-70VS	2-1	8	Q06LM21	4.32	1.48	0.038	0.036	0.098	1.19	2.80	10.7	0.761	0.084	18.6	0.014	0.052
Batch 1	2-1	9	BCHLM1212	2.62	0.883	0.076	0.315	2.49	0.833	1.35	7.23	0.519	0.021	22.0	0.371	0.069
HTLG-76VS	2-1	10	Q01LM11	5.05	1.60	0.078	0.046	0.209	1.21	2.90	10.2	0.576	0.143	18.1	0.027	0.093
HTLG-75VS	2-1	11	Q03LM21	4.55	1.11	0.075	0.047	0.204	1.23	2.74	11.0	0.790	0.124	18.4	0.027	0.086

Table A4. Measured Elemental Concentrations (wt%) for Series "Q" Samples Prepared Using Lithium Metaborate

Glass ID	Block Sub-Blk	Sequence	Lab ID	Al (wt%)	Ca (wt%)	Cr (wt%)	Cu (wt%)	K (wt%)	Mg (wt%)	Mn (wt%)	Na (wt%)	Ni (wt%)	S (wt%)	Si (wt%)	Ti (wt%)	Zr (wt%)
HTLG-74VS	2-1	12	Q07LM11	5.02	1.51	0.072	0.050	0.227	0.952	2.74	11.0	0.763	0.133	18.3	0.025	0.087
HTLG-74VS	2-1	13	Q07LM21	5.01	1.49	0.073	0.049	0.218	0.972	2.78	10.9	0.779	0.134	18.4	0.026	0.091
HTLG-76VS	2-1	14	Q01LM21	5.00	1.54	0.076	0.047	0.211	1.23	3.00	10.0	0.578	0.143	18.5	0.027	0.093
Batch 1	2-1	15	BCHLM1213	2.67	0.874	0.077	0.312	2.49	0.835	1.33	7.29	0.520	0.020	22.1	0.368	0.069
Batch 1	2-2	1	BCHLM1221	2.62	0.878	0.077	0.314	2.51	0.831	1.33	7.04	0.524	0.022	22.2	0.367	0.068
HTLG-67VS	2-2	2	Q12LM22	4.77	1.47	0.070	0.045	0.206	1.17	2.86	9.63	0.570	0.139	19.1	0.025	0.086
HTLG-76VS	2-2	3	Q01LM22	4.93	1.55	0.076	0.046	0.209	1.22	2.93	9.91	0.583	0.142	18.1	0.027	0.092
HTLG-70VS	2-2	4	Q06LM12	4.22	1.45	0.037	0.025	0.102	1.18	2.77	10.3	0.743	0.087	18.4	0.014	0.049
HTLG-71VS	2-2	5	Q11LM12	4.54	1.13	0.086	0.048	0.210	0.981	3.08	10.8	0.002	0.146	18.3	0.027	0.089
HTLG-75VS	2-2	6	Q03LM12	4.50	1.12	0.073	0.046	0.204	1.24	2.75	10.6	0.765	0.128	18.4	0.027	0.089
HTLG-75VS	2-2	7	Q03LM22	4.49	1.11	0.076	0.047	0.205	1.24	2.85	10.7	0.797	0.122	18.6	0.027	0.087
HTLG-67VS	2-2	8	Q12LM12	4.74	1.46	0.069	0.045	0.204	1.16	2.87	9.52	0.556	0.141	19.0	0.025	0.087
Batch 1	2-2	9	BCHLM1222	2.62	0.875	0.072	0.305	2.56	0.817	1.31	7.11	0.511	0.020	21.9	0.391	0.070
HTLG-74VS	2-2	10	Q07LM12	4.98	1.51	0.070	0.049	0.228	0.932	2.62	10.9	0.759	0.134	18.0	0.026	0.086
HTLG-71VS	2-2	11	Q11LM22	4.53	1.12	0.084	0.049	0.217	0.953	3.04	10.7	0.001	0.141	18.2	0.026	0.091
HTLG-70VS	2-2	12	Q06LM22	4.22	1.43	0.037	0.036	0.102	1.16	2.91	10.3	0.748	0.082	18.7	0.014	0.050
HTLG-74VS	2-2	13	Q07LM22	4.93	1.48	0.071	0.048	0.221	0.949	2.80	10.7	0.771	0.131	18.3	0.026	0.089
HTLG-76VS	2-2	14	Q01LM12	4.95	1.55	0.076	0.045	0.217	1.20	3.07	9.80	0.567	0.141	18.4	0.026	0.095
Batch 1	2-2	15	BCHLM1223	2.58	0.871	0.068	0.304	2.61	0.790	1.33	6.98	0.493	0.020	22.0	0.386	0.068

Table A5. Measured Elemental Concentrations (wt%) for Series "Q" Samples Prepared Using Peroxide Fusion

Glass ID	Block	Sub-Block	Sequence	Lab ID	B (wt%)	Fe (wt%)	Li (wt%)	Si (wt%)
Batch 1	1	1	1	BCHLM1111	2.51	8.94	2.04	22.9
HTLG-77VS	1	1	2	Q09PF21	1.37	12.9	1.32	20
HTLG-68VS	1	1	3	Q04PF21	1.39	12.4	1.36	20.1
HTLG-70VS	1	1	4	Q06PF21	1.41	12.5	1.35	20.1
HTLG-72VS	1	1	5	Q02PF21	1.35	13.4	1.33	19.6
HTLG-75VS	1	1	6	Q03PF11	1.29	11.5	1.3	19
HTLG-75VS	1	1	7	Q03PF21	1.29	11.6	1.3	19.3
HTLG-74VS	1	1	8	Q07PF21	1.25	11	1.28	18.5
Batch 1	1	1	9	BCHLM1112	2.3	8.31	1.98	21.9
HTLG-77VS	1	1	10	Q09PF11	1.31	11.9	1.28	19
HTLG-70VS	1	1	11	Q06PF11	1.36	11.8	1.32	19.3
HTLG-72VS	1	1	12	Q02PF11	1.26	12.3	1.28	18.6
HTLG-68VS	1	1	13	Q04PF11	1.32	11.8	1.34	19.7
HTLG-73VS	1	1	14	Q05PF21	1.29	12.5	1.29	19
HTLG-74VS	1	1	15	Q07PF11	1.27	11.2	1.29	18.7
HTLG-73VS	1	1	16	Q05PF11	1.27	12.1	1.29	19
Batch 1	1	1	17	BCHLM1113	2.27	8.09	1.99	22.1
Batch 1	1	2	1	BCHLM1121	2.51	8.95	2.07	22.5
HTLG-73VS	1	2	2	Q05PF12	1.33	13.5	1.36	19.4
HTLG-72VS	1	2	3	Q02PF12	1.34	13.3	1.35	19
HTLG-70VS	1	2	4	Q06PF22	1.4	12.4	1.38	19.9
HTLG-74VS	1	2	5	Q07PF12	1.27	12.4	1.32	18.6
HTLG-75VS	1	2	6	Q03PF12	1.33	12.1	1.37	19.6
HTLG-75VS	1	2	7	Q03PF22	1.32	11.9	1.38	19.7
HTLG-74VS	1	2	8	Q07PF22	1.3	11.8	1.37	19.3
Batch 1	1	2	9	BCHLM1123	2.34	8.52	2.06	22.6
HTLG-68VS	1	2	10	Q04PF22	1.42	12.6	1.45	20.4
HTLG-70VS	1	2	11	Q06PF12	1.4	12.4	1.41	20
HTLG-77VS	1	2	12	Q09PF22	1.31	12.3	1.37	19.4
HTLG-73VS	1	2	13	Q05PF22	1.31	12.8	1.38	19.6
HTLG-77VS	1	2	14	Q09PF12	1.32	12.6	1.38	19.7
HTLG-72VS	1	2	15	Q02PF22	1.33	13.4	1.39	19.5
HTLG-68VS	1	2	16	Q04PF12	1.38	12.8	1.44	20.5
Batch 1	1	2	17	BCHLM1123	2.43	8.96	2.14	23.4
Batch 1	2	1	1	BCHLM1211	2.5	9.01	2.06	22.7
HTLG-76VS	2	1	2	Q01PF11	1.35	13	1.35	19.9
HTLG-79VS	2	1	3	Q13PF21	1.36	12.1	1.31	19
HTLG-71VS	2	1	4	Q11PF11	1.35	12.7	1.38	19.7
HTLG-67VS	2	1	5	Q12PF11	1.4	11.8	1.41	20.1
HTLG-79VS	2	1	6	Q13PF11	1.35	11.9	1.38	19.7
HTLG-69VS	2	1	7	Q10PF11	1.41	13.1	1.42	20.3
HTLG-67VS	2	1	8	Q12PF21	1.38	11.9	1.42	20.3
Batch 1	2	1	9	BCHLM1212	2.48	9.37	2.12	23.5
HTLG-71VS	2	1	10	Q11PF21	1.39	13.4	1.38	19.8
HTLG-78VS	2	1	11	Q08PF11	1.37	13.7	1.35	19.6
HTLG-78VS	2	1	12	Q08PF21	1.39	14.1	1.36	19.7
HTLG-69VS	2	1	13	Q10PF21	1.42	13.3	1.42	20.4
HTLG-76VS	2	1	14	Q01PF21	1.37	12.7	1.37	20.1
Batch 1	2	1	15	BCHLM1213	2.48	9.45	2.11	23.6
Batch 1	2	2	1	BCHLM1221	2.54	9.07	2.04	23.4
HTLG-79VS	2	2	2	Q13PF22	1.34	12	1.26	19.2
HTLG-79VS	2	2	3	Q13PF12	1.35	11.9	1.33	19.8
HTLG-76VS	2	2	4	Q01PF12	1.3	13.1	1.26	19.5
HTLG-78VS	2	2	5	Q08PF22	1.35	13.9	1.31	19.9
HTLG-69VS	2	2	6	Q10PF22	1.38	13	1.36	20.4
HTLG-76VS	2	2	7	Q01PF22	1.34	12.7	1.31	20.2
HTLG-71VS	2	2	8	Q11PF22	1.33	13.5	1.33	20.1
Batch 1	2	2	9	BCHLM1222	2.45	9.29	2.04	23.5
HTLG-71VS	2	2	10	Q11PF12	1.38	13.4	1.35	20.3
HTLG-69VS	2	2	11	Q10PF12	1.42	13.4	1.37	20.7

**Table A5. Measured Elemental Concentrations (wt%)
for Series "Q" Samples Prepared Using Peroxide Fusion**

Glass ID	Block	Sub-Block	Sequence	Lab ID	B (wt%)	Fe (wt%)	Li (wt%)	Si (wt%)
HTLG-78VS	2	2	12	Q08PF12	1.31	13.3	1.31	19.7
HTLG-67VS	2	2	13	Q12PF22	1.34	11.6	1.37	20.4
HTLG-67VS	2	2	14	Q12PF12	1.35	11.9	1.38	20.4
Batch 1	2	2	15	BCHLM1223	2.37	8.92	2.05	23.4

Table A6. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide for the HTL Study Glasses

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas BC	% Diff of Measured	% Diff of Meas BC
Batch 1	Al2O3 (wt%)	4.9930	4.8770	4.8770	0.1160	0.0000	2.4%	0.0%
Batch 1	B2O3 (wt%)	7.9156	7.7770	7.7770	0.1386	0.0000	1.8%	0.0%
Batch 1	CaO (wt%)	1.2158	1.2200	1.2200	-0.0042	0.0000	-0.3%	0.0%
Batch 1	Cr2O3 (wt%)	0.1130	0.1070	0.1070	0.0060	0.0000	5.6%	0.0%
Batch 1	CuO (wt%)	0.3918	0.3990	0.3990	-0.0072	0.0000	-1.8%	0.0%
Batch 1	Fe2O3 (wt%)	12.9245	12.8390	12.8390	0.0855	0.0000	0.7%	0.0%
Batch 1	K2O (wt%)	3.0175	3.3270	3.3270	-0.3095	0.0000	-9.3%	0.0%
Batch 1	Li2O (wt%)	4.4117	4.4290	4.4290	-0.0173	0.0000	-0.4%	0.0%
Batch 1	MgO (wt%)	1.3851	1.4190	1.4190			-2.4%	0.0%
Batch 1	MnO (wt%)	1.7496	1.7260	1.7260	0.0236	0.0000	1.4%	0.0%
Batch 1	Na2O (wt%)	9.6876	9.0030	9.0030	0.6846	0.0000	7.6%	0.0%
Batch 1	NiO (wt%)	0.6722	0.7510	0.7510	-0.0788	0.0000	-10.5%	0.0%
Batch 1	SiO2 (wt%)	48.7047	50.2200	50.2200	-1.5153	0.0000	-3.0%	0.0%
Batch 1	SO4 (wt%)	0.0649	0.0649	0.0000	0.0649	0.0649		
Batch 1	TiO2 (wt%)	0.6179	0.6770	0.6770	-0.0591	0.0000	-8.7%	0.0%
Batch 1	ZrO2 (wt%)	0.0872	0.0872	0.0980	-0.0108	-0.0108	-11.0%	-11.0%
Batch 1	Oxide Sum (wt%)	97.9521	98.9232	98.8690	-0.9169	0.0542	-0.9%	0.1%
HTLG-53VS	Al2O3 (wt%)	7.8745	7.7230	7.7700	0.1045	-0.0470	1.3%	-0.6%
HTLG-53VS	B2O3 (wt%)	4.4757	4.3823	4.5000	-0.0243	-0.1177	-0.5%	-2.6%
HTLG-53VS	CaO (wt%)	1.4727	1.4765	1.4100	0.0627	0.0665	4.4%	4.7%
HTLG-53VS	Cr2O3 (wt%)	0.0884	0.0857	0.1300	-0.0416	-0.0443	-32.0%	-34.0%
HTLG-53VS	CuO (wt%)	0.1824	0.1864	0.0500	0.1324	0.1364	264.9%	272.8%
HTLG-53VS	Fe2O3 (wt%)	20.5519	20.1039	20.5200	0.0319	-0.4161	0.2%	-2.0%
HTLG-53VS	K2O (wt%)	0.2277	0.2527	0.2200	0.0077	0.0327	3.5%	14.9%
HTLG-53VS	Li2O (wt%)	2.9333	2.9461	3.0000	-0.0667	-0.0539	-2.2%	-1.8%
HTLG-53VS	MgO (wt%)	1.9319	2.0059	2.1600	-0.2281	-0.1541	-10.6%	-7.1%
HTLG-53VS	MnO (wt%)	3.3248	3.2557	3.1900	0.1348	0.0657	4.2%	2.1%
HTLG-53VS	Na2O (wt%)	12.1522	11.4462	12.3800	-0.2278	-0.9338	-1.8%	-7.5%
HTLG-53VS	NiO (wt%)	0.7132	0.8110	0.8400	-0.1268	-0.0290	-15.1%	-3.4%
HTLG-53VS	SiO2 (wt%)	43.8022	44.6747	43.2200	0.5822	1.4547	1.3%	3.4%
HTLG-53VS	SO4 (wt%)	0.4239	0.4239	0.4700	-0.0461	-0.0461	-9.8%	-9.8%
HTLG-53VS	TiO2 (wt%)	0.0450	0.0496	0.0400	0.0050	0.0096	12.6%	24.1%
HTLG-53VS	ZrO2 (wt%)	0.1202	0.1202	0.1200	0.0002	0.0002	0.2%	0.2%
HTLG-53VS	Oxide Sum (wt%)	100.3202	99.9438	100.0200	0.3002	-0.0762	0.3%	-0.1%
HTLG-54VS	Al2O3 (wt%)	7.7517	7.6024	7.6100	0.1417	-0.0076	1.9%	-0.1%
HTLG-54VS	B2O3 (wt%)	4.4757	4.4121	4.5000	-0.0243	-0.0879	-0.5%	-2.0%
HTLG-54VS	CaO (wt%)	2.0288	2.0341	1.9100	0.1188	0.1241	6.2%	6.5%
HTLG-54VS	Cr2O3 (wt%)	0.0592	0.0574	0.0600	-0.0008	-0.0026	-1.3%	-4.3%
HTLG-54VS	CuO (wt%)	0.0448	0.0457	0.0300	0.0148	0.0157	49.2%	52.4%
HTLG-54VS	Fe2O3 (wt%)	17.1564	17.3120	18.0100	-0.8536	-0.6980	-4.7%	-3.9%
HTLG-54VS	K2O (wt%)	0.1187	0.1317	0.1200	-0.0013	0.0117	-1.1%	9.7%
HTLG-54VS	Li2O (wt%)	2.9387	2.9491	3.0000	-0.0613	-0.0509	-2.0%	-1.7%
HTLG-54VS	MgO (wt%)	1.9278	2.0015	2.1600	-0.2322	-0.1585	-10.8%	-7.3%
HTLG-54VS	MnO (wt%)	3.2538	3.1850	3.1900	0.0638	-0.0050	2.0%	-0.2%
HTLG-54VS	Na2O (wt%)	14.3562	13.5225	14.7900	-0.4338	-1.2675	-2.9%	-8.6%
HTLG-54VS	NiO (wt%)	0.9560	1.0871	1.0900	-0.1340	-0.0029	-12.3%	-0.3%
HTLG-54VS	SiO2 (wt%)	42.7325	44.5533	43.2200	-0.4875	1.3333	-1.1%	3.1%
HTLG-54VS	SO4 (wt%)	0.2524	0.2524	0.2500	0.0024	0.0024	1.0%	1.0%
HTLG-54VS	TiO2 (wt%)	0.0292	0.0322	0.0200	0.0092	0.0122	46.0%	60.8%
HTLG-54VS	ZrO2 (wt%)	0.0625	0.0625	0.0600	0.0025	0.0025	4.1%	4.1%
HTLG-54VS	Oxide Sum (wt%)	98.1442	99.2409	100.0200	-1.8758	-0.7791	-1.9%	-0.8%
HTLG-55VS	Al2O3 (wt%)	9.5231	9.3401	9.3000	0.2231	0.0401	2.4%	0.4%
HTLG-55VS	B2O3 (wt%)	4.5079	4.4140	4.5000	0.0079	-0.0860	0.2%	-1.9%
HTLG-55VS	CaO (wt%)	2.0288	2.0342	1.9100	0.1188	0.1242	6.2%	6.5%
HTLG-55VS	Cr2O3 (wt%)	0.1378	0.1336	0.1300	0.0078	0.0036	6.0%	2.7%
HTLG-55VS	CuO (wt%)	0.0563	0.0575	0.0500	0.0063	0.0075	12.7%	15.1%
HTLG-55VS	Fe2O3 (wt%)	17.0134	16.6411	16.7900	0.2234	-0.1489	1.3%	-0.9%
HTLG-55VS	K2O (wt%)	0.2376	0.2637	0.2200	0.0176	0.0437	8.0%	19.9%
HTLG-55VS	Li2O (wt%)	2.9441	2.9569	3.0000	-0.0559	-0.0431	-1.9%	-1.4%
HTLG-55VS	MgO (wt%)	1.8905	1.9628	2.1600	-0.2695	-0.1972	-12.5%	-9.1%
HTLG-55VS	MnO (wt%)	3.3378	3.2660	3.1900	0.1478	0.0760	4.6%	2.4%
HTLG-55VS	Na2O (wt%)	14.0529	13.2374	14.5800	-0.5271	-1.3426	-3.6%	-9.2%
HTLG-55VS	NiO (wt%)	0.7314	0.8317	0.8400	-0.1086	-0.0083	-12.9%	-1.0%
HTLG-55VS	SiO2 (wt%)	43.2139	44.0743	42.7200	0.4939	1.3543	1.2%	3.2%
HTLG-55VS	SO4 (wt%)	0.4329	0.4329	0.4700	-0.0371	-0.0371	-7.9%	-7.9%
HTLG-55VS	TiO2 (wt%)	0.0430	0.0473	0.0400	0.0030	0.0073	7.4%	18.3%
HTLG-55VS	ZrO2 (wt%)	0.1192	0.1192	0.1200	-0.0008	-0.0008	-0.7%	-0.7%
HTLG-55VS	Oxide Sum (wt%)	100.2704	99.8126	100.0200	0.2504	-0.2074	0.3%	-0.2%

Table A6. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide for the HTL Study Glasses

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas BC	% Diff of Measured	% Diff of Meas BC
HTLG-56VS	Al2O3 (wt%)	7.7422	7.5935	7.6100	0.1322	-0.0165	1.7%	-0.2%
HTLG-56VS	B2O3 (wt%)	4.4274	4.3644	4.5000	-0.0726	-0.1356	-1.6%	-3.0%
HTLG-56VS	CaO (wt%)	2.0323	2.0377	1.9100	0.1223	0.1277	6.4%	6.7%
HTLG-56VS	Cr2O3 (wt%)	0.1111	0.1077	0.1300	-0.0189	-0.0223	-14.6%	-17.1%
HTLG-56VS	CuO (wt%)	0.0538	0.0550	0.0500	0.0038	0.0050	7.7%	10.0%
HTLG-56VS	Fe2O3 (wt%)	17.5138	17.6730	18.7600	-1.2462	-1.0870	-6.6%	-5.8%
HTLG-56VS	K2O (wt%)	0.2515	0.2791	0.2200	0.0315	0.0591	14.3%	26.9%
HTLG-56VS	Li2O (wt%)	3.1594	3.1705	3.0000	0.1594	0.1705	5.3%	5.7%
HTLG-56VS	MgO (wt%)	1.5074	1.5650	1.6600	-0.1526	-0.0950	-9.2%	-5.7%
HTLG-56VS	MnO (wt%)	3.2506	3.1801	3.1900	0.0606	-0.0099	1.9%	-0.3%
HTLG-56VS	Na2O (wt%)	14.4236	13.5868	14.7900	-0.3664	-1.2032	-2.5%	-8.1%
HTLG-56VS	NiO (wt%)	0.7282	0.8280	0.8400	-0.1118	-0.0120	-13.3%	-1.4%
HTLG-56VS	SiO2 (wt%)	42.0907	43.8799	42.7200	-0.6293	1.1599	-1.5%	2.7%
HTLG-56VS	SO4 (wt%)	0.4404	0.4404	0.4700	-0.0296	-0.0296	-6.3%	-6.3%
HTLG-56VS	TiO2 (wt%)	0.0421	0.0464	0.0400	0.0021	0.0064	5.3%	16.0%
HTLG-56VS	ZrO2 (wt%)	0.1138	0.1138	0.1200	-0.0062	-0.0062	-5.2%	-5.2%
HTLG-56VS	Oxide Sum (wt%)	97.8883	98.9214	100.0100	-2.1217	-1.0886	-2.1%	-1.1%
HTLG-57VS	Al2O3 (wt%)	9.5042	9.2459	9.3000	0.2042	-0.0541	2.2%	-0.6%
HTLG-57VS	B2O3 (wt%)	4.5159	4.4222	4.5000	0.0159	-0.0778	0.4%	-1.7%
HTLG-57VS	CaO (wt%)	1.4901	1.4966	1.4100	0.0801	0.0866	5.7%	6.1%
HTLG-57VS	Cr2O3 (wt%)	0.0559	0.0517	0.0600	-0.0041	-0.0083	-6.8%	-13.9%
HTLG-57VS	CuO (wt%)	0.0288	0.0292	0.0300	-0.0012	-0.0008	-4.0%	-2.6%
HTLG-57VS	Fe2O3 (wt%)	19.4082	18.9823	20.2400	-0.8318	-1.2577	-4.1%	-6.2%
HTLG-57VS	K2O (wt%)	0.1120	0.1227	0.1200	-0.0080	0.0027	-6.6%	2.3%
HTLG-57VS	Li2O (wt%)	2.9710	2.9839	3.0000	-0.0290	-0.0161	-1.0%	-0.5%
HTLG-57VS	MgO (wt%)	1.5588	1.5762	1.6600	-0.1012	-0.0838	-6.1%	-5.0%
HTLG-57VS	MnO (wt%)	3.1731	3.1550	3.1900	-0.0169	-0.0350	-0.5%	-1.1%
HTLG-57VS	Na2O (wt%)	12.5431	11.5025	12.3800	0.1631	-0.8775	1.3%	-7.1%
HTLG-57VS	NiO (wt%)	0.9181	1.0082	1.0900	-0.1719	-0.0818	-15.8%	-7.5%
HTLG-57VS	SiO2 (wt%)	43.1604	44.0195	42.7200	0.4404	1.2995	1.0%	3.0%
HTLG-57VS	SO4 (wt%)	0.2636	0.2636	0.2500	0.0136	0.0136	5.5%	5.5%
HTLG-57VS	TiO2 (wt%)	0.0254	0.0277	0.0200	0.0054	0.0077	27.2%	38.6%
HTLG-57VS	ZrO2 (wt%)	0.0648	0.0648	0.0600	0.0048	0.0048	8.1%	8.1%
HTLG-57VS	Oxide Sum (wt%)	99.7936	98.9521	100.0300	-0.2364	-1.0779	-0.2%	-1.1%
HTLG-58VS	Al2O3 (wt%)	7.7611	7.6121	7.6100	0.1511	0.0021	2.0%	0.0%
HTLG-58VS	B2O3 (wt%)	4.5240	4.4299	4.5000	0.0240	-0.0701	0.5%	-1.6%
HTLG-58VS	CaO (wt%)	1.4797	1.4835	1.4100	0.0697	0.0735	4.9%	5.2%
HTLG-58VS	Cr2O3 (wt%)	0.1085	0.1052	0.1300	-0.0215	-0.0248	-16.5%	-19.1%
HTLG-58VS	CuO (wt%)	0.0541	0.0553	0.0500	0.0041	0.0053	8.3%	10.6%
HTLG-58VS	Fe2O3 (wt%)	17.5853	17.2005	17.8000	-0.2147	-0.5995	-1.2%	-3.4%
HTLG-58VS	K2O (wt%)	0.2346	0.2604	0.2200	0.0146	0.0404	6.6%	18.4%
HTLG-58VS	Li2O (wt%)	2.9118	2.9244	3.0000	-0.0882	-0.0756	-2.9%	-2.5%
HTLG-58VS	MgO (wt%)	1.9651	2.0402	2.1600	-0.1949	-0.1198	-9.0%	-5.5%
HTLG-58VS	MnO (wt%)	3.9995	3.9191	3.9000	0.0995	0.0191	2.6%	0.5%
HTLG-58VS	Na2O (wt%)	14.3562	13.5229	14.7900	-0.4338	-1.2671	-2.9%	-8.6%
HTLG-58VS	NiO (wt%)	0.9741	1.1077	1.0900	-0.1159	0.0177	-10.6%	1.6%
HTLG-58VS	SiO2 (wt%)	42.9999	43.8567	42.7200	0.2799	1.1367	0.7%	2.7%
HTLG-58VS	SO4 (wt%)	0.4599	0.4599	0.4700	-0.0101	-0.0101	-2.2%	-2.2%
HTLG-58VS	TiO2 (wt%)	0.0430	0.0473	0.0400	0.0030	0.0073	7.4%	18.3%
HTLG-58VS	ZrO2 (wt%)	0.1091	0.1091	0.1200	-0.0109	-0.0109	-9.1%	-9.1%
HTLG-58VS	Oxide Sum (wt%)	99.5658	99.1343	100.0100	-0.4442	-0.8757	-0.4%	-0.9%
HTLG-59VS	Al2O3 (wt%)	7.8131	7.6629	7.6100	0.2031	0.0529	2.7%	0.7%
HTLG-59VS	B2O3 (wt%)	4.4354	4.3428	4.5000	-0.0646	-0.1572	-1.4%	-3.5%
HTLG-59VS	CaO (wt%)	2.0533	2.0587	1.9100	0.1433	0.1487	7.5%	7.8%
HTLG-59VS	Cr2O3 (wt%)	0.0548	0.0531	0.0600	-0.0052	-0.0069	-8.7%	-11.4%
HTLG-59VS	CuO (wt%)	0.0307	0.0313	0.0300	0.0007	0.0013	2.2%	4.4%
HTLG-59VS	Fe2O3 (wt%)	19.8013	19.3719	20.4700	-0.6687	-1.0981	-3.3%	-5.4%
HTLG-59VS	K2O (wt%)	0.1247	0.1384	0.1200	0.0047	0.0184	3.9%	15.3%
HTLG-59VS	Li2O (wt%)	2.9333	2.9461	3.0000	-0.0667	-0.0539	-2.2%	-1.8%
HTLG-59VS	MgO (wt%)	1.9070	1.9800	2.1600	-0.2530	-0.1800	-11.7%	-8.3%
HTLG-59VS	MnO (wt%)	4.0382	3.9536	3.9000	0.1382	0.0536	3.5%	1.4%
HTLG-59VS	Na2O (wt%)	12.2938	11.5799	12.3800	-0.0862	-0.8001	-0.7%	-6.5%
HTLG-59VS	NiO (wt%)	0.7126	0.8103	0.8400	-0.1274	-0.0297	-15.2%	-3.5%
HTLG-59VS	SiO2 (wt%)	42.8395	43.6939	42.7200	0.1195	0.9739	0.3%	2.3%
HTLG-59VS	SO4 (wt%)	0.2561	0.2561	0.2500	0.0061	0.0061	2.5%	2.5%
HTLG-59VS	TiO2 (wt%)	0.0242	0.0267	0.0200	0.0042	0.0067	20.9%	33.3%
HTLG-59VS	ZrO2 (wt%)	0.0655	0.0655	0.0600	0.0055	0.0055	9.2%	9.2%
HTLG-59VS	Oxide Sum (wt%)	99.3836	98.9713	100.0300	-0.6464	-1.0587	-0.6%	-1.1%

Table A6. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide for the HTL Study Glasses

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas BC	% Diff of Measured	% Diff of Meas BC
HTLG-60VS	Al2O3 (wt%)	9.5231	9.2633	9.3000	0.2231	-0.0367	2.4%	-0.4%
HTLG-60VS	B2O3 (wt%)	4.6286	4.5629	4.5000	0.1286	0.0629	2.9%	1.4%
HTLG-60VS	CaO (wt%)	2.0708	2.0800	1.9100	0.1608	0.1700	8.4%	8.9%
HTLG-60VS	Cr2O3 (wt%)	0.1133	0.1047	0.1300	-0.0167	-0.0253	-12.9%	-19.4%
HTLG-60VS	CuO (wt%)	0.0554	0.0562	0.0500	0.0054	0.0062	10.8%	12.5%
HTLG-60VS	Fe2O3 (wt%)	17.5138	17.6678	18.0300	-0.5162	-0.3622	-2.9%	-2.0%
HTLG-60VS	K2O (wt%)	0.2460	0.2695	0.2200	0.0260	0.0495	11.8%	22.5%
HTLG-60VS	Li2O (wt%)	2.9818	2.9923	3.0000	-0.0182	-0.0077	-0.6%	-0.3%
HTLG-60VS	MgO (wt%)	1.5717	1.5891	1.6600	-0.0883	-0.0709	-5.3%	-4.3%
HTLG-60VS	MnO (wt%)	3.9349	3.9127	3.9000	0.0349	0.0127	0.9%	0.3%
HTLG-60VS	Na2O (wt%)	12.9644	11.8872	12.3800	0.5844	-0.4928	4.7%	-4.0%
HTLG-60VS	NiO (wt%)	0.9932	1.0906	1.0900	-0.0968	0.0006	-8.9%	0.1%
HTLG-60VS	SiO2 (wt%)	43.3208	45.1605	43.2200	0.1008	1.9405	0.2%	4.5%
HTLG-60VS	SO4 (wt%)	0.4501	0.4501	0.4700	-0.0199	-0.0199	-4.2%	-4.2%
HTLG-60VS	TiO2 (wt%)	0.0425	0.0464	0.0400	0.0025	0.0064	6.3%	15.9%
HTLG-60VS	ZrO2 (wt%)	0.1128	0.1128	0.1200	-0.0072	-0.0072	-6.0%	-6.0%
HTLG-60VS	Oxide Sum (wt%)	100.5232	101.2460	100.0200	0.5032	1.2260	0.5%	1.2%
HTLG-61VS	Al2O3 (wt%)	9.4475	9.1906	9.3000	0.1475	-0.1094	1.6%	-1.2%
HTLG-61VS	B2O3 (wt%)	4.4354	4.3727	4.5000	-0.0646	-0.1273	-1.4%	-2.8%
HTLG-61VS	CaO (wt%)	1.4936	1.5002	1.4100	0.0836	0.0902	5.9%	6.4%
HTLG-61VS	Cr2O3 (wt%)	0.0636	0.0588	0.0600	0.0036	-0.0012	6.0%	-2.0%
HTLG-61VS	CuO (wt%)	0.0279	0.0283	0.0300	-0.0021	-0.0017	-7.2%	-5.7%
HTLG-61VS	Fe2O3 (wt%)	16.0841	16.2327	16.8600	-0.7759	-0.6273	-4.6%	-3.7%
HTLG-61VS	K2O (wt%)	0.1156	0.1267	0.1200	-0.0044	0.0067	-3.6%	5.6%
HTLG-61VS	Li2O (wt%)	2.9387	2.9491	3.0000	-0.0613	-0.0509	-2.0%	-1.7%
HTLG-61VS	MgO (wt%)	1.5596	1.5769	1.6600	-0.1004	-0.0831	-6.0%	-5.0%
HTLG-61VS	MnO (wt%)	3.9317	3.9093	3.9000	0.0317	0.0093	0.8%	0.2%
HTLG-61VS	Na2O (wt%)	14.7269	13.5056	14.7900	-0.0631	-1.2844	-0.4%	-8.7%
HTLG-61VS	NiO (wt%)	0.7746	0.8505	0.8400	-0.0654	0.0105	-7.8%	1.3%
HTLG-61VS	SiO2 (wt%)	42.7325	44.5519	43.2200	-0.4875	1.3319	-1.1%	3.1%
HTLG-61VS	SO4 (wt%)	0.2681	0.2681	0.2500	0.0181	0.0181	7.3%	7.3%
HTLG-61VS	TiO2 (wt%)	0.0234	0.0255	0.0200	0.0034	0.0055	16.8%	27.3%
HTLG-61VS	ZrO2 (wt%)	0.0631	0.0631	0.0600	0.0031	0.0031	5.2%	5.2%
HTLG-61VS	Oxide Sum (wt%)	98.6865	99.2100	100.0200	-1.3335	-0.8100	-1.3%	-0.8%
HTLG-62VS	Al2O3 (wt%)	8.2524	8.0938	8.0500	0.2024	0.0438	2.5%	0.5%
HTLG-62VS	B2O3 (wt%)	4.5320	4.4677	4.5000	0.0320	-0.0323	0.7%	-0.7%
HTLG-62VS	CaO (wt%)	1.4797	1.4835	1.4100	0.0697	0.0735	4.9%	5.2%
HTLG-62VS	Cr2O3 (wt%)	0.1078	0.1045	0.1300	-0.0222	-0.0255	-17.1%	-19.6%
HTLG-62VS	CuO (wt%)	0.0551	0.0563	0.0500	0.0051	0.0063	10.2%	12.5%
HTLG-62VS	Fe2O3 (wt%)	17.8355	17.9986	18.8800	-1.0445	-0.8814	-5.5%	-4.7%
HTLG-62VS	K2O (wt%)	0.2527	0.2804	0.2200	0.0327	0.0604	14.8%	27.5%
HTLG-62VS	Li2O (wt%)	2.9710	2.9815	3.0000	-0.0290	-0.0185	-1.0%	-0.6%
HTLG-62VS	MgO (wt%)	1.5372	1.5961	1.6600	-0.1228	-0.0639	-7.4%	-3.9%
HTLG-62VS	MnO (wt%)	3.8833	3.8046	3.7200	0.1633	0.0846	4.4%	2.3%
HTLG-62VS	Na2O (wt%)	14.0192	13.2054	14.1900	-0.1708	-0.9846	-1.2%	-6.9%
HTLG-62VS	NiO (wt%)	0.7864	0.8942	0.8400	-0.0536	0.0542	-6.4%	6.5%
HTLG-62VS	SiO2 (wt%)	42.4116	44.2159	42.7200	-0.3084	1.4959	-0.7%	3.5%
HTLG-62VS	SO4 (wt%)	0.4322	0.4322	0.4700	-0.0378	-0.0378	-8.1%	-8.1%
HTLG-62VS	TiO2 (wt%)	0.0409	0.0450	0.0400	0.0009	0.0050	2.2%	12.6%
HTLG-62VS	ZrO2 (wt%)	0.1148	0.1148	0.1200	-0.0052	-0.0052	-4.3%	-4.3%
HTLG-62VS	Oxide Sum (wt%)	98.7117	99.7746	100.0000	-1.2883	-0.2254	-1.3%	-0.2%
HTLG-63VS	Al2O3 (wt%)	9.0696	8.8228	8.8700	0.1996	-0.0472	2.3%	-0.5%
HTLG-63VS	B2O3 (wt%)	4.4757	4.4121	4.5000	-0.0243	-0.0879	-0.5%	-2.0%
HTLG-63VS	CaO (wt%)	1.5006	1.5073	1.4100	0.0906	0.0973	6.4%	6.9%
HTLG-63VS	Cr2O3 (wt%)	0.0548	0.0507	0.0600	-0.0052	-0.0093	-8.7%	-15.5%
HTLG-63VS	CuO (wt%)	0.0279	0.0283	0.0300	-0.0021	-0.0017	-7.2%	-5.7%
HTLG-63VS	Fe2O3 (wt%)	18.4074	18.5795	19.5800	-1.1726	-1.0005	-6.0%	-5.1%
HTLG-63VS	K2O (wt%)	0.1150	0.1260	0.1200	-0.0050	0.0060	-4.1%	5.0%
HTLG-63VS	Li2O (wt%)	2.9602	2.9707	3.0000	-0.0398	-0.0293	-1.3%	-1.0%
HTLG-63VS	MgO (wt%)	1.9817	2.0035	2.1600	-0.1783	-0.1565	-8.3%	-7.2%
HTLG-63VS	MnO (wt%)	3.3507	3.3330	3.3700	-0.0193	-0.0370	-0.6%	-1.1%
HTLG-63VS	Na2O (wt%)	13.2980	12.1939	13.0300	0.2680	-0.8361	2.1%	-6.4%
HTLG-63VS	NiO (wt%)	0.7155	0.7856	0.8400	-0.1245	-0.0544	-14.8%	-6.5%
HTLG-63VS	SiO2 (wt%)	42.1977	43.9929	42.7200	-0.5223	1.2729	-1.2%	3.0%
HTLG-63VS	SO4 (wt%)	0.2689	0.2689	0.2500	0.0189	0.0189	7.6%	7.6%
HTLG-63VS	TiO2 (wt%)	0.0254	0.0277	0.0200	0.0054	0.0077	27.2%	38.6%
HTLG-63VS	ZrO2 (wt%)	0.0669	0.0669	0.0600	0.0069	0.0069	11.4%	11.4%
HTLG-63VS	Oxide Sum (wt%)	98.5159	99.1698	100.0200	-1.5041	-0.8502	-1.5%	-0.9%

Table A6. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide for the HTL Study Glasses

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas BC	% Diff of Measured	% Diff of Meas BC
HTLG-64VS	Al2O3 (wt%)	8.2052	7.9821	8.0300	0.1752	-0.0479	2.2%	-0.6%
HTLG-64VS	B2O3 (wt%)	4.3871	4.2957	4.5000	-0.1129	-0.2043	-2.5%	-4.5%
HTLG-64VS	CaO (wt%)	2.0568	2.0658	1.9100	0.1468	0.1558	7.7%	8.2%
HTLG-64VS	Cr2O3 (wt%)	0.0658	0.0608	0.0600	0.0058	0.0008	9.6%	1.3%
HTLG-64VS	CuO (wt%)	0.0288	0.0292	0.0300	-0.0012	-0.0008	-4.0%	-2.6%
HTLG-64VS	Fe2O3 (wt%)	17.7998	17.4112	18.7700	-0.9702	-1.3588	-5.2%	-7.2%
HTLG-64VS	K2O (wt%)	0.1196	0.1309	0.1200	-0.0004	0.0109	-0.4%	9.1%
HTLG-64VS	Li2O (wt%)	2.9656	2.9785	3.0000	-0.0344	-0.0215	-1.1%	-0.7%
HTLG-64VS	MgO (wt%)	1.5401	1.5573	1.6600	-0.1199	-0.1027	-7.2%	-6.2%
HTLG-64VS	MnO (wt%)	3.3765	3.3576	3.3700	0.0065	-0.0124	0.2%	-0.4%
HTLG-64VS	Na2O (wt%)	14.2214	13.0416	14.1900	0.0314	-1.1484	0.2%	-8.1%
HTLG-64VS	NiO (wt%)	0.7514	0.8251	0.8400	-0.0886	-0.0149	-10.5%	-1.8%
HTLG-64VS	SiO2 (wt%)	43.4813	44.3468	43.2200	0.2613	1.1268	0.6%	2.6%
HTLG-64VS	SO4 (wt%)	0.2666	0.2666	0.2500	0.0166	0.0166	6.7%	6.7%
HTLG-64VS	TiO2 (wt%)	0.0246	0.0268	0.0200	0.0046	0.0068	23.0%	34.1%
HTLG-64VS	ZrO2 (wt%)	0.0689	0.0689	0.0600	0.0089	0.0089	14.8%	14.8%
HTLG-64VS	Oxide Sum (wt%)	99.3594	98.4450	100.0300	-0.6706	-1.5850	-0.7%	-1.6%
HTLG-65VS	Al2O3 (wt%)	8.2288	8.0050	8.8700	-0.6412	-0.8650	-7.2%	-9.8%
HTLG-65VS	B2O3 (wt%)	4.4354	4.3724	4.5000	-0.0646	-0.1276	-1.4%	-2.8%
HTLG-65VS	CaO (wt%)	1.4901	1.4967	1.8600	-0.3699	-0.3633	-19.9%	-19.5%
HTLG-65VS	Cr2O3 (wt%)	0.1078	0.0997	0.1300	-0.0222	-0.0303	-17.1%	-23.3%
HTLG-65VS	CuO (wt%)	0.0523	0.0531	0.0500	0.0023	0.0031	4.5%	6.1%
HTLG-65VS	Fe2O3 (wt%)	16.6917	16.8471	17.7200	-1.0283	-0.8729	-5.8%	-4.9%
HTLG-65VS	K2O (wt%)	0.2213	0.2424	0.2200	0.0013	0.0224	0.6%	10.2%
HTLG-65VS	Li2O (wt%)	2.9979	3.0085	3.0000	-0.0021	0.0085	-0.1%	0.3%
HTLG-65VS	MgO (wt%)	2.0273	2.0498	1.6600	0.3673	0.3898	22.1%	23.5%
HTLG-65VS	MnO (wt%)	3.3894	3.3700	3.3700	0.0194	0.0000	0.6%	0.0%
HTLG-65VS	Na2O (wt%)	14.1540	12.9798	14.1900	-0.0360	-1.2102	-0.3%	-8.5%
HTLG-65VS	NiO (wt%)	0.9700	1.0651	1.0900	-0.1200	-0.0249	-11.0%	-2.3%
HTLG-65VS	SiO2 (wt%)	42.6790	44.4955	42.7200	-0.0410	1.7755	-0.1%	4.2%
HTLG-65VS	SO4 (wt%)	0.4539	0.4539	0.4700	-0.0161	-0.0161	-3.4%	-3.4%
HTLG-65VS	TiO2 (wt%)	0.0455	0.0495	0.0400	0.0055	0.0095	13.6%	23.8%
HTLG-65VS	ZrO2 (wt%)	0.1162	0.1162	0.1200	-0.0038	-0.0038	-3.2%	-3.2%
HTLG-65VS	Oxide Sum (wt%)	98.0606	98.7045	100.0100	-1.9494	-1.3055	-1.9%	-1.3%
HTLG-66VS	Al2O3 (wt%)	9.1027	8.8550	8.0300	1.0727	0.8250	13.4%	10.3%
HTLG-66VS	B2O3 (wt%)	4.4998	4.4059	4.5000	-0.0002	-0.0941	0.0%	-2.1%
HTLG-66VS	CaO (wt%)	2.0183	2.0272	1.4100	0.6083	0.6172	43.1%	43.8%
HTLG-66VS	Cr2O3 (wt%)	0.1045	0.0966	0.1300	-0.0255	-0.0334	-19.6%	-25.7%
HTLG-66VS	CuO (wt%)	0.0516	0.0524	0.0500	0.0016	0.0024	3.3%	4.8%
HTLG-66VS	Fe2O3 (wt%)	17.1207	16.7455	18.0200	-0.8993	-1.2745	-5.0%	-7.1%
HTLG-66VS	K2O (wt%)	0.2521	0.2761	0.2200	0.0321	0.0561	14.6%	25.5%
HTLG-66VS	Li2O (wt%)	2.9172	2.9298	3.0000	-0.0828	-0.0702	-2.8%	-2.3%
HTLG-66VS	MgO (wt%)	1.5178	1.5346	2.1600	-0.6422	-0.6254	-29.7%	-29.0%
HTLG-66VS	MnO (wt%)	3.3216	3.3028	3.3700	-0.0484	-0.0672	-1.4%	-2.0%
HTLG-66VS	Na2O (wt%)	14.2888	13.1026	14.1900	0.0988	-1.0874	0.7%	-7.7%
HTLG-66VS	NiO (wt%)	0.9502	1.0434	1.0900	-0.1398	-0.0466	-12.8%	-4.3%
HTLG-66VS	SiO2 (wt%)	42.5721	43.4192	43.2200	-0.6479	0.1992	-1.5%	0.5%
HTLG-66VS	SO4 (wt%)	0.4419	0.4419	0.4700	-0.0281	-0.0281	-6.0%	-6.0%
HTLG-66VS	TiO2 (wt%)	0.0434	0.0473	0.0400	0.0034	0.0073	8.4%	18.2%
HTLG-66VS	ZrO2 (wt%)	0.1050	0.1050	0.1200	-0.0150	-0.0150	-12.5%	-12.5%
HTLG-66VS	Oxide Sum (wt%)	99.3076	98.3854	100.0200	-0.7124	-1.6346	-0.7%	-1.6%

Table A6. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide for the HTL Study Glasses

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas BC	% Diff of Measured	% Diff of Meas BC
Batch 1	Al2O3 (wt%)	4.9599	4.8770	4.8770	0.0829	0.0000	1.7%	0.0%
Batch 1	B2O3 (wt%)	7.8297	7.7770	7.7770	0.0527	0.0000	0.7%	0.0%
Batch 1	CaO (wt%)	1.2250	1.2200	1.2200	0.0050	0.0000	0.4%	0.0%
Batch 1	Cr2O3 (wt%)	0.1100	0.1070	0.1070	0.0030	0.0000	2.8%	0.0%
Batch 1	CuO (wt%)	0.3883	0.3990	0.3990	-0.0107	0.0000	-2.7%	0.0%
Batch 1	Fe2O3 (wt%)	12.7339	12.8390	12.8390	-0.1051	0.0000	-0.8%	0.0%
Batch 1	K2O (wt%)	3.0195	3.3270	3.3270	-0.3075	0.0000	-9.2%	0.0%
Batch 1	Li2O (wt%)	4.4314	4.4290	4.4290	0.0024	0.0000	0.1%	0.0%
Batch 1	MgO (wt%)	1.3812	1.4190	1.4190	-0.0378	0.0000	-2.7%	0.0%
Batch 1	MnO (wt%)	1.7205	1.7260	1.7260	-0.0055	0.0000	-0.3%	0.0%
Batch 1	Na2O (wt%)	9.6146	9.0030	9.0030	0.6116	0.0000	6.8%	0.0%
Batch 1	NiO (wt%)	0.6612	0.7510	0.7510	-0.0898	0.0000	-12.0%	0.0%
Batch 1	SiO2 (wt%)	48.2412	50.2200	50.2200	-1.9788	0.0000	-3.9%	0.0%
Batch 1	SO4 (wt%)	0.0567	0.0567	0.0000	0.0567	0.0567		
Batch 1	TiO2 (wt%)	0.6223	0.6770	0.6770	-0.0547	0.0000	-8.1%	0.0%
Batch 1	ZrO2 (wt%)	0.0895	0.0895	0.0980	-0.0085	-0.0085	-8.7%	-8.7%
Batch 1	Oxide Sum (wt%)	97.0849	98.9172	98.8690	-1.7841	0.0482	-1.8%	0.0%
HTLG-67VS	Al2O3 (wt%)	9.0035	8.8532	8.8700	0.1335	-0.0168	1.5%	-0.2%
HTLG-67VS	B2O3 (wt%)	4.4032	4.3054	4.5000	-0.0968	-0.1946	-2.2%	-4.3%
HTLG-67VS	CaO (wt%)	2.0393	2.0326	1.9100	0.1293	0.1226	6.8%	6.4%
HTLG-67VS	Cr2O3 (wt%)	0.1012	0.0996	0.1300	-0.0288	-0.0304	-22.1%	-23.4%
HTLG-67VS	CuO (wt%)	0.0570	0.0585	0.0500	0.0070	0.0085	13.9%	17.0%
HTLG-67VS	Fe2O3 (wt%)	16.8705	16.4953	17.7700	-0.8995	-1.2747	-5.1%	-7.2%
HTLG-67VS	K2O (wt%)	0.2475	0.2712	0.2200	0.0275	0.0512	12.5%	23.3%
HTLG-67VS	Li2O (wt%)	3.0033	2.9847	3.0000	0.0033	-0.0153	0.1%	-0.5%
HTLG-67VS	MgO (wt%)	1.9319	2.0066	2.1600	-0.2281	-0.1534	-10.6%	-7.1%
HTLG-67VS	MnO (wt%)	3.7671	3.7859	3.7200	0.0471	0.0659	1.3%	1.8%
HTLG-67VS	Na2O (wt%)	12.9374	12.1063	12.9800	-0.0426	-0.8737	-0.3%	-6.7%
HTLG-67VS	NiO (wt%)	0.7155	0.8203	0.8400	-0.1245	-0.0197	-14.8%	-2.3%
HTLG-67VS	SiO2 (wt%)	42.1977	43.6375	43.2200	-1.0223	0.4175	-2.4%	1.0%
HTLG-67VS	SO4 (wt%)	0.4202	0.4202	0.4700	-0.0498	-0.0498	-10.6%	-10.6%
HTLG-67VS	TiO2 (wt%)	0.0417	0.0451	0.0400	0.0017	0.0051	4.3%	12.8%
HTLG-67VS	ZrO2 (wt%)	0.1179	0.1179	0.1200	-0.0021	-0.0021	-1.8%	-1.8%
HTLG-67VS	Oxide Sum (wt%)	97.8548	98.0402	100.0000	-2.1452	-1.9598	-2.1%	-2.0%
HTLG-68VS	Al2O3 (wt%)	8.9137	8.7647	8.8700	0.0437	-0.1053	0.5%	-1.2%
HTLG-68VS	B2O3 (wt%)	4.4354	4.4760	4.5000	-0.0646	-0.0240	-1.4%	-0.5%
HTLG-68VS	CaO (wt%)	1.4657	1.4586	1.4100	0.0557	0.0486	3.9%	3.4%
HTLG-68VS	Cr2O3 (wt%)	0.0566	0.0546	0.0600	-0.0034	-0.0054	-5.6%	-9.1%
HTLG-68VS	CuO (wt%)	0.0316	0.0325	0.0300	0.0016	0.0025	5.4%	8.3%
HTLG-68VS	Fe2O3 (wt%)	17.7283	18.4500	19.0200	-1.2917	-0.5700	-6.8%	-3.0%
HTLG-68VS	K2O (wt%)	0.1120	0.1242	0.1200	-0.0080	0.0042	-6.6%	3.5%
HTLG-68VS	Li2O (wt%)	3.0087	3.0234	3.0000	0.0087	0.0234	0.3%	0.8%
HTLG-68VS	MgO (wt%)	1.5613	1.5873	1.6600	-0.0987	-0.0727	-5.9%	-4.4%
HTLG-68VS	MnO (wt%)	3.7251	3.7300	3.7200	0.0051	0.0100	0.1%	0.3%
HTLG-68VS	Na2O (wt%)	12.7959	11.9918	12.9800	-0.1841	-0.9882	-1.4%	-7.6%
HTLG-68VS	NiO (wt%)	0.9448	1.0636	1.0900	-0.1452	-0.0264	-13.3%	-2.4%
HTLG-68VS	SiO2 (wt%)	41.8768	43.8798	43.2200	-1.3432	0.6598	-3.1%	1.5%
HTLG-68VS	SO4 (wt%)	0.2517	0.2517	0.2500	0.0017	0.0017	0.7%	0.7%
HTLG-68VS	TiO2 (wt%)	0.0229	0.0251	0.0200	0.0029	0.0051	14.7%	25.5%
HTLG-68VS	ZrO2 (wt%)	0.0621	0.0621	0.0600	0.0021	0.0021	3.6%	3.6%
HTLG-68VS	Oxide Sum (wt%)	96.9927	98.9753	100.0100	-3.0173	-1.0347	-3.0%	-1.0%
HTLG-69VS	Al2O3 (wt%)	8.2004	8.0633	8.0300	0.1704	0.0333	2.1%	0.4%
HTLG-69VS	B2O3 (wt%)	4.5320	4.4317	4.5000	0.0320	-0.0683	0.7%	-1.5%
HTLG-69VS	CaO (wt%)	2.0603	2.0504	1.9100	0.1503	0.1404	7.9%	7.3%
HTLG-69VS	Cr2O3 (wt%)	0.0968	0.0933	0.1300	-0.0332	-0.0367	-25.5%	-28.3%
HTLG-69VS	CuO (wt%)	0.0519	0.0534	0.0500	0.0019	0.0034	3.9%	6.8%
HTLG-69VS	Fe2O3 (wt%)	18.8720	18.4531	19.5800	-0.7080	-1.1269	-3.6%	-5.8%
HTLG-69VS	K2O (wt%)	0.2352	0.2607	0.2200	0.0152	0.0407	6.9%	18.5%
HTLG-69VS	Li2O (wt%)	2.9979	2.9791	3.0000	-0.0021	-0.0209	-0.1%	-0.7%
HTLG-69VS	MgO (wt%)	1.6658	1.6933	1.8000	-0.1342	-0.1067	-7.5%	-5.9%
HTLG-69VS	MnO (wt%)	3.4443	3.4485	3.3700	0.0743	0.0785	2.2%	2.3%
HTLG-69VS	Na2O (wt%)	13.0217	12.2034	12.9800	0.0417	-0.7766	0.3%	-6.0%
HTLG-69VS	NiO (wt%)	0.9369	1.0546	1.0900	-0.1531	-0.0354	-14.0%	-3.3%
HTLG-69VS	SiO2 (wt%)	42.4116	43.6742	42.7200	-0.3084	0.9542	-0.7%	2.2%
HTLG-69VS	SO4 (wt%)	0.4082	0.4082	0.4700	-0.0618	-0.0618	-13.2%	-13.2%
HTLG-69VS	TiO2 (wt%)	0.0396	0.0433	0.0400	-0.0004	0.0033	-1.0%	8.3%
HTLG-69VS	ZrO2 (wt%)	0.1145	0.1145	0.1200	-0.0055	-0.0055	-4.6%	-4.6%
HTLG-69VS	Oxide Sum (wt%)	99.0892	99.0249	100.0100	-0.9208	-0.9851	-0.9%	-1.0%

Table A6. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide for the HTL Study Glasses

