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# IMPACT OF COOLING RATE ON THE DURABILITY OF PHA GLASSES (U)

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# SUMMARY AND CONCLUSION

This study was conducted to determine the effect, if any, on the PCT responses of glasses cooled at different rates. Two bounding cooling profiles were used in this study: rapidly quenched and a canister centerline cooling curve. Glasses were selected based on a number of criteria, but mainly to challenge the regions where amorphous phase separation is expected based upon current model predictions. The current DWPF homogeneity constraint, imposed to preclude regions of phase separation, predicted that most of the glasses selected would be phase separated. It was, therefore, important to ensure that deleterious phase separation does not occur at either cooling profile. In this case, deleterious phase separation is defined as the formation of an amorphous phase in the glass that significantly decreases the glass durability as measured by the PCT response.

X-ray diffraction and scanning electron microscopy were used to evaluate crystalline phases observed in the centerline cooled glasses. In one glass, pha17, a phase rich in copper was detected that had formed on the surface of Trevorite crystals. Trevorite crystals were also detected in several other clc glasses. A secondary phase precipitated out on the surface of Trevorite crystals in glasses that had low sludge loadings (~22 wt% oxide) and high PHA (~13% wt% oxides in the glass). This phase was rich in potassium and titanium.

The results showed that there was no practical difference between the PCT responses for glasses subjected to the two cooling profiles. In fact, although to a small extent, the centerline-cooled (clc) glasses were generally more durable than the rapidly quenched glasses in this study. These results reveal that no deleterious phase separation (amorphous or crystalline) occurred under either cooling regime.

All of the glasses readily satisfied the requirement that the PCT responses be at least two standard deviations below the PCT response of the EA glass. Furthermore, the PCT responses were almost entirely within the prediction intervals of the DWPF durability model. These results are detailed in the report.

# INTRODUCTION

One of the Alternative Salt Disposition Flowsheets being considered would require that the Defense Waste Processing Facility (DWPF) vitrify a coupled feed containing High Level Waste (HLW) and Precipitate Hydrolysis Aqueous (PHA). A Technical Task Request (TTR) [1] was received by the Savannah River Technology Center (SRTC) requesting that a glass variability study be conducted to explore the impact of cooling rate on glass durability for this alternative under consideration as part of the Salt Processing Program. A Task Technical and Quality Assurance (TT&QA) plan [2] was issued by SRTC in response to the TTR. The objective of this task is to study the impact of cooling rate on the durability of glass with anticipated levels of PHA in DWPF glasses with nominal levels of monosodium titanate (MST).

The selection of targeted glass compositions for this task was provided in a separate memorandum.[1] The study glasses were selected from a set of candidate glasses that covered Purex, HM, and Blend sludge types at sludge loadings (in the glass) of 22 to 30 oxide weight percent (wt%), utilized PHA loadings (in the glass) of 7, 10, and 13 oxide wt%, and included MST concentrations (in the glass) mainly at 2.5 wt%. A ±10% variation in the composition of each sludge type and of the PHA was also utilized in the development of the set of candidate glass compositions. For each composition, the remainder of the glass consisted of Frit 202.

1 The memorandum – Edwards, T. B., "Selecting Test Compositions for the FY01 Glass Studies of the Salt Processing Program," SRT-SCS-2000-00069, December 15, 2000 – details the selection of targeted compositions for the PHA and CST studies. Some information contained in this memo is proprietary making the full details of the memorandum unavailable for discussion in this report.

Compositions were selected from the set of candidate points that increased the opportunity of seeing any significant cooling impact on glass durability as measured by the PCT. Several glasses were chosen that would also demonstrate reproducibility of the results from an earlier study [3]. The target compositions for the PHA glasses are provided in Table 1.

**Table 1: Target Compositions (in wt%) for the PHA FY01 Study**

| Glass ID | Sludge Type | Sludge | MST | PHA | Frit | $Al_2O_3$ | $B_2O_3$ | CaO | CuO | $Fe_2O_3$ | $K_2O$ | $Li_2O$ | MgO | MnO | $Na_2O$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pha01 | Purex | 26 | 2.50 | 13 | 58.50 | 2.856 | 9.247 | 0.992 | 1.033 | 11.613 | 6.180 | 4.037 | 1.334 | 2.037 | 8.503 |
| pha02 | HM | 26 | 1.25 | 10 | 62.75 | 7.040 | 8.520 | 0.470 | 0.790 | 7.450 | 4.750 | 4.330 | 1.380 | 2.310 | 8.000 |
| pha03 | HM | 22 | 2.50 | 13 | 62.50 | 5.450 | 9.100 | 0.360 | 0.910 | 6.030 | 6.710 | 4.310 | 1.350 | 2.150 | 8.220 |
| pha04 | Blend | 22 | 2.50 | 13 | 62.50 | 3.370 | 9.102 | 0.801 | 0.926 | 8.662 | 6.748 | 4.313 | 1.386 | 2.178 | 7.073 |
| pha05 | Purex | 22 | 2.50 | 13 | 62.50 | 2.707 | 10.025 | 0.807 | 1.119 | 8.844 | 5.553 | 4.313 | 1.388 | 1.896 | 8.567 |
| pha06 | Purex | 28 | 2.50 | 13 | 56.50 | 3.306 | 8.627 | 1.176 | 0.942 | 12.292 | 6.795 | 3.899 | 1.307 | 1.974 | 8.926 |
| pha07 | Purex | 24 | 2.50 | 13 | 60.50 | 2.907 | 9.867 | 1.008 | 0.932 | 10.536 | 5.942 | 4.175 | 1.361 | 1.692 | 8.532 |
| pha08 | Purex | 30 | 2.50 | 13 | 54.50 | 3.506 | 9.392 | 1.029 | 1.140 | 12.867 | 5.795 | 3.761 | 1.280 | 2.586 | 8.238 |
| pha09 | Purex | 28 | 2.50 | 13 | 56.50 | 2.766 | 8.627 | 1.176 | 0.942 | 12.832 | 6.795 | 3.899 | 1.307 | 1.974 | 8.926 |
| pha10 | Purex | 28 | 2.50 | 7 | 62.50 | 3.343 | 7.185 | 0.960 | 0.644 | 11.323 | 3.552 | 4.313 | 1.427 | 2.414 | 8.752 |
| pha11 | Purex | 30 | 2.50 | 7 | 60.50 | 3.542 | 7.027 | 1.260 | 0.545 | 12.372 | 3.770 | 4.175 | 1.400 | 2.115 | 8.799 |
| pha12 | Purex | 22 | 2.50 | 7 | 68.50 | 2.319 | 7.660 | 0.755 | 0.628 | 9.321 | 3.507 | 4.727 | 1.507 | 1.896 | 8.312 |
| pha13 | Purex | 22 | 2.50 | 13 | 62.50 | 2.283 | 9.102 | 0.755 | 1.119 | 9.321 | 6.372 | 4.313 | 1.388 | 1.896 | 8.671 |
| pha14 | Purex | 28 | 2.50 | 13 | 56.50 | 2.766 | 8.627 | 0.960 | 1.135 | 11.864 | 6.417 | 3.899 | 1.307 | 2.414 | 9.112 |
| pha15 | Purex | 22 | 2.50 | 7 | 68.50 | 2.319 | 8.157 | 0.924 | 0.628 | 10.756 | 3.164 | 4.727 | 1.507 | 1.551 | 7.619 |
| pha16 | Purex | 26 | 2.50 | 7 | 64.50 | 2.641 | 7.841 | 1.092 | 0.535 | 12.711 | 3.297 | 4.451 | 1.453 | 1.833 | 7.814 |
| pha17 | Purex | 30 | 2.50 | 13 | 54.50 | 2.927 | 9.392 | 1.029 | 1.140 | 13.446 | 5.795 | 3.761 | 1.280 | 2.586 | 8.238 |
| **Glass ID** | **Sludge Type** | **Sludge** | **MST** | **PHA** | **Frit** | **NiO** | $P_2O_5$ | $SiO_2$ | $TiO_2$ | $U_3O_8$ | **ZnO** | $ZrO_2$ | $Cl^-$ | $F^-$ | $SO_4^-$ |
| pha01 | Purex | 26 | 2.50 | 13 | 58.50 | 1.097 | 0.046 | 45.523 | 2.197 | 2.363 | 0.104 | 0.169 | 0.308 | 0.053 | 0.310 |
| pha02 | HM | 26 | 1.25 | 10 | 62.75 | 0.400 | 0.030 | 51.940 | 1.100 | 0.800 | 0.080 | 0.130 | 0.230 | 0.040 | 0.230 |
| pha03 | HM | 22 | 2.50 | 13 | 62.50 | 0.370 | 0.030 | 51.470 | 2.200 | 0.740 | 0.070 | 0.110 | 0.190 | 0.030 | 0.190 |
| pha04 | Blend | 22 | 2.50 | 13 | 62.50 | 0.858 | 0.039 | 50.108 | 2.197 | 1.452 | 0.087 | 0.142 | 0.257 | 0.046 | 0.220 |
| pha05 | Purex | 22 | 2.50 | 13 | 62.50 | 1.021 | 0.039 | 48.526 | 2.197 | 2.200 | 0.088 | 0.143 | 0.261 | 0.046 | 0.260 |
| pha06 | Purex | 28 | 2.50 | 13 | 56.50 | 1.064 | 0.050 | 44.140 | 2.197 | 2.290 | 0.112 | 0.182 | 0.332 | 0.059 | 0.330 |
| pha07 | Purex | 24 | 2.50 | 13 | 60.50 | 0.912 | 0.043 | 47.064 | 2.197 | 1.963 | 0.096 | 0.156 | 0.284 | 0.050 | 0.280 |
| pha08 | Purex | 30 | 2.50 | 13 | 54.50 | 1.392 | 0.053 | 42.678 | 2.197 | 3.000 | 0.120 | 0.195 | 0.355 | 0.063 | 0.360 |
| pha09 | Purex | 28 | 2.50 | 13 | 56.50 | 1.064 | 0.050 | 44.140 | 2.197 | 2.290 | 0.112 | 0.182 | 0.332 | 0.059 | 0.330 |
| pha10 | Purex | 28 | 2.50 | 7 | 62.50 | 1.299 | 0.050 | 48.728 | 2.197 | 2.800 | 0.112 | 0.182 | 0.332 | 0.059 | 0.330 |
| pha11 | Purex | 30 | 2.50 | 7 | 60.50 | 1.392 | 0.053 | 47.266 | 2.197 | 3.000 | 0.120 | 0.195 | 0.355 | 0.063 | 0.360 |
| pha12 | Purex | 22 | 2.50 | 7 | 68.50 | 1.021 | 0.039 | 53.114 | 2.197 | 2.200 | 0.088 | 0.143 | 0.261 | 0.046 | 0.260 |
| pha13 | Purex | 22 | 2.50 | 13 | 62.50 | 1.021 | 0.039 | 48.526 | 2.197 | 2.200 | 0.088 | 0.143 | 0.261 | 0.046 | 0.260 |
| pha14 | Purex | 28 | 2.50 | 13 | 56.50 | 1.299 | 0.050 | 44.140 | 2.197 | 2.800 | 0.112 | 0.182 | 0.332 | 0.059 | 0.330 |
| pha15 | Purex | 22 | 2.50 | 7 | 68.50 | 0.836 | 0.039 | 52.979 | 2.197 | 1.800 | 0.088 | 0.143 | 0.261 | 0.046 | 0.260 |
| pha16 | Purex | 26 | 2.50 | 7 | 64.50 | 0.988 | 0.046 | 50.031 | 2.197 | 2.127 | 0.104 | 0.169 | 0.308 | 0.055 | 0.310 |
| pha17 | Purex | 30 | 2.50 | 13 | 54.50 | 1.392 | 0.053 | 42.678 | 2.197 | 3.000 | 0.120 | 0.195 | 0.369 | 0.063 | 0.360 |

Property models [4] utilized by the DWPF for process and product quality control were used to help in the selection of the study glasses. The process properties of interest included viscosity and liquidus temperature. The product property of interest for the study glasses is durability (as measured by the 7-day Product Consistency Test (PCT) [5]). Predictions for the "Homogeneity" discriminator [6], used by the DWPF to avoid glass compositions that may undergo amorphous phase separation upon cooling, played an important role in the selection of the study glasses. The property predictions along with other key characteristics of the targeted compositions are provided in Table 2.

**Table 2: Property Predictions for the PHA Study Glasses**

| | | | | | | | | | | Normalized Releases | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Glass | Sludge | Loadings | | | | $Al_2O_3$ | alkalis | Homo | | B | Li | Na | Visc. | $T_L$ |
| ID | Type | S | MST | PHA | Frit | (wt%) | (wt%) | (wt%) | del Gp | (g/L) | (g/L) | (g/L) | (P) | °C |
| pha01 | Purex | 26 | 2.50 | 13 | 58.50 | 2.856 | 18.72 | 205.2 | -12.572 | 2.37 | 2.00 | 2.23 | 28.9 | 1009.7 |
| pha02 | HM | 26 | 1.30 | 10 | 62.70 | 7.040 | 17.08 | 208.8 | -9.652 | 0.70 | 0.75 | 0.71 | 97.6 | 933.7 |
| pha03 | HM | 22 | 2.50 | 13 | 62.50 | 5.450 | 19.24 | 194.8 | -11.948 | 1.83 | 1.62 | 1.75 | 71.5 | 904.9 |
| pha04 | Blend | 22 | 2.50 | 13 | 62.50 | 3.370 | 18.13 | 196.5 | -11.760 | 1.69 | 1.52 | 1.62 | 55.7 | 944.3 |
| pha05 | Purex | 22 | 2.50 | 13 | 62.50 | 2.707 | 18.43 | 193.2 | -12.480 | 2.28 | 1.94 | 2.15 | 39.6 | 949.4 |
| pha06 | Purex | 28 | 2.50 | 13 | 56.50 | 3.306 | 19.62 | 210.8 | -13.104 | 2.96 | 2.40 | 2.75 | 24.3 | 1032.7 |
| pha07 | Purex | 24 | 2.50 | 13 | 60.50 | 2.907 | 18.65 | 202.8 | -12.457 | 2.26 | 1.93 | 2.13 | 33.2 | 984.2 |
| pha08 | Purex | 30 | 2.50 | 13 | 54.50 | 3.506 | 17.79 | 210.3 | -11.880 | 1.77 | 1.59 | 1.70 | 25.4 | 1054.3 |
| pha09 | Purex | 28 | 2.50 | 13 | 56.50 | 2.766 | 19.62 | 210.8 | -13.255 | 3.15 | 2.53 | 2.92 | 22.4 | 1038.4 |
| pha10 | Purex | 28 | 2.50 | 7 | 62.50 | 3.343 | 16.62 | 204.6 | -10.320 | 0.93 | 0.94 | 0.92 | 52.0 | 993.0 |
| pha11 | Purex | 30 | 2.50 | 7 | 60.50 | 3.542 | 16.74 | 210.9 | -10.296 | 0.92 | 0.93 | 0.91 | 45.8 | 1018.9 |
| pha12 | Purex | 22 | 2.50 | 7 | 68.50 | 2.319 | 16.55 | 194.0 | -10.348 | 0.94 | 0.94 | 0.93 | 66.1 | 941.5 |
| pha13 | Purex | 22 | 2.50 | 13 | 62.50 | 2.283 | 19.36 | 193.2 | -13.196 | 3.07 | 2.48 | 2.85 | 36.0 | 955.3 |
| pha14 | Purex | 28 | 2.50 | 13 | 56.50 | 2.766 | 19.43 | 203.8 | -13.320 | 3.23 | 2.58 | 3.00 | 24.0 | 1020.7 |
| pha15 | Purex | 22 | 2.50 | 7 | 68.50 | 2.319 | 15.51 | 202.0 | -9.341 | 0.62 | 0.67 | 0.63 | 66.8 | 963.2 |
| pha16 | Purex | 26 | 2.50 | 7 | 64.50 | 2.641 | 15.56 | 210.6 | -9.378 | 0.63 | 0.68 | 0.63 | 53.8 | 1005.8 |
| pha17 | Purex | 30 | 2.50 | 13 | 54.50 | 2.927 | 17.79 | 210.3 | -12.041 | 1.90 | 1.67 | 1.81 | 23.1 | 1060.3 |

The purpose of this report is to provide and investigate comparisons between

- the measured and target compositions of the PHA glasses,
- the PCT measurements and durability model predictions, and
- the PCT measurements for quenched versus centerline-cooled glasses.

Evaluating the results from these comparisons provides the basis for assessing the impact of cooling rate on the durability of PHA glasses.

# RESULTS AND DISCUSSION

The 17 glasses comprising the PHA study were designated as pha01 through pha17. Composition and PCT measurements of these glasses were conducted in accordance with analytical plans that were used to generate the measurements supporting the PHA study. These plans, which are identified in the discussion that follows, were prepared to support the overall Task Technical and QA plan [2] and the analytical study plan [7]. The results of these measurements (both composition and properties) are presented in this section.

Predictions for the properties of interest generated for these target compositions by the models utilized by the DWPF are also included in the discussion provided in Attachment I. These properties, for a given composition, relate to its processability and its product quality. For a given composition, acceptable property characteristics and reliable property predictions (using the current DWPF models) are of interest. The critical property for this study is glass durability, and comparisons between predictions and measurements for this property for both cooling treatments are provided in the discussion that follows.

## Glass Batching and Cooling

The PHA glasses, corresponding to rows pha01 though pha17 of Table 1, were batched to the targeted compositions (combinations of sludge, glass formers, PHA, and MST) indicated in that table. Since the compositions of the simulated sludges were allowed to vary ±10% around their respective nominal compositions, their contributions to the PHA glasses had to be represented via dry chemicals (e.g., reagent grade nitrates, carbonates, and oxides). This was also true for the contribution of PHA in the glasses. The contributions of MST to the composition of the study glasses were also handled the same way. The contributions of the glass formers were represented by appropriate additions of Frit 202, Lot 14, available from the DWPF. The Frit 202 composition is given in Table 10 of the memorandum identified in footnote #1.

For each glass, the combined raw materials (~110 grams) were added to a 100 mL Pt-Au crucible and placed in a calibrated furnace, heated to 1150°C at a rate of 10°C/minute, and then held for four hours at 1150°C. The crucible was then removed and the glass immediately poured onto a clean stainless steel plate.

A portion of each glass cooled by quenching (as described in the preceding paragraph) was then remelted and allowed to cool following a centerline cooling profile. This was accomplished by taking a portion of each glass and placing it in a smaller crucible. Then, the crucible was introduced to the furnace at 1150$^{o}$C, and the furnace was programmed to cool at a rate that simulated the centerline cooling profile of DWPF canisters.

## Chemical Compositions

In addition to the PHA glasses, a standard glass (Batch 1) and a standard uranium-bearing glass were included in the planning of these analyses (for possible bias correction). An analytical plan (in the form of a memorandum [8]) was provided to assist the SRTC-Mobile Laboratory (SRTC-ML) in conducting these analyses (see Attachment I of this report).

Tables A.1 and A.2 in Appendix A provide the composition measurements obtained by the SRTC-ML for the plan covering these analyses. As indicated by these tables, two dissolution methods were used to perform these analyses: lithium metaborate and peroxide fusion dissolutions. The lithium metaborate method was used to generate measurements for Al, Ca Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Si, Ti, and Zr. Peroxide fusion was used for B, Li, and U. The values are presented as weight percent (wt%) elemental concentrations. Table entries preceded by a "<" indicate measurements below the analytical detection limit (value shown). The elemental concentrations were converted to their corresponding oxide concentrations via multiplication by the appropriate gravimetric factor. Values below detection were replaced by ½ of the detection limit during the conversion process.

Exhibits A.1 and A.2 in Appendix A provide a plot of the measurements by oxide in analytical sequence for the two preparation methods. The analytical plan called for four measurements on each oxide of interest for each glass [8].

A review of the results from the standards was used to provide insight into the possibility that the ICP calibration contributes (in a systematic way) to the variation seen in the oxide measurements for the study glasses. Exhibits A.3 and A.4 in Appendix A provide plots of the oxide measurements per analytical block by oxide by preparation method. Statistical tests for significant differences among the analytical block averages are also included in these exhibits. Some statistically significant differences are indicated. Also, note that the pattern of behavior demonstrated by the measurements of one standard over a set of analytical blocks is frequently demonstrated by the measurements of the other standard.

Table 3 provides the average measured compositions by analytical block and the reference values for the two standards included in the analytical plan.

**Table 3: Measurements from Glass Standards for Both Preparation Methods**

| | std (Batch 1) | | | | | Ustd (Uranium-bearing Standard) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Analytical Block | | | | Reference Value | Analytical Block | | | | Reference Value |
| | 1-1 | 1-2 | 2-1 | 2-2 | | 1-1 | 1-2 | 2-1 | 2-2 | |
| Oxide | 3 obs | 3 obs | 3 obs | 3 obs | | 2 obs | 2 obs | 2 obs | 2 obs | |
| $Al_2O_3$ | 4.812 | 4.818 | 4.894 | 4.862 | 4.877 | 3.892 | 3.892 | 3.958 | 3.934 | 4.100 |
| $B_2O_3$ | 8.007 | 7.975 | 8.103 | 8.07 | 7.777 | 9.483 | 9.128 | 9.466 | 8.951 | 9.209 |
| CaO | 1.255 | 1.262 | 1.300 | 1.283 | 1.220 | 1.284 | 1.303 | 1.325 | 1.320 | 1.301 |
| $Cr_2O_3$ | 0.102 | 0.094 | 0.100 | 0.100 | 0.107 | 0.236 | 0.226 | 0.236 | 0.240 | 0.000 |
| CuO | 0.386 | 0.387 | 0.394 | 0.393 | 0.399 | 0.009 | 0.008 | 0.009 | 0.011 | 0.000 |
| $Fe_2O_3$ | 13.029 | 13.172 | 13.244 | 13.225 | 12.839 | 13.075 | 13.375 | 13.325 | 13.339 | 13.196 |
| $K_2O$ | 3.670 | 3.650 | 3.734 | 3.662 | 3.327 | 2.861 | 2.897 | 2.933 | 2.891 | 2.999 |
| $Li_2O$ | 4.406 | 4.449 | 4.600 | 4.485 | 4.429 | 3.079 | 3.003 | 3.143 | 2.928 | 3.057 |
| MgO | 1.394 | 1.389 | 1.401 | 1.454 | 1.419 | 1.171 | 1.155 | 1.180 | 1.222 | 1.210 |
| MnO | 1.648 | 1.636 | 1.666 | 1.709 | 1.726 | 2.628 | 2.582 | 2.653 | 2.712 | 2.892 |
| $Na_2O$ | 8.847 | 8.811 | 8.982 | 8.852 | 9.003 | 10.211 | 10.225 | 10.353 | 10.252 | 11.795 |
| NiO | 0.649 | 0.649 | 0.660 | 0.671 | 0.751 | 0.936 | 0.924 | 0.947 | 0.966 | 1.120 |
| $SiO_2$ | 51.771 | 52.056 | 51.985 | 51.985 | 50.220 | 46.530 | 47.386 | 47.492 | 47.278 | 45.353 |
| $TiO_2$ | 0.643 | 0.634 | 0.656 | 0.657 | 0.677 | 0.930 | 0.918 | 0.949 | 0.957 | 1.049 |
| $U_3O_8$ | 0.059 | 0.059 | 0.059 | 0.059 | 0.000 | 2.364 | 2.323 | 2.423 | 2.258 | 2.406 |
| $ZrO_2$ | 0.074 | 0.066 | 0.077 | 0.071 | 0.098 | 0.008 | 0.008 | 0.008 | 0.008 | 0.000 |
| Sum of Oxides | 100.75 | 101.11 | 101.86 | 101.54 | 98.87 | 98.70 | 99.35 | 100.40 | 99.27 | 99.69 |

The measurements of the standards and the results from Exhibits A3 and A4 suggest bias correcting the measurements of the study glasses for potential analytical block effects. How was the bias correction conducted? For each dissolution method, let $\bar{a}_{ij}$ be the average measurement for the $i^{th}$ oxide at analytical block j for Batch 1 (or Ustd for uranium), and let $t_i$ be the reference value for the $i^{th}$ oxide. (The averages and reference values are provided in Table 3 for each oxide of interest.) Let $\bar{c}_{ijk}$ be the average measurement for the $i^{th}$ oxide at analytical block j for the $k^{th}$ glass prepared by the given dissolution method. The bias adjustment was conducted as follows for each of the two dissolution methods

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

Bias corrected measurements are indicated by additional “bc” suffix, and such adjustments were performed for all of the oxides and both of the dissolution methods of this study. This approach was used to bias correct the composition measurements of the PHA and standard glasses. Both measured and measured “bc” values are included in the discussion that follows.

Exhibit A.5 and A.6 provide plots of the measurements and bias-corrected (bc) measurements for each oxide by glass number (including the standards) by preparation method. The repeatability of the 4 measurements for each oxide for each glass is of interest in these plots.

Exhibit A.7 in Appendix A provides comparison plots for each oxide over all of the glasses (including the standards). These plots provide three views of the (average) chemical composition of the glasses: measured, measured bias-corrected, and targeted. Table 4 provides summary information for these compositional views. The sums of oxides for the targeted, measured, and measured bias-corrected compositions are also provided. A review of these sums shows that they all are within the interval of 95 to 105 weight percent with the smallest value being 95.3 wt% for the measured bias-corrected composition of pha13 and the largest being 101.3 wt% for the measured composition of Batch 1. One observation from this exhibit and table is that the $K_2O$ measurements are consistently low for the PHA glasses (and bias-correction does not help). Also, the NiO and $U_3O_8$ measurements for pha07 and the $U_3O_8$ measurements for pha08 and pha17 indicate likely errors in the batching of these 3 glasses.[2]

2 Additional samples of pha07, pha08, and pha17 were subsequently re-measured by the SRTC-ML yielding information supporting the conclusions regarding the batching of these glasses.

No other serious problems are seen in the comparisons of these compositional views of the PHA study glasses.

**Table 4: Target, Measured and Bias-Corrected Compositions (in wt%) for the Study Glasses**

| Oxide | *Batch 1* | | | *Uranium Standard (u-std)* | | | *pha01* | | | *pha02* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. |
| $Al_2O_3$ | 4.877 | 4.847 | 4.877 | 4.100 | 3.921 | 3.945 | 2.856 | 2.924 | 2.962 | 7.040 | 6.916 | 6.914 |
| $B_2O_3$ | 7.777 | 8.039 | 7.777 | 9.209 | 9.257 | 8.956 | 9.247 | 8.831 | 8.491 | 8.520 | 8.404 | 8.179 |
| CaO | 1.220 | 1.275 | 1.220 | 1.301 | 1.308 | 1.252 | 0.992 | 1.055 | 1.023 | 0.470 | 0.561 | 0.530 |
| $Cr_2O_3$ | 0.107 | 0.099 | 0.107 | 0.000 | 0.234 | 0.253 | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 |
| CuO | 0.399 | 0.390 | 0.399 | 0.000 | 0.009 | 0.009 | 1.033 | 1.035 | 1.069 | 0.790 | 0.757 | 0.767 |
| $Fe_2O_3$ | 12.839 | 13.168 | 12.839 | 13.196 | 13.278 | 12.947 | 11.613 | 11.541 | 11.311 | 7.450 | 7.270 | 7.053 |
| $K_2O$ | 3.327 | 3.679 | 3.327 | 2.999 | 2.896 | 2.619 | 6.180 | 5.306 | 4.824 | 4.750 | 4.204 | 3.782 |
| $Li_2O$ | 4.429 | 4.485 | 4.429 | 3.057 | 3.038 | 3.000 | 4.037 | 3.956 | 3.856 | 4.330 | 4.333 | 4.335 |
| MgO | 1.419 | 1.410 | 1.419 | 1.210 | 1.182 | 1.190 | 1.334 | 1.363 | 1.390 | 1.380 | 1.410 | 1.402 |
| MnO | 1.726 | 1.665 | 1.726 | 2.892 | 2.644 | 2.741 | 2.037 | 2.001 | 2.104 | 2.310 | 2.201 | 2.252 |
| $Na_2O$ | 9.003 | 8.873 | 9.003 | 11.795 | 10.260 | 10.410 | 8.503 | 7.926 | 8.082 | 8.000 | 7.845 | 7.921 |
| NiO | 0.751 | 0.657 | 0.751 | 1.120 | 0.943 | 1.078 | 1.097 | 0.984 | 1.138 | 0.400 | 0.350 | 0.395 |
| $SiO_2$ | 50.220 | 51.949 | 50.220 | 45.353 | 47.172 | 45.601 | 45.523 | 47.011 | 45.478 | 51.940 | 53.429 | 51.615 |
| $TiO_2$ | 0.677 | 0.647 | 0.677 | 1.049 | 0.939 | 0.981 | 2.197 | 2.156 | 2.287 | 1.100 | 1.053 | 1.086 |
| $U_3O_8$ | 0.000 | 0.059 | 0.061 | 2.406 | 2.342 | 2.406 | 2.363 | 2.291 | 2.354 | 0.800 | 0.828 | 0.850 |
| $ZrO_2$ | 0.098 | 0.072 | 0.098 | 0.000 | 0.007 | 0.009 | 0.169 | 0.158 | 0.221 | 0.130 | 0.111 | 0.147 |
| Sum of Oxides | 98.869 | 101.314 | 98.930 | 99.687 | 99.430 | 97.398 | 99.181 | 98.546 | 96.596 | 99.410 | 99.680 | 97.235 |

| Oxide | *pha03* | | | *pha04* | | | *pha05* | | | *pha06* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. |
| $Al_2O_3$ | 5.450 | 5.262 | 5.330 | 3.370 | 3.666 | 3.665 | 2.707 | 2.707 | 2.742 | 3.306 | 3.722 | 3.770 |
| $B_2O_3$ | 9.100 | 9.177 | 8.931 | 9.102 | 9.024 | 8.677 | 10.025 | 9.764 | 9.503 | 8.627 | 8.887 | 8.649 |
| CaO | 0.360 | 0.423 | 0.410 | 0.801 | 0.898 | 0.849 | 0.807 | 0.886 | 0.860 | 1.176 | 1.272 | 1.233 |
| $Cr_2O_3$ | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 |
| CuO | 0.910 | 0.920 | 0.950 | 0.926 | 0.945 | 0.958 | 1.119 | 1.264 | 1.306 | 0.942 | 0.902 | 0.931 |
| $Fe_2O_3$ | 6.030 | 5.812 | 5.696 | 8.662 | 8.257 | 8.010 | 8.844 | 8.546 | 8.376 | 12.292 | 12.042 | 11.801 |
| $K_2O$ | 6.710 | 5.776 | 5.251 | 6.748 | 5.776 | 5.197 | 5.553 | 4.897 | 4.451 | 6.795 | 5.860 | 5.327 |
| $Li_2O$ | 4.310 | 4.370 | 4.372 | 4.313 | 4.257 | 4.150 | 4.313 | 4.317 | 4.318 | 3.899 | 4.064 | 4.066 |
| MgO | 1.350 | 1.396 | 1.423 | 1.386 | 1.413 | 1.405 | 1.388 | 1.394 | 1.422 | 1.307 | 1.310 | 1.336 |
| MnO | 2.150 | 2.134 | 2.243 | 2.178 | 2.160 | 2.210 | 1.896 | 1.853 | 1.948 | 1.974 | 1.905 | 2.002 |
| $Na_2O$ | 8.220 | 7.781 | 7.934 | 7.073 | 6.801 | 6.866 | 8.567 | 7.957 | 8.113 | 8.926 | 8.300 | 8.463 |
| NiO | 0.370 | 0.345 | 0.399 | 0.858 | 0.780 | 0.880 | 1.021 | 0.889 | 1.029 | 1.064 | 0.945 | 1.094 |
| $SiO_2$ | 51.470 | 53.483 | 51.738 | 50.108 | 52.092 | 50.323 | 48.526 | 50.434 | 48.790 | 44.140 | 45.728 | 44.236 |
| $TiO_2$ | 2.200 | 2.118 | 2.247 | 2.197 | 2.139 | 2.206 | 2.197 | 2.056 | 2.181 | 2.197 | 2.114 | 2.242 |
| $U_3O_8$ | 0.740 | 0.759 | 0.779 | 1.452 | 1.386 | 1.424 | 2.200 | 2.223 | 2.282 | 2.290 | 2.385 | 2.448 |
| $ZrO_2$ | 0.110 | 0.098 | 0.136 | 0.142 | 0.123 | 0.162 | 0.143 | 0.125 | 0.174 | 0.182 | 0.161 | 0.225 |
| Sum of Oxides | 99.480 | 99.861 | 97.847 | 99.316 | 99.722 | 96.988 | 99.306 | 99.319 | 97.500 | 99.117 | 99.603 | 97.831 |

| Oxide | *pha07* | | | *pha08* | | | *pha09* | | | *pha10* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. |
| $Al_2O_3$ | 2.907 | 3.085 | 3.124 | 3.506 | 3.566 | 3.566 | 2.766 | 2.985 | 3.024 | 3.343 | 3.335 | 3.334 |
| $B_2O_3$ | 9.867 | 10.223 | 9.949 | 9.392 | 9.499 | 9.244 | 8.627 | 8.235 | 7.918 | 7.185 | 7.156 | 6.964 |
| CaO | 1.008 | 1.124 | 1.090 | 1.029 | 1.165 | 1.100 | 1.176 | 1.221 | 1.184 | 0.960 | 1.064 | 1.005 |
| $Cr_2O_3$ | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 | 0.000 | 0.010 | 0.010 |
| CuO | 0.932 | 0.946 | 0.977 | 1.140 | 1.267 | 1.285 | 0.942 | 0.903 | 0.932 | 0.644 | 0.665 | 0.674 |
| $Fe_2O_3$ | 10.536 | 10.805 | 10.589 | 12.867 | 12.857 | 12.473 | 12.832 | 12.649 | 12.397 | 11.323 | 11.141 | 10.808 |
| $K_2O$ | 5.942 | 5.351 | 4.865 | 5.795 | 5.318 | 4.785 | 6.795 | 5.616 | 5.105 | 3.552 | 3.439 | 3.094 |
| $Li_2O$ | 4.175 | 4.338 | 4.340 | 3.761 | 3.859 | 3.860 | 3.899 | 3.870 | 3.771 | 4.313 | 4.306 | 4.308 |
| MgO | 1.361 | 1.433 | 1.461 | 1.280 | 1.351 | 1.343 | 1.307 | 1.297 | 1.322 | 1.427 | 1.497 | 1.488 |
| MnO | 1.692 | 1.711 | 1.798 | 2.586 | 2.647 | 2.708 | 1.974 | 1.917 | 2.016 | 2.414 | 2.421 | 2.477 |
| $Na_2O$ | 8.532 | 8.176 | 8.336 | 8.238 | 7.876 | 7.952 | 8.926 | 8.287 | 8.450 | 8.752 | 8.290 | 8.370 |
| NiO | 0.912 | 0.006 | 0.007 | 1.392 | 0.838 | 0.945 | 1.064 | 0.958 | 1.108 | 1.299 | 1.186 | 1.338 |
| $SiO_2$ | 47.064 | 49.953 | 48.324 | 42.678 | 45.407 | 43.865 | 44.140 | 45.728 | 44.236 | 48.728 | 49.953 | 48.257 |
| $TiO_2$ | 2.197 | 2.210 | 2.344 | 2.197 | 2.218 | 2.287 | 2.197 | 2.089 | 2.216 | 2.197 | 2.189 | 2.257 |
| $U_3O_8$ | 1.963 | 0.059 | 0.061 | 3.000 | 2.008 | 2.061 | 2.290 | 2.182 | 2.241 | 2.800 | 2.854 | 2.929 |
| $ZrO_2$ | 0.156 | 0.141 | 0.198 | 0.195 | 0.183 | 0.242 | 0.182 | 0.154 | 0.216 | 0.182 | 0.174 | 0.230 |
| Sum of Oxides | 99.244 | 99.569 | 97.471 | 99.056 | 100.066 | 97.724 | 99.117 | 98.098 | 96.143 | 99.119 | 99.679 | 97.544 |

**Table 4: Target, Measured and Bias-Corrected Compositions (in wt%) for the Study Glasses** *(continued)*

| Oxide | *pha11* Target | *pha11* Measured | *pha11* Measured Bias-cor. | *pha12* Target | *pha12* Measured | *pha12* Measured Bias-cor. | *pha13* Target | *pha13* Measured | *pha13* Measured Bias-cor. | *pha14* Target | *pha14* Measured | *pha14* Measured Bias-cor. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **$Al_2O_3$** | 3.542 | 3.434 | 3.433 | 2.319 | 2.352 | 2.383 | 2.283 | 2.485 | 2.484 | 2.766 | 2.721 | 2.756 |
| **$B_2O_3$** | 7.027 | 6.858 | 6.595 | 7.660 | 7.615 | 7.411 | 9.102 | 8.927 | 8.585 | 8.627 | 8.573 | 8.343 |
| **CaO** | 1.260 | 1.309 | 1.237 | 0.755 | 0.844 | 0.819 | 0.755 | 0.856 | 0.809 | 0.960 | 1.054 | 1.022 |
| **$Cr_2O_3$** | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 |
| **CuO** | 0.545 | 0.551 | 0.559 | 0.628 | 0.634 | 0.655 | 1.119 | 1.122 | 1.137 | 1.135 | 1.139 | 1.177 |
| **$Fe_2O_3$** | 12.372 | 11.863 | 11.509 | 9.321 | 9.175 | 8.992 | 9.321 | 9.200 | 8.925 | 11.864 | 11.902 | 11.665 |
| **$K_2O$** | 3.770 | 3.454 | 3.108 | 3.507 | 3.400 | 3.091 | 6.372 | 5.523 | 4.969 | 6.417 | 5.520 | 5.018 |
| **$Li_2O$** | 4.175 | 4.091 | 3.987 | 4.727 | 4.683 | 4.685 | 4.313 | 4.333 | 4.225 | 3.899 | 3.897 | 3.898 |
| **MgO** | 1.400 | 1.397 | 1.389 | 1.507 | 1.507 | 1.536 | 1.388 | 1.426 | 1.418 | 1.307 | 1.331 | 1.357 |
| **MnO** | 2.115 | 2.050 | 2.097 | 1.896 | 1.834 | 1.927 | 1.896 | 1.888 | 1.932 | 2.414 | 2.363 | 2.484 |
| **$Na_2O$** | 8.799 | 7.970 | 8.047 | 8.312 | 7.815 | 7.969 | 8.671 | 7.997 | 8.074 | 9.112 | 8.307 | 8.470 |
| **NiO** | 1.392 | 1.207 | 1.362 | 1.021 | 0.914 | 1.058 | 1.021 | 0.925 | 1.044 | 1.299 | 1.175 | 1.360 |
| **$SiO_2$** | 47.266 | 50.274 | 48.567 | 53.114 | 54.606 | 52.825 | 48.526 | 48.830 | 47.172 | 44.140 | 45.621 | 44.133 |
| **$TiO_2$** | 2.197 | 2.118 | 2.184 | 2.197 | 2.131 | 2.260 | 2.197 | 2.160 | 2.227 | 2.197 | 2.127 | 2.256 |
| **$U_3O_8$** | 3.000 | 2.969 | 3.052 | 2.200 | 2.249 | 2.309 | 2.200 | 2.126 | 2.185 | 2.800 | 2.833 | 2.908 |
| **$ZrO_2$** | 0.195 | 0.186 | 0.246 | 0.143 | 0.119 | 0.167 | 0.143 | 0.118 | 0.156 | 0.182 | 0.159 | 0.223 |
| **Sum of Oxides** | 99.055 | 99.739 | 97.379 | 99.307 | 99.886 | 98.094 | 99.307 | 97.923 | 95.348 | 99.119 | 98.730 | 97.077 |

| Oxide | *pha15* Target | *pha15* Measured | *pha15* Measured Bias-cor. | *pha16* Target | *pha16* Measured | *pha16* Measured Bias-cor. | *pha17* Target | *pha17* Measured | *pha17* Measured Bias-cor. |
|---|---|---|---|---|---|---|---|---|---|
| **$Al_2O_3$** | 2.319 | 2.551 | 2.550 | 2.641 | 2.844 | 2.843 | 2.927 | 3.307 | 3.349 |
| **$B_2O_3$** | 8.157 | 7.816 | 7.516 | 7.841 | 7.768 | 7.470 | 9.392 | 7.317 | 7.036 |
| **CaO** | 0.924 | 1.026 | 0.970 | 1.092 | 1.089 | 1.029 | 1.029 | 1.082 | 1.049 |
| **$Cr_2O_3$** | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 | 0.000 | 0.007 | 0.008 |
| **CuO** | 0.628 | 0.620 | 0.628 | 0.535 | 0.560 | 0.567 | 1.140 | 1.153 | 1.190 |
| **$Fe_2O_3$** | 10.756 | 10.351 | 10.042 | 12.711 | 12.456 | 12.084 | 13.446 | 13.639 | 13.366 |
| **$K_2O$** | 3.164 | 3.075 | 2.766 | 3.297 | 3.126 | 2.812 | 5.795 | 3.192 | 2.902 |
| **$Li_2O$** | 4.727 | 4.596 | 4.480 | 4.451 | 4.500 | 4.386 | 3.761 | 4.021 | 3.919 |
| **MgO** | 1.507 | 1.548 | 1.539 | 1.453 | 1.531 | 1.522 | 1.280 | 1.379 | 1.405 |
| **MnO** | 1.551 | 1.569 | 1.605 | 1.833 | 1.885 | 1.928 | 2.586 | 2.673 | 2.809 |
| **$Na_2O$** | 7.619 | 7.202 | 7.271 | 7.814 | 7.171 | 7.241 | 8.238 | 7.037 | 7.175 |
| **NiO** | 0.836 | 0.760 | 0.858 | 0.988 | 0.911 | 1.028 | 1.392 | 1.292 | 1.495 |
| **$SiO_2$** | 52.979 | 55.194 | 53.320 | 50.031 | 52.413 | 50.633 | 42.678 | 48.936 | 47.340 |
| **$TiO_2$** | 2.197 | 2.127 | 2.193 | 2.197 | 2.164 | 2.231 | 2.197 | 2.239 | 2.375 |
| **$U_3O_8$** | 1.800 | 1.745 | 1.793 | 2.127 | 1.781 | 1.831 | 3.000 | 1.854 | 1.906 |
| **$ZrO_2$** | 0.143 | 0.120 | 0.159 | 0.169 | 0.174 | 0.230 | 0.195 | 0.187 | 0.261 |
| **Sum of Oxides** | 99.307 | 100.307 | 97.697 | 99.180 | 100.380 | 97.844 | 99.056 | 99.314 | 97.587 |

As stated earlier, two glasses for this study were repeats of glasses studied as part of the FY99 PHA work [3]. Table 5 provides the details of the chemical compositions of the glasses from the two studies. The two glasses for the current study are labeled FY01 pha01 and FY01 pha02. These glasses are repeats of pha12c and pha26, respectively, from the FY99 results.