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas BC	% Diff of Measured	% Diff of Meas BC
HTLG-70VS	Al2O3 (wt%)	8.0398	7.9053	8.0300	0.0098	-0.1247	0.1%	-1.6%
HTLG-70VS	B2O3 (wt%)	4.4837	4.5254	4.5000	-0.0163	0.0254	-0.4%	0.6%
HTLG-70VS	CaO (wt%)	2.0253	2.0186	1.9100	0.1153	0.1086	6.0%	5.7%
HTLG-70VS	Cr2O3 (wt%)	0.0548	0.0539	0.0600	-0.0052	-0.0061	-8.7%	-10.2%
HTLG-70VS	CuO (wt%)	0.0382	0.0392	0.0300	0.0082	0.0092	27.3%	30.7%
HTLG-70VS	Fe2O3 (wt%)	17.5496	18.2694	18.1600	-0.6104	0.1094	-3.4%	0.6%
HTLG-70VS	K2O (wt%)	0.1217	0.1333	0.1200	0.0017	0.0133	1.4%	11.1%
HTLG-70VS	Li2O (wt%)	2.9387	2.9538	3.0000	-0.0613	-0.0462	-2.0%	-1.5%
HTLG-70VS	MgO (wt%)	1.9568	2.0322	2.1600	-0.2032	-0.1278	-9.4%	-5.9%
HTLG-70VS	MnO (wt%)	3.6767	3.6954	3.7200	-0.0433	-0.0246	-1.2%	-0.7%
HTLG-70VS	Na2O (wt%)	14.0866	13.1796	14.1900	-0.1034	-1.0104	-0.7%	-7.1%
HTLG-70VS	NiO (wt%)	0.9537	1.0934	1.0900	-0.1363	0.0034	-12.5%	0.3%
HTLG-70VS	SiO2 (wt%)	41.1013	43.2420	42.7200	-1.6187	0.5220	-3.8%	1.2%
HTLG-70VS	SO4 (wt%)	0.2517	0.2517	0.2500	0.0017	0.0017	0.7%	0.7%
HTLG-70VS	TiO2 (wt%)	0.0238	0.0257	0.0200	0.0038	0.0057	18.8%	28.6%
HTLG-70VS	ZrO2 (wt%)	0.0679	0.0679	0.0600	0.0079	0.0079	13.1%	13.1%
HTLG-70VS	Oxide Sum (wt%)	97.3702	99.4867	100.0200	-2.6498	-0.5333	-2.6%	-0.5%
HTLG-71VS	Al2O3 (wt%)	8.5972	8.4537	8.3800	0.2172	0.0737	2.6%	0.9%
HTLG-71VS	B2O3 (wt%)	4.3871	4.2900	4.3200	0.0671	-0.0300	1.6%	-0.7%
HTLG-71VS	CaO (wt%)	1.5636	1.5584	1.4600	0.1036	0.0984	7.1%	6.7%
HTLG-71VS	Cr2O3 (wt%)	0.1253	0.1232	0.1300	-0.0047	-0.0068	-3.6%	-5.2%
HTLG-71VS	CuO (wt%)	0.0613	0.0630	0.0500	0.0113	0.0130	22.7%	26.0%
HTLG-71VS	Fe2O3 (wt%)	18.9435	18.5258	19.6400	-0.6965	-1.1142	-3.5%	-5.7%
HTLG-71VS	K2O (wt%)	0.2563	0.2807	0.2300	0.0263	0.0507	11.4%	22.1%
HTLG-71VS	Li2O (wt%)	2.9279	2.9098	2.8800	0.0479	0.0298	1.7%	1.0%
HTLG-71VS	MgO (wt%)	1.6119	1.6741	1.7200	-0.1081	-0.0459	-6.3%	-2.7%
HTLG-71VS	MnO (wt%)	3.9834	4.0035	3.8700	0.1134	0.1335	2.9%	3.4%
HTLG-71VS	Na2O (wt%)	14.6258	13.6850	14.6400	-0.0142	-0.9550	-0.1%	-6.5%
HTLG-71VS	NiO (wt%)	0.0022	0.0025	0.8700	-0.8678	-0.8675	-99.7%	-99.7%
HTLG-71VS	SiO2 (wt%)	40.9676	42.3480	41.1500	-0.1824	1.1980	-0.4%	2.9%
HTLG-71VS	SO4 (wt%)	0.4322	0.4322	0.4900	-0.0578	-0.0578	-11.8%	-11.8%
HTLG-71VS	TiO2 (wt%)	0.0446	0.0483	0.0400	0.0046	0.0083	11.5%	20.7%
HTLG-71VS	ZrO2 (wt%)	0.1219	0.1219	0.1200	0.0019	0.0019	1.6%	1.6%
HTLG-71VS	Oxide Sum (wt%)	98.6519	98.5201	99.9900	-1.3381	-1.4699	-1.3%	-1.5%
HTLG-72VS	Al2O3 (wt%)	9.3294	9.1734	9.2300	0.0994	-0.0566	1.1%	-0.6%
HTLG-72VS	B2O3 (wt%)	4.2503	4.2894	4.3200	-0.0697	-0.0306	-1.6%	-0.7%
HTLG-72VS	CaO (wt%)	1.5391	1.5317	1.4600	0.0791	0.0717	5.4%	4.9%
HTLG-72VS	Cr2O3 (wt%)	0.0599	0.0577	0.0700	-0.0101	-0.0123	-14.4%	-17.5%
HTLG-72VS	CuO (wt%)	0.0313	0.0322	0.0300	0.0013	0.0022	4.3%	7.3%
HTLG-72VS	Fe2O3 (wt%)	18.7291	19.4937	20.3700	-1.6409	-0.8763	-8.1%	-4.3%
HTLG-72VS	K2O (wt%)	0.1190	0.1319	0.1200	-0.0010	0.0119	-0.9%	9.9%
HTLG-72VS	Li2O (wt%)	2.8795	2.8942	2.8800	-0.0005	0.0142	0.0%	0.5%
HTLG-72VS	MgO (wt%)	2.0563	2.0901	2.2400	-0.1837	-0.1499	-8.2%	-6.7%
HTLG-72VS	MnO (wt%)	3.5637	3.5679	3.5000	0.0637	0.0679	1.8%	1.9%
HTLG-72VS	Na2O (wt%)	13.4025	12.5601	13.4300	-0.0275	-0.8699	-0.2%	-6.5%
HTLG-72VS	NiO (wt%)	0.7244	0.8153	0.8700	-0.1456	-0.0547	-16.7%	-6.3%
HTLG-72VS	SiO2 (wt%)	40.2188	42.1454	41.1500	-0.9312	0.9954	-2.3%	2.4%
HTLG-72VS	SO4 (wt%)	0.2554	0.2554	0.2600	-0.0046	-0.0046	-1.8%	-1.8%
HTLG-72VS	TiO2 (wt%)	0.0234	0.0255	0.0200	0.0034	0.0055	16.8%	27.7%
HTLG-72VS	ZrO2 (wt%)	0.0659	0.0659	0.0600	0.0059	0.0059	9.8%	9.8%
HTLG-72VS	Oxide Sum (wt%)	97.2479	99.1298	100.0100	-2.7621	-0.8802	-2.8%	-0.9%
HTLG-73VS	Al2O3 (wt%)	8.4272	8.2863	8.3500	0.0772	-0.0637	0.9%	-0.8%
HTLG-73VS	B2O3 (wt%)	4.1859	4.2242	4.3200	-0.1341	-0.0958	-3.1%	-2.2%
HTLG-73VS	CaO (wt%)	2.1233	2.1130	1.9800	0.1433	0.1330	7.2%	6.7%
HTLG-73VS	Cr2O3 (wt%)	0.0610	0.0588	0.0700	-0.0090	-0.0112	-12.8%	-16.0%
HTLG-73VS	CuO (wt%)	0.0291	0.0299	0.0300	-0.0009	-0.0001	-3.0%	-0.3%
HTLG-73VS	Fe2O3 (wt%)	18.1929	18.9299	19.5200	-1.3271	-0.5901	-6.8%	-3.0%
HTLG-73VS	K2O (wt%)	0.1268	0.1405	0.1200	0.0068	0.0205	5.7%	17.1%
HTLG-73VS	Li2O (wt%)	2.8634	2.8776	2.8800	-0.0166	-0.0024	-0.6%	-0.1%
HTLG-73VS	MgO (wt%)	1.5824	1.6087	1.7200	-0.1376	-0.1113	-8.0%	-6.5%
HTLG-73VS	MnO (wt%)	3.5153	3.5197	3.5000	0.0153	0.0197	0.4%	0.6%
HTLG-73VS	Na2O (wt%)	14.5247	13.6119	14.6400	-0.1153	-1.0281	-0.8%	-7.0%
HTLG-73VS	NiO (wt%)	0.7594	0.8548	0.8700	-0.1106	-0.0152	-12.7%	-1.7%
HTLG-73VS	SiO2 (wt%)	40.3258	42.2563	41.6700	-1.3442	0.5863	-3.2%	1.4%
HTLG-73VS	SO4 (wt%)	0.2606	0.2606	0.2600	0.0006	0.0006	0.2%	0.2%
HTLG-73VS	TiO2 (wt%)	0.0234	0.0255	0.0200	0.0034	0.0055	16.8%	27.7%
HTLG-73VS	ZrO2 (wt%)	0.0638	0.0638	0.0600	0.0038	0.0038	6.4%	6.4%
HTLG-73VS	Oxide Sum (wt%)	97.0649	98.8617	100.0100	-2.9451	-1.1483	-2.9%	-1.1%

Table A6. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide for the HTL Study Glasses

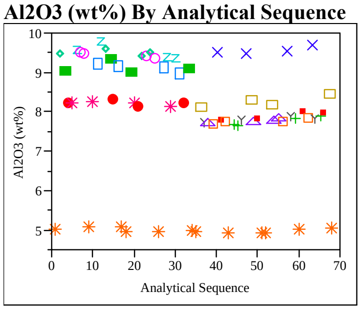
Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas BC	% Diff of Measured	% Diff of Meas BC
HTLG-74VS	Al2O3 (wt%)	9.4192	9.2617	9.2300	0.1892	0.0317	2.0%	0.3%
HTLG-74VS	B2O3 (wt%)	4.0973	4.1352	4.3200	-0.2227	-0.1848	-5.2%	-4.3%
HTLG-74VS	CaO (wt%)	2.0953	2.0883	1.9300	0.1653	0.1583	8.6%	8.2%
HTLG-74VS	Cr2O3 (wt%)	0.1045	0.1027	0.1300	-0.0255	-0.0273	-19.6%	-21.0%
HTLG-74VS	CuO (wt%)	0.0613	0.0630	0.0500	0.0113	0.0130	22.7%	26.0%
HTLG-74VS	Fe2O3 (wt%)	16.5845	17.2528	18.4300	-1.8455	-1.1772	-10.0%	-6.4%
HTLG-74VS	K2O (wt%)	0.2692	0.2949	0.2300	0.0392	0.0649	17.1%	28.2%
HTLG-74VS	Li2O (wt%)	2.8311	2.8456	2.8800	-0.0489	-0.0344	-1.7%	-1.2%
HTLG-74VS	MgO (wt%)	1.5775	1.6382	1.7200	-0.1425	-0.0818	-8.3%	-4.8%
HTLG-74VS	MnO (wt%)	3.5314	3.5493	3.5000	0.0314	0.0493	0.9%	1.4%
HTLG-74VS	Na2O (wt%)	14.6595	13.7169	14.6400	0.0195	-0.9231	0.1%	-6.3%
HTLG-74VS	NiO (wt%)	0.9773	1.1204	1.1300	-0.1527	-0.0096	-13.5%	-0.9%
HTLG-74VS	SiO2 (wt%)	39.6038	41.6742	41.1500	-1.5462	0.5242	-3.8%	1.3%
HTLG-74VS	SO4 (wt%)	0.3985	0.3985	0.4900	-0.0915	-0.0915	-18.7%	-18.7%
HTLG-74VS	TiO2 (wt%)	0.0430	0.0465	0.0400	0.0030	0.0065	7.4%	16.2%
HTLG-74VS	ZrO2 (wt%)	0.1192	0.1192	0.1200	-0.0008	-0.0008	-0.7%	-0.7%
HTLG-74VS	Oxide Sum (wt%)	96.3725	98.3074	99.9900	-3.6175	-1.6826	-3.6%	-1.7%
HTLG-75VS	Al2O3 (wt%)	8.5405	8.3978	8.3500	0.1905	0.0478	2.3%	0.6%
HTLG-75VS	B2O3 (wt%)	4.2100	4.2487	4.3200	-0.1100	-0.0713	-2.5%	-1.7%
HTLG-75VS	CaO (wt%)	1.5566	1.5514	1.4600	0.0966	0.0914	6.6%	6.3%
HTLG-75VS	Cr2O3 (wt%)	0.1082	0.1064	0.1300	-0.0218	-0.0236	-16.8%	-18.2%
HTLG-75VS	CuO (wt%)	0.0582	0.0598	0.0500	0.0082	0.0098	16.4%	19.6%
HTLG-75VS	Fe2O3 (wt%)	16.8347	17.5220	18.7400	-1.9053	-1.2180	-10.2%	-6.5%
HTLG-75VS	K2O (wt%)	0.2457	0.2692	0.2300	0.0157	0.0392	6.8%	17.0%
HTLG-75VS	Li2O (wt%)	2.8795	2.8939	2.8800	-0.0005	0.0139	0.0%	0.5%
HTLG-75VS	MgO (wt%)	2.0480	2.1273	2.2400	-0.1920	-0.1127	-8.6%	-5.0%
HTLG-75VS	MnO (wt%)	3.6089	3.6273	3.5000	0.1089	0.1273	3.1%	3.6%
HTLG-75VS	Na2O (wt%)	14.5247	13.5899	14.6400	-0.1153	-1.0501	-0.8%	-7.2%
HTLG-75VS	NiO (wt%)	0.9894	1.1343	1.1300	-0.1406	0.0043	-12.4%	0.4%
HTLG-75VS	SiO2 (wt%)	40.5665	42.6820	41.6700	-1.1035	1.0120	-2.6%	2.4%
HTLG-75VS	SO4 (wt%)	0.3767	0.3767	0.4900	-0.1133	-0.1133	-23.1%	-23.1%
HTLG-75VS	TiO2 (wt%)	0.0450	0.0487	0.0400	0.0050	0.0087	12.6%	21.8%
HTLG-75VS	ZrO2 (wt%)	0.1182	0.1182	0.1200	-0.0018	-0.0018	-1.5%	-1.5%
HTLG-75VS	Oxide Sum (wt%)	96.7109	98.7538	99.9900	-3.2791	-1.2362	-3.3%	-1.2%
HTLG-76VS	Al2O3 (wt%)	9.4144	9.2569	9.2300	0.1844	0.0269	2.0%	0.3%
HTLG-76VS	B2O3 (wt%)	4.3147	4.2189	4.3200	-0.0053	-0.1011	-0.1%	-2.3%
HTLG-76VS	CaO (wt%)	2.1828	2.1755	1.9800	0.2028	0.1955	10.2%	9.9%
HTLG-76VS	Cr2O3 (wt%)	0.1118	0.1099	0.1300	-0.0182	-0.0201	-14.0%	-15.4%
HTLG-76VS	CuO (wt%)	0.0576	0.0591	0.0500	0.0076	0.0091	15.2%	18.3%
HTLG-76VS	Fe2O3 (wt%)	18.4074	17.9991	18.4800	-0.0726	-0.4809	-0.4%	-2.6%
HTLG-76VS	K2O (wt%)	0.2548	0.2791	0.2300	0.0248	0.0491	10.8%	21.3%
HTLG-76VS	Li2O (wt%)	2.8472	2.8291	2.8800	-0.0328	-0.0509	-1.1%	-1.8%
HTLG-76VS	MgO (wt%)	2.0148	2.0926	2.2400	-0.2252	-0.1474	-10.1%	-6.6%
HTLG-76VS	MnO (wt%)	3.8413	3.8610	3.8700	-0.0287	-0.0090	-0.7%	-0.2%
HTLG-76VS	Na2O (wt%)	13.4497	12.5840	13.3800	0.0697	-0.7960	0.5%	-5.9%
HTLG-76VS	NiO (wt%)	0.7330	0.8403	0.8700	-0.1370	-0.0297	-15.8%	-3.4%
HTLG-76VS	SiO2 (wt%)	40.8606	42.2385	41.6700	-0.8094	0.5685	-1.9%	1.4%
HTLG-76VS	SO4 (wt%)	0.4262	0.4262	0.4900	-0.0638	-0.0638	-13.0%	-13.0%
HTLG-76VS	TiO2 (wt%)	0.0446	0.0483	0.0400	0.0046	0.0083	11.5%	20.7%
HTLG-76VS	ZrO2 (wt%)	0.1260	0.1260	0.1200	0.0060	0.0060	5.0%	5.0%
HTLG-76VS	Oxide Sum (wt%)	99.0868	99.1445	99.9800	-0.8932	-0.8355	-0.9%	-0.8%
HTLG-77VS	Al2O3 (wt%)	9.4617	9.3035	9.2300	0.2317	0.0735	2.5%	0.8%
HTLG-77VS	B2O3 (wt%)	4.2744	4.3150	4.3200	-0.0456	-0.0050	-1.1%	-0.1%
HTLG-77VS	CaO (wt%)	1.5566	1.5491	1.4600	0.0966	0.0891	6.6%	6.1%
HTLG-77VS	Cr2O3 (wt%)	0.0555	0.0535	0.0700	-0.0145	-0.0165	-20.7%	-23.6%
HTLG-77VS	CuO (wt%)	0.0316	0.0325	0.0300	0.0016	0.0025	5.4%	8.3%
HTLG-77VS	Fe2O3 (wt%)	17.7640	18.4959	19.7800	-2.0160	-1.2841	-10.2%	-6.5%
HTLG-77VS	K2O (wt%)	0.1313	0.1455	0.1200	0.0113	0.0255	9.4%	21.3%
HTLG-77VS	Li2O (wt%)	2.8795	2.8939	2.8800	-0.0005	0.0139	0.0%	0.5%
HTLG-77VS	MgO (wt%)	1.5837	1.6100	1.7200	-0.1363	-0.1100	-7.9%	-6.4%
HTLG-77VS	MnO (wt%)	3.9930	3.9980	3.8700	0.1230	0.1280	3.2%	3.3%
HTLG-77VS	Na2O (wt%)	13.5474	12.6959	13.3800	0.1674	-0.6841	1.3%	-5.1%
HTLG-77VS	NiO (wt%)	0.9722	1.0944	1.1300	-0.1578	-0.0356	-14.0%	-3.2%
HTLG-77VS	SiO2 (wt%)	41.0478	43.0162	41.6700	-0.6222	1.3462	-1.5%	3.2%
HTLG-77VS	SO4 (wt%)	0.2614	0.2614	0.2600	0.0014	0.0014	0.5%	0.5%
HTLG-77VS	TiO2 (wt%)	0.0238	0.0260	0.0200	0.0038	0.0060	18.8%	30.0%
HTLG-77VS	ZrO2 (wt%)	0.0686	0.0686	0.0600	0.0086	0.0086	14.3%	14.3%
HTLG-77VS	Oxide Sum (wt%)	97.6525	99.5594	100.0000	-2.3475	-0.4406	-2.3%	-0.4%

Table A6. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide for the HTL Study Glasses

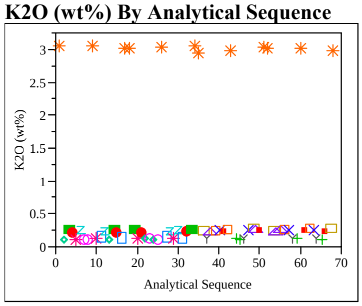
Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas BC	% Diff of Measured	% Diff of Meas BC
HTLG-78VS	Al2O3 (wt%)	8.4791	8.3374	8.3500	0.1291	-0.0126	1.5%	-0.2%
HTLG-78VS	B2O3 (wt%)	4.3630	4.2660	4.3200	0.0430	-0.0540	1.0%	-1.3%
HTLG-78VS	CaO (wt%)	2.1128	2.1026	1.9800	0.1328	0.1226	6.7%	6.2%
HTLG-78VS	Cr2O3 (wt%)	0.1030	0.0993	0.1300	-0.0270	-0.0307	-20.7%	-23.6%
HTLG-78VS	CuO (wt%)	0.0566	0.0582	0.0500	0.0066	0.0082	13.3%	16.5%
HTLG-78VS	Fe2O3 (wt%)	19.6584	19.2199	20.3700	-0.7116	-1.1501	-3.5%	-5.6%
HTLG-78VS	K2O (wt%)	0.2454	0.2721	0.2300	0.0154	0.0421	6.7%	18.3%
HTLG-78VS	Li2O (wt%)	2.8687	2.8509	2.8800	-0.0113	-0.0291	-0.4%	-1.0%
HTLG-78VS	MgO (wt%)	1.6998	1.7281	1.8700	-0.1702	-0.1419	-9.1%	-7.6%
HTLG-78VS	MnO (wt%)	3.5573	3.5618	3.5000	0.0573	0.0618	1.6%	1.8%
HTLG-78VS	Na2O (wt%)	13.3789	12.5378	13.3800	-0.0011	-0.8422	0.0%	-6.3%
HTLG-78VS	NiO (wt%)	0.9665	1.0879	1.1300	-0.1635	-0.0421	-14.5%	-3.7%
HTLG-78VS	SiO2 (wt%)	40.7269	41.9371	41.1500	-0.4231	0.7871	-1.0%	1.9%
HTLG-78VS	SO4 (wt%)	0.4015	0.4015	0.4900	-0.0885	-0.0885	-18.1%	-18.1%
HTLG-78VS	TiO2 (wt%)	0.0417	0.0456	0.0400	0.0017	0.0056	4.3%	14.1%
HTLG-78VS	ZrO2 (wt%)	0.1168	0.1168	0.1200	-0.0032	-0.0032	-2.6%	-2.6%
HTLG-78VS	Oxide Sum (wt%)	98.7764	98.6232	99.9900	-1.2136	-1.3668	-1.2%	-1.4%
HTLG-79VS	Al2O3 (wt%)	8.5453	8.4024	8.3500	0.1953	0.0524	2.3%	0.6%
HTLG-79VS	B2O3 (wt%)	4.3469	4.2507	4.3200	0.0269	-0.0693	0.6%	-1.6%
HTLG-79VS	CaO (wt%)	2.1583	2.1479	1.9800	0.1783	0.1679	9.0%	8.5%
HTLG-79VS	Cr2O3 (wt%)	0.0574	0.0553	0.0700	-0.0126	-0.0147	-18.0%	-21.1%
HTLG-79VS	CuO (wt%)	0.0347	0.0357	0.0300	0.0047	0.0057	15.8%	19.1%
HTLG-79VS	Fe2O3 (wt%)	17.1207	16.7402	18.8900	-1.7693	-2.1498	-9.4%	-11.4%
HTLG-79VS	K2O (wt%)	0.1364	0.1512	0.1200	0.0164	0.0312	13.7%	26.0%
HTLG-79VS	Li2O (wt%)	2.8418	2.8241	2.8800	-0.0382	-0.0559	-1.3%	-1.9%
HTLG-79VS	MgO (wt%)	1.9941	2.0271	2.2400	-0.2459	-0.2129	-11.0%	-9.5%
HTLG-79VS	MnO (wt%)	3.8833	3.8883	3.8700	0.0133	0.0183	0.3%	0.5%
HTLG-79VS	Na2O (wt%)	14.6595	13.7382	14.6400	0.0195	-0.9018	0.1%	-6.2%
HTLG-79VS	NiO (wt%)	0.9445	1.0632	1.1300	-0.1855	-0.0668	-16.4%	-5.9%
HTLG-79VS	SiO2 (wt%)	40.3525	41.5580	41.1500	-0.7975	0.4080	-1.9%	1.0%
HTLG-79VS	SO4 (wt%)	0.2569	0.2569	0.2600	-0.0031	-0.0031	-1.2%	-1.2%
HTLG-79VS	TiO2 (wt%)	0.0234	0.0255	0.0200	0.0034	0.0055	16.8%	27.7%
HTLG-79VS	ZrO2 (wt%)	0.0601	0.0601	0.0600	0.0001	0.0001	0.2%	0.2%
HTLG-79VS	Oxide Sum (wt%)	97.4157	97.2248	100.0100	-2.5943	-2.7852	-2.6%	-2.8%

Exhibit A1. Oxide Measurements in Analytical Sequence for Series "P" Samples Prepared Using the LM Method

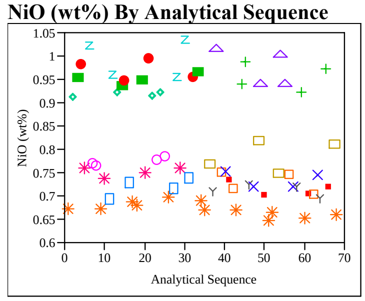
Al2O3 (wt%) By Analytical Sequence



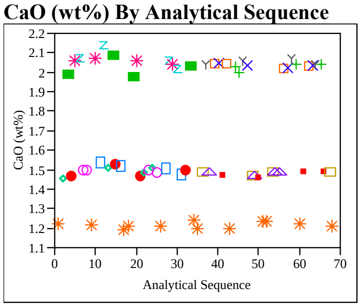
K2O (wt%) By Analytical Sequence



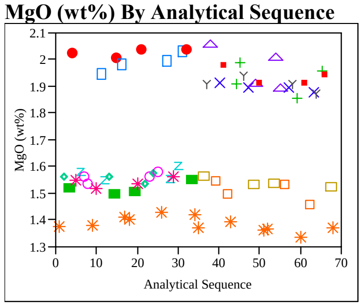
NiO (wt%) By Analytical Sequence



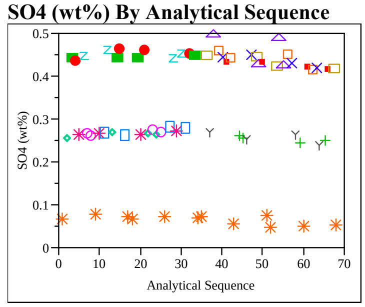
CaO (wt%) By Analytical Sequence



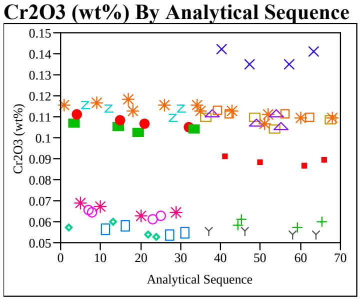
MgO (wt%) By Analytical Sequence



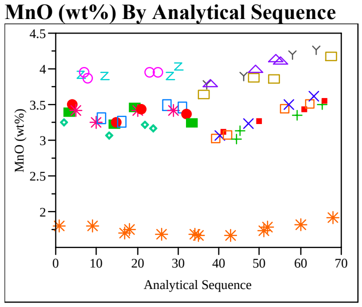
SO4 (wt%) By Analytical Sequence



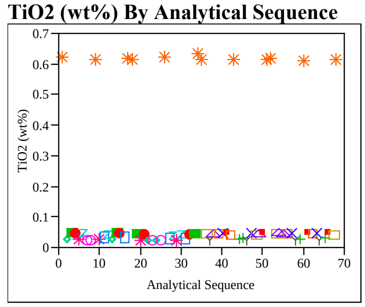
Cr2O3 (wt%) By Analytical Sequence



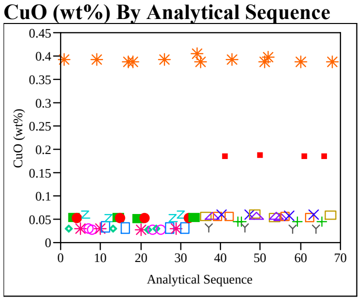
MnO (wt%) By Analytical Sequence



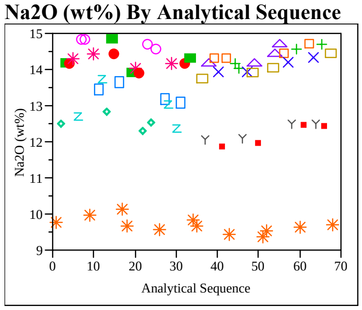
TiO2 (wt%) By Analytical Sequence



CuO (wt%) By Analytical Sequence



Na2O (wt%) By Analytical Sequence



ZrO2 (wt%) By Analytical Sequence

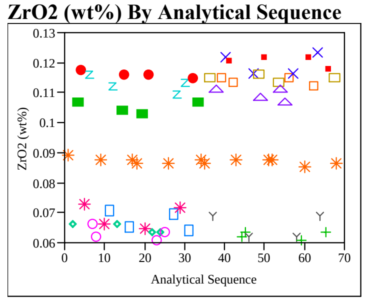
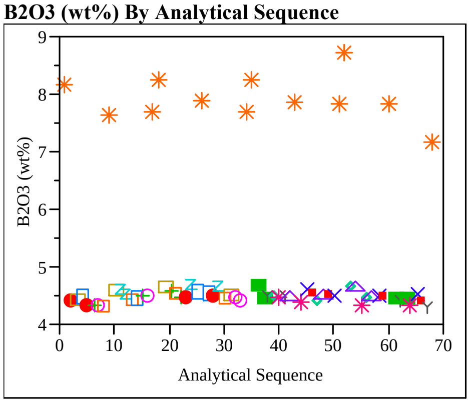
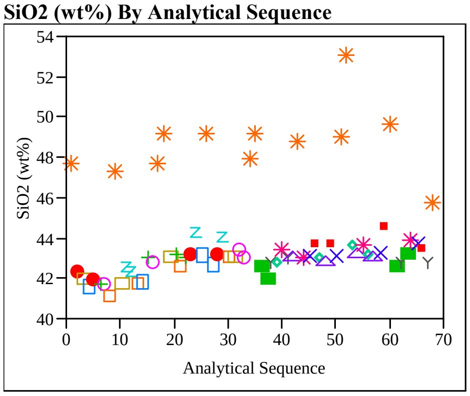


Exhibit A2. Measurements in Analytical Sequence for Series "P" Samples Prepared Using the PF Method

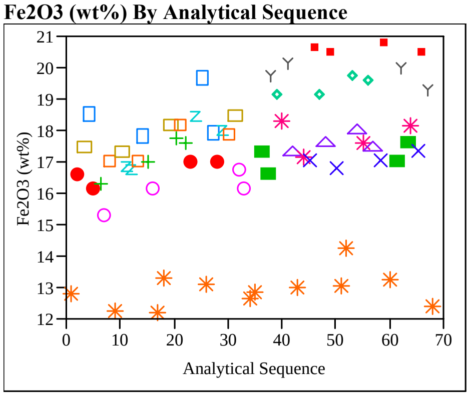
B2O3 (wt%) By Analytical Sequence



SiO2 (wt%) By Analytical Sequence



Fe2O3 (wt%) By Analytical Sequence



Li2O (wt%) By Analytical Sequence

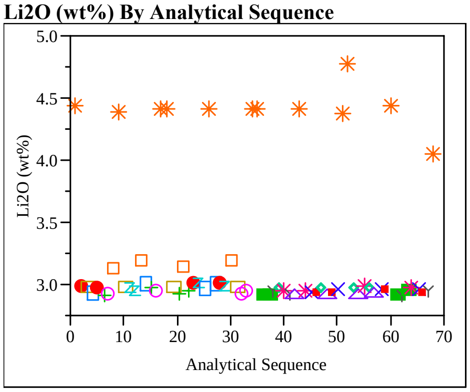
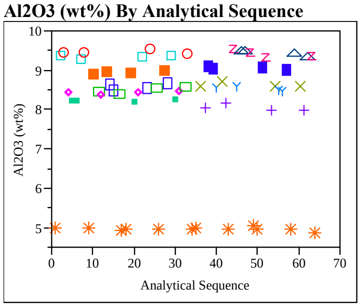
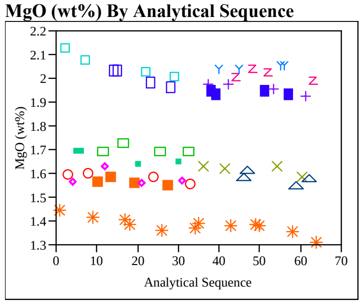


Exhibit A3. Measurements in Analytical Sequence for Series "Q" Samples Prepared Using the LM Method

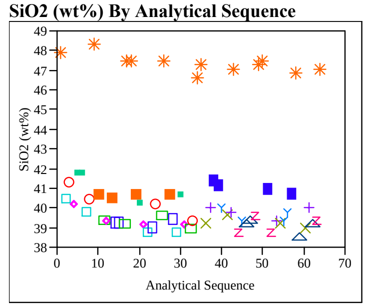
Al2O3 (wt%) By Analytical Sequence



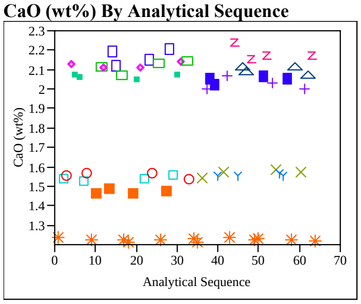
MgO (wt%) By Analytical Sequence



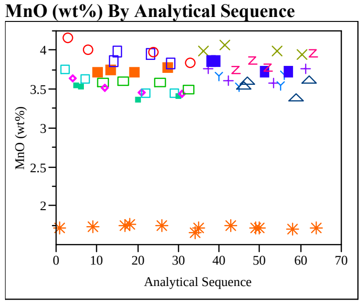
SiO2 (wt%) By Analytical Sequence



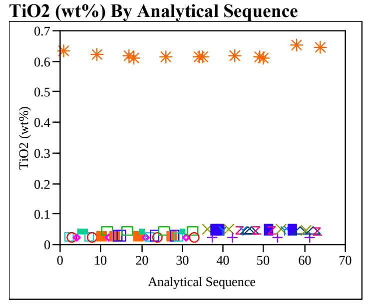
CaO (wt%) By Analytical Sequence



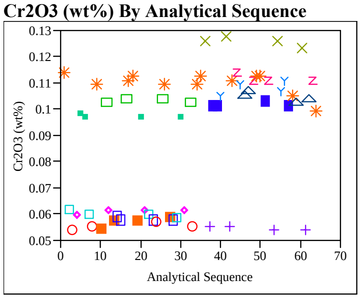
MnO (wt%) By Analytical Sequence



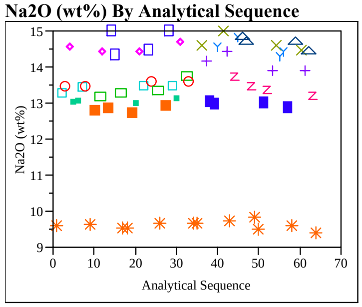
TiO2 (wt%) By Analytical Sequence



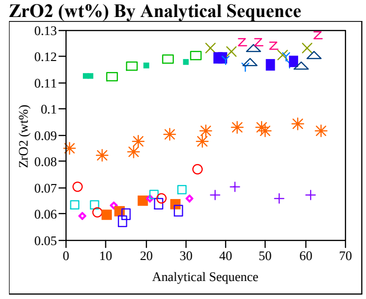
Cr2O3 (wt%) By Analytical Sequence



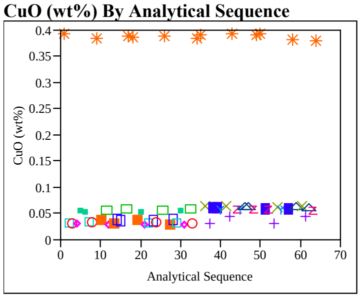
Na2O (wt%) By Analytical Sequence



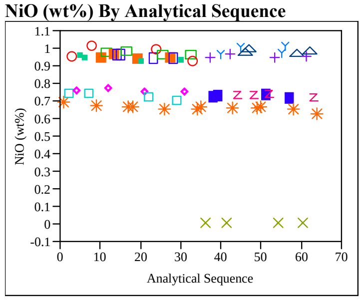
ZrO2 (wt%) By Analytical Sequence



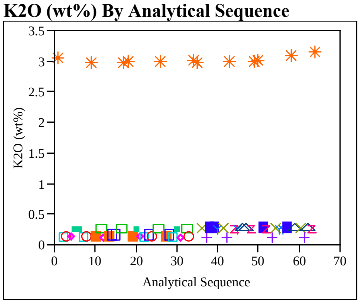
CuO (wt%) By Analytical Sequence



NiO (wt%) By Analytical Sequence



K2O (wt%) By Analytical Sequence



SO4 (wt%) By Analytical Sequence

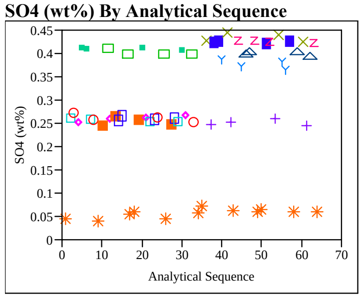
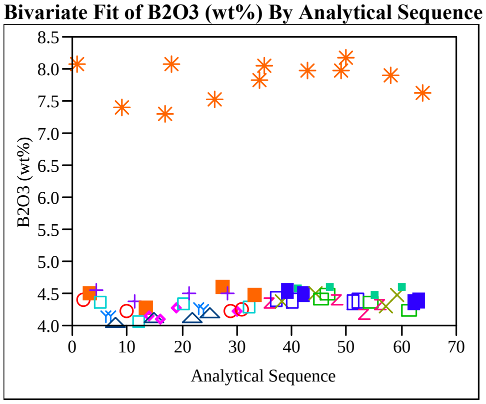
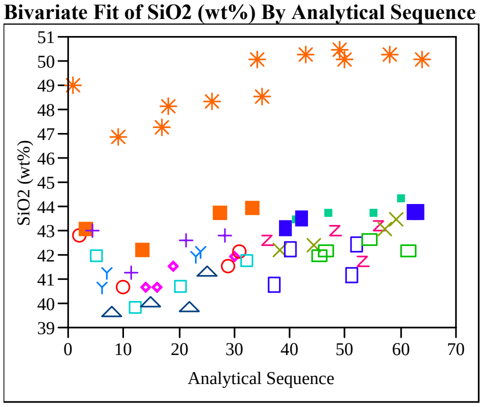
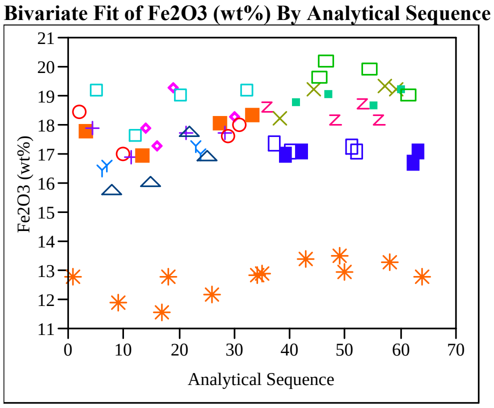


Exhibit A4. Measurements in Analytical Sequence for Series "Q" Samples Prepared Using the PF Method







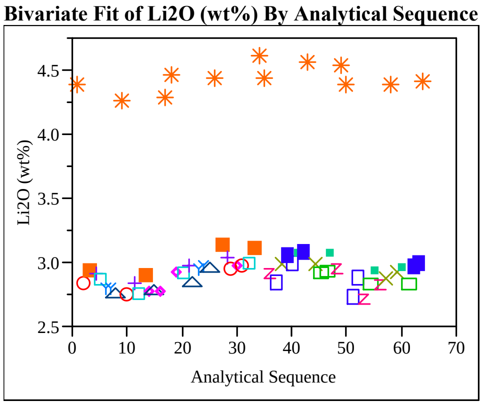
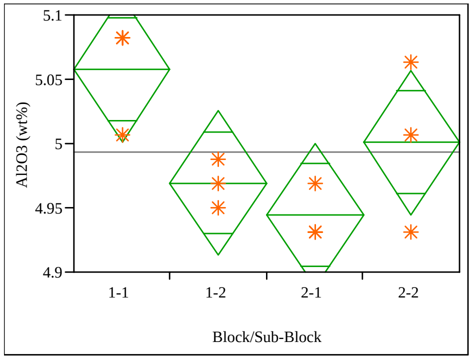


Exhibit A5. PSAL Measurements by Analytical Block for Series "Q" Samples of the Batch 1 Standard Glass Prepared Using the LM Method

Oneway Analysis of Al2O3 (wt%) By Block/Sub-Block
Reference Value = 4.877 wt%



Oneway Anova
Summary of Fit

Rsquare	0.600998
Adj Rsquare	0.451372
Root Mean Square Error	0.042251
Mean of Response	4.993004
Observations (or Sum Wgts)	12

Analysis of Variance

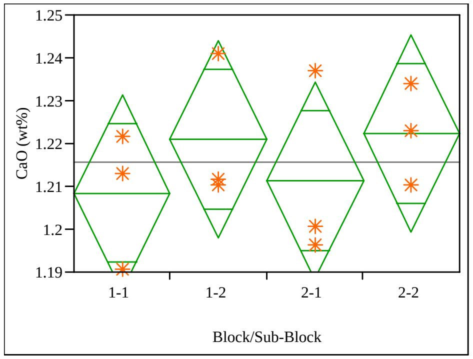
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.02151052	0.007170	4.0167	0.0514
Error	8	0.01428084	0.001785		
C. Total	11	0.03579136			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	5.05756	0.02439	5.0013	5.1138
1-2	3	4.96939	0.02439	4.9131	5.0256
2-1	3	4.94419	0.02439	4.8879	5.0004
2-2	3	5.00088	0.02439	4.9446	5.0571

Std Error uses a pooled estimate of error variance

Oneway Analysis of CaO (wt%) By Block/Sub-Block
Reference Value = 1.220 wt%



Oneway Anova
Summary of Fit

Rsquare	0.155199
Adj Rsquare	-0.1616
Root Mean Square Error	0.017284
Mean of Response	1.215788
Observations (or Sum Wgts)	12

Analysis of Variance

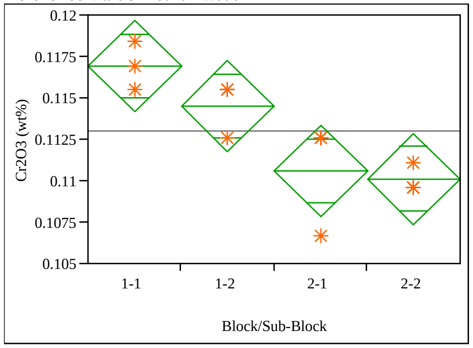
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00043903	0.000146	0.4899	0.6989
Error	8	0.00238977	0.000299		
C. Total	11	0.00282880			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.20844	0.00998	1.1854	1.2315
1-2	3	1.22104	0.00998	1.1980	1.2440
2-1	3	1.21124	0.00998	1.1882	1.2343
2-2	3	1.22243	0.00998	1.1994	1.2454

Std Error uses a pooled estimate of error variance

Oneway Analysis of Cr2O3 (wt%) By Block/Sub-Block
Reference Value = 0.107 wt%



Oneway Anova
Summary of Fit

Rsquare	0.736264
Adj Rsquare	0.637363
Root Mean Square Error	0.002067
Mean of Response	0.11303
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00009542	0.000032	7.4444	0.0106
Error	8	0.00003418	4.273e-6		
C. Total	11	0.00012960			

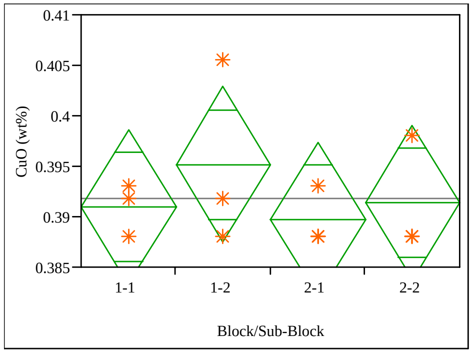
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.116928	0.00119	0.11418	0.11968
1-2	3	0.114492	0.00119	0.11174	0.11724
2-1	3	0.110594	0.00119	0.10784	0.11335
2-2	3	0.110107	0.00119	0.10736	0.11286

Std Error uses a pooled estimate of error variance

Exhibit A5. PSAL Measurements by Analytical Block for Series "Q" Samples of the Batch 1 Standard Glass Prepared Using the LM Method

Oneway Analysis of CuO (wt%) By Block/Sub-Block
Reference Value = 0.399 wt%



Oneway Anova
Summary of Fit

Rsquare	0.155116
Adj Rsquare	-0.16172
Root Mean Square Error	0.005782
Mean of Response	0.391813
Observations (or Sum Wgts)	12

Analysis of Variance

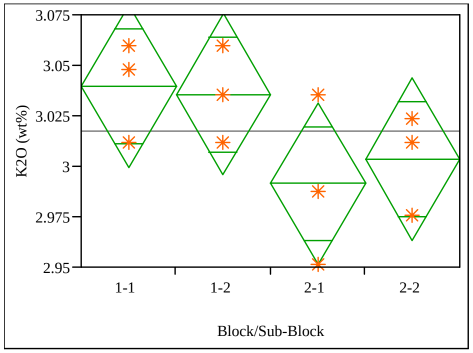
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00004910	0.000016	0.4896	0.6991
Error	8	0.00026744	0.000033		
C. Total	11	0.00031653			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.390979	0.00334	0.38328	0.39868
1-2	3	0.395152	0.00334	0.38745	0.40285
2-1	3	0.389727	0.00334	0.38203	0.39742
2-2	3	0.391396	0.00334	0.38370	0.39909

Std Error uses a pooled estimate of error variance

Oneway Analysis of K2O (wt%) By Block/Sub-Block
Reference Value = 3.327 wt%



Oneway Anova
Summary of Fit

Rsquare	0.411765
Adj Rsquare	0.191176
Root Mean Square Error	0.030115
Mean of Response	3.017523
Observations (or Sum Wgts)	12

Analysis of Variance

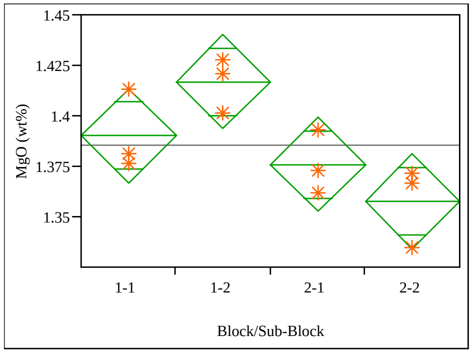
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00507871	0.001693	1.8667	0.2136
Error	8	0.00725531	0.000907		
C. Total	11	0.01233402			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	3.03961	0.01739	2.9995	3.0797
1-2	3	3.03559	0.01739	2.9955	3.0757
2-1	3	2.99142	0.01739	2.9513	3.0315
2-2	3	3.00347	0.01739	2.9634	3.0436

Std Error uses a pooled estimate of error variance

Oneway Analysis of MgO (wt%) By Block/Sub-Block
Reference Value = 1.419 wt%



Oneway Anova
Summary of Fit

Rsquare	0.695569
Adj Rsquare	0.581408
Root Mean Square Error	0.017517
Mean of Response	1.385095
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00560877	0.001870	6.0929	0.0184
Error	8	0.00245480	0.000307		
C. Total	11	0.00806357			

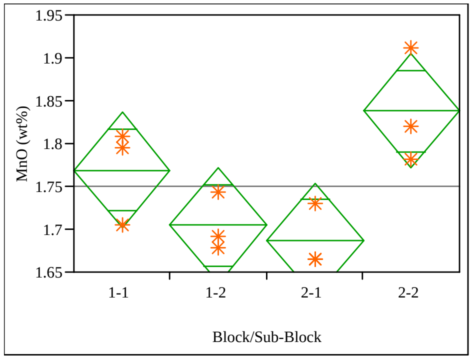
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.39021	0.01011	1.3669	1.4135
1-2	3	1.41674	0.01011	1.3934	1.4401
2-1	3	1.37584	0.01011	1.3525	1.3992
2-2	3	1.35759	0.01011	1.3343	1.3809

Std Error uses a pooled estimate of error variance

Exhibit A5. PSAL Measurements by Analytical Block for Series "Q" Samples of the Batch 1 Standard Glass Prepared Using the LM Method

Oneway Analysis of MnO (wt%) By Block/Sub-Block
Reference Value = 1.726 wt%



Oneway Anova
Summary of Fit

Rsquare	0.676444
Adj Rsquare	0.555111
Root Mean Square Error	0.050285
Mean of Response	1.749576
Observations (or Sum Wgts)	12

Analysis of Variance

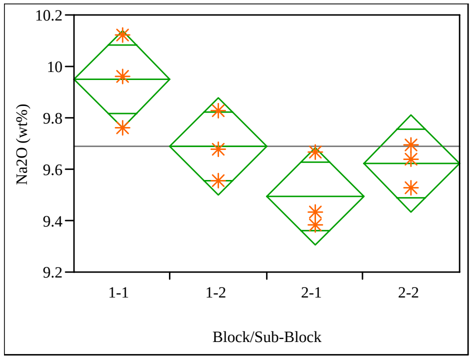
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.04229124	0.014097	5.5751	0.0232
Error	8	0.02022866	0.002529		
C. Total	11	0.06251990			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.76894	0.02903	1.7020	1.8359
1-2	3	1.70438	0.02903	1.6374	1.7713
2-1	3	1.68717	0.02903	1.6202	1.7541
2-2	3	1.83781	0.02903	1.7709	1.9048

Std Error uses a pooled estimate of error variance

Oneway Analysis of Na2O (wt%) By Block/Sub-Block
Reference Value = 9.003 wt%



Oneway Anova
Summary of Fit

Rsquare	0.670696
Adj Rsquare	0.547206
Root Mean Square Error	0.14218
Mean of Response	9.687627
Observations (or Sum Wgts)	12

Analysis of Variance

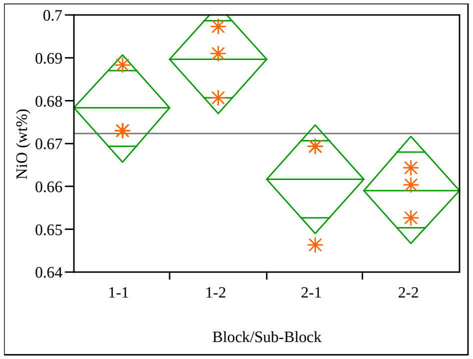
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.32938039	0.109793	5.4312	0.0248
Error	8	0.16172226	0.020215		
C. Total	11	0.49110264			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	9.94824	0.08209	9.7589	10.138
1-2	3	9.68763	0.08209	9.4983	9.877
2-1	3	9.49441	0.08209	9.3051	9.684
2-2	3	9.62023	0.08209	9.4309	9.810

Std Error uses a pooled estimate of error variance

Oneway Analysis of NiO (wt%) By Block/Sub-Block
Reference Value = 0.751wt%



Oneway Anova
Summary of Fit

Rsquare	0.724008
Adj Rsquare	0.620511
Root Mean Square Error	0.009437
Mean of Response	0.672198
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00186903	0.000623	6.9955	0.0126
Error	8	0.00071247	0.000089		
C. Total	11	0.00258150			

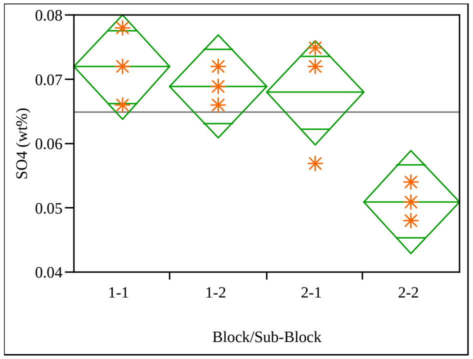
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.678243	0.00545	0.66568	0.69081
1-2	3	0.689695	0.00545	0.67713	0.70226
2-1	3	0.661700	0.00545	0.64914	0.67426
2-2	3	0.659155	0.00545	0.64659	0.67172

Std Error uses a pooled estimate of error variance

Exhibit A5. PSAL Measurements by Analytical Block for Series "Q" Samples of the Batch 1 Standard Glass Prepared Using the LM Method

Oneway Analysis of SO4 (wt%) By Block/Sub-Block
Reference Value = 0.0 wt%



Oneway Anova
Summary of Fit

Rsquare	0.733696
Adj Rsquare	0.633832
Root Mean Square Error	0.006054
Mean of Response	0.064911
Observations (or Sum Wgts)	12

Analysis of Variance

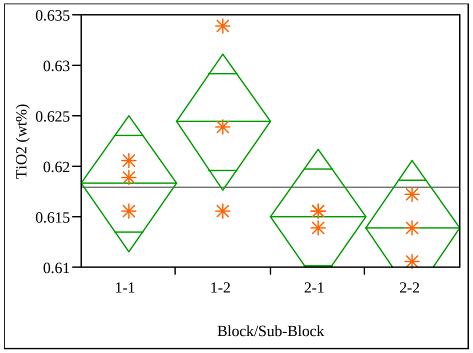
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00080779	0.000269	7.3469	0.0110
Error	8	0.00029320	0.000037		
C. Total	11	0.00110098			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.071902	0.00350	0.06384	0.07996
1-2	3	0.068906	0.00350	0.06085	0.07697
2-1	3	0.067907	0.00350	0.05985	0.07597
2-2	3	0.050930	0.00350	0.04287	0.05899

Std Error uses a pooled estimate of error variance

Oneway Analysis of TiO2 (wt%) By Block/Sub-Block
Reference Value = 0.677 wt%



Oneway Anova
Summary of Fit

Rsquare	0.496313
Adj Rsquare	0.307431
Root Mean Square Error	0.005073
Mean of Response	0.617855
Observations (or Sum Wgts)	12

Analysis of Variance

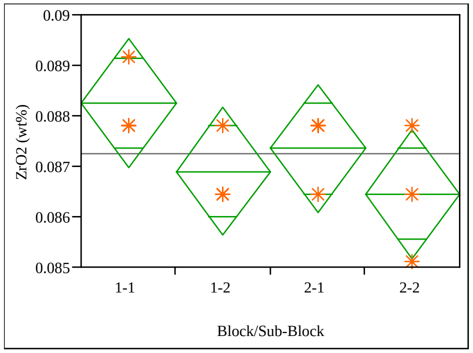
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00020287	0.000068	2.6276	0.1221
Error	8	0.00020588	0.000026		
C. Total	11	0.00040876			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.618272	0.00293	0.61152	0.62503
1-2	3	0.624388	0.00293	0.61763	0.63114
2-1	3	0.614936	0.00293	0.60818	0.62169
2-2	3	0.613824	0.00293	0.60707	0.62058

Std Error uses a pooled estimate of error variance

Oneway Analysis of ZrO2 (wt%) By Block/Sub-Block
Reference Value = 0.098 wt%



Oneway Anova
Summary of Fit

Rsquare	0.421687
Adj Rsquare	0.204819
Root Mean Square Error	0.000955
Mean of Response	0.087239
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00000532	1.774e-6	1.9444	0.2011
Error	8	0.00000730	9.1233e-7		
C. Total	11	0.00001262			

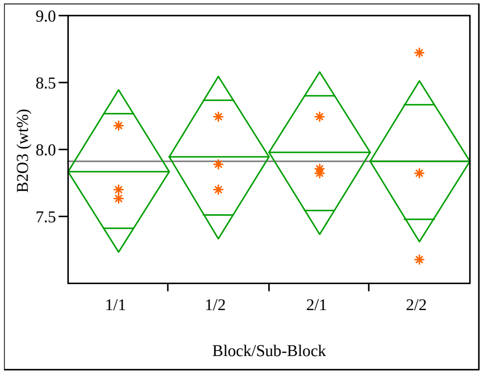
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.088252	0.00055	0.08698	0.08952
1-2	3	0.086901	0.00055	0.08563	0.08817
2-1	3	0.087352	0.00055	0.08608	0.08862
2-2	3	0.086451	0.00055	0.08518	0.08772

Std Error uses a pooled estimate of error variance

Exhibit A6. PSAL Measurements by Analytical Block for Series "Q" Samples of the Batch 1 Standard Glass Prepared Using the PF Method

Oneway Analysis of B2O3 (wt%) By Block/Sub-Block
Reference Value = 7.777wt%



Oneway Anova
Summary of Fit

Rsquare	0.01914
Adj Rsquare	-0.34868
Root Mean Square Error	0.453747
Mean of Response	7.915588
Observations (or Sum Wgts)	12

Analysis of Variance

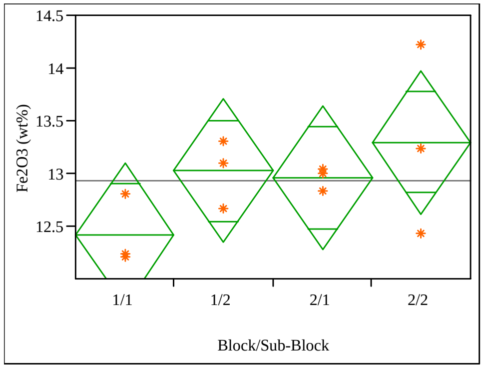
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.0321400	0.010713	0.0520	0.9832
Error	8	1.6470908	0.205886		
C. Total	11	1.6792309			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	7.83509	0.26197	7.2310	8.4392
1/2	3	7.94242	0.26197	7.3383	8.5465
2/1	3	7.97462	0.26197	7.3705	8.5787
2/2	3	7.91022	0.26197	7.3061	8.5143

Std Error uses a pooled estimate of error variance

Oneway Analysis of Fe2O3 (wt%) By Block/Sub-Block
Reference Value = 12.839 wt%



Oneway Anova
Summary of Fit

Rsquare	0.366914
Adj Rsquare	0.129507
Root Mean Square Error	0.511588
Mean of Response	12.92449
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	1.2134797	0.404493	1.5455	0.2763
Error	8	2.0937804	0.261723		
C. Total	11	3.3072601			

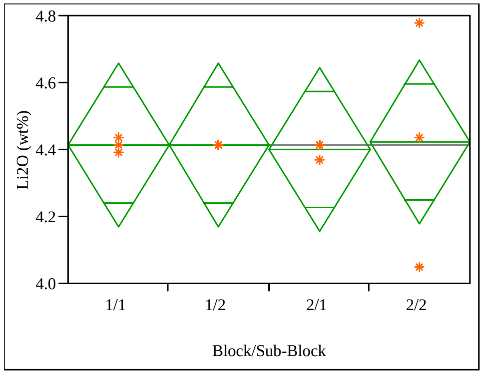
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	12.4193	0.29537	11.738	13.100
1/2	3	13.0246	0.29537	12.343	13.706
2/1	3	12.9578	0.29537	12.277	13.639
2/2	3	13.2962	0.29537	12.615	13.977

Std Error uses a pooled estimate of error variance

Exhibit A6. PSAL Measurements by Analytical Block for Series "Q" Samples of the Batch 1 Standard Glass Prepared Using the PF Method

Oneway Analysis of Li2O (wt%) By Block/Sub-Block
Reference Value = 4.429 wt%



Oneway Anova
Summary of Fit

Rsquare	0.002707
Adj Rsquare	-0.37128
Root Mean Square Error	0.183839
Mean of Response	4.411651
Observations (or Sum Wgts)	12

Analysis of Variance

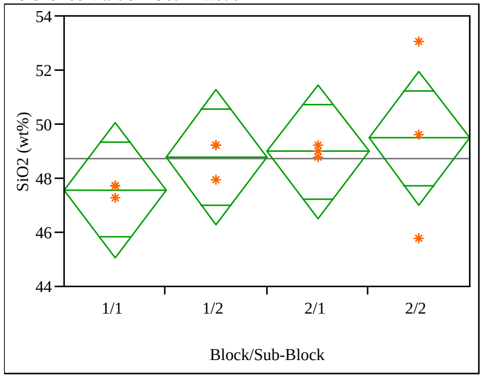
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00073387	0.000245	0.0072	0.9991
Error	8	0.27037374	0.033797		
C. Total	11	0.27110761			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	4.41345	0.10614	4.1687	4.6582
1/2	3	4.41345	0.10614	4.1687	4.6582
2/1	3	4.39909	0.10614	4.1543	4.6439
2/2	3	4.42062	0.10614	4.1759	4.6654

Std Error uses a pooled estimate of error variance

Oneway Analysis of SiO2 (wt%) By Block/Sub-Block
Reference Value = 50.22 wt%



Oneway Anova
Summary of Fit

Rsquare	0.177798
Adj Rsquare	-0.13053
Root Mean Square Error	1.863976
Mean of Response	48.70473
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	6.010607	2.00354	0.5767	0.6464
Error	8	27.795245	3.47441		
C. Total	11	33.805852			

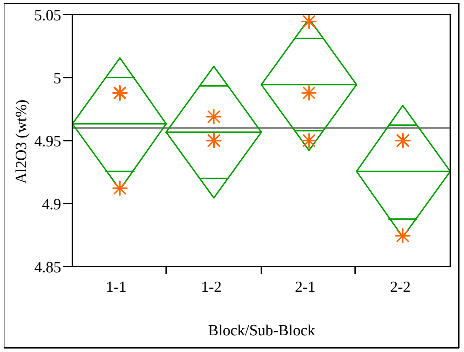
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	47.5638	1.0762	45.082	50.045
1/2	3	48.7760	1.0762	46.294	51.258
2/1	3	48.9900	1.0762	46.508	51.472
2/2	3	49.4891	1.0762	47.007	51.971

Std Error uses a pooled estimate of error variance

Exhibit A7. PSAL Measurements by Analytical Block for Series "P" Samples of the Batch 1 Standard Glass Prepared by LM

Oneway Analysis of Al2O3 (wt%) By Block/Sub-Block
Reference Value = 4.8777wt%



Oneway Anova
Summary of Fit

Rsquare	0.369697
Adj Rsquare	0.133333
Root Mean Square Error	0.039333
Mean of Response	4.959938
Observations (or Sum Wgts)	12

Analysis of Variance

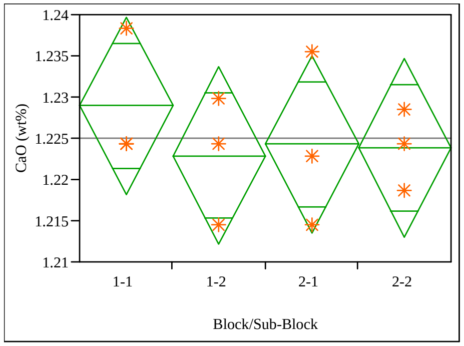
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00725943	0.002420	1.5641	0.2721
Error	8	0.01237673	0.001547		
C. Total	11	0.01963616			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	4.96309	0.02271	4.9107	5.0155
1-2	3	4.95679	0.02271	4.9044	5.0092
2-1	3	4.99458	0.02271	4.9422	5.0469
2-2	3	4.92530	0.02271	4.8729	4.9777

Std Error uses a pooled estimate of error variance

Oneway Analysis of CaO (wt%) By Block/Sub-Block
Reference Value = 1.220 wt%



Oneway Anova
Summary of Fit

Rsquare	0.111849
Adj Rsquare	-0.22121
Root Mean Square Error	0.008088
Mean of Response	1.225
Observations (or Sum Wgts)	12

Analysis of Variance

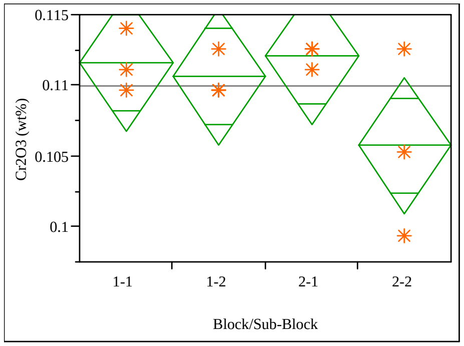
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00006591	0.000022	0.3358	0.8001
Error	8	0.00052337	0.000065		
C. Total	11	0.00058929			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.22896	0.00467	1.2182	1.2397
1-2	3	1.22290	0.00467	1.2121	1.2337
2-1	3	1.22430	0.00467	1.2135	1.2351
2-2	3	1.22383	0.00467	1.2131	1.2346

Std Error uses a pooled estimate of error variance

Oneway Analysis of Cr2O3 (wt%) By Block/Sub-Block
Reference Value = 0.1.07 wt%



Oneway Anova
Summary of Fit

Rsquare	0.422354
Adj Rsquare	0.205737
Root Mean Square Error	0.003605
Mean of Response	0.109985
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00007602	0.000025	1.9498	0.2002
Error	8	0.00010397	0.000013		
C. Total	11	0.00017998			