The repeats are arranged together in Table 5, and they demonstrate good reproducibility between the two studies even though the FY01 sludge contribution to each glass was prepared individually from oxides in contrast to the FY99 approach where a large quantity of each sludge type was prepared for use in batching the glasses.

**Table 5: Target, Measured and Bias-Corrected Compositions (in wt%) for the FY01 and FY99 Repeated Glasses**

| Oxide | *FY01 pha01* | | | *FY99 pha12c* | | | *FY01 pha02* | | | *FY99 pha26* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. | Target | Measured | Measured Bias-cor. |
| $Al_2O_3$ | 2.856 | 2.924 | 2.962 | 2.858 | 2.705 | 2.707 | 7.040 | 6.916 | 6.914 | 7.048 | 6.453 | 6.457 |
| $B_2O_3$ | 9.247 | 8.831 | 8.491 | 9.219 | 9.283 | 9.297 | 8.520 | 8.404 | 8.179 | 8.488 | 8.365 | 8.373 |
| CaO | 0.992 | 1.055 | 1.023 | 1.081 | 1.159 | 0.999 | 0.470 | 0.561 | 0.530 | 0.562 | 0.660 | 0.531 |
| $Cr_2O_3$ | 0.000 | 0.007 | 0.008 | 0.125 | 0.146 | 0.146 | 0.000 | 0.007 | 0.008 | 0.086 | 0.120 | 0.120 |
| CuO | 1.033 | 1.035 | 1.069 | 1.023 | 0.991 | 0.985 | 0.790 | 0.757 | 0.767 | 0.764 | 0.691 | 0.687 |
| $Fe_2O_3$ | 11.613 | 11.541 | 11.311 | 11.680 | 11.348 | 10.842 | 7.450 | 7.270 | 7.053 | 7.507 | 7.348 | 7.020 |
| $K_2O$ | 6.180 | 5.306 | 4.824 | 6.125 | 5.397 | 5.661 | 4.750 | 4.204 | 3.782 | 4.736 | 4.445 | 4.662 |
| $Li_2O$ | 4.037 | 3.956 | 3.856 | 4.013 | 4.280 | 4.126 | 4.330 | 4.333 | 4.335 | 4.305 | 4.391 | 4.233 |
| MgO | 1.334 | 1.363 | 1.390 | 1.237 | 1.248 | 1.224 | 1.380 | 1.410 | 1.402 | 1.409 | 1.286 | 1.262 |
| MnO | 2.037 | 2.001 | 2.104 | 2.041 | 1.984 | 1.969 | 2.310 | 2.201 | 2.252 | 2.311 | 2.320 | 2.303 |
| $Na_2O$ | 8.503 | 7.926 | 8.082 | 8.487 | 8.510 | 8.289 | 8.000 | 7.845 | 7.921 | 7.980 | 7.952 | 7.745 |
| NiO | 1.097 | 0.984 | 1.138 | 1.099 | 0.980 | 0.940 | 0.400 | 0.350 | 0.395 | 0.397 | 0.377 | 0.362 |
| $SiO_2$ | 45.523 | 47.011 | 45.478 | 45.256 | 46.927 | 47.333 | 51.940 | 53.429 | 51.615 | 51.656 | 52.378 | 52.548 |
| $TiO_2$ | 2.197 | 2.156 | 2.287 | 2.222 | 2.222 | 2.143 | 1.100 | 1.053 | 1.086 | 1.125 | 1.173 | 1.131 |
| $U_3O_8$ | 2.363 | 2.291 | 2.354 | 2.367 | 2.328 | 2.328 | 0.800 | 0.828 | 0.850 | 0.800 | 0.954 | 0.954 |
| $ZrO_2$ | 0.169 | 0.158 | 0.221 | 0.129 | 0.155 | 0.125 | 0.130 | 0.111 | 0.147 | 0.141 | 0.171 | 0.138 |
| Sum of Oxides | 99.181 | 98.546 | 96.596 | 98.962 | 99.737 | 99.187 | 99.410 | 99.680 | 97.235 | 99.315 | 99.102 | 98.814 |

## PCT Results

Samples of the 17 PHA glasses, after being batched and fabricated (via quenching), were subjected to a second heat treatment – they were cooled to simulate a centerline canister cooling profile. Differences in glass durability for these two cooling regimes (quenched versus centerline cooled) are of primary interest to this study. The investigation into this question required durability to be measured for the quenched and centerline cooled versions of each of the study glasses.

The 7-day Product Consistency Test (PCT) was used as the assessment of glass durability [5]. More specifically, Method A of the PCT (ASTM C1285) was used for these measurements. The PCTs were conducted in triplicate for the PHA glasses. In addition, PCTs were also conducted in triplicate for samples of the Environmental Assessment (EA) glass, the Approved Reference Material (ARM) glass, and a blank (ASTM Type I water). An analytical plan [9] supporting these tests was provided in the form of a memorandum (see Attachment II). This plan assisted the SRTC-ML in measuring the compositions of the solutions resulting from these PCTs. Of primary interest were the concentrations (in parts per million, ppm) of boron (B), lithium (Li), sodium (Na), and silicon (Si). Samples of a multi-element solution standard were also included in the analytical plan (as a check on the accuracy of the Inductively Coupled Plasma (ICP) – Emission Spectrometer used for these measurements).

The results from these tests are given in Table A.3 of Appendix A. The PCT results for the centerline-cooled version of each PHA study glass are indicated by the "clc" suffix on the glass ID. One of the quality control checkpoints for the PCT procedure is solution-weight loss over the course of the 7-day test. The shaded entries of Table A3 indicate those solutions that fell outside the weight-loss guidelines (weight loss must be less than 5%). Two successful solutions out of the 3 conducted for a glass are required to generate a representative PCT for that glass [5]. Although this criterion is not met for all of the PHA study glasses, the results are believed to provide meaningful and representative comparisons for assessing the impact of the cooling regimes since the impact must be larger than the measurement variability to be of consequence.

Any measurement in the "as reported" columns of Table A.3 proceeded by a "<" was below the detection limit for the ICP, and the measurement was replaced by ½ of the detection limit in the determination of the parts per million (ppm) columns of the table. The values in the ppm columns were also adjusted for the dilution factors by multiplying the "as-reported" values by 1.6667 for the PHA and ARM glasses and by 16.6667 for the EA glass. Thus, the concentrations in the ppm columns reflect detection and dilution adjustments.

Exhibit A.8 in the Appendix provides pairs of plots of the leachate concentrations and standards in the analytical sequence reported by the SRTC-ML. For each element of interest, one plot includes the values from the EA PCTs and the blanks. These values expand the scales of these plots, making it difficult to distinguish among the results of the other analyses. The other plot excludes the EA and blank results.

Exhibit A.9 in the Appendix provides pairs of plots of the leachate concentrations for each type of submitted solution: the standards, the blanks, EA, ARM, and the PHA glasses. One plot includes EA and the blank the other does not.

PCT leachate concentrations are typically normalized using the corresponding cation concentration (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 concentrations will also be 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 will be 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 (where these values are provided in Table A.3 of Appendix A),

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.

As a preliminary step to completing these normalizations of the PCTs, statistical analyses were conducted of the results from the three analyses of the multi-element standard solution per analytical block. Exhibit A.10 in the Appendix provides these analyses. Although there appears to be statistical differences among the block averages, 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 blocks. Averaging the ppm's for each set of triplicates helps to minimize the impact of the ICP effects.

The block averages are presented in Table 6, and they indicate consistent and reasonably accurate results (differences of overall averages versus reference values $< 5\%$) from these analyses.

**Table 6: Measurements of Standard Solution**

| Analytical Block | Avg B (ppm) | Avg Li (ppm) | Avg Na (ppm) | Avg Si (ppm) |
|---|---|---|---|---|
| 1 | 21.1 | 9.4 | 80.9 | 51.0 |
| 2 | 19.2 | 9.5 | 80.6 | 48.3 |
| 3 | 20.3 | 9.7 | 82.6 | 51.6 |
| 4 | 19.6 | 9.7 | 80.0 | 48.5 |
| 5 | 19.2 | 9.3 | 79.7 | 47.3 |
| 6 | 20.2 | 9.9 | 85.2 | 51.4 |
| Grand Average | 19.9 | 9.6 | 81.5 | 49.7 |
| Reference Value | 20 | 10 | 81 | 50 |
| % difference | -0.3% | -4.3% | 0.6% | -0.6% |

Table 7 provides the results from the normalization process using the information in Table 4 and all of the data of Table A.3 (i.e., before screening the PCT results for solution-weight problems). Exhibit A.11 in Appendix A provides scatter plots for these results (both quenched and centerline cooled) offering an opportunity to investigate the consistency in the leaching across the elements for the glasses of this study. The consistency is typically demonstrated by a high degree of linear correlation among the values. PCT values normalized using targeted, measured, and bias-corrected compositions are investigated. A high degree of correlation is seen for these data for most pairs of elements. The smallest correlation (88%) is between B and Si for the PCTs normalized using the targeted compositions.

**Table 7: Normalized PCTs before Screening for Solution-Weight Problems**

| | | Quenched | | | | | | | | Centerline Cooled | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Glass ID | Composition | log NL [B(g/L)] | log NL [Li(g/L)] | log NL [Na(g/L)] | log NL [Si(g/L)] | NL B(g/L) | NL Li(g/L) | NL Na(g/L) | NL Si(g/L) | log NL [B(g/L)] | log NL [Li(g/L)] | log NL [Na(g/L)] | log NL [Si(g/L)] | NL B(g/L) | NL Li(g/L) | NL Na(g/L) | NL Si(g/L) |
| ARM | see [10] | -0.2997 | -0.2428 | -0.3010 | -0.5639 | 0.50 | 0.57 | 0.50 | 0.27 | | | | | | | | |
| EA | see [10] | 1.1941 | 0.9326 | 1.0925 | 0.5577 | 15.64 | 8.56 | 12.37 | 3.61 | | | | | | | | |
| | Meas. | 0.1157 | 0.0745 | 0.0951 | -0.2363 | 1.31 | 1.19 | 1.24 | 0.58 | 0.1225 | 0.0890 | 0.1079 | -0.2253 | 1.33 | 1.23 | 1.28 | 0.60 |
| pha01 | Meas. bc | 0.1328 | 0.0856 | 0.0866 | -0.2219 | 1.36 | 1.22 | 1.22 | 0.60 | 0.1395 | 0.1001 | 0.0995 | -0.2109 | 1.38 | 1.26 | 1.26 | 0.62 |
| | Target | 0.0957 | 0.0657 | 0.0646 | -0.2224 | 1.25 | 1.16 | 1.16 | 0.60 | 0.1025 | 0.0802 | 0.0774 | -0.2113 | 1.27 | 1.20 | 1.20 | 0.61 |
| | Meas. | -0.3407 | -0.2899 | -0.3282 | -0.5529 | 0.46 | 0.51 | 0.47 | 0.28 | -0.3556 | -0.3027 | -0.3400 | -0.5555 | 0.44 | 0.50 | 0.46 | 0.28 |
| pha02 | Meas. bc | -0.3289 | -0.2901 | -0.3324 | -0.5379 | 0.47 | 0.51 | 0.47 | 0.29 | -0.3438 | -0.3029 | -0.3442 | -0.5405 | 0.45 | 0.50 | 0.45 | 0.29 |
| | Target | -0.3467 | -0.2896 | -0.3367 | -0.5406 | 0.45 | 0.51 | 0.46 | 0.29 | -0.3615 | -0.3024 | -0.3485 | -0.5433 | 0.43 | 0.50 | 0.45 | 0.29 |
| | Meas. | -0.1017 | -0.1062 | -0.1023 | -0.4604 | 0.79 | 0.78 | 0.79 | 0.35 | -0.1806 | -0.1811 | -0.1919 | -0.4761 | 0.66 | 0.66 | 0.64 | 0.33 |
| pha03 | Meas. bc | -0.0899 | -0.1064 | -0.1108 | -0.4460 | 0.81 | 0.78 | 0.77 | 0.36 | -0.1688 | -0.1813 | -0.2003 | -0.4617 | 0.68 | 0.66 | 0.63 | 0.35 |
| | Target | -0.0981 | -0.1001 | -0.1262 | -0.4438 | 0.80 | 0.79 | 0.75 | 0.36 | -0.1770 | -0.1751 | -0.2157 | -0.4595 | 0.67 | 0.67 | 0.61 | 0.35 |
| | Meas. | -0.0157 | -0.0090 | -0.0187 | -0.3546 | 0.96 | 0.98 | 0.96 | 0.44 | -0.0933 | -0.0779 | -0.0884 | -0.3943 | 0.81 | 0.84 | 0.82 | 0.40 |
| pha04 | Meas. bc | 0.0013 | 0.0021 | -0.0228 | -0.3396 | 1.00 | 1.00 | 0.95 | 0.46 | -0.0763 | -0.0669 | -0.0925 | -0.3792 | 0.84 | 0.86 | 0.81 | 0.42 |
| | Target | -0.0194 | -0.0147 | -0.0357 | -0.3377 | 0.96 | 0.97 | 0.92 | 0.46 | -0.0971 | -0.0836 | -0.1054 | -0.3774 | 0.80 | 0.82 | 0.78 | 0.42 |
| | Meas. | 0.2204 | 0.1835 | 0.2032 | -0.1655 | 1.66 | 1.53 | 1.60 | 0.68 | 0.1615 | 0.1318 | 0.1551 | -0.1914 | 1.45 | 1.35 | 1.43 | 0.64 |
| pha05 | Meas. bc | 0.2322 | 0.1834 | 0.1948 | -0.1511 | 1.71 | 1.53 | 1.57 | 0.71 | 0.1733 | 0.1317 | 0.1467 | -0.1770 | 1.49 | 1.35 | 1.40 | 0.67 |
| | Target | 0.2089 | 0.1839 | 0.1711 | -0.1487 | 1.62 | 1.53 | 1.48 | 0.71 | 0.1501 | 0.1323 | 0.1230 | -0.1746 | 1.41 | 1.36 | 1.33 | 0.67 |
| | Meas. | 0.0297 | 0.0239 | 0.0748 | -0.2735 | 1.07 | 1.06 | 1.19 | 0.53 | 0.0165 | 0.0006 | 0.0424 | -0.2606 | 1.04 | 1.00 | 1.10 | 0.55 |
| pha06 | Meas. bc | 0.0415 | 0.0237 | 0.0664 | -0.2591 | 1.10 | 1.06 | 1.17 | 0.55 | 0.0283 | 0.0004 | 0.0340 | -0.2462 | 1.07 | 1.00 | 1.08 | 0.57 |
| | Target | 0.0426 | 0.0419 | 0.0432 | -0.2581 | 1.10 | 1.10 | 1.10 | 0.55 | 0.0294 | 0.0186 | 0.0109 | -0.2453 | 1.07 | 1.04 | 1.03 | 0.57 |
| | Meas. | 0.1116 | 0.1004 | 0.1163 | -0.2709 | 1.29 | 1.26 | 1.31 | 0.54 | 0.0640 | 0.0549 | 0.0772 | -0.2743 | 1.16 | 1.13 | 1.19 | 0.53 |
| pha07 | Meas. bc | 0.1234 | 0.1002 | 0.1079 | -0.2565 | 1.33 | 1.26 | 1.28 | 0.55 | 0.0758 | 0.0547 | 0.0688 | -0.2599 | 1.19 | 1.13 | 1.17 | 0.55 |
| | Target | 0.1270 | 0.1170 | 0.0978 | -0.2450 | 1.34 | 1.31 | 1.25 | 0.57 | 0.0794 | 0.0715 | 0.0587 | -0.2484 | 1.20 | 1.18 | 1.14 | 0.56 |
| | Meas. | 0.0506 | 0.0202 | 0.0320 | -0.3083 | 1.12 | 1.05 | 1.08 | 0.49 | 0.0132 | -0.0106 | -0.0011 | -0.3208 | 1.03 | 0.98 | 1.00 | 0.48 |
| pha08 | Meas. bc | 0.0624 | 0.0201 | 0.0278 | -0.2933 | 1.15 | 1.05 | 1.07 | 0.51 | 0.0250 | -0.0107 | -0.0053 | -0.3058 | 1.06 | 0.98 | 0.99 | 0.49 |
| | Target | 0.0555 | 0.0313 | 0.0124 | -0.2814 | 1.14 | 1.07 | 1.03 | 0.52 | 0.0181 | 0.0006 | -0.0206 | -0.2939 | 1.04 | 1.00 | 0.95 | 0.51 |
| | Meas. | 0.3415 | 0.2985 | 0.3460 | -0.0727 | 2.20 | 1.99 | 2.22 | 0.85 | 0.3935 | 0.3434 | 0.3941 | -0.0445 | 2.47 | 2.20 | 2.48 | 0.90 |
| pha09 | Meas. bc | 0.3585 | 0.3097 | 0.3376 | -0.0583 | 2.28 | 2.04 | 2.18 | 0.87 | 0.4106 | 0.3546 | 0.3857 | -0.0301 | 2.57 | 2.26 | 2.43 | 0.93 |
| | Target | 0.3213 | 0.2952 | 0.3138 | -0.0574 | 2.10 | 1.97 | 2.06 | 0.88 | 0.3734 | 0.3401 | 0.3619 | -0.0291 | 2.36 | 2.19 | 2.30 | 0.94 |
| | Meas. | -0.0486 | -0.0622 | -0.0530 | -0.2864 | 0.89 | 0.87 | 0.89 | 0.52 | -0.0557 | -0.0708 | -0.0674 | -0.2859 | 0.88 | 0.85 | 0.86 | 0.52 |
| pha10 | Meas. bc | -0.0368 | -0.0624 | -0.0571 | -0.2714 | 0.92 | 0.87 | 0.88 | 0.54 | -0.0439 | -0.0710 | -0.0716 | -0.2709 | 0.90 | 0.85 | 0.85 | 0.54 |
| | Target | -0.0504 | -0.0629 | -0.0765 | -0.2756 | 0.89 | 0.87 | 0.84 | 0.53 | -0.0575 | -0.0715 | -0.0910 | -0.2752 | 0.88 | 0.85 | 0.81 | 0.53 |
| | Meas. | -0.0144 | -0.0332 | -0.0012 | -0.2937 | 0.97 | 0.93 | 1.00 | 0.51 | -0.0193 | -0.0400 | -0.0169 | -0.2890 | 0.96 | 0.91 | 0.96 | 0.51 |
| pha11 | Meas. bc | 0.0026 | -0.0220 | -0.0053 | -0.2787 | 1.01 | 0.95 | 0.99 | 0.53 | -0.0023 | -0.0288 | -0.0210 | -0.2740 | 0.99 | 0.94 | 0.95 | 0.53 |
| | Target | -0.0249 | -0.0421 | -0.0441 | -0.2669 | 0.94 | 0.91 | 0.90 | 0.54 | -0.0299 | -0.0488 | -0.0598 | -0.2622 | 0.93 | 0.89 | 0.87 | 0.55 |
| | Meas. | 0.1006 | 0.0756 | 0.0825 | -0.1749 | 1.26 | 1.19 | 1.21 | 0.67 | 0.0400 | 0.0199 | 0.0313 | -0.2053 | 1.10 | 1.05 | 1.07 | 0.62 |
| pha12 | Meas. bc | 0.1124 | 0.0754 | 0.0740 | -0.1605 | 1.30 | 1.19 | 1.19 | 0.69 | 0.0518 | 0.0197 | 0.0228 | -0.1909 | 1.13 | 1.05 | 1.05 | 0.64 |
| | Target | 0.0980 | 0.0715 | 0.0557 | -0.1629 | 1.25 | 1.18 | 1.14 | 0.69 | 0.0375 | 0.0158 | 0.0045 | -0.1933 | 1.09 | 1.04 | 1.01 | 0.64 |
| | Meas. | 0.3667 | 0.3129 | 0.3480 | -0.0126 | 2.33 | 2.06 | 2.23 | 0.97 | 0.3498 | 0.3193 | 0.3523 | -0.0282 | 2.24 | 2.09 | 2.25 | 0.94 |
| pha13 | Meas. bc | 0.3836 | 0.3239 | 0.3438 | 0.0024 | 2.42 | 2.11 | 2.21 | 1.01 | 0.3668 | 0.3303 | 0.3481 | -0.0132 | 2.33 | 2.14 | 2.23 | 0.97 |
| | Target | 0.3582 | 0.3149 | 0.3128 | -0.0099 | 2.28 | 2.06 | 2.06 | 0.98 | 0.3414 | 0.3214 | 0.3171 | -0.0255 | 2.19 | 2.10 | 2.08 | 0.94 |
| | Meas. | 0.3589 | 0.3217 | 0.3676 | -0.0652 | 2.28 | 2.10 | 2.33 | 0.86 | 0.2404 | 0.2144 | 0.2619 | -0.1208 | 1.74 | 1.64 | 1.83 | 0.76 |
| pha14 | Meas. bc | 0.3707 | 0.3216 | 0.3592 | -0.0508 | 2.35 | 2.10 | 2.29 | 0.89 | 0.2522 | 0.2143 | 0.2534 | -0.1064 | 1.79 | 1.64 | 1.79 | 0.78 |
| | Target | 0.3561 | 0.3215 | 0.3275 | -0.0508 | 2.27 | 2.10 | 2.13 | 0.89 | 0.2377 | 0.2142 | 0.2217 | -0.1064 | 1.73 | 1.64 | 1.67 | 0.78 |
| | Meas. | 0.0039 | -0.0027 | -0.0252 | -0.2821 | 1.01 | 0.99 | 0.94 | 0.52 | -0.0287 | -0.0382 | -0.0564 | -0.2873 | 0.94 | 0.92 | 0.88 | 0.52 |
| pha15 | Meas. bc | 0.0209 | 0.0084 | -0.0293 | -0.2671 | 1.05 | 1.02 | 0.93 | 0.54 | -0.0117 | -0.0271 | -0.0605 | -0.2723 | 0.97 | 0.94 | 0.87 | 0.53 |
| | Target | -0.0146 | -0.0149 | -0.0496 | -0.2643 | 0.97 | 0.97 | 0.89 | 0.54 | -0.0473 | -0.0504 | -0.0808 | -0.2695 | 0.90 | 0.89 | 0.83 | 0.54 |
| | Meas. | -0.0200 | -0.0389 | -0.0539 | -0.2917 | 0.96 | 0.91 | 0.88 | 0.51 | -0.0429 | -0.0717 | -0.0842 | -0.2916 | 0.91 | 0.85 | 0.82 | 0.51 |
| pha16 | Meas. bc | -0.0030 | -0.0278 | -0.0581 | -0.2767 | 0.99 | 0.94 | 0.87 | 0.53 | -0.0259 | -0.0606 | -0.0884 | -0.2766 | 0.94 | 0.87 | 0.82 | 0.53 |
| | Target | -0.0240 | -0.0342 | -0.0912 | -0.2715 | 0.95 | 0.92 | 0.81 | 0.54 | -0.0470 | -0.0670 | -0.1215 | -0.2714 | 0.90 | 0.86 | 0.76 | 0.54 |
| | Meas. | 0.0237 | -0.0083 | -0.0203 | -0.3132 | 1.06 | 0.98 | 0.95 | 0.49 | -0.2297 | -0.2478 | -0.2682 | -0.4993 | 0.59 | 0.57 | 0.54 | 0.32 |
| pha17 | Meas. bc | 0.0407 | 0.0029 | -0.0288 | -0.2988 | 1.10 | 1.01 | 0.94 | 0.50 | -0.2127 | -0.2367 | -0.2766 | -0.4849 | 0.61 | 0.58 | 0.53 | 0.33 |
| | Target | -0.0847 | 0.0207 | -0.0888 | -0.2538 | 0.82 | 1.05 | 0.82 | 0.56 | -0.3381 | -0.2188 | -0.3366 | -0.4399 | 0.46 | 0.60 | 0.46 | 0.36 |

Table 8 provides the results from the normalization process using the information in Table 5 and the screened data of Table A.3 (i.e., after screening the PCT results for solution-weight problems). A valid PCT [5] for a glass requires that at least 2 of the 3 triplicates pass the solution-weight criterion. The glasses whose PCT results do not satisfy that criterion are shaded in Table 8. All of the other entries of Table 8 are deemed valid PCTs. Exhibit A.12 in Appendix A provides correlations and scatter plots for the screened results (including both quenched and centerline cooled PCTs) offering an opportunity to investigate the consistency in the leaching across the elements for the glasses of this study. Correlations and scatter plots of just the valid PCTs are also provided as part of this exhibit. The consistency is typically demonstrated by a high degree of linear correlation among the values. PCT values normalized using targeted, measured, and bias-corrected compositions are investigated. A high degree of correlation is seen for these data for most pairs of elements. The smallest correlation (94%) is between Na and Si for the screened PCTs normalized using the targeted compositions.

### Table 8: Normalized PCTs after Screening for Solution-Weight Problems[3]

| | | Quenched | | | | | | | | Centerline Cooled | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Glass ID | Composition | log NL [B(g/L)] | log NL [Li(g/L)] | log NL [Na(g/L)] | log NL [Si(g/L)] | NL B(g/L) | NL Li(g/L) | NL Na(g/L) | NL Si(g/L) | log NL [B(g/L)] | log NL [Li(g/L)] | log NL [Na(g/L)] | log NL [Si(g/L)] | NL B(g/L) | NL Si(g/L) | NL Na(g/L) | NL Li(g/L) |
| ARM | see [10] | -0.2997 | -0.2428 | -0.3010 | -0.5639 | 0.50 | 0.57 | 0.50 | 0.27 | | | | | | | | |
| EA | see [10] | 1.1970 | 0.9341 | 1.0951 | 0.5602 | 15.74 | 8.59 | 12.45 | 3.63 | | | | | | | | |
| pha01 | Meas. | 0.0953 | 0.0630 | 0.0840 | -0.2463 | 1.25 | 1.16 | 1.21 | 0.57 | 0.1110 | 0.0879 | 0.1105 | -0.2311 | 1.29 | 1.22 | 1.29 | 0.59 |
| | Meas. bc | 0.1123 | 0.0741 | 0.0756 | -0.2319 | 1.30 | 1.19 | 1.19 | 0.59 | 0.1281 | 0.0990 | 0.1020 | -0.2167 | 1.34 | 1.26 | 1.26 | 0.61 |
| | Target | 0.0753 | 0.0542 | 0.0535 | -0.2323 | 1.19 | 1.13 | 1.13 | 0.59 | 0.0910 | 0.0790 | 0.0800 | -0.2171 | 1.23 | 1.20 | 1.20 | 0.61 |
| pha02 | Meas. | -0.3407 | -0.2899 | -0.3282 | -0.5529 | 0.46 | 0.51 | 0.47 | 0.28 | -0.3556 | -0.3027 | -0.3400 | -0.5555 | 0.44 | 0.50 | 0.46 | 0.28 |
| | Meas. bc | -0.3289 | -0.2901 | -0.3324 | -0.5379 | 0.47 | 0.51 | 0.47 | 0.29 | -0.3438 | -0.3029 | -0.3442 | -0.5405 | 0.45 | 0.50 | 0.45 | 0.29 |
| | Target | -0.3467 | -0.2896 | -0.3367 | -0.5406 | 0.45 | 0.51 | 0.46 | 0.29 | -0.3615 | -0.3024 | -0.3485 | -0.5433 | 0.43 | 0.50 | 0.45 | 0.29 |
| pha03 | Meas. | -0.1017 | -0.1062 | -0.1023 | -0.4604 | 0.79 | 0.78 | 0.79 | 0.35 | -0.1976 | -0.1853 | -0.1932 | -0.4825 | 0.63 | 0.65 | 0.64 | 0.33 |
| | Meas. bc | -0.0899 | -0.1064 | -0.1108 | -0.4460 | 0.81 | 0.78 | 0.77 | 0.36 | -0.1858 | -0.1854 | -0.2016 | -0.4681 | 0.65 | 0.65 | 0.63 | 0.34 |
| | Target | -0.0981 | -0.1001 | -0.1262 | -0.4438 | 0.80 | 0.79 | 0.75 | 0.36 | -0.1940 | -0.1792 | -0.2170 | -0.4658 | 0.64 | 0.66 | 0.61 | 0.34 |
| pha04 | Meas. | -0.0410 | -0.0368 | -0.0497 | -0.3723 | 0.91 | 0.92 | 0.89 | 0.42 | -0.0890 | -0.0699 | -0.0831 | -0.3836 | 0.81 | 0.85 | 0.83 | 0.41 |
| | Meas. bc | -0.0240 | -0.0257 | -0.0538 | -0.3573 | 0.95 | 0.94 | 0.88 | 0.44 | -0.0720 | -0.0589 | -0.0872 | -0.3686 | 0.85 | 0.87 | 0.82 | 0.43 |
| | Target | -0.0448 | -0.0425 | -0.0667 | -0.3554 | 0.90 | 0.91 | 0.86 | 0.44 | -0.0927 | -0.0756 | -0.1001 | -0.3667 | 0.81 | 0.84 | 0.79 | 0.43 |
| pha05 | Meas. | 0.2149 | 0.1784 | 0.1914 | -0.1710 | 1.64 | 1.51 | 1.55 | 0.67 | 0.1698 | 0.1332 | 0.1591 | -0.1860 | 1.48 | 1.36 | 1.44 | 0.65 |
| | Meas. bc | 0.2266 | 0.1783 | 0.1830 | -0.1566 | 1.69 | 1.51 | 1.52 | 0.70 | 0.1816 | 0.1331 | 0.1506 | -0.1716 | 1.52 | 1.36 | 1.41 | 0.67 |
| | Target | 0.2034 | 0.1788 | 0.1594 | -0.1542 | 1.60 | 1.51 | 1.44 | 0.70 | 0.1584 | 0.1336 | 0.1270 | -0.1692 | 1.44 | 1.36 | 1.34 | 0.68 |
| pha06 | Meas. | 0.0240 | 0.0178 | 0.0629 | -0.2820 | 1.06 | 1.04 | 1.16 | 0.52 | 0.0336 | 0.0153 | 0.0598 | -0.2411 | 1.08 | 1.04 | 1.15 | 0.57 |
| | Meas. bc | 0.0358 | 0.0176 | 0.0545 | -0.2676 | 1.09 | 1.04 | 1.13 | 0.54 | 0.0454 | 0.0151 | 0.0514 | -0.2266 | 1.11 | 1.04 | 1.13 | 0.59 |
| | Target | 0.0369 | 0.0358 | 0.0313 | -0.2666 | 1.09 | 1.09 | 1.07 | 0.54 | 0.0465 | 0.0333 | 0.0283 | -0.2257 | 1.11 | 1.08 | 1.07 | 0.59 |
| pha07 | Meas. | 0.1116 | 0.1004 | 0.1163 | -0.2709 | 1.29 | 1.26 | 1.31 | 0.54 | 0.0361 | 0.0282 | 0.0465 | -0.3013 | 1.09 | 1.07 | 1.11 | 0.50 |
| | Meas. bc | 0.1234 | 0.1002 | 0.1079 | -0.2565 | 1.33 | 1.26 | 1.28 | 0.55 | 0.0479 | 0.0280 | 0.0380 | -0.2869 | 1.12 | 1.07 | 1.09 | 0.52 |
| | Target | 0.1270 | 0.1170 | 0.0978 | -0.2450 | 1.34 | 1.31 | 1.25 | 0.57 | 0.0515 | 0.0448 | 0.0280 | -0.2755 | 1.13 | 1.11 | 1.07 | 0.53 |
| pha08 | Meas. | 0.0506 | 0.0202 | 0.0320 | -0.3083 | 1.12 | 1.05 | 1.08 | 0.49 | . | . | . | . | | | | |
| | Meas. bc | 0.0624 | 0.0201 | 0.0278 | -0.2933 | 1.15 | 1.05 | 1.07 | 0.51 | . | . | . | . | | | | |
| | Target | 0.0555 | 0.0313 | 0.0124 | -0.2814 | 1.14 | 1.07 | 1.03 | 0.52 | . | . | . | . | | | | |
| pha09 | Meas. | . | . | . | . | | | | | 0.3586 | 0.3087 | 0.3579 | -0.0663 | 2.28 | 2.04 | 2.28 | 0.86 |
| | Meas. bc | . | . | . | . | | | | | 0.3757 | 0.3199 | 0.3495 | -0.0519 | 2.38 | 2.09 | 2.24 | 0.89 |
| | Target | . | . | . | . | | | | | 0.3384 | 0.3054 | 0.3257 | -0.0510 | 2.18 | 2.02 | 2.12 | 0.89 |
| pha10 | Meas. | -0.0486 | -0.0622 | -0.0530 | -0.2864 | 0.89 | 0.87 | 0.89 | 0.52 | -0.0570 | -0.0792 | -0.0827 | -0.2900 | 0.88 | 0.83 | 0.83 | 0.51 |
| | Meas. bc | -0.0368 | -0.0624 | -0.0571 | -0.2714 | 0.92 | 0.87 | 0.88 | 0.54 | -0.0452 | -0.0794 | -0.0869 | -0.2750 | 0.90 | 0.83 | 0.82 | 0.53 |
| | Target | -0.0504 | -0.0629 | -0.0765 | -0.2756 | 0.89 | 0.87 | 0.84 | 0.53 | -0.0588 | -0.0799 | -0.1063 | -0.2792 | 0.87 | 0.83 | 0.78 | 0.53 |
| pha11 | Meas. | -0.0079 | -0.0320 | -0.0056 | -0.2922 | 0.98 | 0.93 | 0.99 | 0.51 | -0.0420 | -0.0441 | -0.0184 | -0.3004 | 0.91 | 0.90 | 0.96 | 0.50 |
| | Meas. bc | 0.0091 | -0.0208 | -0.0097 | -0.2772 | 1.02 | 0.95 | 0.98 | 0.53 | -0.0251 | -0.0329 | -0.0226 | -0.2854 | 0.94 | 0.93 | 0.95 | 0.52 |
| | Target | -0.0185 | -0.0408 | -0.0485 | -0.2654 | 0.96 | 0.91 | 0.89 | 0.54 | -0.0526 | -0.0529 | -0.0614 | -0.2736 | 0.89 | 0.89 | 0.87 | 0.53 |
| pha12 | Meas. | 0.1199 | 0.0747 | 0.0767 | -0.1723 | 1.32 | 1.19 | 1.19 | 0.67 | 0.0400 | 0.0199 | 0.0313 | -0.2053 | 1.10 | 1.05 | 1.07 | 0.62 |
| | Meas. bc | 0.1317 | 0.0745 | 0.0682 | -0.1579 | 1.35 | 1.19 | 1.17 | 0.70 | 0.0518 | 0.0197 | 0.0228 | -0.1909 | 1.13 | 1.05 | 1.05 | 0.64 |
| | Target | 0.1173 | 0.0706 | 0.0499 | -0.1602 | 1.31 | 1.18 | 1.12 | 0.69 | 0.0375 | 0.0158 | 0.0045 | -0.1933 | 1.09 | 1.04 | 1.01 | 0.64 |
| pha13 | Meas. | 0.3667 | 0.3129 | 0.3480 | -0.0126 | 2.33 | 2.06 | 2.23 | 0.97 | 0.3498 | 0.3193 | 0.3523 | -0.0282 | 2.24 | 2.09 | 2.25 | 0.94 |
| | Meas. bc | 0.3836 | 0.3239 | 0.3438 | 0.0024 | 2.42 | 2.11 | 2.21 | 1.01 | 0.3668 | 0.3303 | 0.3481 | -0.0132 | 2.33 | 2.14 | 2.23 | 0.97 |
| | Target | 0.3582 | 0.3149 | 0.3128 | -0.0099 | 2.28 | 2.06 | 2.06 | 0.98 | 0.3414 | 0.3214 | 0.3171 | -0.0255 | 2.19 | 2.10 | 2.08 | 0.94 |
| pha14 | Meas. | 0.3223 | 0.2873 | 0.3332 | -0.0909 | 2.10 | 1.94 | 2.15 | 0.81 | 0.2038 | 0.1815 | 0.2296 | -0.1382 | 1.60 | 1.52 | 1.70 | 0.73 |
| | Meas. bc | 0.3341 | 0.2871 | 0.3248 | -0.0765 | 2.16 | 1.94 | 2.11 | 0.84 | 0.2156 | 0.1814 | 0.2211 | -0.1238 | 1.64 | 1.52 | 1.66 | 0.75 |
| | Target | 0.3195 | 0.2870 | 0.2931 | -0.0766 | 2.09 | 1.94 | 1.96 | 0.84 | 0.2010 | 0.1813 | 0.1894 | -0.1239 | 1.59 | 1.52 | 1.55 | 0.75 |
| pha15 | Meas. | 0.0054 | -0.0005 | -0.0204 | -0.2779 | 1.01 | 1.00 | 0.95 | 0.53 | -0.0287 | -0.0382 | -0.0564 | -0.2873 | 0.94 | 0.92 | 0.88 | 0.52 |
| | Meas. bc | 0.0224 | 0.0106 | -0.0246 | -0.2629 | 1.05 | 1.02 | 0.95 | 0.55 | -0.0117 | -0.0271 | -0.0605 | -0.2723 | 0.97 | 0.94 | 0.87 | 0.53 |
| | Target | -0.0132 | -0.0127 | -0.0449 | -0.2601 | 0.97 | 0.97 | 0.90 | 0.55 | -0.0473 | -0.0504 | -0.0808 | -0.2695 | 0.90 | 0.89 | 0.83 | 0.54 |
| pha16 | Meas. | -0.0200 | -0.0389 | -0.0539 | -0.2917 | 0.96 | 0.91 | 0.88 | 0.51 | -0.0429 | -0.0717 | -0.0842 | -0.2916 | 0.91 | 0.85 | 0.82 | 0.51 |
| | Meas. bc | -0.0030 | -0.0278 | -0.0581 | -0.2767 | 0.99 | 0.94 | 0.87 | 0.53 | -0.0259 | -0.0606 | -0.0884 | -0.2766 | 0.94 | 0.87 | 0.82 | 0.53 |
| | Target | -0.0240 | -0.0342 | -0.0912 | -0.2715 | 0.95 | 0.92 | 0.81 | 0.54 | -0.0470 | -0.0670 | -0.1215 | -0.2714 | 0.90 | 0.86 | 0.76 | 0.54 |
| pha17 | Meas. | 0.0237 | -0.0123 | -0.0275 | -0.3141 | 1.06 | 0.97 | 0.94 | 0.49 | -0.2297 | -0.2478 | -0.2682 | -0.4993 | 0.59 | 0.57 | 0.54 | 0.32 |
| | Meas. bc | 0.0407 | -0.0012 | -0.0360 | -0.2997 | 1.10 | 1.00 | 0.92 | 0.50 | -0.2127 | -0.2367 | -0.2766 | -0.4849 | 0.61 | 0.58 | 0.53 | 0.33 |
| | Target | -0.0847 | 0.0167 | -0.0960 | -0.2547 | 0.82 | 1.04 | 0.80 | 0.56 | -0.3381 | -0.2188 | -0.3366 | -0.4399 | 0.46 | 0.60 | 0.46 | 0.36 |

As seen in Tables 7 and 8, the durabilities for the PHA glasses are much better than that of EA. (This is indicated for each glass by its normalized leachate being much smaller than that of EA.) Figures 1-3 provide an opportunity for a closer look at just the valid PCTs using measured, bias-corrected, and targeted compositions. Each of these figures is a plot of the DWPF model that relates the logarithm of the normalized PCT (in this case for B) to a linear function of a free energy of hydration term ($\Delta G_p$, kcal/100g glass) derived from the glass (measured, bias-corrected, or targeted) compositions [10]. Prediction limits (at 95% confidence) for individual PCT results are also plotted around this linear fit. The PCT results for EA (shown as a diamond at $\Delta G_p \sim$ -15.5), ARM (shown as a diamond at

3 Shaded rows in this table indicate glasses whose PCTs would not be considered valid due to less than 2 good results out of the 3 triplicates conducted for that glass. Missing values indicate that none of the three PCTs for the indicated glass were considered valid.

$\Delta G_p$ slightly above -10), and the PHA glasses (quenched shown as small squares and centerline cooled shown as open circles) are presented on these plots. Note that the PHA results reveal acceptable PCTs and that the PCTs are well predicted by the current DWPF durability model for boron. (Most all of the PCT releases fall within the prediction interval for this model.) Exhibit A.13 in Appendix A repeats the plots of Figures 1-3, provides the same plots for Li, Na, and Si for the valid PCTs, and provides similar plots for B, Li, Na, and Si for the unscreened and screened PCTs. The behavior seen in these plots for B, Li, Na, and Si is similar to that demonstrated by the B results in Figures 1-3: acceptable and predictable (for almost all of the results) durabilities.