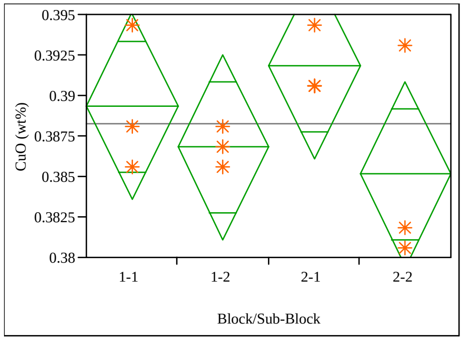
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.111569	0.00208	0.10677	0.11637
1-2	3	0.110594	0.00208	0.10579	0.11539
2-1	3	0.112056	0.00208	0.10726	0.11686
2-2	3	0.105722	0.00208	0.10092	0.11052

Std Error uses a pooled estimate of error variance

Exhibit A7. PSAL Measurements by Analytical Block for Series "P" Samples of the Batch 1 Standard Glass Prepared by LM

Oneway Analysis of CuO (wt%) By Block/Sub-Block
Reference Value = 0.399 wt%



Oneway Anova
Summary of Fit

Rsquare	0.341067
Adj Rsquare	0.093968
Root Mean Square Error	0.004306
Mean of Response	0.388267
Observations (or Sum Wgts)	12

Analysis of Variance

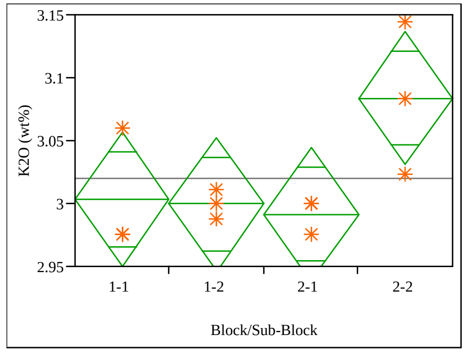
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00007678	0.000026	1.3803	0.3171
Error	8	0.00014834	0.000019		
C. Total	11	0.00022513			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.389310	0.00249	0.38358	0.39504
1-2	3	0.386806	0.00249	0.38107	0.39254
2-1	3	0.391813	0.00249	0.38608	0.39755
2-2	3	0.385137	0.00249	0.37940	0.39087

Std Error uses a pooled estimate of error variance

Oneway Analysis of K2O (wt%) By Block/Sub-Block
Reference Value = 3.327 wt%



Oneway Anova
Summary of Fit

Rsquare	0.569079
Adj Rsquare	0.407484
Root Mean Square Error	0.0398
Mean of Response	3.019531
Observations (or Sum Wgts)	12

Analysis of Variance

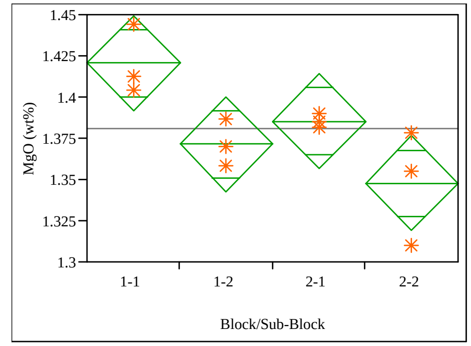
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.01673557	0.005579	3.5216	0.0686
Error	8	0.01267260	0.001584		
C. Total	11	0.02940817			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	3.00347	0.02298	2.9505	3.0565
1-2	3	2.99945	0.02298	2.9465	3.0524
2-1	3	2.99142	0.02298	2.9384	3.0444
2-2	3	3.08378	0.02298	3.0308	3.1368

Std Error uses a pooled estimate of error variance

Oneway Analysis of MgO (wt%) By Block/Sub-Block
Reference Value = 1.419 wt%



Oneway Anova
Summary of Fit

Rsquare	0.693142
Adj Rsquare	0.578071
Root Mean Square Error	0.021526
Mean of Response	1.381226
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00837340	0.002791	6.0236	0.0189
Error	8	0.00370694	0.000463		
C. Total	11	0.01208034			

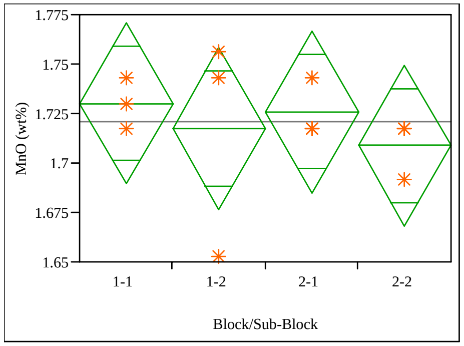
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.42061	0.01243	1.3920	1.4493
1-2	3	1.37141	0.01243	1.3428	1.4001
2-1	3	1.38523	0.01243	1.3566	1.4139
2-2	3	1.34765	0.01243	1.3190	1.3763

Std Error uses a pooled estimate of error variance

Exhibit A7. PSAL Measurements by Analytical Block for Series "P" Samples of the Batch 1 Standard Glass Prepared by LM

Oneway Analysis of MnO (wt%) By Block/Sub-Block
Reference Value = 1.726 wt%



Oneway Anova
Summary of Fit

Rsquare	0.097844
Adj Rsquare	-0.24046
Root Mean Square Error	0.030737
Mean of Response	1.720524
Observations (or Sum Wgts)	12

Analysis of Variance

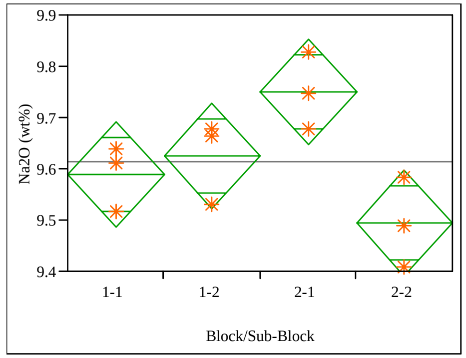
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00081971	0.000273	0.2892	0.8321
Error	8	0.00755796	0.000945		
C. Total	11	0.00837767			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.73021	0.01775	1.6893	1.7711
1-2	3	1.71730	0.01775	1.6764	1.7582
2-1	3	1.72590	0.01775	1.6850	1.7668
2-2	3	1.70869	0.01775	1.6678	1.7496

Std Error uses a pooled estimate of error variance

Oneway Analysis of Na2O (wt%) By Block/Sub-Block
Reference Value = 9.003 wt%



Oneway Anova
Summary of Fit

Rsquare	0.678147
Adj Rsquare	0.557452
Root Mean Square Error	0.077437
Mean of Response	9.61461
Observations (or Sum Wgts)	12

Analysis of Variance

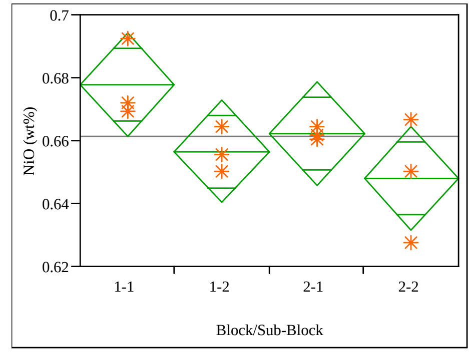
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.10107641	0.033692	5.6187	0.0227
Error	8	0.04797155	0.005996		
C. Total	11	0.14904796			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	9.58877	0.04471	9.4857	9.6919
1-2	3	9.62472	0.04471	9.5216	9.7278
2-1	3	9.75053	0.04471	9.6474	9.8536
2-2	3	9.49441	0.04471	9.3913	9.5975

Std Error uses a pooled estimate of error variance

Oneway Analysis of NiO (wt%) By Block/Sub-Block
Reference Value = 0.751 wt%



Oneway Anova
Summary of Fit

Rsquare	0.538057
Adj Rsquare	0.364828
Root Mean Square Error	0.012288
Mean of Response	0.66117
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00140700	0.000469	3.1060	0.0888
Error	8	0.00120797	0.000151		
C. Total	11	0.00261496			

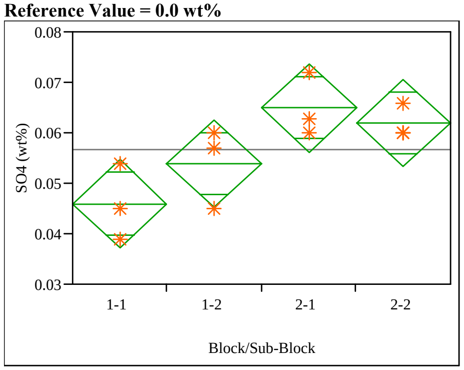
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.677818	0.00709	0.66146	0.69418
1-2	3	0.656610	0.00709	0.64025	0.67297
2-1	3	0.662124	0.00709	0.64576	0.67848
2-2	3	0.648127	0.00709	0.63177	0.66449

Std Error uses a pooled estimate of error variance

Exhibit A7. PSAL Measurements by Analytical Block for Series "P" Samples of the Batch 1 Standard Glass Prepared by LM

Oneway Analysis of SO4 (wt%) By Block/Sub-Block
Reference Value = 0.0 wt%



Oneway Anova
Summary of Fit

Rsquare	0.6574
Adj Rsquare	0.528926
Root Mean Square Error	0.006529
Mean of Response	0.056672
Observations (or Sum Wgts)	12

Analysis of Variance

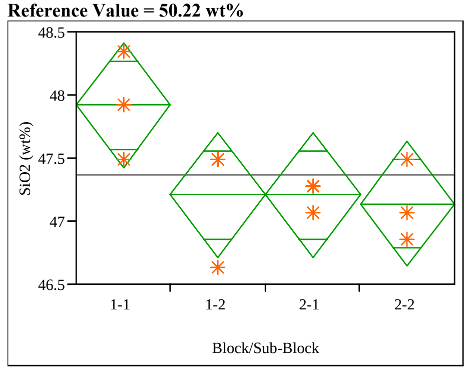
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00065446	0.000218	5.1170	0.0289
Error	8	0.00034107	0.000043		
C. Total	11	0.00099552			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.045937	0.00377	0.03724	0.05463
1-2	3	0.053926	0.00377	0.04523	0.06262
2-1	3	0.064911	0.00377	0.05622	0.07360
2-2	3	0.061915	0.00377	0.05322	0.07061

Std Error uses a pooled estimate of error variance

Oneway Analysis of SiO2 (wt%) By Block/Sub-Block
Reference Value = 50.22 wt%



Oneway Anova
Summary of Fit

Rsquare	0.528642
Adj Rsquare	0.351882
Root Mean Square Error	0.370538
Mean of Response	47.36767
Observations (or Sum Wgts)	12

Analysis of Variance

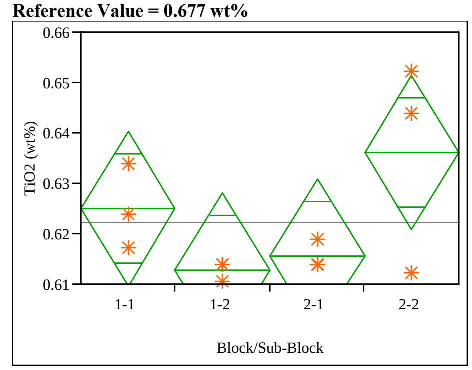
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	1.2318694	0.410623	2.9907	0.0957
Error	8	1.0983851	0.137298		
C. Total	11	2.3302545			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	47.9203	0.21393	47.427	48.414
1-2	3	47.2072	0.21393	46.714	47.701
2-1	3	47.2072	0.21393	46.714	47.701
2-2	3	47.1359	0.21393	46.643	47.629

Std Error uses a pooled estimate of error variance

Oneway Analysis of TiO2 (wt%) By Block/Sub-Block
Reference Value = 0.677 wt%



Oneway Anova
Summary of Fit

Rsquare	0.487122
Adj Rsquare	0.294792
Root Mean Square Error	0.011496
Mean of Response	0.622303
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00100415	0.000335	2.5327	0.1304
Error	8	0.00105725	0.000132		
C. Total	11	0.00206140			

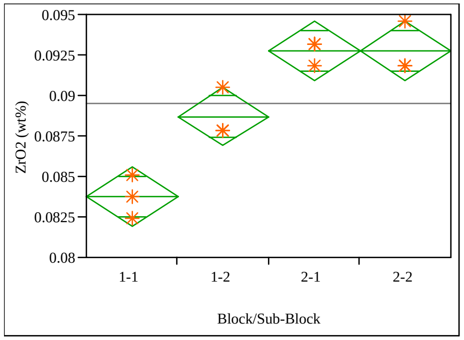
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.624944	0.00664	0.60964	0.64025
1-2	3	0.612712	0.00664	0.59741	0.62802
2-1	3	0.615492	0.00664	0.60019	0.63080
2-2	3	0.636064	0.00664	0.62076	0.65137

Std Error uses a pooled estimate of error variance

Exhibit A7. PSAL Measurements by Analytical Block for Series "P" Samples of the Batch 1 Standard Glass Prepared by LM

Oneway Analysis of ZrO2 (wt%) By Block/Sub-Block
Reference Value = 0.098 wt%



Oneway Anova
Summary of Fit

Rsquare	0.918575
Adj Rsquare	0.888041
Root Mean Square Error	0.001351
Mean of Response	0.089491
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.00016468	0.000055	30.0833	0.0001
Error	8	0.00001460	1.825e-6		
C. Total	11	0.00017927			

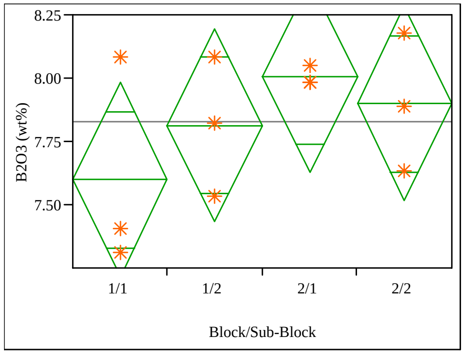
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.083750	0.00078	0.08195	0.08555
1-2	3	0.088703	0.00078	0.08690	0.09050
2-1	3	0.092755	0.00078	0.09096	0.09455
2-2	3	0.092755	0.00078	0.09096	0.09455

Std Error uses a pooled estimate of error variance

Exhibit A8. PSAL Measurements by Analytical Block for Series "P" Samples of the Batch 1 Standard Glass Prepared by PF

Oneway Analysis of B2O3 (wt%) By Block/Sub-Block
Reference Value = 7.777 wt%



Oneway Anova
Summary of Fit

Rsquare	0.290563
Adj Rsquare	0.024524
Root Mean Square Error	0.286643
Mean of Response	7.829724
Observations (or Sum Wgts)	12

Analysis of Variance

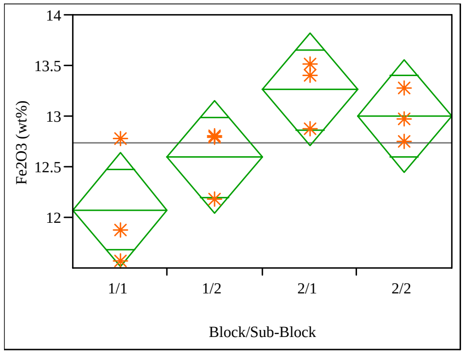
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.26921606	0.089739	1.0922	0.4066
Error	8	0.65731573	0.082164		
C. Total	11	0.92653180			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	7.59896	0.16549	7.2173	7.9806
1/2	3	7.81362	0.16549	7.4320	8.1953
2/1	3	8.00682	0.16549	7.6252	8.3884
2/2	3	7.89949	0.16549	7.5179	8.2811

Std Error uses a pooled estimate of error variance

Oneway Analysis of Fe2O3 (wt%) By Block/Sub-Block
Reference Value = 12.839 wt%



Oneway Anova
Summary of Fit

Rsquare	0.629085
Adj Rsquare	0.489992
Root Mean Square Error	0.421277
Mean of Response	12.73386
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	2.4080179	0.802673	4.5228	0.0390
Error	8	1.4197916	0.177474		
C. Total	11	3.8278095			

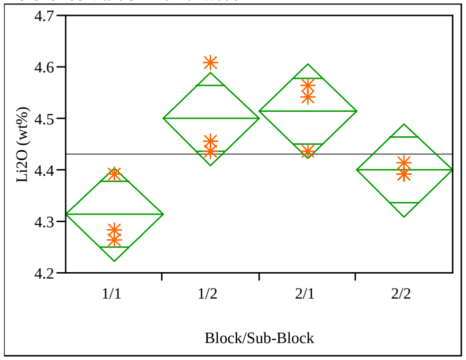
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	12.0762	0.24322	11.515	12.637
1/2	3	12.5957	0.24322	12.035	13.157
2/1	3	13.2629	0.24322	12.702	13.824
2/2	3	13.0007	0.24322	12.440	13.562

Std Error uses a pooled estimate of error variance

Exhibit A8. PSAL Measurements by Analytical Block for Series "P" Samples of the Batch 1 Standard Glass Prepared by PF

Oneway Analysis of Li2O (wt%) By Block/Sub-Block
Reference Value = 4.429 wt%



Oneway Anova
Summary of Fit

Rsquare	0.682119
Adj Rsquare	0.562914
Root Mean Square Error	0.068081
Mean of Response	4.431386
Observations (or Sum Wgts)	12

Analysis of Variance

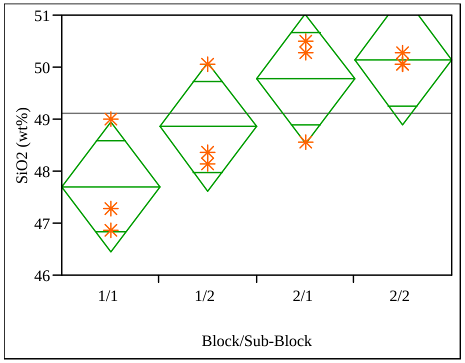
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	0.07956713	0.026522	5.7222	0.0217
Error	8	0.03707983	0.004635		
C. Total	11	0.11664696			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	4.31298	0.03931	4.2223	4.4036
1/2	3	4.49956	0.03931	4.4089	4.5902
2/1	3	4.51391	0.03931	4.4233	4.6046
2/2	3	4.39909	0.03931	4.3085	4.4897

Std Error uses a pooled estimate of error variance

Oneway Analysis of SiO2 (wt%) By Block/Sub-Block
Reference Value = 50.22 wt%



Oneway Anova
Summary of Fit

Rsquare	0.599913
Adj Rsquare	0.449881
Root Mean Square Error	0.938614
Mean of Response	49.11476
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block/Sub-Block	3	10.568143	3.52271	3.9986	0.0519
Error	8	7.047971	0.88100		
C. Total	11	17.616113			

Means for Oneway Anova

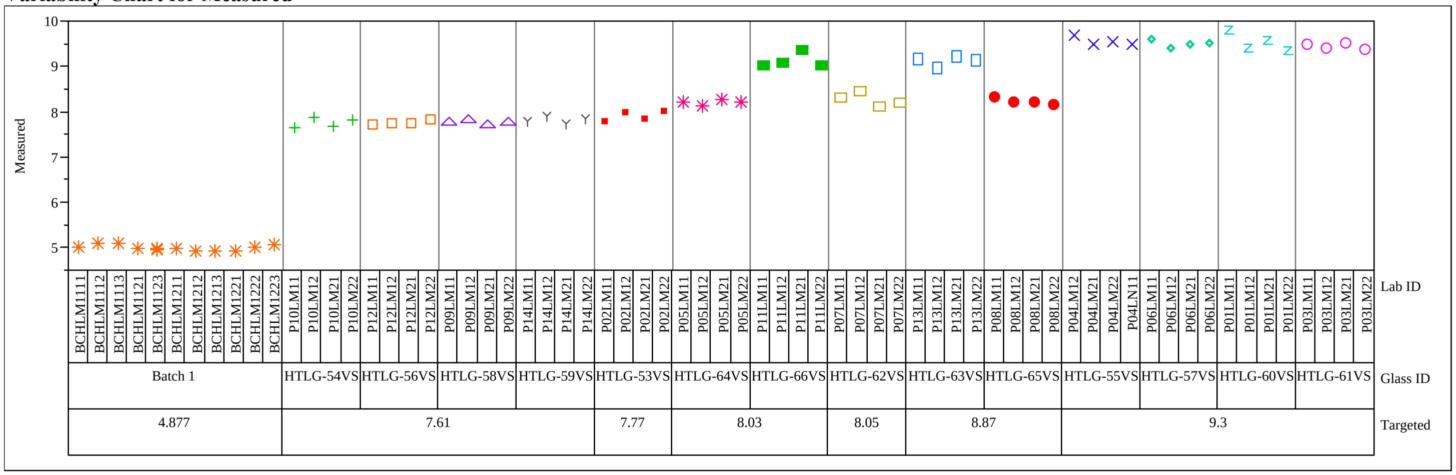
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	47.7064	0.54191	46.457	48.956
1/2	3	48.8474	0.54191	47.598	50.097
2/1	3	49.7744	0.54191	48.525	51.024
2/2	3	50.1309	0.54191	48.881	51.381

Std Error uses a pooled estimate of error variance

Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

Al2O3 (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

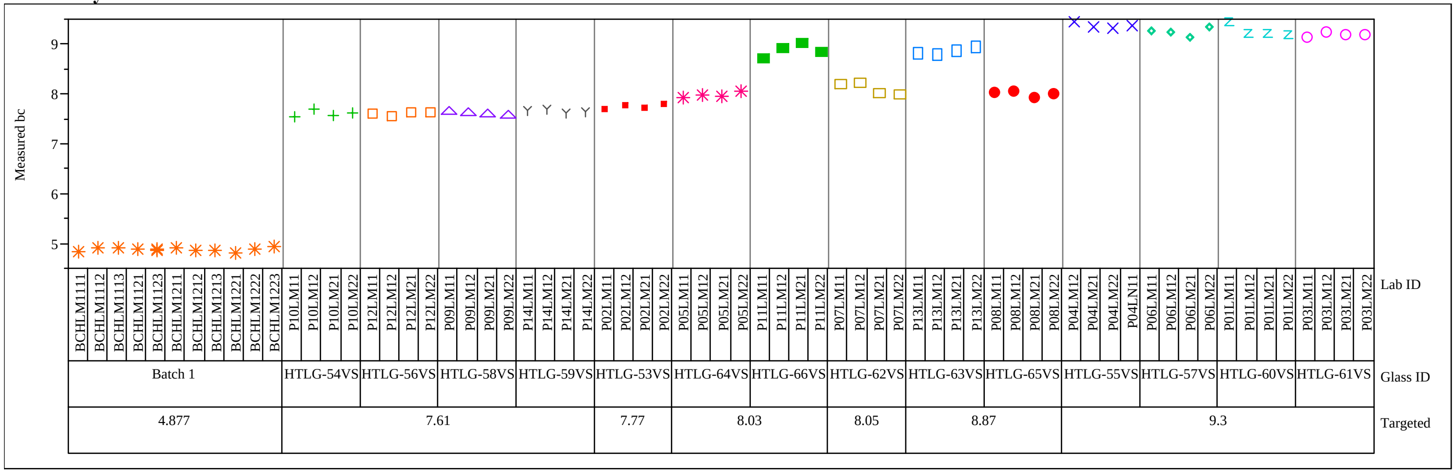
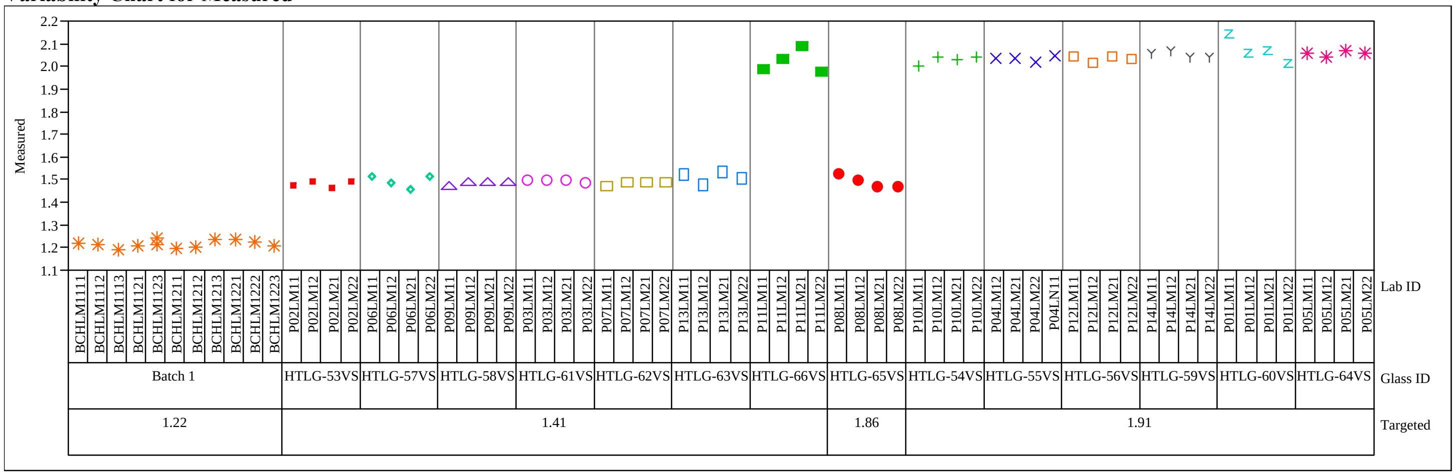


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

CaO (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

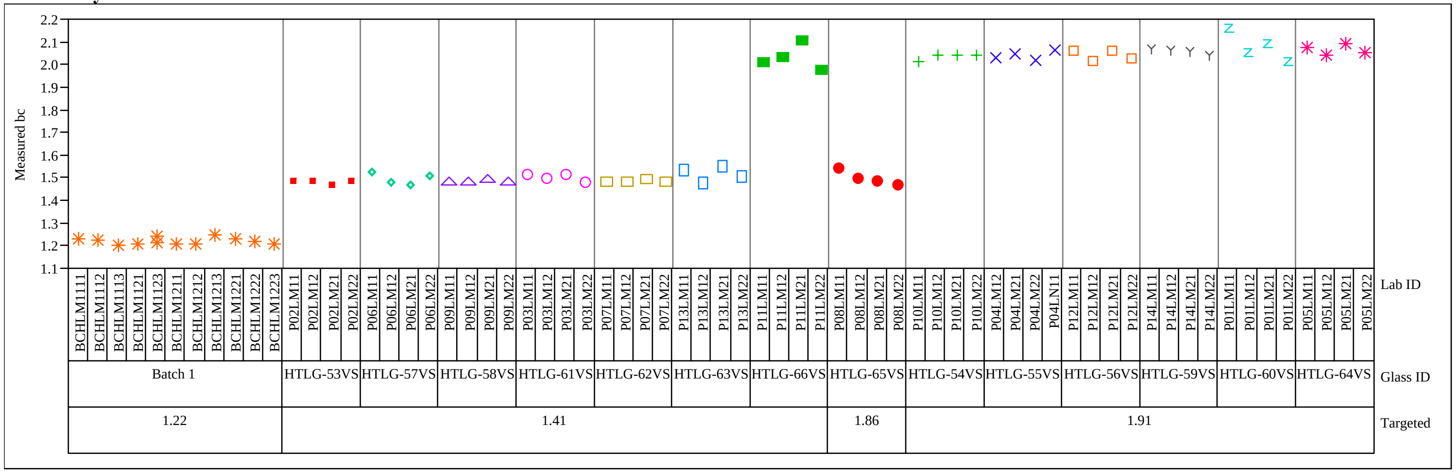
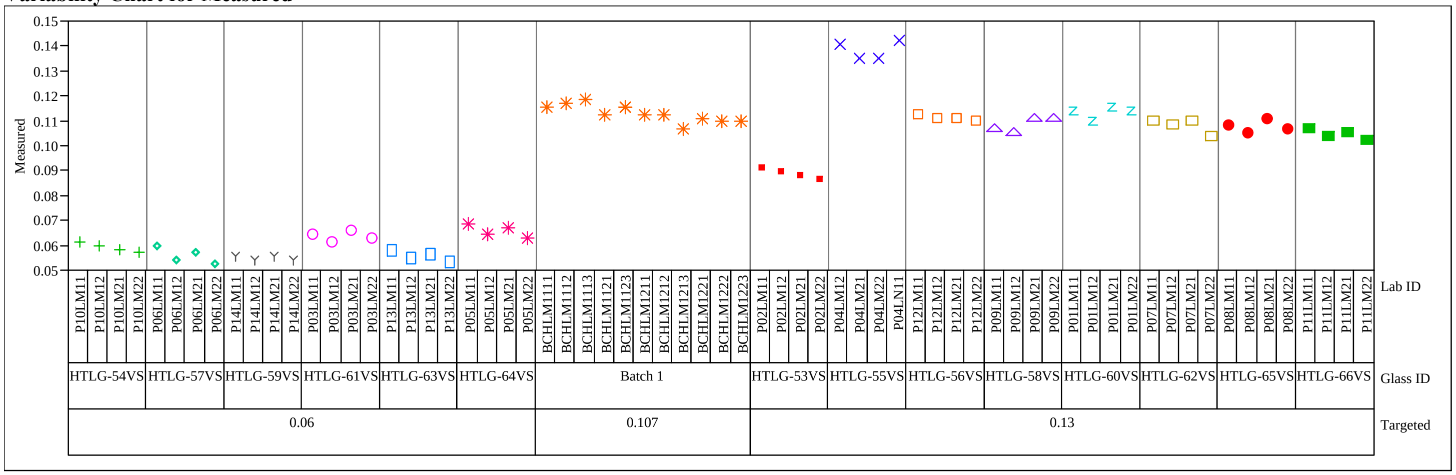


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

Cr2O3 (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

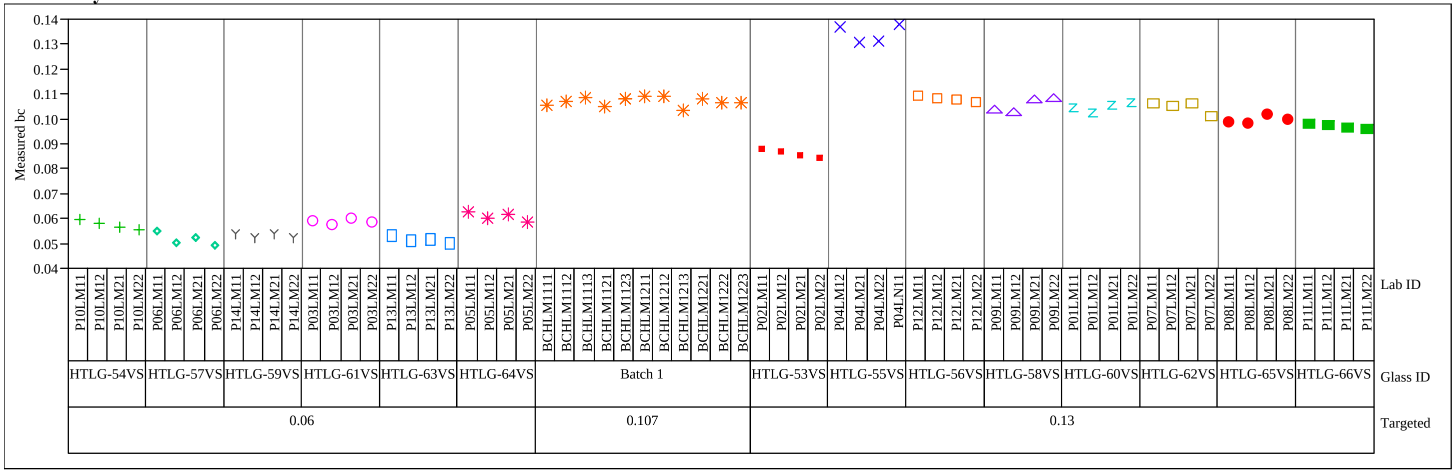
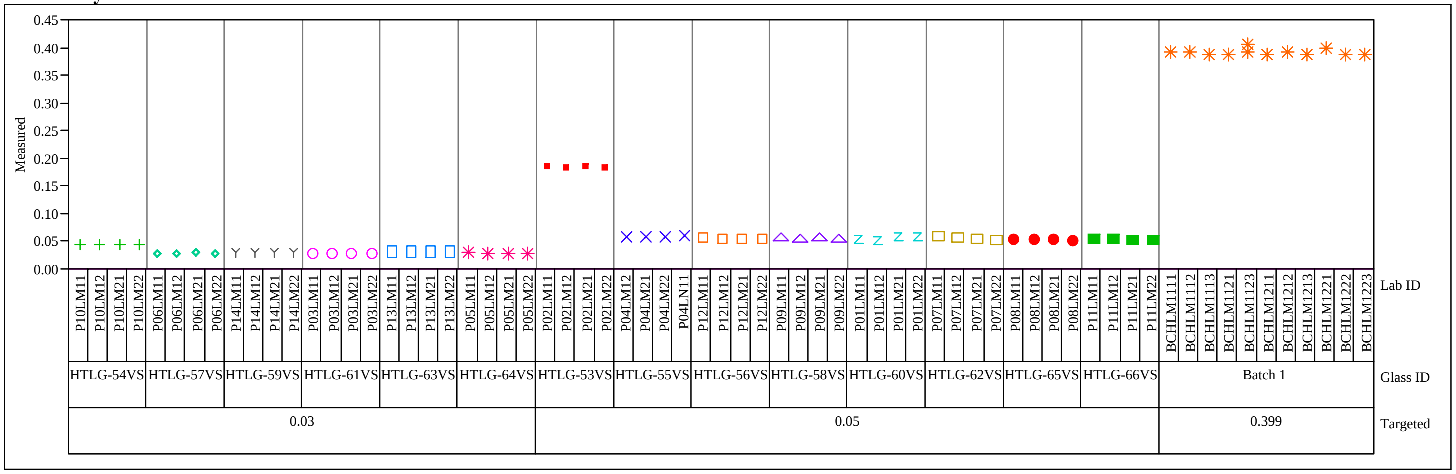


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

CuO (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

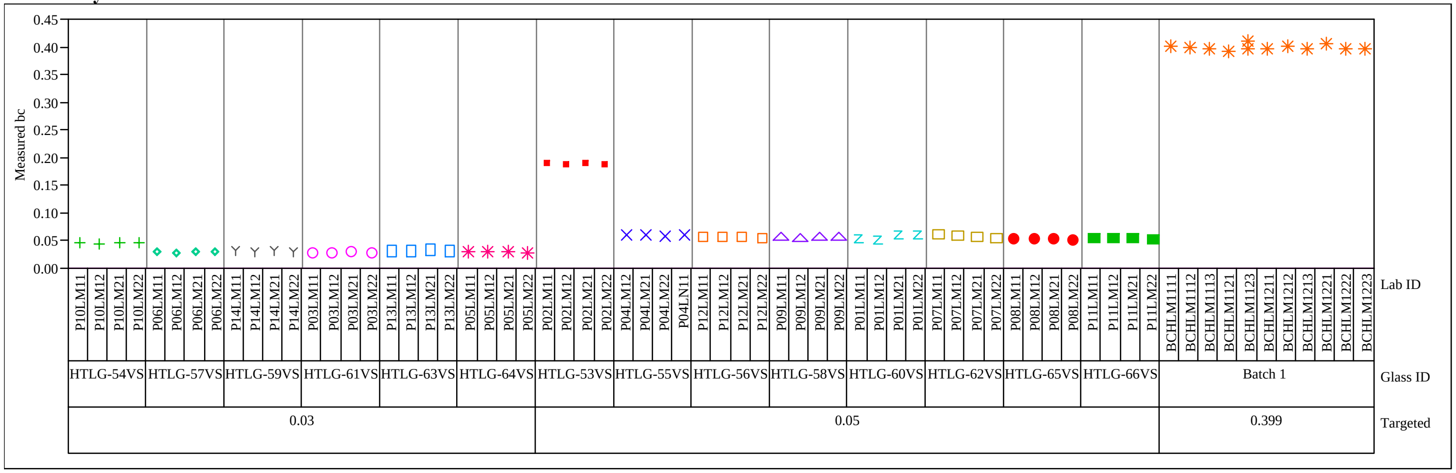
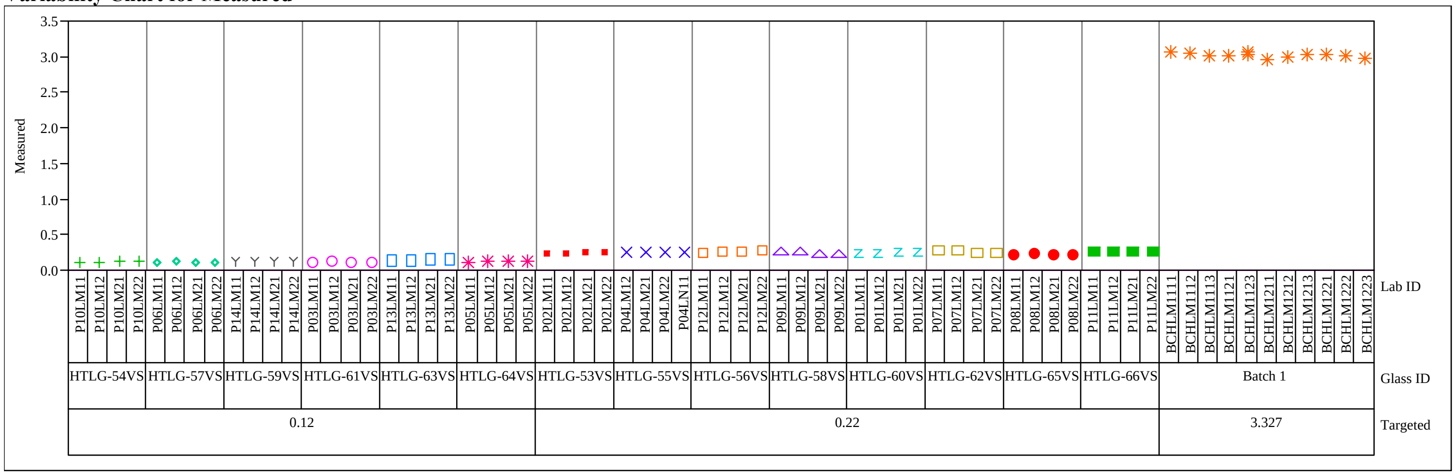


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

K2O (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

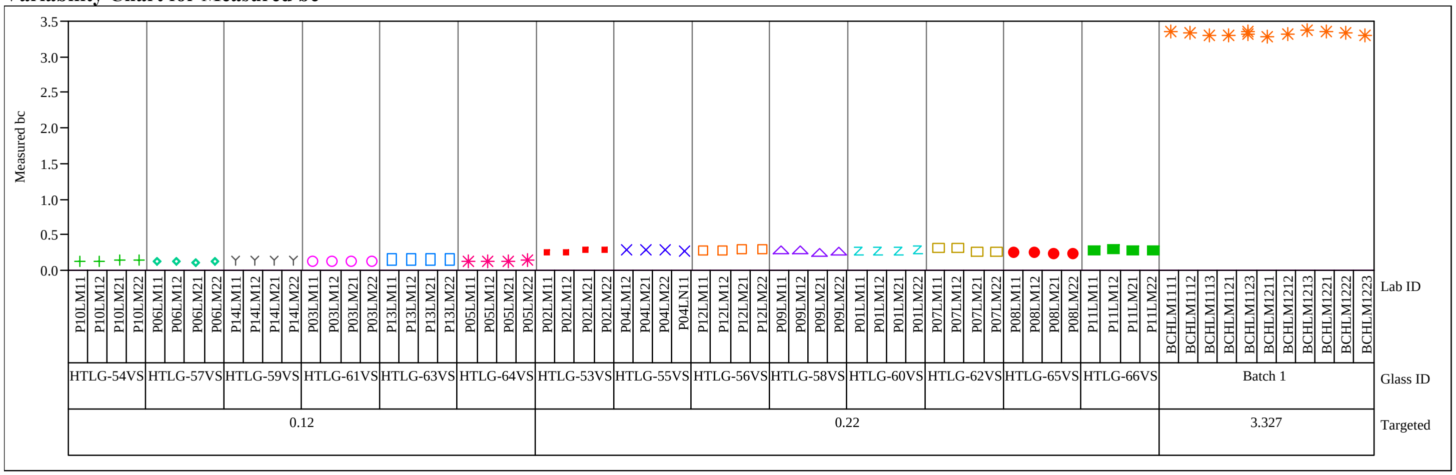
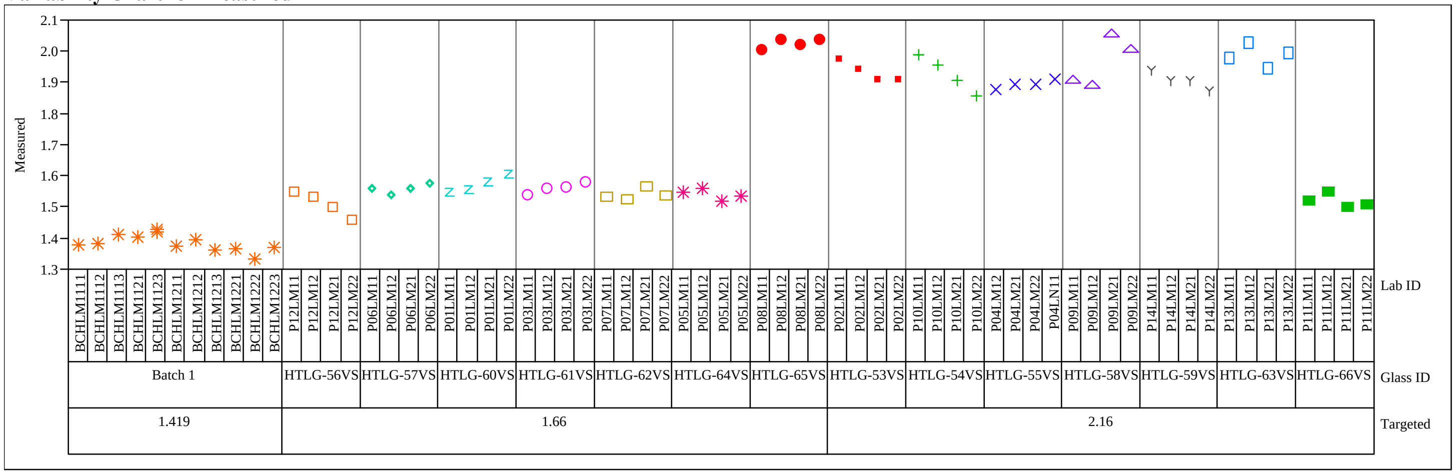


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

MgO (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

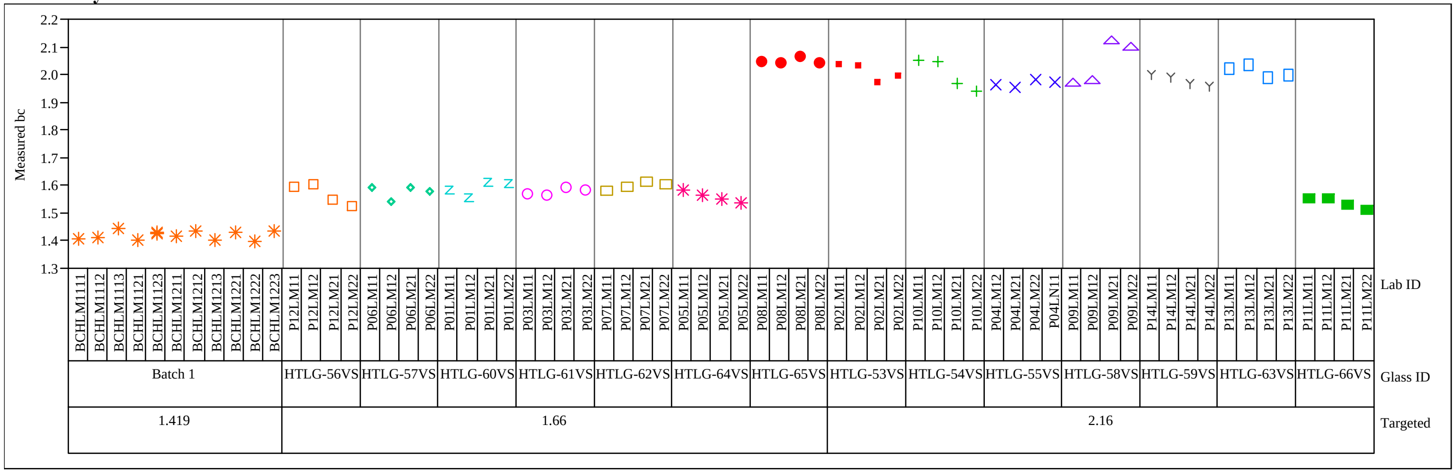
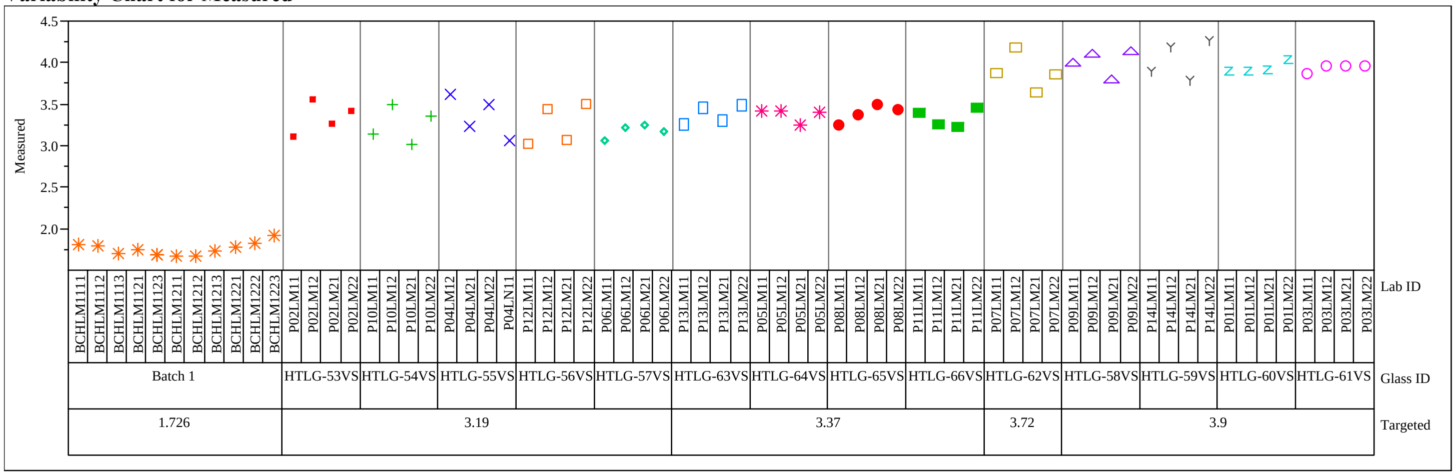


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

MnO (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

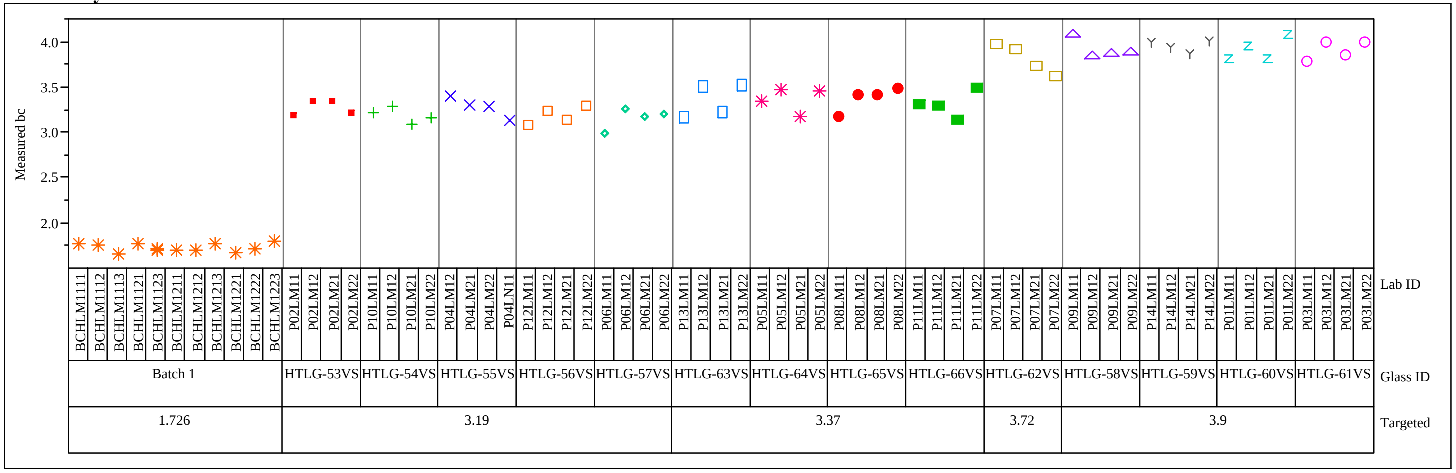
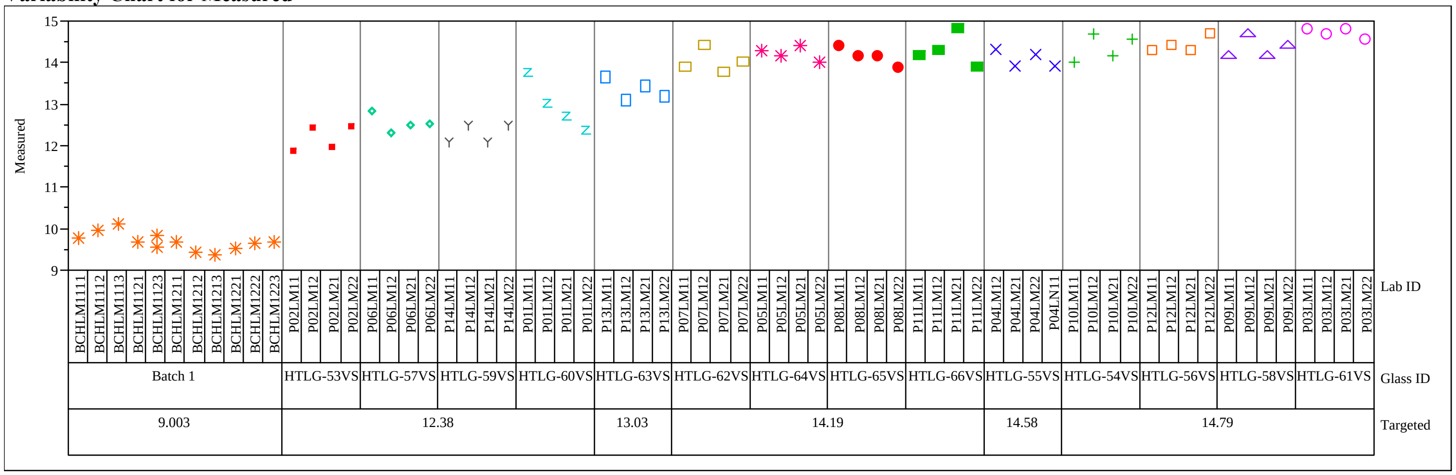


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

Na2O (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

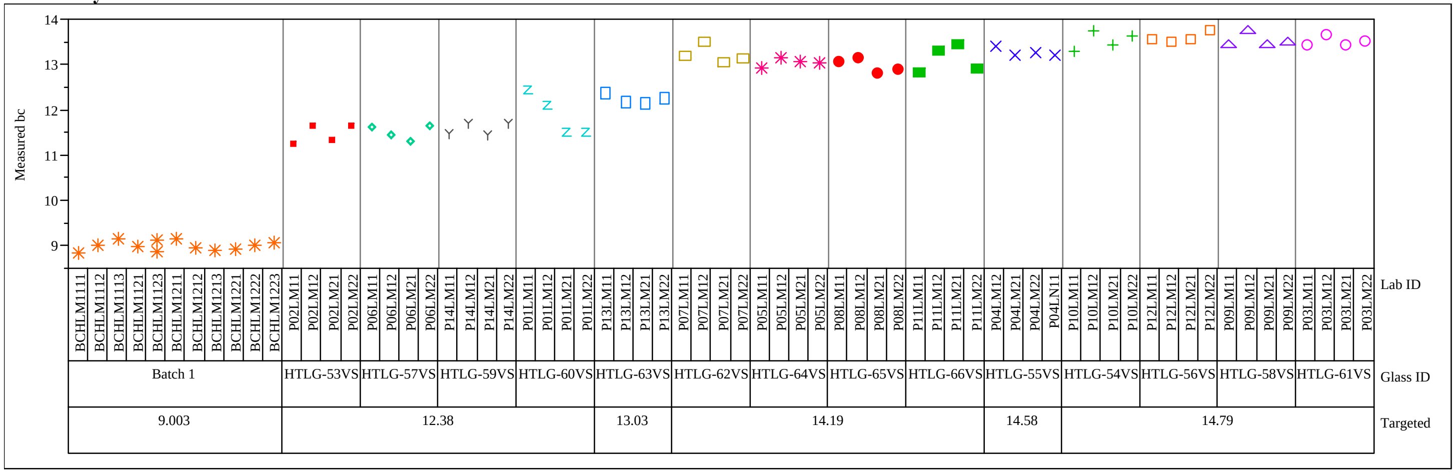
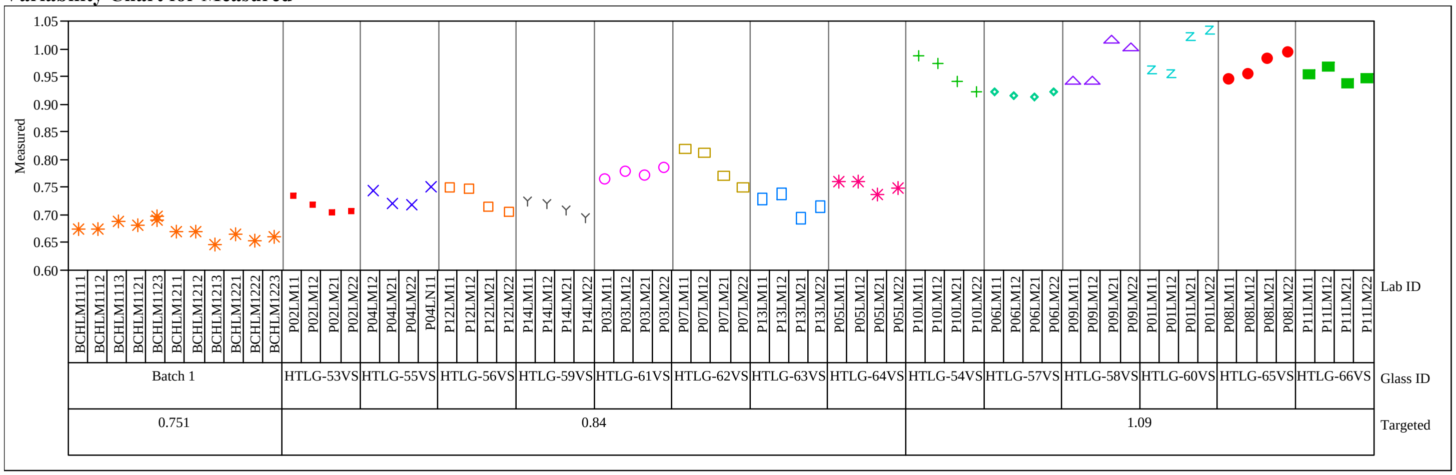


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

NiO (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

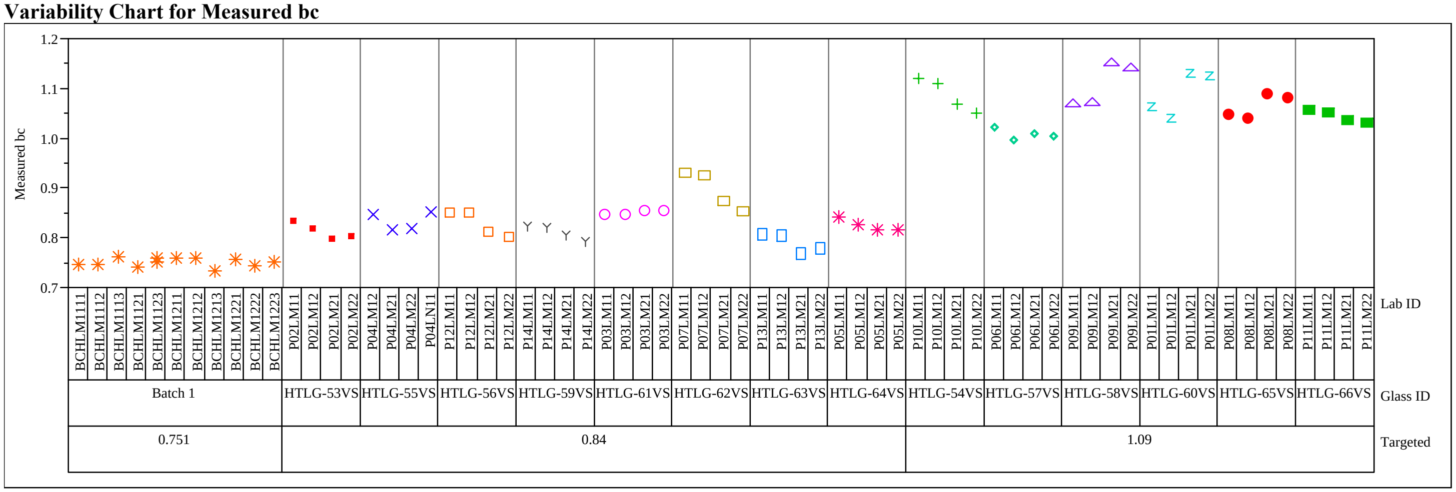
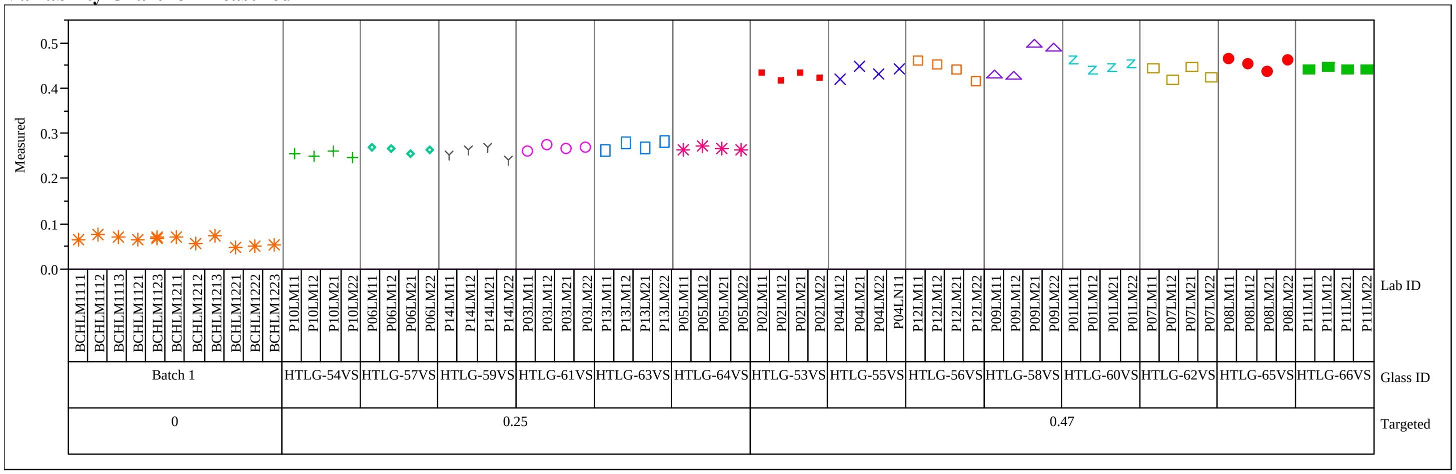


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

SO4 (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

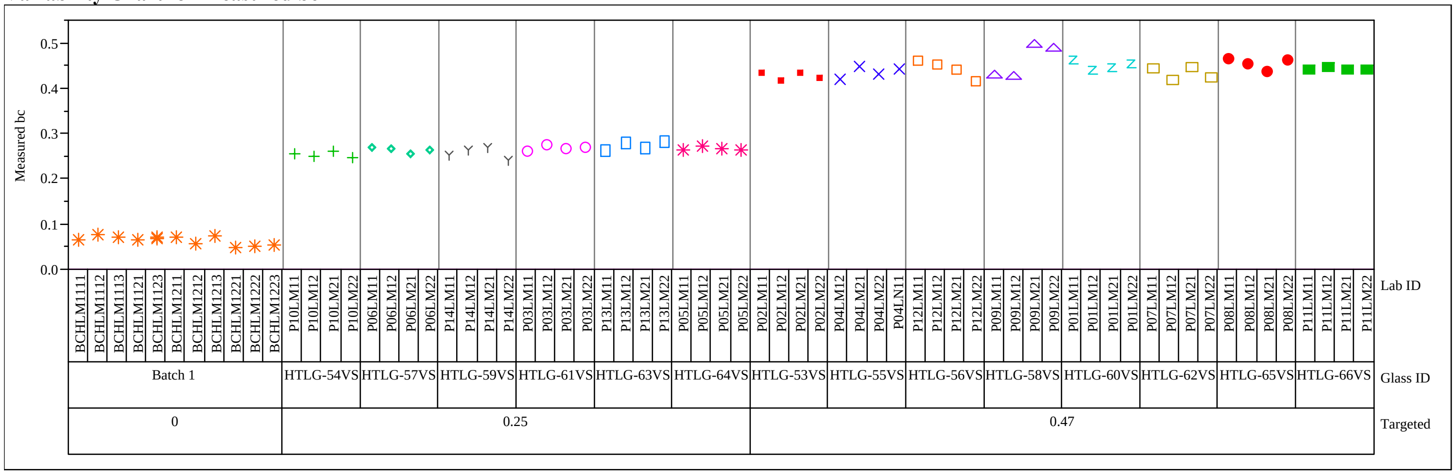
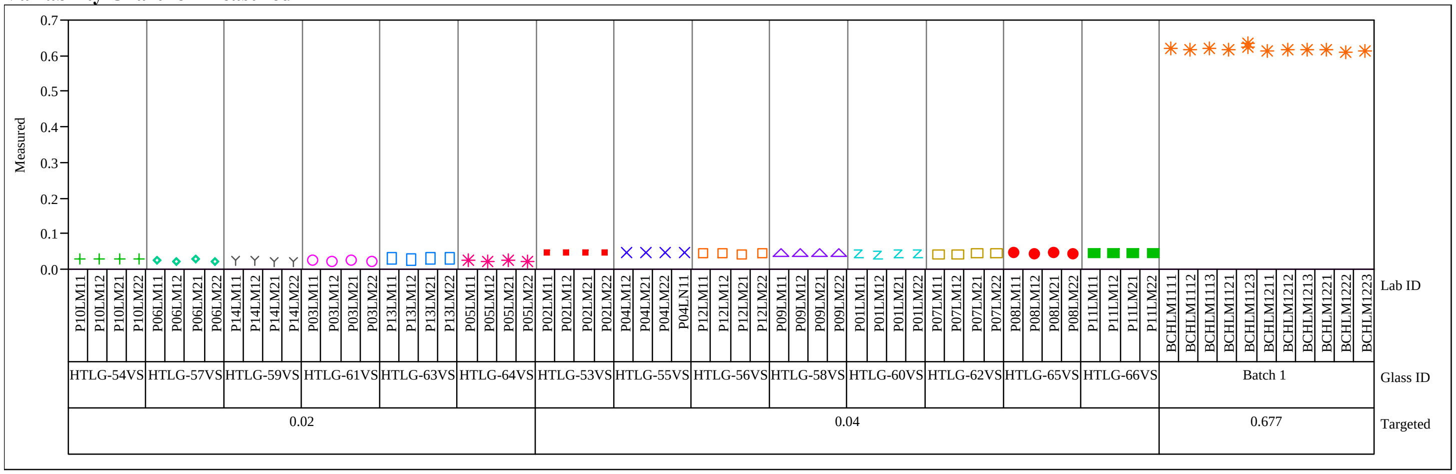


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

TiO2 (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

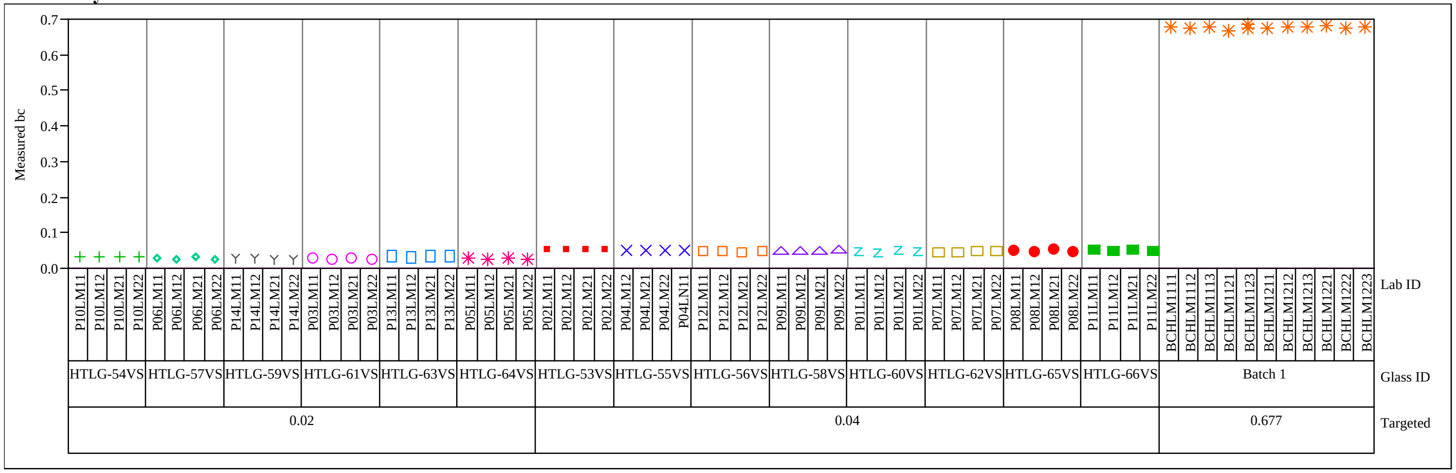
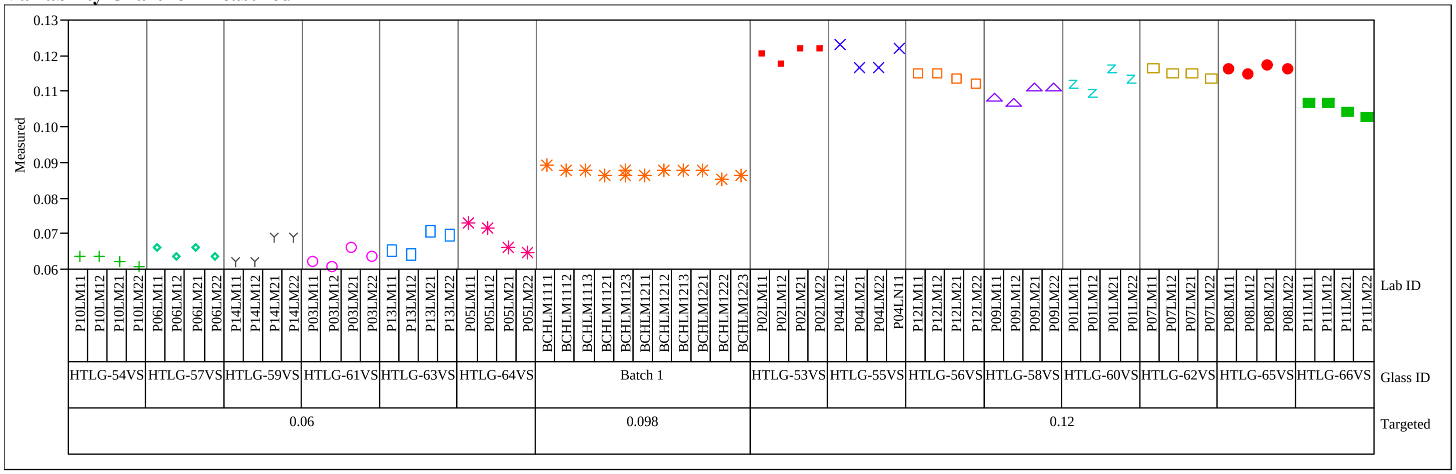


Exhibit A9. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the LM Method

ZrO2 (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

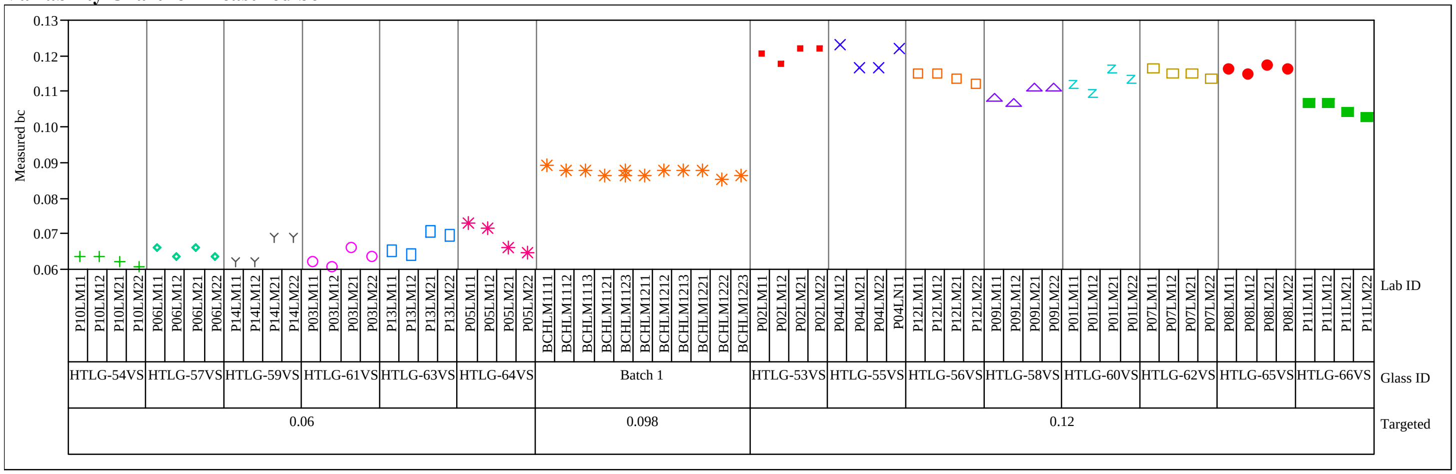
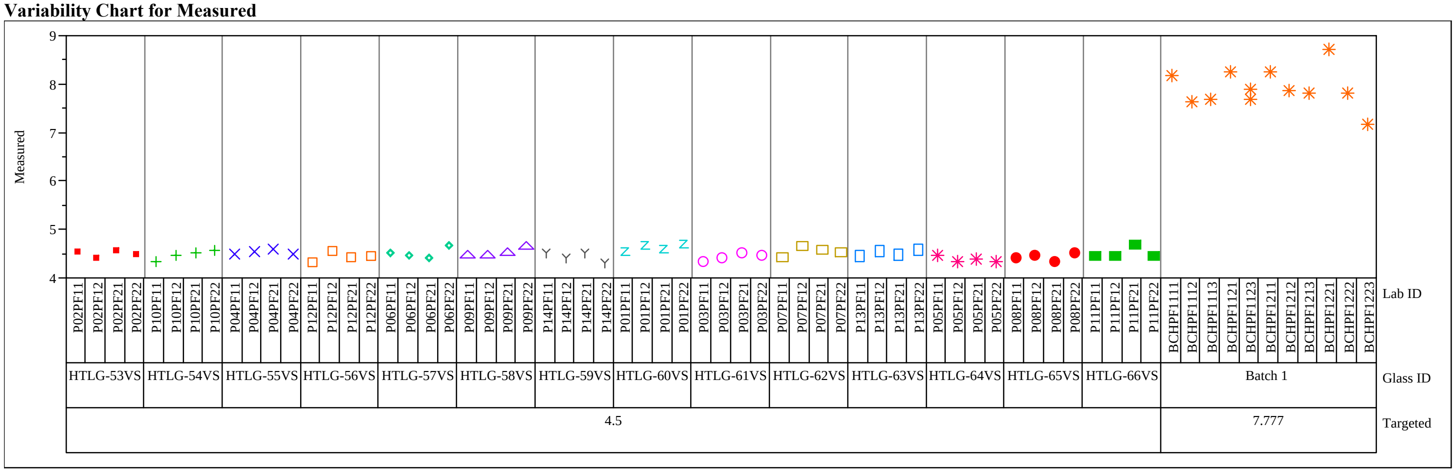


Exhibit A10. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the PF Method

B2O3 (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

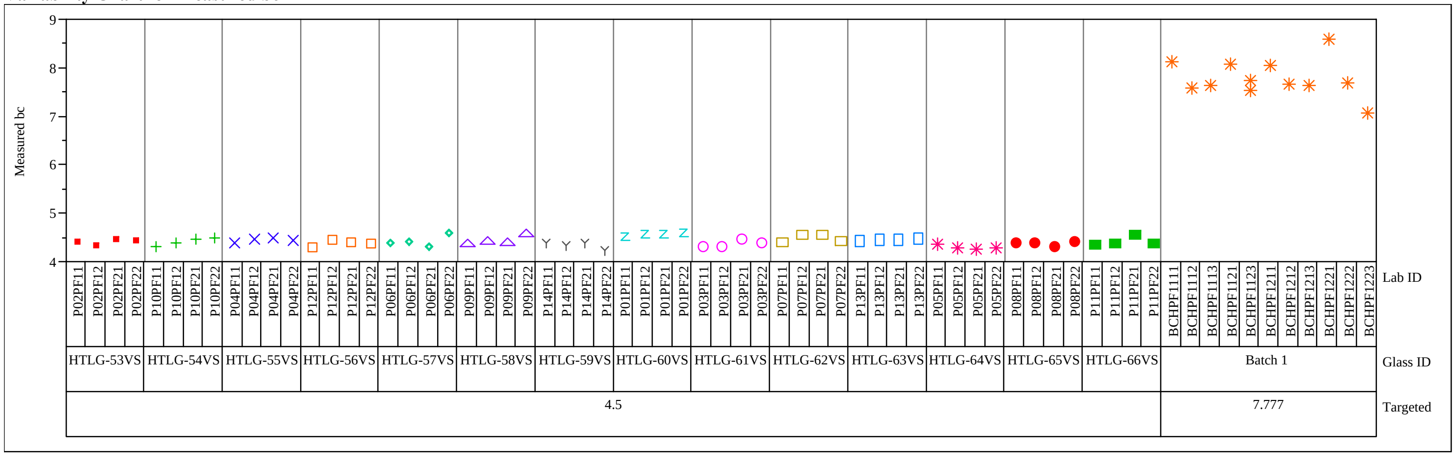
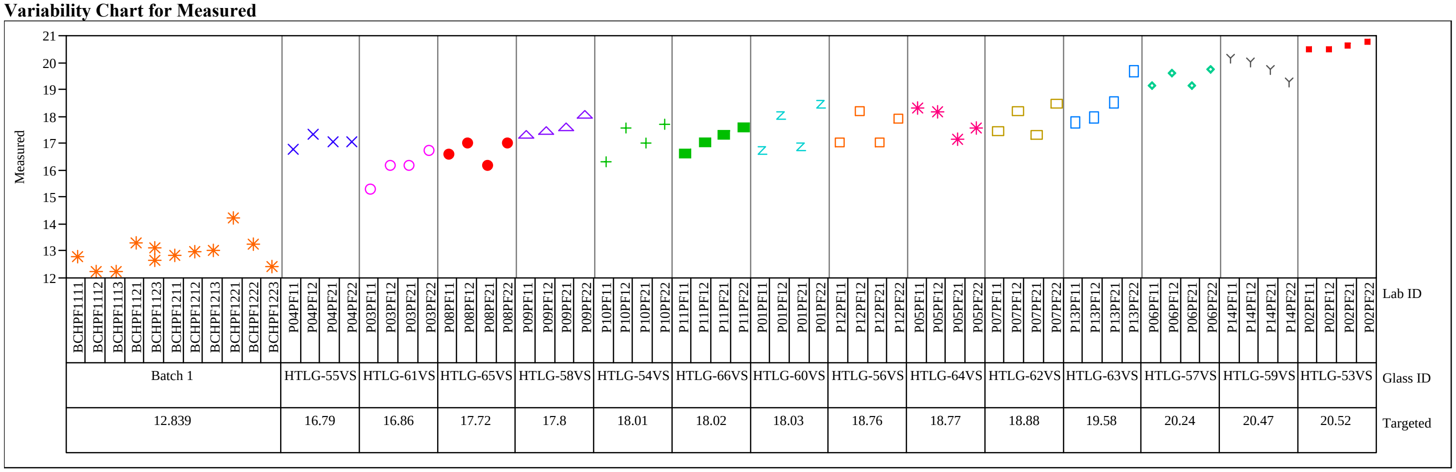


Exhibit A10. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the PF Method

Fe2O3 (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

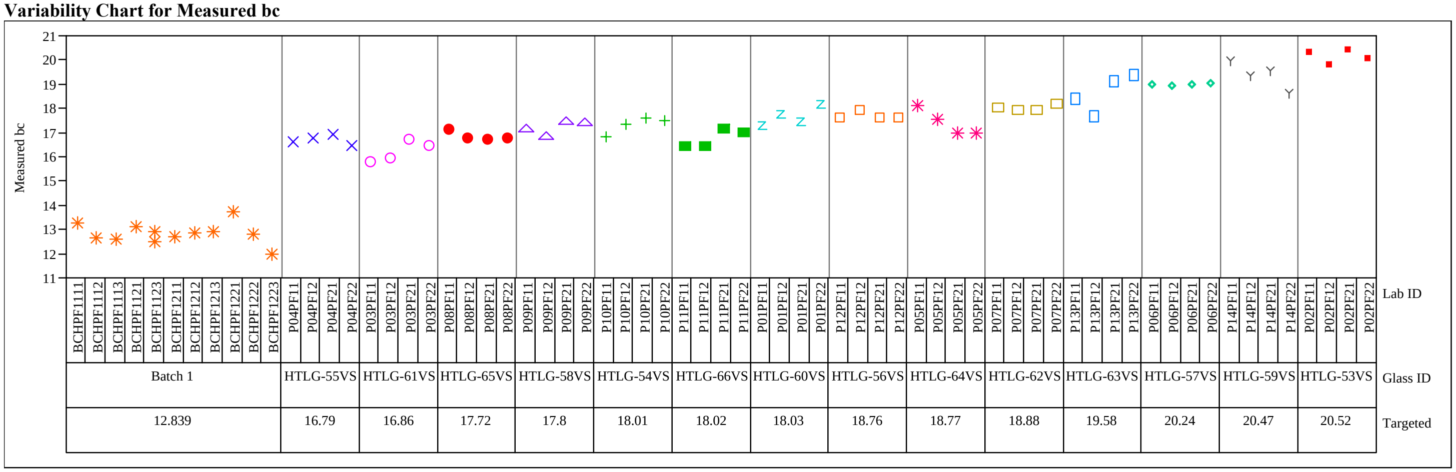
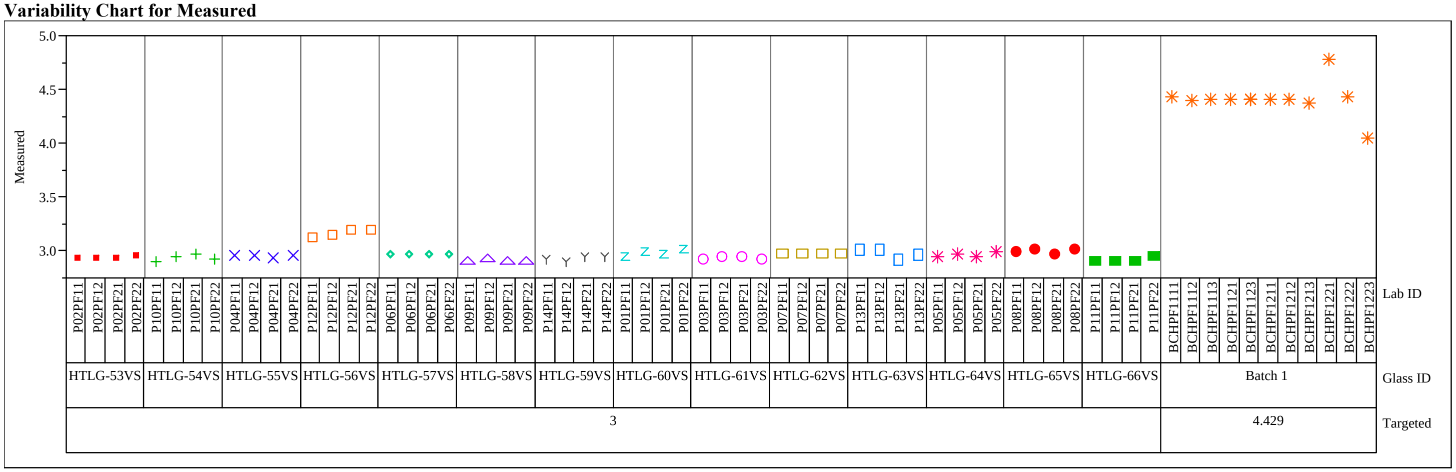


Exhibit A10. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the PF Method

Li2O (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

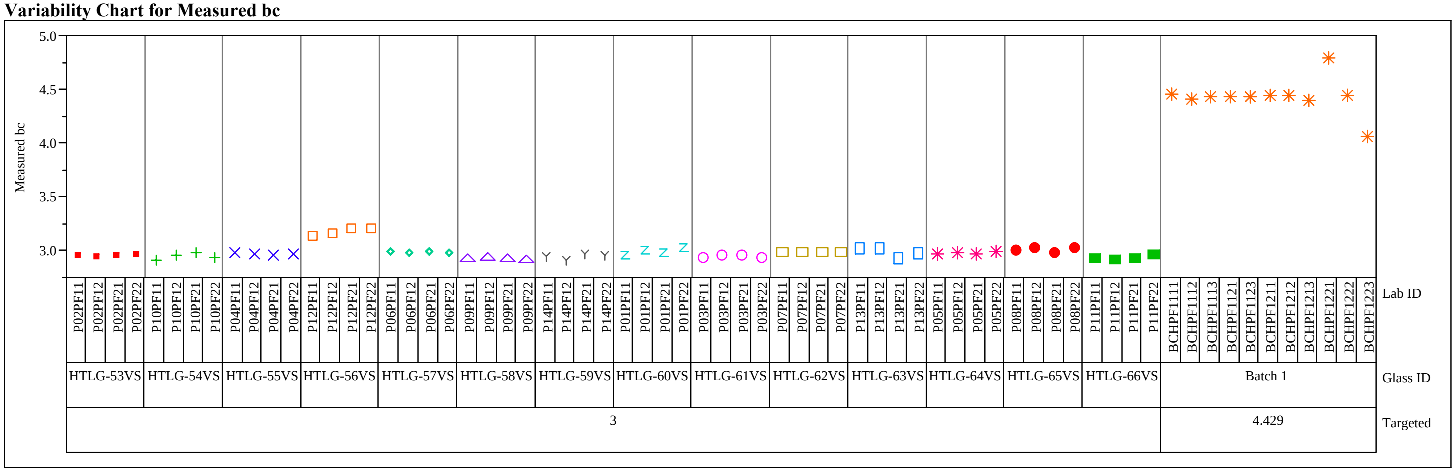
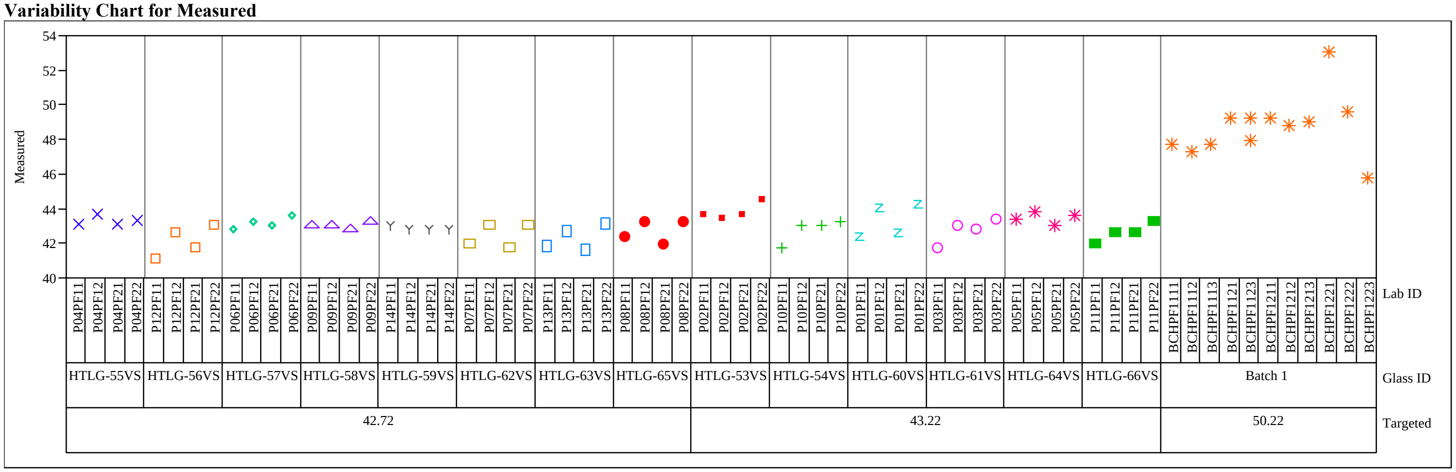


Exhibit A10. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "P" Glasses Prepared Using the PF Method

SiO2 (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

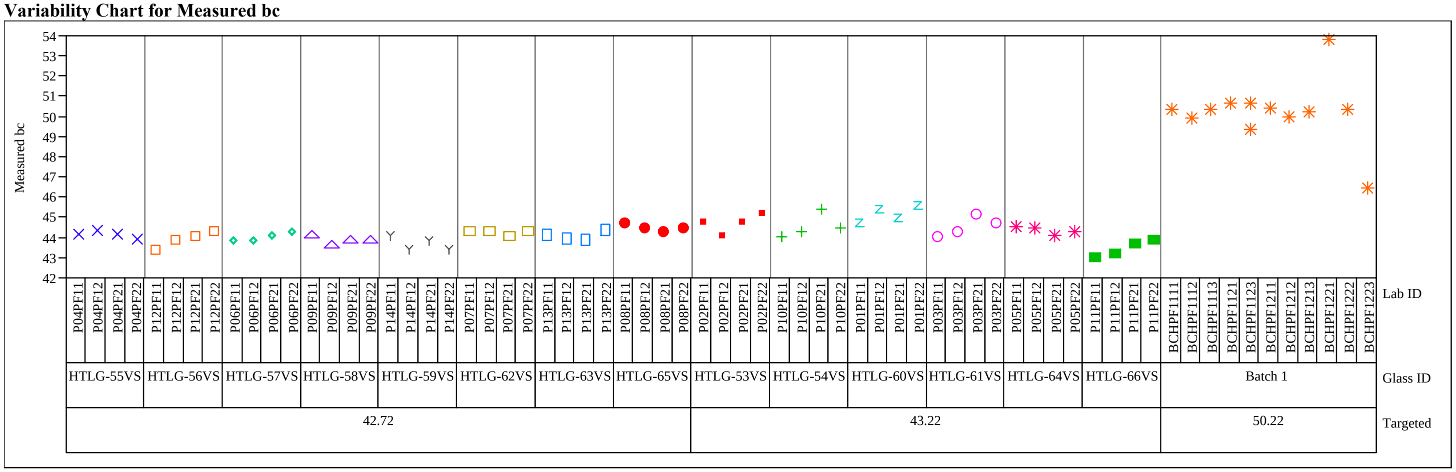
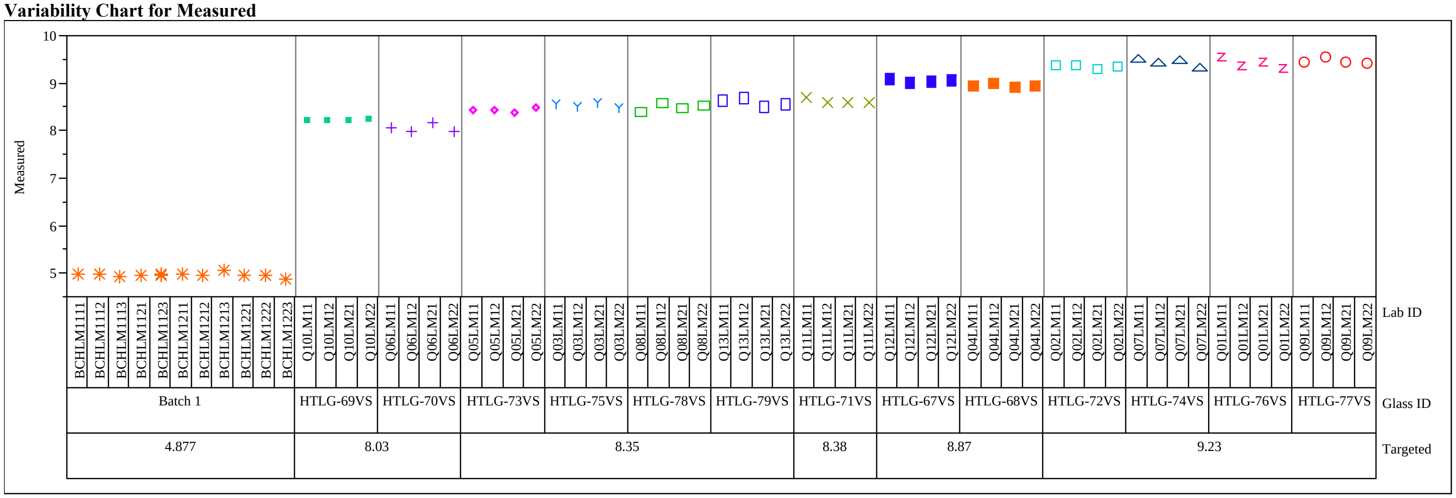


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

Al2O3 (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

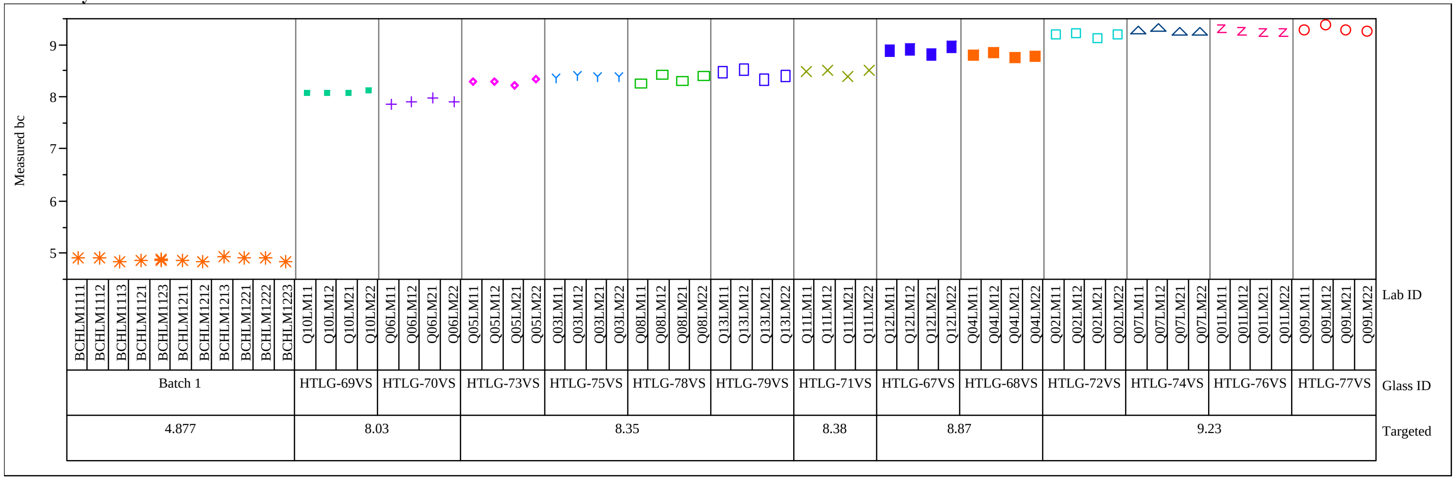
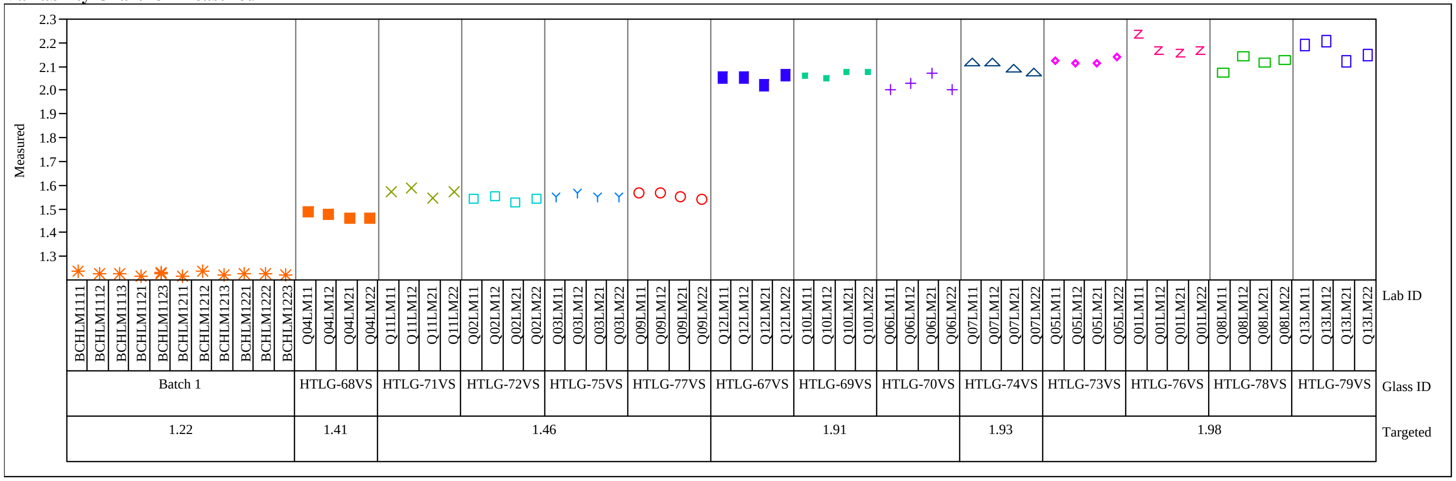


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

CaO (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

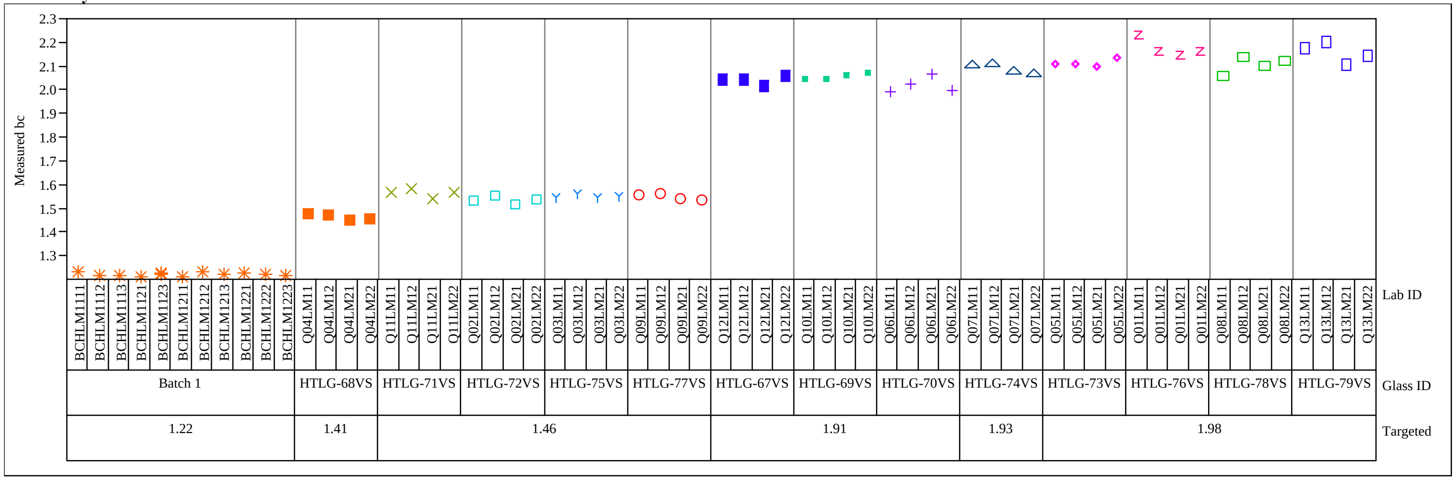
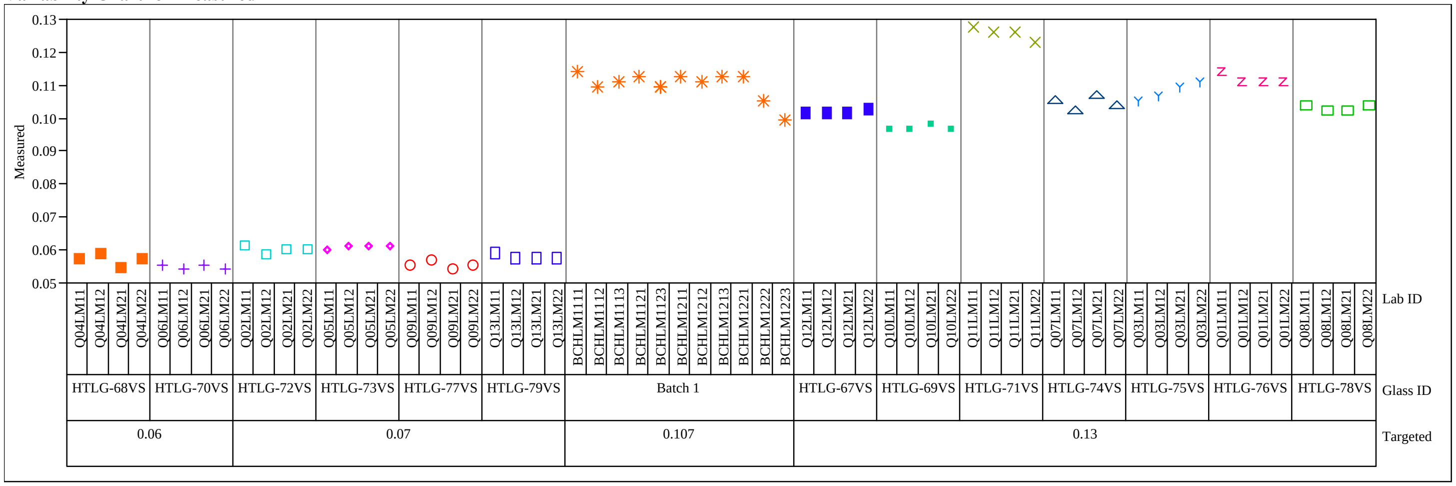


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

Cr2O3 (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

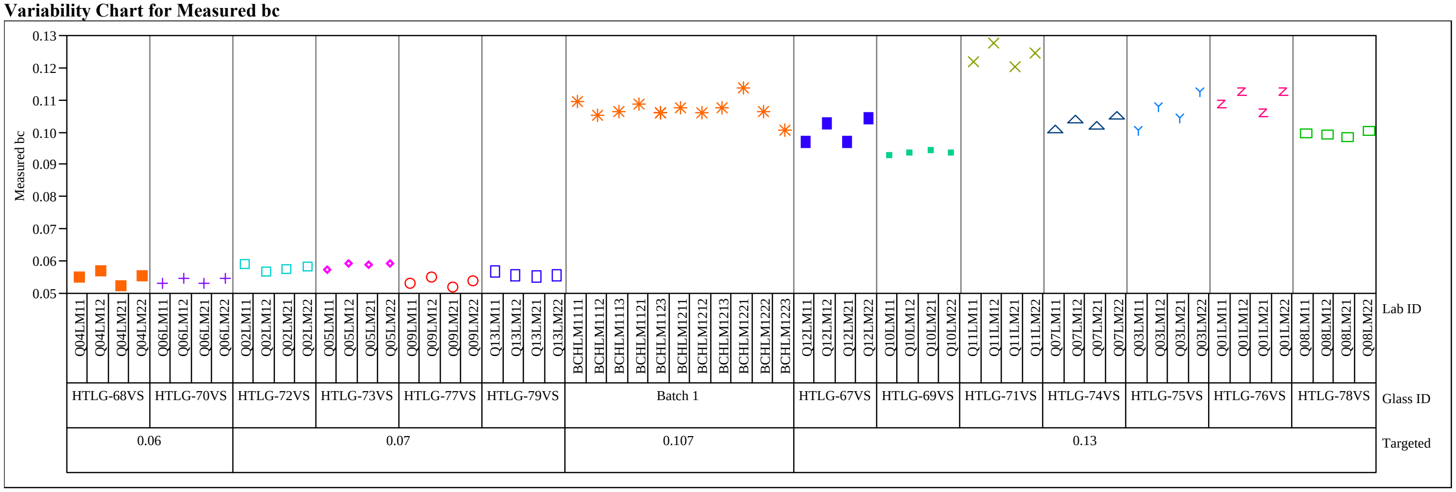
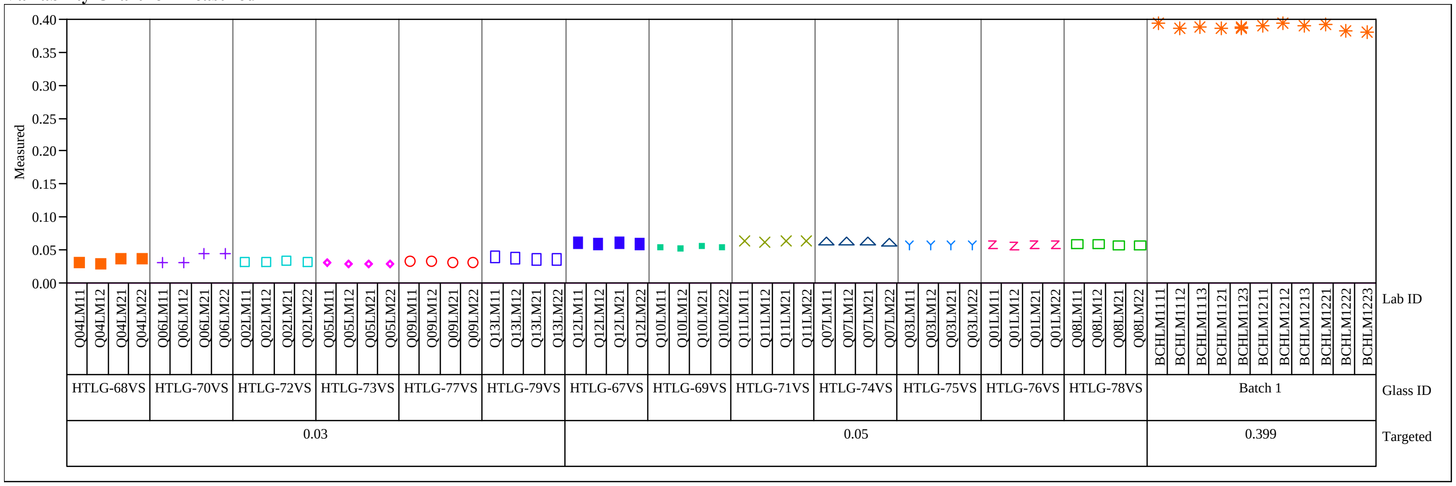


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

CuO (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

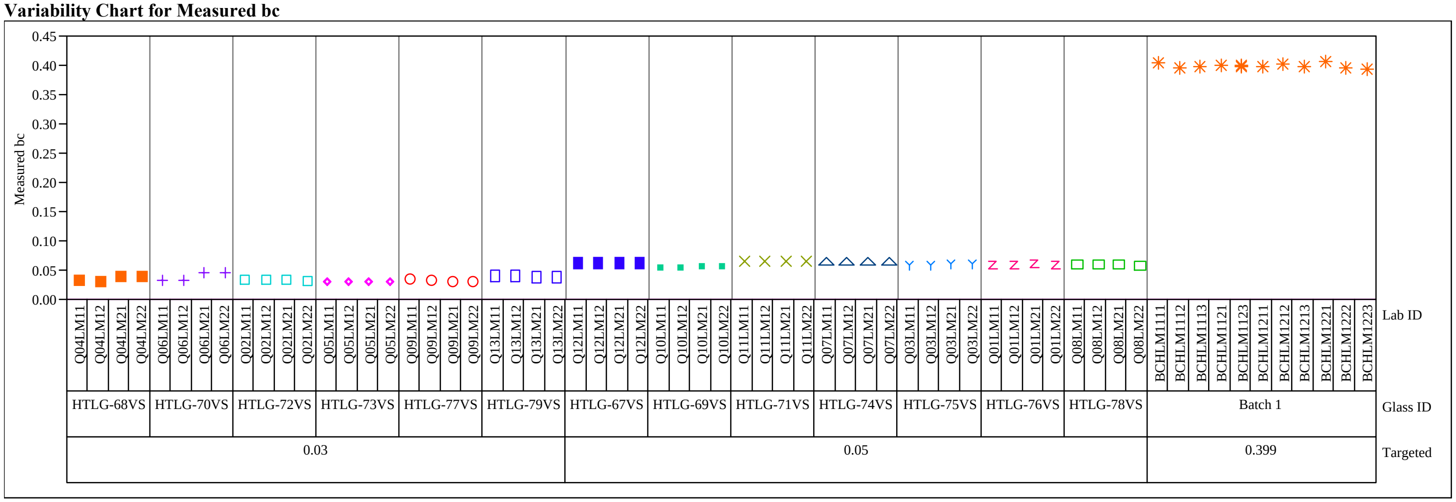
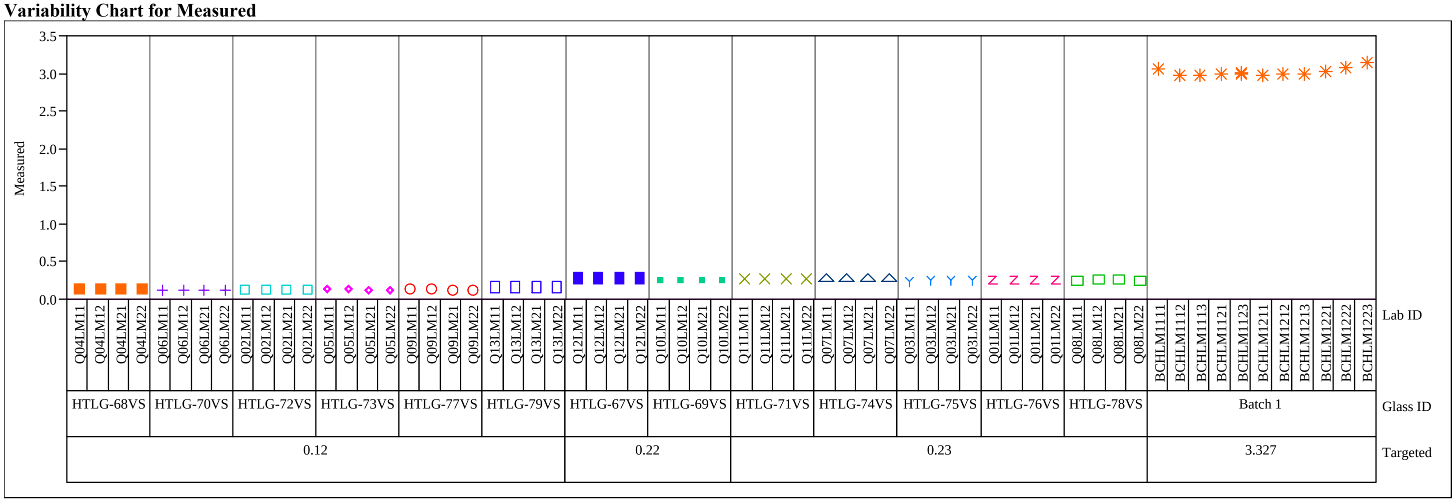


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

K2O (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

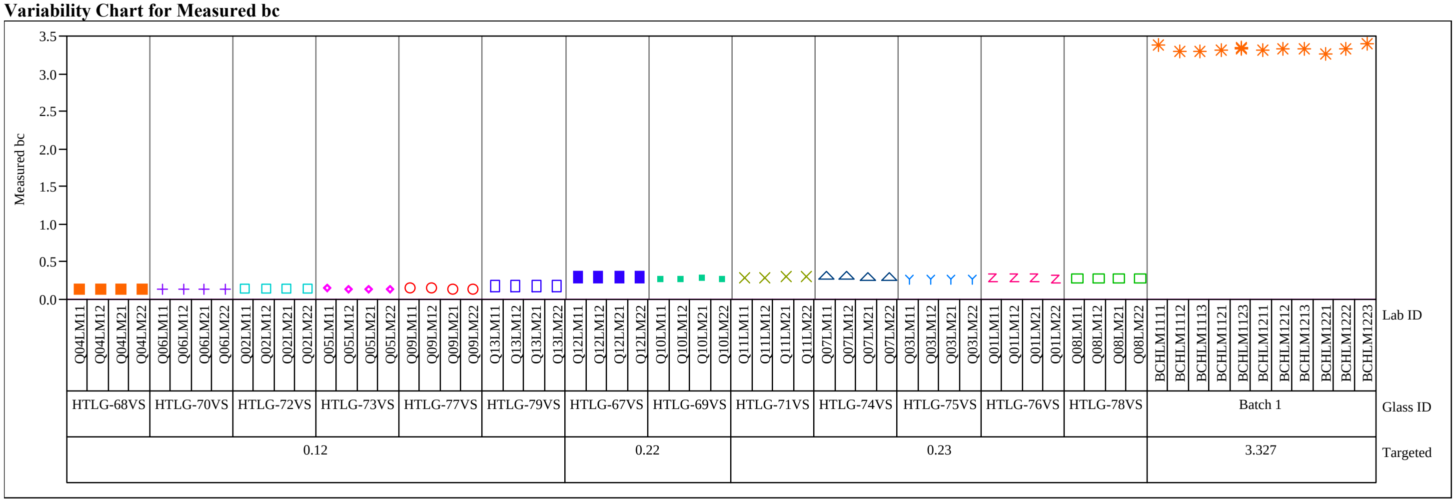
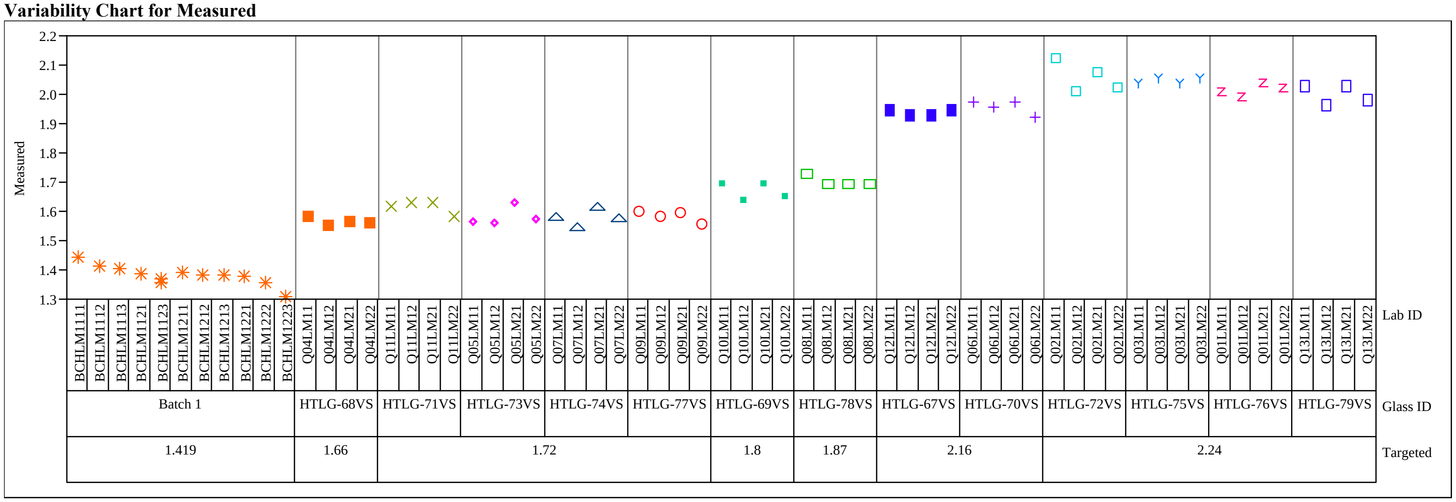


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

MgO (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

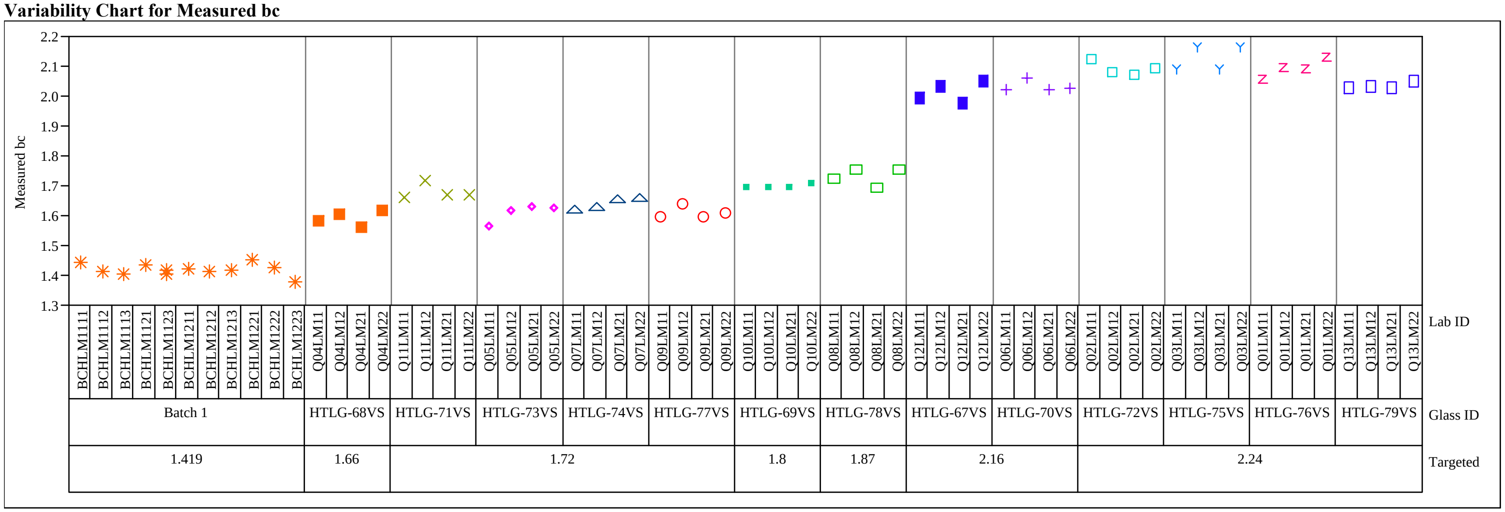
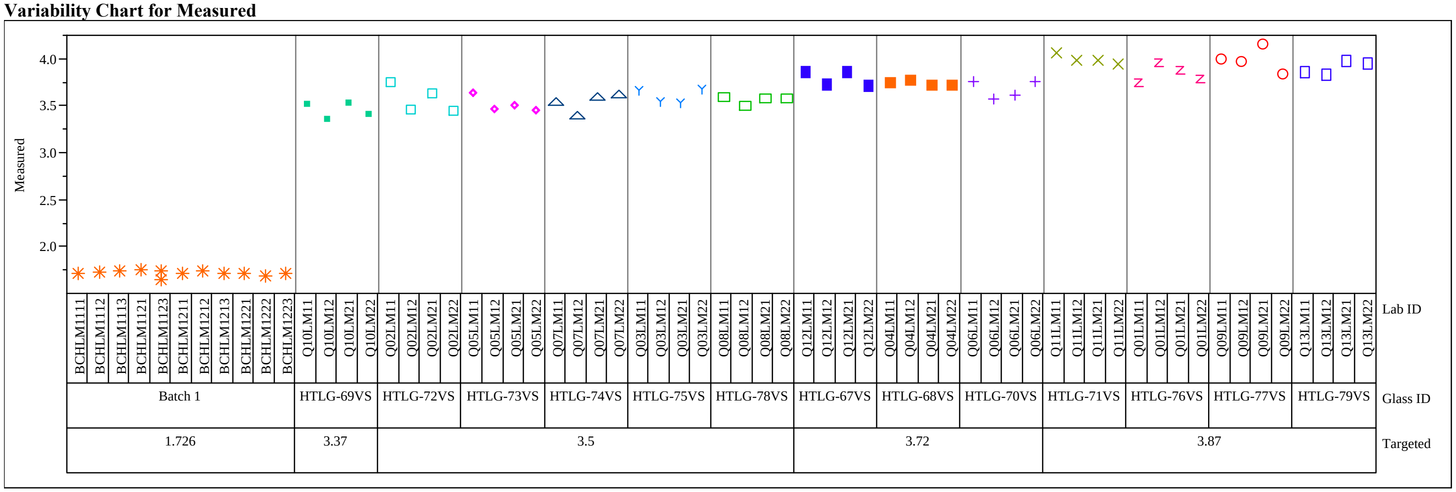


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

MnO (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

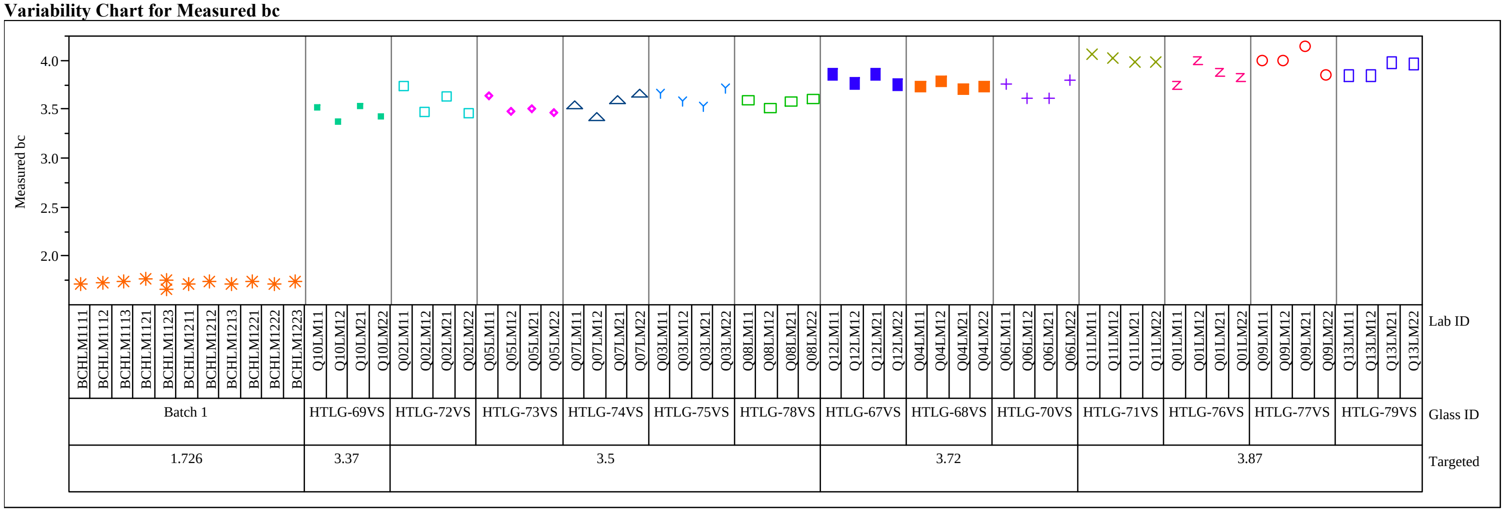
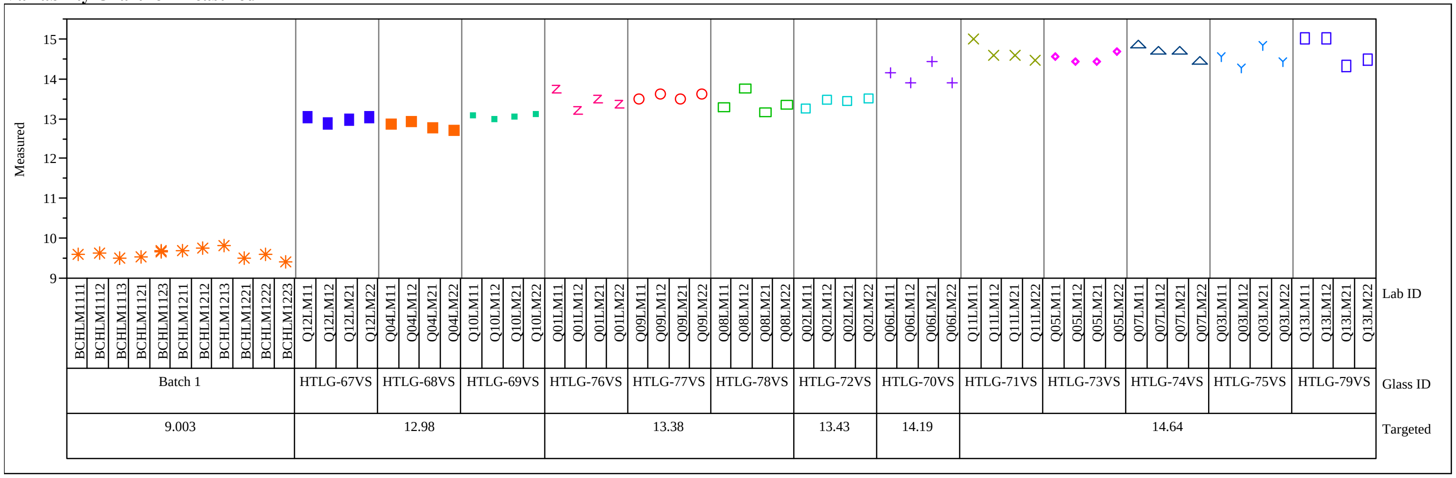