**Figure 1.**
**log NL[B (g/L)] By del Gp**
**(Valid PCTs & Measured Compositions)**

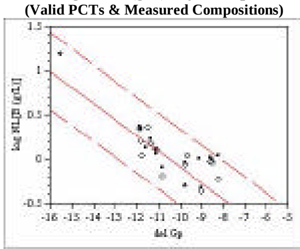


**Figure 2.**
**log NL[B (g/L)] By del Gp**
**(Valid PCTs & Bias-Corrected Compositions)**

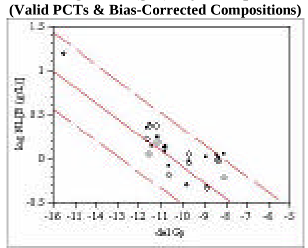
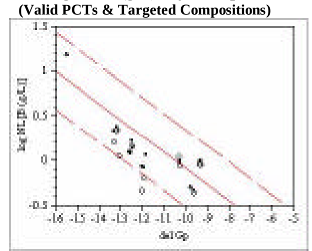


**Figure 3.**
**log NL[B (g/L)] By del Gp**
**(Valid PCTs & Targeted Compositions)**



A look at the reproducibility of the PCT results between this and the FY99 study is provided in Table 9. This table provides the normalized PCT results (in grams/liter) from [3] for the FY99 glasses of interest and from Tables 7 and 8 for the quenched versions of those glasses repeated in this study. Recall that only quenched glasses were studied in the FY99 work. Good reproducibility between the two studies is demonstrated by the results presented in Table 9.

**Table 9: Normalized PCTs for Glasses Common to the FY01 and FY99 Studies**

| Study & Glass ID | Composition Represented By | NL B(g/L) | NL Li(g/L) | NL Na(g/L) | NL Si(g/L) | Study & Glass ID | Composition | NL B(g/L) | NL Li(g/L) | NL Na(g/L) | NL Si(g/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FY01 | Measured | 1.25 | 1.16 | 1.21 | 0.57 | FY01 | Measured | 0.46 | 0.51 | 0.47 | 0.28 |
| pha01 | Measured bias-cor. | 1.30 | 1.19 | 1.19 | 0.59 | pha02 | Measured bias-cor. | 0.47 | 0.51 | 0.47 | 0.29 |
| | Targeted | 1.19 | 1.13 | 1.13 | 0.59 | | Targeted | 0.45 | 0.51 | 0.46 | 0.29 |
| FY99 | Measured | 1.50 | 1.42 | 1.43 | 0.63 | FY99 | Measured | 0.47 | 0.54 | 0.48 | 0.28 |
| pha12 | Measured bias-cor. | 1.50 | 1.47 | 1.47 | 0.63 | pha26 | Measured bias-cor. | 0.47 | 0.56 | 0.50 | 0.28 |
| | Targeted | 1.51 | 1.52 | 1.43 | 0.66 | | Targeted | 0.46 | 0.55 | 0.48 | 0.29 |

## Quenched versus Centerline-Cooled PCTs

A prime objective of this study was the investigation of potential cooling effects on the durability of the PHA glasses. Figures 1-3 and Exhibit A.13 provide a first look at differences in PCT response due to the cooling regime for the glasses. From those plots, there does not appear to be a lack of PCT predictability or acceptability due to cooling regime. A more rigorous comparison of the PCTs from quenched versus centerline cooled glasses is provided in this section.

Exhibit A.14 in Appendix A provides paired comparisons of the average common logarithm of the leachate concentrations in parts per million that were conducted using JMP® Version 4.0[4]. The data that are averaged are provided in Table A.3 of Appendix A. The exhibit investigates the unscreened, screened, and valid PCTs in turn. For boron (regardless of the PCT group: unscreened, screened, or

[4] JMP® Version 4.0 is a commercial software product of SAS Institute, Inc. in Cary, NC. This product was used to support the statistical analyses presented in this report. See JMP® Statistical Discovery Software: Statistics and Graphics Guide (2000) published by SAS Institute for details.

valid), there is a statistically significant difference (at the 5% significance level) between the quenched and centerline cooled results with the boron PCT releases from the quenched glasses being slightly higher than those from the centerline cooled glasses. In log space, the difference (on average) is less than 0.06, which is of no real, practical concern.

The lithium and sodium results mirror those for boron, with the average difference being less than 0.06 in log space for each of these elements. The results for silicon releases for the two heat treatments are not statistically different at the 5% level for either PCT group (unscreened, screened, or valid), and the average log silicon release differences are all less than 0.03 in log space.

Another look at quenched versus centerline cooled PCTs is provided in Figures 4-7 for the valid PCTs. The plots provide the same type of comparisons as provided in Exhibit A.14, only framed in a different manner. These plots provide quenched versus centerline cooled scatter plots with the x and y axes drawn to the same scale. If the PCT response is not affected by cooling regime, the quenched and centerline cooled pair for a given glass should fall along the diagonal line for each of these plots. The 3 other lines (all three show if there is no overlap at the diagonal) on each plot represent the average difference due to cooling regime along with upper and lower confidence (at 95%) limits for this average.

**Figure 4.**

**Special Linear Fit of log NL[B (g/L)] clc By log NL[B (g/L)] quenched**

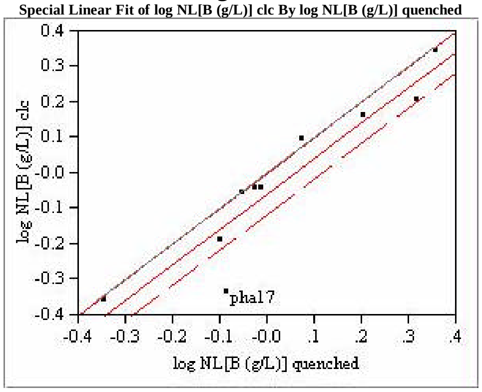



**Figure 5.**

**Special Linear Fit of log NL[Li (g/L)] clc By log NL[Li (g/L)] quenched**

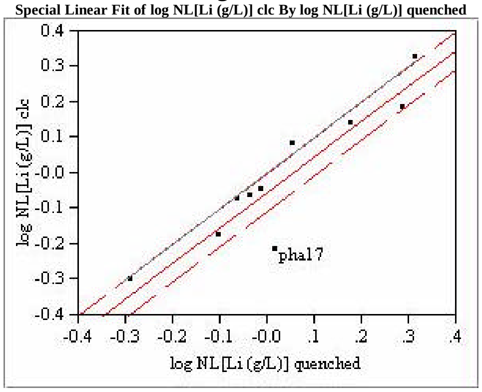



**Figure 6.**

**Special Linear Fit of log NL[Na (g/L)] clc By log NL[Li (g/L)] quenched**

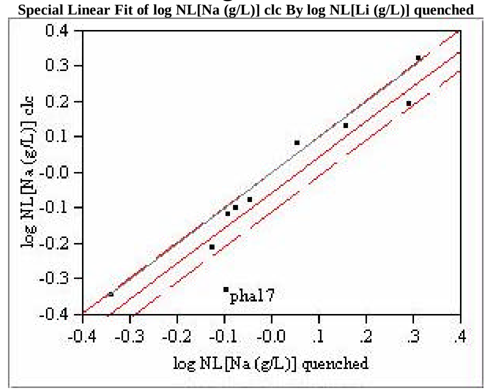
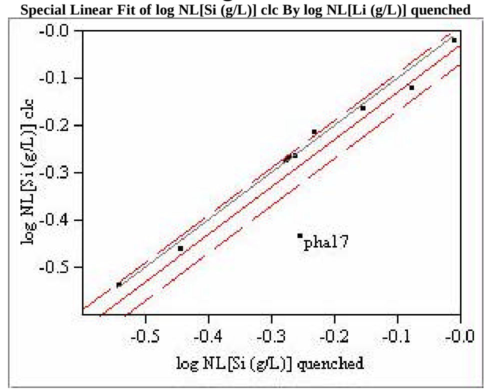



**Figure 7.**

**Special Linear Fit of log NL[Si (g/L)] clc By log NL[Li (g/L)] quenched**



The results for the pha17 glass have been labeled in these figures. This glass reveals the strongest impact of cooling on durability. It shows the clc version being more durable than the quenched version. More will be said regarding pha17 in the discussions that follow.

Overall, these results indicate no impact (of real importance) between the two cooling regimes (quenched and centerline cooled) for the PHA glasses of this study. What little effects that are seen appear to indicate that the quenched versions of the glasses are slightly less durable (on average) than the centerline cooled versions.

## Phase Separation

The formation of separate amorphous phases in glass is referred to as amorphous phase separation or inhomogeneity. Crystal formation may indicate a "separation of phases," but reflects crystalline particles within the glass matrix. Amorphous phase separation is to be avoided since the models currently used to predict durability do not apply for glasses predicted to be phase separated. The limit for the homogeneity constraint in the PCCS is nominally (for the Property Acceptance Region, PAR) a value of ~211 [4]. For the measurement acceptance region (MAR), the value will be even higher. In order for a glass to pass this constraint, the calculated value from chemical composition of the glass must be greater than the MAR value. The homogeneity values calculated using the targeted and measured, bias-corrected chemical compositions are all below the PAR value. Thus, all of these PHA glasses are predicted to be phase separated for these compositional views. The homogeneity values for the PHA glasses are given for all three compositional views in Table 10.

**Table 10: Homogeneity Property Predictions**

| | Homogeneity Property Prediction Based on - Acceptability Requires a Value > 211 - (Shaded Values are Acceptable) | | |
|---|---|---|---|
| Glass ID | Target Composition | Measured Composition | Bias-Corrected Composition |
| pha01 | 205.2 | 204.8 | 199.8 |
| pha02 | 208.8 | 208.7 | 203.5 |
| pha03 | 194.8 | 194.2 | 190.0 |
| pha04 | 196.5 | 197.4 | 191.3 |
| pha05 | 193.2 | 192.6 | 188.2 |
| pha06 | 210.8 | 213.0 | 208.3 |
| pha07 | 202.8 | 209.9 | 205.2 |
| pha08 | 210.3 | 214.7 | 208.6 |
| pha09 | 210.8 | 210.2 | 205.2 |
| pha10 | 204.6 | 205.1 | 199.4 |
| pha11 | 210.9 | 210.3 | 204.1 |
| pha12 | 194.0 | 195.1 | 190.7 |
| pha13 | 193.2 | 192.1 | 186.1 |
| pha14 | 203.8 | 203.9 | 199.2 |
| pha15 | 202.0 | 203.5 | 197.4 |
| pha16 | 210.6 | 212.8 | 206.4 |
| pha17 | 210.3 | 214.9 | 210.0 |

The homogeneity constraint was developed for a glass compositional region that included PHA. Therefore, the predictability of phase separation by this model should be valid. A significant search for amorphous phase separation in these glasses was beyond the scope of work for this task, except when routine SEM analysis was performed.

## XRD and SEM Analysis of the Glasses

None of the quenched glasses exhibited any visually apparent crystalline phases. However, several of the centerline-cooled glasses did have crystalline phases as observed visually. These glasses were submitted to ADS for X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) analyses. This section presents the results of these analyses.

The only glass that exhibited a significant crystalline presence in the glass matrix was pha17 (clc). The crystalline species identified by XRD in this glass was Trevorite ($NiFe_2O_4$). The clc pha17, a glass with 30 wt% sludge loading, also had another phase evident at the Trevorite crystal boundary. This phase consisted mainly of Cu. Therefore, it appears that a Cu phase precipitated out once the Trevorite crystals had formed for this glass. It is not clear if these results have any bearing on the pha17 durabilities shown in Figures 4-7, which indicate that the clc version of pha17 was more durable than the quenched version of this glass.

Crystals on the surface of several clc glasses were analyzed by SEM. Two of the glasses, pha04 and pha05, were at the low end of sludge loading (22 wt% oxide). The glass pha04 contained a blend type of sludge while pha05 contained a Purex type of sludge. These clc glasses had Spinel crystals that contained small amounts of Ti and Mn. In addition, both of these glasses contained phases that were high in K and Ti. These high K and Ti phases formed at the boundary of the smaller Spinel crystals. It appears that the Spinel crystals formed first and acted as a nucleating site for the appearance of the secondary phase. The secondary phase was much larger in size (20 to 50 microns in diameter) than the Spinel crystals (several microns in diameter). For the clc pha06, a glass with 28 wt% Purex loading, crystals of Trevorite were evident.

# CONCLUSIONS

The results showed that there was no practical difference between the PCT responses for glasses subjected to the two cooling profiles. In fact, although small, the centerline cooling glasses were generally more durable than the rapidly quenched glasses. These results reveal that no deleterious phase separation (amorphous or crystalline) occurred under either cooling regime.

X-ray diffraction and scanning electron microscopy were used to evaluate crystalline phases observed in the centerline cooled glasses. In one glass, pha17, a phase rich in copper was detected that had formed at the interface of Trevorite crystals. Trevorite crystals were also detected in several other glasses. A secondary phase precipitated out at the boundary of Trevorite crystals in glasses that had low sludge loadings (~22 wt% oxides in the glass) and high PHA (~13 wt% oxides in the glass). This phase was rich in potassium and titanium.

All of the glasses readily satisfied the requirement that the PCT responses be at least two standard deviations below the PCT response of the EA glass. Furthermore, the PCT responses were almost entirely within the prediction intervals of the DWPF durability model.

The results showed that there was no practical difference between the PCT responses for glasses subjected to the two cooling profiles. In fact, although to a small extent, the centerline-cooled (clc) glasses were generally more durable than the rapidly quenched glasses in this study. These results reveal that no deleterious phase separation (amorphous or crystalline) occurred under either cooling regime.

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# APPENDIX A.

## Supplemental Tables and Exhibits

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**Table A.1: SRTC-ML Measurements for Samples Prepared Using Lithium Metaborate Method**
(Values are in elemental weight percents, wt%'s.)

| Block | Sub-Block | Sequence (LM) | SRTC-ML ID (LM) | Glass ID (LM) | Al(v) | Ca(v) | Cr(v) | Cu(v) | Fe(v) | K(v) | Mg(v) | Mn(v) | Na(v) | Ni(v) | Si(v) | Ti(v) | Zr(v) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | stdlm111 | Batch 1 | 2.57 | 0.897 | 0.072 | 0.311 | 8.98 | 3.04 | 0.858 | 1.31 | 6.57 | 0.521 | 24.0 | 0.390 | 0.056 |
| 1 | 1 | 2 | t07lm11 | pha17 | 1.75 | 0.771 | <0.010 | 0.920 | 9.34 | 2.65 | 0.840 | 2.09 | 5.27 | 1.02 | 22.7 | 1.35 | 0.141 |
| 1 | 1 | 3 | t13lm21 | pha07 | 1.63 | 0.798 | <0.010 | 0.755 | 7.52 | 4.43 | 0.883 | 1.36 | 6.06 | <0.010 | 23.4 | 1.34 | 0.110 |
| 1 | 1 | 4 | t05lm21 | pha03 | 2.79 | 0.303 | <0.010 | 0.744 | 4.02 | 4.76 | 0.861 | 1.71 | 5.80 | 0.275 | 25.0 | 1.28 | 0.075 |
| 1 | 1 | 5 | t07lm21 | pha17 | 1.75 | 0.770 | <0.010 | 0.919 | 9.55 | 2.64 | 0.844 | 2.09 | 5.18 | 1.03 | 22.9 | 1.35 | 0.142 |
| 1 | 1 | 6 | t17lm11 | pha06 | 1.96 | 0.897 | <0.010 | 0.729 | 8.41 | 4.72 | 0.816 | 1.53 | 6.13 | 0.769 | 21.3 | 1.30 | 0.124 |
| 1 | 1 | 7 | ustdlm111 | Ustd | 2.06 | 0.912 | 0.163 | 0.006 | 8.89 | 2.37 | 0.715 | 2.05 | 7.58 | 0.743 | 21.3 | 0.561 | <0.010 |
| 1 | 1 | 8 | t14lm11 | pha01 | 1.54 | 0.741 | <0.010 | 0.816 | 8.04 | 4.40 | 0.829 | 1.54 | 5.88 | 0.789 | 22.0 | 1.3 | 0.107 |
| 1 | 1 | 9 | t06lm11 | pha14 | 1.46 | 0.754 | <0.010 | 0.917 | 8.31 | 4.54 | 0.816 | 1.85 | 6.16 | 0.938 | 21.4 | 1.29 | 0.124 |
| 1 | 1 | 10 | t01lm21 | pha05 | 1.43 | 0.625 | <0.010 | 1.01 | 5.94 | 4.05 | 0.852 | 1.47 | 5.91 | 0.709 | 23.6 | 1.24 | 0.092 |
| 1 | 1 | 11 | t14lm21 | pha01 | 1.54 | 0.748 | <0.010 | 0.828 | 8.11 | 4.37 | 0.825 | 1.57 | 5.84 | 0.762 | 22.1 | 1.29 | 0.131 |
| 1 | 1 | 12 | stdlm112 | Batch 1 | 2.52 | 0.886 | 0.070 | 0.306 | 9.28 | 3.03 | 0.848 | 1.28 | 6.50 | 0.512 | 24.4 | 0.386 | 0.055 |
| 1 | 1 | 13 | t06lm21 | pha14 | 1.43 | 0.749 | <0.010 | 0.905 | 8.32 | 4.66 | 0.805 | 1.84 | 6.25 | 0.920 | 21.4 | 1.27 | 0.119 |
| 1 | 1 | 14 | t04lm11 | pha09 | 1.58 | 0.864 | <0.010 | 0.714 | 8.84 | 4.63 | 0.788 | 1.49 | 6.15 | 0.758 | 21.3 | 1.26 | 0.118 |
| 1 | 1 | 15 | t05lm11 | pha03 | 2.77 | 0.301 | <0.010 | 0.726 | 4.07 | 4.85 | 0.838 | 1.64 | 5.80 | 0.272 | 25.0 | 1.27 | 0.076 |
| 1 | 1 | 16 | t16lm11 | pha12 | 1.25 | 0.606 | <0.010 | 0.502 | 6.45 | 2.85 | 0.909 | 1.43 | 5.84 | 0.717 | 25.5 | 1.28 | 0.091 |
| 1 | 1 | 17 | ustdlm112 | Ustd | 2.06 | 0.923 | 0.160 | 0.008 | 9.4 | 2.38 | 0.698 | 2.02 | 7.57 | 0.728 | 22.2 | 0.554 | <0.010 |
| 1 | 1 | 18 | t01lm11 | pha05 | 1.43 | 0.632 | <0.010 | 1.00 | 6.02 | 4.07 | 0.839 | 1.43 | 5.92 | 0.696 | 23.8 | 1.23 | 0.097 |
| 1 | 1 | 19 | t16lm21 | pha12 | 1.23 | 0.597 | <0.010 | 0.507 | 6.39 | 2.80 | 0.905 | 1.41 | 5.77 | 0.716 | 25.7 | 1.27 | 0.090 |
| 1 | 1 | 20 | t13lm11 | pha07 | 1.62 | 0.800 | <0.010 | 0.754 | 7.54 | 4.45 | 0.857 | 1.30 | 6.05 | <0.010 | 23.4 | 1.32 | 0.106 |
| 1 | 1 | 21 | t17lm21 | pha06 | 1.98 | 0.918 | <0.010 | 0.711 | 8.39 | 5.05 | 0.770 | 1.44 | 6.25 | 0.722 | 21.5 | 1.25 | 0.120 |
| 1 | 1 | 22 | t04lm21 | pha09 | 1.58 | 0.875 | <0.010 | 0.724 | 8.79 | 4.71 | 0.769 | 1.47 | 6.22 | 0.742 | 21.4 | 1.24 | 0.115 |
| 1 | 1 | 23 | stdlm113 | Batch 1 | 2.55 | 0.907 | 0.068 | 0.308 | 9.08 | 3.07 | 0.817 | 1.24 | 6.62 | 0.497 | 24.2 | 0.38 | 0.054 |
| 1 | 2 | 1 | stdlm121 | Batch 1 | 2.57 | 0.906 | 0.065 | 0.311 | 9.13 | 3.06 | 0.842 | 1.27 | 6.60 | 0.513 | 24.1 | 0.383 | 0.050 |
| 1 | 2 | 2 | t14lm22 | pha01 | 1.56 | 0.768 | <0.010 | 0.842 | 8.08 | 4.44 | 0.818 | 1.55 | 5.91 | 0.757 | 22.0 | 1.29 | 0.127 |
| 1 | 2 | 3 | t14lm12 | pha01 | 1.55 | 0.759 | <0.010 | 0.822 | 8.06 | 4.41 | 0.817 | 1.54 | 5.89 | 0.784 | 21.8 | 1.29 | 0.102 |
| 1 | 2 | 4 | t16lm12 | pha12 | 1.26 | 0.611 | <0.010 | 0.508 | 6.37 | 2.86 | 0.917 | 1.43 | 5.83 | 0.725 | 25.3 | 1.29 | 0.087 |
| 1 | 2 | 5 | t04lm22 | pha09 | 1.59 | 0.885 | <0.010 | 0.731 | 8.91 | 4.72 | 0.789 | 1.50 | 6.16 | 0.757 | 21.5 | 1.26 | 0.111 |
| 1 | 2 | 6 | t01lm12 | pha05 | 1.44 | 0.643 | <0.010 | 1.02 | 5.95 | 4.07 | 0.843 | 1.43 | 5.92 | 0.700 | 23.4 | 1.24 | 0.095 |
| 1 | 2 | 7 | ustdlm121 | Ustd | 2.06 | 0.930 | 0.155 | 0.005 | 9.34 | 2.41 | 0.701 | 2.01 | 7.60 | 0.729 | 22.1 | 0.554 | <0.010 |
| 1 | 2 | 8 | t05lm22 | pha03 | 2.81 | 0.306 | <0.010 | 0.747 | 4.08 | 4.76 | 0.840 | 1.64 | 5.74 | 0.267 | 25.1 | 1.27 | 0.068 |
| 1 | 2 | 9 | t13lm12 | pha07 | 1.65 | 0.809 | <0.010 | 0.762 | 7.57 | 4.46 | 0.864 | 1.32 | 6.07 | <0.010 | 23.2 | 1.33 | 0.102 |
| 1 | 2 | 10 | t07lm12 | pha17 | 1.75 | 0.777 | <0.010 | 0.922 | 9.6 | 2.66 | 0.820 | 2.05 | 5.28 | 1.00 | 23.0 | 1.33 | 0.134 |
| 1 | 2 | 11 | t07lm22 | pha17 | 1.75 | 0.775 | <0.010 | 0.922 | 9.67 | 2.65 | 0.822 | 2.05 | 5.15 | 1.01 | 22.9 | 1.34 | 0.136 |
| 1 | 2 | 12 | stdlm122 | Batch 1 | 2.56 | 0.907 | 0.064 | 0.310 | 9.3 | 3.04 | 0.838 | 1.26 | 6.53 | 0.509 | 24.6 | 0.38 | 0.051 |
| 1 | 2 | 13 | t17lm12 | pha06 | 1.96 | 0.900 | <0.010 | 0.728 | 8.43 | 4.70 | 0.795 | 1.47 | 6.03 | 0.752 | 21.3 | 1.27 | 0.117 |
| 1 | 2 | 14 | t16lm22 | pha12 | 1.24 | 0.600 | <0.010 | 0.509 | 6.46 | 2.78 | 0.905 | 1.41 | 5.75 | 0.716 | 25.6 | 1.27 | 0.085 |
| 1 | 2 | 15 | t06lm22 | pha14 | 1.43 | 0.759 | <0.010 | 0.908 | 8.3 | 4.63 | 0.789 | 1.80 | 6.13 | 0.912 | 21.2 | 1.26 | 0.112 |
| 1 | 2 | 16 | t01lm22 | pha05 | 1.43 | 0.634 | <0.010 | 1.01 | 6 | 4.07 | 0.830 | 1.41 | 5.86 | 0.690 | 23.5 | 1.22 | 0.085 |
| 1 | 2 | 17 | ustdlm122 | Ustd | 2.06 | 0.933 | 0.154 | 0.007 | 9.37 | 2.40 | 0.692 | 1.99 | 7.57 | 0.724 | 22.2 | 0.547 | <0.010 |
| 1 | 2 | 18 | t06lm12 | pha14 | 1.44 | 0.752 | <0.010 | 0.911 | 8.37 | 4.50 | 0.801 | 1.83 | 6.11 | 0.923 | 21.3 | 1.28 | 0.117 |
| 1 | 2 | 19 | t17lm22 | pha06 | 1.98 | 0.920 | <0.010 | 0.713 | 8.46 | 4.99 | 0.780 | 1.46 | 6.22 | 0.728 | 21.4 | 1.25 | 0.115 |
| 1 | 2 | 20 | t04lm12 | pha09 | 1.57 | 0.866 | <0.010 | 0.715 | 8.85 | 4.59 | 0.783 | 1.48 | 6.06 | 0.753 | 21.3 | 1.25 | 0.113 |
| 1 | 2 | 21 | t05lm12 | pha03 | 2.77 | 0.299 | <0.010 | 0.724 | 4.09 | 4.81 | 0.829 | 1.62 | 5.75 | 0.270 | 24.9 | 1.26 | 0.070 |
| 1 | 2 | 22 | t13lm22 | pha07 | 1.63 | 0.806 | <0.010 | 0.753 | 7.6 | 4.43 | 0.853 | 1.32 | 6.08 | <0.010 | 23.4 | 1.31 | 0.101 |
| 1 | 2 | 23 | stdlm123 | Batch 1 | 2.52 | 0.892 | 0.063 | 0.306 | 9.21 | 2.99 | 0.834 | 1.27 | 6.48 | 0.508 | 24.3 | 0.377 | 0.046 |
| 2 | 1 | 1 | stdlm211 | Batch 1 | 2.57 | 0.921 | 0.069 | 0.313 | 9.19 | 3.06 | 0.841 | 1.28 | 6.62 | 0.514 | 24.2 | 0.391 | 0.058 |
| 2 | 1 | 2 | t08lm11 | pha13 | 1.32 | 0.615 | <0.010 | 0.899 | 6.43 | 4.59 | 0.847 | 1.45 | 6.03 | 0.724 | 23.3 | 1.29 | 0.090 |

**Table A1: SRTC-ML Measurements for Samples Prepared Using Lithium Metaborate Method – (continued)**
(Values are in elemental weight percents, wt%'s.)

| Block | Sub-Block | Sequence (LM) | SRTC-ML ID (LM) | Glass ID (LM) | Al(v) | Ca(v) | Cr(v) | Cu(v) | Fe(v) | K(v) | Mg(v) | Mn(v) | Na(v) | Ni(v) | Si(v) | Ti(v) | Zr(v) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 3 | t11lm21 | pha02 | 3.65 | 0.400 | <0.010 | 0.598 | 5.05 | 3.52 | 0.835 | 1.64 | 5.84 | 0.273 | 24.8 | 0.624 | 0.084 |
| 2 | 1 | 4 | t03lm21 | pha04 | 1.93 | 0.642 | <0.010 | 0.752 | 5.76 | 4.81 | 0.829 | 1.66 | 5.06 | 0.603 | 24.2 | 1.27 | 0.094 |
| 2 | 1 | 5 | t02lm21 | pha11 | 1.88 | 0.958 | <0.010 | 0.451 | 8.5 | 2.95 | 0.852 | 1.62 | 6.09 | 0.966 | 22.8 | 1.30 | 0.144 |
| 2 | 1 | 6 | t12lm21 | pha16 | 1.50 | 0.781 | <0.010 | 0.447 | 8.6 | 2.62 | 0.904 | 1.44 | 5.35 | 0.705 | 24.5 | 1.29 | 0.130 |
| 2 | 1 | 7 | ustdlm211 | Ustd | 2.09 | 0.946 | 0.161 | 0.008 | 9.33 | 2.43 | 0.707 | 2.05 | 7.67 | 0.739 | 22.1 | 0.566 | <0.010 |
| 2 | 1 | 8 | t10lm21 | pha08 | 1.88 | 0.836 | <0.010 | 1.01 | 8.89 | 4.42 | 0.796 | 2.02 | 5.82 | 0.650 | 21.1 | 1.31 | 0.136 |
| 2 | 1 | 9 | t10lm11 | pha08 | 1.89 | 0.836 | <0.010 | 1.02 | 8.93 | 4.47 | 0.803 | 2.03 | 5.88 | 0.651 | 21.2 | 1.32 | 0.138 |
| 2 | 1 | 10 | t08lm21 | pha13 | 1.32 | 0.618 | <0.010 | 0.896 | 6.37 | 4.65 | 0.840 | 1.44 | 5.94 | 0.716 | 22.3 | 1.28 | 0.089 |
| 2 | 1 | 11 | t12lm11 | pha16 | 1.52 | 0.783 | <0.010 | 0.449 | 8.73 | 2.62 | 0.905 | 1.43 | 5.35 | 0.714 | 24.4 | 1.29 | 0.131 |
| 2 | 1 | 12 | stdlm212 | Batch 1 | 2.58 | 0.928 | 0.068 | 0.314 | 9.33 | 3.09 | 0.845 | 1.29 | 6.62 | 0.522 | 24.2 | 0.394 | 0.056 |
| 2 | 1 | 13 | t15lm11 | pha15 | 1.36 | 0.735 | <0.010 | 0.498 | 7.19 | 2.58 | 0.930 | 1.21 | 5.41 | 0.596 | 25.2 | 1.28 | 0.097 |
| 2 | 1 | 14 | t02lm11 | pha11 | 1.77 | 0.920 | <0.010 | 0.429 | 8.02 | 2.82 | 0.814 | 1.54 | 5.82 | 0.926 | 23.6 | 1.24 | 0.136 |
| 2 | 1 | 15 | t15lm21 | pha15 | 1.34 | 0.734 | <0.010 | 0.493 | 7.11 | 2.55 | 0.916 | 1.20 | 5.30 | 0.597 | 26.1 | 1.26 | 0.086 |
| 2 | 1 | 16 | t03lm11 | pha04 | 1.96 | 0.652 | <0.010 | 0.759 | 5.76 | 4.85 | 0.852 | 1.68 | 5.09 | 0.614 | 24.3 | 1.29 | 0.092 |
| 2 | 1 | 17 | ustdlm212 | Ustd | 2.10 | 0.948 | 0.162 | 0.007 | 9.31 | 2.44 | 0.716 | 2.06 | 7.69 | 0.749 | 22.3 | 0.572 | <0.010 |
| 2 | 1 | 18 | t09lm11 | pha10 | 1.77 | 0.766 | 0.011 | 0.531 | 7.73 | 2.88 | 0.885 | 1.89 | 6.14 | 0.923 | 22.9 | 1.30 | 0.140 |
| 2 | 1 | 19 | t09lm21 | pha10 | 1.78 | 0.765 | <0.010 | 0.532 | 7.78 | 2.86 | 0.890 | 1.84 | 6.21 | 0.929 | 23.7 | 1.31 | 0.122 |
| 2 | 1 | 20 | t11lm11 | pha02 | 3.72 | 0.409 | <0.010 | 0.617 | 5.19 | 3.54 | 0.851 | 1.74 | 5.91 | 0.277 | 25.4 | 0.642 | 0.086 |
| 2 | 1 | 21 | stdlm213 | Batch 1 | 2.62 | 0.938 | 0.069 | 0.317 | 9.27 | 3.15 | 0.849 | 1.30 | 6.75 | 0.520 | 24.5 | 0.395 | 0.058 |
| 2 | 2 | 1 | stdlm221 | Batch 1 | 2.56 | 0.913 | 0.067 | 0.312 | 9.13 | 3.03 | 0.861 | 1.30 | 6.52 | 0.517 | 24.1 | 0.389 | 0.053 |
| 2 | 2 | 2 | t11lm12 | pha02 | 3.64 | 0.396 | <0.010 | 0.605 | 5.09 | 3.43 | 0.858 | 1.73 | 5.75 | 0.275 | 25.0 | 0.631 | 0.080 |
| 2 | 2 | 3 | t02lm12 | pha11 | 1.74 | 0.904 | <0.010 | 0.426 | 8.04 | 2.77 | 0.826 | 1.55 | 5.74 | 0.920 | 24.6 | 1.23 | 0.130 |
| 2 | 2 | 4 | t03lm12 | pha04 | 1.93 | 0.639 | <0.010 | 0.750 | 5.75 | 4.75 | 0.857 | 1.66 | 4.99 | 0.611 | 24.5 | 1.28 | 0.086 |
| 2 | 2 | 5 | t08lm12 | pha13 | 1.31 | 0.605 | <0.010 | 0.895 | 6.48 | 4.52 | 0.878 | 1.48 | 5.89 | 0.737 | 23.3 | 1.31 | 0.085 |
| 2 | 2 | 6 | t11lm22 | pha02 | 3.63 | 0.398 | <0.010 | 0.599 | 5.01 | 3.47 | 0.858 | 1.71 | 5.78 | 0.276 | 24.7 | 0.629 | 0.079 |
| 2 | 2 | 7 | ustdlm221 | Ustd | 2.07 | 0.943 | 0.163 | 0.009 | 9.31 | 2.40 | 0.731 | 2.09 | 7.56 | 0.755 | 22.1 | 0.570 | <0.010 |
| 2 | 2 | 8 | t15lm12 | pha15 | 1.36 | 0.735 | <0.010 | 0.496 | 7.51 | 2.55 | 0.941 | 1.22 | 5.38 | 0.596 | 25.2 | 1.29 | 0.091 |
| 2 | 2 | 9 | t12lm22 | pha16 | 1.49 | 0.775 | <0.010 | 0.446 | 8.59 | 2.58 | 0.939 | 1.48 | 5.32 | 0.719 | 24.5 | 1.30 | 0.126 |
| 2 | 2 | 10 | t10lm22 | pha08 | 1.88 | 0.826 | <0.010 | 1.00 | 9.01 | 4.36 | 0.819 | 2.03 | 5.77 | 0.657 | 21.2 | 1.33 | 0.133 |
| 2 | 2 | 11 | t08lm22 | pha13 | 1.31 | 0.609 | <0.010 | 0.896 | 6.46 | 4.58 | 0.875 | 1.48 | 5.87 | 0.731 | 22.4 | 1.30 | 0.085 |
| 2 | 2 | 12 | stdlm222 | Batch 1 | 2.58 | 0.917 | 0.068 | 0.314 | 9.24 | 3.04 | 0.878 | 1.32 | 6.58 | 0.527 | 24.3 | 0.394 | 0.054 |
| 2 | 2 | 13 | t15lm22 | pha15 | 1.34 | 0.730 | <0.010 | 0.493 | 7.15 | 2.53 | 0.947 | 1.23 | 5.28 | 0.600 | 26.7 | 1.27 | 0.082 |
| 2 | 2 | 14 | t02lm22 | pha11 | 1.88 | 0.961 | <0.010 | 0.455 | 8.63 | 2.93 | 0.879 | 1.64 | 6.00 | 0.982 | 23.0 | 1.31 | 0.141 |
| 2 | 2 | 15 | t12lm12 | pha16 | 1.51 | 0.774 | <0.010 | 0.447 | 8.93 | 2.56 | 0.945 | 1.49 | 5.26 | 0.727 | 24.6 | 1.31 | 0.128 |
| 2 | 2 | 16 | t03lm22 | pha04 | 1.94 | 0.635 | <0.010 | 0.758 | 5.83 | 4.77 | 0.871 | 1.69 | 5.04 | 0.623 | 24.4 | 1.29 | 0.091 |
| 2 | 2 | 17 | ustdlm222 | Ustd | 2.10 | 0.944 | 0.165 | 0.009 | 9.35 | 2.40 | 0.743 | 2.11 | 7.65 | 0.764 | 22.1 | 0.578 | <0.010 |
| 2 | 2 | 18 | t09lm12 | pha10 | 1.76 | 0.756 | <0.010 | 0.531 | 7.81 | 2.87 | 0.916 | 1.88 | 6.09 | 0.932 | 23.0 | 1.31 | 0.136 |
| 2 | 2 | 19 | t09lm22 | pha10 | 1.75 | 0.755 | <0.010 | 0.530 | 7.85 | 2.81 | 0.920 | 1.89 | 6.16 | 0.943 | 23.8 | 1.33 | 0.118 |
| 2 | 2 | 20 | t10lm12 | pha08 | 1.90 | 0.832 | <0.010 | 1.02 | 9.14 | 4.41 | 0.841 | 2.12 | 5.90 | 0.675 | 21.4 | 1.36 | 0.136 |
| 2 | 2 | 21 | stdlm223 | Batch 1 | 2.58 | 0.921 | 0.070 | 0.317 | 9.38 | 3.05 | 0.891 | 1.35 | 6.60 | 0.538 | 24.5 | 0.399 | 0.051 |

**Table A2: SRTC-ML Measurements for Samples Prepared Using the Peroxide Fusion Method**
(Values are in elemental weight percents, wt%'s.)

| Block | Sub-Block | Sequence | SRTC-ML ID (pf) | Glass ID | B(v) | Li(v) | U(v) | Block | Sub-Block | Sequence | SRTC-ML ID (pf) | Glass ID | B(v) | Li(v) | U(v) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | stdpf111 | Batch 1 | 2.47 | 1.97 | <0.100 | 1 | 2 | 22 | t11pf12 | pha02 | 2.49 | 1.96 | 0.705 |
| 1 | 1 | 2 | t05pf11 | pha03 | 2.97 | 2.10 | 0.659 | 1 | 2 | 23 | stdpf123 | Batch 1 | 2.52 | 2.13 | <0.100 |
| 1 | 1 | 3 | t11pf21 | pha02 | 2.83 | 2.14 | 0.734 | 2 | 1 | 1 | stdpf211 | Batch 1 | 2.57 | 2.13 | <0.100 |
| 1 | 1 | 4 | t17pf21 | pha06 | 2.98 | 2.04 | 2.19 | 2 | 1 | 2 | t08pf21 | pha13 | 2.79 | 2.00 | 1.83 |
| 1 | 1 | 5 | t13pf11 | pha07 | 3.30 | 2.07 | <0.100 | 2 | 1 | 3 | t15pf11 | pha15 | 2.52 | 2.21 | 1.55 |
| 1 | 1 | 6 | t16pf21 | pha12 | 2.44 | 2.22 | 1.91 | 2 | 1 | 4 | t03pf11 | pha04 | 2.85 | 2.02 | 1.21 |
| 1 | 1 | 7 | ustdpf111 | Ustd | 2.95 | 1.44 | 2.02 | 2 | 1 | 5 | t07pf21 | pha17 | 2.33 | 1.93 | 1.63 |
| 1 | 1 | 8 | t17pf11 | pha06 | 2.78 | 1.87 | 1.98 | 2 | 1 | 6 | t02pf21 | pha11 | 2.19 | 1.99 | 2.61 |
| 1 | 1 | 9 | t01pf21 | pha05 | 3.11 | 2.02 | 1.87 | 2 | 1 | 7 | ustdpf211 | Ustd | 2.96 | 1.47 | 2.07 |
| 1 | 1 | 10 | t05pf21 | pha03 | 2.96 | 2.09 | 0.638 | 2 | 1 | 8 | t04pf11 | pha09 | 2.64 | 1.84 | 1.93 |
| 1 | 1 | 11 | t09pf21 | pha10 | 2.32 | 2.08 | 2.50 | 2 | 1 | 9 | t14pf11 | pha01 | 2.84 | 1.89 | 2.03 |
| 1 | 1 | 12 | stdpf112 | Batch 1 | 2.51 | 2.10 | <0.100 | 2 | 1 | 10 | t02pf11 | pha11 | 2.16 | 1.94 | 2.57 |
| 1 | 1 | 13 | t06pf21 | pha14 | 2.75 | 1.86 | 2.46 | 2 | 1 | 11 | t15pf21 | pha15 | 2.50 | 2.24 | 1.57 |
| 1 | 1 | 14 | t16pf11 | pha12 | 2.47 | 2.27 | 1.99 | 2 | 1 | 12 | stdpf212 | Batch 1 | 2.49 | 2.15 | <0.100 |
| 1 | 1 | 15 | t13pf21 | pha07 | 3.19 | 2.04 | <0.100 | 2 | 1 | 13 | t07pf11 | pha17 | 2.32 | 1.91 | 1.61 |
| 1 | 1 | 16 | t11pf11 | pha02 | 2.61 | 2.01 | 0.683 | 2 | 1 | 14 | t12pf21 | pha16 | 2.45 | 2.13 | 1.51 |
| 1 | 1 | 17 | ustd112 | Ustd | 2.94 | 1.42 | 1.99 | 2 | 1 | 15 | t04pf21 | pha09 | 2.73 | 1.96 | 1.97 |
| 1 | 1 | 18 | t10pf11 | pha08 | 2.98 | 1.80 | 1.70 | 2 | 1 | 16 | t08pf11 | pha13 | 2.78 | 2.04 | 1.90 |
| 1 | 1 | 19 | t10pf21 | pha08 | 3.03 | 1.83 | 1.74 | 2 | 1 | 17 | ustdpf212 | Ustd | 2.92 | 1.45 | 2.04 |
| 1 | 1 | 20 | t06pf11 | pha14 | 2.70 | 1.84 | 2.44 | 2 | 1 | 18 | t03pf21 | pha04 | 2.87 | 2.04 | 1.21 |
| 1 | 1 | 21 | t01pf11 | pha05 | 3.08 | 2.03 | 1.92 | 2 | 1 | 19 | t12pf11 | pha16 | 2.48 | 2.18 | 1.59 |
| 1 | 1 | 22 | t09pf11 | pha10 | 2.26 | 2.02 | 2.44 | 2 | 1 | 20 | t14pf21 | pha01 | 2.84 | 1.92 | 2.03 |
| 1 | 1 | 23 | stdpf113 | Batch 1 | 2.48 | 2.07 | <0.100 | 2 | 1 | 21 | stdpf213 | Batch 1 | 2.49 | 2.13 | <0.100 |
| 1 | 2 | 1 | stdpf121 | Batch 1 | 2.42 | 1.98 | <0.100 | 2 | 2 | 1 | stdpf221 | Batch 1 | 2.62 | 2.13 | <0.100 |
| 1 | 2 | 2 | t17pf12 | pha06 | 2.61 | 1.80 | 1.95 | 2 | 2 | 2 | t02pf22 | pha11 | 2.07 | 1.80 | 2.41 |
| 1 | 2 | 3 | t06pf12 | pha14 | 2.62 | 1.78 | 2.37 | 2 | 2 | 3 | t02pf12 | pha11 | 2.10 | 1.87 | 2.48 |
| 1 | 2 | 4 | t10pf22 | pha08 | 2.92 | 1.76 | 1.68 | 2 | 2 | 4 | t07pf22 | pha17 | 2.20 | 1.80 | 1.52 |
| 1 | 2 | 5 | t05pf12 | pha03 | 2.73 | 1.94 | 0.639 | 2 | 2 | 5 | t12pf12 | pha16 | 2.31 | 2.00 | 1.45 |
| 1 | 2 | 6 | t09pf12 | pha10 | 2.14 | 1.95 | 2.36 | 2 | 2 | 6 | t08pf12 | pha13 | 2.83 | 2.08 | 1.71 |
| 1 | 2 | 7 | ustdpf121 | Ustd | 2.82 | 1.39 | 1.97 | 2 | 2 | 7 | ustdpf221 | Ustd | 2.79 | 1.36 | 1.92 |
| 1 | 2 | 8 | t09pf22 | pha10 | 2.17 | 1.95 | 2.38 | 2 | 2 | 8 | t15pf22 | pha15 | 2.26 | 1.97 | 1.37 |
| 1 | 2 | 9 | t17pf22 | pha06 | 2.67 | 1.84 | 1.97 | 2 | 2 | 9 | t08pf22 | pha13 | 2.69 | 1.93 | 1.77 |
| 1 | 2 | 10 | t11pf22 | pha02 | 2.51 | 1.94 | 0.687 | 2 | 2 | 10 | t12pf22 | pha16 | 2.41 | 2.05 | 1.49 |
| 1 | 2 | 11 | t05pf22 | pha03 | 2.74 | 1.99 | 0.638 | 2 | 2 | 11 | t04pf22 | pha09 | 2.35 | 1.65 | 1.69 |
| 1 | 2 | 12 | stdpf122 | Batch 1 | 2.49 | 2.09 | <0.100 | 2 | 2 | 12 | stdpf222 | Batch 1 | 2.50 | 2.11 | <0.100 |
| 1 | 2 | 13 | t10pf12 | pha08 | 2.87 | 1.78 | 1.69 | 2 | 2 | 13 | t03pf12 | pha04 | 2.69 | 1.89 | 1.11 |
| 1 | 2 | 14 | t16pf12 | pha12 | 2.27 | 2.09 | 1.86 | 2 | 2 | 14 | t14pf22 | pha01 | 2.62 | 1.76 | 1.85 |
| 1 | 2 | 15 | t01pf22 | pha05 | 2.98 | 1.99 | 1.87 | 2 | 2 | 15 | t07pf12 | pha17 | 2.24 | 1.83 | 1.53 |
| 1 | 2 | 16 | t06pf22 | pha14 | 2.58 | 1.76 | 2.34 | 2 | 2 | 16 | t14pf12 | pha01 | 2.67 | 1.78 | 1.86 |
| 1 | 2 | 17 | ustdpf122 | Ustd | 2.85 | 1.40 | 1.97 | 2 | 2 | 17 | ustdpf222 | Ustd | 2.77 | 1.36 | 1.91 |
| 1 | 2 | 18 | t01pf12 | pha05 | 2.96 | 1.98 | 1.88 | 2 | 2 | 18 | t15pf12 | pha15 | 2.43 | 2.12 | 1.43 |
| 1 | 2 | 19 | t13pf22 | pha07 | 3.06 | 1.94 | <0.100 | 2 | 2 | 19 | t04pf12 | pha09 | 2.51 | 1.74 | 1.81 |
| 1 | 2 | 20 | t16pf22 | pha12 | 2.28 | 2.12 | 1.87 | 2 | 2 | 20 | t03pf22 | pha04 | 2.80 | 1.96 | 1.17 |
| 1 | 2 | 21 | t13pf12 | pha07 | 3.15 | 2.01 | <0.100 | 2 | 2 | 21 | stdpf223 | Batch 1 | 2.40 | 2.01 | <0.100 |

## Table A.3: Composition of PCT Leachate Solutions

| | | | | Concentrations in ppm (as reported) | | | | Concentrations in ppm (after correcting for dilution) | | | | Common Logarithm of ppm Concentrations | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Glass ID | Lab ID | Blk | Seq | B | Li | Na | Si | B | Li | Na | Si | log[B] | log[Li] | log[Na] | log[Si] |
| std | std-b1-1 | 1 | 1 | 20.9 | 9.34 | 79.4 | 50.7 | 20.9 | 9.34 | 79.4 | 50.7 | 1.320146 | 0.970347 | 1.899821 | 1.705008 |
| pha11clc | ab059 | 1 | 2 | 12.8 | 10.3 | 33.2 | 73.0 | 21.33376 | 17.16701 | 55.33444 | 121.6691 | 1.329067 | 1.234695 | 1.742996 | 2.08518 |
| pha01clc | ab108 | 1 | 3 | 23.0 | 13.6 | 44.7 | 80.6 | 38.3341 | 22.66712 | 74.50149 | 134.336 | 1.583585 | 1.355396 | 1.872165 | 2.128192 |
| pha16 | ab064 | 1 | 4 | 14.5 | 11.4 | 27.3 | 76.7 | 24.16715 | 19.00038 | 45.50091 | 127.8359 | 1.383225 | 1.278762 | 1.65802 | 2.106653 |
| pha05 | ab085 | 1 | 5 | 31.8 | 18.7 | 56.3 | 99.4 | 53.00106 | 31.16729 | 93.83521 | 165.67 | 1.724285 | 1.493699 | 1.972366 | 2.219244 |
| pha03clc | ab069 | 1 | 6 | 12.2 | 8.18 | 22.4 | 51.6 | 20.33374 | 13.63361 | 37.33408 | 86.00172 | 1.308217 | 1.134611 | 1.572105 | 1.934507 |
| pha10clc | ab044 | 1 | 7 | 12.1 | 9.90 | 30.3 | 72.0 | 20.16707 | 16.50033 | 50.50101 | 120.0024 | 1.304643 | 1.217493 | 1.7033 | 2.07919 |
| pha12 | ab082 | 1 | 8 | 18.7 | 15.5 | 41.5 | 103 | 31.16729 | 25.83385 | 69.16805 | 171.6701 | 1.493699 | 1.412189 | 1.839906 | 2.234695 |
| pha16clc | ab052 | 1 | 9 | 14.1 | 10.8 | 26.5 | 77.1 | 23.50047 | 18.00036 | 44.16755 | 128.5026 | 1.371077 | 1.255281 | 1.645103 | 2.108912 |
| pha17clc | ab067 | 1 | 10 | 11.3 | 8.39 | 21.6 | 59.2 | 18.83371 | 13.98361 | 36.00072 | 98.66864 | 1.274936 | 1.145619 | 1.556311 | 1.994179 |
| std | std-b1-2 | 1 | 11 | 21.2 | 9.41 | 81.6 | 51.1 | 21.2 | 9.41 | 81.6 | 51.1 | 1.326336 | 0.97359 | 1.91169 | 1.708421 |
| pha08clc | ab104 | 1 | 12 | 18.7 | 10.4 | 34.6 | 60.6 | 31.16729 | 17.33368 | 57.66782 | 101.002 | 1.493699 | 1.238891 | 1.760934 | 2.00433 |
| pha17 | ab045 | 1 | 13 | 14.3 | 10.5 | 29.0 | 65.5 | 23.83381 | 17.50035 | 48.3343 | 109.1689 | 1.377193 | 1.243047 | 1.684255 | 2.038099 |
| pha05clc | ab037 | 1 | 14 | 26.9 | 16.1 | 49.8 | 90.0 | 44.83423 | 26.83387 | 83.00166 | 150.003 | 1.65161 | 1.428683 | 1.919087 | 2.1761 |
| pha10 | ab070 | 1 | 15 | 12.6 | 10.5 | 32.8 | 73.3 | 21.00042 | 17.50035 | 54.66776 | 122.1691 | 1.322228 | 1.243047 | 1.737731 | 2.086961 |
| blank | ab046 | 1 | 16 | 0.477 | 0.026 | <0.100 | <0.790 | 0.795016 | 0.043334 | 0.083335 | 0.658347 | -0.09962 | -1.36317 | -1.07917 | -0.18155 |
| pha12clc | ab055 | 1 | 17 | 17.2 | 14.2 | 39.1 | 101 | 28.66724 | 23.66714 | 65.16797 | 168.3367 | 1.457386 | 1.374146 | 1.814034 | 2.226179 |
| pha03 | ab110 | 1 | 18 | 14.0 | 9.29 | 26.7 | 51.4 | 23.3338 | 15.48364 | 44.50089 | 85.66838 | 1.367985 | 1.189873 | 1.648369 | 1.932821 |
| pha11 | ab088 | 1 | 19 | 12.7 | 10.2 | 33.7 | 71.0 | 21.16709 | 17.00034 | 56.16779 | 118.3357 | 1.325661 | 1.230458 | 1.749487 | 2.073116 |
| pha08 | ab022 | 1 | 20 | 20.9 | 11.3 | 37.7 | 64.5 | 34.83403 | 18.83371 | 62.83459 | 107.5022 | 1.542004 | 1.274936 | 1.798199 | 2.031417 |
| pha01 | ab056 | 1 | 21 | 23.6 | 13.8 | 46.2 | 80.1 | 39.33412 | 23.00046 | 77.00154 | 133.5027 | 1.594769 | 1.361737 | 1.886499 | 2.12549 |
| std | std-b1-3 | 1 | 22 | 21.3 | 9.40 | 81.8 | 51.3 | 21.3 | 9.4 | 81.8 | 51.3 | 1.32838 | 0.973128 | 1.912753 | 1.710117 |
| std | std-b2-1 | 2 | 1 | 18.8 | 9.18 | 77.0 | 48.0 | 18.8 | 9.18 | 77 | 48 | 1.274158 | 0.962843 | 1.886491 | 1.681241 |
| pha10clc | ab053 | 2 | 2 | 11.3 | 10.1 | 30.7 | 71.7 | 18.83371 | 16.83367 | 51.16769 | 119.5024 | 1.274936 | 1.226179 | 1.708996 | 2.077377 |
| pha17 | ab003 | 2 | 3 | 14.5 | 11.3 | 29.8 | 67.7 | 24.16715 | 18.83371 | 49.66766 | 112.8356 | 1.383225 | 1.274936 | 1.696074 | 2.052446 |
| pha16clc | ab065 | 2 | 4 | 12.3 | 10.4 | 25.5 | 72.9 | 20.50041 | 17.33368 | 42.50085 | 121.5024 | 1.311763 | 1.238891 | 1.628398 | 2.084585 |
| pha11clc | ab054 | 2 | 5 | 11.6 | 10.3 | 34.0 | 70.6 | 19.33372 | 17.16701 | 56.6678 | 117.669 | 1.286315 | 1.234695 | 1.753336 | 2.070662 |
| pha11 | ab084 | 2 | 6 | 12.4 | 11.0 | 36.4 | 72.9 | 20.66708 | 18.3337 | 60.66788 | 121.5024 | 1.315279 | 1.26325 | 1.782959 | 2.084585 |
| pha16 | ab105 | 2 | 7 | 13.3 | 11.6 | 28.8 | 73.7 | 22.16711 | 19.33372 | 48.00096 | 122.8358 | 1.345709 | 1.286315 | 1.68125 | 2.089325 |
| pha12clc | ab097 | 2 | 8 | 14.6 | 13.4 | 36.3 | 92.2 | 24.33382 | 22.33378 | 60.50121 | 153.6697 | 1.38621 | 1.348962 | 1.781764 | 2.186588 |
| pha05clc | ab038 | 2 | 9 | 25.4 | 16.2 | 49.7 | 88.8 | 42.33418 | 27.00054 | 82.83499 | 148.003 | 1.626691 | 1.431372 | 1.918214 | 2.17027 |
| pha05 | ab109 | 2 | 10 | 28.0 | 17.6 | 53.8 | 91.6 | 46.6676 | 29.33392 | 89.66846 | 152.6697 | 1.669015 | 1.46737 | 1.95264 | 2.183753 |
| std | std-b2-2 | 2 | 11 | 19.2 | 9.67 | 83.4 | 48.1 | 19.2 | 9.67 | 83.4 | 48.1 | 1.283301 | 0.985426 | 1.921166 | 1.682145 |
| pha03clc | ab048 | 2 | 12 | 10.7 | 7.89 | 21.9 | 48.3 | 17.83369 | 13.15026 | 36.50073 | 80.50161 | 1.251241 | 1.118934 | 1.562302 | 1.905805 |
| pha17clc | ab015 | 2 | 13 | 4.25 | 3.48 | 9.70 | 22.9 | 7.083475 | 5.800116 | 16.16699 | 38.16743 | 0.850246 | 0.763437 | 1.208629 | 1.581693 |
| pha01 | ab098 | 2 | 14 | 19.9 | 12.4 | 41.0 | 73.2 | 33.16733 | 20.66708 | 68.3347 | 122.0024 | 1.520711 | 1.315279 | 1.834641 | 2.086369 |
| pha08clc | ab016 | 2 | 15 | 17.1 | 10.2 | 33.3 | 57.9 | 28.50057 | 17.00034 | 55.50111 | 96.50193 | 1.454854 | 1.230458 | 1.744302 | 1.984536 |
| pha01clc | ab030 | 2 | 16 | 21.4 | 13.8 | 45.9 | 76.6 | 35.66738 | 23.00046 | 76.50153 | 127.6692 | 1.552271 | 1.361737 | 1.88367 | 2.106086 |
| pha12 | ab006 | 2 | 17 | 17.1 | 15.4 | 41.5 | 99.2 | 28.50057 | 25.66718 | 69.16805 | 165.3366 | 1.454854 | 1.409378 | 1.839906 | 2.218369 |
| pha08 | ab051 | 2 | 18 | 19.3 | 11.4 | 38.1 | 60.7 | 32.16731 | 19.00038 | 63.50127 | 101.1687 | 1.507415 | 1.278762 | 1.802782 | 2.005046 |
| pha10 | ab029 | 2 | 19 | 11.3 | 10.3 | 31.9 | 70.3 | 18.83371 | 17.16701 | 53.16773 | 117.169 | 1.274936 | 1.234695 | 1.725648 | 2.068813 |
| pha03 | ab020 | 2 | 20 | 13.3 | 9.78 | 27.7 | 51.2 | 22.16711 | 16.30033 | 46.16759 | 85.33504 | 1.345709 | 1.212196 | 1.664337 | 1.931127 |
| std | std-b2-3 | 2 | 21 | 19.5 | 9.58 | 81.3 | 48.9 | 19.5 | 9.58 | 81.3 | 48.9 | 1.290035 | 0.981366 | 1.910091 | 1.689309 |
| std | std-b3-1 | 3 | 1 | 20.8 | 9.89 | 83.4 | 53 | 20.8 | 9.89 | 83.4 | 53 | 1.318063 | 0.995196 | 1.921166 | 1.724276 |
| pha03clc | ab083 | 3 | 2 | 11.0 | 8.01 | 22.5 | 50.5 | 18.3337 | 13.35027 | 37.50075 | 84.16835 | 1.26325 | 1.12549 | 1.57404 | 1.925149 |
| pha11clc | ab009 | 3 | 3 | 12.3 | 10.6 | 35.2 | 73.9 | 20.50041 | 17.66702 | 58.66784 | 123.1691 | 1.311763 | 1.247163 | 1.7684 | 2.090502 |
| pha12clc | ab099 | 3 | 4 | 15.0 | 13.4 | 36.8 | 93.4 | 25.0005 | 22.33378 | 61.33456 | 155.6698 | 1.397949 | 1.348962 | 1.787705 | 2.192204 |
| pha11 | ab077 | 3 | 5 | 12.0 | 10.5 | 36.1 | 71.2 | 20.0004 | 17.50035 | 60.16787 | 118.669 | 1.301039 | 1.243047 | 1.779365 | 2.074337 |
| pha01 | ab041 | 3 | 6 | 21.1 | 13.1 | 44.7 | 76.4 | 35.16737 | 21.83377 | 74.50149 | 127.3359 | 1.54614 | 1.339129 | 1.872165 | 2.104951 |
| pha08clc | ab100 | 3 | 7 | 19.0 | 10.9 | 37.1 | 64.2 | 31.6673 | 18.16703 | 61.83457 | 107.0021 | 1.500611 | 1.259284 | 1.791231 | 2.029392 |
| pha05 | ab068 | 3 | 8 | 31.0 | 18.8 | 59.7 | 99.1 | 51.6677 | 31.33396 | 99.50199 | 165.17 | 1.713219 | 1.496015 | 1.997832 | 2.217931 |
| pha01clc | ab080 | 3 | 9 | 21.1 | 13.2 | 45.1 | 78.3 | 35.16737 | 22.00044 | 75.16817 | 130.5026 | 1.54614 | 1.342431 | 1.876034 | 2.115619 |
| pha17 | ab090 | 3 | 10 | 14.4 | 11.2 | 30.9 | 67.0 | 24.00048 | 18.66704 | 51.50103 | 111.6689 | 1.38022 | 1.271075 | 1.711816 | 2.047932 |
| std | std-b3-2 | 3 | 11 | 20.2 | 9.59 | 83.5 | 50.8 | 20.2 | 9.59 | 83.5 | 50.8 | 1.305351 | 0.981819 | 1.921686 | 1.705864 |
| pha16 | ab076 | 3 | 12 | 13.7 | 11.4 | 28.5 | 74.9 | 22.83379 | 19.00038 | 47.50095 | 124.8358 | 1.358578 | 1.278762 | 1.676702 | 2.096339 |
| pha10clc | ab062 | 3 | 13 | 11.8 | 10.6 | 33.9 | 73.9 | 19.66706 | 17.66702 | 56.50113 | 123.1691 | 1.293739 | 1.247163 | 1.752057 | 2.090502 |
| pha16clc | ab032 | 3 | 14 | 13.0 | 10.7 | 26.9 | 75.4 | 21.6671 | 17.83369 | 44.83423 | 125.6692 | 1.335801 | 1.251241 | 1.65161 | 2.099229 |
| pha05clc | ab063 | 3 | 15 | 26.9 | 16.6 | 52.4 | 94.4 | 44.83423 | 27.66722 | 87.33508 | 157.3365 | 1.65161 | 1.441966 | 1.941189 | 2.196829 |
| pha08 | ab091 | 3 | 16 | 19.5 | 11.1 | 37.4 | 62.7 | 32.50065 | 18.50037 | 62.33458 | 104.5021 | 1.511892 | 1.26718 | 1.794729 | 2.019125 |
| pha10 | ab095 | 3 | 17 | 11.9 | 10.4 | 33.3 | 73.8 | 19.83373 | 17.33368 | 55.50111 | 123.0025 | 1.297404 | 1.238891 | 1.744302 | 2.089914 |
| pha17clc | ab010 | 3 | 18 | 10.8 | 8.70 | 23.0 | 60.6 | 18.00036 | 14.50029 | 38.3341 | 101.002 | 1.255281 | 1.161377 | 1.583585 | 2.00433 |
| pha12 | ab049 | 3 | 19 | 17.9 | 15.7 | 43.2 | 105 | 29.83393 | 26.16719 | 72.00144 | 175.0035 | 1.47471 | 1.417757 | 1.857341 | 2.243047 |
| pha03 | ab043 | 3 | 20 | 13.3 | 9.55 | 27.7 | 53.3 | 22.16711 | 15.91699 | 46.16759 | 88.83511 | 1.345709 | 1.201861 | 1.664337 | 1.948585 |
| std | std-b3-3 | 3 | 21 | 20.0 | 9.49 | 81 | 51.1 | 20 | 9.49 | 81 | 51.1 | 1.30103 | 0.977266 | 1.908485 | 1.708421 |

**Notes:**

(1). Values that were below detection (indicated by a "<") were converted to ½ the detection limit.

(2) The shaded entries indicate that the solution-weight fell outside of the guidelines for a successful PCT result.

### Table A.3: Composition of PCT Leachate Solutions *(continued)*

| Glass ID | Lab ID | Blk | Seq | Concentrations in ppm (as reported) B | Li | Na | Si | Concentrations in ppm (after correcting for dilution) B | Li | Na | Si | Common Logarithm of ppm Concentrations log[B] | log[Li] | log[Na] | log[Si] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| std | std-b4-1 | 4 | 1 | 19.6 | 9.47 | 79.5 | 48.6 | 19.6 | 9.47 | 79.5 | 48.6 | 1.292256 | 0.97635 | 1.900367 | 1.686636 |
| pha15clc | ab103 | 4 | 2 | 13.6 | 11.5 | 27.5 | 80.2 | 22.66712 | 19.16705 | 45.83425 | 133.6693 | 1.355396 | 1.282555 | 1.66119 | 2.126032 |
| pha04 | ab035 | 4 | 3 | 15.3 | 10.9 | 27.0 | 62.0 | 25.50051 | 18.16703 | 45.0009 | 103.3354 | 1.406549 | 1.259284 | 1.653221 | 2.014249 |
| pha13clc | ab089 | 4 | 4 | 37.4 | 25.2 | 80.1 | 127 | 62.33458 | 42.00084 | 133.5027 | 211.6709 | 1.794729 | 1.623258 | 2.12549 | 2.325661 |
| pha06 | ab075 | 4 | 5 | 17.5 | 11.8 | 42.7 | 67.0 | 29.16725 | 19.66706 | 71.16809 | 111.6689 | 1.464895 | 1.293739 | 1.852285 | 2.047932 |
| pha07 | ab086 | 4 | 6 | 24.6 | 15.4 | 47.2 | 73.7 | 41.00082 | 25.66718 | 78.66824 | 122.8358 | 1.612793 | 1.409378 | 1.895799 | 2.089325 |
| pha15 | ab008 | 4 | 7 | 14.4 | 12.4 | 29.6 | 78.5 | 24.00048 | 20.66708 | 49.33432 | 130.836 | 1.38022 | 1.315279 | 1.693149 | 2.116727 |
| pha07clc | ab042 | 4 | 8 | 20.7 | 12.9 | 40.5 | 70.0 | 34.50069 | 21.50043 | 67.50135 | 116.669 | 1.537828 | 1.332447 | 1.829312 | 2.066955 |
| ARM | ab031 | 4 | 9 | 10.1 | 7.75 | 20.7 | 35.2 | 16.83367 | 12.91693 | 34.50069 | 58.66784 | 1.226179 | 1.111159 | 1.537828 | 1.7684 |
| pha09 | ab001 | 4 | 10 | 36.8 | 23.2 | 88.0 | 114 | 61.33456 | 38.66744 | 146.6696 | 190.0038 | 1.787705 | 1.587345 | 2.16634 | 2.278762 |
| std | std-b4-2 | 4 | 11 | 19.2 | 9.58 | 79.3 | 48.1 | 19.2 | 9.58 | 79.3 | 48.1 | 1.283301 | 0.981366 | 1.899273 | 1.682145 |
| pha02 | ab066 | 4 | 12 | 7.09 | 6.07 | 16.3 | 42.0 | 11.8169 | 10.11687 | 27.16721 | 70.0014 | 1.072504 | 1.005046 | 1.434045 | 1.845107 |
| pha06clc | ab012 | 4 | 13 | 16.5 | 11.1 | 40.4 | 66.1 | 27.50055 | 18.50037 | 67.33468 | 110.1689 | 1.439341 | 1.26718 | 1.828239 | 2.042059 |
| EA | ab047 | 4 | 14 | 32.5 | 10.1 | 91.4 | 48.8 | 541.6677 | 168.3337 | 1523.336 | 813.335 | 2.733733 | 2.226171 | 3.182796 | 2.910269 |
| pha04clc | ab081 | 4 | 15 | 13.8 | 10 | 24.9 | 60.1 | 23.00046 | 16.667 | 41.50083 | 100.1687 | 1.361737 | 1.221857 | 1.618057 | 2.000732 |
| pha09clc | ab057 | 4 | 16 | 30.7 | 19.2 | 75.0 | 101 | 51.16769 | 32.00064 | 125.0025 | 168.3367 | 1.708996 | 1.505159 | 2.096919 | 2.226179 |
| pha14clc | ab036 | 4 | 17 | 32.9 | 20.7 | 78.4 | 105 | 54.83443 | 34.50069 | 130.6693 | 175.0035 | 1.739053 | 1.537828 | 2.116173 | 2.243047 |
| pha13 | ab039 | 4 | 18 | 33.3 | 22.2 | 72.0 | 113 | 55.50111 | 37.00074 | 120.0024 | 188.3371 | 1.744302 | 1.56821 | 2.07919 | 2.274936 |
| pha02clc | ab060 | 4 | 19 | 7.05 | 6.06 | 16.0 | 42.0 | 11.75024 | 10.1002 | 26.6672 | 70.0014 | 1.070047 | 1.00433 | 1.425977 | 1.845107 |
| pha14 | ab087 | 4 | 20 | 26.3 | 16.4 | 62.8 | 90.5 | 43.83421 | 27.33388 | 104.6688 | 150.8364 | 1.641813 | 1.436701 | 2.019817 | 2.178506 |
| std | std-b4-3 | 4 | 21 | 20.0 | 10.1 | 81.2 | 48.8 | 20 | 10.1 | 81.2 | 48.8 | 1.30103 | 1.004321 | 1.909556 | 1.68842 |
| std | std-b5-1 | 5 | 1 | 19.8 | 9.35 | 79.6 | 49.1 | 19.8 | 9.35 | 79.6 | 49.1 | 1.296665 | 0.970812 | 1.900913 | 1.691081 |
| pha06clc | ab023 | 5 | 2 | 15.9 | 10.6 | 37.6 | 64.3 | 26.50053 | 17.66702 | 62.66792 | 107.1688 | 1.423255 | 1.247163 | 1.797045 | 2.030068 |
| pha07clc | ab027 | 5 | 3 | 22.3 | 13.8 | 43.9 | 74.4 | 37.16741 | 23.00046 | 73.16813 | 124.0025 | 1.570162 | 1.361737 | 1.864322 | 2.09343 |
| pha13clc | ab028 | 5 | 4 | 38.2 | 26.0 | 83.0 | 129 | 63.66794 | 43.3342 | 138.3361 | 215.0043 | 1.803921 | 1.636831 | 2.140936 | 2.332447 |
| pha07 | ab025 | 5 | 5 | 24.8 | 15.2 | 48.4 | 74.5 | 41.33416 | 25.33384 | 80.66828 | 124.1692 | 1.616309 | 1.403701 | 1.906703 | 2.094014 |
| ARM | ab102 | 5 | 6 | 10.8 | 8.10 | 21.5 | 35.2 | 18.00036 | 13.50027 | 35.83405 | 58.66784 | 1.255281 | 1.130342 | 1.554296 | 1.7684 |
| pha09clc | ab078 | 5 | 7 | 40.0 | 25.1 | 94.3 | 120 | 66.668 | 41.83417 | 157.1698 | 200.004 | 1.823917 | 1.621531 | 2.196369 | 2.301039 |
| EA | ab014 | 5 | 8 | 34.0 | 10.2 | 94.6 | 48.8 | 566.6678 | 170.0003 | 1576.67 | 813.335 | 2.753329 | 2.23045 | 3.197741 | 2.910269 |
| pha15clc | ab093 | 5 | 9 | 13.4 | 11.6 | 27.7 | 77.8 | 22.33378 | 19.33372 | 46.16759 | 129.6693 | 1.348962 | 1.286315 | 1.664337 | 2.112837 |
| pha04 | ab058 | 5 | 10 | 17.0 | 12.1 | 30.5 | 65.9 | 28.3339 | 20.16707 | 50.83435 | 109.8355 | 1.452306 | 1.304643 | 1.706157 | 2.040743 |
| std | std-b5-2 | 5 | 11 | 18.7 | 9.04 | 78.0 | 45.9 | 18.7 | 9.04 | 78 | 45.9 | 1.271842 | 0.956168 | 1.892095 | 1.661813 |
| pha02 | ab040 | 5 | 12 | 7.13 | 6.13 | 16.6 | 40.7 | 11.88357 | 10.21687 | 27.66722 | 67.83469 | 1.074947 | 1.009318 | 1.441966 | 1.831452 |
| pha14clc | ab072 | 5 | 13 | 24.8 | 16.1 | 61.1 | 88.4 | 41.33416 | 26.83387 | 101.8354 | 147.3363 | 1.616309 | 1.428683 | 2.007899 | 2.16831 |
| pha04clc | ab013 | 5 | 14 | 13.2 | 9.65 | 24.2 | 56.4 | 22.00044 | 16.08366 | 40.33414 | 94.00188 | 1.342431 | 1.206385 | 1.605673 | 1.973137 |
| pha14 | ab101 | 5 | 15 | 42.8 | 27.0 | 101 | 119 | 71.33476 | 45.0009 | 168.3367 | 198.3373 | 1.853301 | 1.653221 | 2.226179 | 2.297404 |
| pha09 | ab034 | 5 | 16 | 36.7 | 23.1 | 87.8 | 113 | 61.16789 | 38.50077 | 146.3363 | 188.3371 | 1.786523 | 1.585469 | 2.165352 | 2.274936 |
| pha02clc | ab050 | 5 | 17 | 6.82 | 5.79 | 15.4 | 41.1 | 11.36689 | 9.650193 | 25.66718 | 68.50137 | 1.055642 | 0.984536 | 1.409378 | 1.835699 |
| pha06 | ab061 | 5 | 18 | 18.0 | 12.0 | 43.9 | 69.3 | 30.0006 | 20.0004 | 73.16813 | 115.5023 | 1.47713 | 1.301039 | 1.864322 | 2.062591 |
| pha13 | ab073 | 5 | 19 | 36.4 | 24.0 | 77.0 | 124 | 60.66788 | 40.0008 | 128.3359 | 206.6708 | 1.782959 | 1.602069 | 2.108348 | 2.315279 |
| pha15 | ab074 | 5 | 20 | 14.6 | 12.6 | 29.6 | 79.3 | 24.33382 | 21.00042 | 49.33432 | 132.1693 | 1.38621 | 1.322228 | 1.693149 | 2.121131 |
| std | std-b5-3 | 5 | 21 | 19.1 | 9.38 | 81.4 | 46.9 | 19.1 | 9.38 | 81.4 | 46.9 | 1.281033 | 0.972203 | 1.910624 | 1.671173 |
| std | std-b6-1 | 6 | 1 | 20.0 | 9.87 | 83.5 | 50.3 | 20 | 9.87 | 83.5 | 50.3 | 1.30103 | 0.994317 | 1.921686 | 1.701568 |
| pha04 | ab021 | 6 | 2 | 16.4 | 11.9 | 29.6 | 65.9 | 27.33388 | 19.83373 | 49.33432 | 109.8355 | 1.436701 | 1.297404 | 1.693149 | 2.040743 |
| pha04clc | ab106 | 6 | 3 | 13.7 | 10.1 | 25.0 | 60.4 | 22.83379 | 16.83367 | 41.6675 | 100.6687 | 1.358578 | 1.226179 | 1.619797 | 2.002894 |
| pha09 | ab005 | 6 | 4 | 28.3 | 18.4 | 70.9 | 99.1 | 47.16761 | 30.66728 | 118.169 | 165.17 | 1.673644 | 1.486675 | 2.072504 | 2.217931 |
| pha15clc | ab002 | 6 | 5 | 13.9 | 12.1 | 29.3 | 81.7 | 23.16713 | 20.16707 | 48.83431 | 136.1694 | 1.364872 | 1.304643 | 1.688725 | 2.134079 |
| pha09clc | ab107 | 6 | 6 | 44.6 | 27.9 | 108 | 128 | 74.33482 | 46.50093 | 180.0036 | 213.3376 | 1.871192 | 1.667462 | 2.255281 | 2.329067 |
| pha02clc | ab017 | 6 | 7 | 6.85 | 6.20 | 16.5 | 42.0 | 11.4169 | 10.33354 | 27.50055 | 70.0014 | 1.057548 | 1.014249 | 1.439341 | 1.845107 |
| ARM | ab007 | 6 | 8 | 10.8 | 8.45 | 22.4 | 36.4 | 18.00036 | 14.08362 | 37.33408 | 60.66788 | 1.255281 | 1.148714 | 1.572105 | 1.782959 |
| pha06clc | ab018 | 6 | 9 | 19.4 | 12.4 | 44.5 | 82.0 | 32.33398 | 20.66708 | 74.16815 | 136.6694 | 1.509659 | 1.315279 | 1.870217 | 2.135671 |
| pha13 | ab019 | 6 | 10 | 47.8 | 28.7 | 90.0 | 168 | 79.66826 | 47.83429 | 150.003 | 280.0056 | 1.901285 | 1.679739 | 2.1761 | 2.447167 |
| std | std-b6-2 | 6 | 11 | 20.1 | 9.85 | 85.4 | 52.3 | 20.1 | 9.85 | 85.4 | 52.3 | 1.303196 | 0.993436 | 1.931458 | 1.718502 |
| blank | ab071 | 6 | 12 | <0.150 | 0.500 | 0.239 | <0.790 | 0.125002 | 0.83335 | 0.398341 | 0.658347 | -0.90308 | -0.07917 | -0.39974 | -0.18155 |
| pha14clc | ab094 | 6 | 13 | 26.3 | 16.9 | 64.4 | 98.0 | 43.83421 | 28.16723 | 107.3355 | 163.3366 | 1.641813 | 1.449744 | 2.030743 | 2.213084 |
| pha07clc | ab033 | 6 | 14 | 23.3 | 14.5 | 46.2 | 79.4 | 38.83411 | 24.16715 | 77.00154 | 132.336 | 1.589213 | 1.383225 | 1.886499 | 2.121678 |
| EA | ab092 | 6 | 15 | 32.3 | 10.2 | 91.6 | 50.5 | 538.3344 | 170.0003 | 1526.67 | 841.6683 | 2.731052 | 2.23045 | 3.183745 | 2.925141 |
| pha14 | ab096 | 6 | 16 | 43.2 | 26.7 | 101 | 124 | 72.00144 | 44.50089 | 168.3367 | 206.6708 | 1.857341 | 1.648369 | 2.226179 | 2.315279 |
| pha06 | ab026 | 6 | 17 | 17.7 | 12.1 | 45.1 | 68.7 | 29.50059 | 20.16707 | 75.16817 | 114.5023 | 1.469831 | 1.304643 | 1.876034 | 2.058814 |
| pha15 | ab079 | 6 | 18 | 15.1 | 13.2 | 31.6 | 84.9 | 25.16717 | 22.00044 | 52.66772 | 141.5028 | 1.400834 | 1.342431 | 1.721545 | 2.150765 |
| pha13clc | ab024 | 6 | 19 | 36.1 | 24.4 | 77.3 | 129 | 60.16787 | 40.66748 | 128.8359 | 215.0043 | 1.779365 | 1.609247 | 2.110037 | 2.332447 |
| pha02 | ab004 | 6 | 20 | 7.22 | 6.39 | 16.3 | 43.2 | 12.03357 | 10.65021 | 27.16721 | 72.00144 | 1.080395 | 1.027358 | 1.434045 | 1.857341 |
| pha07 | ab011 | 6 | 21 | 24.5 | 15.1 | 47.1 | 77.1 | 40.83415 | 25.16717 | 78.50157 | 128.5026 | 1.611024 | 1.400834 | 1.894878 | 2.108912 |
| std | std-b6-3 | 6 | 22 | 20.4 | 10.1 | 86.6 | 51.7 | 20.4 | 10.1 | 86.6 | 51.7 | 1.30963 | 1.004321 | 1.937518 | 1.713491 |

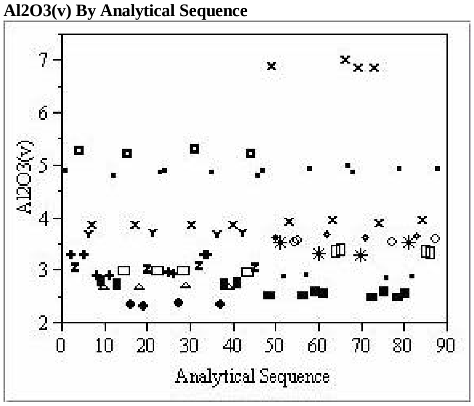
**Notes:**

(1). Values that were below detection (indicated by a "<") were converted to ½ the detection limit.

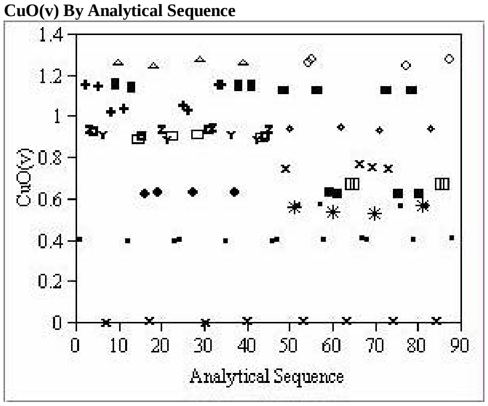
(3) The shaded entries indicate that the solution-weight fell outside of the guidelines for a successful PCT result.