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

Na2O (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

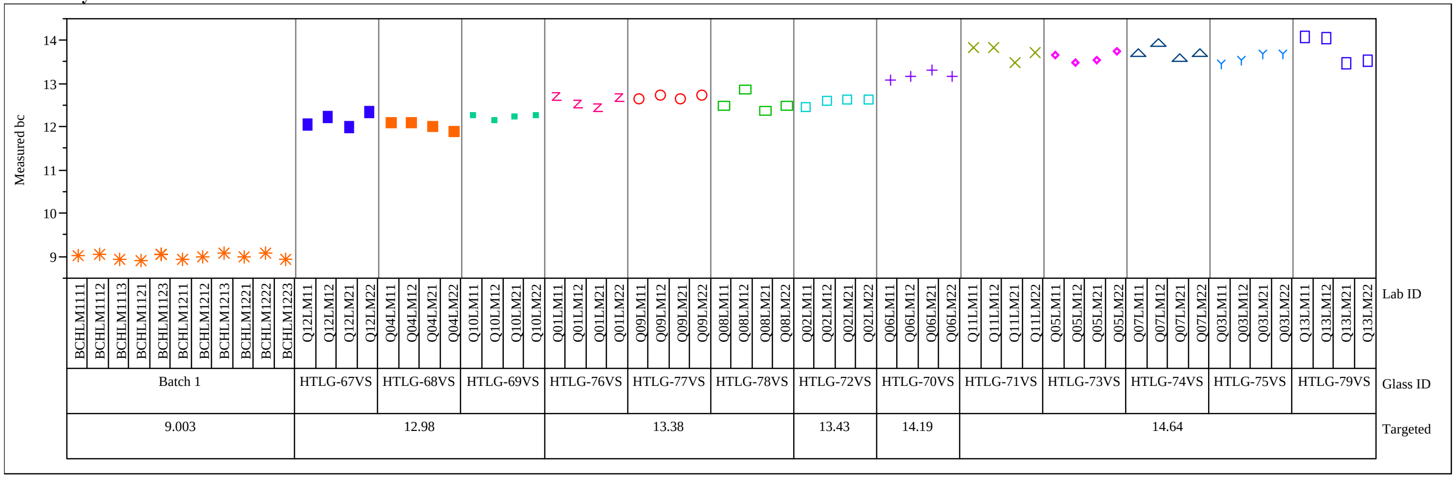
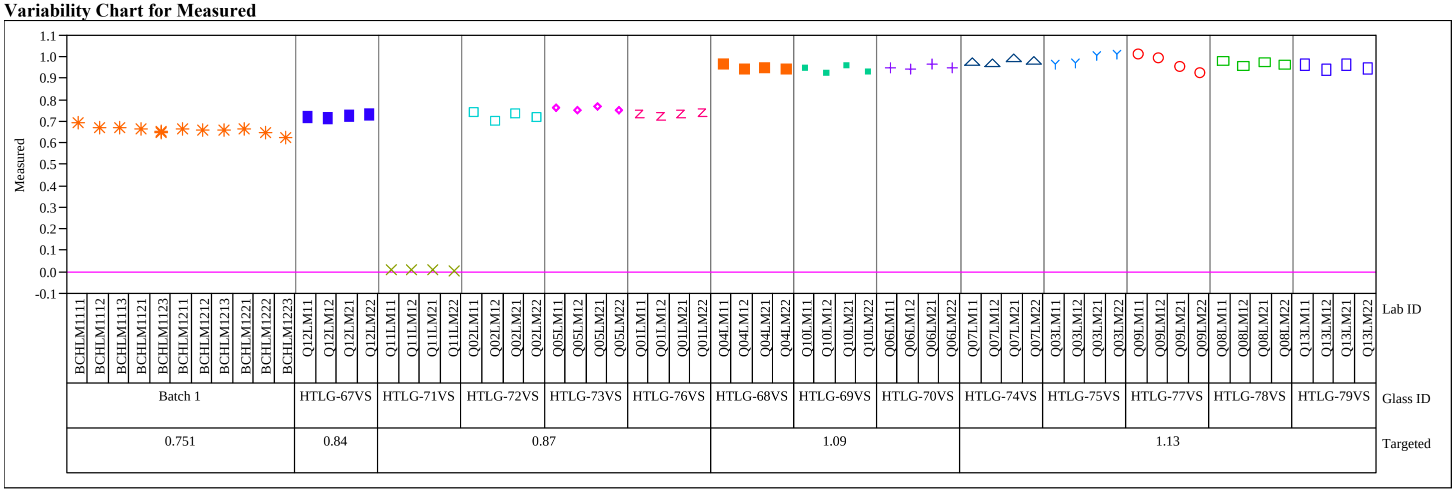


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

NiO (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

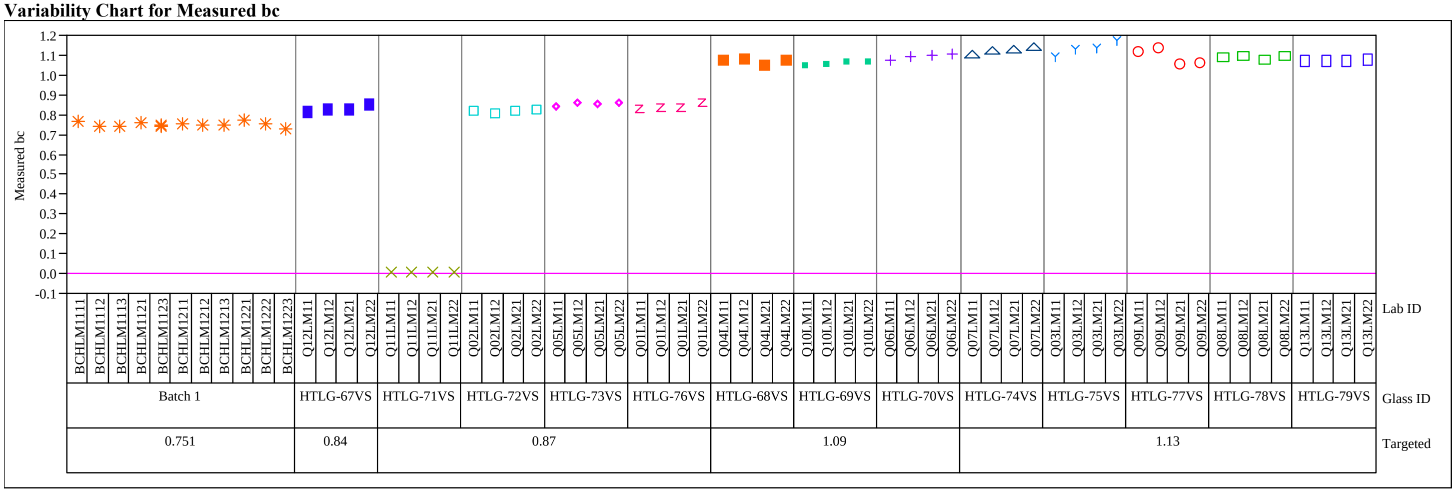
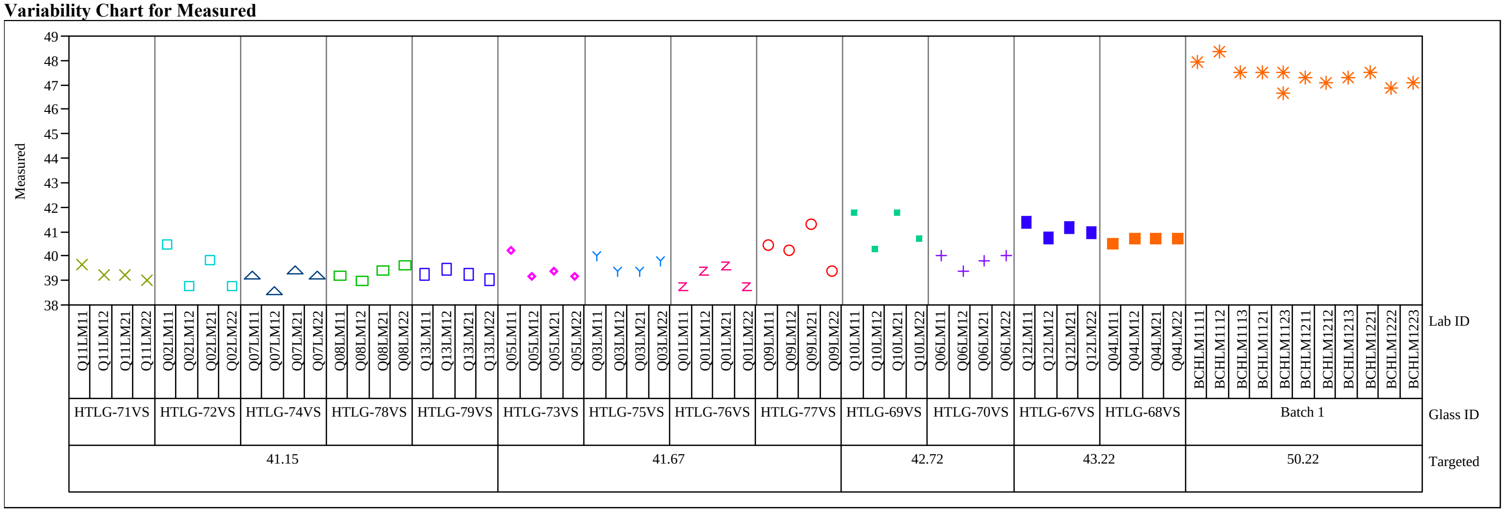


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

SiO2 (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

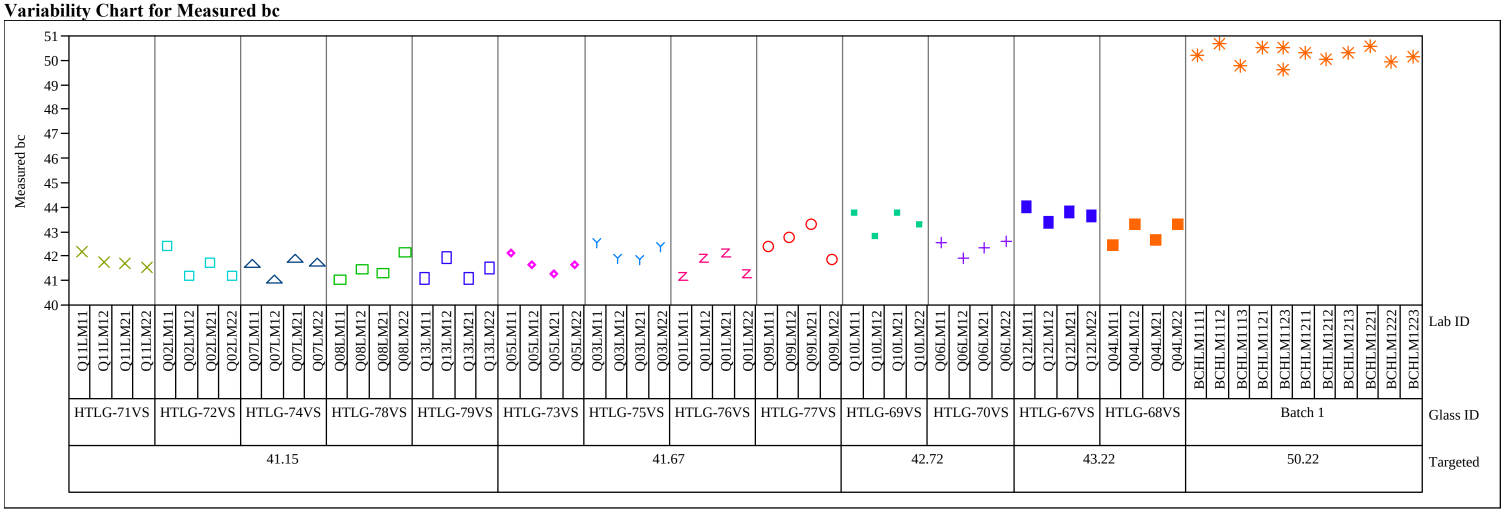
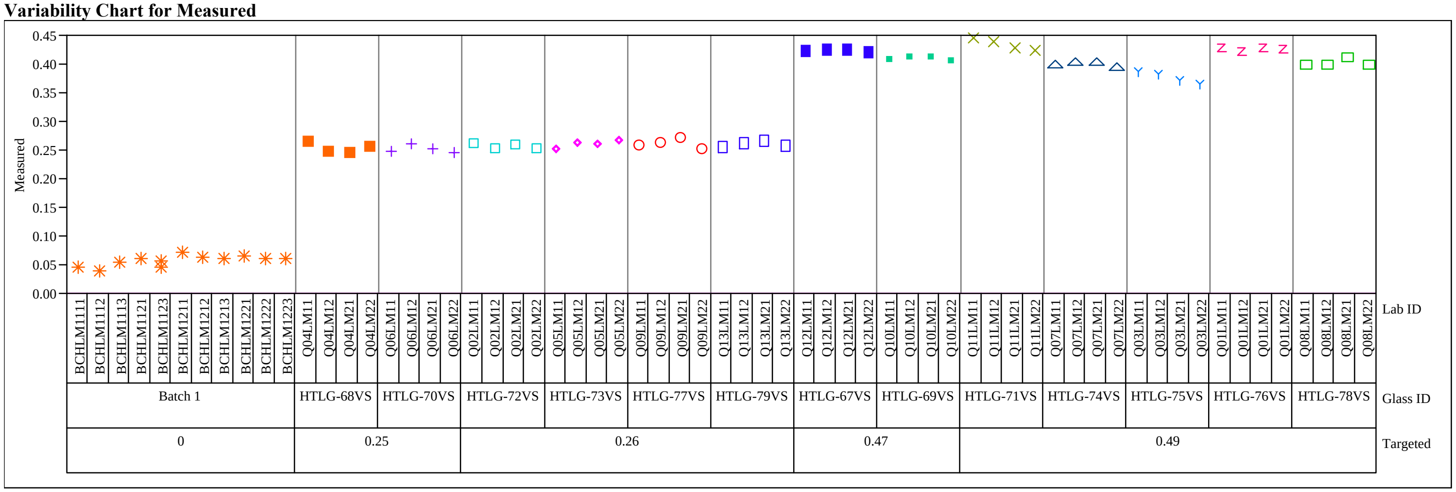


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

SO4 (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

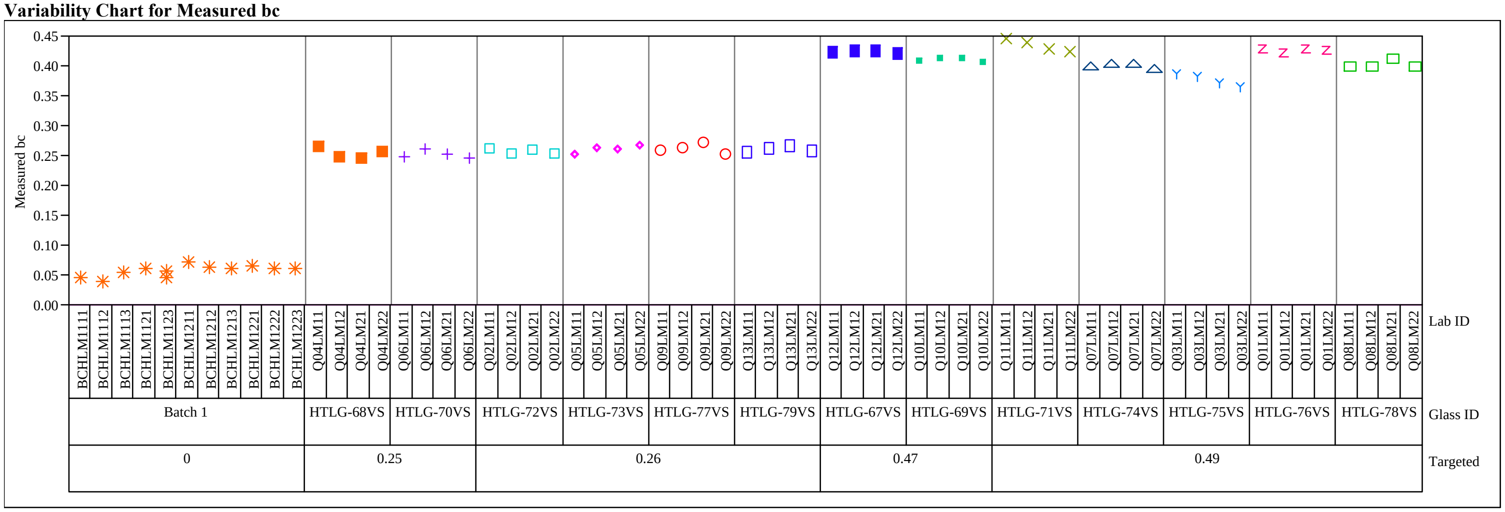
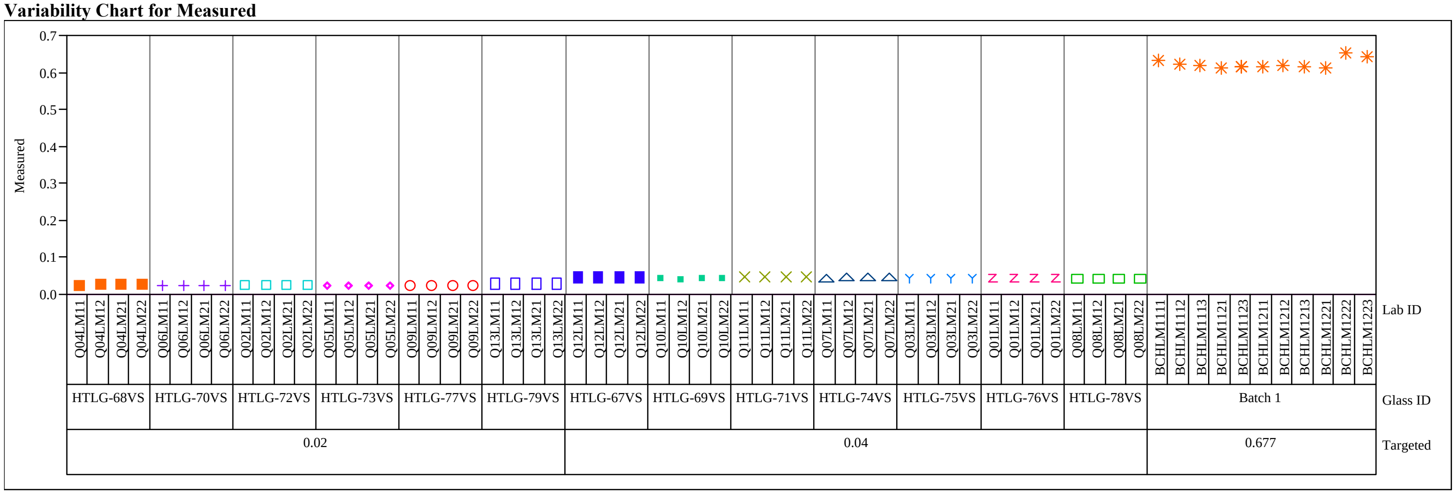


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

TiO2 (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

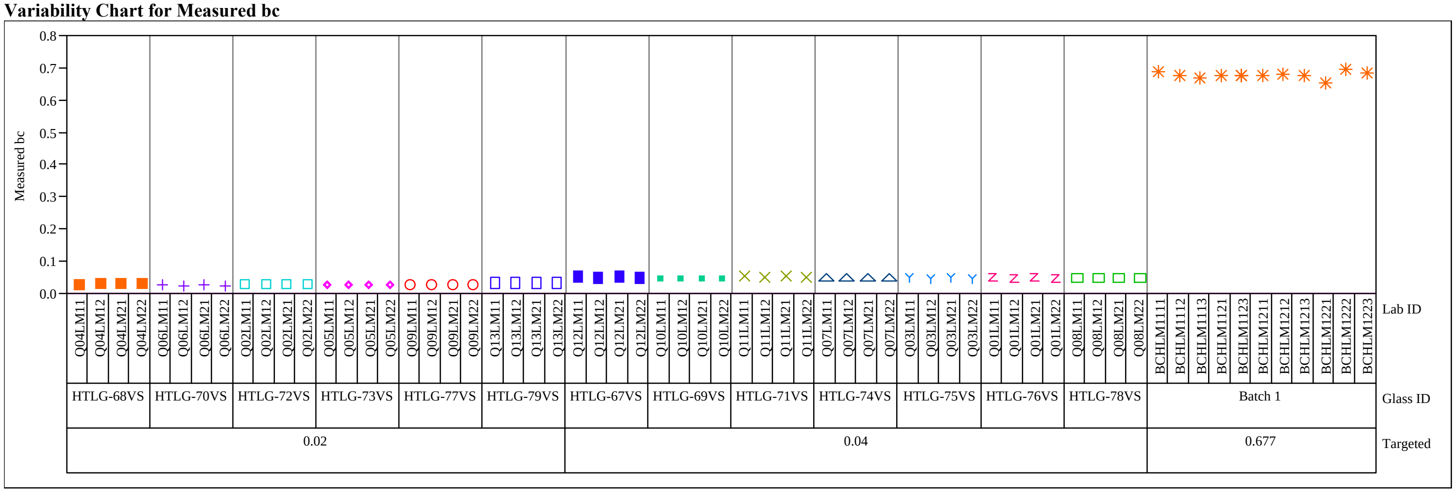
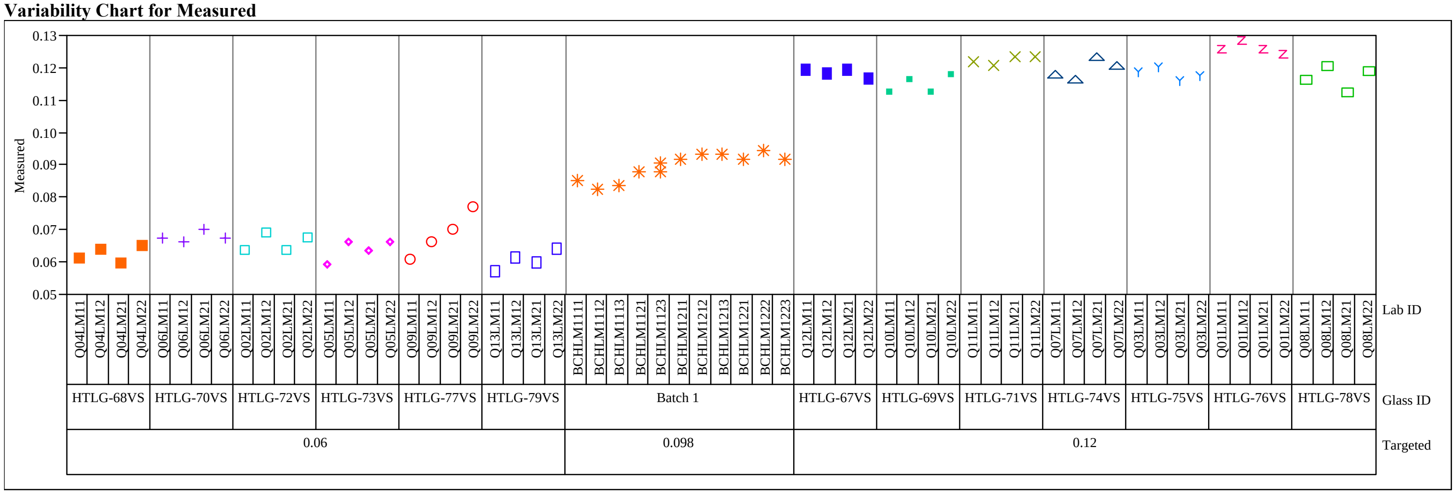


Exhibit A11. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the LM Method

ZrO2 (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

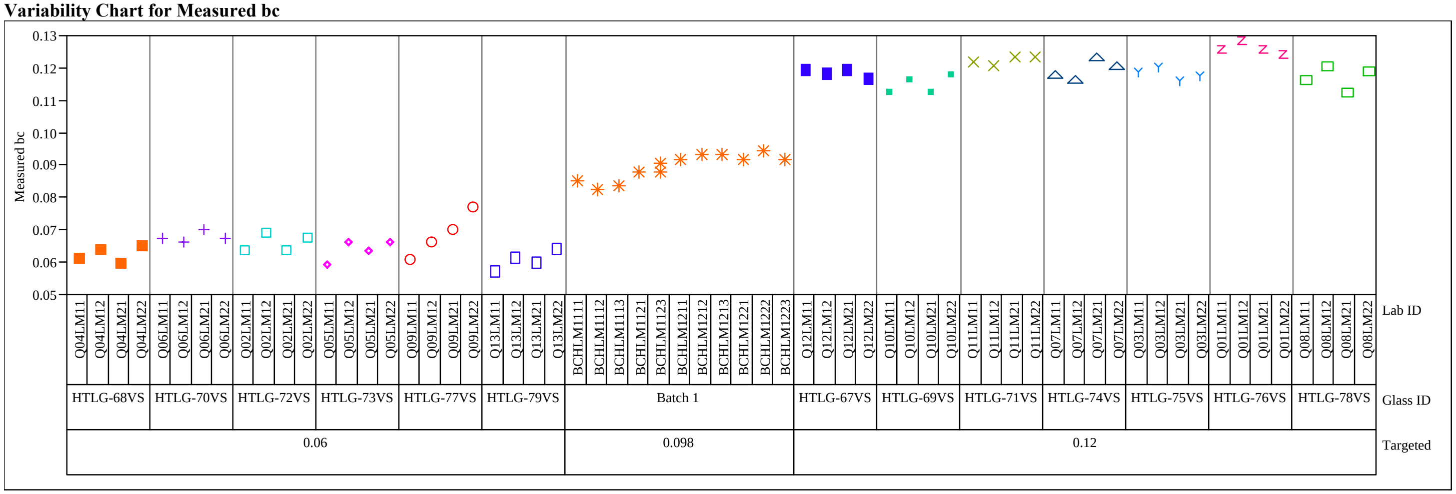
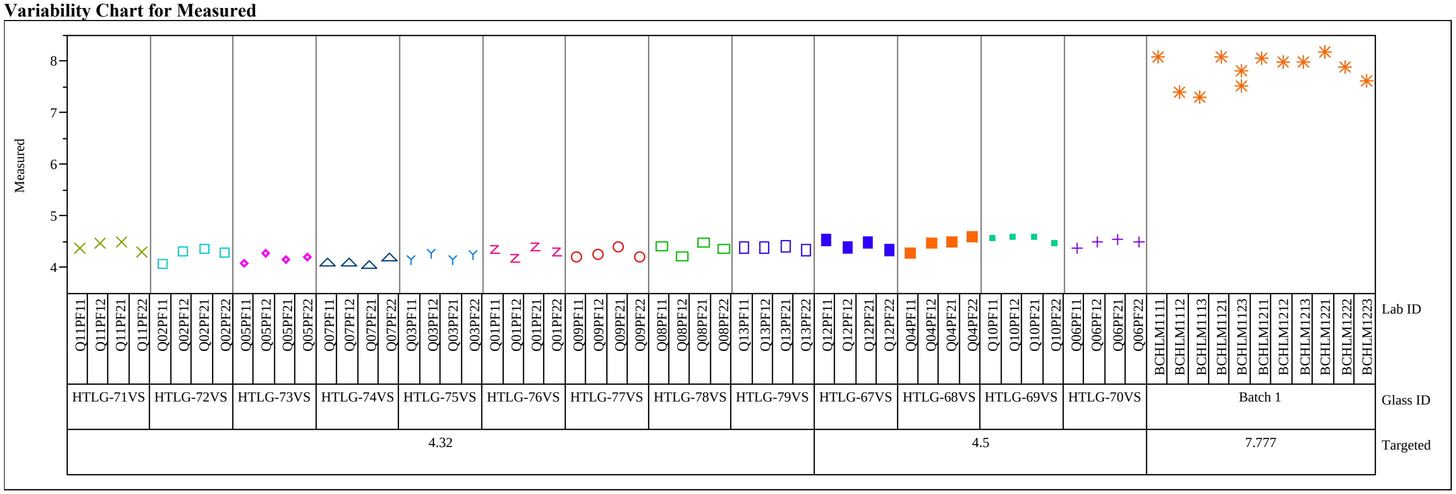


Exhibit A12. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the PF Method

B2O3 (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

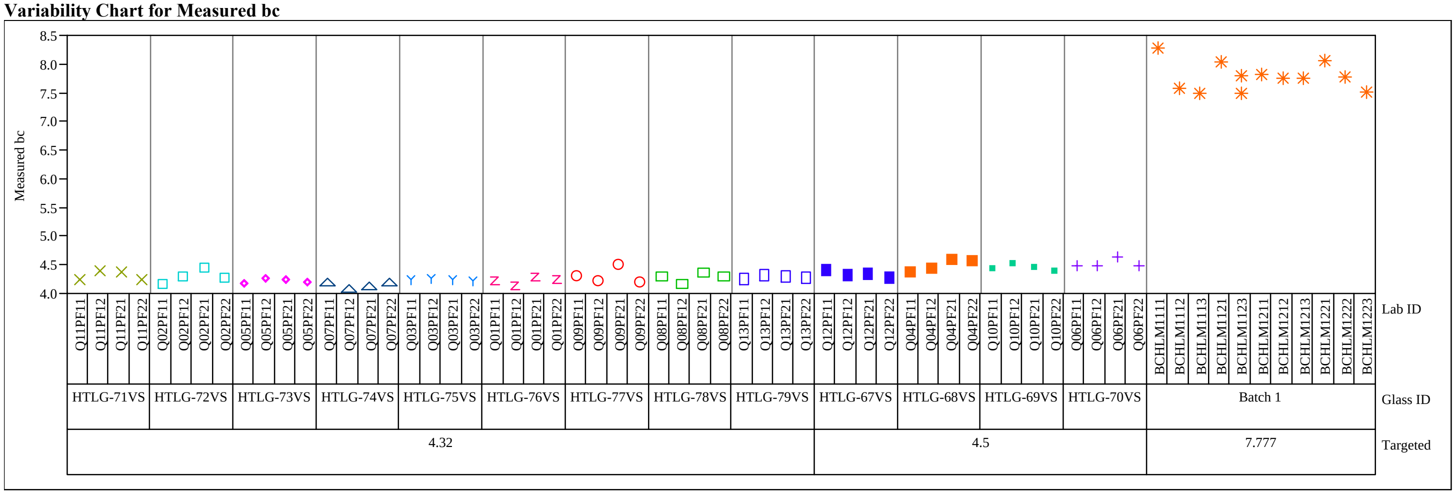
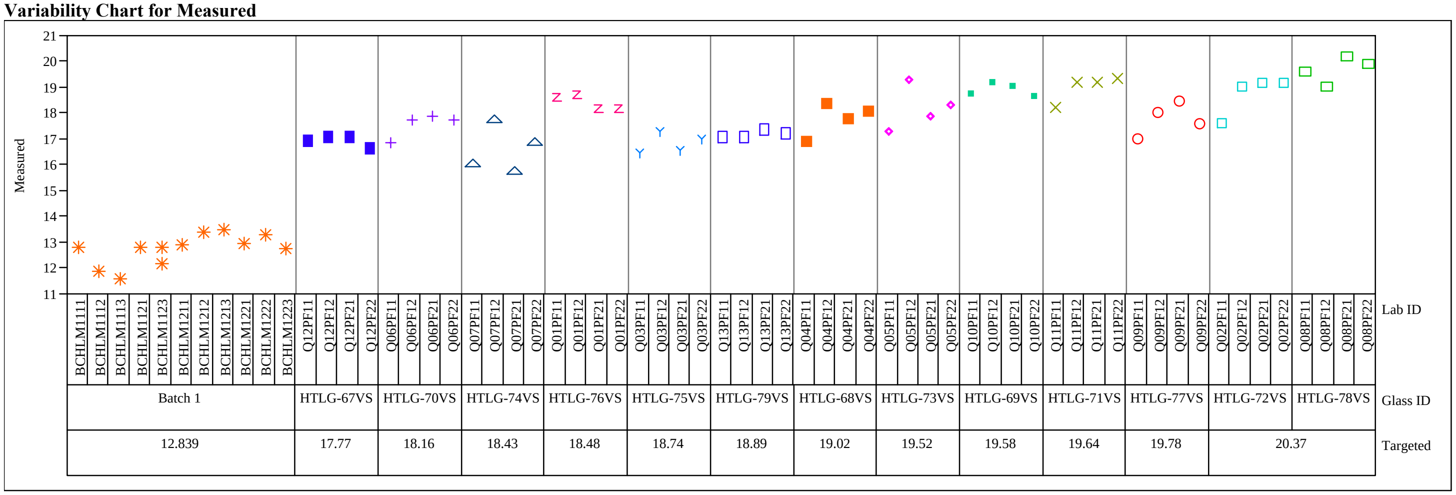


Exhibit A12. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the PF Method

Fe2O3 (wt%)

Variability Chart for Measured



Variability Chart for Measured bc

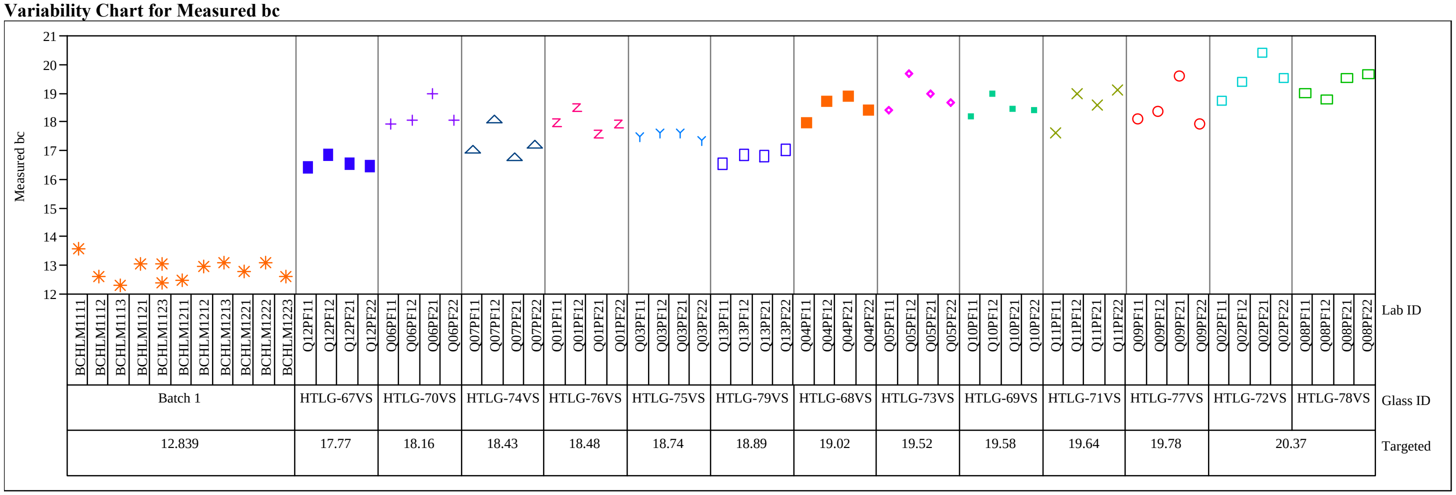
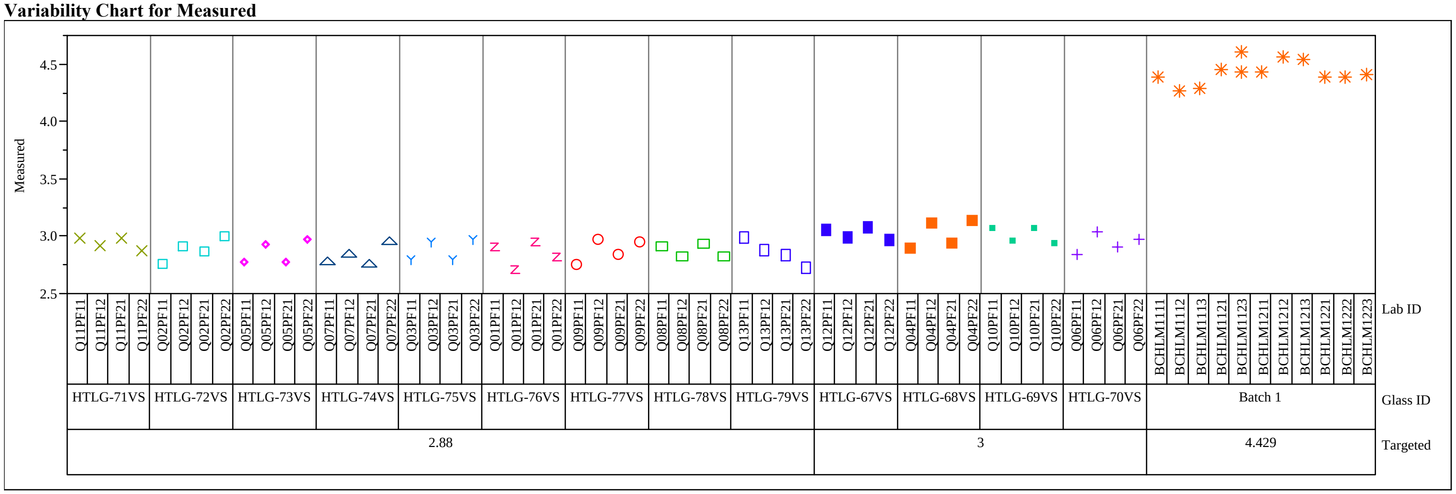


Exhibit A12. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the PF Method

Li2O (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

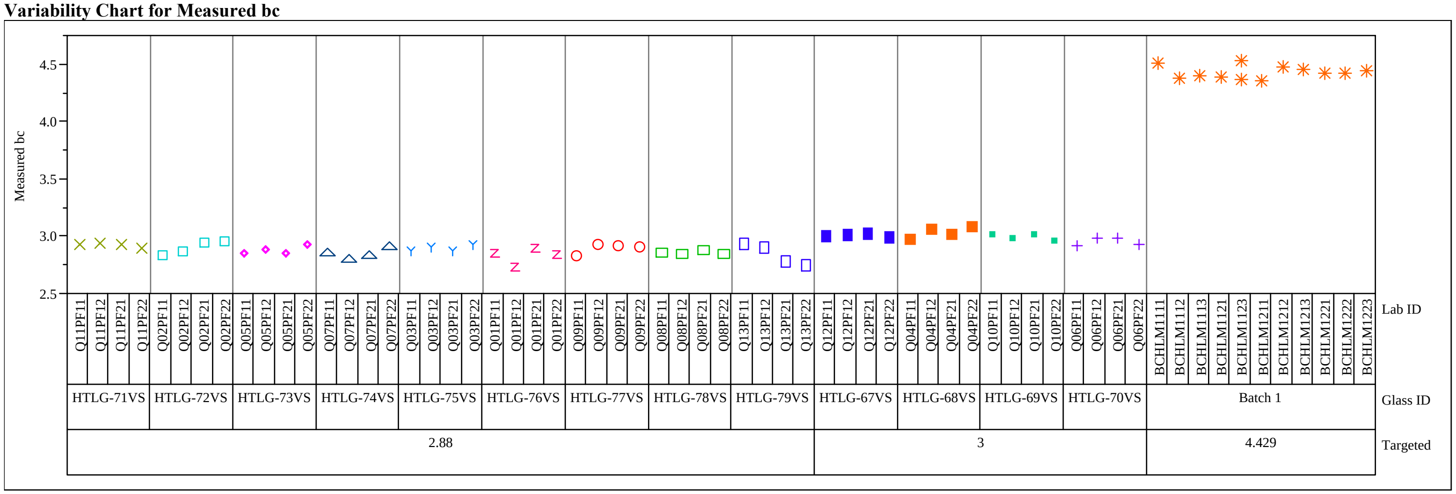
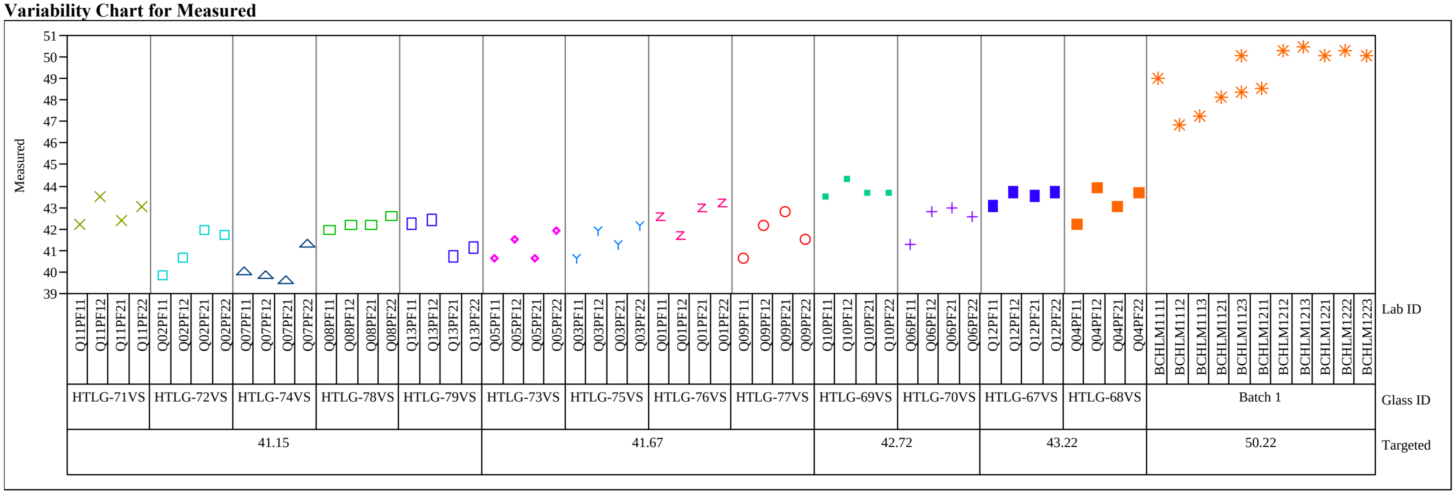


Exhibit A12. Measured and Measured Bias-Corrected Oxide Weight Percents by Glass ID by Targeted Value for the Series "Q" Glasses Prepared Using the PF Method

SiO2 (wt%)
Variability Chart for Measured



Variability Chart for Measured bc

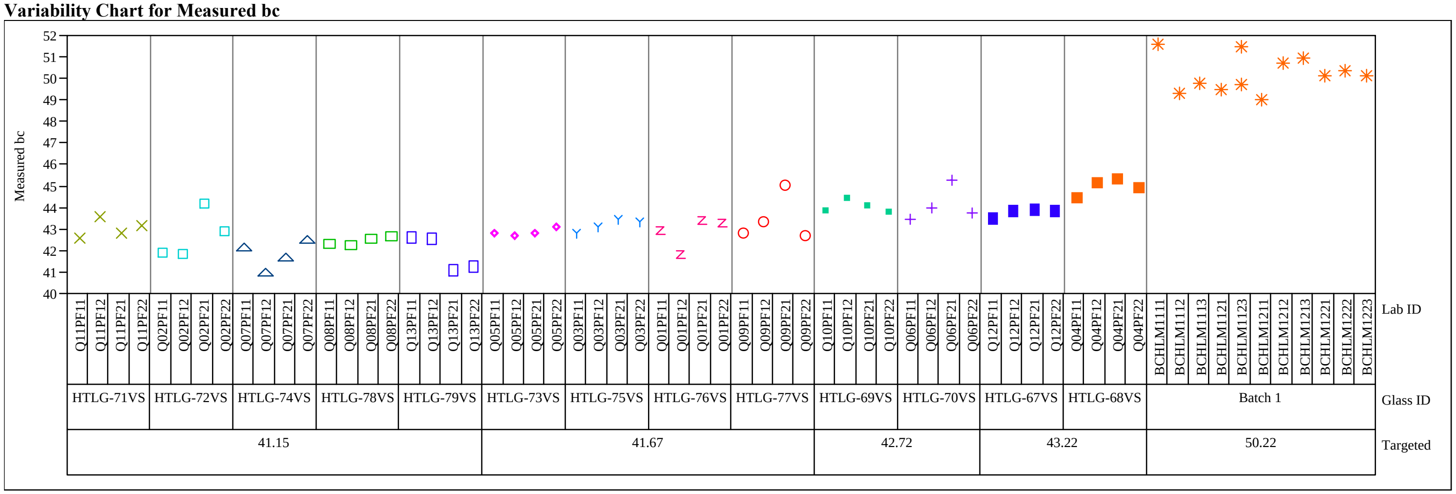
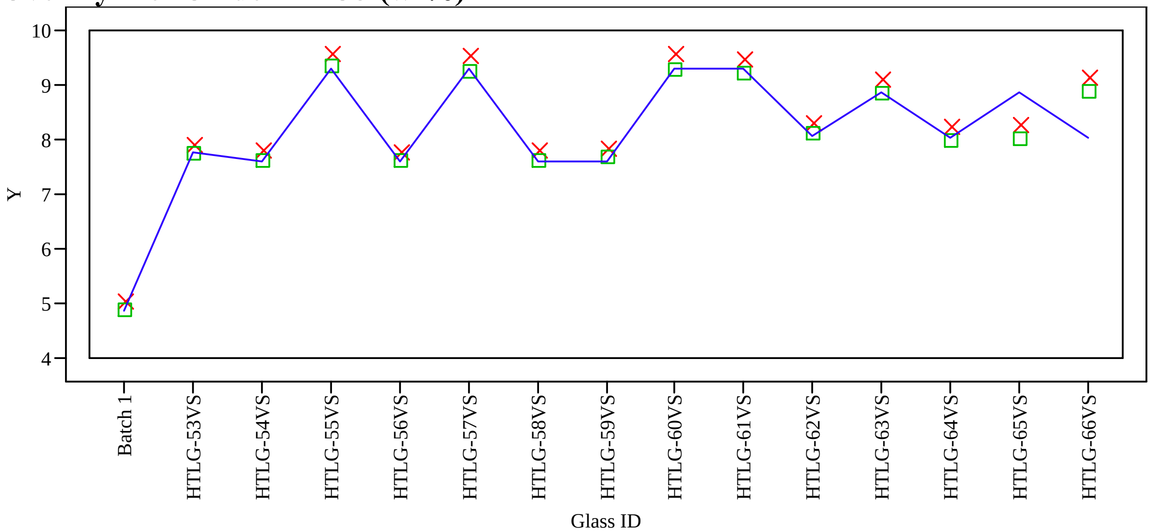


Exhibit A13. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "P" Series

Overlay Plot Oxide=Al2O3 (wt%)



Overlay Plot Oxide=B2O3 (wt%)

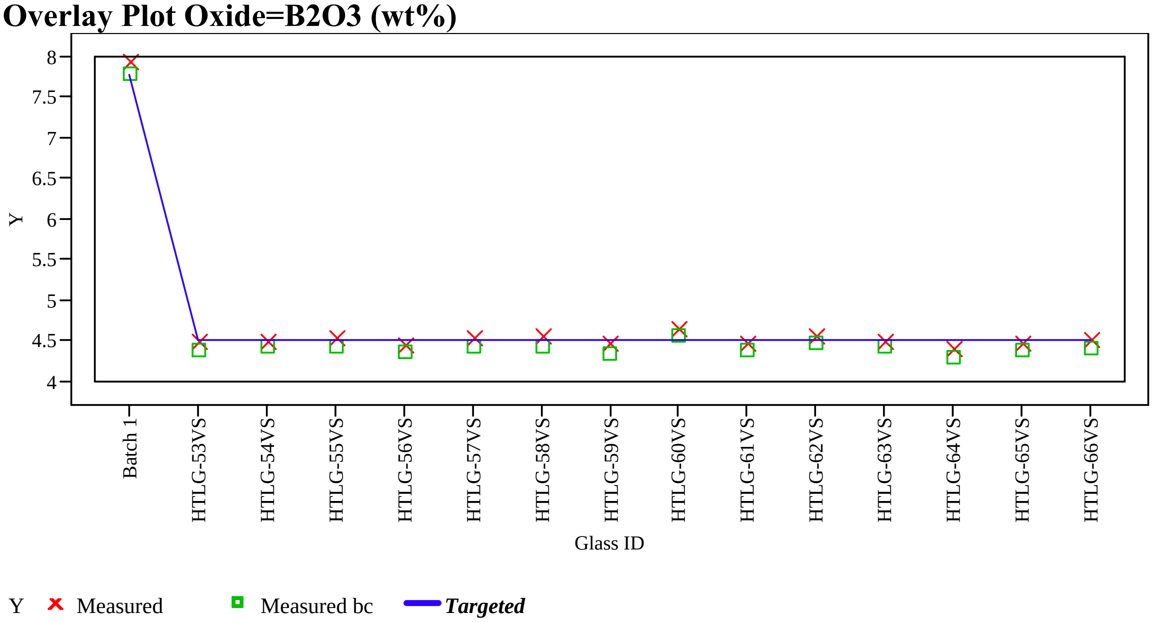
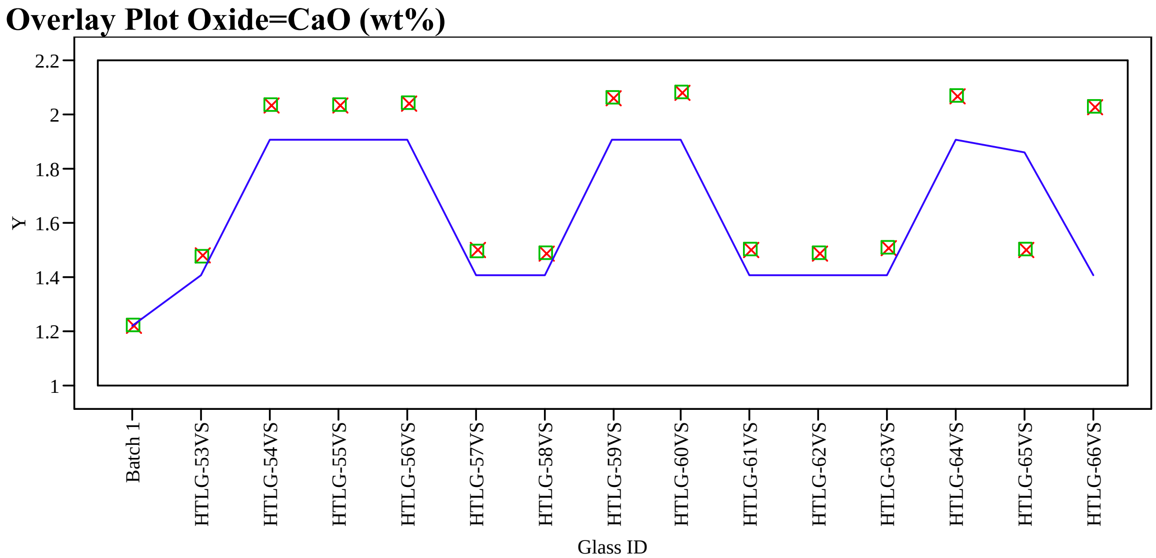


Exhibit A13. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the “P” Series



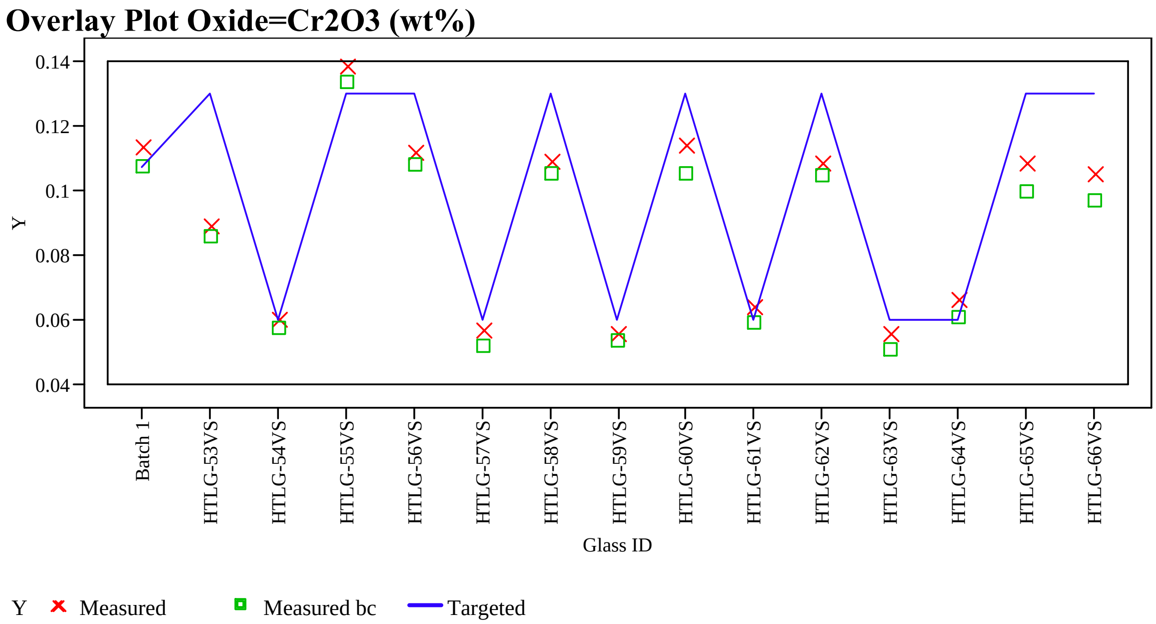
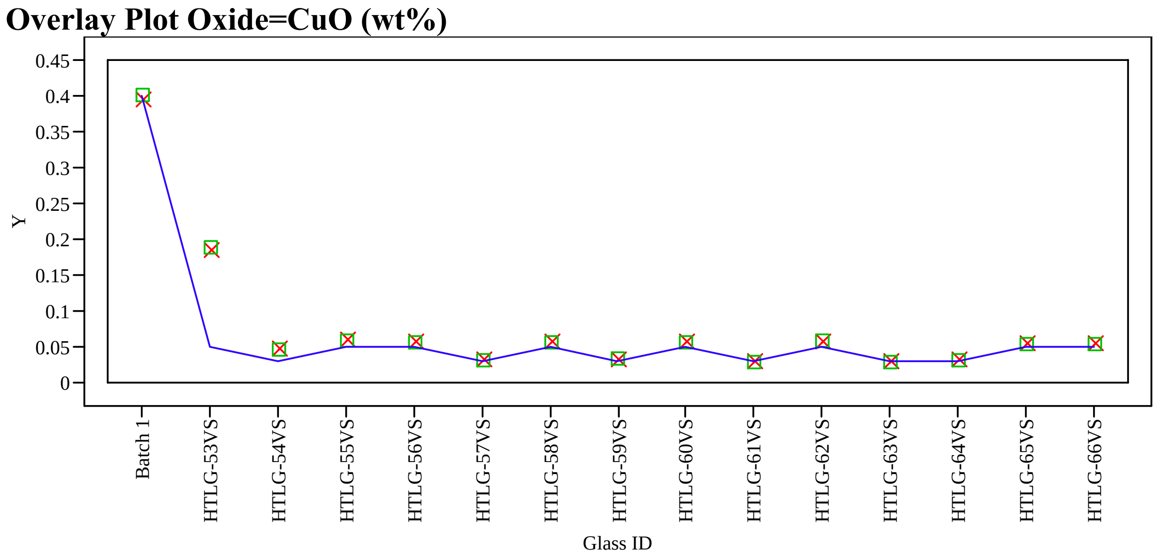


Exhibit A13. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "P" Series



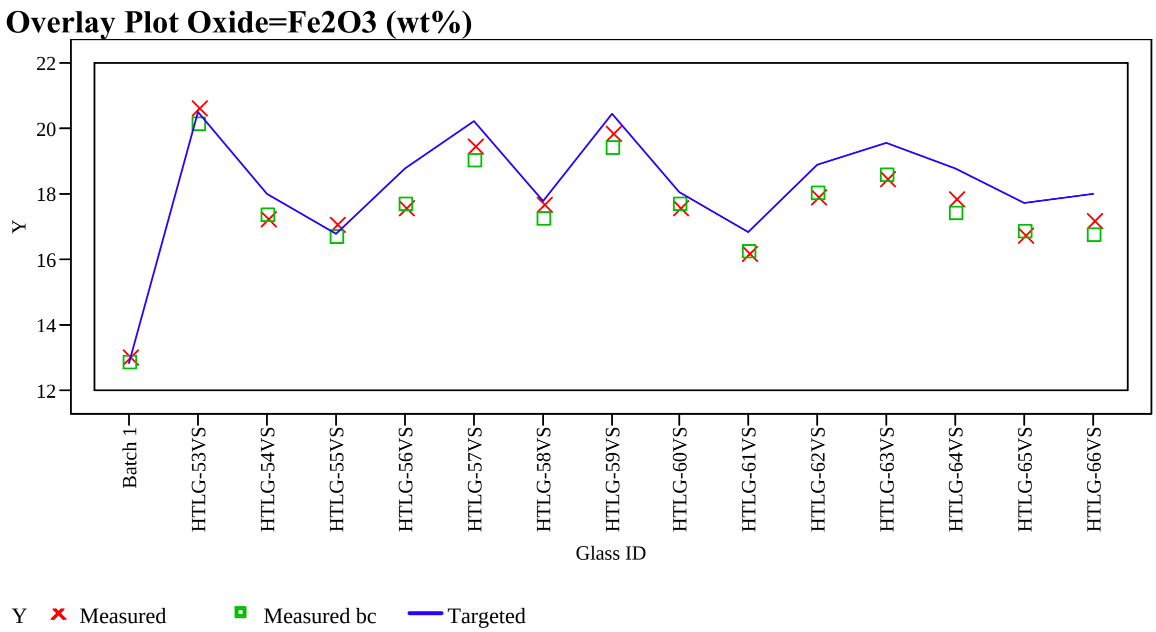
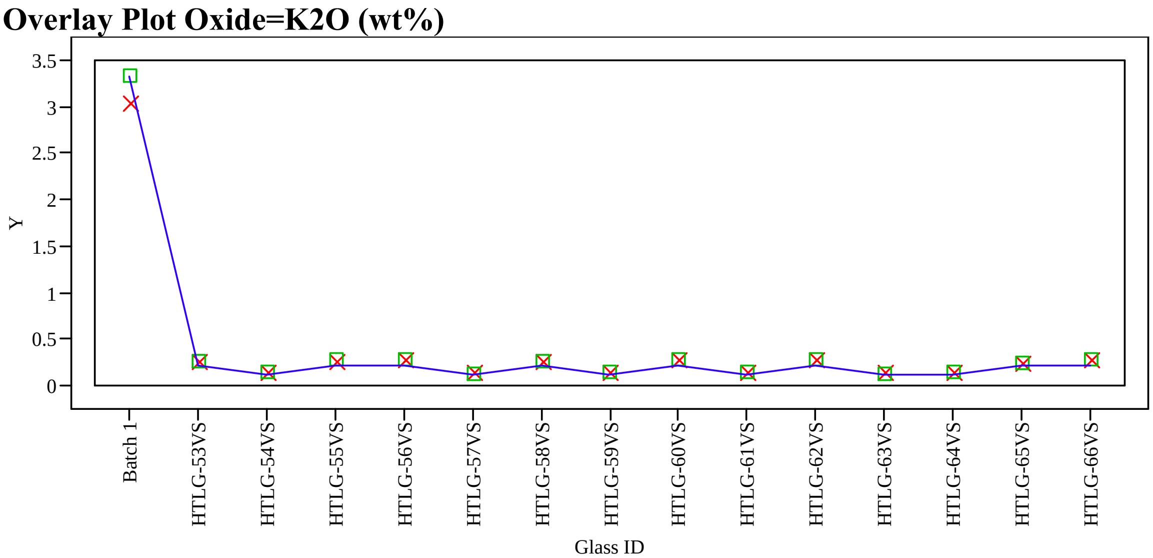


Exhibit A13. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "P" Series



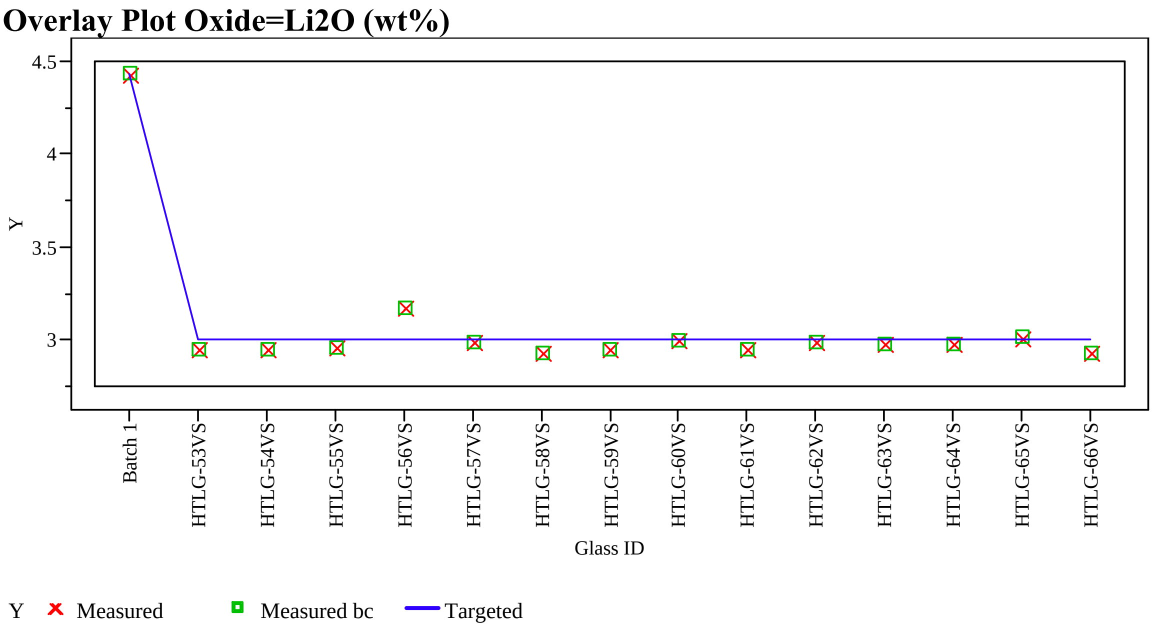
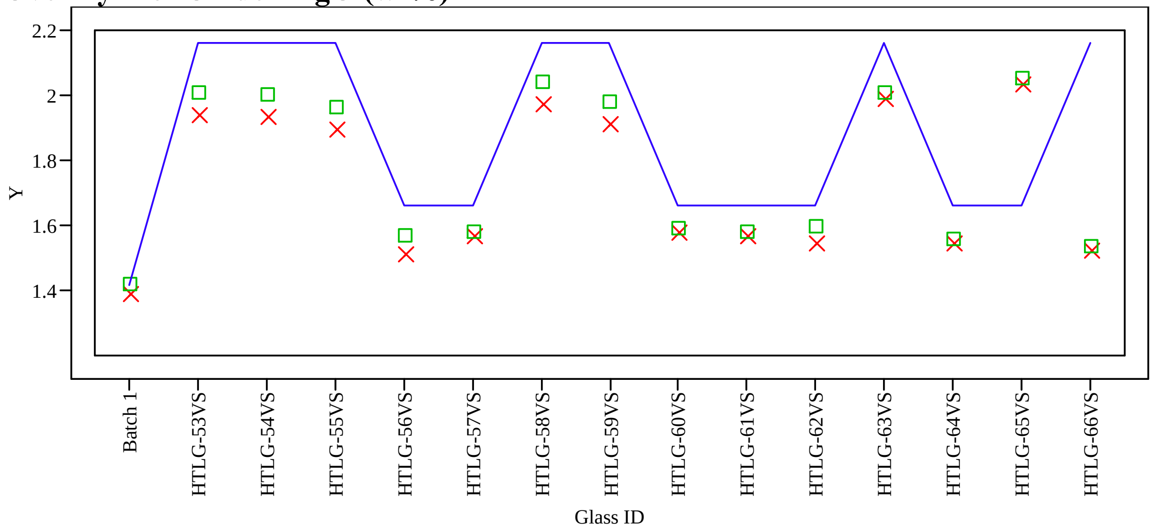


Exhibit A13. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "P" Series

Overlay Plot Oxide=MgO (wt%)



Overlay Plot Oxide=MnO (wt%)

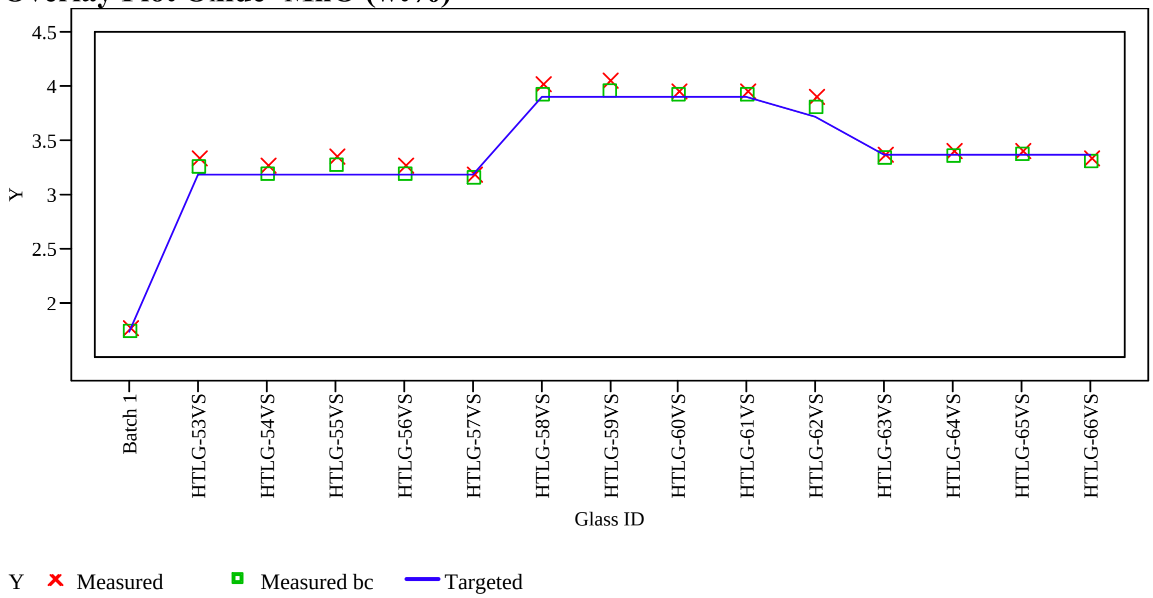
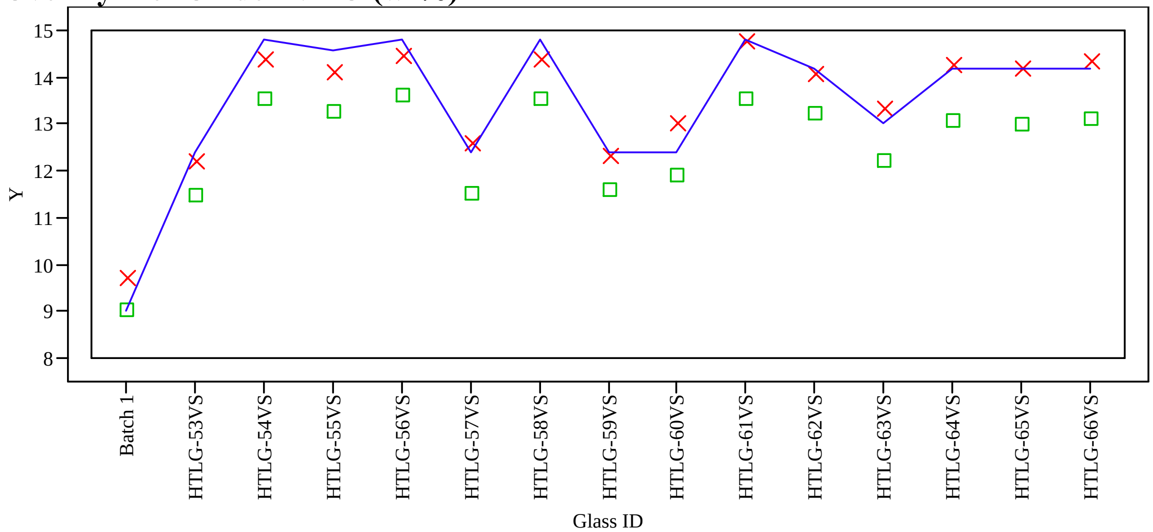


Exhibit A13. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "P" Series

Overlay Plot Oxide=Na2O (wt%)



Overlay Plot Oxide=NiO (wt%)

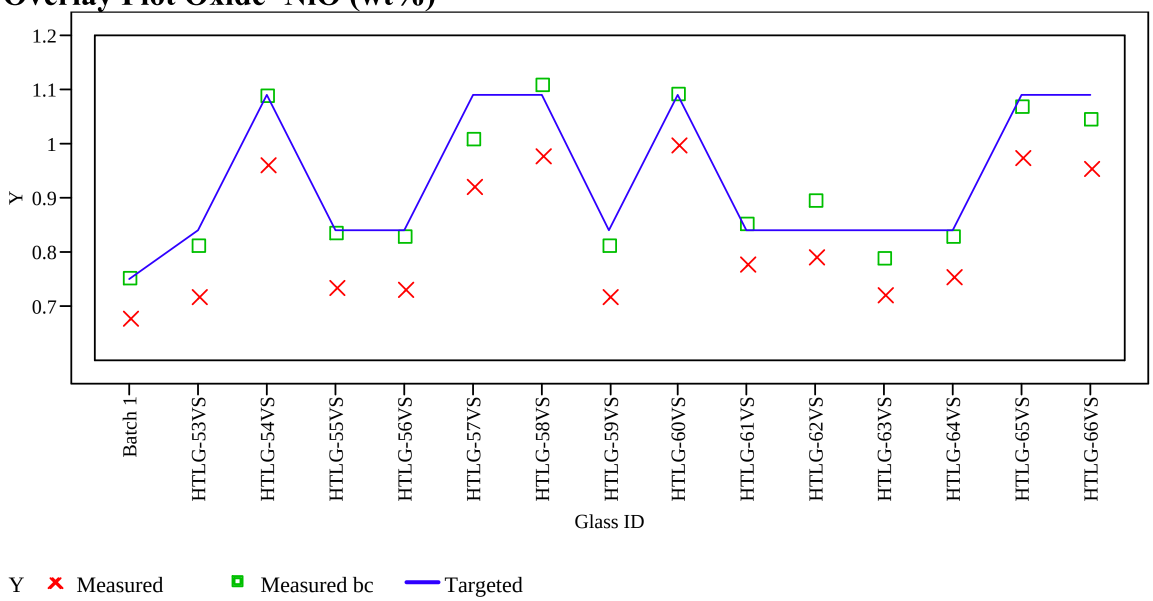
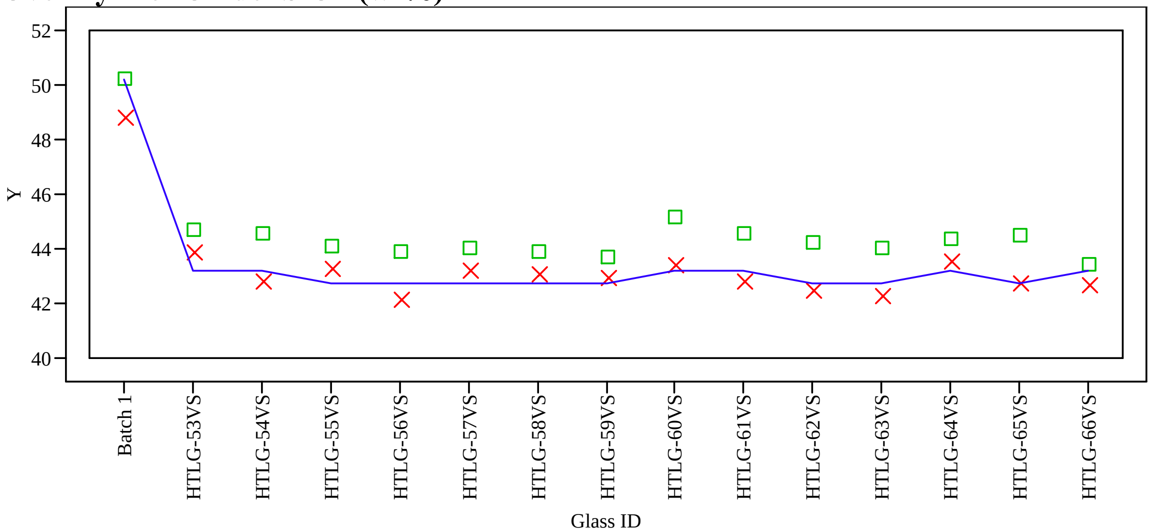
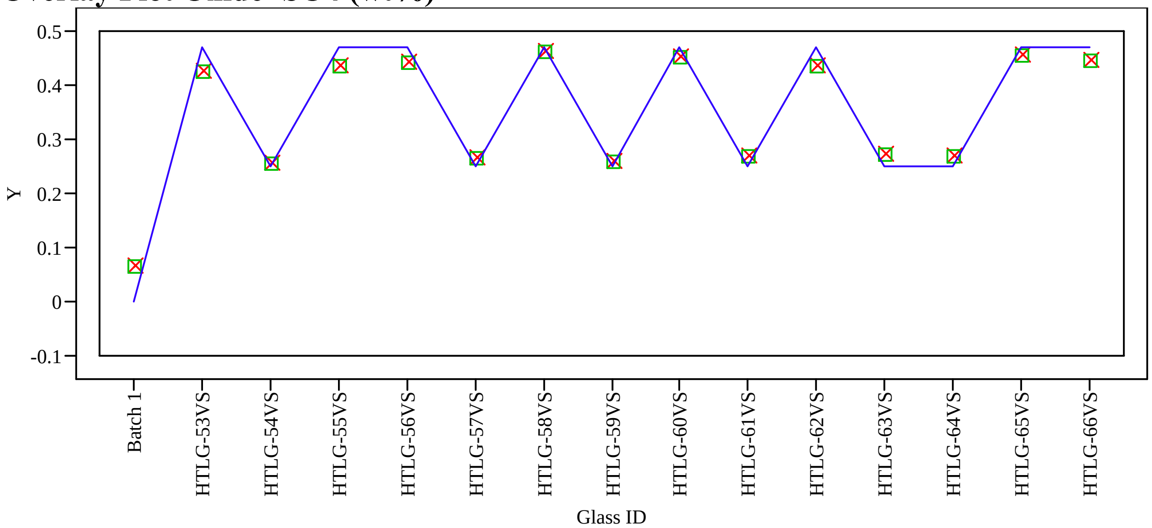


Exhibit A13. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "P" Series

Overlay Plot Oxide=SiO2 (wt%)



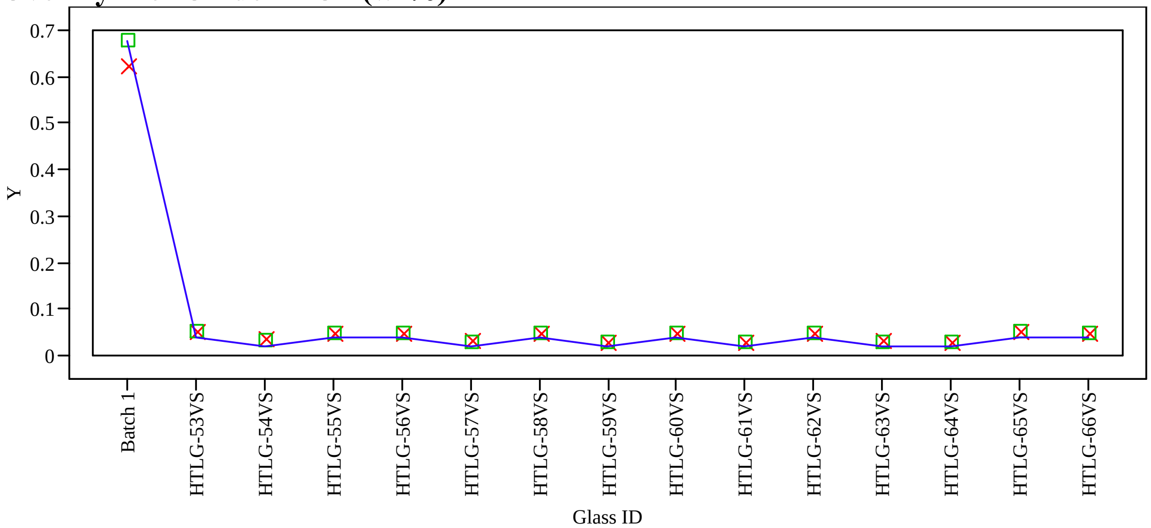
Overlay Plot Oxide=SO4 (wt%)



Y × Measured ▫ Measured bc — *Targeted*

Exhibit A13. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "P" Series

Overlay Plot Oxide=TiO2 (wt%)



Overlay Plot Oxide=ZrO2 (wt%)

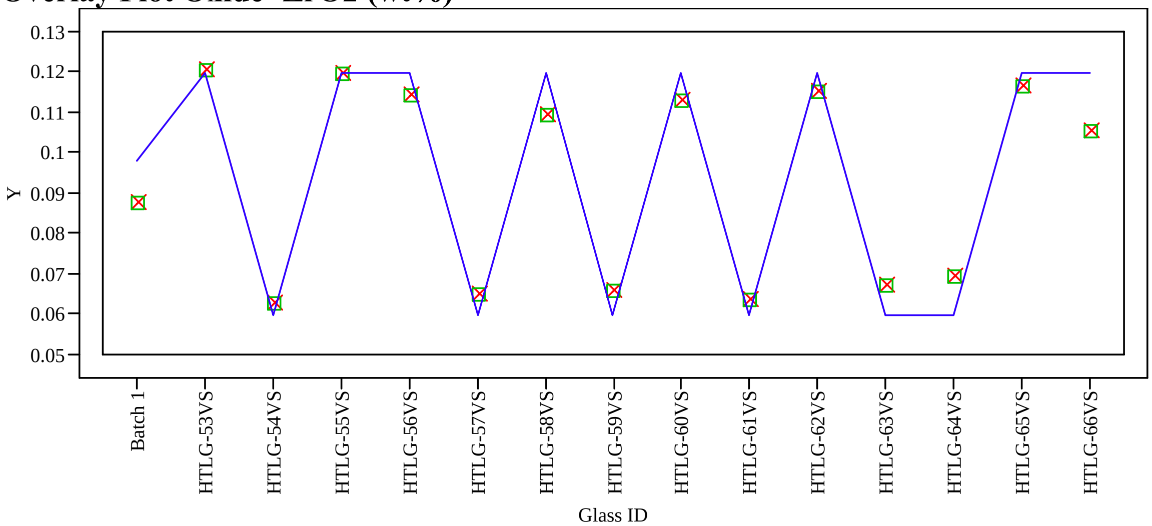


Exhibit A13. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "P" Series

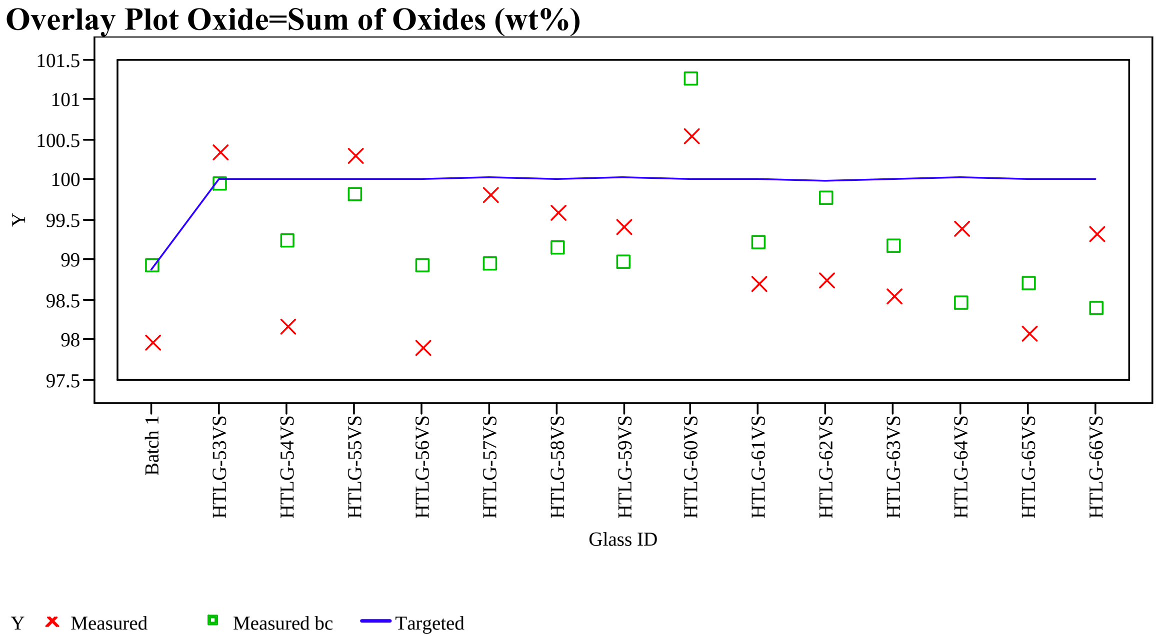
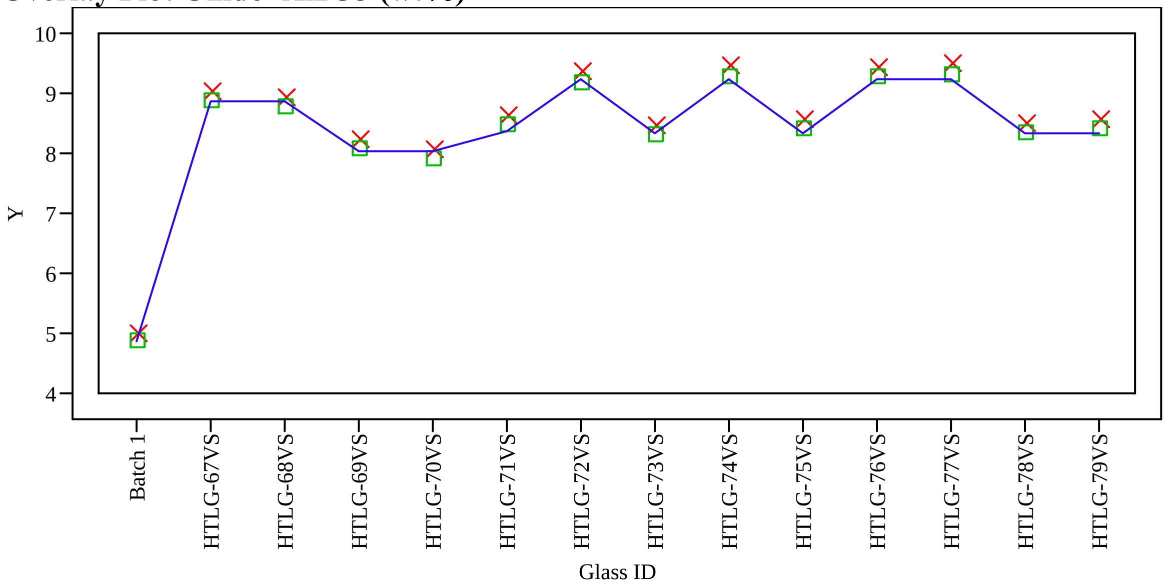


Exhibit A14. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "Q" Series

Overlay Plot Oxide=Al2O3 (wt%)



Overlay Plot Oxide=B2O3 (wt%)

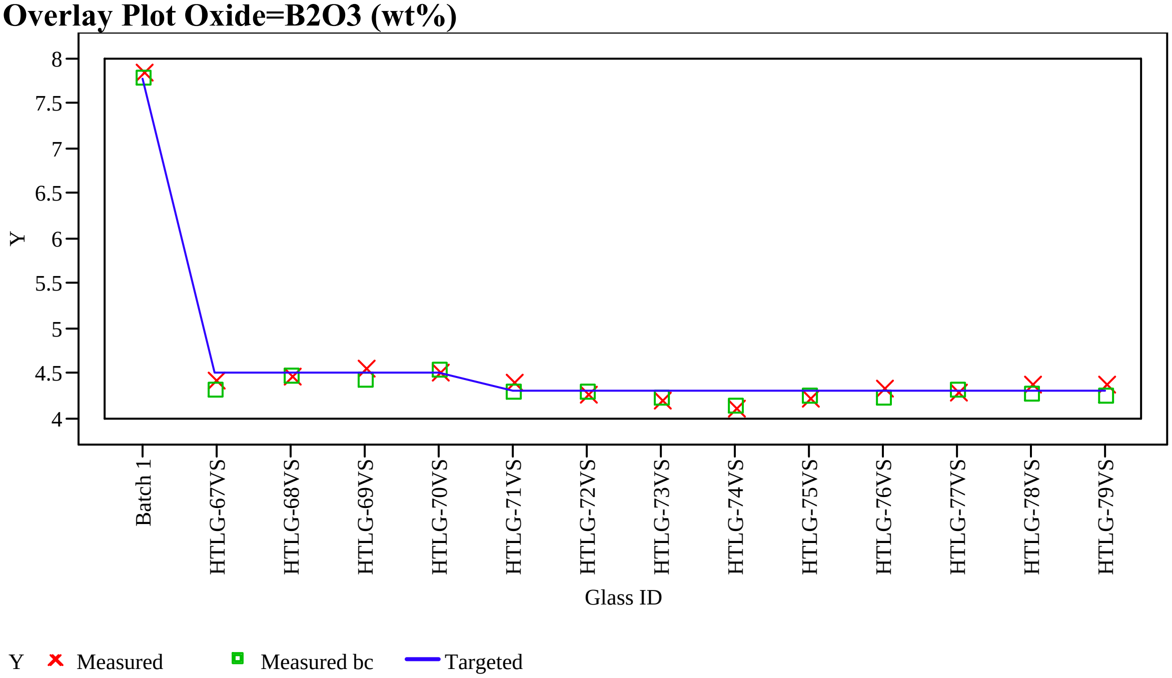
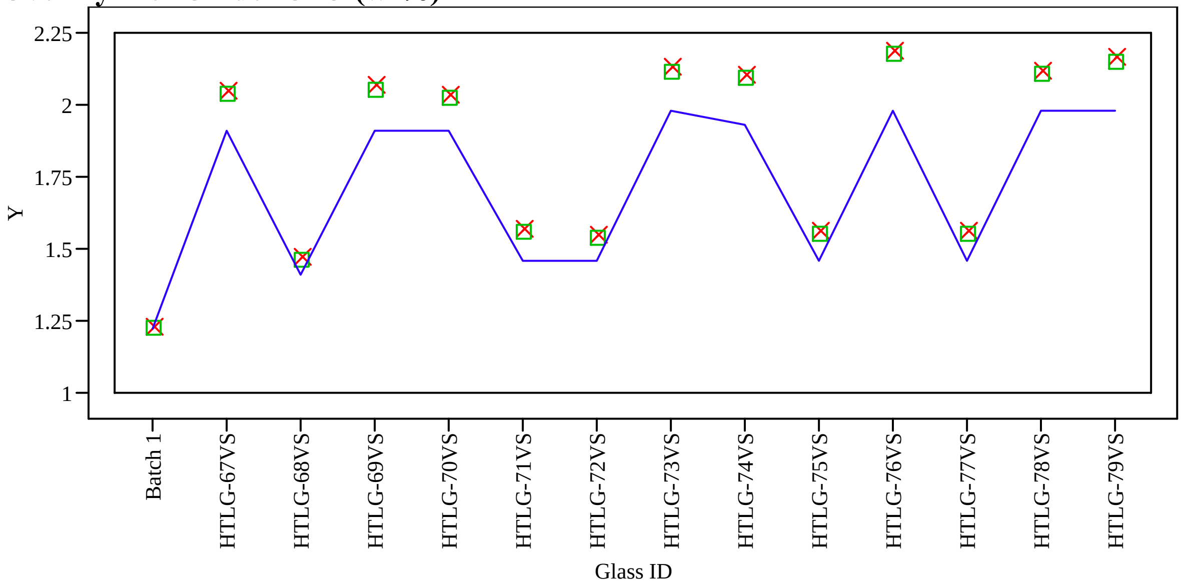
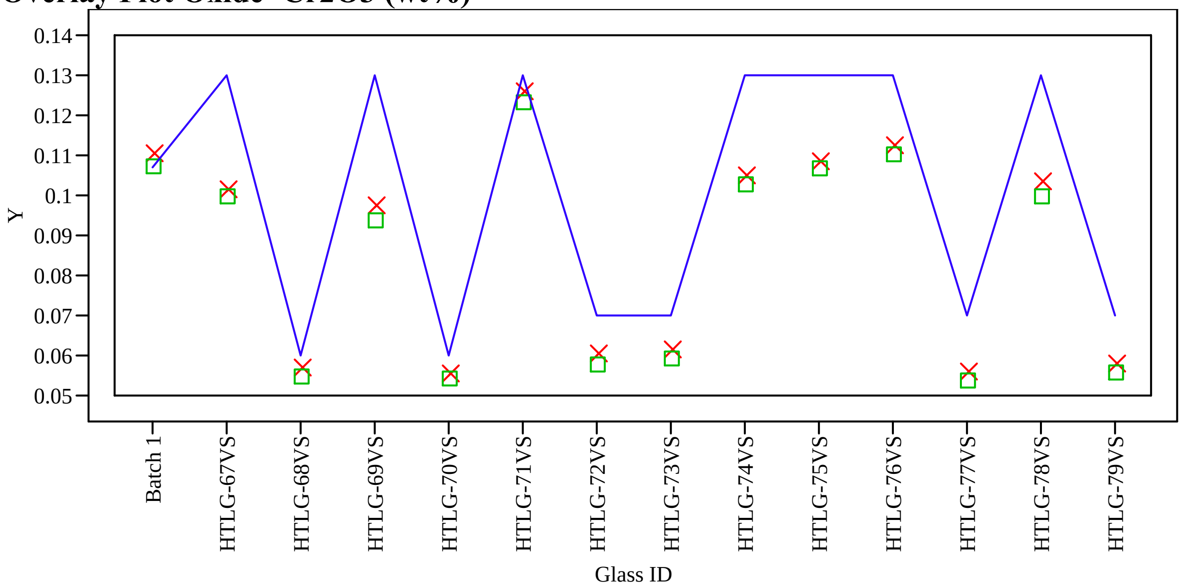


Exhibit A14. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "Q" Series

Overlay Plot Oxide=CaO (wt%)



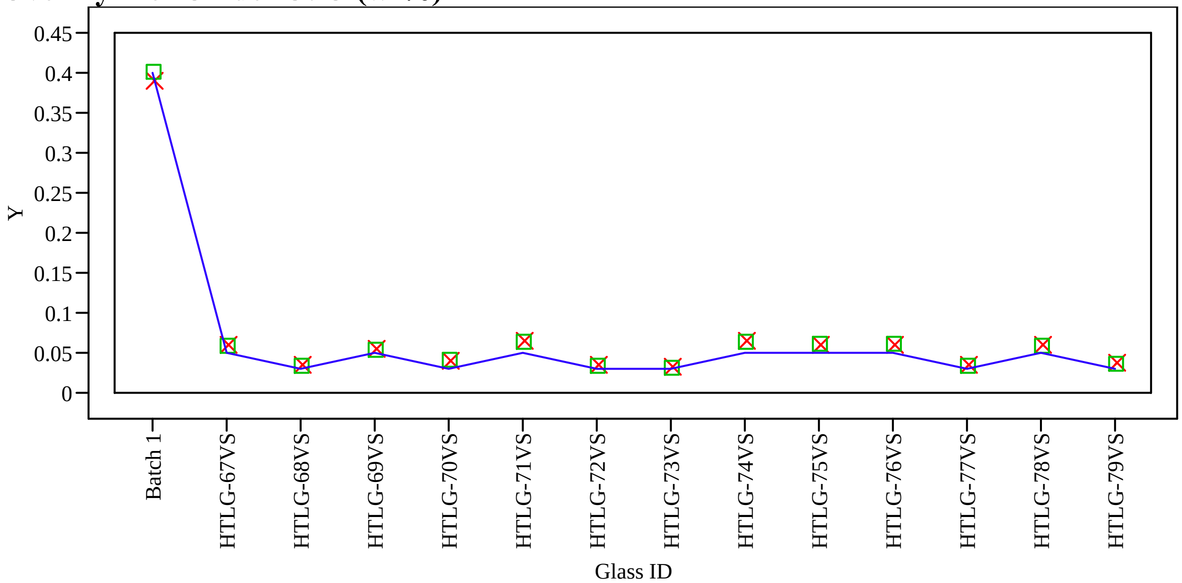
Overlay Plot Oxide=Cr2O3 (wt%)



Y × Measured ▫ Measured bc — Targeted

Exhibit A14. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "Q" Series

Overlay Plot Oxide=CuO (wt%)



Overlay Plot Oxide=Fe2O3 (wt%)

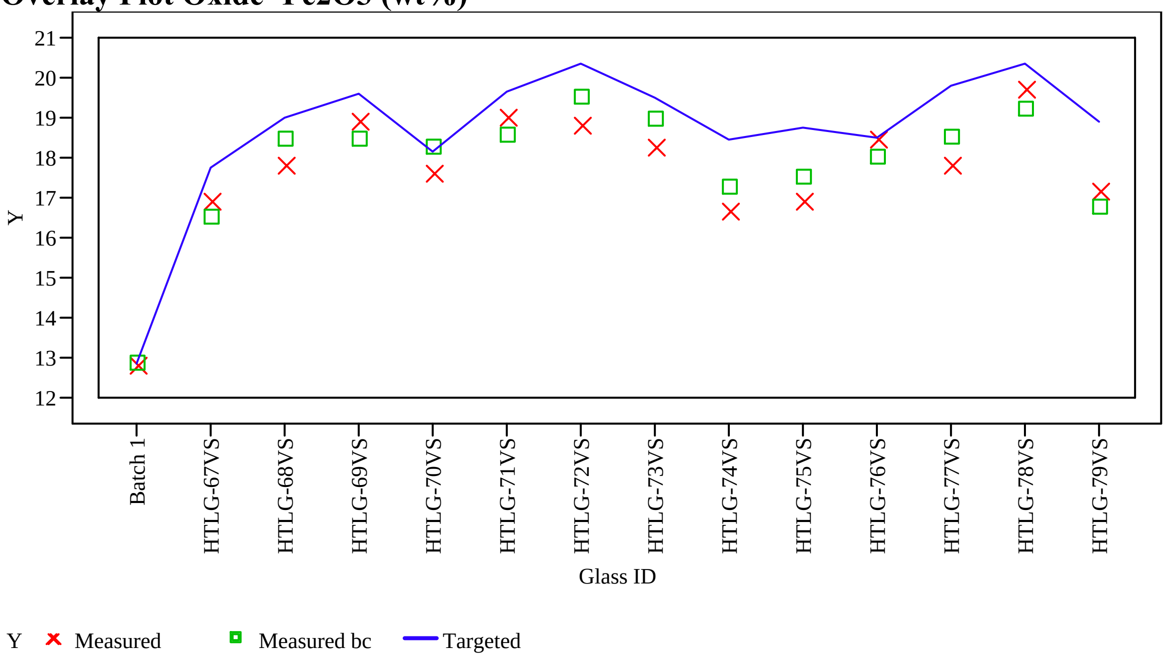
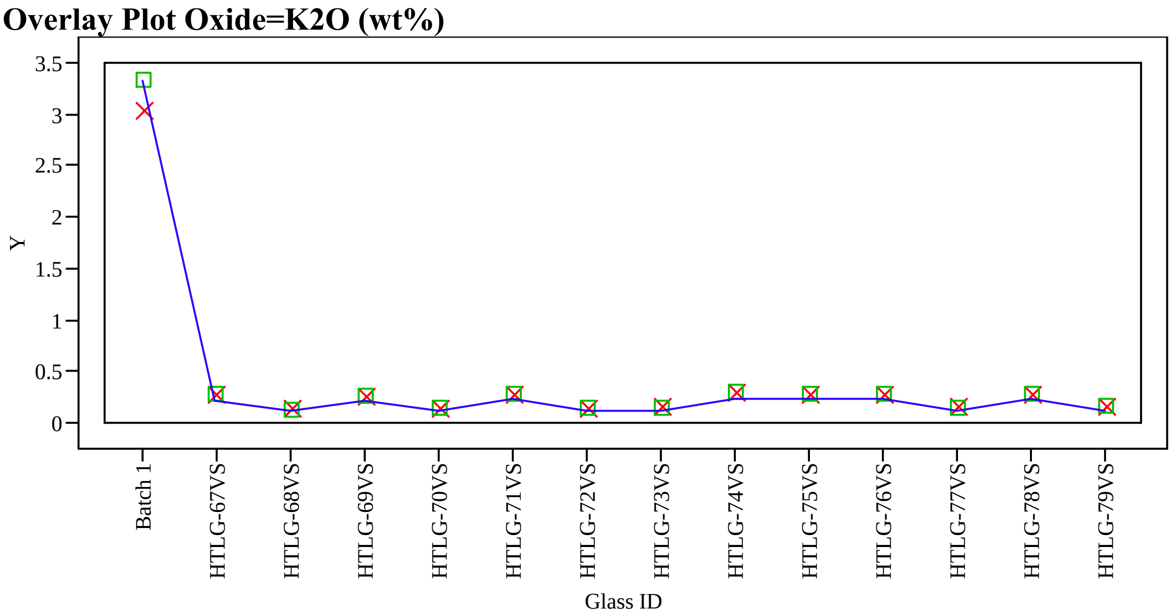


Exhibit A14. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "Q" Series



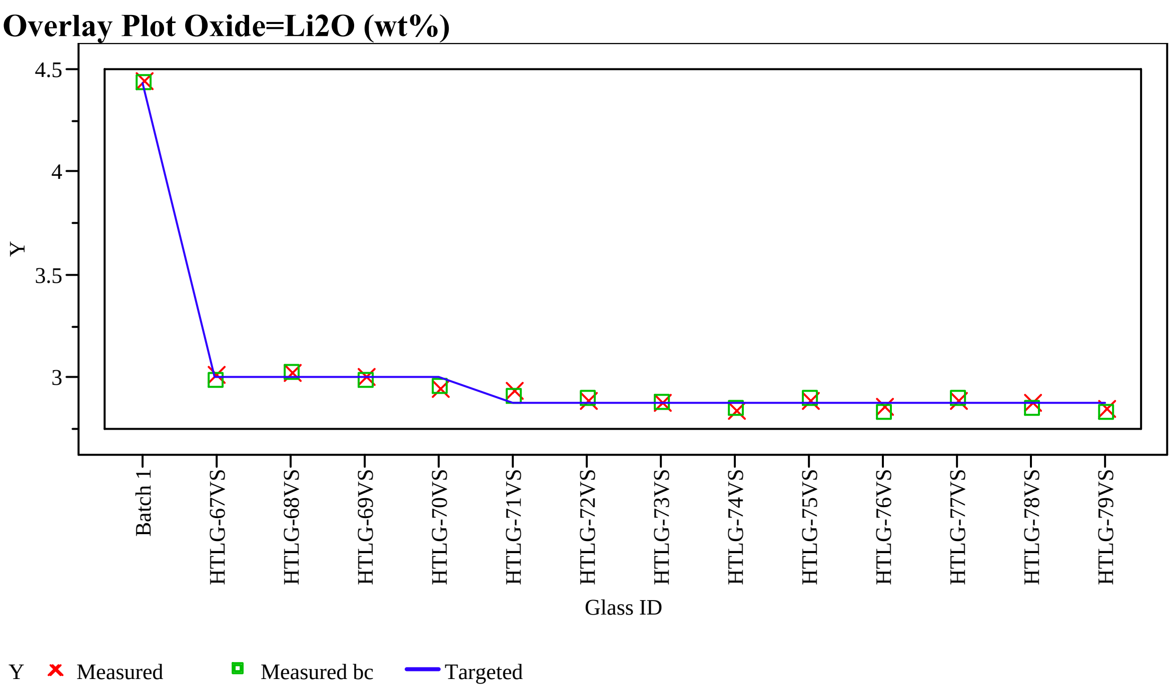
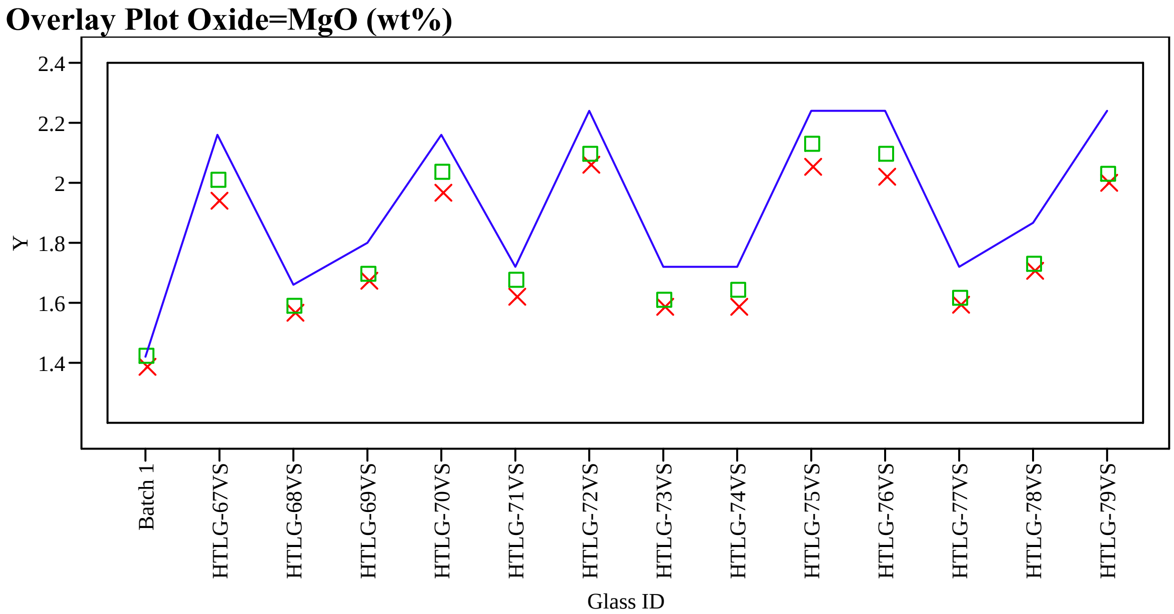


Exhibit A14. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "Q" Series



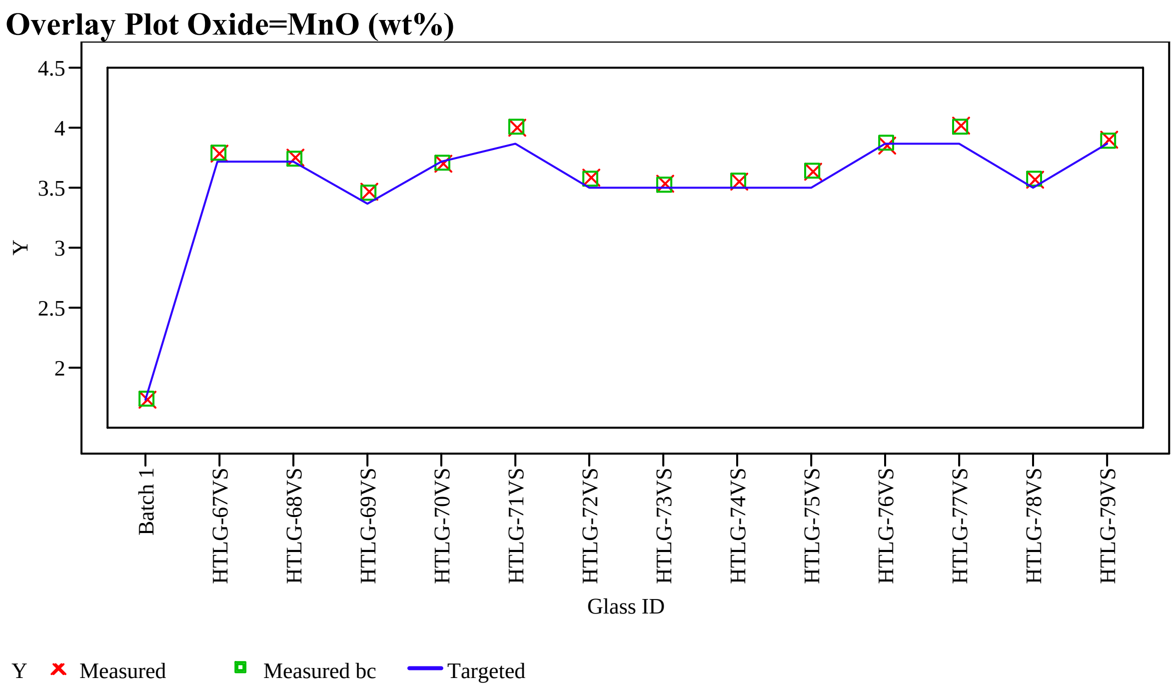
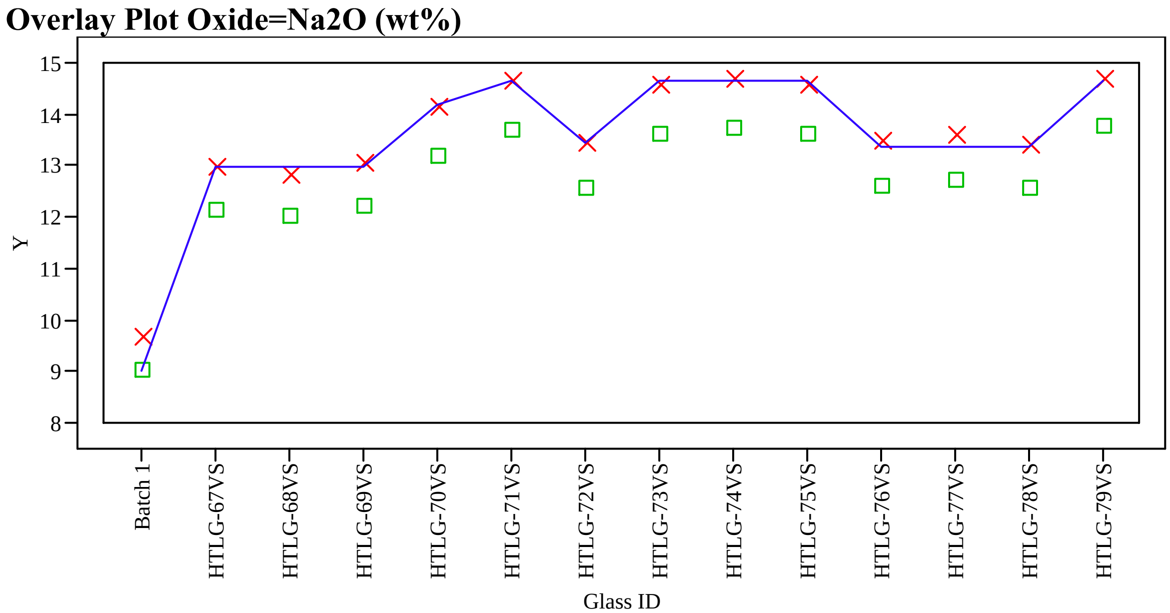


Exhibit A14. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "Q" Series



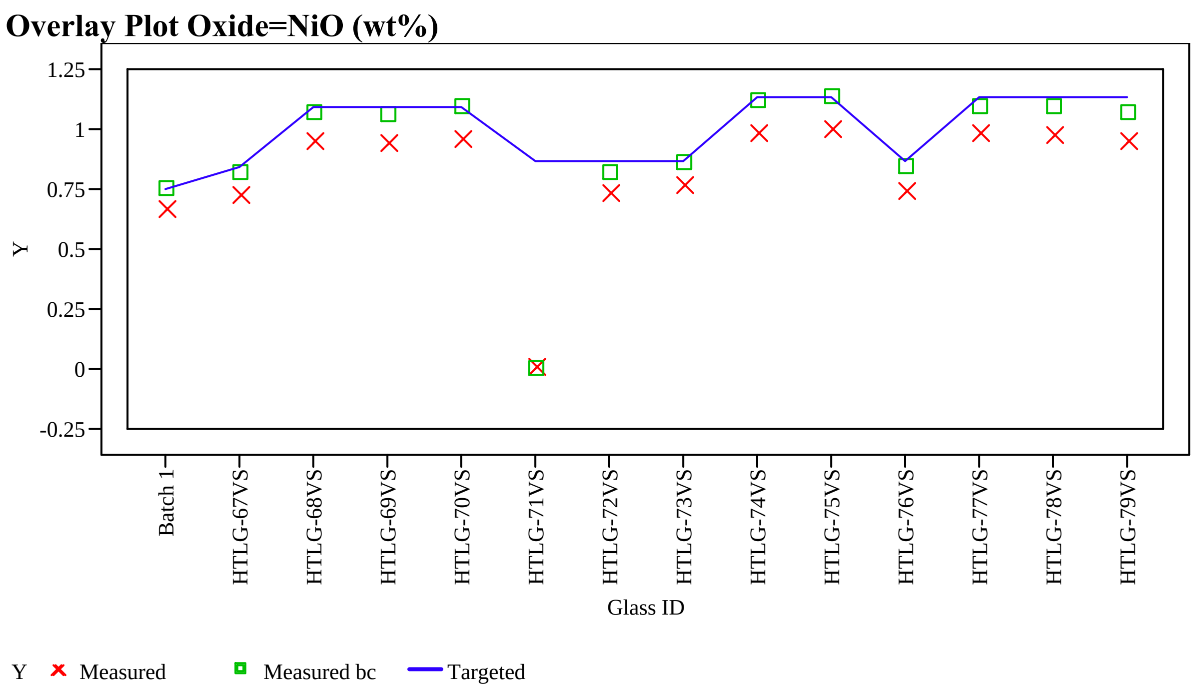
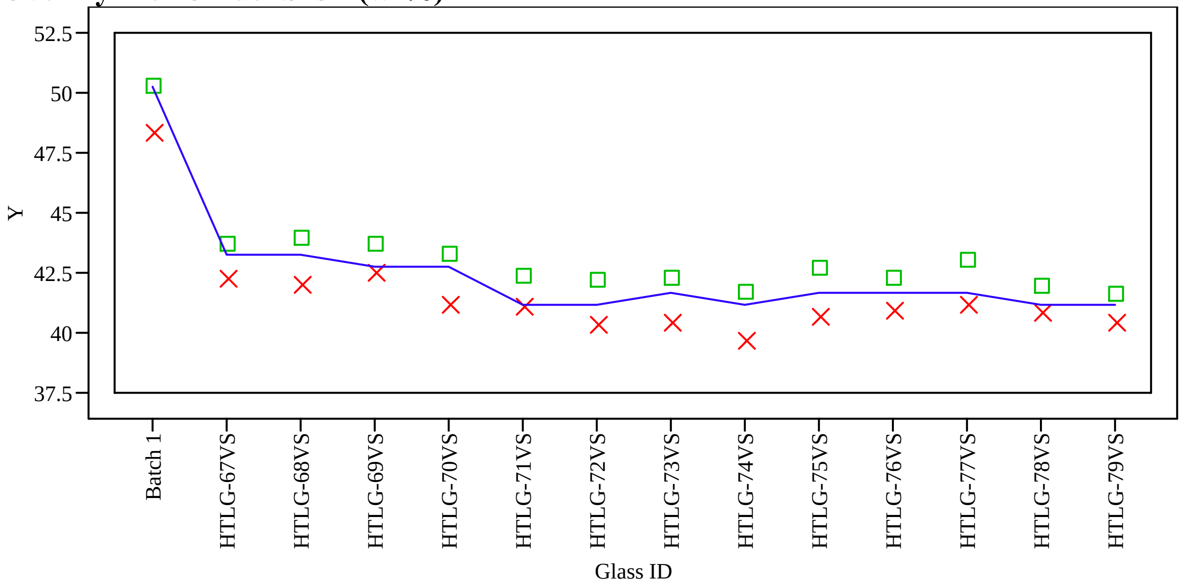
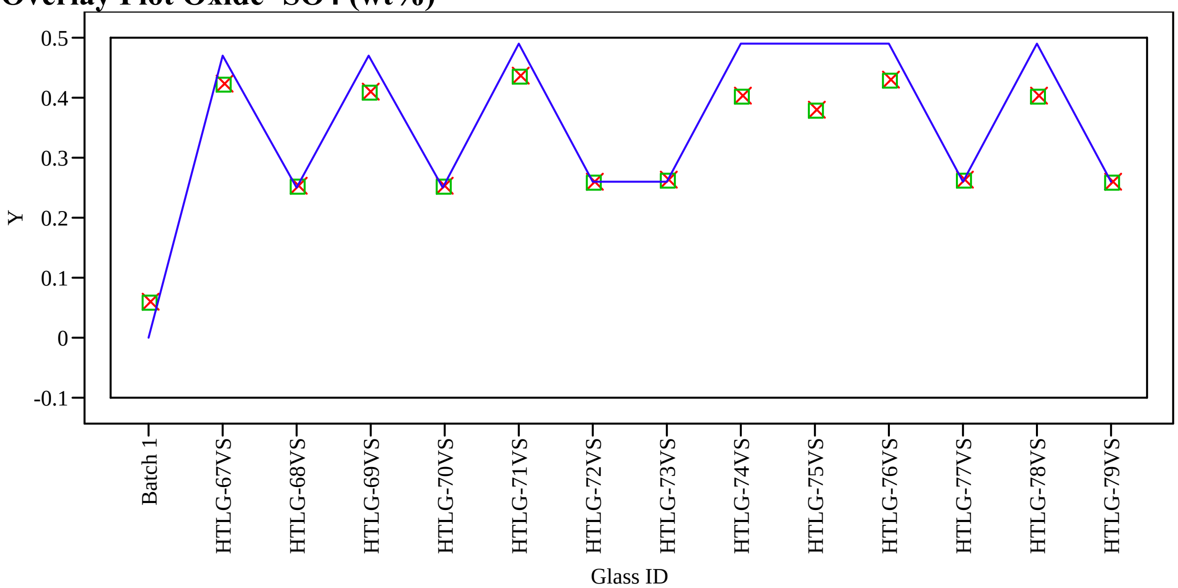


Exhibit A14. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "Q" Series

Overlay Plot Oxide=SiO2 (wt%)

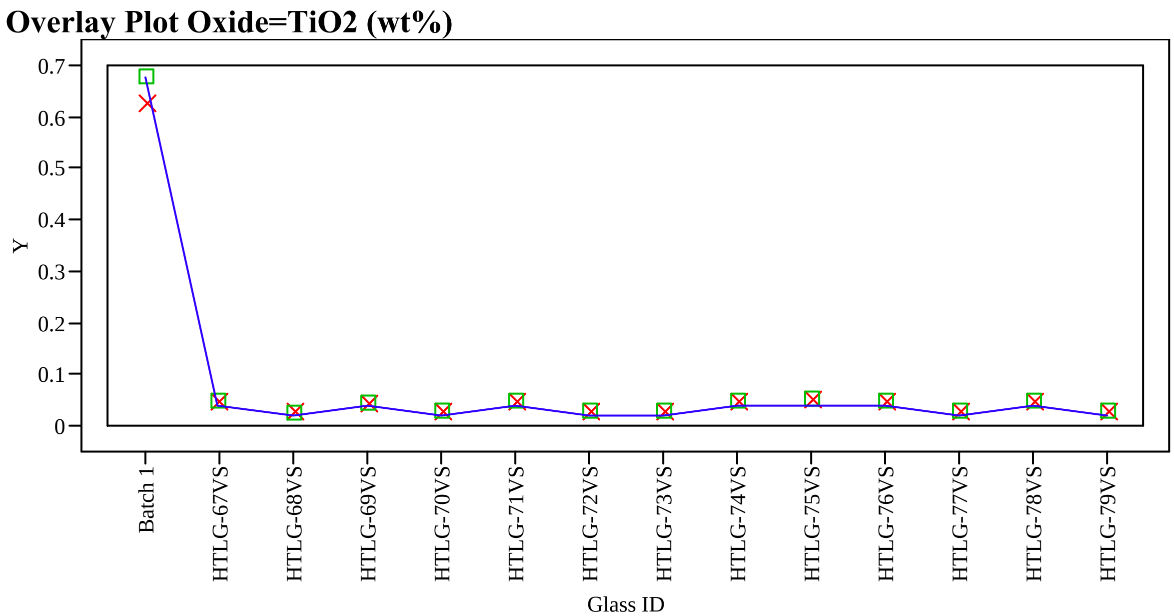


Overlay Plot Oxide=SO4 (wt%)