**Exhibit A.1: Measurements of Samples Prepared Using Lithium Metaborate (LM) Method in Analytical Sequence by Oxide**
(x – Ustd; small square – Batch 1; PHA Study glasses – Other symbols)

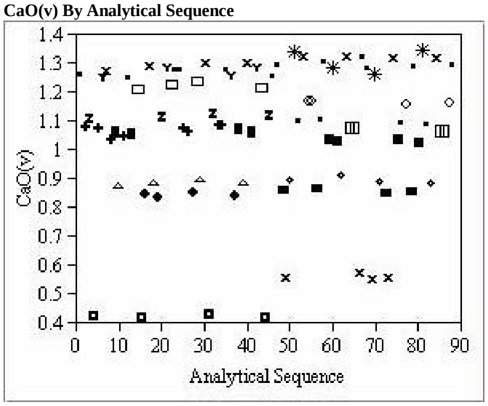
**Al2O3(v) By Analytical Sequence**



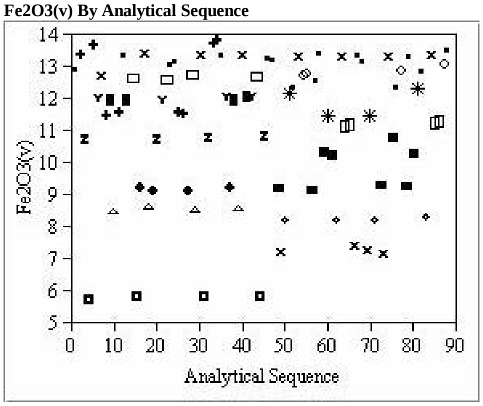

**CuO(v) By Analytical Sequence**



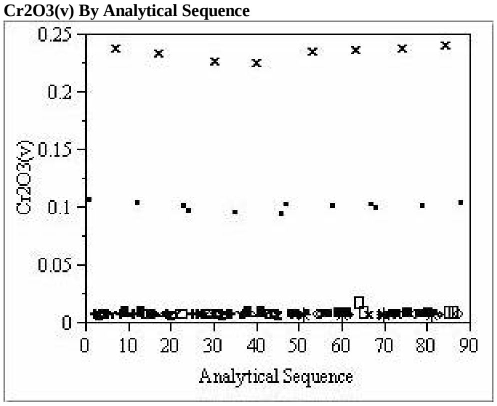

**CaO(v) By Analytical Sequence**




**Fe2O3(v) By Analytical Sequence**




**Cr2O3(v) By Analytical Sequence**




**K2O(v) By Analytical Sequence**

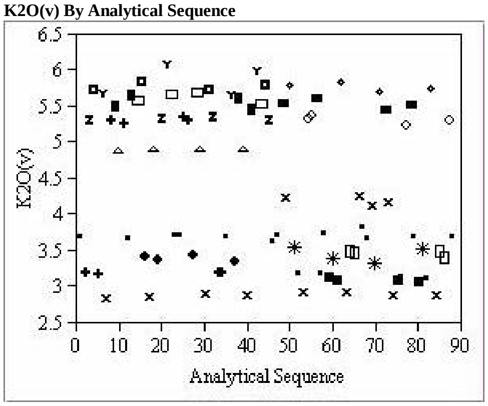
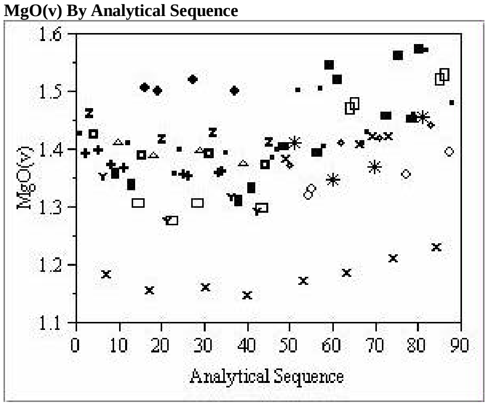
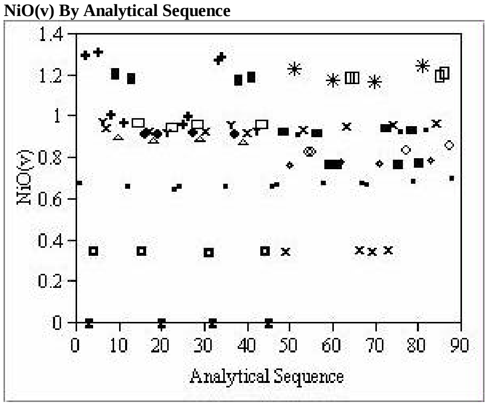


**Exhibit A.1: Measurements of Samples Prepared Using Lithium Metaborate (LM) Method in Analytical Sequence by Oxide (continued)**
(x – Ustd; small square – Batch 1; PHA Study glasses – Other symbols)

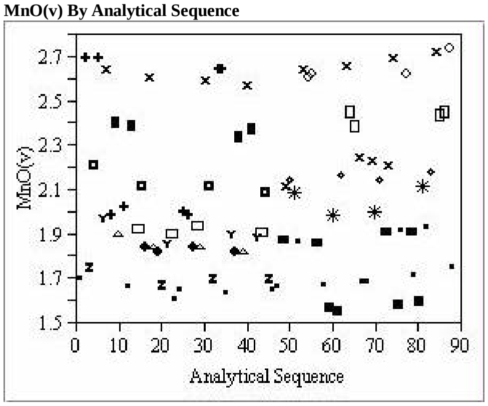
**MgO(v) By Analytical Sequence**



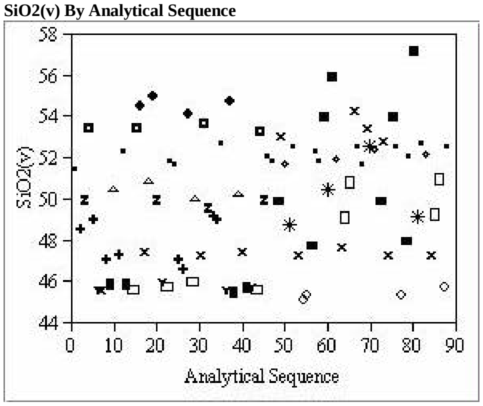

**NiO(v) By Analytical Sequence**



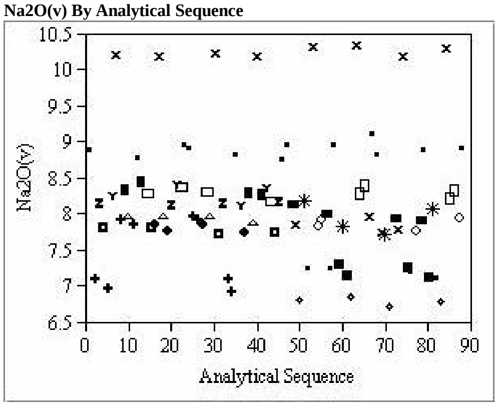

**MnO(v) By Analytical Sequence**




**SiO2(v) By Analytical Sequence**




**Na2O(v) By Analytical Sequence**




**TiO2(v) By Analytical Sequence**

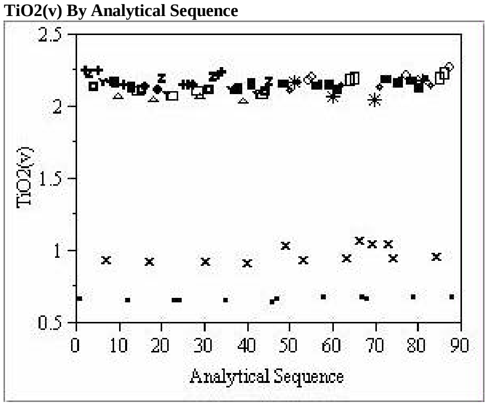


**Exhibit A.1: Measurements of Samples Prepared Using Lithium Metaborate (LM) Method in Analytical Sequence by Oxide (continued)**
(x – Ustd; small square – Batch 1; PHA Study glasses – Other symbols)

ZrO2(v) By Analytical Sequence

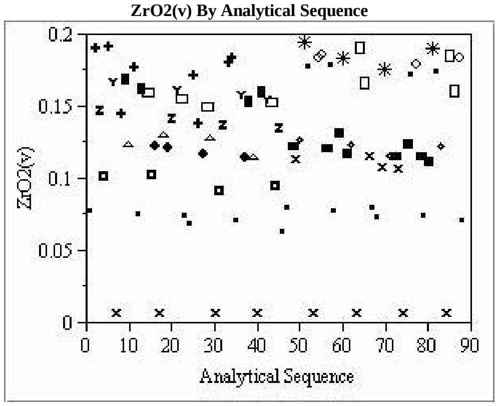
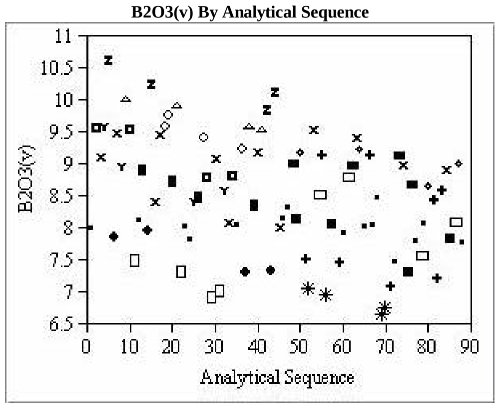
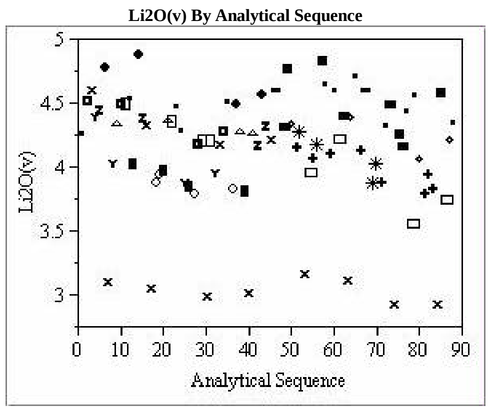


**Exhibit A.2: Measurements of Samples Prepared**
**Using Peroxide Fusion (pf) Method in Analytical Sequence by Oxide (continued)**
(x – Ustd; small square – Batch 1; PHA Study glasses – Other symbols)



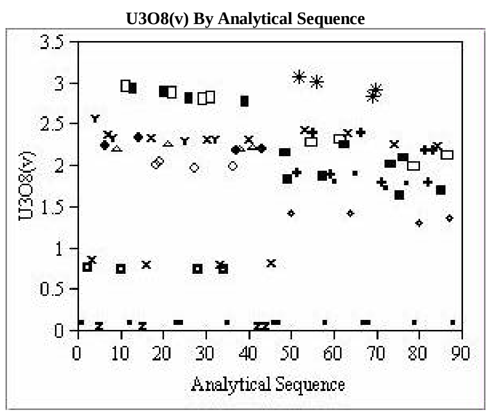
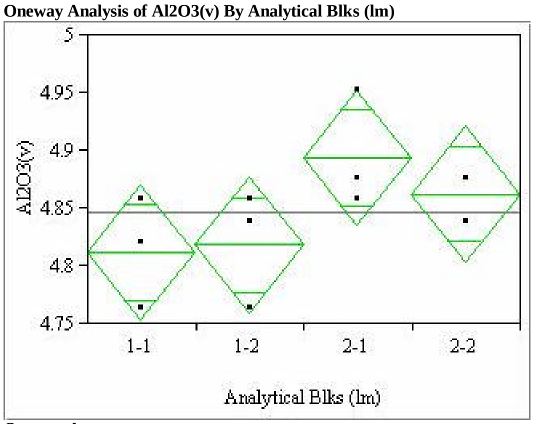



**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of Al2O3(v) By Analytical Blks (lm)**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.465021 |
| Adj Rsquare | 0.264403 |
| Root Mean Square Error | 0.043976 |
| Mean of Response | 4.846567 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

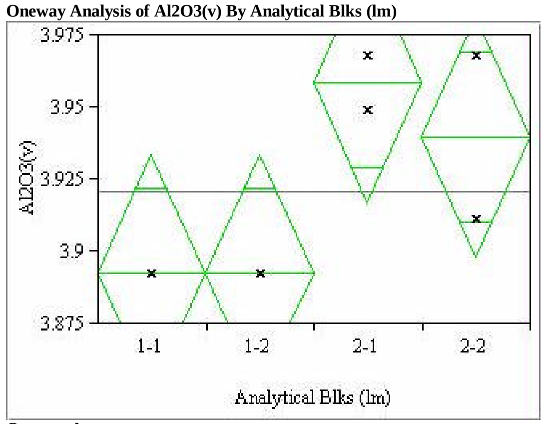
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.01344779 | 0.004483 | 2.3179 | 0.1520 |
| Error | 8 | 0.01547091 | 0.001934 | | |
| C. Total | 11 | 0.02891870 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 4.81193 | 0.02539 | 4.7534 | 4.8705 |
| 1-2 | 3 | 4.81822 | 0.02539 | 4.7597 | 4.8768 |
| 2-1 | 3 | 4.89380 | 0.02539 | 4.8353 | 4.9524 |
| 2-2 | 3 | 4.86231 | 0.02539 | 4.8038 | 4.9209 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of Al2O3(v) By Analytical Blks (lm)**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.791667 |
| Adj Rsquare | 0.635417 |
| Root Mean Square Error | 0.021125 |
| Mean of Response | 3.920713 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00678340 | 0.002261 | 5.0667 | 0.0755 |
| Error | 4 | 0.00178511 | 0.000446 | | |
| C. Total | 7 | 0.00856850 | | | |

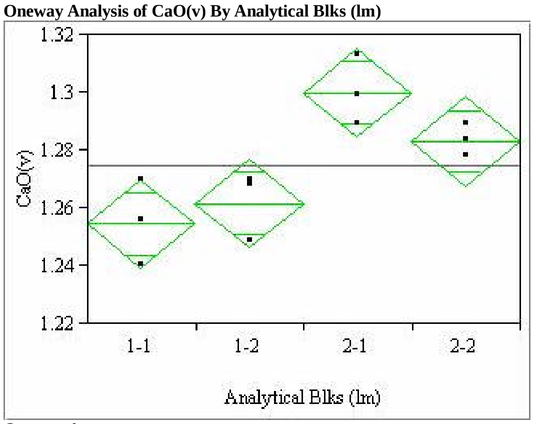
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 3.89237 | 0.01494 | 3.8509 | 3.9338 |
| 1-2 | 2 | 3.89237 | 0.01494 | 3.8509 | 3.9338 |
| 2-1 | 2 | 3.95850 | 0.01494 | 3.9170 | 4.0000 |
| 2-2 | 2 | 3.93961 | 0.01494 | 3.8981 | 3.9811 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of CaO(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.784 |
| Adj Rsquare | 0.703 |
| Root Mean Square Error | 0.011489 |
| Mean of Response | 1.274788 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

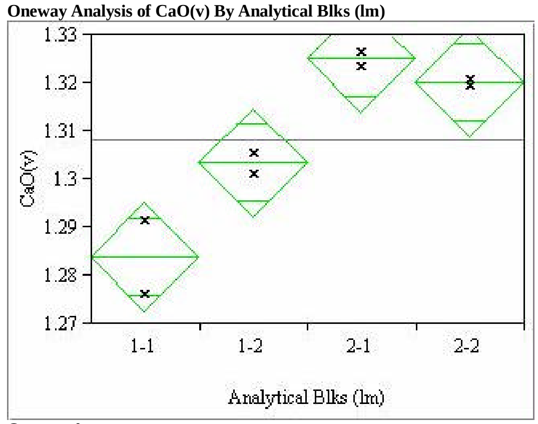
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00383248 | 0.001277 | 9.6790 | 0.0049 |
| Error | 8 | 0.00105589 | 0.000132 | | |
| C. Total | 11 | 0.00488837 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 1.25462 | 0.00663 | 1.2393 | 1.2699 |
| 1-2 | 3 | 1.26161 | 0.00663 | 1.2463 | 1.2769 |
| 2-1 | 3 | 1.29986 | 0.00663 | 1.2846 | 1.3152 |
| 2-2 | 3 | 1.28307 | 0.00663 | 1.2678 | 1.2984 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of CaO(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.940627 |
| Adj Rsquare | 0.896097 |
| Root Mean Square Error | 0.005748 |
| Mean of Response | 1.308077 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00209358 | 0.000698 | 21.1235 | 0.0065 |
| Error | 4 | 0.00013215 | 0.000033 | | |
| C. Total | 7 | 0.00222573 | | | |

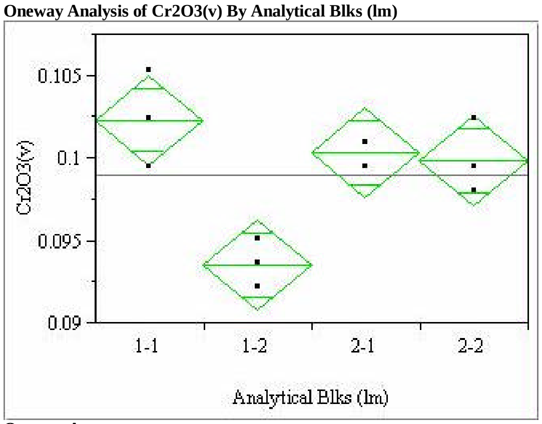
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 1.28377 | 0.00406 | 1.2725 | 1.2951 |
| 1-2 | 2 | 1.30335 | 0.00406 | 1.2921 | 1.3146 |
| 2-1 | 2 | 1.32504 | 0.00406 | 1.3138 | 1.3363 |
| 2-2 | 2 | 1.32015 | 0.00406 | 1.3089 | 1.3314 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of Cr2O3(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.798907 |
| Adj Rsquare | 0.723497 |
| Root Mean Square Error | 0.002023 |
| Mean of Response | 0.099023 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

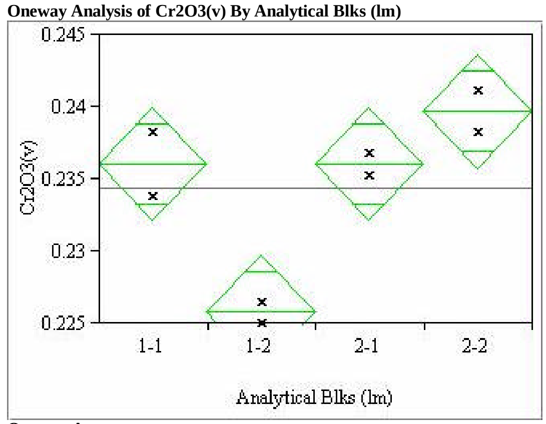
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00013013 | 0.000043 | 10.5942 | 0.0037 |
| Error | 8 | 0.00003276 | 0.000004 | | |
| C. Total | 11 | 0.00016289 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 0.102312 | 0.00117 | 0.09962 | 0.10501 |
| 1-2 | 3 | 0.093542 | 0.00117 | 0.09085 | 0.09624 |
| 2-1 | 3 | 0.100363 | 0.00117 | 0.09767 | 0.10306 |
| 2-2 | 3 | 0.099876 | 0.00117 | 0.09718 | 0.10257 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of Cr2O3(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.930475 |
| Adj Rsquare | 0.878331 |
| Root Mean Square Error | 0.002001 |
| Mean of Response | 0.234404 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00021443 | 0.000071 | 17.8444 | 0.0089 |
| Error | 4 | 0.00001602 | 0.000004 | | |
| C. Total | 7 | 0.00023045 | | | |

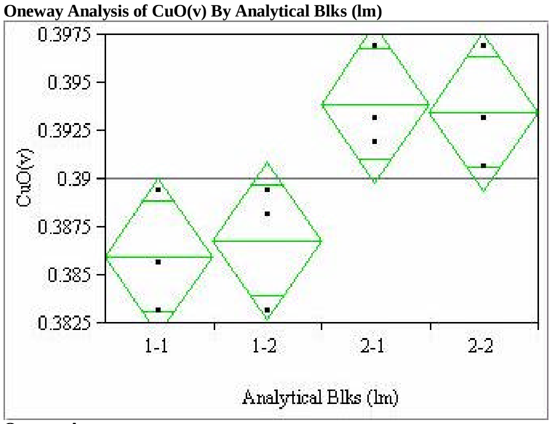
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 0.236048 | 0.00142 | 0.23212 | 0.23998 |
| 1-2 | 2 | 0.225817 | 0.00142 | 0.22189 | 0.22975 |
| 2-1 | 2 | 0.236048 | 0.00142 | 0.23212 | 0.23998 |
| 2-2 | 2 | 0.239702 | 0.00142 | 0.23577 | 0.24363 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of CuO(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.681944 |
| Adj Rsquare | 0.562673 |
| Root Mean Square Error | 0.003066 |
| Mean of Response | 0.39004 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

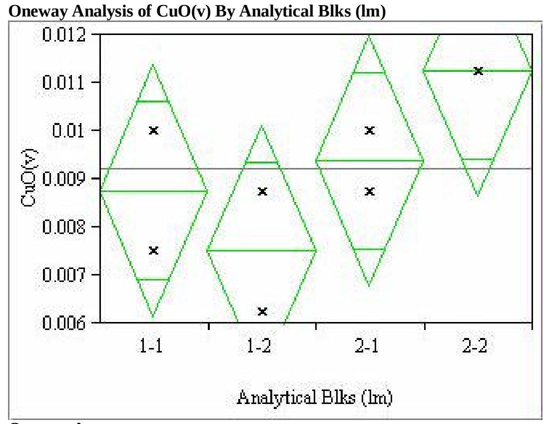
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00016127 | 0.000054 | 5.7176 | 0.0217 |
| Error | 8 | 0.00007522 | 0.000009 | | |
| C. Total | 11 | 0.00023649 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 0.385972 | 0.00177 | 0.38189 | 0.39005 |
| 1-2 | 3 | 0.386806 | 0.00177 | 0.38272 | 0.39089 |
| 2-1 | 3 | 0.393900 | 0.00177 | 0.38982 | 0.39798 |
| 2-2 | 3 | 0.393482 | 0.00177 | 0.38940 | 0.39756 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of CuO(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.675676 |
| Adj Rsquare | 0.432432 |
| Root Mean Square Error | 0.001328 |
| Mean of Response | 0.009232 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00001469 | 0.0000049 | 2.7778 | 0.1744 |
| Error | 4 | 0.00000705 | 0.0000018 | | |
| C. Total | 7 | 0.00002174 | | | |

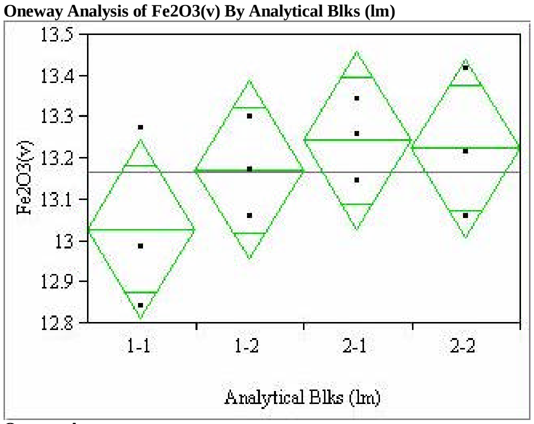
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 0.008763 | 0.00094 | 0.00616 | 0.01137 |
| 1-2 | 2 | 0.007511 | 0.00094 | 0.00490 | 0.01012 |
| 2-1 | 2 | 0.009389 | 0.00094 | 0.00678 | 0.01200 |
| 2-2 | 2 | 0.011266 | 0.00094 | 0.00866 | 0.01387 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of Fe2O3(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.2879 |
| Adj Rsquare | 0.020862 |
| Root Mean Square Error | 0.161752 |
| Mean of Response | 13.16754 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

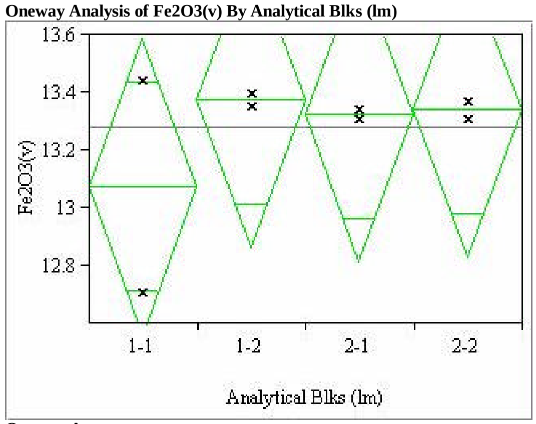
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.08462334 | 0.028208 | 1.0781 | 0.4116 |
| Error | 8 | 0.20930991 | 0.026164 | | |
| C. Total | 11 | 0.29393325 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 13.0293 | 0.09339 | 12.814 | 13.245 |
| 1-2 | 3 | 13.1723 | 0.09339 | 12.957 | 13.388 |
| 2-1 | 3 | 13.2438 | 0.09339 | 13.028 | 13.459 |
| 2-2 | 3 | 13.2247 | 0.09339 | 13.009 | 13.440 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of Fe2O3(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.296603 |
| Adj Rsquare | -0.23094 |
| Root Mean Square Error | 0.259226 |
| Mean of Response | 13.27834 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.11334213 | 0.037781 | 0.5622 | 0.6680 |
| Error | 4 | 0.26879153 | 0.067198 | | |
| C. Total | 7 | 0.38213367 | | | |

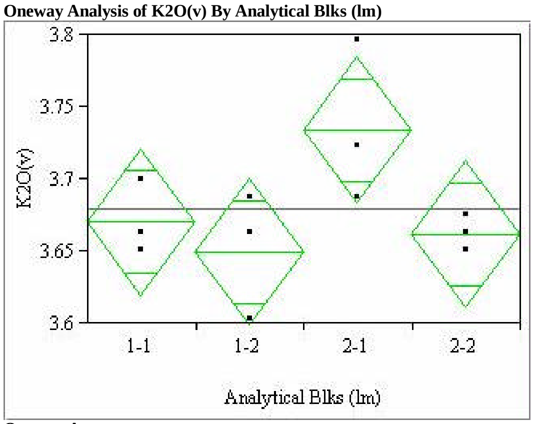
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 13.0746 | 0.18330 | 12.566 | 13.584 |
| 1-2 | 2 | 13.3748 | 0.18330 | 12.866 | 13.884 |
| 2-1 | 2 | 13.3248 | 0.18330 | 12.816 | 13.834 |
| 2-2 | 2 | 13.3391 | 0.18330 | 12.830 | 13.848 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of K2O(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.528707 |
| Adj Rsquare | 0.351972 |
| Root Mean Square Error | 0.037774 |
| Mean of Response | 3.679049 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

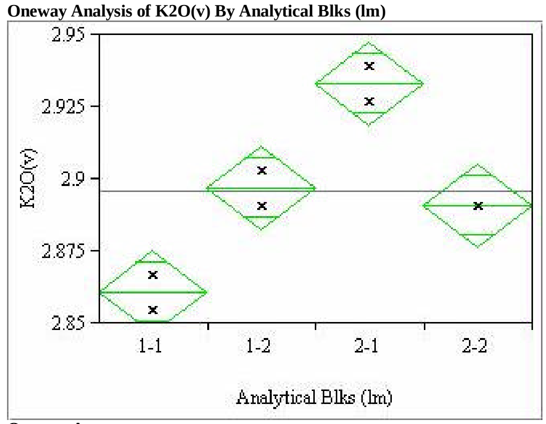
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.01280561 | 0.004269 | 2.9915 | 0.0957 |
| Error | 8 | 0.01141501 | 0.001427 | | |
| C. Total | 11 | 0.02422063 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 3.67001 | 0.02181 | 3.6197 | 3.7203 |
| 1-2 | 3 | 3.64994 | 0.02181 | 3.5996 | 3.7002 |
| 2-1 | 3 | 3.73426 | 0.02181 | 3.6840 | 3.7846 |
| 2-2 | 3 | 3.66198 | 0.02181 | 3.6117 | 3.7123 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of K2O(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.960396 |
| Adj Rsquare | 0.930693 |
| Root Mean Square Error | 0.007377 |
| Mean of Response | 2.895557 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00527823 | 0.001759 | 32.3333 | 0.0029 |
| Error | 4 | 0.00021766 | 0.000054 | | |
| C. Total | 7 | 0.00549589 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 2.86092 | 0.00522 | 2.8464 | 2.8754 |
| 1-2 | 2 | 2.89706 | 0.00522 | 2.8826 | 2.9115 |
| 2-1 | 2 | 2.93320 | 0.00522 | 2.9187 | 2.9477 |
| 2-2 | 2 | 2.89104 | 0.00522 | 2.8766 | 2.9055 |

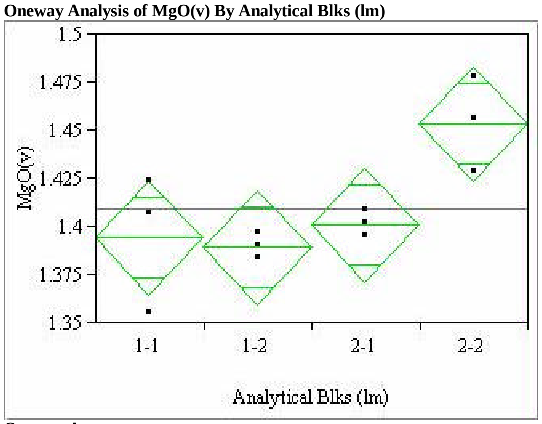
Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**

(continued)

(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of MgO(v) By Analytical Blks (lm)**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.668341 |
| Adj Rsquare | 0.543969 |
| Root Mean Square Error | 0.022174 |
| Mean of Response | 1.409661 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

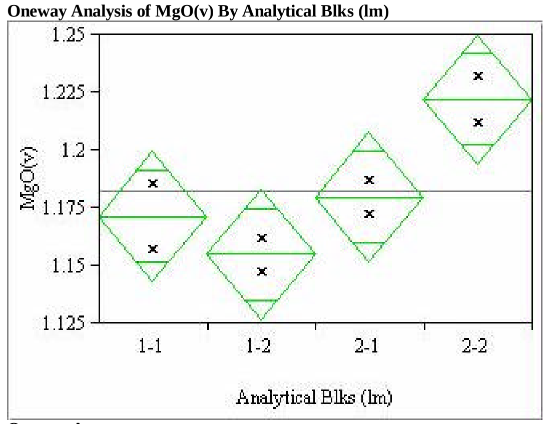
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00792622 | 0.002642 | 5.3737 | 0.0255 |
| Error | 8 | 0.00393333 | 0.000492 | | |
| C. Total | 11 | 0.01185954 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 1.39446 | 0.01280 | 1.3649 | 1.4240 |
| 1-2 | 3 | 1.38949 | 0.01280 | 1.3600 | 1.4190 |
| 2-1 | 3 | 1.40109 | 0.01280 | 1.3716 | 1.4306 |
| 2-2 | 3 | 1.45360 | 0.01280 | 1.4241 | 1.4831 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of MgO(v) By Analytical Blks (lm)**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.857169 |
| Adj Rsquare | 0.750045 |
| Root Mean Square Error | 0.0143 |
| Mean of Response | 1.182018 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00490852 | 0.001636 | 8.0017 | 0.0364 |
| Error | 4 | 0.00081792 | 0.000204 | | |
| C. Total | 7 | 0.00572644 | | | |

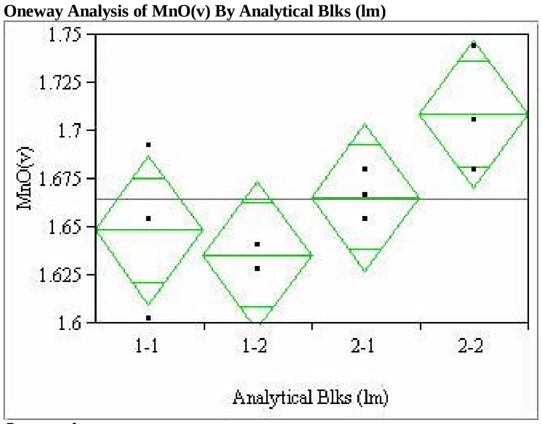
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 1.17145 | 0.01011 | 1.1434 | 1.1995 |
| 1-2 | 2 | 1.15487 | 0.01011 | 1.1268 | 1.1829 |
| 2-1 | 2 | 1.17974 | 0.01011 | 1.1517 | 1.2078 |
| 2-2 | 2 | 1.22202 | 0.01011 | 1.1939 | 1.2501 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of MnO(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.578578 |
| Adj Rsquare | 0.420544 |
| Root Mean Square Error | 0.028872 |
| Mean of Response | 1.664572 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

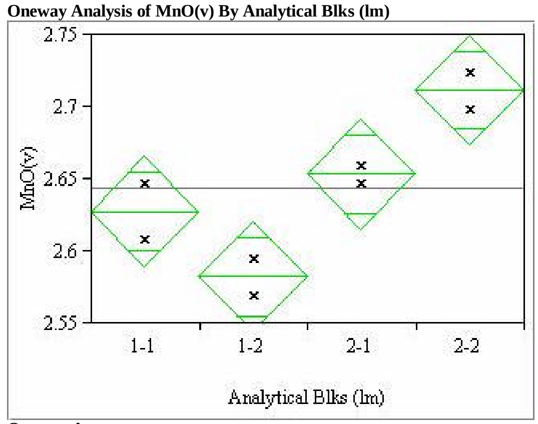
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00915569 | 0.003052 | 3.6611 | 0.0631 |
| Error | 8 | 0.00666879 | 0.000834 | | |
| C. Total | 11 | 0.01582448 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 1.64843 | 0.01667 | 1.6100 | 1.6869 |
| 1-2 | 3 | 1.63552 | 0.01667 | 1.5971 | 1.6740 |
| 2-1 | 3 | 1.66565 | 0.01667 | 1.6272 | 1.7041 |
| 2-2 | 3 | 1.70869 | 0.01667 | 1.6702 | 1.7471 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of MnO(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.920705 |
| Adj Rsquare | 0.861233 |
| Root Mean Square Error | 0.019368 |
| Mean of Response | 2.643732 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.01742221 | 0.005807 | 15.4815 | 0.0115 |
| Error | 4 | 0.00150048 | 0.000375 | | |
| C. Total | 7 | 0.01892269 | | | |

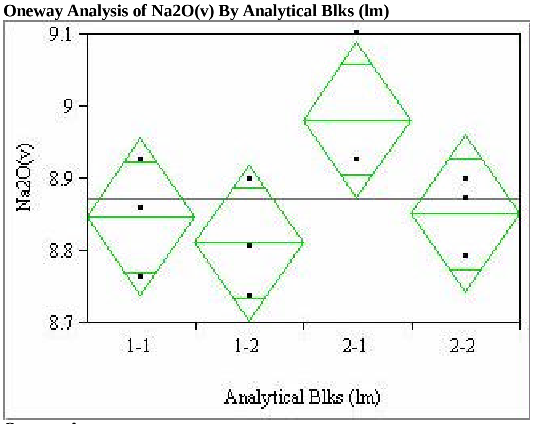
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 2.62759 | 0.01370 | 2.5896 | 2.6656 |
| 1-2 | 2 | 2.58240 | 0.01370 | 2.5444 | 2.6204 |
| 2-1 | 2 | 2.65342 | 0.01370 | 2.6154 | 2.6914 |
| 2-2 | 2 | 2.71152 | 0.01370 | 2.6735 | 2.7495 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of Na2O(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.486775 |
| Adj Rsquare | 0.294315 |
| Root Mean Square Error | 0.081533 |
| Mean of Response | 8.87321 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

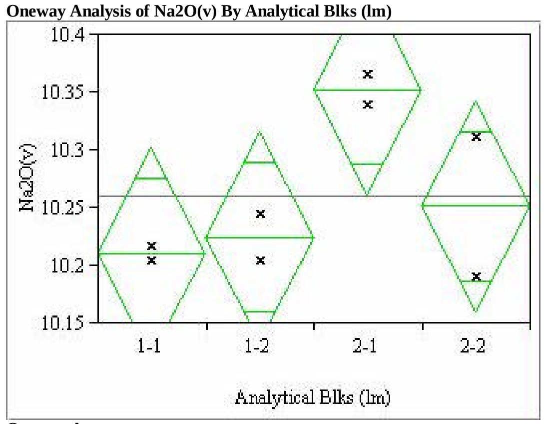
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.05043978 | 0.016813 | 2.5292 | 0.1308 |
| Error | 8 | 0.05318058 | 0.006648 | | |
| C. Total | 11 | 0.10362036 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 8.84737 | 0.04707 | 8.7388 | 8.9559 |
| 1-2 | 3 | 8.81143 | 0.04707 | 8.7029 | 8.9200 |
| 2-1 | 3 | 8.98217 | 0.04707 | 8.8736 | 9.0907 |
| 2-2 | 3 | 8.85187 | 0.04707 | 8.7433 | 8.9604 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of Na2O(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.74026 |
| Adj Rsquare | 0.545455 |
| Root Mean Square Error | 0.046452 |
| Mean of Response | 10.25997 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.02459905 | 0.008200 | 3.8000 | 0.1149 |
| Error | 4 | 0.00863124 | 0.002158 | | |
| C. Total | 7 | 0.03323029 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 10.2111 | 0.03285 | 10.120 | 10.302 |
| 1-2 | 2 | 10.2246 | 0.03285 | 10.133 | 10.316 |
| 2-1 | 2 | 10.3526 | 0.03285 | 10.261 | 10.444 |
| 2-2 | 2 | 10.2515 | 0.03285 | 10.160 | 10.343 |

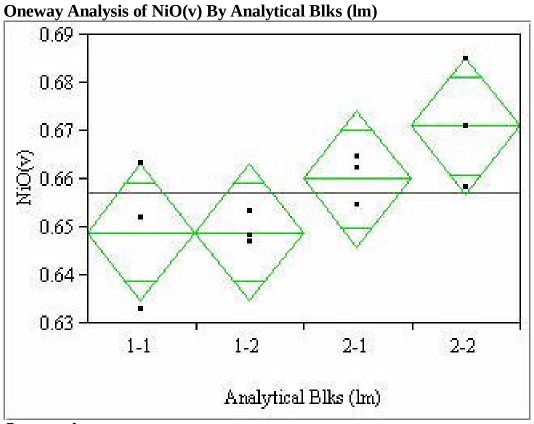
Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**

(continued)

(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of NiO(v) By Analytical Blks (lm)**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.52381 |
| Adj Rsquare | 0.345238 |
| Root Mean Square Error | 0.010678 |
| Mean of Response | 0.657246 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

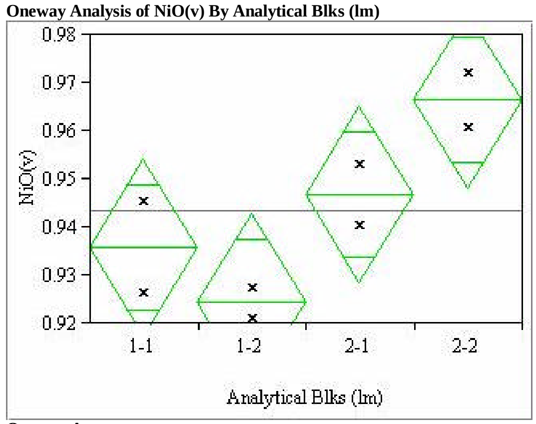
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00100340 | 0.000334 | 2.9333 | 0.0994 |
| Error | 8 | 0.00091218 | 0.000114 | | |
| C. Total | 11 | 0.00191558 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 0.648975 | 0.00617 | 0.63476 | 0.66319 |
| 1-2 | 3 | 0.648975 | 0.00617 | 0.63476 | 0.66319 |
| 2-1 | 3 | 0.660003 | 0.00617 | 0.64579 | 0.67422 |
| 2-2 | 3 | 0.671032 | 0.00617 | 0.65682 | 0.68525 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of NiO(v) By Analytical Blks (lm)**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.845837 |
| Adj Rsquare | 0.730216 |
| Root Mean Square Error | 0.00934 |
| Mean of Response | 0.9434 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00191457 | 0.000638 | 7.3155 | 0.0422 |
| Error | 4 | 0.00034895 | 0.000087 | | |
| C. Total | 7 | 0.00226352 | | | |

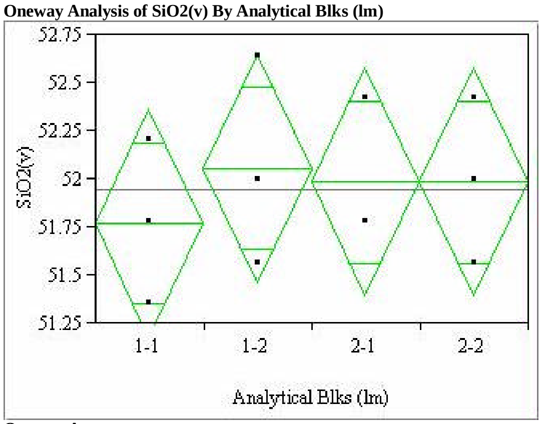
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 0.935924 | 0.00660 | 0.91759 | 0.95426 |
| 1-2 | 2 | 0.924471 | 0.00660 | 0.90613 | 0.94281 |
| 2-1 | 2 | 0.946740 | 0.00660 | 0.92840 | 0.96508 |
| 2-2 | 2 | 0.966464 | 0.00660 | 0.94813 | 0.98480 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of SiO2(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.079646 |
| Adj Rsquare | -0.26549 |
| Root Mean Square Error | 0.445331 |
| Mean of Response | 51.94933 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

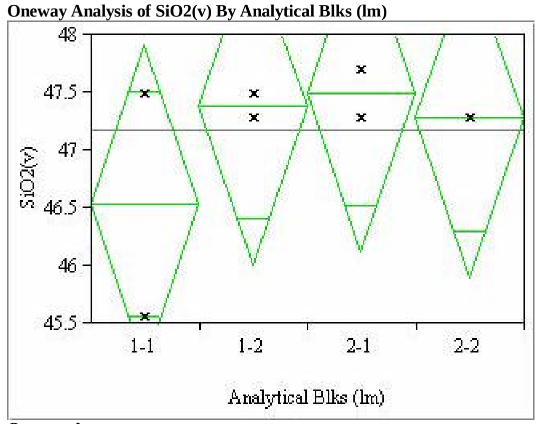
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.1372981 | 0.045766 | 0.2308 | 0.8725 |
| Error | 8 | 1.5865562 | 0.198320 | | |
| C. Total | 11 | 1.7238544 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 51.7711 | 0.25711 | 51.178 | 52.364 |
| 1-2 | 3 | 52.0563 | 0.25711 | 51.463 | 52.649 |
| 2-1 | 3 | 51.9850 | 0.25711 | 51.392 | 52.578 |
| 2-2 | 3 | 51.9850 | 0.25711 | 51.392 | 52.578 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of SiO2(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.367647 |
| Adj Rsquare | -0.10662 |
| Root Mean Square Error | 0.701416 |
| Mean of Response | 47.17157 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 1.1441511 | 0.381384 | 0.7752 | 0.5656 |
| Error | 4 | 1.9679399 | 0.491985 | | |
| C. Total | 7 | 3.1120911 | | | |

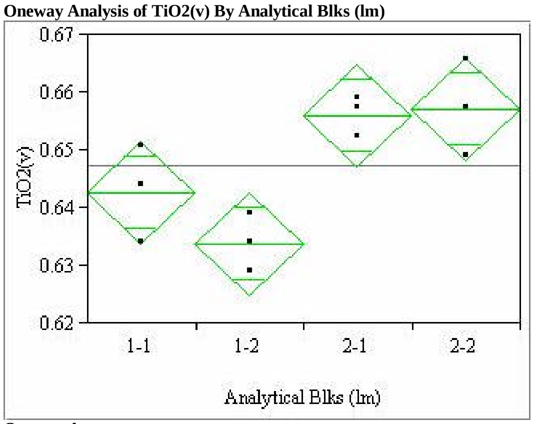
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 46.5298 | 0.49598 | 45.153 | 47.907 |
| 1-2 | 2 | 47.3855 | 0.49598 | 46.008 | 48.763 |
| 2-1 | 2 | 47.4925 | 0.49598 | 46.115 | 48.870 |
| 2-2 | 2 | 47.2785 | 0.49598 | 45.901 | 48.656 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of TiO2(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.761399 |
| Adj Rsquare | 0.671924 |
| Root Mean Square Error | 0.006655 |
| Mean of Response | 0.647462 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

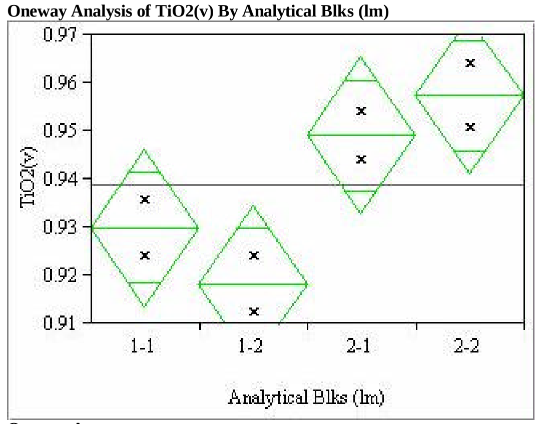
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00113051 | 0.000377 | 8.5096 | 0.0072 |
| Error | 8 | 0.00035427 | 0.000044 | | |
| C. Total | 11 | 0.00148478 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 0.642736 | 0.00384 | 0.63388 | 0.65160 |
| 1-2 | 3 | 0.633840 | 0.00384 | 0.62498 | 0.64270 |
| 2-1 | 3 | 0.656080 | 0.00384 | 0.64722 | 0.66494 |
| 2-2 | 3 | 0.657192 | 0.00384 | 0.64833 | 0.66605 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of TiO2(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.873966 |
| Adj Rsquare | 0.77944 |
| Root Mean Square Error | 0.008298 |
| Mean of Response | 0.938667 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00191000 | 0.000637 | 9.2458 | 0.0285 |
| Error | 4 | 0.00027544 | 0.000069 | | |
| C. Total | 7 | 0.00218544 | | | |

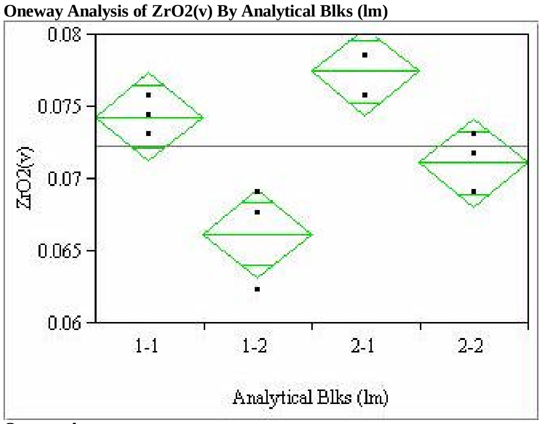
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 0.929910 | 0.00587 | 0.91362 | 0.94620 |
| 1-2 | 2 | 0.918234 | 0.00587 | 0.90194 | 0.93453 |
| 2-1 | 2 | 0.949092 | 0.00587 | 0.93280 | 0.96538 |
| 2-2 | 2 | 0.957432 | 0.00587 | 0.94114 | 0.97372 |