Y × Measured ▫ Measured bc — Targeted

Exhibit A14. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the "Q" Series



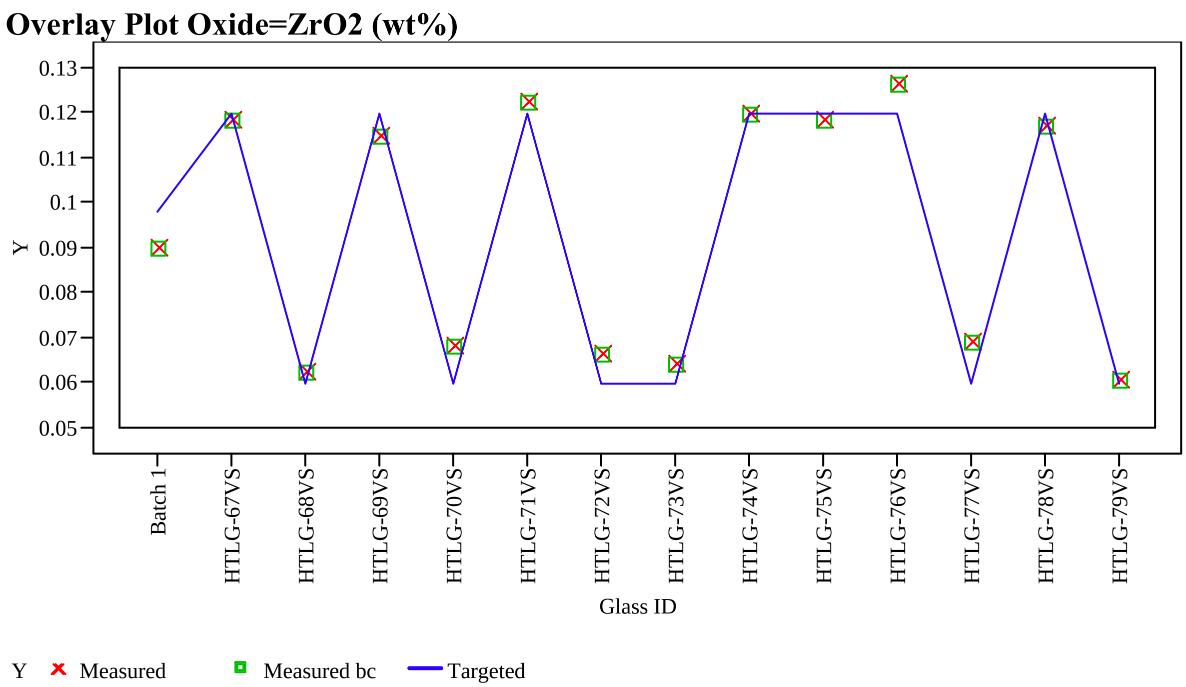
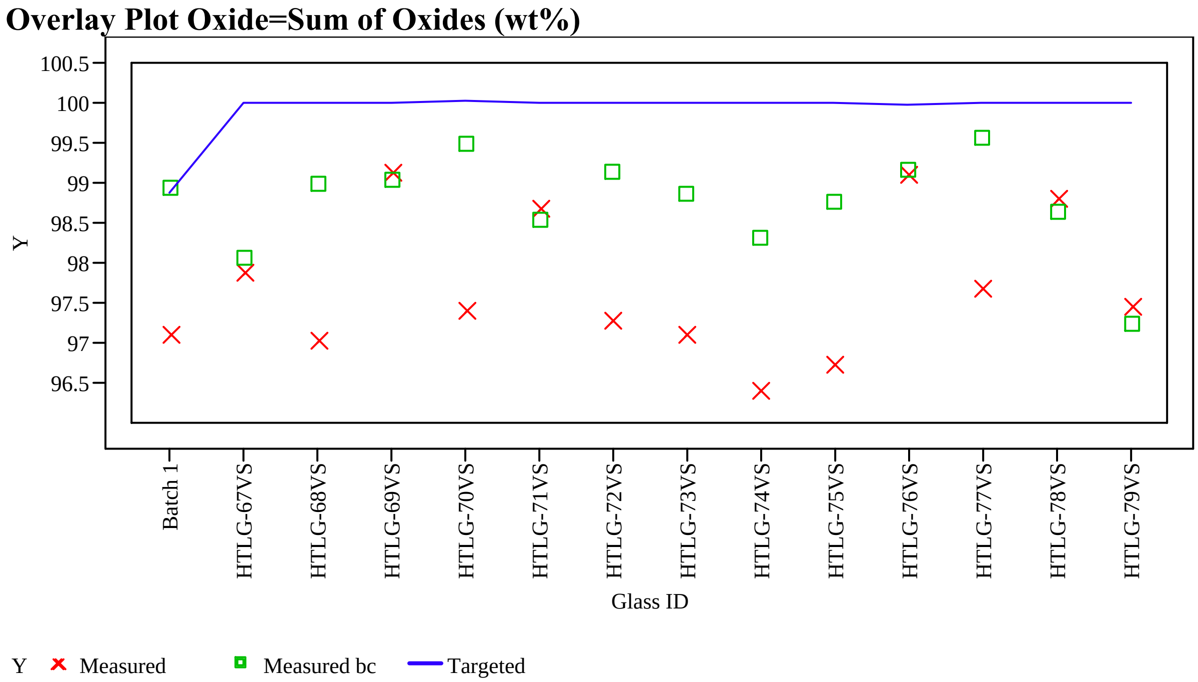


Exhibit A14. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Analyte for the “Q” Series



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Appendix B

Tables and Exhibits Supporting the Review of the PCT Measurements

Table B1. PSAL Measurements of the PCT Solutions for the HTL Study Glasses As Reported (ar) and After the Appropriate Adjustments (in parts per million, ppm)

Set	Glass ID	Heat Treatment	Block	Seq	SRTC-ML ID	Al ar	B ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
1	Std Soln		1	1	STD-11-1	3.64	21.4	3.89	9.98	83.4	50.6	3.64	21.40	3.89	9.98	83.40	50.60
1	HTLG-61VS	ccc	1	2	F23	13.4	7.33	6.37	7.84	63.3	65.1	22.33	12.22	10.62	13.07	105.50	108.50
1	HTLG-64VS	quenched	1	3	F28	10.5	9.53	4.22	8.59	73.3	67.7	17.50	15.88	7.03	14.32	122.17	112.84
1	HTLG-64VS	ccc	1	4	F65	11.7	55.1	14.5	46.7	198	169	19.50	91.84	24.17	77.83	330.01	281.67
1	HTLG-56VS	ccc	1	5	F36	20.3	22.5	7.21	22.3	124	119	33.83	37.50	12.02	37.17	206.67	198.34
1	HTLG-53VS	quenched	1	6	F82	9.28	8.8	4.21	7.77	56.1	59.2	15.47	14.67	7.02	12.95	93.50	98.67
1	HTLG-60VS	ccc	1	7	F33	12.7	5.38	2.72	6.44	41	51.6	21.17	8.97	4.53	10.73	68.33	86.00
1	HTLG-53VS	ccc	1	8	F37	14.2	6.93	3.46	7.85	54	60.6	23.67	11.55	5.77	13.08	90.00	101.00
1	HTLG-65VS	quenched	1	9	F14	9.6	8.88	3.72	7.85	68.4	63.4	16.00	14.80	6.20	13.08	114.00	105.67
1	Std Soln		1	10	STD-11-2	3.81	19	3.75	9.9	83.9	48.9	3.81	19.00	3.75	9.90	83.90	48.90
1	HTLG-65VS	ccc	1	11	F17	11.5	8.2	3.77	9.16	66.2	66.6	19.17	13.67	6.28	15.27	110.34	111.00
1	EA		1	12	F90	<1.00	36.5	<1.00	11.4	103	54.7	8.33	608.33	8.33	190.00	1716.67	911.67
1	blank		1	13	F81	<1.00	<1.00	1.84	<1.00	1.4	<1.00	0.83	0.83	3.07	0.83	2.33	0.83
1	HTLG-57VS	ccc	1	14	F85	10.6	4.78	1.69	5.73	39.7	49.5	17.67	7.97	2.82	9.55	66.17	82.50
1	HTLG-61VS	quenched	1	15	F35	12.6	7.9	4.34	7.29	67.1	61.6	21.00	13.17	7.23	12.15	111.84	102.67
1	HTLG-60VS	quenched	1	16	F12	10.8	6.63	3.71	7	47.4	53.6	18.00	11.05	6.18	11.67	79.00	89.34
1	HTLG-57VS	quenched	1	17	F74	12	6.66	5.36	7.1	48.2	56.6	20.00	11.10	8.93	11.83	80.33	94.34
1	HTLG-56VS	quenched	1	18	F54	11.9	10.7	8.42	9.68	84.9	74.4	19.83	17.83	14.03	16.13	141.50	124.00
1	Std Soln		1	19	STD-11-3	3.97	19.4	3.96	10	84.3	50.7	3.97	19.40	3.96	10.00	84.30	50.70
1	Std Soln		2	1	STD-12-1	3.37	21.1	3.69	9.65	79	49	3.37	21.10	3.69	9.65	79.00	49.00
1	HTLG-53VS	quenched	2	2	F41	8.75	9.1	4.58	7.68	51.8	59.6	14.58	15.17	7.63	12.80	86.34	99.34
1	HTLG-60VS	quenched	2	3	F06	10.5	7.06	3.53	6.77	49.4	52.6	17.50	11.77	5.88	11.28	82.33	87.67
1	HTLG-65VS	quenched	2	4	F92	9.73	9.3	3.31	7.88	69.6	64.3	16.22	15.50	5.52	13.13	116.00	107.17
1	HTLG-60VS	ccc	2	5	F18	12.8	5.37	2.12	6.52	43.7	52.7	21.33	8.95	3.53	10.87	72.83	87.84
1	HTLG-61VS	quenched	2	6	F16	11.8	7.88	3.23	7.11	63.6	59.2	19.67	13.13	5.38	11.85	106.00	98.67
1	EA		2	7	F59	<1.00	37.1	<1.00	11.3	104	53.6	8.33	618.33	8.33	188.33	1733.34	893.34
1	HTLG-65VS	ccc	2	8	F26	10.3	7.87	3.89	8.74	62.1	65.2	17.17	13.12	6.48	14.57	103.50	108.67
1	HTLG-56VS	quenched	2	9	F68	9.62	10.6	4.59	9.31	81.3	70.9	16.03	17.67	7.65	15.52	135.50	118.17
1	Std Soln		2	10	STD-12-2	3.36	19.3	3.48	9.71	78.9	48.2	3.36	19.30	3.48	9.71	78.90	48.20
1	HTLG-61VS	ccc	2	11	F46	12.5	7.97	5.93	7.67	60.6	64.4	20.83	13.28	9.88	12.78	101.00	107.34
1	HTLG-64VS	quenched	2	12	F80	9.72	9.56	4.41	8.24	68.5	66.1	16.20	15.93	7.35	13.73	114.17	110.17
1	HTLG-57VS	ccc	2	13	F31	10.5	4.94	1.86	5.7	41.6	50.4	17.50	8.23	3.10	9.50	69.33	84.00
1	HTLG-57VS	quenched	2	14	F83	11.9	6.88	5.07	6.99	45.8	56.6	19.83	11.47	8.45	11.65	76.33	94.34
1	HTLG-53VS	ccc	2	15	F67	13.7	7.18	3.55	7.77	49.2	62.1	22.83	11.97	5.92	12.95	82.00	103.50
1	HTLG-56VS	ccc	2	16	F15	9.48	21.4	7.11	21.8	117	116	15.80	35.67	11.85	36.33	195.00	193.34
1	HTLG-64VS	ccc	2	17	F73	28.8	58	17.3	48	198	173	48.00	96.67	28.83	80.00	330.01	288.34
1	Std Soln		2	18	STD-12-3	3.35	20.3	3.75	9.83	78.5	49.7	3.35	20.30	3.75	9.83	78.50	49.70
1	Std Soln		3	1	STD-13-1	3.77	20.6	3.58	9.68	81	48.6	3.77	20.60	3.58	9.68	81.00	48.60
1	HTLG-53VS	quenched	3	2	F56	9.31	9.12	3.39	7.74	53.5	59.1	15.52	15.20	5.65	12.90	89.17	98.50

Table B1. PSAL Measurements of the PCT Solutions for the HTL Study Glasses As Reported (ar) and After the Appropriate Adjustments (in parts per million, ppm)

Set	Glass ID	Heat Treatment	Block	Seq	SRTC-ML ID	Al ar	B ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
1	HTLG-64VS	ccc	3	3	F64	12.1	55.9	15.9	46.4	198	167	20.17	93.17	26.50	77.33	330.01	278.34
1	HTLG-57VS	ccc	3	4	F03	10.6	5.65	1.62	5.56	37.2	48.5	17.67	9.42	2.70	9.27	62.00	80.83
1	HTLG-64VS	quenched	3	5	F21	10.2	9.65	3.73	8.13	68.4	63.9	17.00	16.08	6.22	13.55	114.00	106.50
1	HTLG-60VS	quenched	3	6	F40	10.9	7.09	3.69	6.88	46.9	53.8	18.17	11.82	6.15	11.47	78.17	89.67
1	HTLG-60VS	ccc	3	7	F47	13	5.43	2.37	6.34	41.5	52.4	21.67	9.05	3.95	10.57	69.17	87.34
1	HTLG-56VS	quenched	3	8	F61	9.62	10.7	4.43	9.41	79.8	70.1	16.03	17.83	7.38	15.68	133.00	116.84
1	EA		3	9	F42	<1.00	37.6	<1.00	11.3	102	53.8	8.33	626.67	8.33	188.33	1700.00	896.67
1	Std Soln		3	10	STD-13-2	3.77	19.8	3.62	9.8	80.8	49	3.77	19.80	3.62	9.80	80.80	49.00
1	HTLG-61VS	quenched	3	11	F49	12.5	8.92	3.58	7.25	66	62.1	20.83	14.87	5.97	12.08	110.00	103.50
1	HTLG-56VS	ccc	3	12	F43	9.87	21.49	7.5	21.5	118	113	16.45	35.82	12.50	35.83	196.67	188.34
1	HTLG-65VS	quenched	3	13	F07	10.4	9.69	3.78	8	68.9	66.7	17.33	16.15	6.30	13.33	114.84	111.17
1	HTLG-57VS	quenched	3	14	F09	11.6	6.97	4.35	6.83	45.9	54.9	19.33	11.62	7.25	11.38	76.50	91.50
1	HTLG-65VS	ccc	3	15	F19	10.5	7.72	3.22	8.94	65.6	66.2	17.50	12.87	5.37	14.90	109.34	110.34
1	HTLG-61VS	ccc	3	16	F50	13	7.27	6.32	7.53	63.3	63.5	21.67	12.12	10.53	12.55	105.50	105.84
1	HTLG-53VS	ccc	3	17	F57	13.9	6.68	3.78	7.37	48.2	59.1	23.17	11.13	6.30	12.28	80.33	98.50
1	blank		3	18	F94	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	0.83	0.83	0.83	0.83	0.83	0.83
1	Std Soln		3	19	STD-13-3	3.91	19.9	3.76	9.88	84.5	49.7	3.91	19.90	3.76	9.88	84.50	49.70
1	Std Soln		4	1	STD-14-1	3.61	20.2	3.88	9.63	80.6	49.1	3.61	20.20	3.88	9.63	80.60	49.10
1	HTLG-58VS	ccc	4	2	F45	10.6	7.87	4.15	7.6	67.8	67.8	17.67	13.12	6.92	12.67	113.00	113.00
1	HTLG-54VS	ccc	4	3	F10	12.6	34.5	15.4	21.5	137	123	21.00	57.50	25.67	35.83	228.34	205.00
1	HTLG-63VS	ccc	4	4	F89	11.9	5.93	3	6.25	45.8	54.5	19.83	9.88	5.00	10.42	76.33	90.84
1	HTLG-59VS	ccc	4	5	F25	15.4	15.4	5.59	16.6	76	82.3	25.67	25.67	9.32	27.67	126.67	137.17
1	HTLG-58VS	quenched	4	6	F88	9.25	10.4	4.27	8.27	85.5	69.8	15.42	17.33	7.12	13.78	142.50	116.34
1	HTLG-66VS	quenched	4	7	F01	10.7	8.13	3.68	7.14	66	58.9	17.83	13.55	6.13	11.90	110.00	98.17
1	HTLG-62VS	quenched	4	8	F91	9.89	8.75	3.89	7.48	64	61.9	16.48	14.58	6.48	12.47	106.67	103.17
1	HTLG-59VS	quenched	4	9	F75	8.49	10.1	4.53	8.47	63.7	64.1	14.15	16.83	7.55	14.12	106.17	106.84
1	Std Soln		4	10	STD-14-2	3.5	20.3	4.08	9.81	83.1	50.2	3.50	20.30	4.08	9.81	83.10	50.20
1	HTLG-62VS	ccc	4	11	F84	8.17	20.6	4.39	17.7	104	105	13.62	34.33	7.32	29.50	173.34	175.00
1	ARM-1		4	12	F58	2.43	10.1	<1.00	7.97	24	36	4.05	16.83	0.83	13.28	40.00	60.00
1	HTLG-63VS	quenched	4	13	F63	11.3	8.21	5.08	7.39	54.2	60.4	18.83	13.68	8.47	12.32	90.34	100.67
1	HTLG-55VS	ccc	4	14	F08	9.88	55.8	8.19	43.7	195	165	16.47	93.00	13.65	72.83	325.01	275.01
1	HTLG-66VS	ccc	4	15	F52	11.7	7.38	3.33	8.5	62.9	61.9	19.50	12.30	5.55	14.17	104.84	103.17
1	HTLG-55VS	quenched	4	16	F20	11.8	8.31	3.29	7.13	65.8	58.5	19.67	13.85	5.48	11.88	109.67	97.50
1	HTLG-54VS	quenched	4	17	F05	10.7	10.9	5.01	8.63	82	72.7	17.83	18.17	8.35	14.38	136.67	121.17
1	blank		4	18	F93	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	0.83	0.83	0.83	0.83	0.83	0.83
1	Std Soln		4	19	STD-14-3	3.45	20.6	4.24	9.86	82.2	51.5	3.45	20.60	4.24	9.86	82.20	51.50
1	Std Soln		5	1	STD-15-1	3.86	21	3.8	9.91	86.3	50.3	3.86	21.00	3.80	9.91	86.30	50.30
1	HTLG-54VS	ccc	5	2	F02	13.1	34.6	14.1	21.7	141	106	21.83	57.67	23.50	36.17	235.00	176.67
1	HTLG-62VS	ccc	5	3	F27	8.05	20	3.9	17.11	101	99	13.42	33.33	6.50	28.52	168.34	165.00

Table B1. PSAL Measurements of the PCT Solutions for the HTL Study Glasses As Reported (ar) and After the Appropriate Adjustments (in parts per million, ppm)

Set	Glass ID	Heat Treatment	Block	Seq	SRTC-ML ID	Al ar	B ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
1	HTLG-54VS	quenched	5	4	F70	9.78	10.9	5.13	8.56	81	71.2	16.30	18.17	8.55	14.27	135.00	118.67
1	HTLG-55VS	quenched	5	5	F79	11.4	8.55	3.09	7.18	66.5	57.3	19.00	14.25	5.15	11.97	110.84	95.50
1	HTLG-59VS	ccc	5	6	F30	15.6	15.2	5.17	16.5	74.6	80	26.00	25.33	8.62	27.50	124.34	133.34
1	HTLG-62VS	quenched	5	7	F51	10.5	9.65	2.67	8	69.4	64.3	17.50	16.08	4.45	13.33	115.67	107.17
1	HTLG-59VS	quenched	5	8	F55	8.33	9.26	3.51	8.22	58.8	59.6	13.88	15.43	5.85	13.70	98.00	99.34
1	HTLG-58VS	ccc	5	9	F38	10.4	7.1	3.76	7.41	70.3	64.3	17.33	11.83	6.27	12.35	117.17	107.17
1	Std Soln		5	10	STD-15-2	3.93	19.8	3.56	9.69	85.3	48.4	3.93	19.80	3.56	9.69	85.30	48.40
1	HTLG-63VS	ccc	5	11	F29	12.9	6.25	2.65	6.53	49.2	55.8	21.50	10.42	4.42	10.88	82.00	93.00
1	HTLG-63VS	quenched	5	12	F87	11	8.06	4.16	7.26	56.1	56.5	18.33	13.43	6.93	12.10	93.50	94.17
1	HTLG-66VS	ccc	5	13	F48	11.4	7.3	1.85	8.74	61.8	58.7	19.00	12.17	3.08	14.57	103.00	97.84
1	HTLG-55VS	ccc	5	14	F72	10.4	54.4	7.72	43.9	202	157	17.33	90.67	12.87	73.17	336.67	261.67
1	HTLG-66VS	quenched	5	15	F78	10.6	8.31	2.93	7.08	64.2	56	17.67	13.85	4.88	11.80	107.00	93.34
1	ARM-1		5	16	F66	2.51	9.97	<1.00	7.98	22	35.4	4.18	16.62	0.83	13.30	36.67	59.00
1	HTLG-58VS	quenched	5	17	F44	9.42	10.2	3.59	8.16	79.3	67.5	15.70	17.00	5.98	13.60	132.17	112.50
1	Std Soln		5	18	STD-15-3	3.8	19.3	3.52	9.62	83	47.6	3.80	19.30	3.52	9.62	83.00	47.60
1	Std Soln		6	1	STD-16-1	3.74	20.8	3.39	9.7	80.2	50.2	3.74	20.80	3.39	9.70	80.20	50.20
1	HTLG-66VS	ccc	6	2	F62	11.3	7.32	1.58	8.74	58.4	61.7	18.83	12.20	2.63	14.57	97.34	102.84
1	HTLG-63VS	ccc	6	3	F71	12.5	6.08	2.4	6.49	61.2	57.5	20.83	10.13	4.00	10.82	102.00	95.84
1	ARM-1		6	4	F76	2.43	10.7	<1.00	8.33	21.9	37	4.05	17.83	0.83	13.88	36.50	61.67
1	HTLG-62VS	quenched	6	5	F24	10.2	9.49	2.1	7.95	67.8	65.7	17.00	15.82	3.50	13.25	113.00	109.50
1	HTLG-62VS	ccc	6	6	F22	7.83	18.5	3.14	16.6	97.5	96.8	13.05	30.83	5.23	27.67	162.50	161.34
1	HTLG-63VS	quenched	6	7	F53	11	8.22	4.06	7.22	52.6	58.3	18.33	13.70	6.77	12.03	87.67	97.17
1	HTLG-66VS	quenched	6	8	F60	10.6	7.98	2.77	7.04	60.8	58.4	17.67	13.30	4.62	11.73	101.34	97.34
1	HTLG-54VS	ccc	6	9	F69	13.1	34.1	14.6	21.4	138	106	21.83	56.83	24.33	35.67	230.00	176.67
1	Std Soln		6	10	STD-16-2	3.65	19.2	3.23	9.46	78.9	48.8	3.65	19.20	3.23	9.46	78.90	48.80
1	HTLG-55VS	ccc	6	11	F32	10.5	57.3	7.8	44.7	199	166	17.50	95.50	13.00	74.50	331.67	276.67
1	HTLG-59VS	quenched	6	12	F13	8.83	9.62	3.93	8.21	58.4	62.1	14.72	16.03	6.55	13.68	97.34	103.50
1	HTLG-58VS	quenched	6	13	F77	9.22	10.5	3.62	8.25	75.9	71	15.37	17.50	6.03	13.75	126.50	118.34
1	HTLG-58VS	ccc	6	14	F39	10.4	6.84	3.2	7.31	67.4	64.8	17.33	11.40	5.33	12.18	112.34	108.00
1	HTLG-54VS	quenched	6	15	F86	8.36	9.9	3.51	7.86	74.3	66.6	13.93	16.50	5.85	13.10	123.84	111.00
1	blank		6	16	F34	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	0.83	0.83	0.83	0.83	0.83	0.83
1	HTLG-55VS	quenched	6	17	F04	11.6	7.94	2.85	7.1	67.3	57.3	19.33	13.23	4.75	11.83	112.17	95.50
1	HTLG-59VS	ccc	6	18	F11	15.7	14.8	4.84	16.2	73.6	81.1	26.17	24.67	8.07	27.00	122.67	135.17
1	Std Soln		6	19	STD-16-3	3.74	19.4	3.27	9.56	80.6	49.1	3.74	19.40	3.27	9.56	80.60	49.10
2	Std Soln		1	1	STD-21-1	4.08	21.5	4.19	10.2	79.5	51.2	4.08	21.50	4.19	10.20	79.50	51.20
2	HTLG-79VS	quenched	1	2	G07	11.3	11.3	4.2	8.95	81.7	70	18.83	18.83	7.00	14.92	136.17	116.67
2	HTLG-74VS	ccc	1	3	G31	12	7.4	3.59	7.03	60.8	57.1	20.00	12.33	5.98	11.72	101.34	95.17
2	blank		1	4	G23	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	0.83	0.83	0.83	0.83	0.83	0.83
2	HTLG-74VS	quenched	1	5	G17	12.6	8.8	3.66	7.36	67.8	58.9	21.00	14.67	6.10	12.27	113.00	98.17

Table B1. PSAL Measurements of the PCT Solutions for the HTL Study Glasses As Reported (ar) and After the Appropriate Adjustments (in parts per million, ppm)

Set	Glass ID	Heat Treatment	Block	Seq	SRTC-ML ID	Al ar	B ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
2	HTLG-73VS	ccc	1	6	G62	10.1	31.5	7.37	31.2	140	143	16.83	52.50	12.28	52.00	233.34	238.34
2	EA		1	7	G73	<1.00	39.8	<1.00	11.9	101	56.1	8.33	663.33	8.33	198.33	1683.34	935.00
2	HTLG-79VS	ccc	1	8	G44	11.6	11.2	3.56	10.9	77.3	71.6	19.33	18.67	5.93	18.17	128.84	119.34
2	HTLG-72VS	quenched	1	9	G64	13.1	8.61	6.41	7.25	57.8	59.3	21.83	14.35	10.68	12.08	96.34	98.84
2	Std Soln		1	10	STD-21-2	4.07	20.9	4.11	10.3	81.3	51.6	4.07	20.90	4.11	10.30	81.30	51.60
2	HTLG-72VS	ccc	1	11	G16	10.7	6.12	1.59	5.52	46	49.9	17.83	10.20	2.65	9.20	76.67	83.17
2	HTLG-71VS	quenched	1	12	G29	12.2	9.78	4.16	7.9	71.5	62.4	20.33	16.30	6.93	13.17	119.17	104.00
2	HTLG-70VS	quenched	1	13	G66	10.9	11.9	4.11	9.26	81.7	73.4	18.17	19.83	6.85	15.43	136.17	122.34
2	HTLG-70VS	ccc	1	14	G35	11.7	25.1	6.69	19.1	106	102	19.50	41.83	11.15	31.83	176.67	170.00
2	HTLG-71VS	ccc	1	15	G28	4.5	68.9	1.5	50.3	315	225	7.50	114.84	2.50	83.84	525.01	375.01
2	HTLG-73VS	quenched	1	16	G09	11.4	11.6	2.4	8.61	79.8	66.6	19.00	19.33	4.00	14.35	133.00	111.00
2	HTLG-75VS	quenched	1	17	G04	11.3	10.2	3.86	7.67	72.4	64	18.83	17.00	6.43	12.78	120.67	106.67
2	HTLG-75VS	ccc	1	18	G71	11	6.91	2.51	6.28	61	58.4	18.33	11.52	4.18	10.47	101.67	97.34
2	Std Soln		1	19	STD-21-3	4.21	21.6	4.36	10.5	83.5	52.9	4.21	21.60	4.36	10.50	83.50	52.90
2	Std Soln		2	1	STD-22-1	4.18	21.6	4.3	10.3	83.6	50.5	4.18	21.60	4.30	10.30	83.60	50.50
2	HTLG-70VS	ccc	2	2	G81	11.6	25	6.6	19	107	98	19.33	41.67	11.00	31.67	178.34	163.34
2	HTLG-72VS	quenched	2	3	G80	13.1	8.57	6.21	7.28	58.9	57.6	21.83	14.28	10.35	12.13	98.17	96.00
2	HTLG-73VS	ccc	2	4	G53	10.1	31.3	6.65	31.4	147	138	16.83	52.17	11.08	52.33	245.00	230.00
2	EA		2	5	G01	<1.00	38.2	<1.00	12	102	54.2	8.33	636.67	8.33	200.00	1700.00	903.34
2	HTLG-79VS	ccc	2	6	G30	11.8	10.9	3.58	10.8	80.4	67.7	19.67	18.17	5.97	18.00	134.00	112.84
2	HTLG-71VS	ccc	2	7	G48	4.31	66.7	1.28	49.1	313	227	7.18	111.17	2.13	81.83	521.68	378.34
2	HTLG-73VS	quenched	2	8	G85	11	10.2	3.44	8.04	73.7	59.6	18.33	17.00	5.73	13.40	122.84	99.34
2	HTLG-79VS	quenched	2	9	G43	11.1	11	3.94	8.54	82.6	63.1	18.50	18.33	6.57	14.23	137.67	105.17
2	Std Soln		2	10	STD-22-2	4.18	20.4	4.24	10.2	84.6	49.2	4.18	20.40	4.24	10.20	84.60	49.20
2	HTLG-74VS	quenched	2	11	G51	12.1	8.42	3.51	7.13	68.8	52.9	20.17	14.03	5.85	11.88	114.67	88.17
2	HTLG-74VS	ccc	2	12	G68	12.4	7.39	3.62	7.25	63.3	56.1	20.67	12.32	6.03	12.08	105.50	93.50
2	HTLG-72VS	ccc	2	13	G82	10.8	5.48	1.79	5.59	47.3	48.5	18.00	9.13	2.98	9.32	78.83	80.83
2	HTLG-71VS	quenched	2	14	G03	12.3	9.46	4.13	8.01	74.6	60.8	20.50	15.77	6.88	13.35	124.34	101.34
2	HTLG-75VS	ccc	2	15	G50	11.2	6.53	2.25	6.65	65.2	57.8	18.67	10.88	3.75	11.08	108.67	96.34
2	HTLG-70VS	quenched	2	16	G61	10.1	10.1	3.89	8.53	76.9	63.3	16.83	16.83	6.48	14.22	128.17	105.50
2	HTLG-75VS	quenched	2	17	G67	11.4	9.18	3.74	7.73	76.9	60.1	19.00	15.30	6.23	12.88	128.17	100.17
2	Std Soln		2	18	STD-22-3	4.12	19.4	3.94	10	84.7	46.9	4.12	19.40	3.94	10.00	84.70	46.90
2	Std Soln		3	1	STD-23-1	4.02	20.7	4.2	10.1	81.1	49.4	4.02	20.70	4.20	10.10	81.10	49.40
2	HTLG-79VS	ccc	3	2	G22	11.6	11.4	3.71	10.9	76.8	71	19.33	19.00	6.18	18.17	128.00	118.34
2	HTLG-70VS	ccc	3	3	G83	11.6	24.8	6.4	18.9	107	99.4	19.33	41.33	10.67	31.50	178.34	165.67
2	HTLG-72VS	ccc	3	4	G20	11.3	6.06	2.02	5.82	48.8	51.8	18.83	10.10	3.37	9.70	81.33	86.34
2	HTLG-70VS	quenched	3	5	G63	9.8	10.2	3.83	8.35	72.1	63.8	16.33	17.00	6.38	13.92	120.17	106.34
2	HTLG-71VS	quenched	3	6	G25	12.6	10.3	3.78	8.42	75.7	65.3	21.00	17.17	6.30	14.03	126.17	108.84
2	EA		3	7	G72	<1.00	37.4	<1.00	11.8	105	53.9	8.33	623.33	8.33	196.67	1750.00	898.34

Table B1. PSAL Measurements of the PCT Solutions for the HTL Study Glasses As Reported (ar) and After the Appropriate Adjustments (in parts per million, ppm)

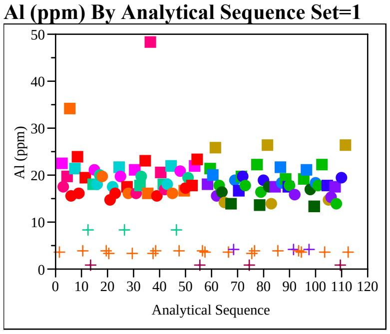
Set	Glass ID	Heat Treatment	Block	Seq	SRTC-ML ID	Al ar	B ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
2	HTLG-75VS	ccc	3	8	G54	11	6.65	2.52	6.47	63.6	57.9	18.33	11.08	4.20	10.78	106.00	96.50
2	HTLG-72VS	quenched	3	9	G15	13	8.05	6.31	7.21	59.8	57.6	21.67	13.42	10.52	12.02	99.67	96.00
2	Std Soln		3	10	STD-23-2	3.99	19.6	4.18	9.94	81.2	49	3.99	19.60	4.18	9.94	81.20	49.00
2	HTLG-75VS	quenched	3	11	G45	10.9	9.54	3.41	7.62	72.9	61.8	18.17	15.90	5.68	12.70	121.50	103.00
2	HTLG-74VS	ccc	3	12	G46	11.6	7.02	3.74	6.97	59.2	56.2	19.33	11.70	6.23	11.62	98.67	93.67
2	HTLG-79VS	quenched	3	13	G58	11.2	10.6	3.74	8.69	83.4	65.6	18.67	17.67	6.23	14.48	139.00	109.34
2	HTLG-73VS	quenched	3	14	G13	11.2	9.48	3.47	8.19	75.1	62.2	18.67	15.80	5.78	13.65	125.17	103.67
2	HTLG-74VS	quenched	3	15	G57	13	8.6	3.69	7.56	73.9	59.7	21.67	14.33	6.15	12.60	123.17	99.50
2	HTLG-73VS	ccc	3	16	G49	10.3	31.1	6.78	31.9	152	145	17.17	51.83	11.30	53.17	253.34	241.67
2	HTLG-71VS	ccc	3	17	G76	4.11	64.6	1.06	49	301	199	6.85	107.67	1.77	81.67	501.68	331.67
2	Std Soln		3	18	STD-23-3	4.11	20.7	4.26	10.3	86	50.3	4.11	20.70	4.26	10.30	86.00	50.30
2	Std Soln		4	1	STD-24-1	3.93	19.6	4.52	9.98	78.4	49.5	3.93	19.60	4.52	9.98	78.40	49.50
2	HTLG-68VS	quenched	4	2	G38	11.3	8.06	5.01	7.1	49.8	57.9	18.83	13.43	8.35	11.83	83.00	96.50
2	HTLG-77VS	ccc	4	3	G78	10.6	5.27	2.54	5.6	43.9	48.6	17.67	8.78	4.23	9.33	73.17	81.00
2	HTLG-69VS	ccc	4	4	G14	12.2	5.88	3.73	6.18	46.3	53.5	20.33	9.80	6.22	10.30	77.17	89.17
2	HTLG-67VS	ccc	4	5	G60	7.05	78.2	3.1	63.2	246	197	11.75	130.34	5.17	105.34	410.01	328.34
2	HTLG-76VS	ccc	4	6	G12	11.8	12.6	3.41	8.94	62.7	60	19.67	21.00	5.68	14.90	104.50	100.00
2	HTLG-68VS	ccc	4	7	G37	12.1	5.76	3.61	5.8	42.7	53.2	20.17	9.60	6.02	9.67	71.17	88.67
2	HTLG-78VS	quenched	4	8	G24	10.9	8.33	6.02	7.52	61.9	58	18.17	13.88	10.03	12.53	103.17	96.67
2	HTLG-69VS	quenched	4	9	G19	9.5	8.17	4.4	7.55	56.5	56.6	15.83	13.62	7.33	12.58	94.17	94.34
2	Std Soln		4	10	STD-14-2	4.1	20	4.77	10.3	83.1	50.7	4.10	20.00	4.77	10.30	83.10	50.70
2	ARM-1		4	11	G36	2.98	10.2	<1.00	8.11	21	35.8	4.97	17.00	0.83	13.52	35.00	59.67
2	HTLG-78VS	ccc	4	12	G77	10.4	6.07	2.41	6.88	52.8	53.6	17.33	10.12	4.02	11.47	88.00	89.34
2	HTLG-67VS	quenched	4	13	G84	10.1	7.8	3.03	7.2	53.2	53.4	16.83	13.00	5.05	12.00	88.67	89.00
2	HTLG-76VS	quenched	4	14	G40	11.4	7.91	4.32	7.16	57.5	54.6	19.00	13.18	7.20	11.93	95.84	91.00
2	HTLG-77VS	quenched	4	15	G52	12.9	7.53	4.83	7.18	57.8	57.9	21.50	12.55	8.05	11.97	96.34	96.50
2	Std Soln		4	16	STD-24-3	4.06	20.2	4.26	10.3	82.5	50.7	4.06	20.20	4.26	10.30	82.50	50.70
2	Std Soln		5	1	STD-25-1	4.03	20.4	4.22	10.1	83.4	49.2	4.03	20.40	4.22	10.10	83.40	49.20
2	HTLG-68VS	quenched	5	2	G02	11.2	8.05	4.46	6.98	49.9	54.3	18.67	13.42	7.43	11.63	83.17	90.50
2	HTLG-69VS	ccc	5	3	G69	11.7	5.89	3.34	5.81	44.6	49.1	19.50	9.82	5.57	9.68	74.33	81.83
2	HTLG-78VS	quenched	5	4	G47	11.2	8.59	5.56	7.65	64	57.6	18.67	14.32	9.27	12.75	106.67	96.00
2	HTLG-68VS	ccc	5	5	G55	12	5.32	3.13	5.64	43.2	50.2	20.00	8.87	5.22	9.40	72.00	83.67
2	ARM-1		5	6	G86	2.96	10.2	<1.00	8.12	22.4	34.8	4.93	17.00	0.83	13.53	37.33	58.00
2	HTLG-76VS	ccc	5	7	G26	12.3	11.9	3.12	9.13	66.8	59.8	20.50	19.83	5.20	15.22	111.34	99.67
2	HTLG-67VS	quenched	5	8	G74	10.3	7.67	2.67	7.15	53.7	52.2	17.17	12.78	4.45	11.92	89.50	87.00
2	HTLG-67VS	ccc	5	9	G10	8.45	73.5	4.55	61.2	246	202	14.08	122.50	7.58	102.00	410.01	336.67
2	Std Soln		5	10	STD-15-2	4.05	20.6	4.28	10.2	82.8	49	4.05	20.60	4.28	10.20	82.80	49.00
2	HTLG-77VS	quenched	5	11	G11	13.3	8.69	4.8	7.32	59.8	58.7	22.17	14.48	8.00	12.20	99.67	97.84
2	HTLG-77VS	ccc	5	12	G59	10.9	5.44	2.22	5.59	45.8	47.7	18.17	9.07	3.70	9.32	76.33	79.50

Table B1. PSAL Measurements of the PCT Solutions for the HTL Study Glasses As Reported (ar) and After the Appropriate Adjustments (in parts per million, ppm)

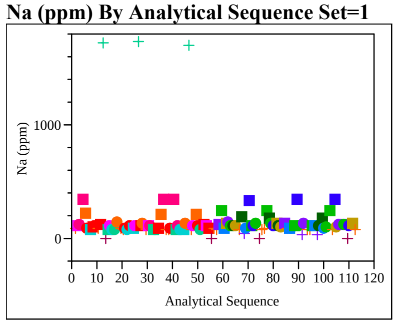
Set	Glass ID	Heat Treatment	Block	Seq	SRTC-ML ID	Al ar	B ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
2	HTLG-76VS	quenched	5	13	G27	11.5	7.81	3.63	7.1	68.3	51.9	19.17	13.02	6.05	11.83	113.84	86.50
2	HTLG-69VS	quenched	5	14	G41	9.56	8.05	3.77	7.45	58.1	54.5	15.93	13.42	6.28	12.42	96.84	90.84
2	HTLG-78VS	ccc	5	15	G65	10.5	5.81	2.29	6.79	55.5	51.4	17.50	9.68	3.82	11.32	92.50	85.67
2	Std Soln		5	16	STD-25-3	4.15	19.5	4.27	10	83.2	48.2	4.15	19.50	4.27	10.00	83.20	48.20
2	Std Soln		6	1	STD-26-1	4.16	21.7	4.55	10.3	81.9	50.8	4.16	21.70	4.55	10.30	81.90	50.80
2	HTLG-67VS	quenched	6	2	G18	9.78	8.3	2.58	6.93	49.9	51	16.30	13.83	4.30	11.55	83.17	85.00
2	HTLG-67VS	ccc	6	3	G32	8.04	75.1	4.21	61.3	239	206	13.40	125.17	7.02	102.17	398.34	343.34
2	blank		6	4	G39	<1.00	1.16	<1.00	<1.00	<1.00	<1.00	0.83	1.93	0.83	0.83	0.83	0.83
2	HTLG-78VS	quenched	6	5	G08	11.3	9.22	4.73	8	67.1	59.7	18.83	15.37	7.88	13.33	111.84	99.50
2	HTLG-68VS	ccc	6	6	G21	11.8	5.68	3.12	5.68	43	50.9	19.67	9.47	5.20	9.47	71.67	84.84
2	HTLG-77VS	quenched	6	7	G42	13.4	7.77	5.84	7.05	58.9	57.4	22.33	12.95	9.73	11.75	98.17	95.67
2	HTLG-69VS	quenched	6	8	G34	9.72	8.43	4.27	7.52	56.4	55.8	16.20	14.05	7.12	12.53	94.00	93.00
2	HTLG-69VS	ccc	6	9	G70	12.6	5.96	3.51	6.19	48.6	51.7	21.00	9.93	5.85	10.32	81.00	86.17
2	Std Soln		6	10	STD-26-2	3.92	20.4	4.59	10.3	82.6	50.1	3.92	20.40	4.59	10.30	82.60	50.10
2	HTLG-77VS	ccc	6	11	G56	11.3	5.84	2.57	5.81	45.8	50.4	18.83	9.73	4.28	9.68	76.33	84.00
2	HTLG-76VS	ccc	6	12	G05	13.4	13.1	4.72	9.71	68.8	65.8	22.33	21.83	7.87	16.18	114.67	109.67
2	ARM-1		6	13	G75	3.05	11.2	<1.00	8.54	22.3	36.8	5.08	18.67	0.83	14.23	37.17	61.33
2	HTLG-76VS	quenched	6	14	G79	11.6	8.36	4.27	7.24	57.5	55.7	19.33	13.93	7.12	12.07	95.84	92.84
2	HTLG-68VS	quenched	6	15	G33	11.7	7.6	5.23	7.1	53.3	56.1	19.50	12.67	8.72	11.83	88.84	93.50
2	HTLG-78VS	ccc	6	16	G06	10.1	5.58	3.08	6.51	51.2	50.2	16.83	9.30	5.13	10.85	85.34	83.67
2	Std Soln		6	17	STD-26-3	3.93	20.5	4.51	10.2	82.7	50.2	3.93	20.50	4.51	10.20	82.70	50.20

Exhibit B1. Laboratory PCT Measurements in Analytical Sequence for Quenched Study Glasses with and without EA, ARM, Blanks, and Solution Standards

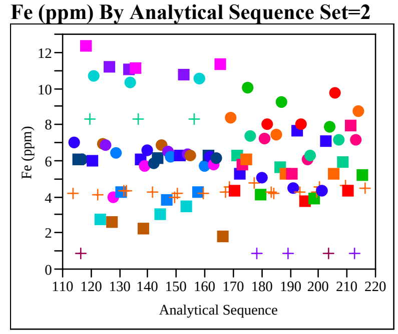
Al (ppm) By Analytical Sequence Set=1



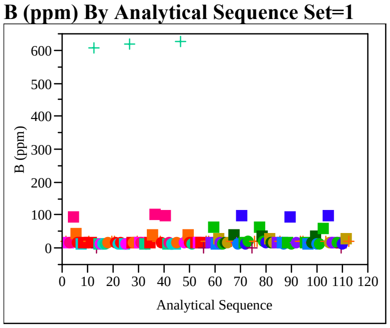
Na (ppm) By Analytical Sequence Set=1



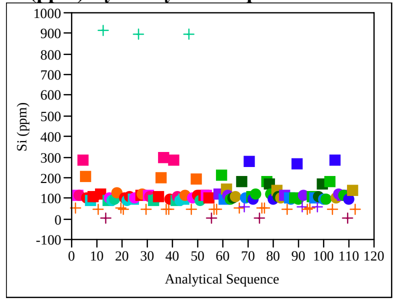
Fe (ppm) By Analytical Sequence Set=2



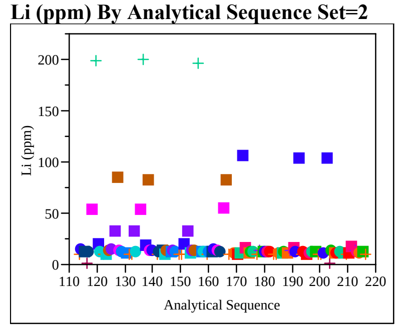
B (ppm) By Analytical Sequence Set=1



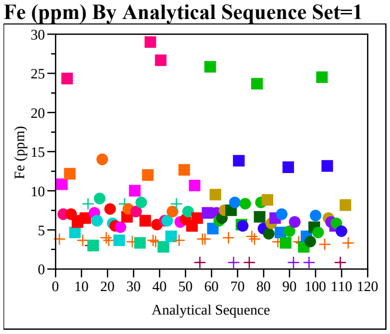
Si (ppm) By Analytical Sequence Set=1



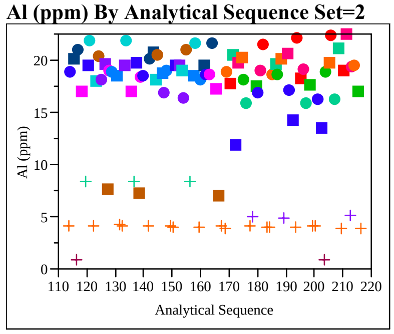
Li (ppm) By Analytical Sequence Set=2



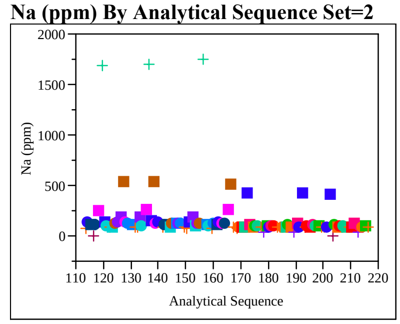
Fe (ppm) By Analytical Sequence Set=1



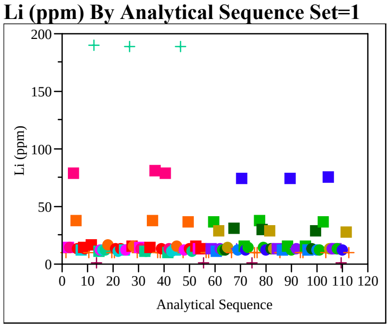
Al (ppm) By Analytical Sequence Set=2



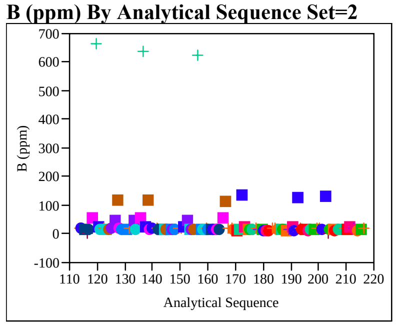
Na (ppm) By Analytical Sequence Set=2



Li (ppm) By Analytical Sequence Set=1



B (ppm) By Analytical Sequence Set=2



Si (ppm) By Analytical Sequence Set=2

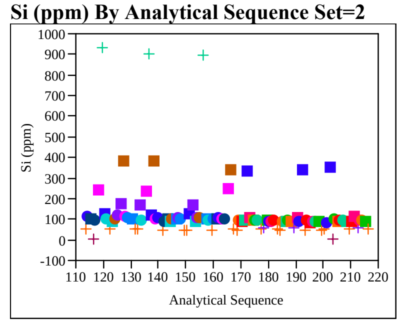
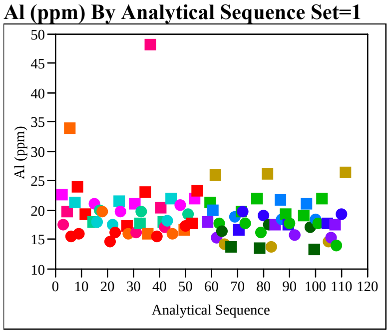
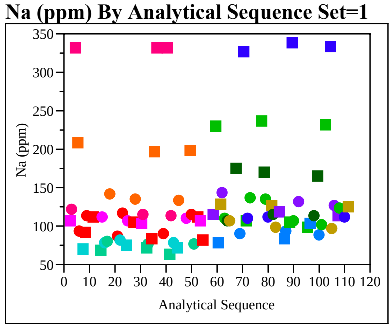


Exhibit B2. Laboratory PCT Measurements in Analytical Sequence for CCC Study Glasses with and without EA, ARM, Blanks, and Solution Standards

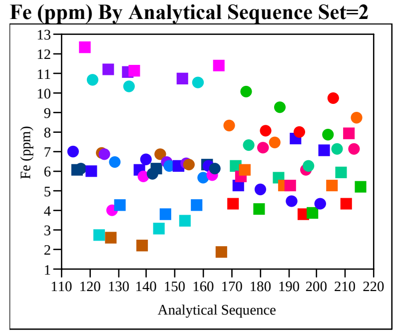
Al (ppm) By Analytical Sequence Set=1



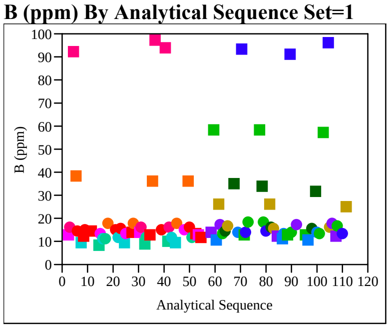
Na (ppm) By Analytical Sequence Set=1



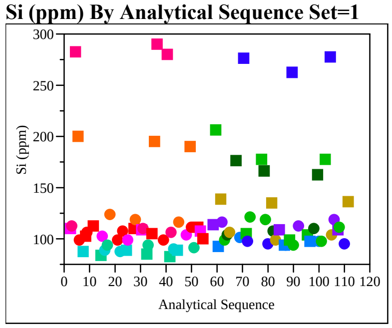
Fe (ppm) By Analytical Sequence Set=2



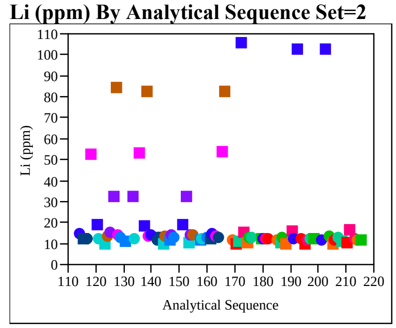
B (ppm) By Analytical Sequence Set=1



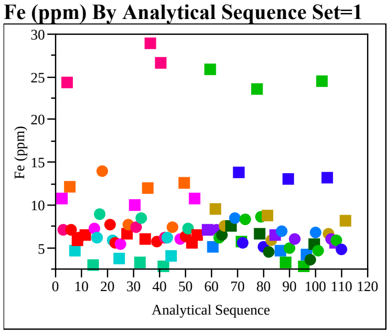
Si (ppm) By Analytical Sequence Set=1



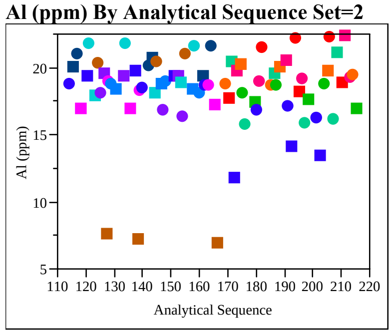
Li (ppm) By Analytical Sequence Set=2



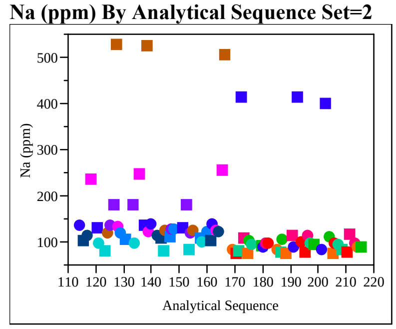
Fe (ppm) By Analytical Sequence Set=1



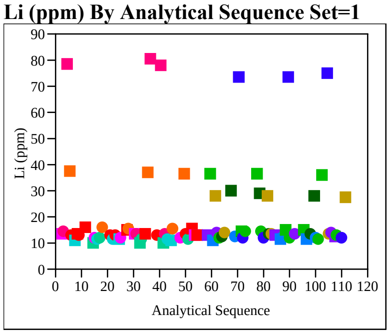
Al (ppm) By Analytical Sequence Set=2



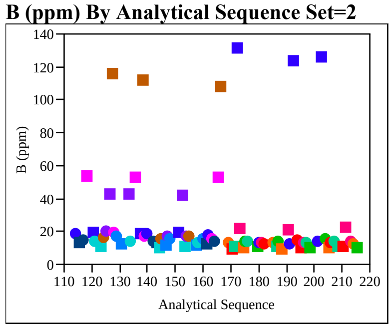
Na (ppm) By Analytical Sequence Set=2



Li (ppm) By Analytical Sequence Set=1



B (ppm) By Analytical Sequence Set=2



Si (ppm) By Analytical Sequence Set=2

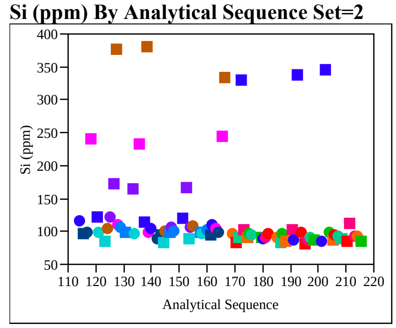
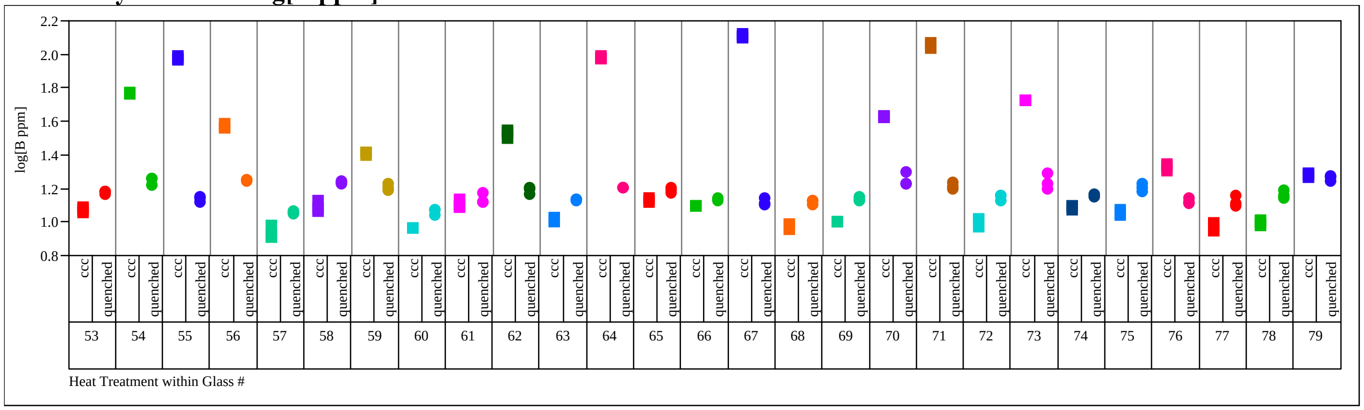


Exhibit B3. PSAL PCT Measurements byHeat Treatment by Study Glass

Variability Chart for log[B ppm]



Variability Chart for log[Li ppm]

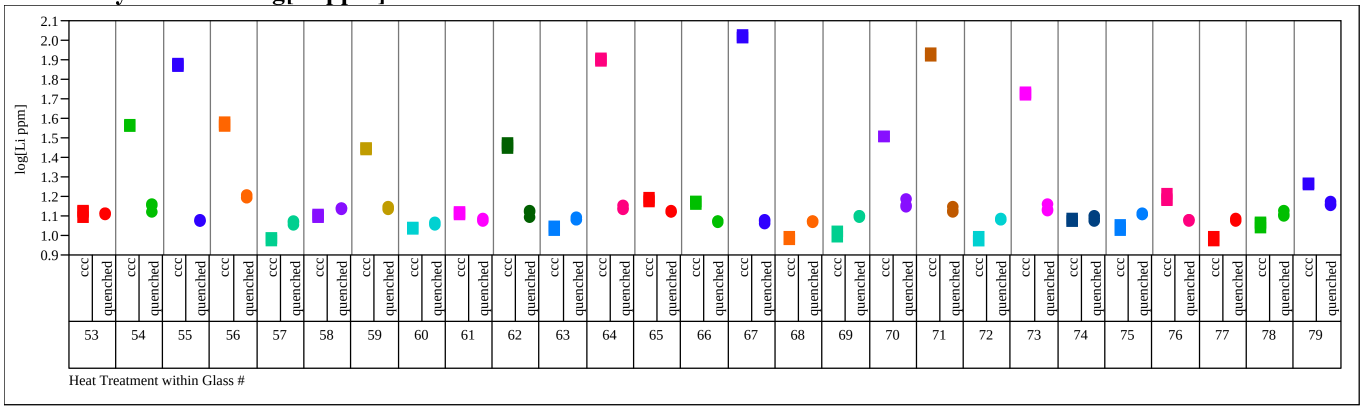
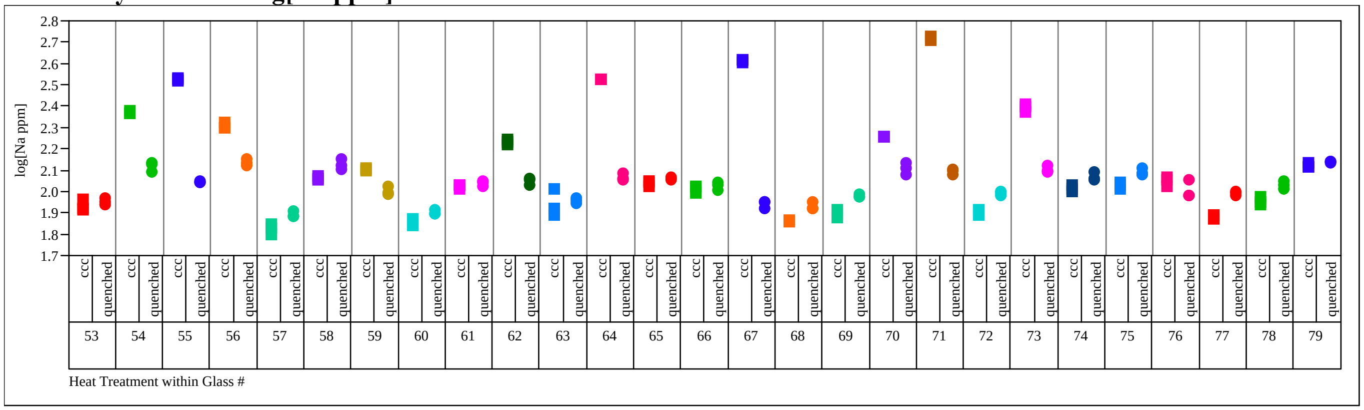


Exhibit B3. PSAL PCT Measurements byHeat Treatment by Study Glass

Variability Chart for log[Na ppm]



Variability Chart for log[Si ppm]

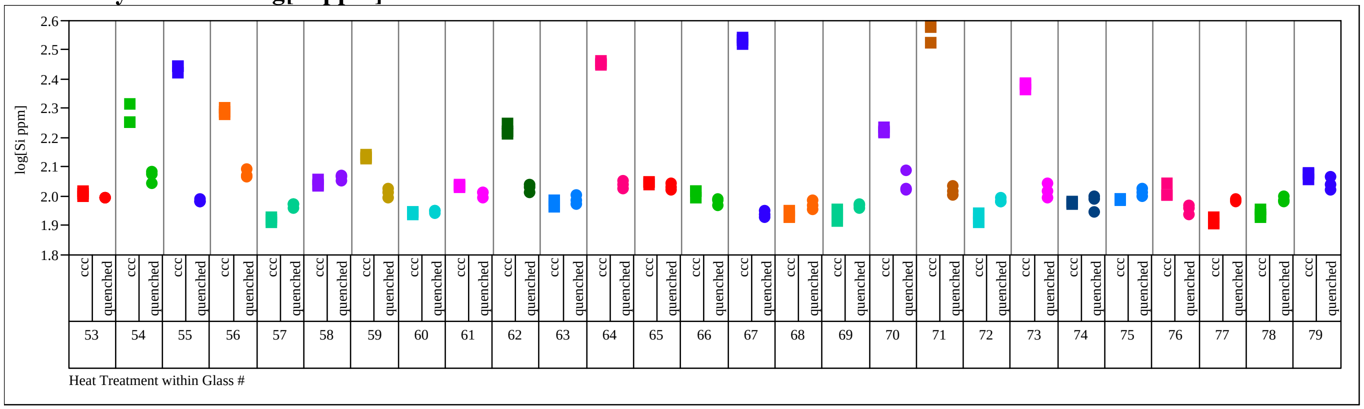
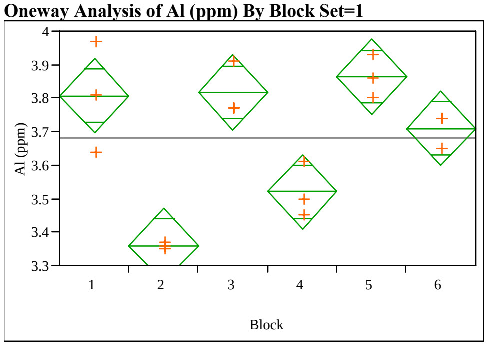