Std Error uses a pooled estimate of error variance

**Exhibit A.3: Measurements of Standards Prepared Using the Lithium Metaborate (LM) Method by Oxide by Analytical Block**
(continued)
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of ZrO2(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.829684 |
| Adj Rsquare | 0.765815 |
| Root Mean Square Error | 0.002307 |
| Mean of Response | 0.072268 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

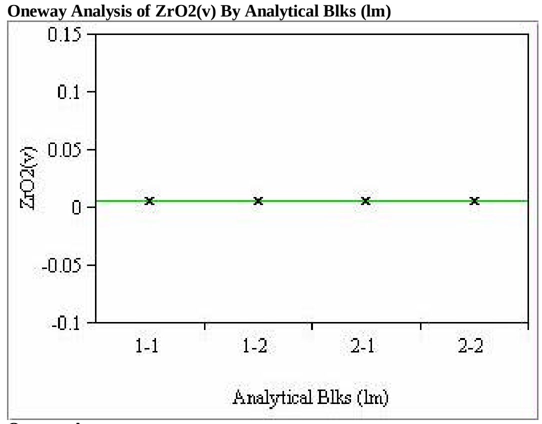
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0.00020740 | 0.000069 | 12.9905 | 0.0019 |
| Error | 8 | 0.00004258 | 0.000005 | | |
| C. Total | 11 | 0.00024998 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 0.074294 | 0.00133 | 0.07122 | 0.07737 |
| 1-2 | 3 | 0.066189 | 0.00133 | 0.06312 | 0.06926 |
| 2-1 | 3 | 0.077446 | 0.00133 | 0.07437 | 0.08052 |
| 2-2 | 3 | 0.071142 | 0.00133 | 0.06807 | 0.07421 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of ZrO2(v) By Analytical Blks (lm)**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | . |
| Adj Rsquare | . |
| Root Mean Square Error | 0 |
| Mean of Response | 0.006754 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Blks (lm) | 3 | 0 | 0 | . | -1.0000 |
| Error | 4 | 0 | 0 | | |
| C. Total | 7 | 0 | | | |

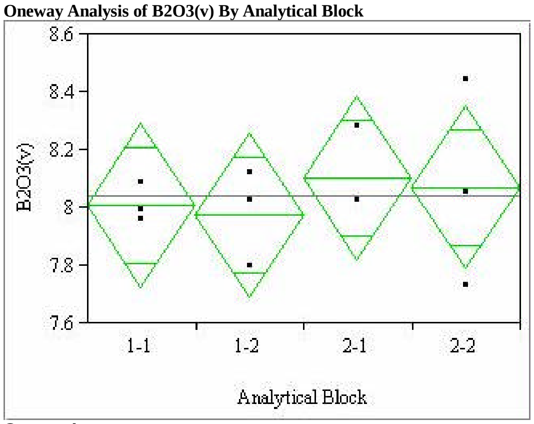
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 0.006754 | 0 | 0.00675 | 0.00675 |
| 1-2 | 2 | 0.006754 | 0 | 0.00675 | 0.00675 |
| 2-1 | 2 | 0.006754 | 0 | 0.00675 | 0.00675 |
| 2-2 | 2 | 0.006754 | 0 | 0.00675 | 0.00675 |

Std Error uses a pooled estimate of error variance

**Exhibit A.4: Measurements of Standards Prepared Using the Peroxide Fusion (pf) Method by Oxide by Analytical Block**
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of B2O3(v) By Analytical Block**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.079646 |
| Adj Rsquare | -0.26549 |
| Root Mean Square Error | 0.21196 |
| Mean of Response | 8.039017 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

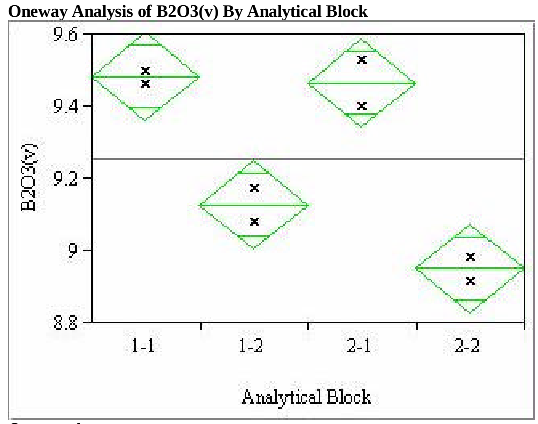
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Block | 3 | 0.03110327 | 0.010368 | 0.2308 | 0.8725 |
| Error | 8 | 0.35941554 | 0.044927 | | |
| C. Total | 11 | 0.39051881 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 8.00682 | 0.12238 | 7.7246 | 8.2890 |
| 1-2 | 3 | 7.97462 | 0.12238 | 7.6924 | 8.2568 |
| 2-1 | 3 | 8.10342 | 0.12238 | 7.8212 | 8.3856 |
| 2-2 | 3 | 8.07122 | 0.12238 | 7.7890 | 8.3534 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of B2O3(v) By Analytical Block**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.963415 |
| Adj Rsquare | 0.935976 |
| Root Mean Square Error | 0.062353 |
| Mean of Response | 9.257212 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Block | 3 | 0.40952636 | 0.136509 | 35.1111 | 0.0025 |
| Error | 4 | 0.01555163 | 0.003888 | | |
| C. Total | 7 | 0.42507800 | | | |

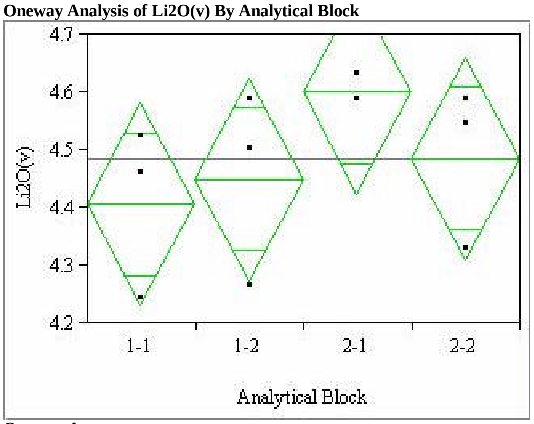
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 9.48261 | 0.04409 | 9.3602 | 9.6050 |
| 1-2 | 2 | 9.12842 | 0.04409 | 9.0060 | 9.2508 |
| 2-1 | 2 | 9.46651 | 0.04409 | 9.3441 | 9.5889 |
| 2-2 | 2 | 8.95132 | 0.04409 | 8.8289 | 9.0737 |

Std Error uses a pooled estimate of error variance

**Exhibit A.4: Measurements of Standards Prepared Using the Peroxide Fusion (pf) Method by Oxide by Analytical Block**
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of Li2O(v) By Analytical Block**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.309707 |
| Adj Rsquare | 0.050847 |
| Root Mean Square Error | 0.131544 |
| Mean of Response | 4.485208 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

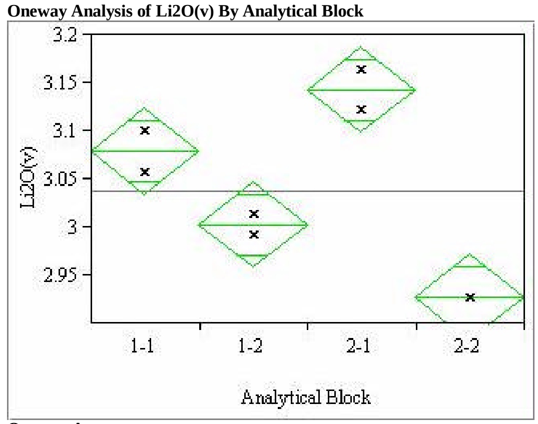
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Block | 3 | 0.06210871 | 0.020703 | 1.1964 | 0.3712 |
| Error | 8 | 0.13843136 | 0.017304 | | |
| C. Total | 11 | 0.20054007 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 4.40627 | 0.07595 | 4.2311 | 4.5814 |
| 1-2 | 3 | 4.44933 | 0.07595 | 4.2742 | 4.6245 |
| 2-1 | 3 | 4.60003 | 0.07595 | 4.4249 | 4.7752 |
| 2-2 | 3 | 4.48521 | 0.07595 | 4.3101 | 4.6603 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of Li2O(v) By Analytical Block**




**Oneway Anova**
**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.961497 |
| Adj Rsquare | 0.93262 |
| Root Mean Square Error | 0.022835 |
| Mean of Response | 3.03828 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Block | 3 | 0.05208557 | 0.017362 | 33.2963 | 0.0027 |
| Error | 4 | 0.00208574 | 0.000521 | | |
| C. Total | 7 | 0.05417131 | | | |

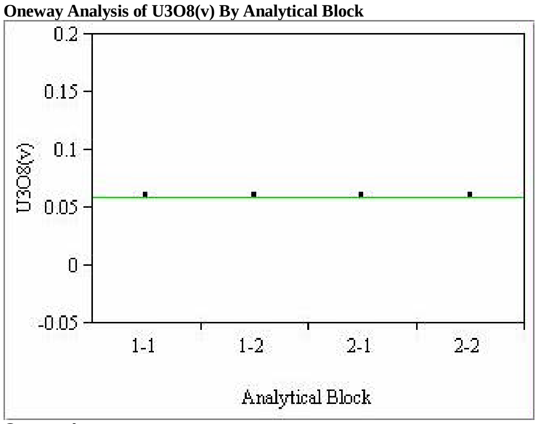
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 3.07865 | 0.01615 | 3.0338 | 3.1235 |
| 1-2 | 2 | 3.00330 | 0.01615 | 2.9585 | 3.0481 |
| 2-1 | 2 | 3.14323 | 0.01615 | 3.0984 | 3.1881 |
| 2-2 | 2 | 2.92794 | 0.01615 | 2.8831 | 2.9728 |

Std Error uses a pooled estimate of error variance

**Exhibit A.4: Measurements of Standards Prepared Using the Peroxide Fusion (pf) Method by Oxide by Analytical Block**
(small square – Batch 1 standard; x – Ustd;)

**Oneway Analysis of U3O8(v) By Analytical Block**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | . |
| Adj Rsquare | . |
| Root Mean Square Error | 0 |
| Mean of Response | 0.05896 |
| Observations (or Sum Wgts) | 12 |

**Analysis of Variance**

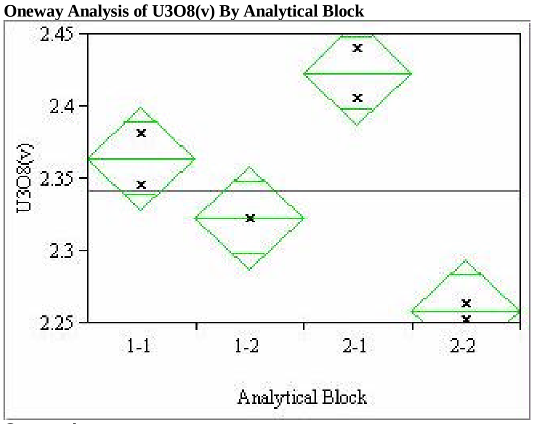
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Block | 3 | 0 | 0 | . | -1.0000 |
| Error | 8 | 0 | 0 | | |
| C. Total | 11 | 0 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 3 | 0.058960 | 0 | 0.05896 | 0.05896 |
| 1-2 | 3 | 0.058960 | 0 | 0.05896 | 0.05896 |
| 2-1 | 3 | 0.058960 | 0 | 0.05896 | 0.05896 |
| 2-2 | 3 | 0.058960 | 0 | 0.05896 | 0.05896 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of U3O8(v) By Analytical Block**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.956397 |
| Adj Rsquare | 0.923695 |
| Root Mean Square Error | 0.018173 |
| Mean of Response | 2.342186 |
| Observations (or Sum Wgts) | 8 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Analytical Block | 3 | 0.02897481 | 0.009658 | 29.2456 | 0.0035 |
| Error | 4 | 0.00132099 | 0.000330 | | |
| C. Total | 7 | 0.03029579 | | | |

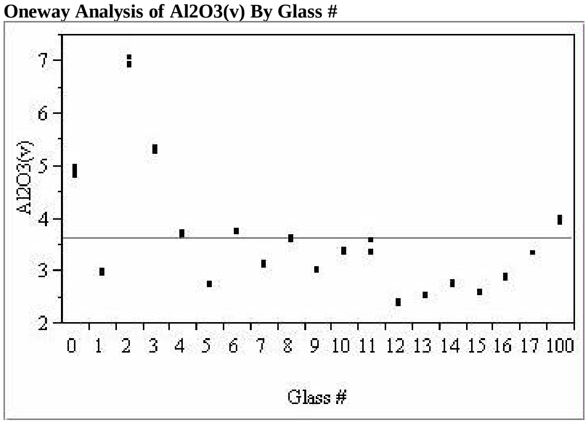
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1-1 | 2 | 2.36430 | 0.01285 | 2.3286 | 2.4000 |
| 1-2 | 2 | 2.32302 | 0.01285 | 2.2873 | 2.3587 |
| 2-1 | 2 | 2.42326 | 0.01285 | 2.3876 | 2.4589 |
| 2-2 | 2 | 2.25817 | 0.01285 | 2.2225 | 2.2938 |

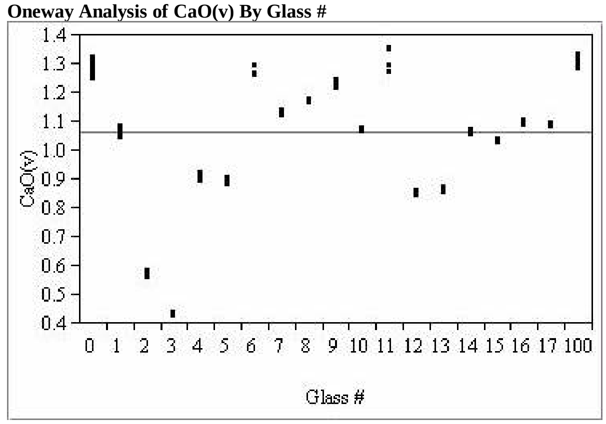
Std Error uses a pooled estimate

**Exhibit A.5: Lithium Metaborate (LM) Measurements and Bias-Corrected Measurements by Glass Number by Oxide**
(0 – Batch 1, 100 – Ustd, and 1-17 PHA glasses)

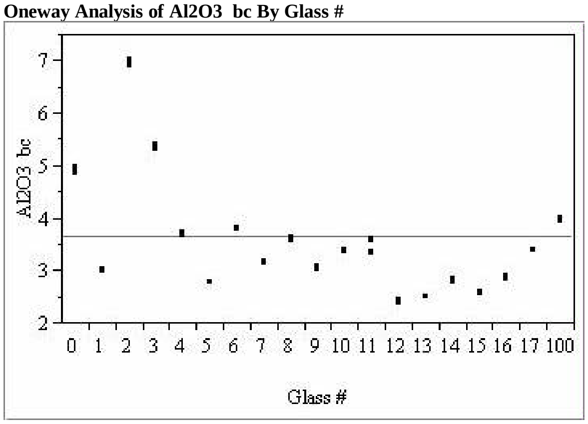
**Oneway Analysis of Al2O3(v) By Glass #**




**Oneway Analysis of CaO(v) By Glass #**




**Oneway Analysis of Al2O3 bc By Glass #**




**Oneway Analysis of Ca2O3 bc By Glass #**

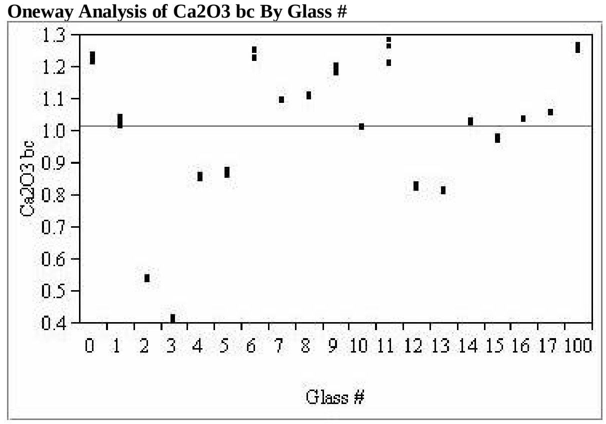
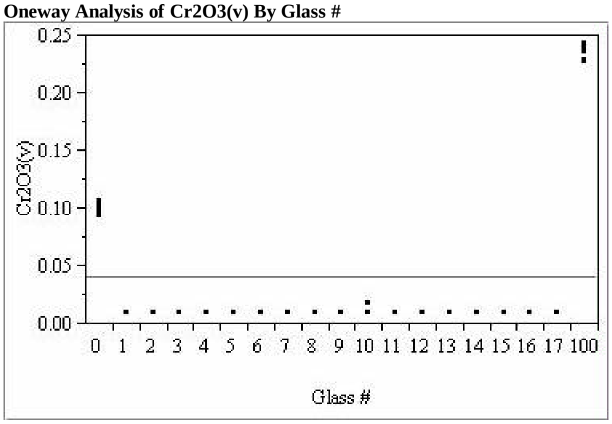
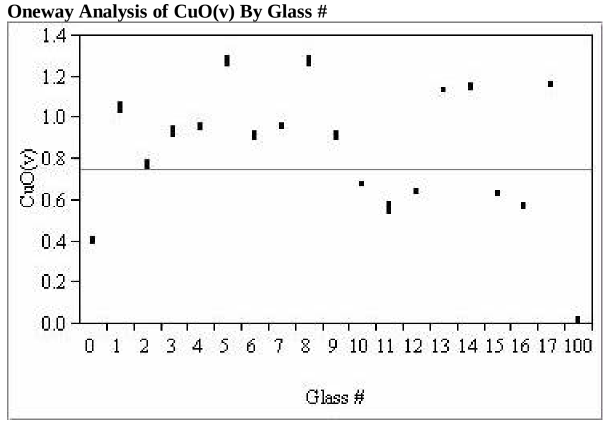


**Exhibit A.5: Lithium Metaborate (LM) Measurements and Bias-Corrected Measurements by Glass Number by Oxide** *(continued)*
(0 – Batch 1, 100 – Ustd, and 1-17 PHA glasses)

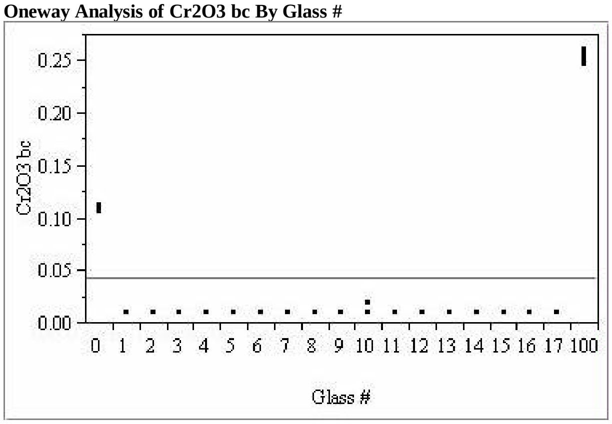
**Oneway Analysis of Cr2O3(v) By Glass #**




**Oneway Analysis of CuO(v) By Glass #**




**Oneway Analysis of Cr2O3 bc By Glass #**




**Oneway Analysis of CuO bc By Glass #**

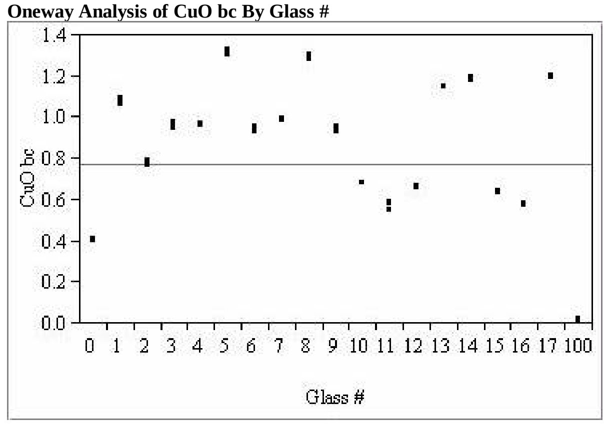
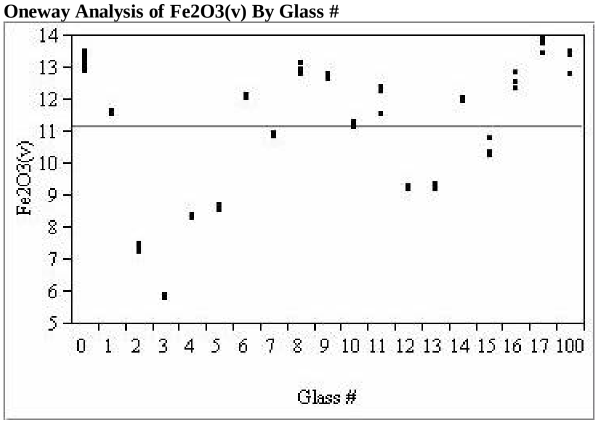
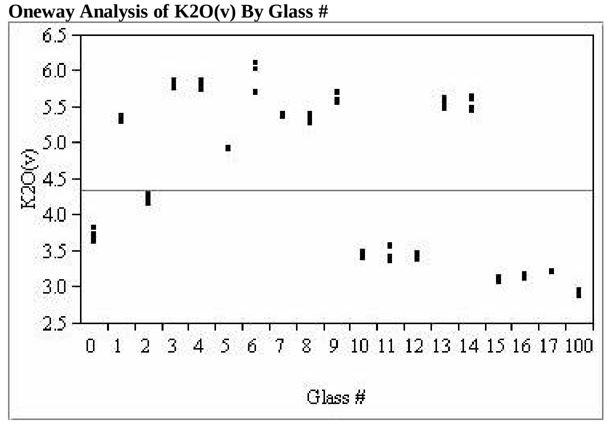


**Exhibit A.5: Lithium Metaborate (LM) Measurements and Bias-Corrected Measurements by Glass Number by Oxide** *(continued)*
(0 – Batch 1, 100 – Ustd, and 1-17 PHA glasses)

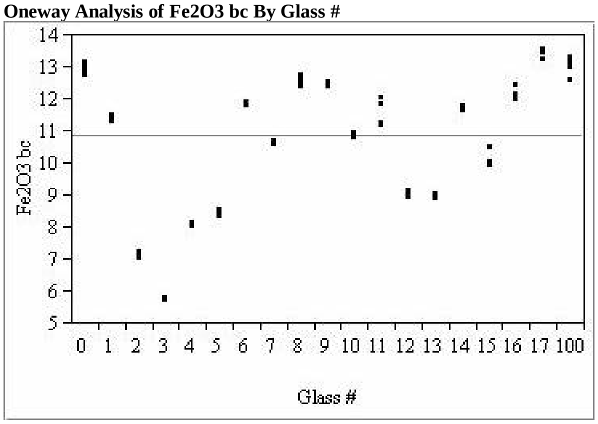
**Oneway Analysis of Fe2O3(v) By Glass #**




**Oneway Analysis of K2O(v) By Glass #**




**Oneway Analysis of Fe2O3 bc By Glass #**




**Oneway Analysis of K2O bc By Glass #**

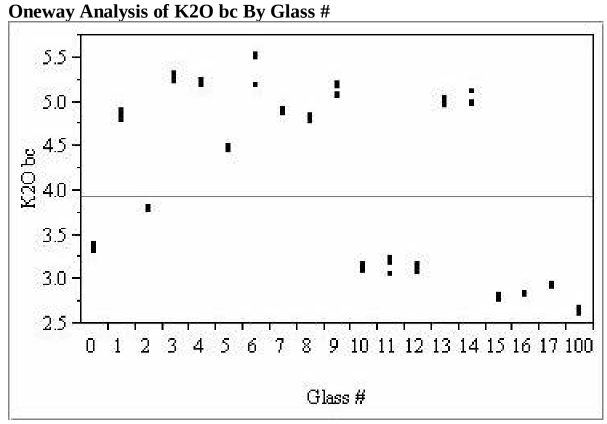
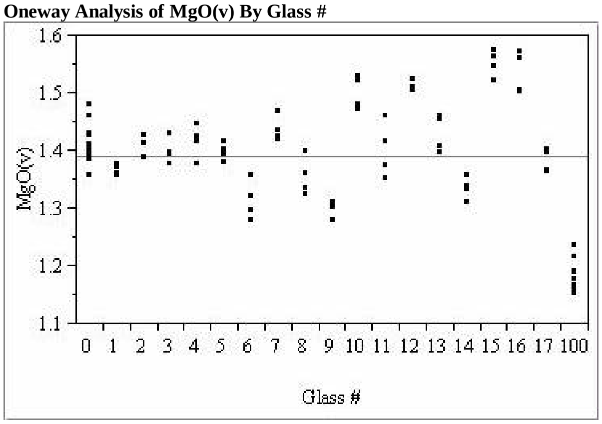


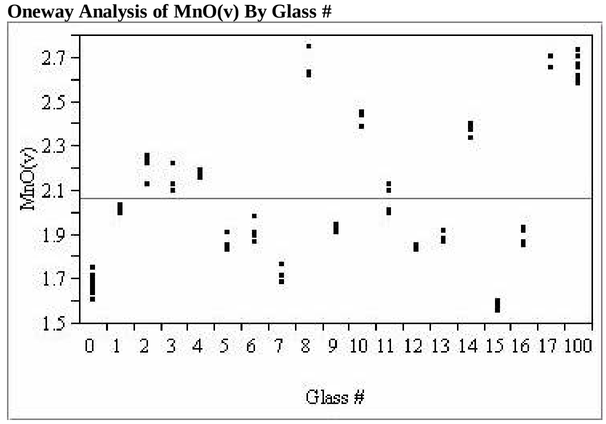
**Exhibit A.5: Lithium Metaborate (LM) Measurements and Bias-Corrected Measurements by Glass Number by Oxide** *(continued)*

(0 – Batch 1, 100 – Ustd, and 1-17 PHA glasses)

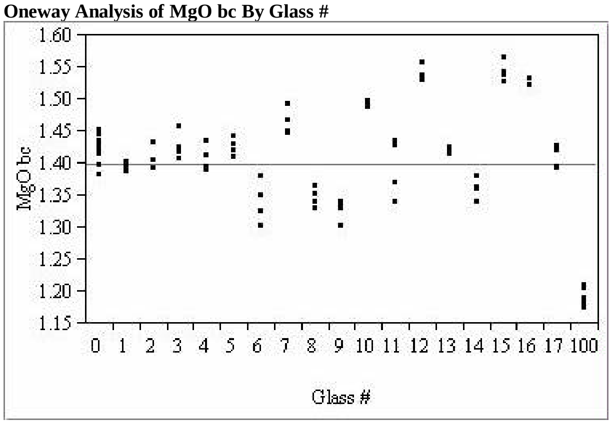
**Oneway Analysis of MgO(v) By Glass #**




**Oneway Analysis of MnO(v) By Glass #**




**Oneway Analysis of MgO bc By Glass #**




**Oneway Analysis of MnO bc By Glass #**

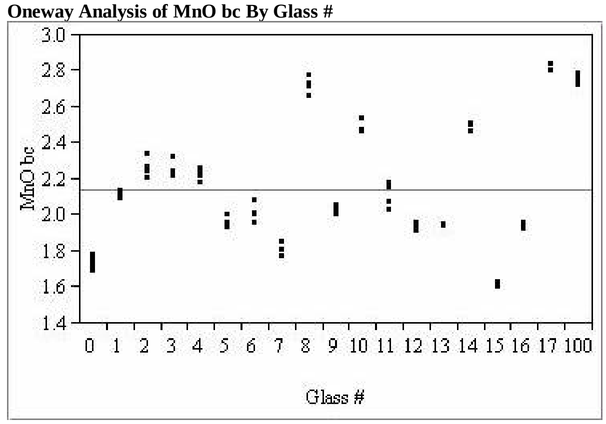
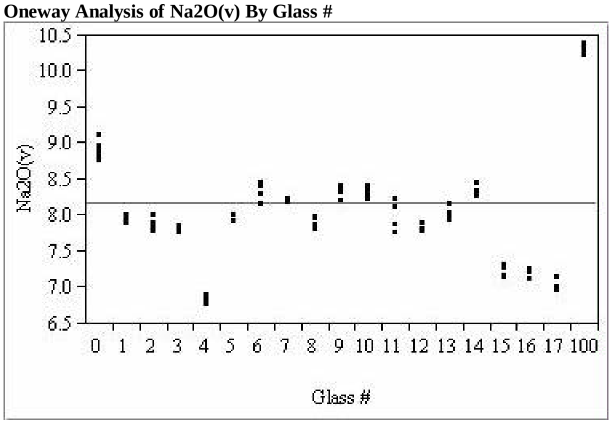
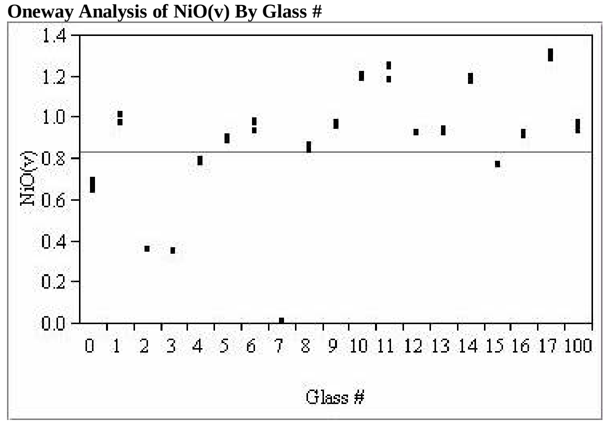


**Exhibit A.5: Lithium Metaborate (LM) Measurements and Bias-Corrected Measurements by Glass Number by Oxide** *(continued)*
(0 – Batch 1, 100 – Ustd, and 1-17 PHA glasses)

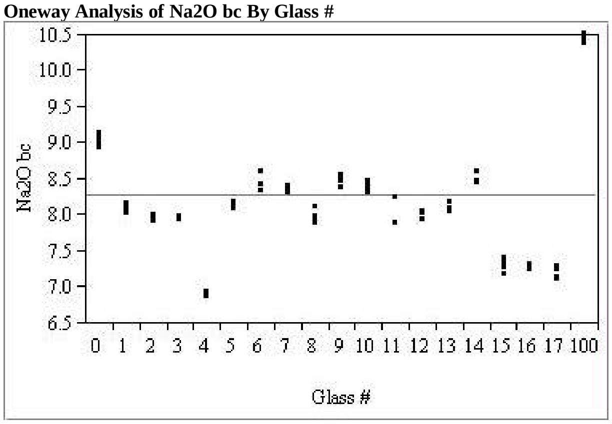
**Oneway Analysis of Na2O(v) By Glass #**




**Oneway Analysis of NiO(v) By Glass #**




**Oneway Analysis of Na2O bc By Glass #**




**Oneway Analysis of NiO bc By Glass #**

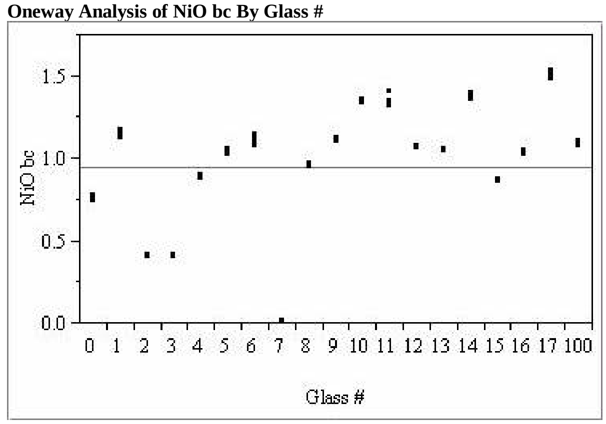
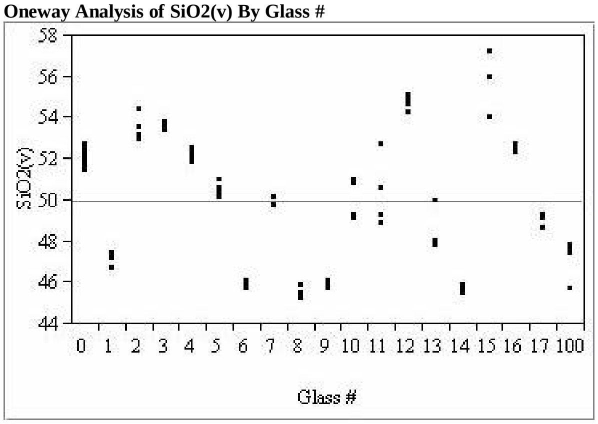
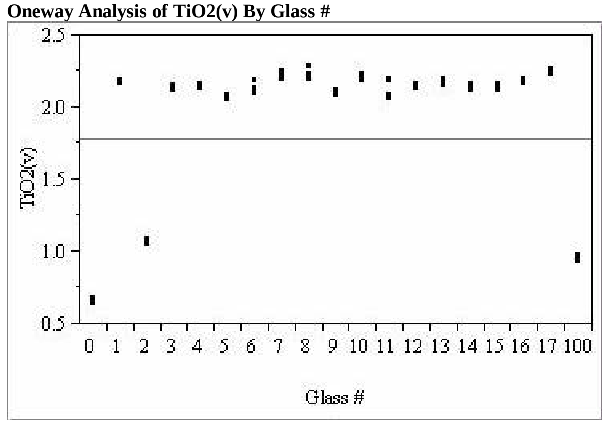


**Exhibit A.5: Lithium Metaborate (LM) Measurements and Bias-Corrected Measurements by Glass Number by Oxide** *(continued)*
(0 – Batch 1, 100 – Ustd, and 1-17 PHA glasses)

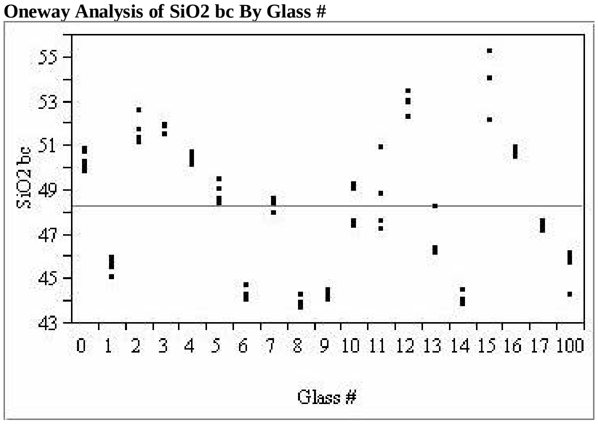
**Oneway Analysis of SiO2(v) By Glass #**




**Oneway Analysis of TiO2(v) By Glass #**




**Oneway Analysis of SiO2 bc By Glass #**




**Oneway Analysis of TiO2 bc By Glass #**

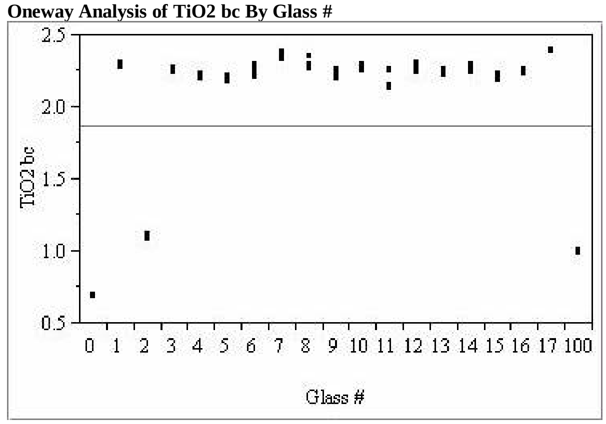
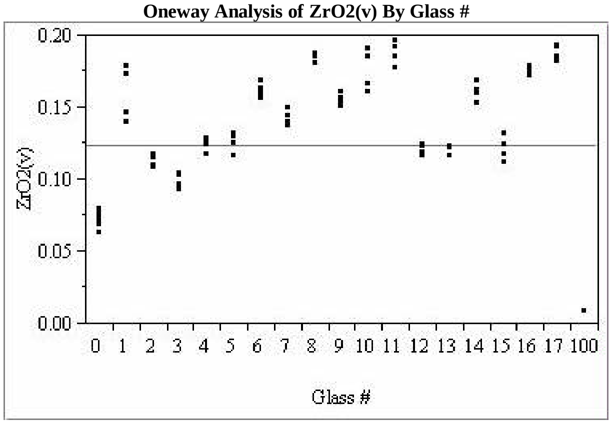


**Exhibit A.5: Lithium Metaborate (LM) Measurements and Bias-Corrected Measurements by Glass Number by Oxide** *(continued)*
(0 – Batch 1, 100 – Ustd, and 1-17 PHA glasses)

**Oneway Analysis of ZrO2(v) By Glass #**




**Oneway Analysis of ZrO2 bc By Glass #**

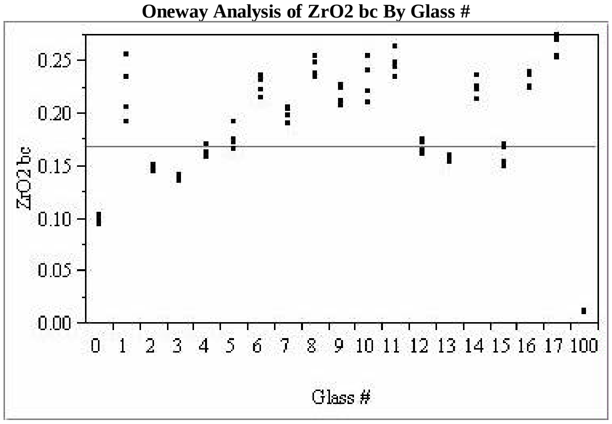
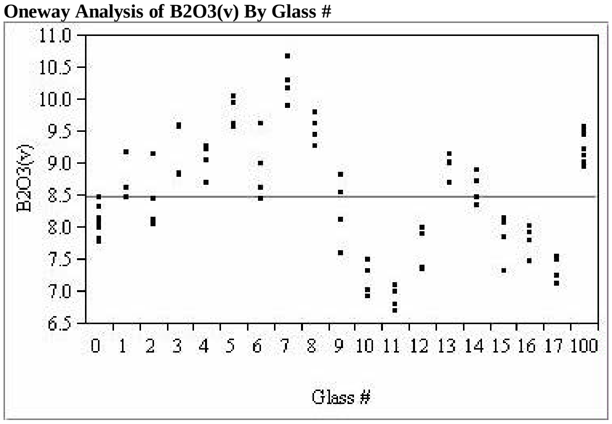
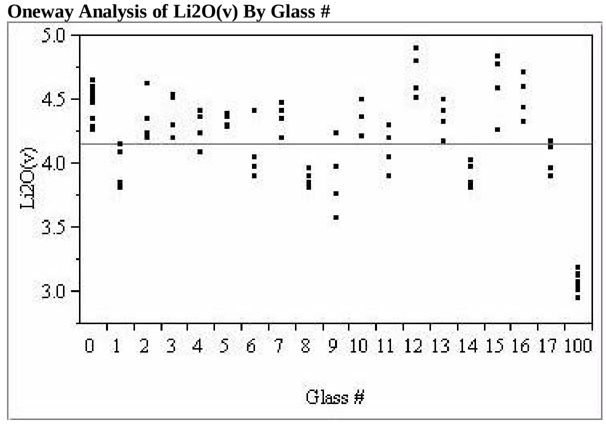


**Exhibit A.6: Peroxide Fusion (pf) Measurements and Bias-Corrected Measurements by Glass Number by Oxide** *(continued)*
(0 – Batch 1, 100 – Ustd, and 1-17 PHA glasses)

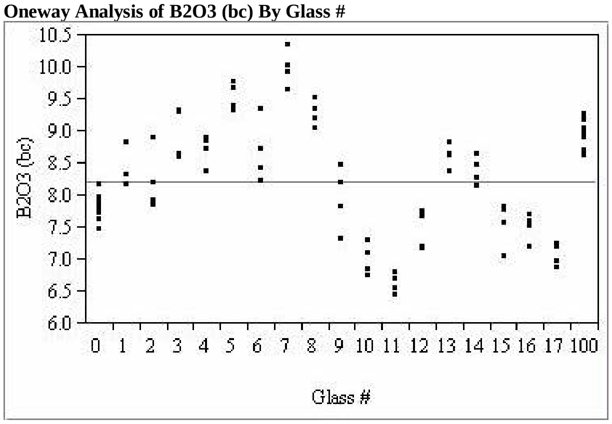
**Oneway Analysis of B2O3(v) By Glass #**




**Oneway Analysis of Li2O(v) By Glass #**




**Oneway Analysis of B2O3 (bc) By Glass #**




**Oneway Analysis of Li2O (bc) By Glass #**

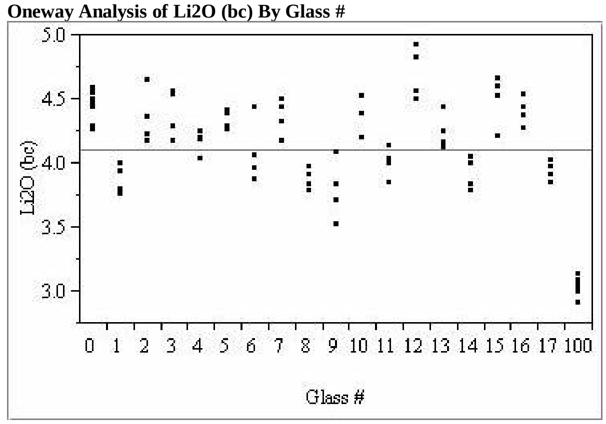
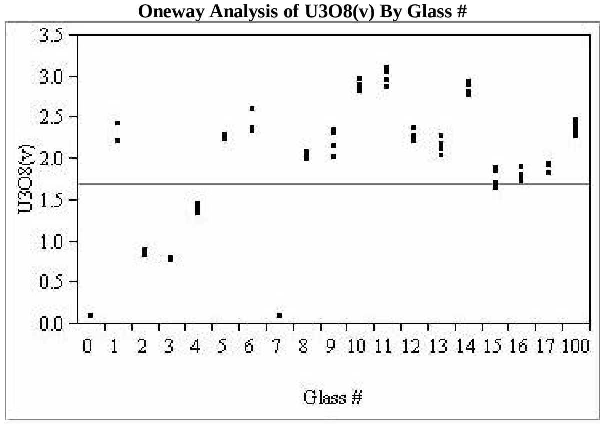


**Exhibit A.6: Peroxide Fusion (pf) Measurements and Bias-Corrected (bc) Measurements by Glass Number by Oxide** *(continued)*
(0 – Batch 1, 100 – Ustd, and 1-17 PHA glasses)

**Oneway Analysis of U3O8(v) By Glass #**




**Oneway Analysis of U3O8 (bc) By Glass #**

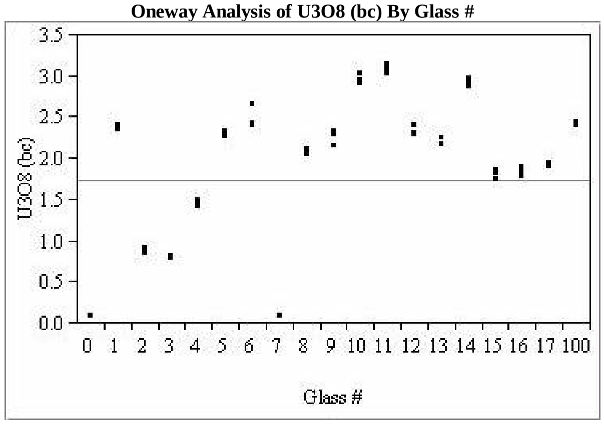
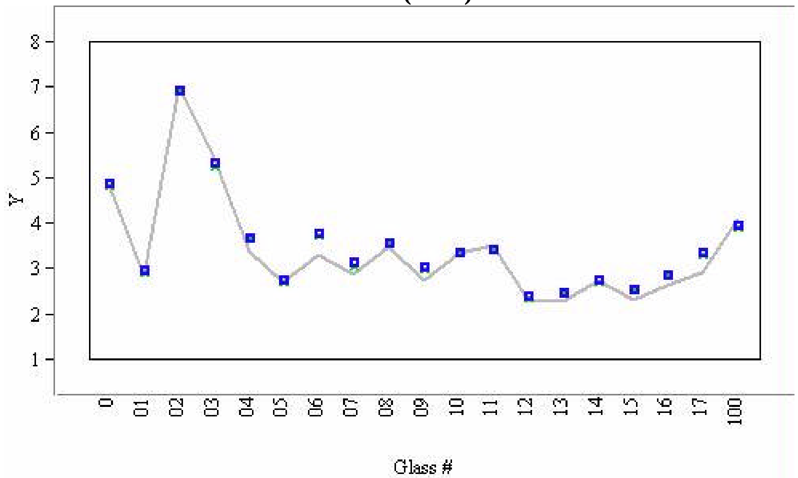
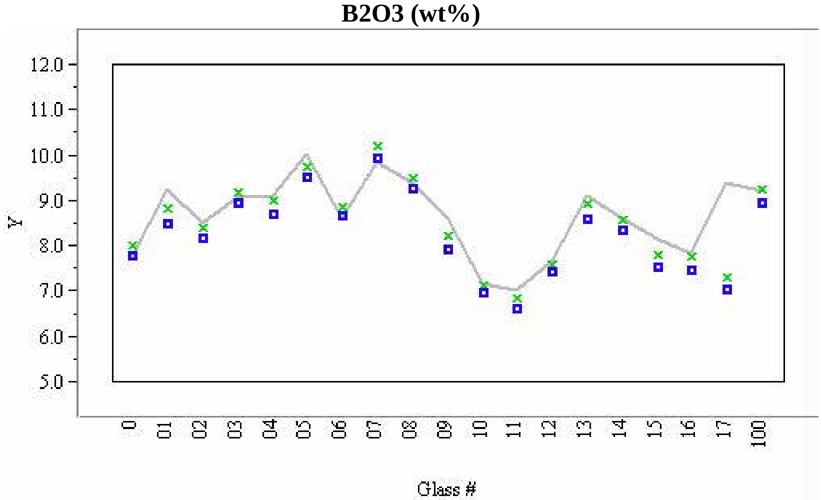


**Exhibit A.7: Comparisons of Measurements versus Target Compositions by Glass #**
(Concentrations in weight percents; 0 – Batch 1, 100 – Ustd, and 1-17 PHA Glasses)

**Al2O3 (wt%)**




**B2O3 (wt%)**



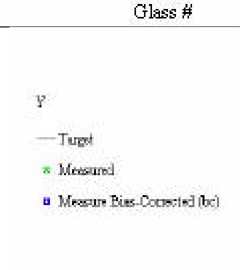
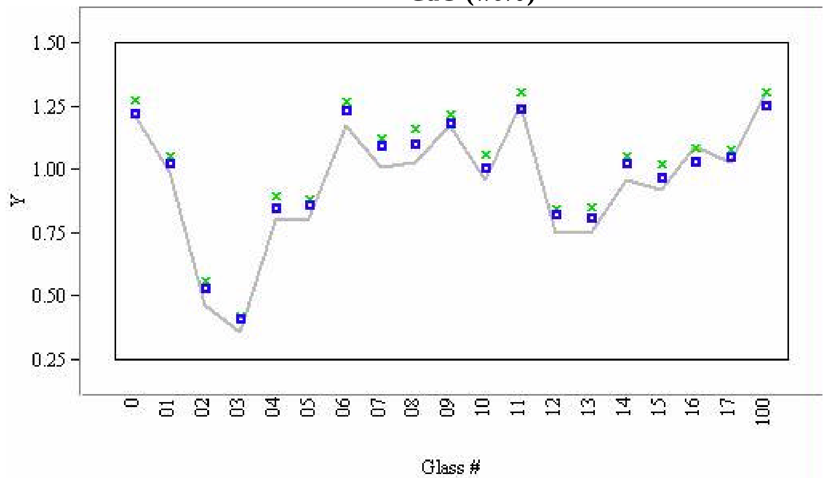
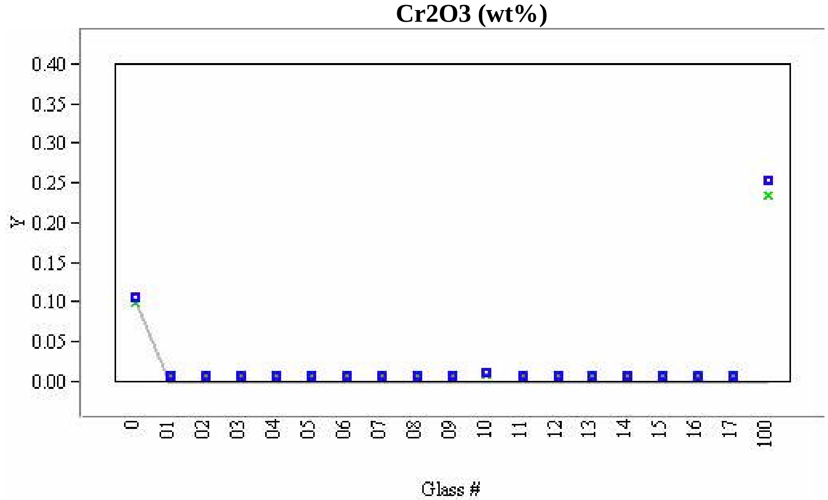



**Exhibit A.7: Comparisons of Measurements versus Target Compositions by Glass #**
(Concentrations in weight percents; 0 – Batch 1, 100 – Ustd, and 1-17 PHA Glasses)

**CaO (wt%)**




**Cr2O3 (wt%)**



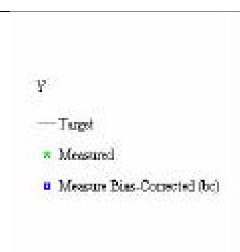
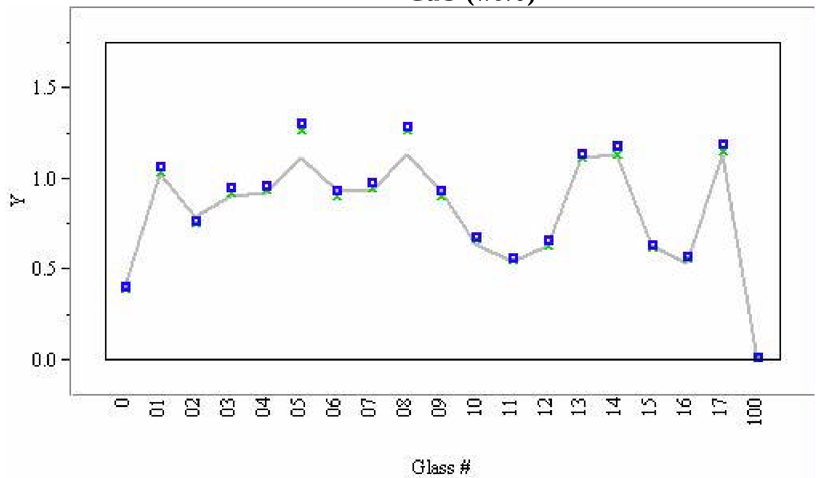
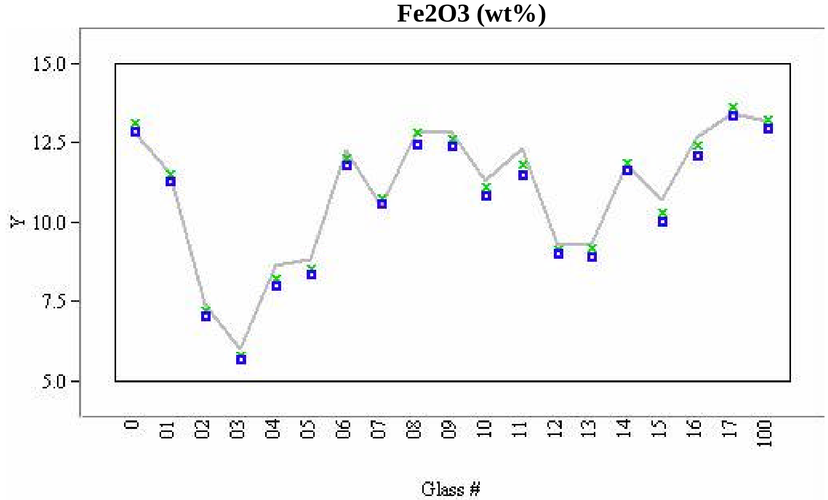



**Exhibit A.7: Comparisons of Measurements versus Target Compositions by Glass #**
(Concentrations in weight percents; 0 – Batch 1, 100 – Ustd, and 1-17 PHA Glasses)

**CuO (wt%)**




**Fe2O3 (wt%)**



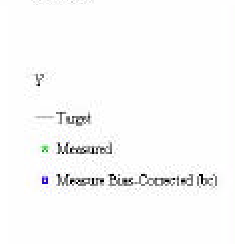
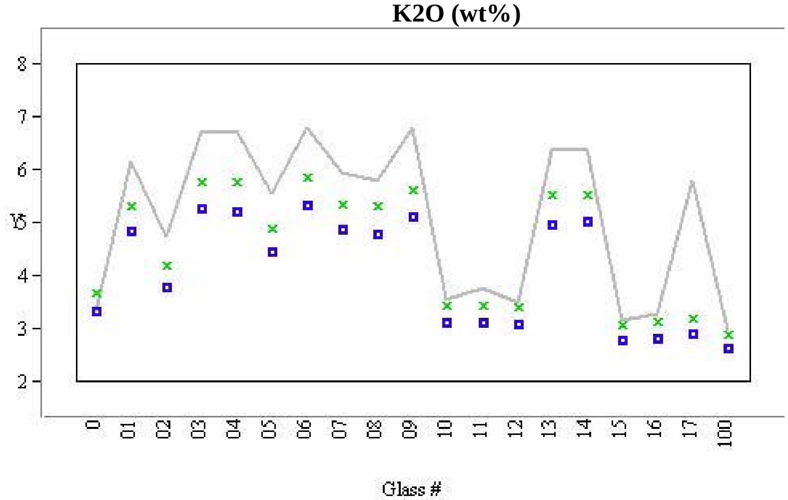
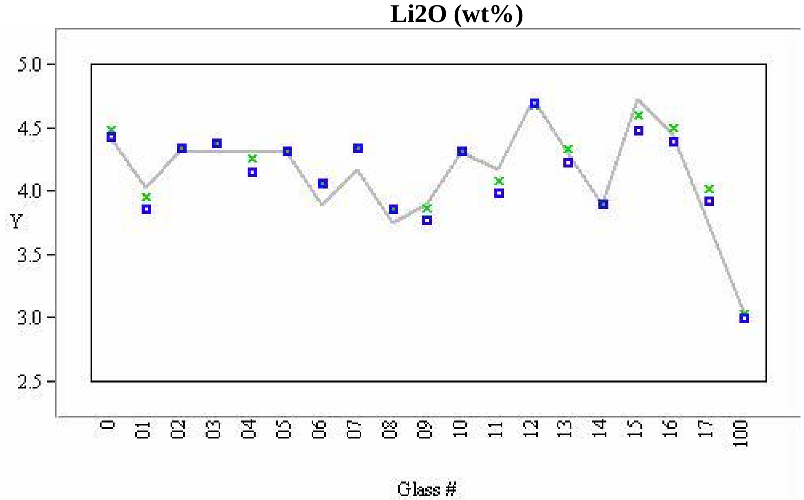



**Exhibit A.7: Comparisons of Measurements versus Target Compositions by Glass #**
(Concentrations in weight percents; 0 – Batch 1, 100 – Ustd, and 1-17 PHA Glasses)



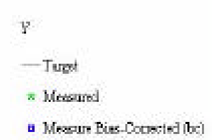
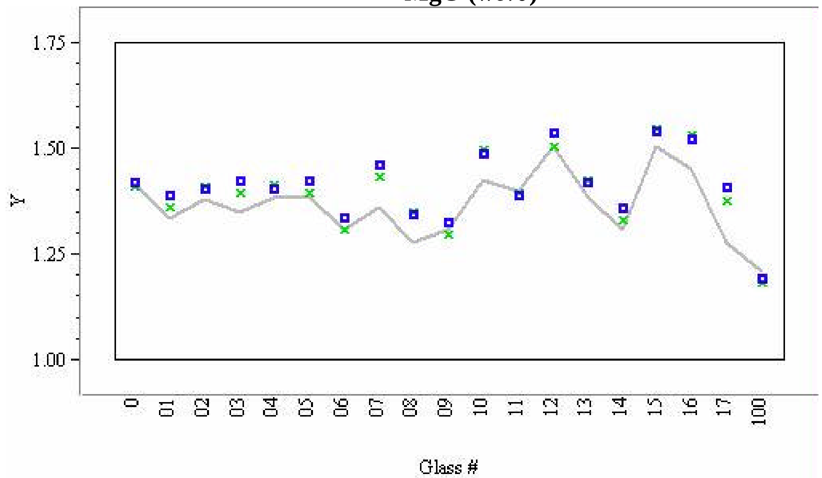



**Exhibit A.7: Comparisons of Measurements versus Target Compositions by Glass #**
(Concentrations in weight percents; 0 – Batch 1, 100 – Ustd, and 1-17 PHA Glasses)

**MgO (wt%)**




**MnO (wt%)**

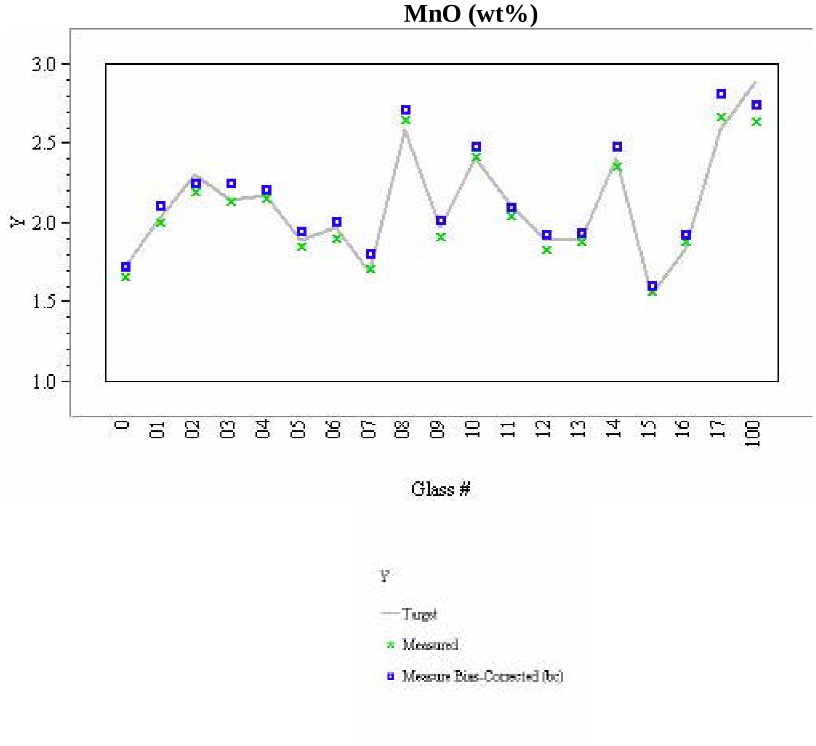
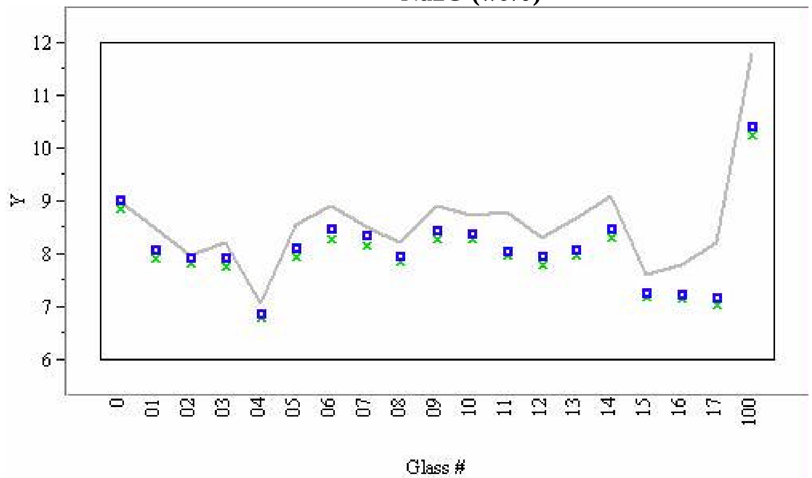
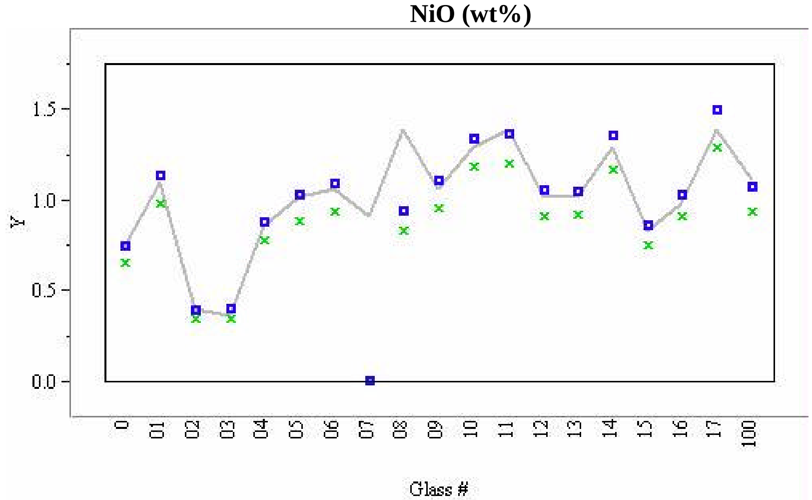


**Exhibit A.7: Comparisons of Measurements versus Target Compositions by Glass #**
(Concentrations in weight percents; 0 – Batch 1, 100 – Ustd, and 1-17 PHA Glasses)

**Na2O (wt%)**




**NiO (wt%)**



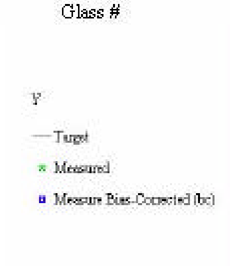



**Exhibit A.7: Comparisons of Measurements versus Target Compositions by Glass #**
(Concentrations in weight percents; 0 – Batch 1, 100 – Ustd, and 1-17 PHA Glasses)

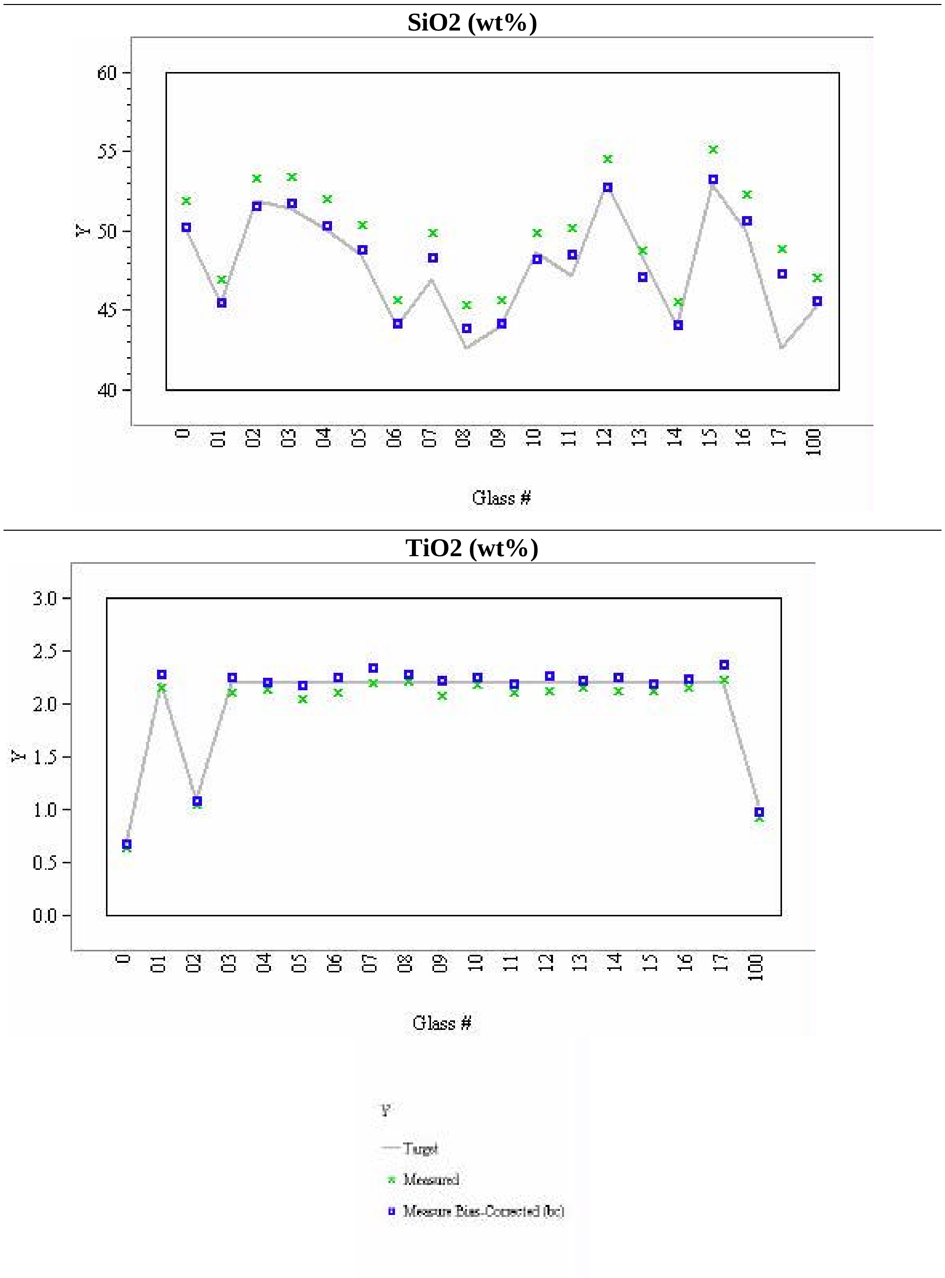
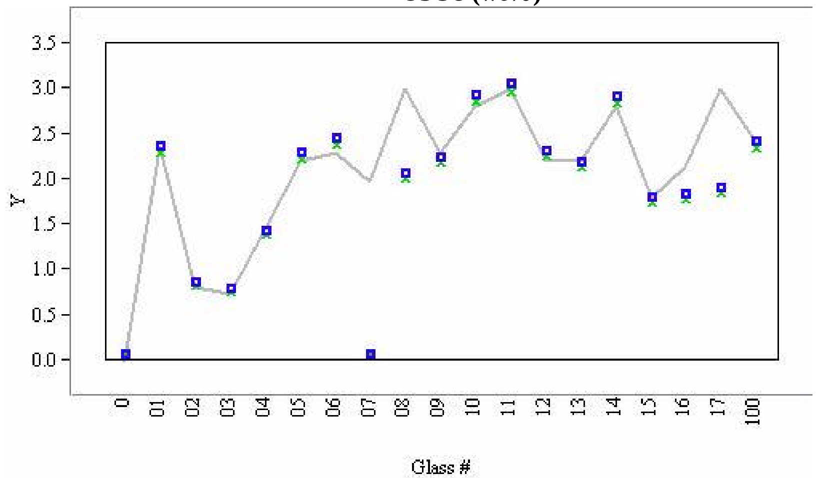
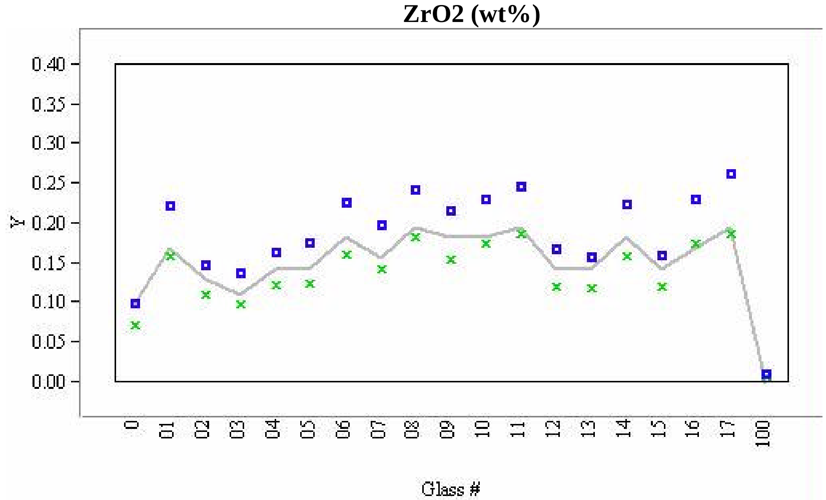


**Exhibit A.7: Comparisons of Measurements versus Target Compositions by Glass #**
(Concentrations in weight percents; 0 – Batch 1, 100 – Ustd, and 1-17 PHA Glasses)

**U3O8 (wt%)**




**ZrO2 (wt%)**



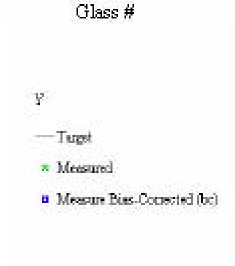



**Exhibit A.7: Comparisons of Measurements versus Target Compositions by Glass #**
(Concentrations in weight percents; 0 – Batch 1, 100 – Ustd, and 1-17 PHA Glasses)

**Sum of Oxides (wt%)**

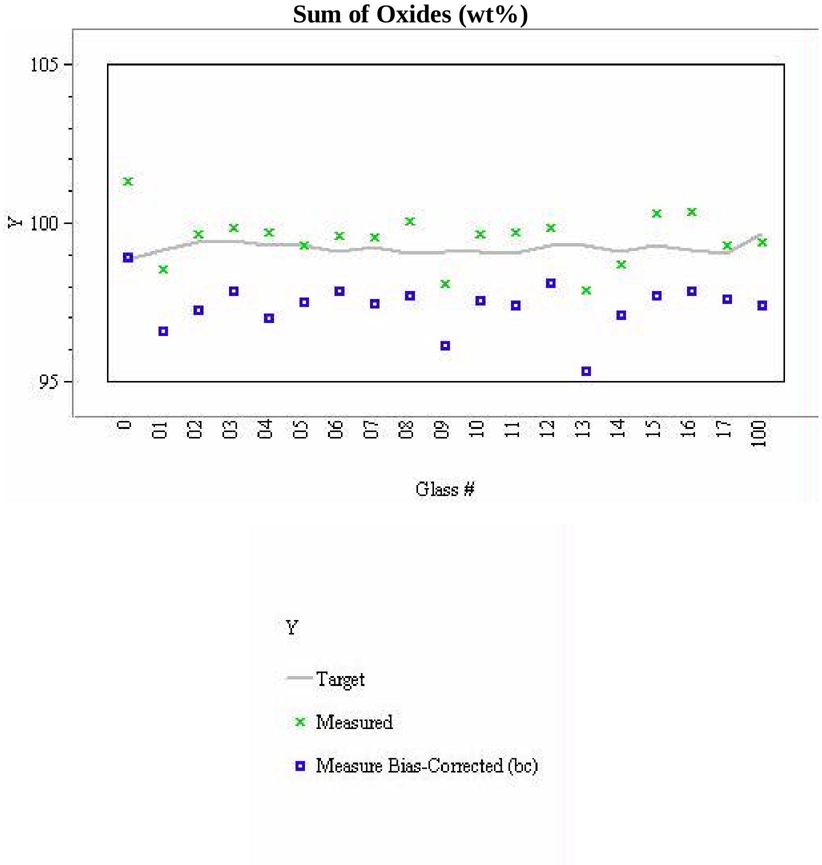
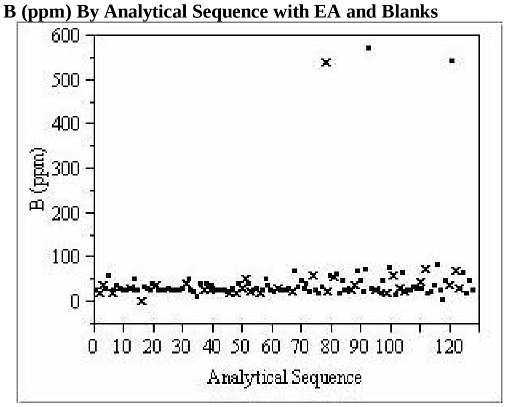
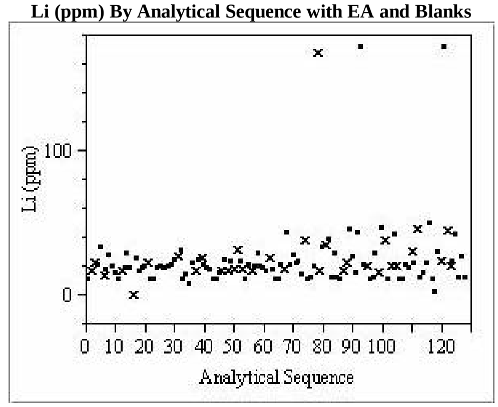


**Exhibit A.8: Plots of the Leachate Concentrations in Analytical Sequence by Element**

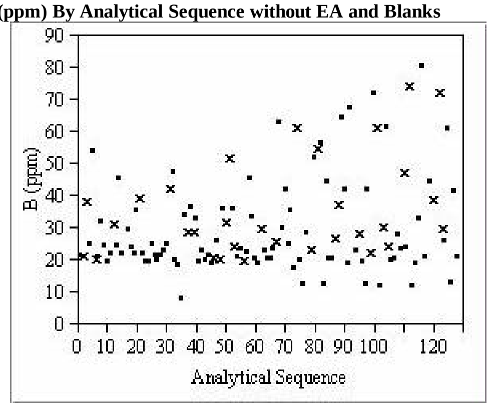
**B (ppm) By Analytical Sequence with EA and Blanks**




**Li (ppm) By Analytical Sequence with EA and Blanks**




**B (ppm) By Analytical Sequence without EA and Blanks**




**Li (ppm) By Analytical Sequence without EA and Blanks**

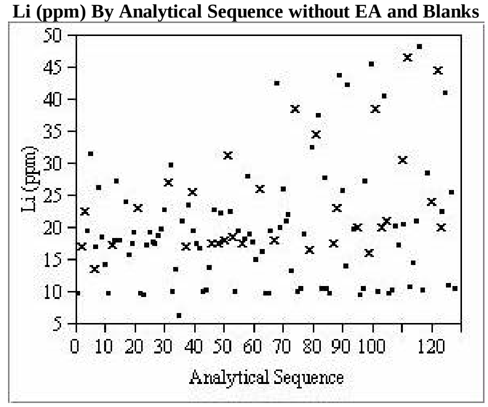
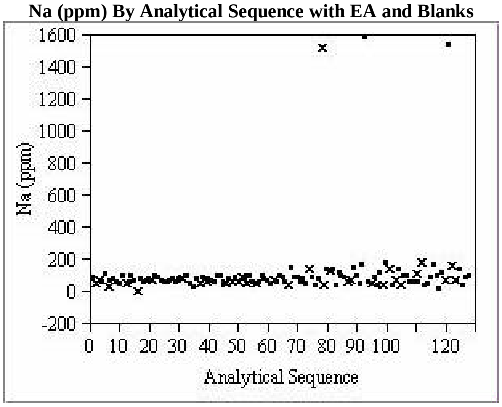
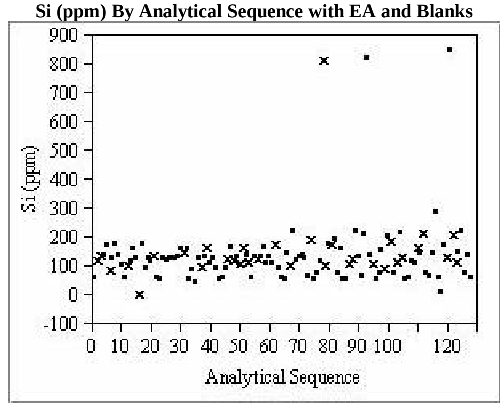


**Exhibit A.8: Plots of the Leachate Concentrations in Analytical Sequence by Element**

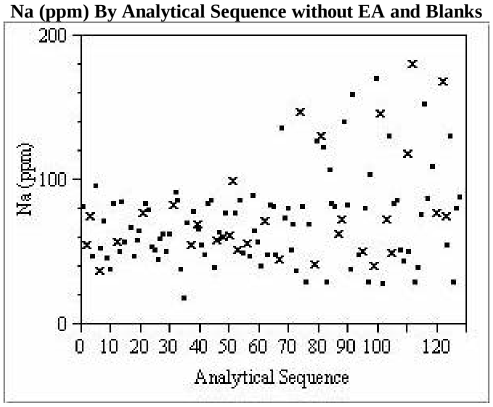
**Na (ppm) By Analytical Sequence with EA and Blanks**




**Si (ppm) By Analytical Sequence with EA and Blanks**




**Na (ppm) By Analytical Sequence without EA and Blanks**




**Si (ppm) By Analytical Sequence without EA and Blanks**

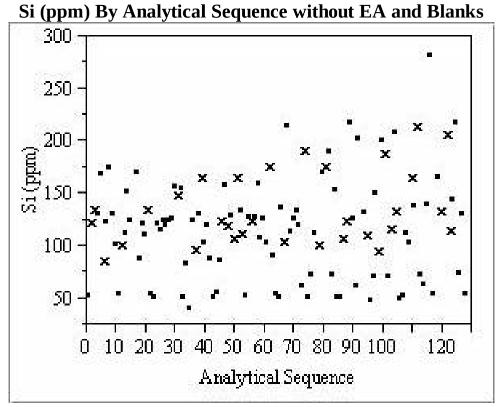
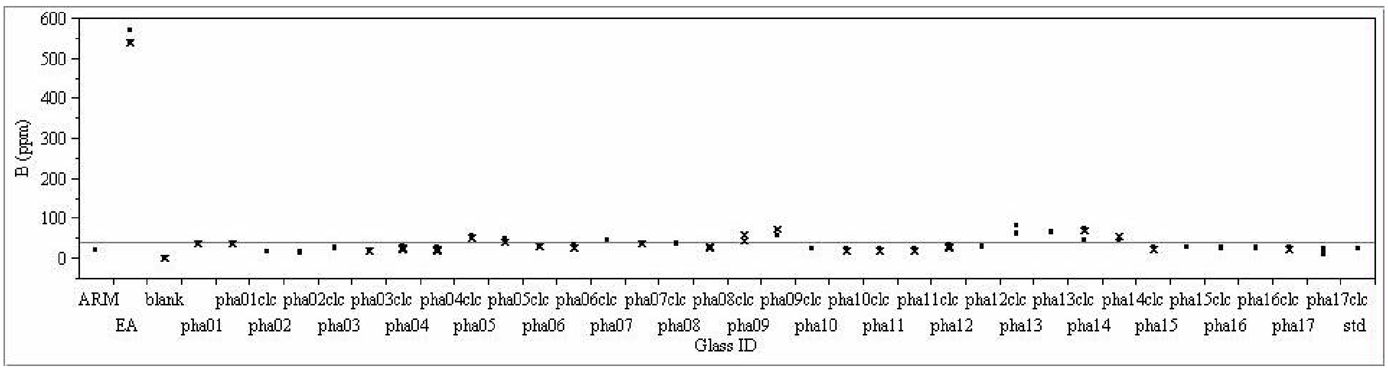


**Exhibit A.9: Plots of the Leachate Concentrations by Glass ID by Element**

## B (ppm) By Sample ID



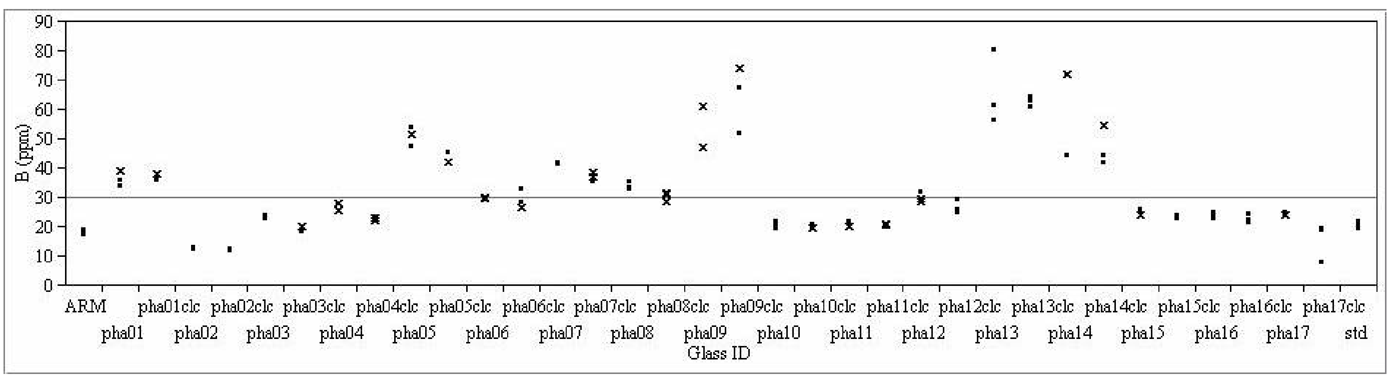
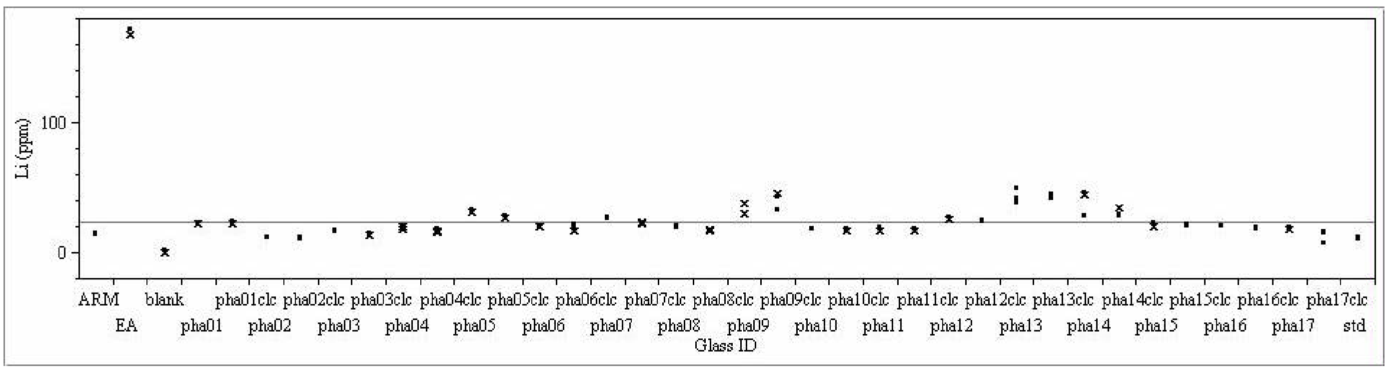