Exhibit B4. Measurements of the Multi-Element Solution Standard for Each PCT Set and Element by ICP-AES Calibration Block

Oneway Analysis of Al (ppm) By Block Set=1



Oneway Anova
Summary of Fit

Rsquare	0.861656
Adj Rsquare	0.804013
Root Mean Square Error	0.088976
Mean of Response	3.679444
Observations (or Sum Wgts)	18

Analysis of Variance

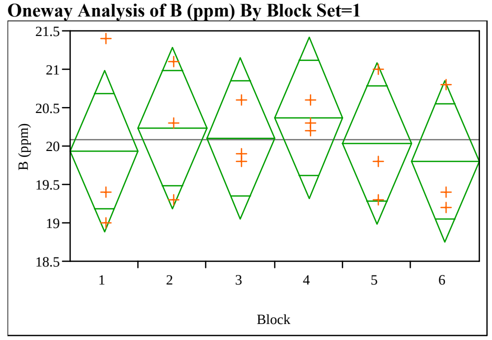
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	0.59169444	0.118339	14.9481	<.0001
Error	12	0.09500000	0.007917		
C. Total	17	0.68669444			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	3.80667	0.05137	3.6947	3.9186
2	3	3.36000	0.05137	3.2481	3.4719
3	3	3.81667	0.05137	3.7047	3.9286
4	3	3.52000	0.05137	3.4081	3.6319
5	3	3.86333	0.05137	3.7514	3.9753
6	3	3.71000	0.05137	3.5981	3.8219

Std Error uses a pooled estimate of error variance

Oneway Analysis of B (ppm) By Block Set=1



Oneway Anova
Summary of Fit

Rsquare	0.068839
Adj Rsquare	-0.31915
Root Mean Square Error	0.838981
Mean of Response	20.07778
Observations (or Sum Wgts)	18

Analysis of Variance

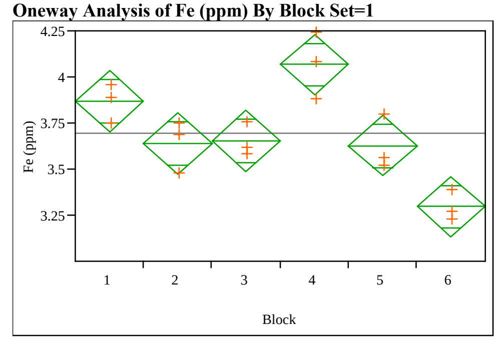
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	0.6244444	0.124889	0.1774	0.9659
Error	12	8.4466667	0.703889		
C. Total	17	9.0711111			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	19.9333	0.48439	18.878	20.989
2	3	20.2333	0.48439	19.178	21.289
3	3	20.1000	0.48439	19.045	21.155
4	3	20.3667	0.48439	19.311	21.422
5	3	20.0333	0.48439	18.978	21.089
6	3	19.8000	0.48439	18.745	20.855

Std Error uses a pooled estimate of error variance

Oneway Analysis of Fe (ppm) By Block Set=1



Oneway Anova
Summary of Fit

Rsquare	0.830344
Adj Rsquare	0.759654
Root Mean Square Error	0.130937
Mean of Response	3.691667
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	1.0069167	0.201383	11.7463	0.0003
Error	12	0.2057333	0.017144		
C. Total	17	1.2126500			

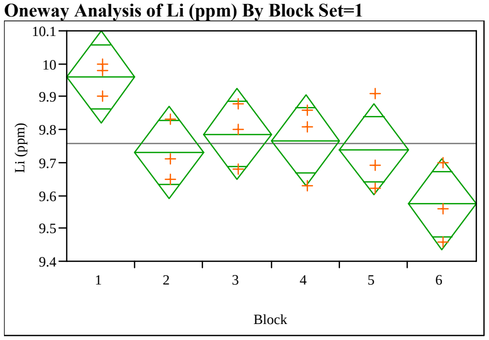
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	3.86667	0.07560	3.7020	4.0314
2	3	3.64000	0.07560	3.4753	3.8047
3	3	3.65333	0.07560	3.4886	3.8180
4	3	4.06667	0.07560	3.9020	4.2314
5	3	3.62667	0.07560	3.4620	3.7914
6	3	3.29667	0.07560	3.1320	3.4614

Std Error uses a pooled estimate of error variance

Exhibit B4. Measurements of the Multi-Element Solution Standard for Each PCT Set and Element by ICP-AES Calibration Block

Oneway Analysis of Li (ppm) By Block Set=1



Oneway Anova
Summary of Fit

Rsquare	0.61112
Adj Rsquare	0.449087
Root Mean Square Error	0.110604
Mean of Response	9.759444
Observations (or Sum Wgts)	18

Analysis of Variance

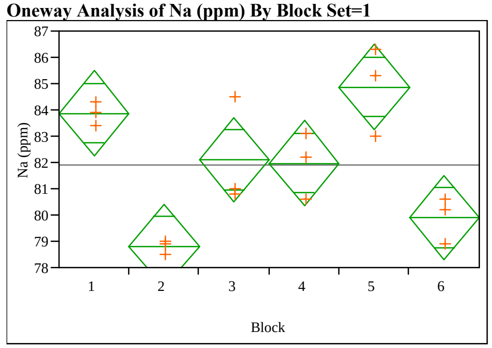
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	0.23069444	0.046139	3.7716	0.0277
Error	12	0.14680000	0.012233		
C. Total	17	0.37749444			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	9.96000	0.06386	9.8209	10.099
2	3	9.73000	0.06386	9.5909	9.869
3	3	9.78667	0.06386	9.6475	9.926
4	3	9.76667	0.06386	9.6275	9.906
5	3	9.74000	0.06386	9.6009	9.879
6	3	9.57333	0.06386	9.4342	9.712

Std Error uses a pooled estimate of error variance

Oneway Analysis of Na (ppm) By Block Set=1



Oneway Anova
Summary of Fit

Rsquare	0.800172
Adj Rsquare	0.716911
Root Mean Square Error	1.281926
Mean of Response	81.91667
Observations (or Sum Wgts)	18

Analysis of Variance

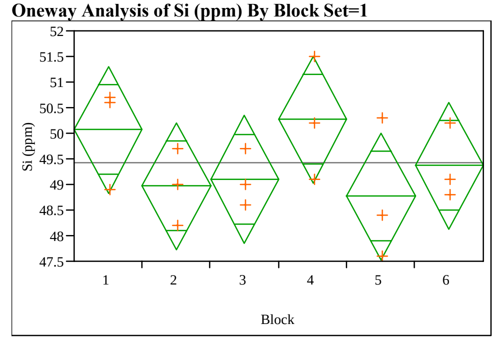
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	78.965000	15.7930	9.6103	0.0007
Error	12	19.720000	1.6433		
C. Total	17	98.685000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	83.8667	0.74012	82.254	85.479
2	3	78.8000	0.74012	77.187	80.413
3	3	82.1000	0.74012	80.487	83.713
4	3	81.9667	0.74012	80.354	83.579
5	3	84.8667	0.74012	83.254	86.479
6	3	79.9000	0.74012	78.287	81.513

Std Error uses a pooled estimate of error variance

Oneway Analysis of Si (ppm) By Block Set=1



Oneway Anova
Summary of Fit

Rsquare	0.326025
Adj Rsquare	0.045202
Root Mean Square Error	0.983757
Mean of Response	49.42222
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	5.617778	1.12356	1.1610	0.3825
Error	12	11.613333	0.96778		
C. Total	17	17.231111			

Means for Oneway Anova

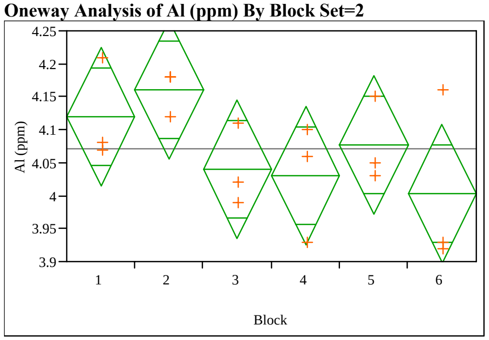
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	50.0667	0.56797	48.829	51.304
2	3	48.9667	0.56797	47.729	50.204
3	3	49.1000	0.56797	47.862	50.338
4	3	50.2667	0.56797	49.029	51.504
5	3	48.7667	0.56797	47.529	50.004
6	3	49.3667	0.56797	48.129	50.604

Std Error uses a pooled estimate of error variance

Exhibit B4. Measurements of the Multi-Element Solution Standard for Each PCT Set and Element by ICP-AES Calibration Block

Fit Y by X Group

Oneway Analysis of Al (ppm) By Block Set=2



Oneway Anova

Summary of Fit

Rsquare	0.38748
Adj Rsquare	0.132263
Root Mean Square Error	0.083333
Mean of Response	4.071667
Observations (or Sum Wgts)	18

Analysis of Variance

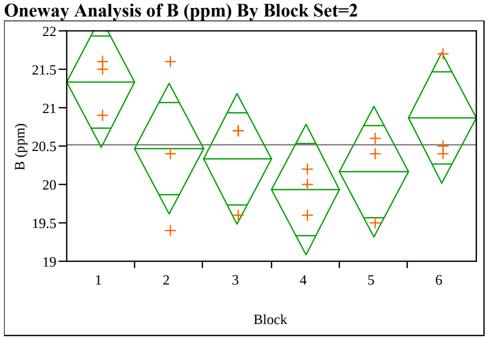
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	0.05271667	0.010543	1.5182	0.2558
Error	12	0.08333333	0.006944		
C. Total	17	0.13605000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	4.12000	0.04811	4.0152	4.2248
2	3	4.16000	0.04811	4.0552	4.2648
3	3	4.04000	0.04811	3.9352	4.1448
4	3	4.03000	0.04811	3.9252	4.1348
5	3	4.07667	0.04811	3.9718	4.1815
6	3	4.00333	0.04811	3.8985	4.1082

Std Error uses a pooled estimate of error variance

Oneway Analysis of B (ppm) By Block Set=2



Oneway Anova

Summary of Fit

Rsquare	0.415368
Adj Rsquare	0.171771
Root Mean Square Error	0.6733
Mean of Response	20.51667
Observations (or Sum Wgts)	18

Analysis of Variance

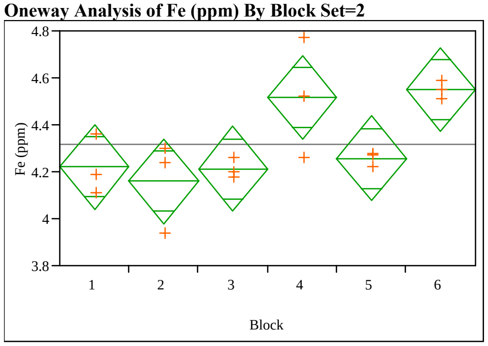
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	3.8650000	0.773000	1.7051	0.2079
Error	12	5.4400000	0.453333		
C. Total	17	9.3050000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	21.3333	0.38873	20.486	22.180
2	3	20.4667	0.38873	19.620	21.314
3	3	20.3333	0.38873	19.486	21.180
4	3	19.9333	0.38873	19.086	20.780
5	3	20.1667	0.38873	19.320	21.014
6	3	20.8667	0.38873	20.020	21.714

Std Error uses a pooled estimate of error variance

Oneway Analysis of Fe (ppm) By Block Set=2



Oneway Anova

Summary of Fit

Rsquare	0.635038
Adj Rsquare	0.48297
Root Mean Square Error	0.14312
Mean of Response	4.319444
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	0.42769444	0.085539	4.1760	0.0198
Error	12	0.24580000	0.020483		
C. Total	17	0.67349444			

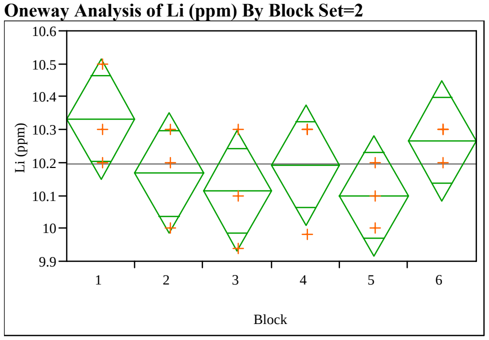
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	4.22000	0.08263	4.0400	4.4000
2	3	4.16000	0.08263	3.9800	4.3400
3	3	4.21333	0.08263	4.0333	4.3934
4	3	4.51667	0.08263	4.3366	4.6967
5	3	4.25667	0.08263	4.0766	4.4367
6	3	4.55000	0.08263	4.3700	4.7300

Std Error uses a pooled estimate of error variance

Exhibit B4. Measurements of the Multi-Element Solution Standard for Each PCT Set and Element by ICP-AES Calibration Block

Oneway Analysis of Li (ppm) By Block Set=2



Oneway Anova
Summary of Fit

Rsquare	0.325603
Adj Rsquare	0.044605
Root Mean Square Error	0.145297
Mean of Response	10.19556
Observations (or Sum Wgts)	18

Analysis of Variance

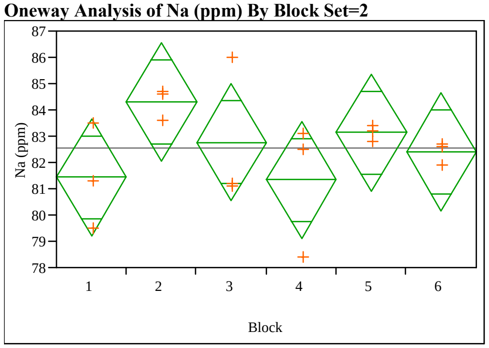
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	0.12231111	0.024462	1.1587	0.3835
Error	12	0.25333333	0.021111		
C. Total	17	0.37564444			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	10.3333	0.08389	10.151	10.516
2	3	10.1667	0.08389	9.984	10.349
3	3	10.1133	0.08389	9.931	10.296
4	3	10.1933	0.08389	10.011	10.376
5	3	10.1000	0.08389	9.917	10.283
6	3	10.2667	0.08389	10.084	10.449

Std Error uses a pooled estimate of error variance

Oneway Analysis of Na (ppm) By Block Set=2



Oneway Anova
Summary of Fit

Rsquare	0.327958
Adj Rsquare	0.04794
Root Mean Square Error	1.782009
Mean of Response	82.56111
Observations (or Sum Wgts)	18

Analysis of Variance

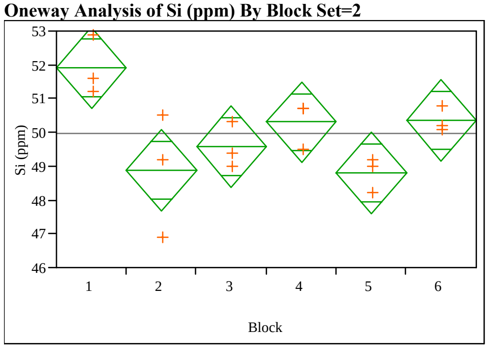
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	18.596111	3.71922	1.1712	0.3781
Error	12	38.106667	3.17556		
C. Total	17	56.702778			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	81.4333	1.0288	79.192	83.675
2	3	84.3000	1.0288	82.058	86.542
3	3	82.7667	1.0288	80.525	85.008
4	3	81.3333	1.0288	79.092	83.575
5	3	83.1333	1.0288	80.892	85.375
6	3	82.4000	1.0288	80.158	84.642

Std Error uses a pooled estimate of error variance

Oneway Analysis of Si (ppm) By Block Set=2



Oneway Anova
Summary of Fit

Rsquare	0.649326
Adj Rsquare	0.503211
Root Mean Square Error	0.953939
Mean of Response	49.96667
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	20.220000	4.04400	4.4440	0.0160
Error	12	10.920000	0.91000		
C. Total	17	31.140000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	51.9000	0.55076	50.700	53.100
2	3	48.8667	0.55076	47.667	50.067
3	3	49.5667	0.55076	48.367	50.767
4	3	50.3000	0.55076	49.100	51.500
5	3	48.8000	0.55076	47.600	50.000
6	3	50.3667	0.55076	49.167	51.567

Std Error uses a pooled estimate of error variance

Exhibit B5. Correlations of Leachate Responses for Each PCT Set

First Set of PCTs

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	0.9794	0.9706	0.9697
log NL[Li(g/L)]	0.9794	1.0000	0.9442	0.9660
log NL[Na (g/L)]	0.9706	0.9442	1.0000	0.9825
log NL[Si (g/L)]	0.9697	0.9660	0.9825	1.0000

Scatterplot Matrix

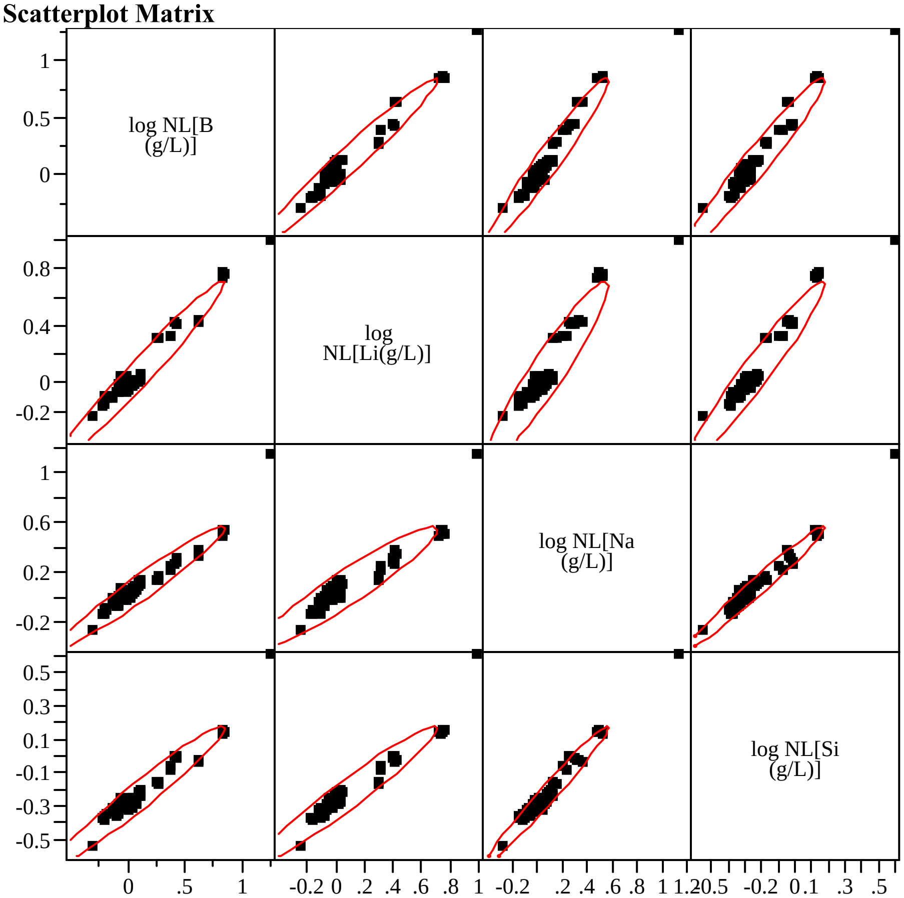


Exhibit B5. Correlations of Leachate Responses for Each PCT Set

Second Set of PCTs

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	0.9890	0.9789	0.9807
log NL[Li(g/L)]	0.9890	1.0000	0.9657	0.9808
log NL[Na (g/L)]	0.9789	0.9657	1.0000	0.9858
log NL[Si (g/L)]	0.9807	0.9808	0.9858	1.0000

Scatterplot Matrix

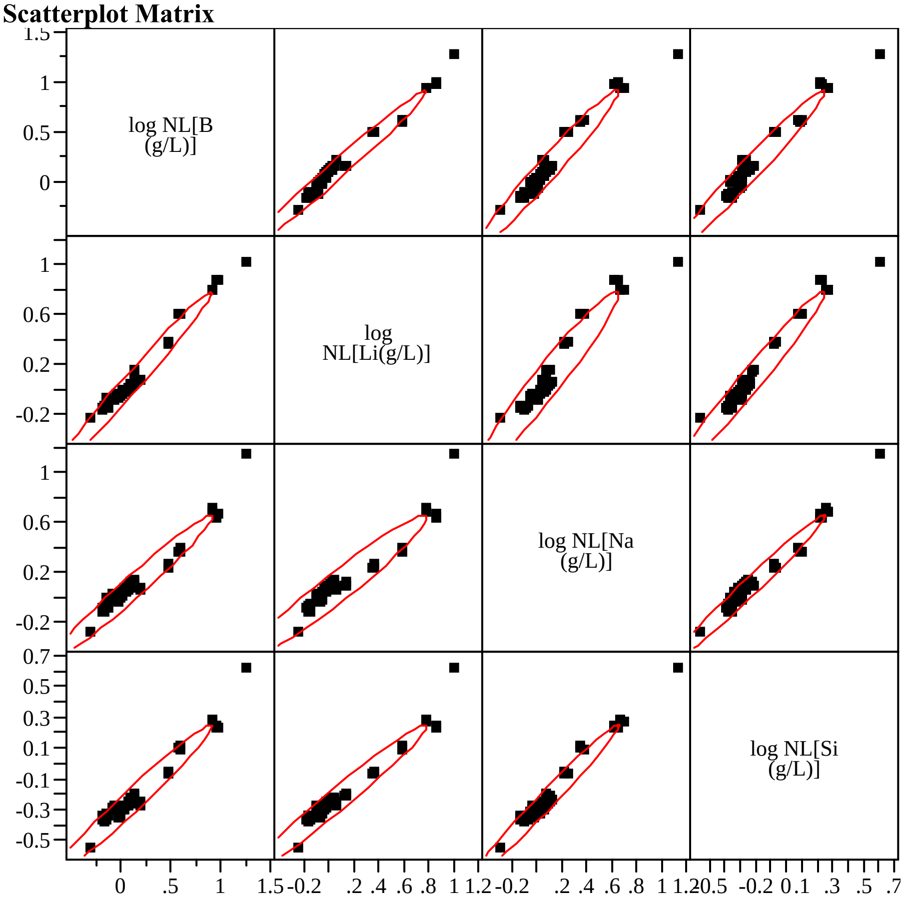
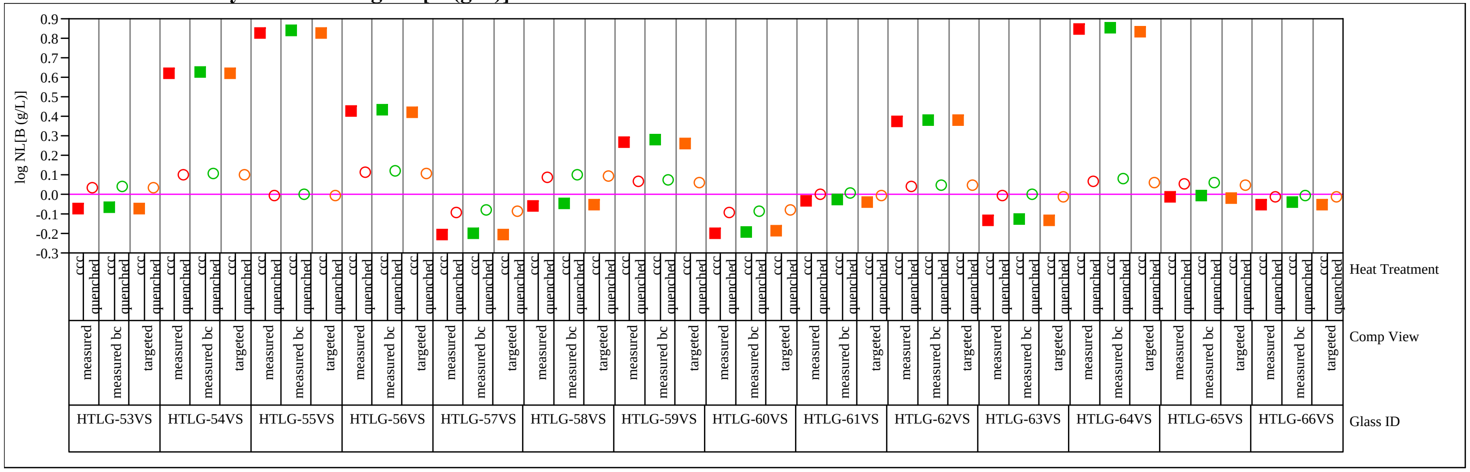


Exhibit B6. PSAL PCT Measurements for Quenched and CCC Versions of Each Study Glass by Glass Series ("P" and "Q")

Series=P — Variability Chart for log NL[B (g/L)]



Series=P — Variability Chart for log NL[Li(g/L)]

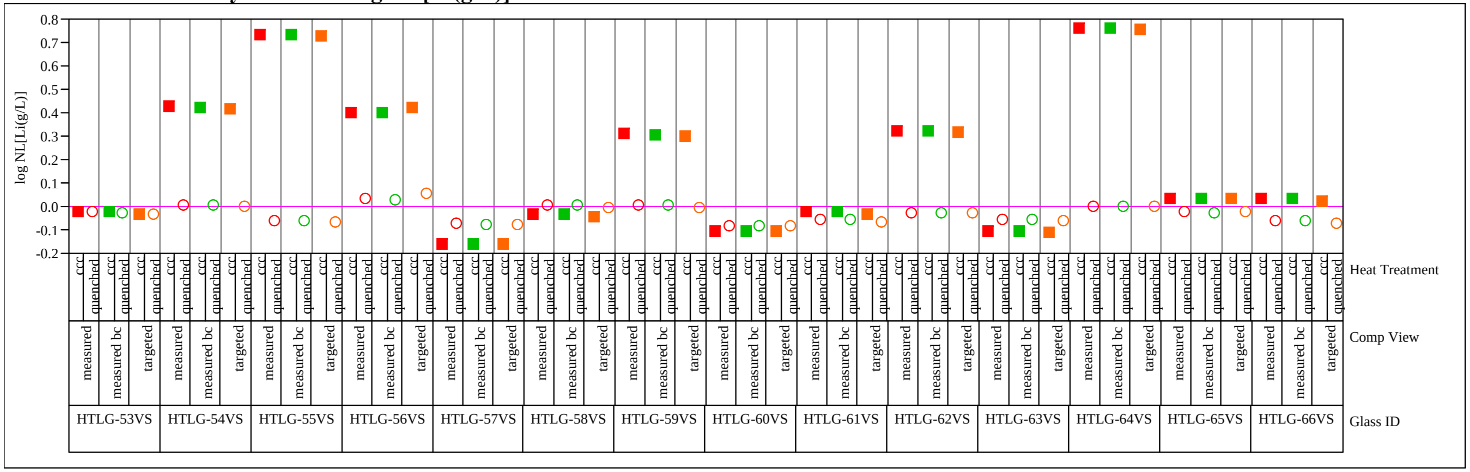
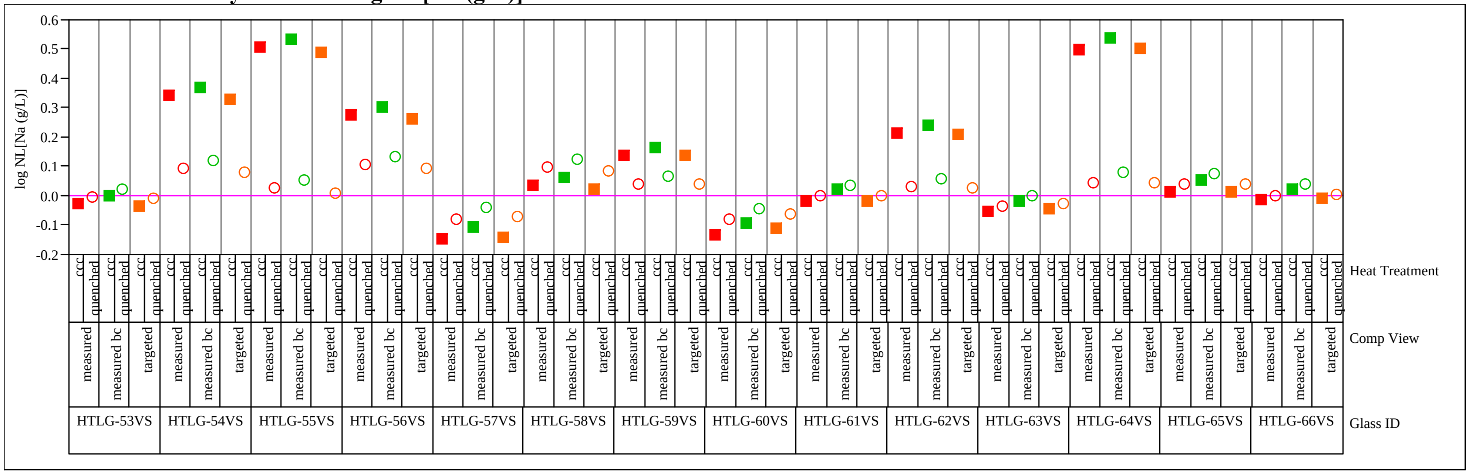


Exhibit B6. PSAL PCT Measurements for Quenched and CCC Versions of Each Study Glass by Glass Series ("P" and "Q")

Series=P — Variability Chart for log NL[Na (g/L)]



Series=P — Variability Chart for log NL[Si (g/L)]

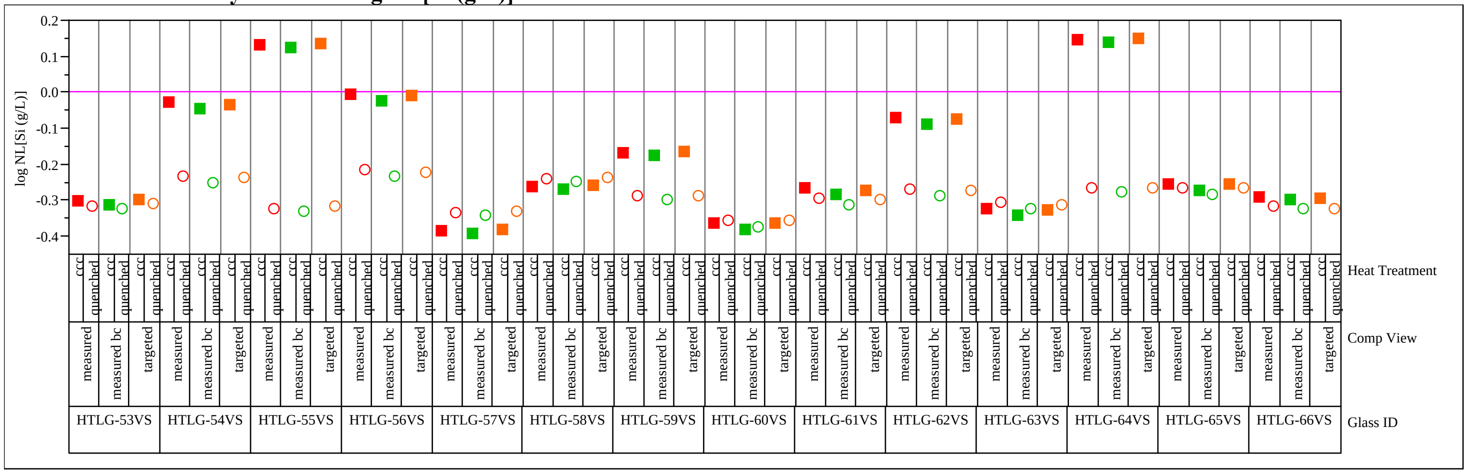
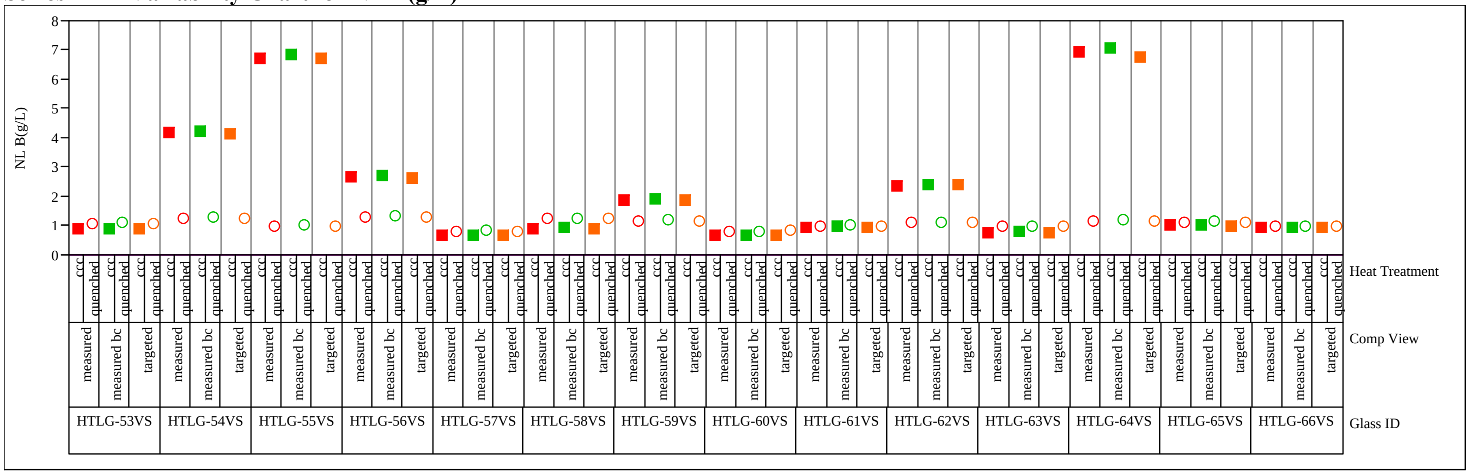


Exhibit B6. PSAL PCT Measurements for Quenched and CCC Versions of Each Study Glass by Glass Series ("P" and "Q")

Series=P — Variability Chart for NL B(g/L)



Series=P — Variability Chart for NL Li (g/L)

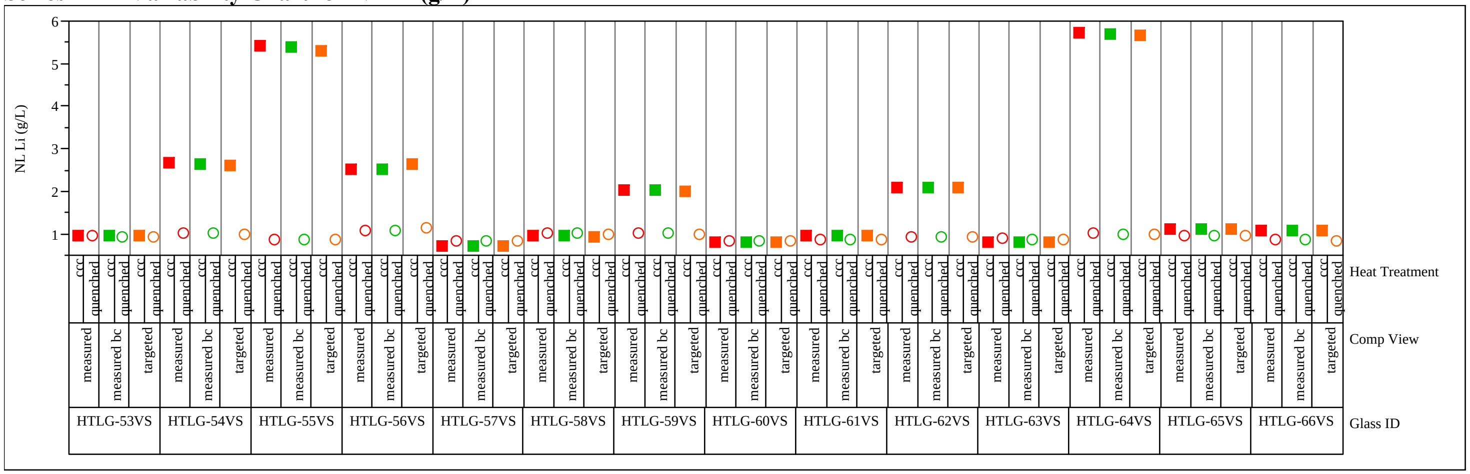
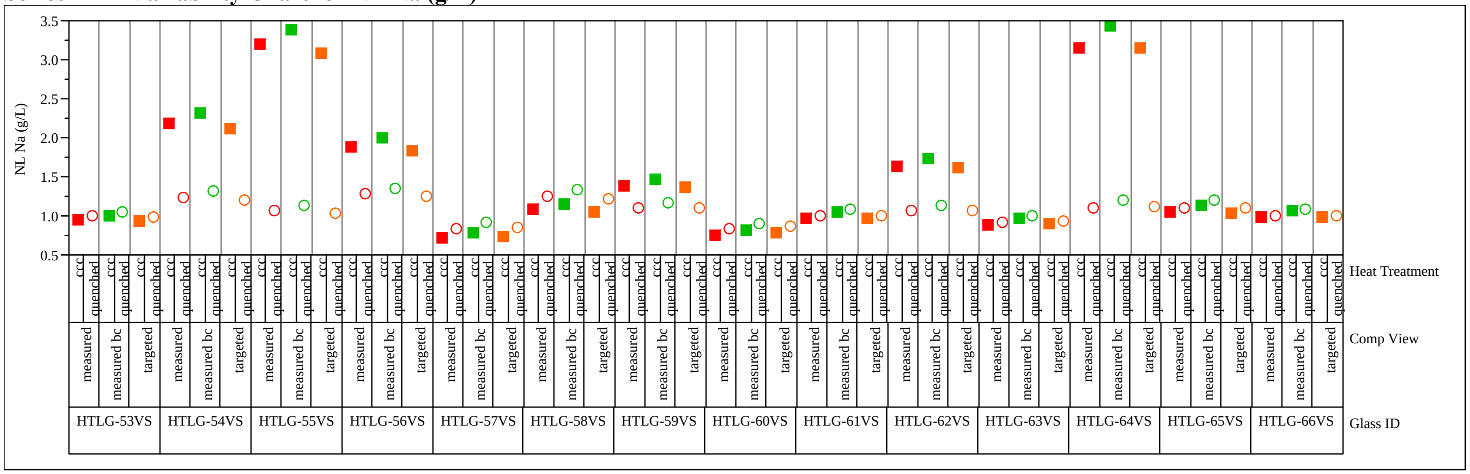


Exhibit B6. PSAL PCT Measurements for Quenched and CCC Versions of Each Study Glass by Glass Series ("P" and "Q")

Series=P — Variability Chart for NL Na (g/L)



Series=P — Variability Chart for NL Si (g/L)

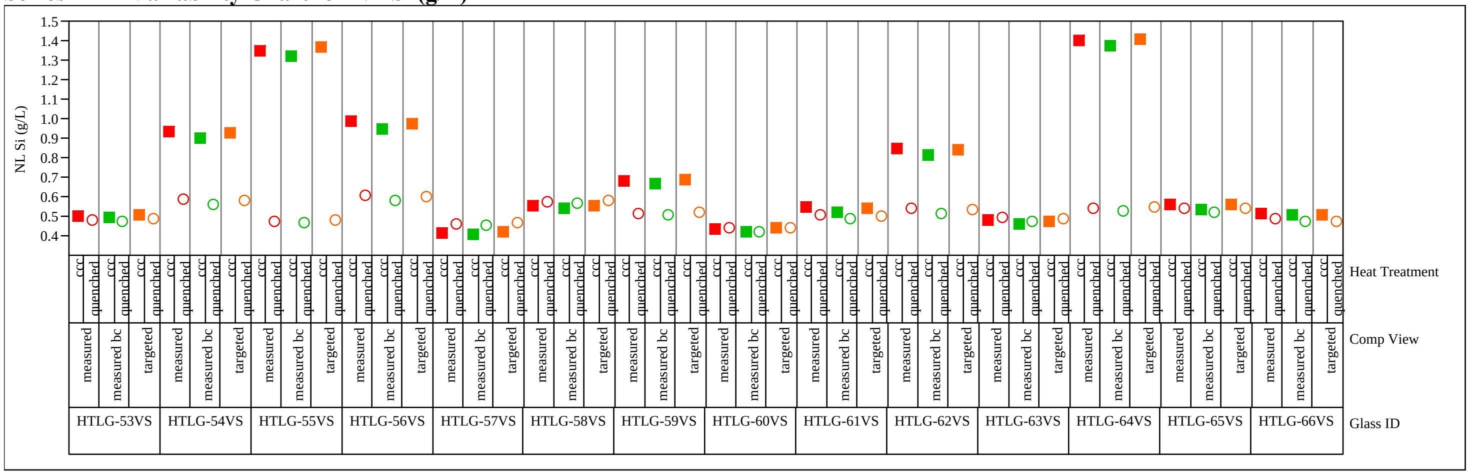
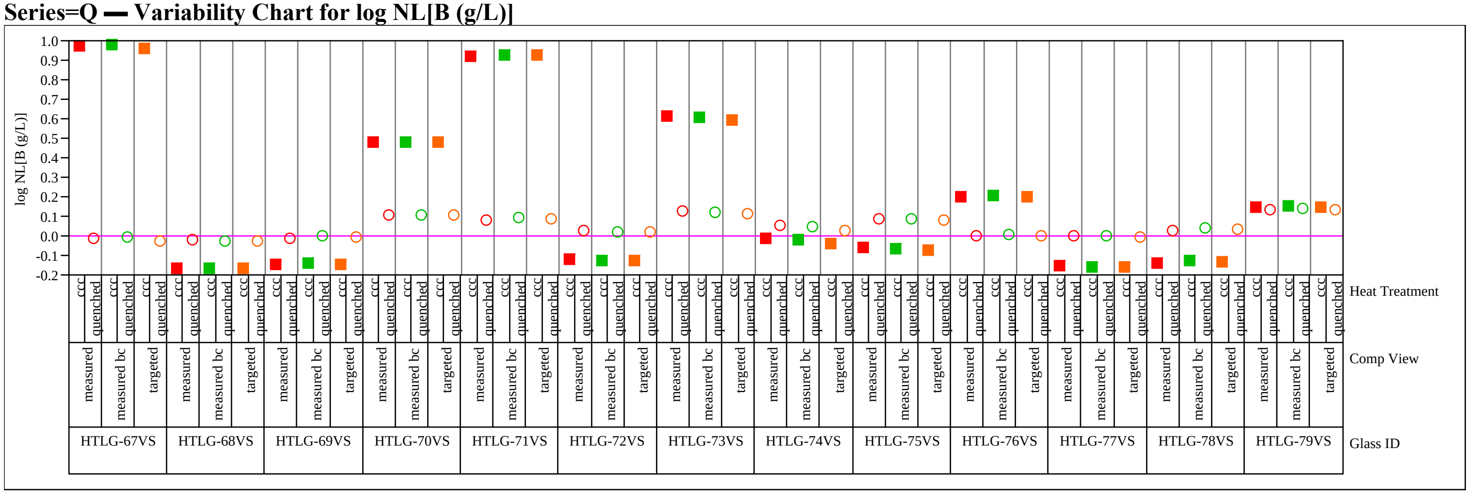


Exhibit B6. PSAL PCT Measurements for Quenched and CCC Versions of Each Study Glass by Glass Series ("P" and "Q")



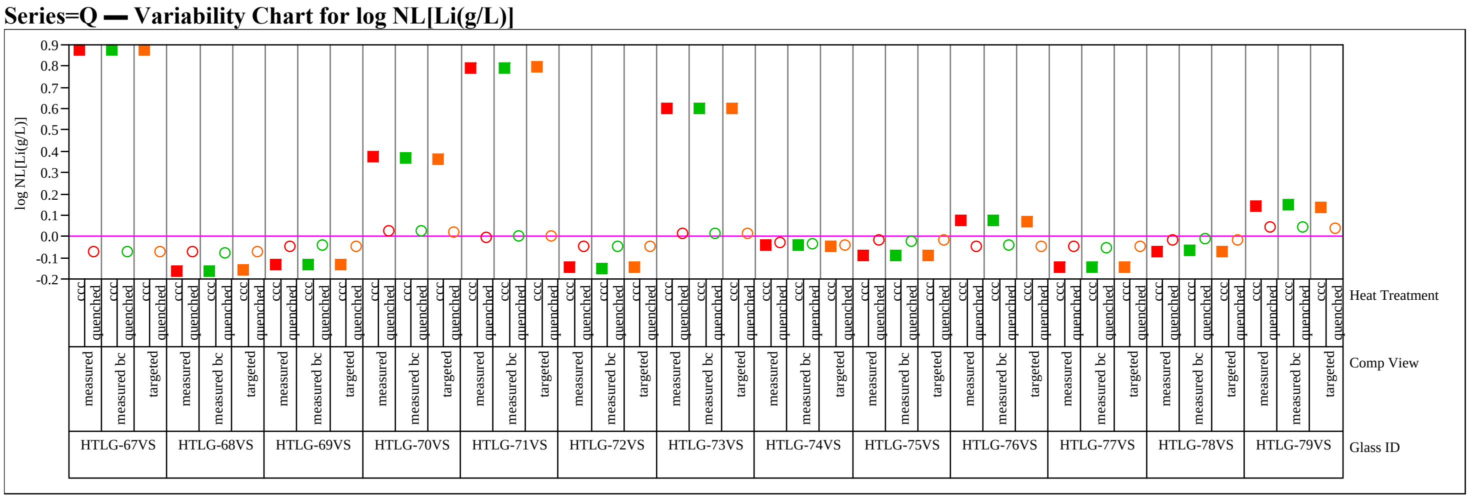
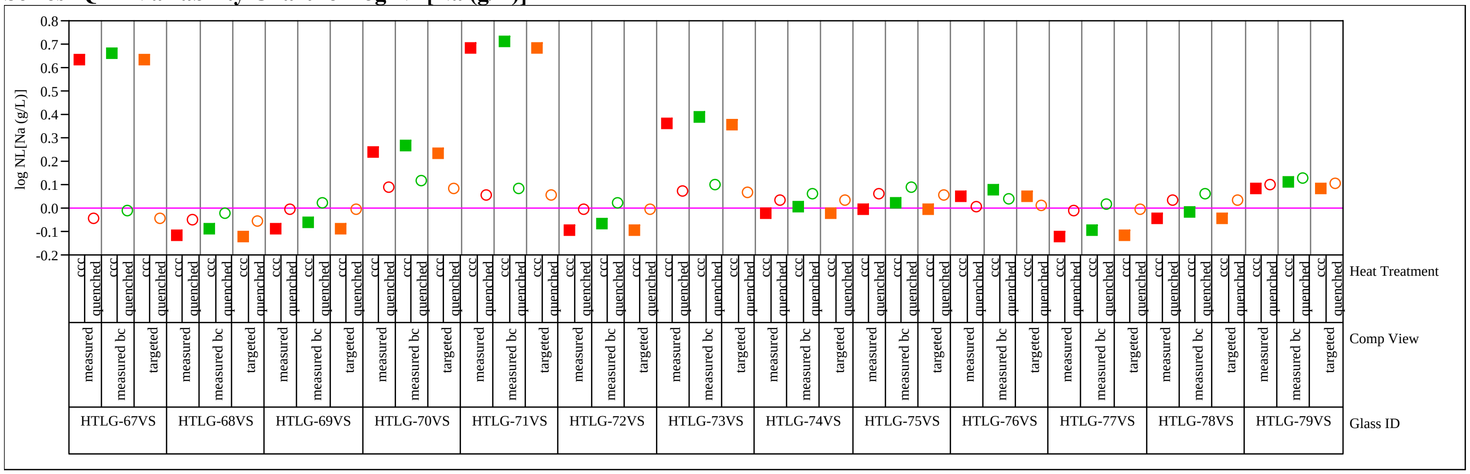


Exhibit B6. PSAL PCT Measurements for Quenched and CCC Versions of Each Study Glass by Glass Series ("P" and "Q")

Series=Q — Variability Chart for log NL[Na (g/L)]



Series=Q — Variability Chart for log NL[Si (g/L)]

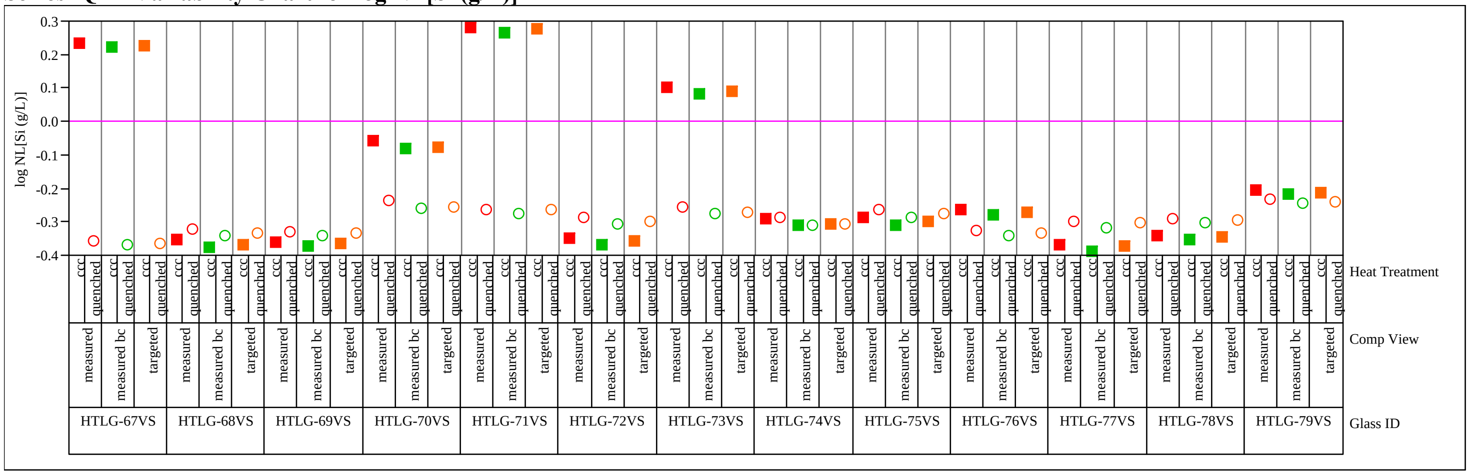
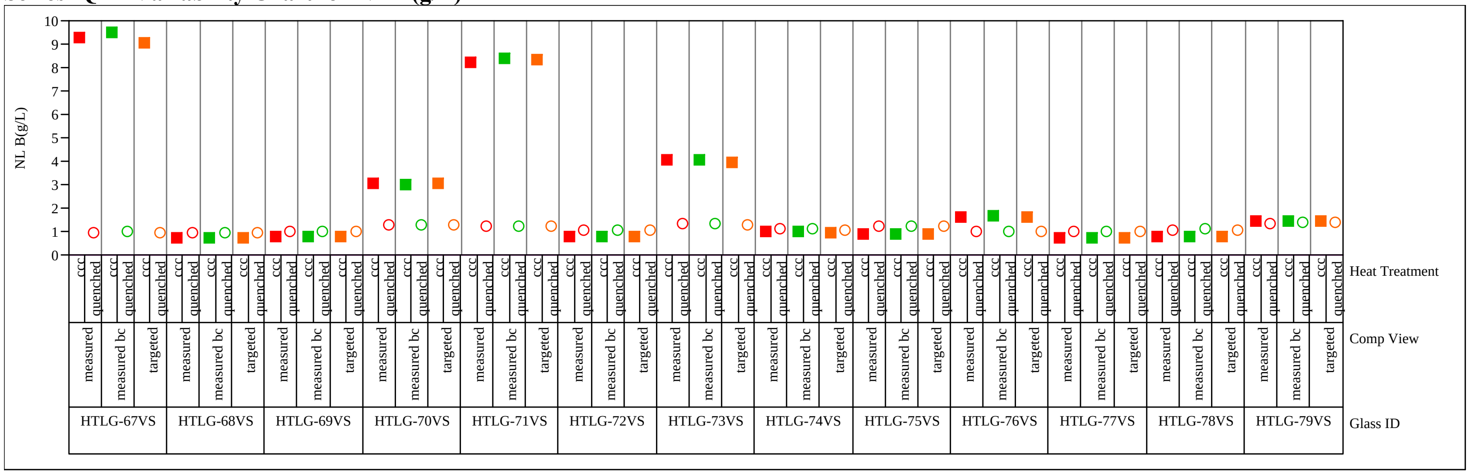


Exhibit B6. PSAL PCT Measurements for Quenched and CCC Versions of Each Study Glass by Glass Series ("P" and "Q")

Series=Q — Variability Chart for NL B(g/L)



Series=Q — Variability Chart for NL Li (g/L)

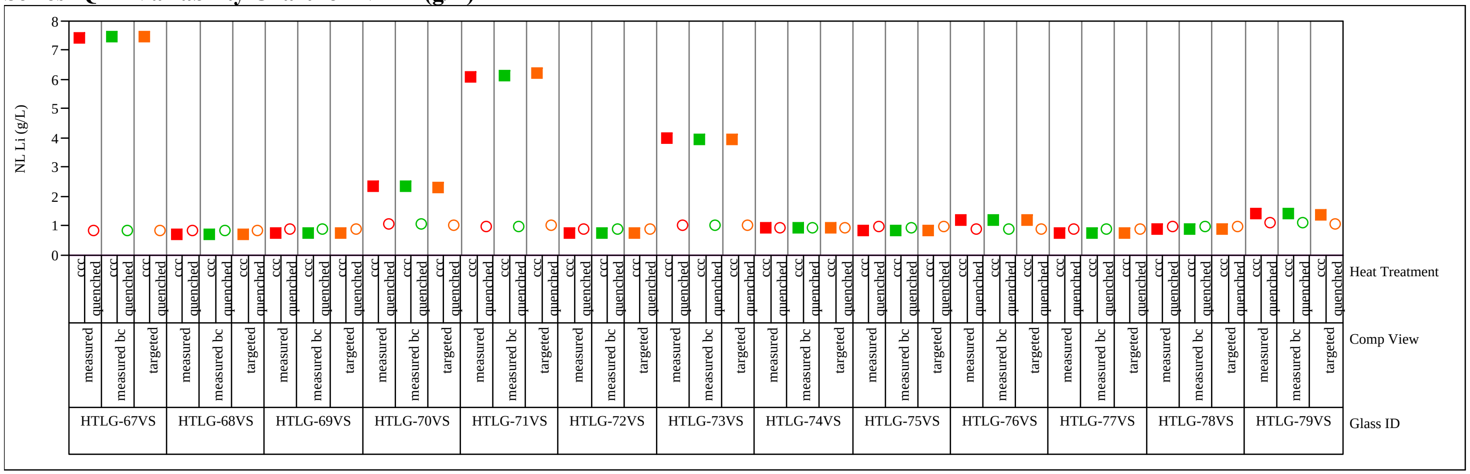
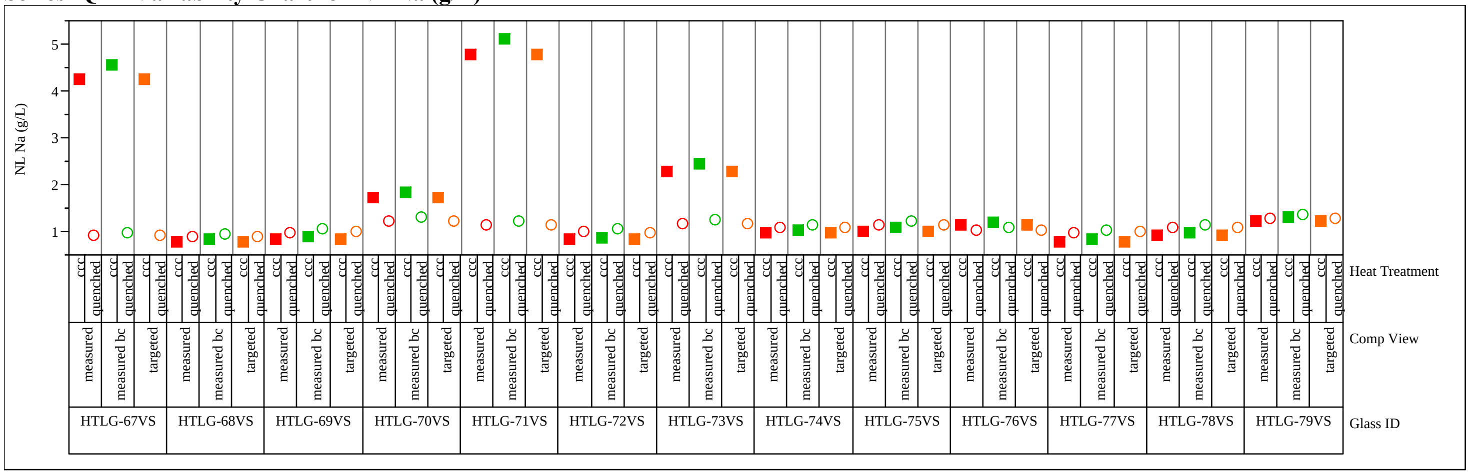
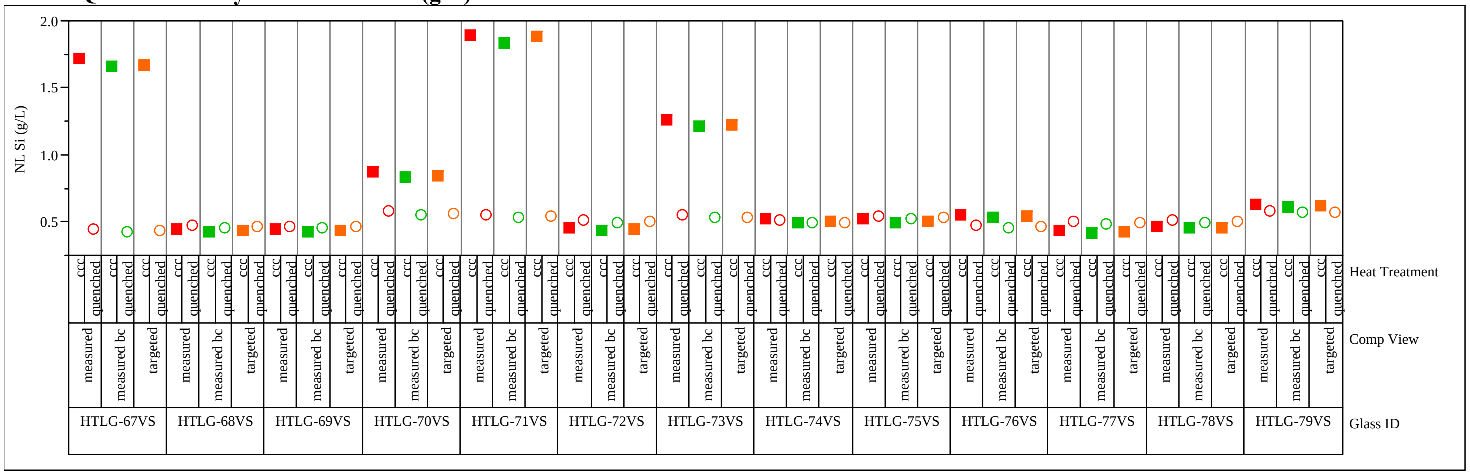


Exhibit B6. PSAL PCT Measurements for Quenched and CCC Versions of Each Study Glass by Glass Series ("P" and "Q")

Series=Q — Variability Chart for NL Na (g/L)



Series=Q — Variability Chart for NL Si (g/L)



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