**Exhibit A.9: Plots of the Leachate Concentrations by Glass ID by Element *(continued)***

**Li (ppm) By Sample ID**



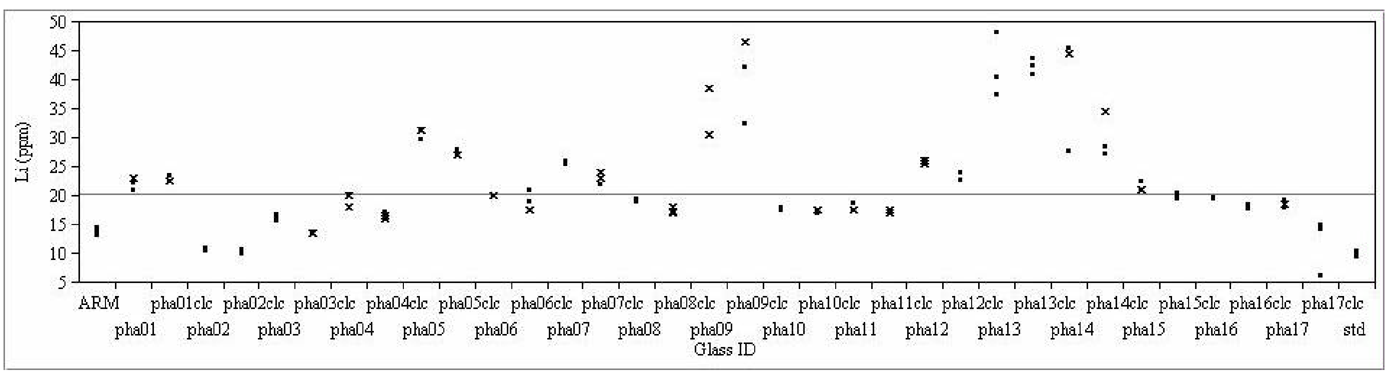
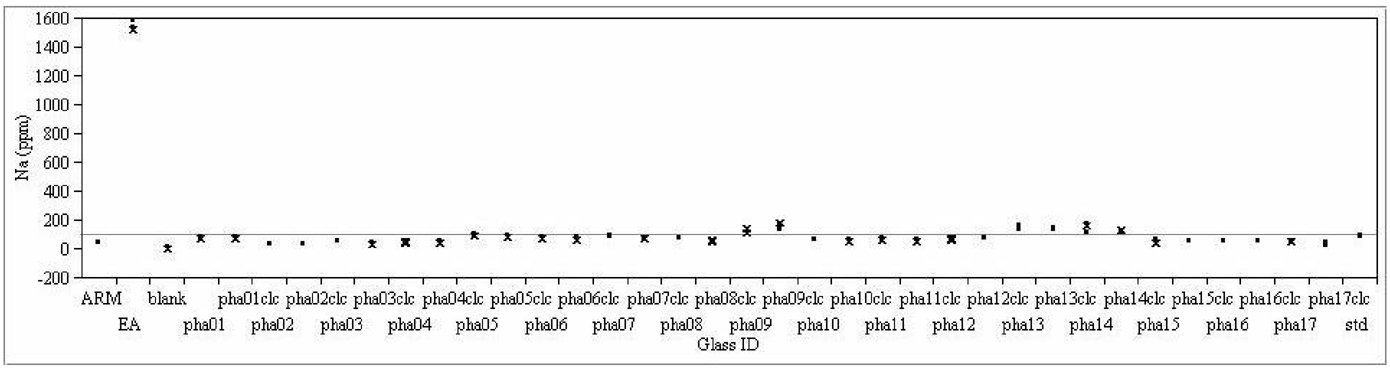



**Exhibit A.9: Plots of the Leachate Concentrations by Glass ID by Element** ***(continued)***

## Na (ppm) By Sample ID



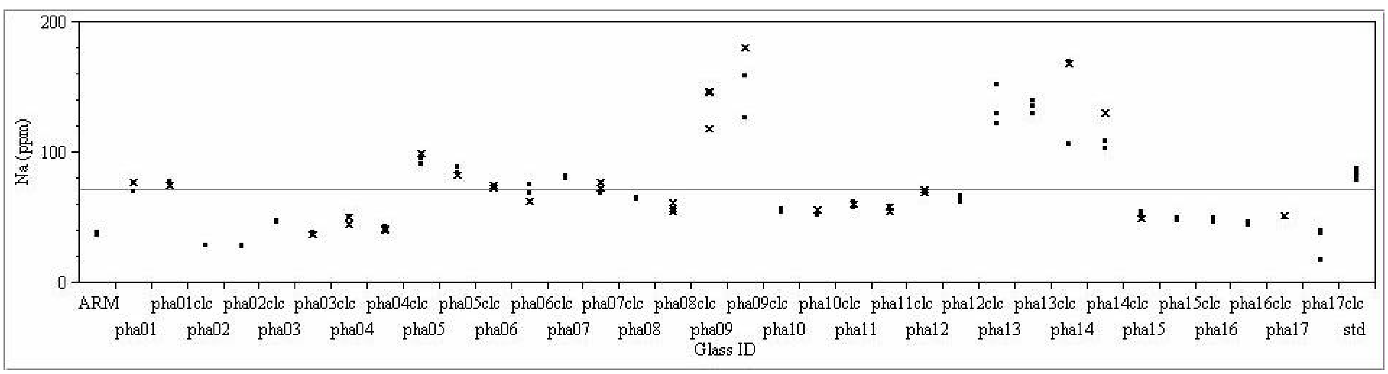
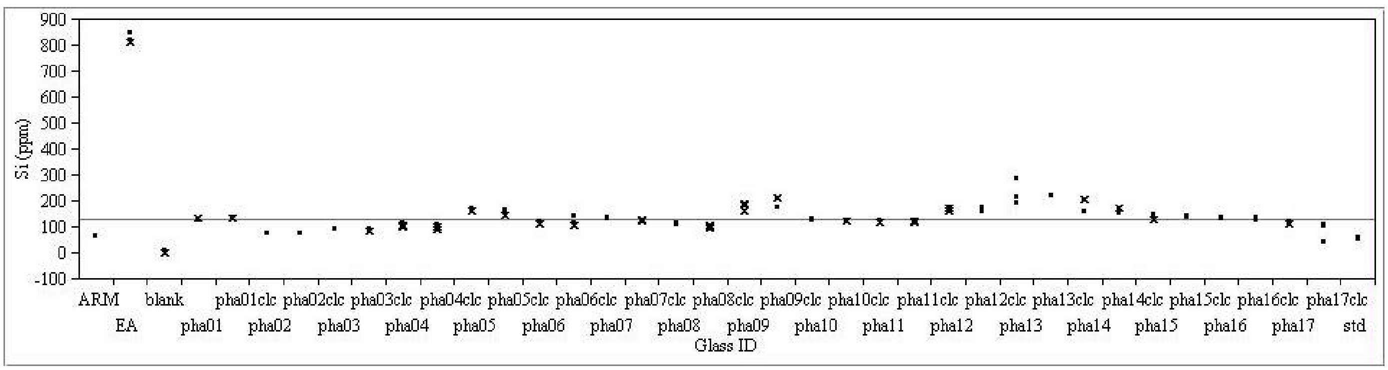
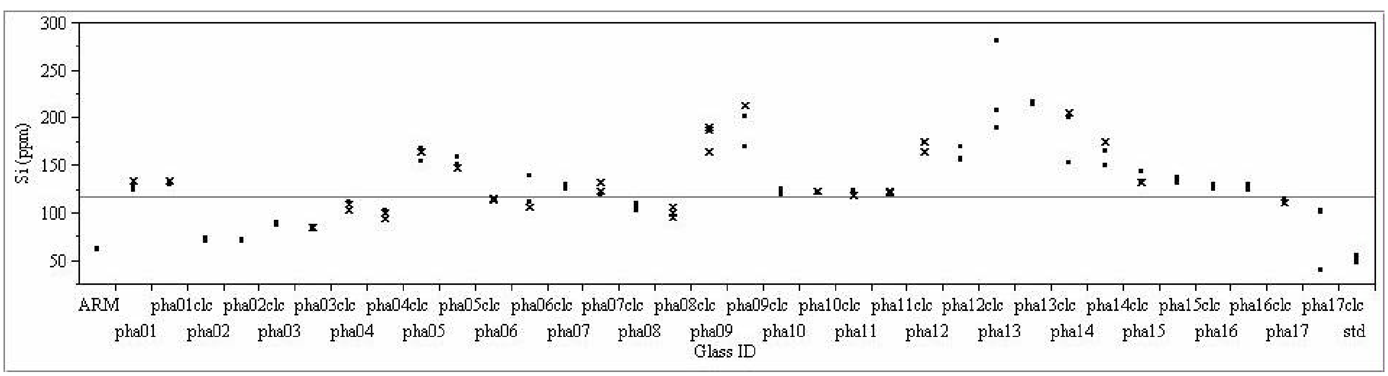



**Exhibit A.9: Plots of the Leachate Concentrations by Glass ID by Element** ***(continued)***

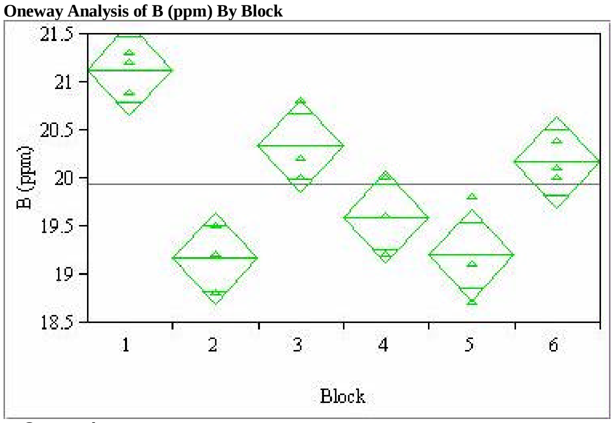
**Si (ppm) By Sample ID**



## Exhibit A.10: Plots of the Multi-Element Solution Standard by Element

**Oneway Analysis of B (ppm) By Block**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.835581 |
| Adj Rsquare | 0.767073 |
| Root Mean Square Error | 0.377124 |
| Mean of Response | 19.93333 |
| Observations (or Sum Wgts) | 18 |

**Analysis of Variance**

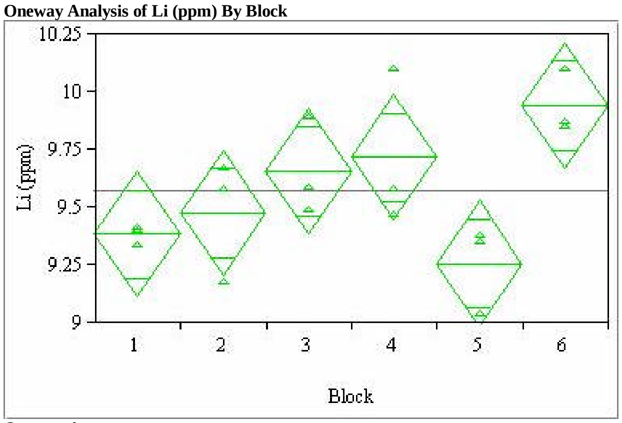
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Block | 5 | 8.673333 | 1.73467 | 12.1969 | 0.0002 |
| Error | 12 | 1.706667 | 0.14222 | | |
| C. Total | 17 | 10.380000 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1 | 3 | 21.1333 | 0.21773 | 20.659 | 21.608 |
| 2 | 3 | 19.1667 | 0.21773 | 18.692 | 19.641 |
| 3 | 3 | 20.3333 | 0.21773 | 19.859 | 20.808 |
| 4 | 3 | 19.6000 | 0.21773 | 19.126 | 20.074 |
| 5 | 3 | 19.2000 | 0.21773 | 18.726 | 19.674 |
| 6 | 3 | 20.1667 | 0.21773 | 19.692 | 20.641 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of Li (ppm) By Block**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.621723 |
| Adj Rsquare | 0.464108 |
| Root Mean Square Error | 0.21632 |
| Mean of Response | 9.571667 |
| Observations (or Sum Wgts) | 18 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Block | 5 | 0.9229167 | 0.184583 | 3.9446 | 0.0239 |
| Error | 12 | 0.5615333 | 0.046794 | | |
| C. Total | 17 | 1.4844500 | | | |

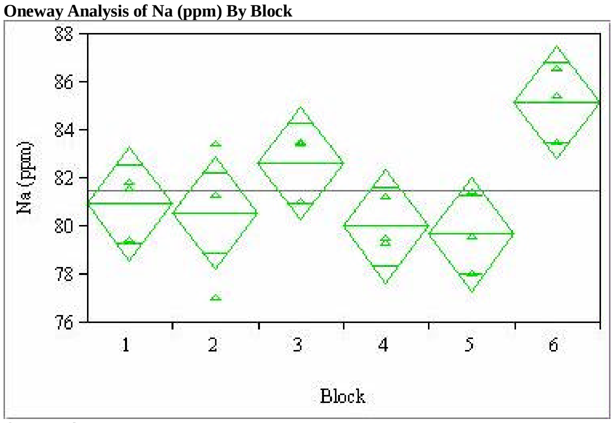
**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1 | 3 | 9.38333 | 0.12489 | 9.1112 | 9.655 |
| 2 | 3 | 9.47667 | 0.12489 | 9.2045 | 9.749 |
| 3 | 3 | 9.65667 | 0.12489 | 9.3845 | 9.929 |
| 4 | 3 | 9.71667 | 0.12489 | 9.4445 | 9.989 |
| 5 | 3 | 9.25667 | 0.12489 | 8.9845 | 9.529 |
| 6 | 3 | 9.94000 | 0.12489 | 9.6679 | 10.212 |

Std Error uses a pooled estimate of error variance

## Exhibit A.10: Plots of the Multi-Element Solution Standard by Element *(continued)*

**Oneway Analysis of Na (ppm) By Block**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.607738 |
| Adj Rsquare | 0.444295 |
| Root Mean Square Error | 1.863986 |
| Mean of Response | 81.49444 |
| Observations (or Sum Wgts) | 18 |

**Analysis of Variance**

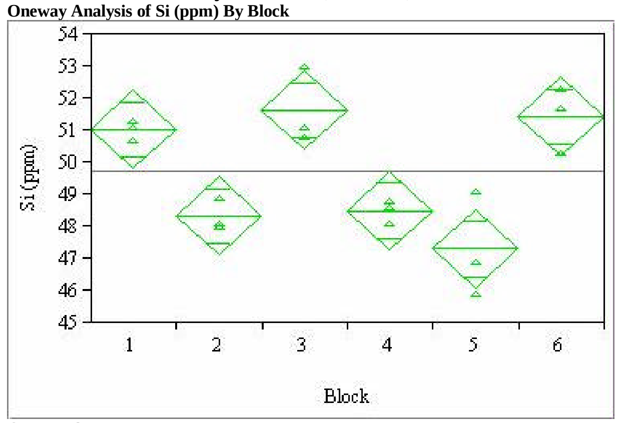
| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Block | 5 | 64.59611 | 12.9192 | 3.7184 | 0.0289 |
| Error | 12 | 41.69333 | 3.4744 | | |
| C. Total | 17 | 106.28944 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1 | 3 | 80.9333 | 1.0762 | 78.589 | 83.278 |
| 2 | 3 | 80.5667 | 1.0762 | 78.222 | 82.911 |
| 3 | 3 | 82.6333 | 1.0762 | 80.289 | 84.978 |
| 4 | 3 | 80.0000 | 1.0762 | 77.655 | 82.345 |
| 5 | 3 | 79.6667 | 1.0762 | 77.322 | 82.011 |
| 6 | 3 | 85.1667 | 1.0762 | 82.822 | 87.511 |

Std Error uses a pooled estimate of error variance

**Oneway Analysis of Si (ppm) By Block**




**Oneway Anova**

**Summary of Fit**

| | |
|---|---|
| Rsquare | 0.824297 |
| Adj Rsquare | 0.751087 |
| Root Mean Square Error | 0.968102 |
| Mean of Response | 49.70556 |
| Observations (or Sum Wgts) | 18 |

**Analysis of Variance**

| Source | DF | Sum of Squares | Mean Square | F Ratio | Prob > F |
|---|---|---|---|---|---|
| Block | 5 | 52.762778 | 10.5526 | 11.2594 | 0.0003 |
| Error | 12 | 11.246667 | 0.9372 | | |
| C. Total | 17 | 64.009444 | | | |

**Means for Oneway Anova**

| Level | Number | Mean | Std Error | Lower 95% | Upper 95% |
|---|---|---|---|---|---|
| 1 | 3 | 51.0333 | 0.55893 | 49.816 | 52.251 |
| 2 | 3 | 48.3333 | 0.55893 | 47.116 | 49.551 |
| 3 | 3 | 51.6333 | 0.55893 | 50.416 | 52.851 |
| 4 | 3 | 48.5000 | 0.55893 | 47.282 | 49.718 |
| 5 | 3 | 47.3000 | 0.55893 | 46.082 | 48.518 |
| 6 | 3 | 51.4333 | 0.55893 | 50.216 | 52.651 |

Std Error uses a pooled estimate of error variance

**Exhibit A.11: Correlations and Scatter Plots of the Normalized PCT's before Screening for Solution Weight Loss Problems**

## Measured Compositions – Linear Correlations & Scatter Plots

### 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 | 0.9968 | 0.9943 | 0.9669 |
| log NL[Li (g/L)] | 0.9968 | 1.0000 | 0.9967 | 0.9619 |
| log NL[Na (g/L)] | 0.9943 | 0.9967 | 1.0000 | 0.9600 |
| log NL[Si (g/L)] | 0.9669 | 0.9619 | 0.9600 | 1.0000 |

### Scatterplot Matrix

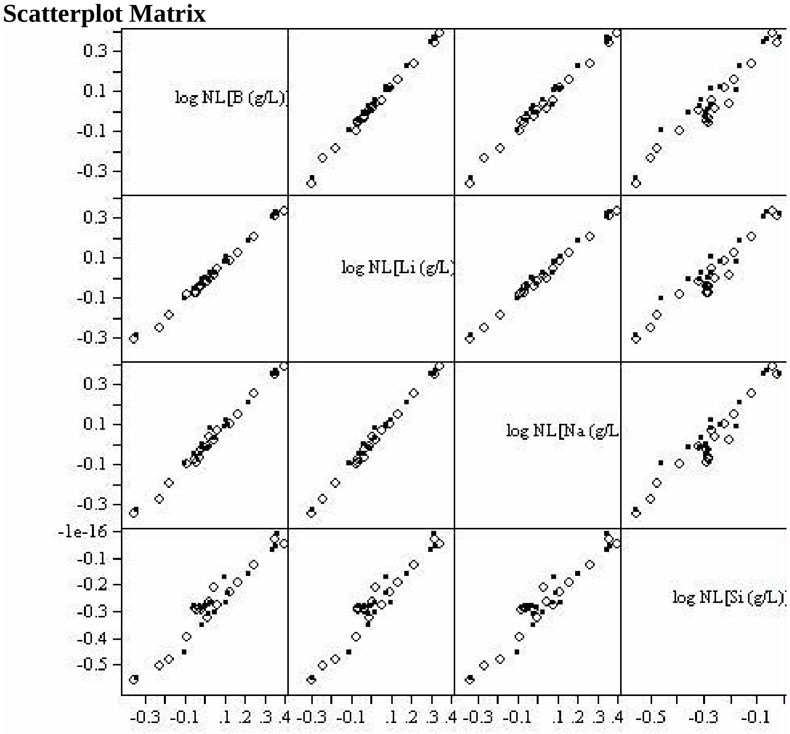


**Exhibit A.11: Correlations and Scatter Plots of the Normalized PCT's before Screening for Solution Weight Loss Problems** *(continued)*

## Measured Bias-Corrected Compositions – Linear Correlations & Scatter Plots

### 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 | 0.9970 | 0.9937 | 0.9667 |
| log NL[Li (g/L)] | 0.9970 | 1.0000 | 0.9955 | 0.9623 |
| log NL[Na (g/L)] | 0.9937 | 0.9955 | 1.0000 | 0.9608 |
| log NL[Si (g/L)] | 0.9667 | 0.9623 | 0.9608 | 1.0000 |

### Scatterplot Matrix

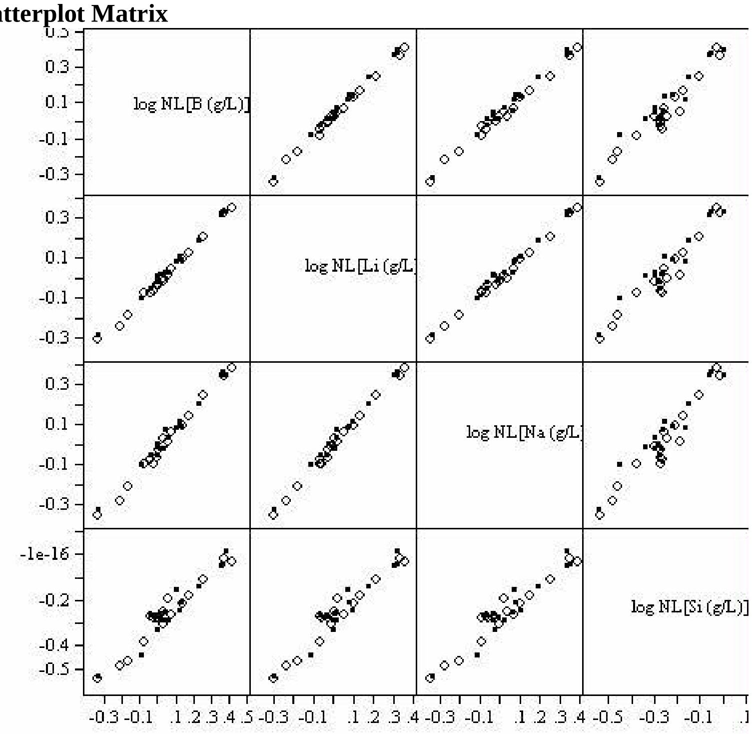


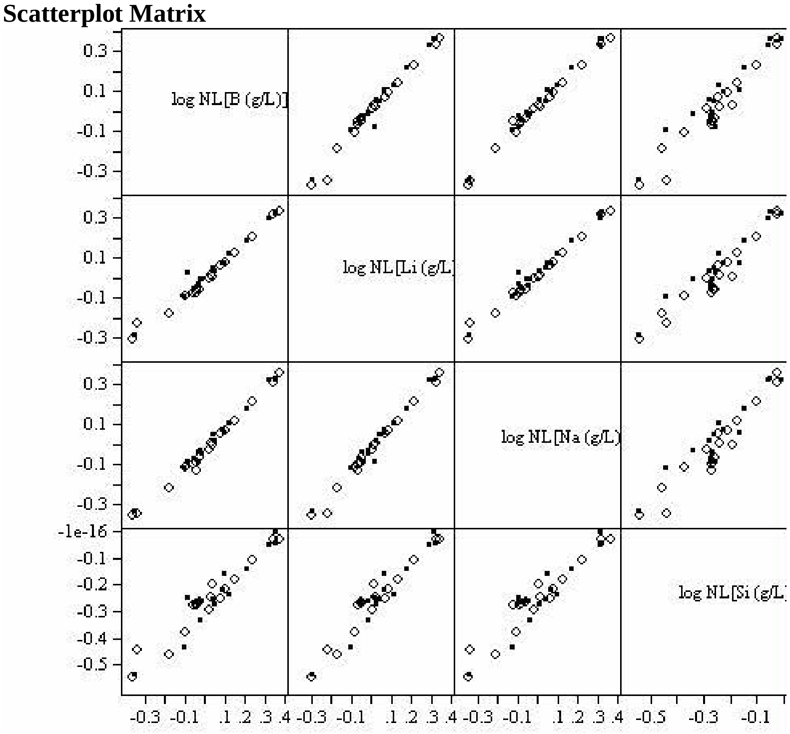
**Exhibit A.11: Correlations and Scatter Plots of the Normalized PCT's before Screening for Solution Weight Loss Problems** *(continued)*

## Target Compositions – Linear Correlations & Scatter Plots

### 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 | 0.9883 | 0.9952 | 0.9558 |
| log NL[Li (g/L)] | 0.9883 | 1.0000 | 0.9921 | 0.9577 |
| log NL[Na (g/L)] | 0.9952 | 0.9921 | 1.0000 | 0.9486 |
| log NL[Si (g/L)] | 0.9558 | 0.9577 | 0.9486 | 1.0000 |

### Scatterplot Matrix



## Exhibit A.12: Correlations and Scatter Plots of the Normalized PCTs after Screening for Solution Weight Loss Problems

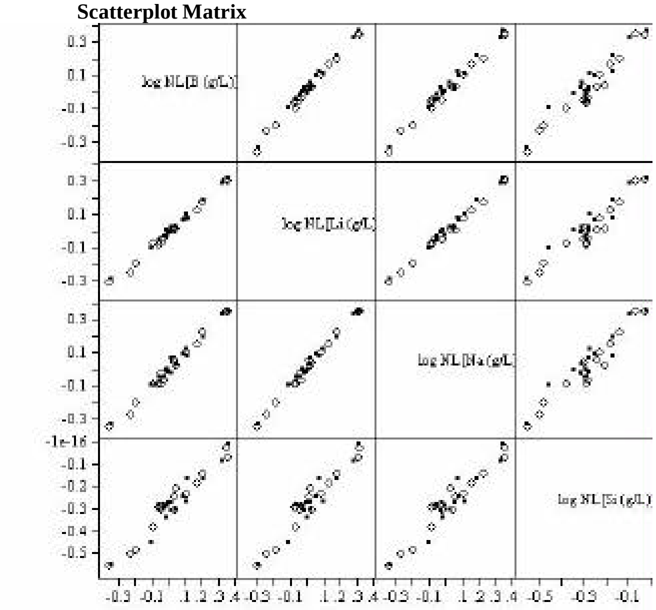
### Measured Compositions

### Correlations of Screened PCTs

| | 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 | 0.9958 | 0.9923 | 0.9655 |
| log NL[Li (g/L)] | 0.9958 | 1.0000 | 0.9961 | 0.9575 |
| log NL[Na (g/L)] | 0.9923 | 0.9961 | 1.0000 | 0.9545 |
| log NL[Si (g/L)] | 0.9655 | 0.9575 | 0.9545 | 1.0000 |

2 rows not used due to missing values.

### Scatterplot Matrix

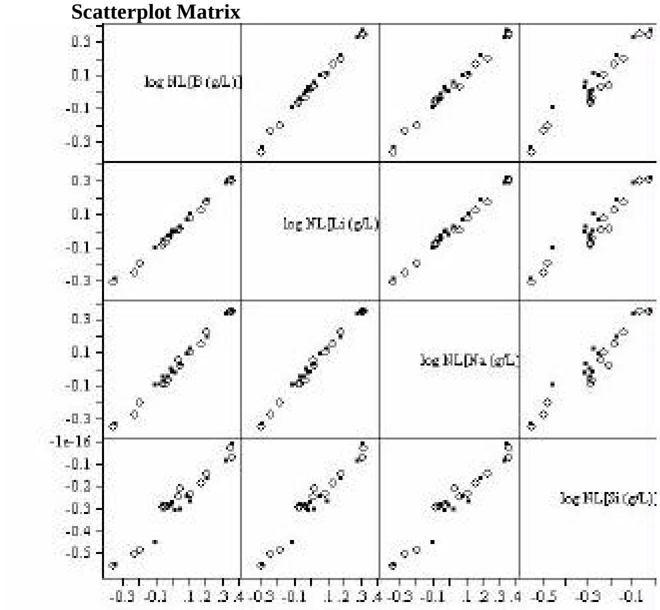



### Correlations of Valid PCTs

| | 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 | 0.9968 | 0.9947 | 0.9685 |
| log NL[Li (g/L)] | 0.9968 | 1.0000 | 0.9973 | 0.9645 |
| log NL[Na (g/L)] | 0.9947 | 0.9973 | 1.0000 | 0.9617 |
| log NL[Si (g/L)] | 0.9685 | 0.9645 | 0.9617 | 1.0000 |

8 rows not used due to missing values.

### Scatterplot Matrix



## Exhibit A.12: Correlations and Scatter Plots of the Normalized PCTs after Screening for Solution Weight Loss Problems *(continued)*

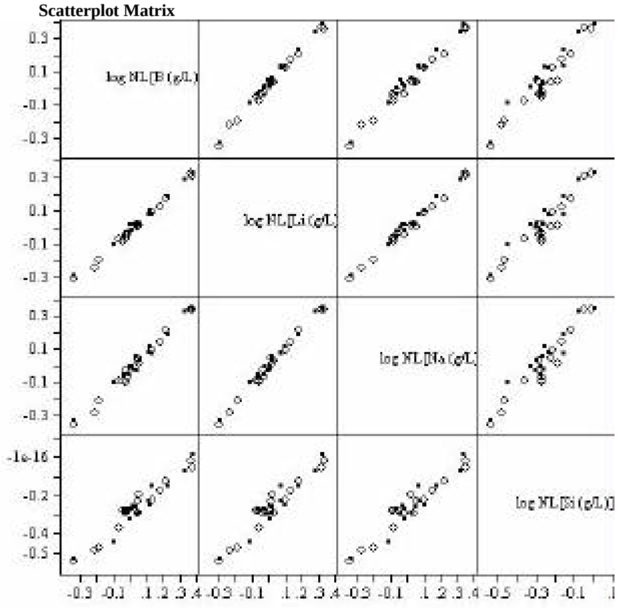
### Measured Bias-Corrected Compositions

### Correlations of Screened PCTs

| | 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 | 0.9959 | 0.9917 | 0.9654 |
| log NL[Li (g/L)] | 0.9959 | 1.0000 | 0.9949 | 0.9578 |
| log NL[Na (g/L)] | 0.9917 | 0.9949 | 1.0000 | 0.9555 |
| log NL[Si (g/L)] | 0.9654 | 0.9578 | 0.9555 | 1.0000 |

2 rows not used due to missing values.

**Scatterplot Matrix**

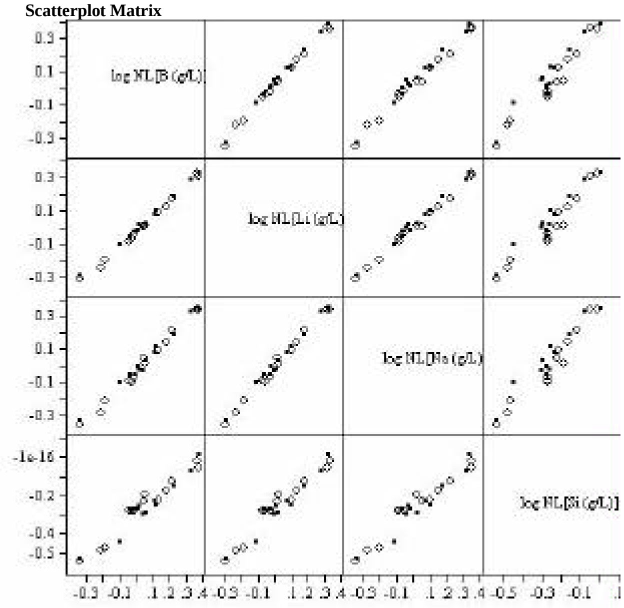


### Correlations of Valid PCTs Correlations

| | 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 | 0.9972 | 0.9940 | 0.9686 |
| log NL[Li (g/L)] | 0.9972 | 1.0000 | 0.9963 | 0.9657 |
| log NL[Na (g/L)] | 0.9940 | 0.9963 | 1.0000 | 0.9629 |
| log NL[Si (g/L)] | 0.9686 | 0.9657 | 0.9629 | 1.0000 |

2 rows not used due to missing values.

**Scatterplot Matrix**



## Exhibit A.12: Correlations and Scatter Plots of the Normalized PCTs after Screening for Solution Weight Loss Problems *(continued)*

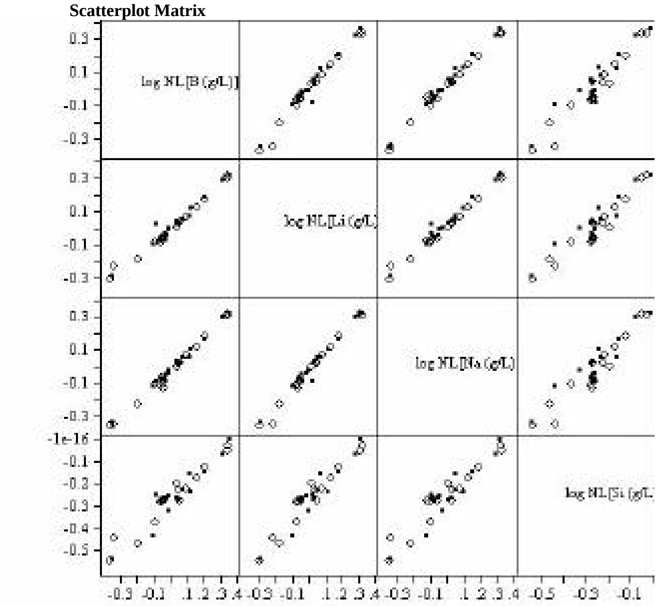
### Targeted Compositions

**Correlations for Screened PCTs**

| | 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 | 0.9873 | 0.9941 | 0.9530 |
| log NL[Li (g/L)] | 0.9873 | 1.0000 | 0.9907 | 0.9524 |
| log NL[Na (g/L)] | 0.9941 | 0.9907 | 1.0000 | 0.9412 |
| log NL[Si (g/L)] | 0.9530 | 0.9524 | 0.9412 | 1.0000 |

2 rows not used due to missing values.

**Scatterplot Matrix**




**Correlations for Screened PCTs**

| | 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 | 0.9877 | 0.9953 | 0.9578 |
| log NL[Li (g/L)] | 0.9877 | 1.0000 | 0.9911 | 0.9608 |
| log NL[Na (g/L)] | 0.9953 | 0.9911 | 1.0000 | 0.9503 |
| log NL[Si (g/L)] | 0.9578 | 0.9608 | 0.9503 | 1.0000 |

8 rows not used due to missing values.

**Scatterplot Matrix**

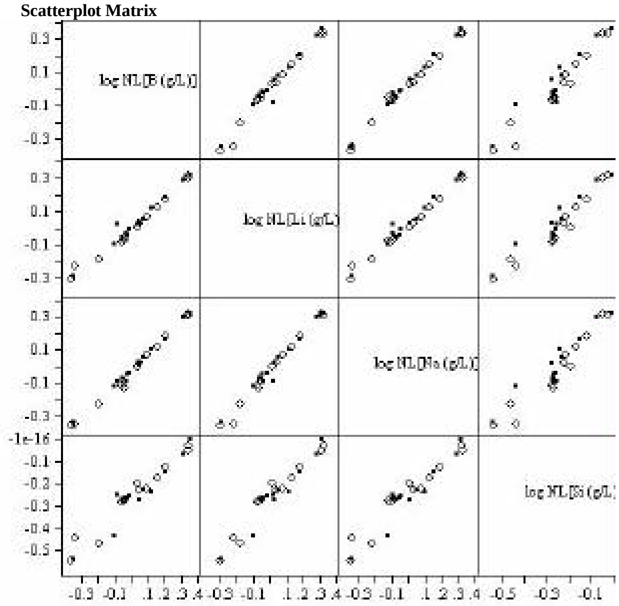
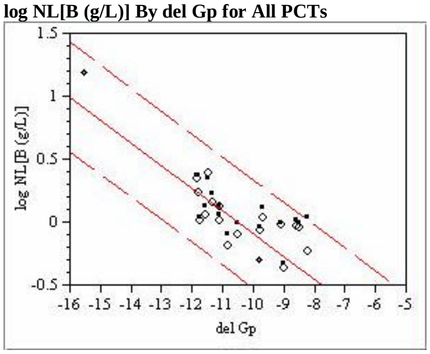
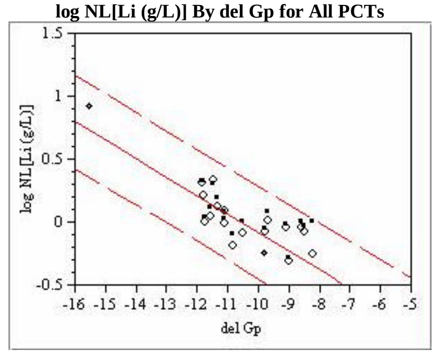


**Exhibit A.13: Durability Model Predictions versus PCT Results**
**Based Upon Measured Glass Compositions**

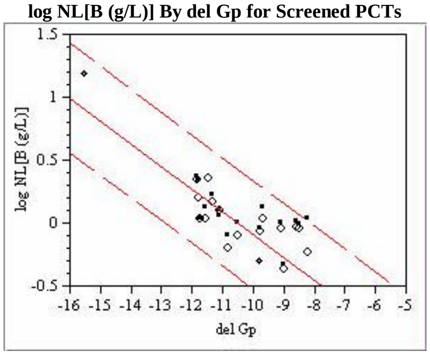
**log NL[B (g/L)] By del Gp for All PCTs**



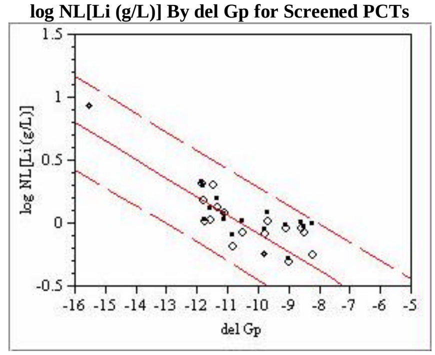

**log NL[Li (g/L)] By del Gp for All PCTs**



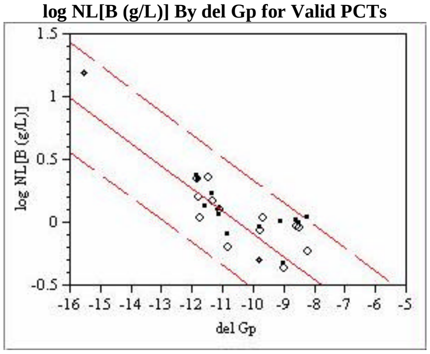

**log NL[B (g/L)] By del Gp for Screened PCTs**




**log NL[Li (g/L)] By del Gp for Screened PCTs**




**log NL[B (g/L)] By del Gp for Valid PCTs**




**log NL[Li (g/L)] By del Gp for Valid PCTs**

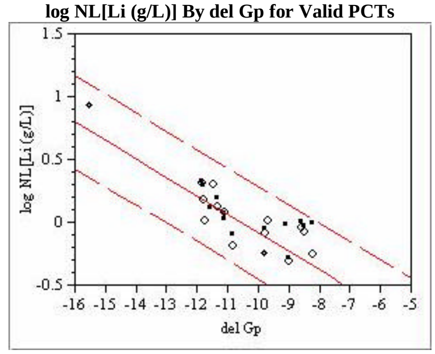
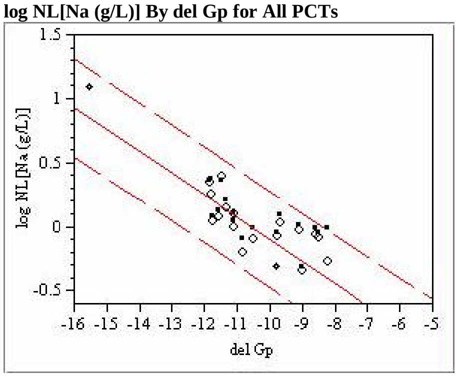
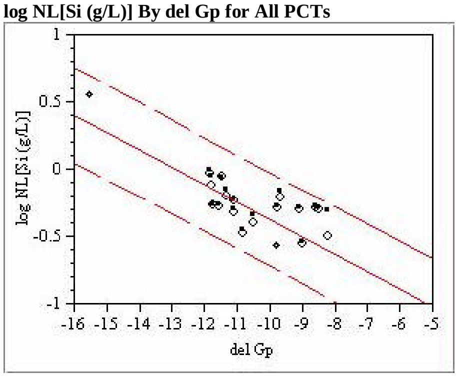


**Exhibit A.13: Durability Model Predictions versus PCT Results**
**Based Upon Measured Glass Compositions** *(continued)*

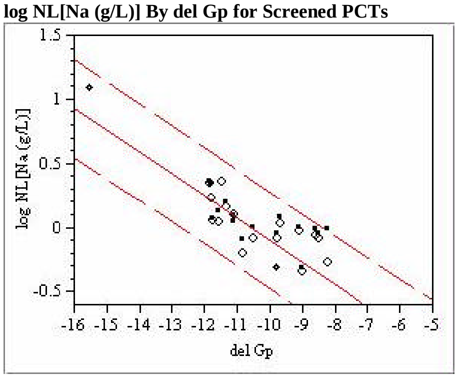
**log NL[Na (g/L)] By del Gp for All PCTs**



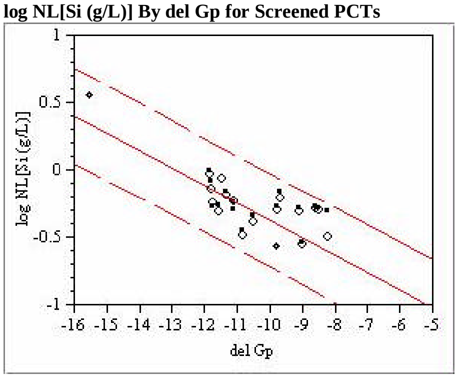

**log NL[Si (g/L)] By del Gp for All PCTs**



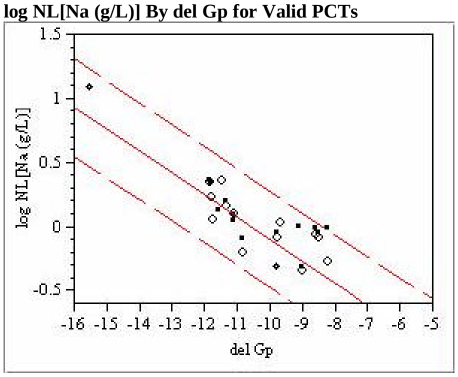

**log NL[Na (g/L)] By del Gp for Screened PCTs**




**log NL[Si (g/L)] By del Gp for Screened PCTs**




**log NL[Na (g/L)] By del Gp for Valid PCTs**




**log NL[Si (g/L)] By del Gp for Valid PCTs**

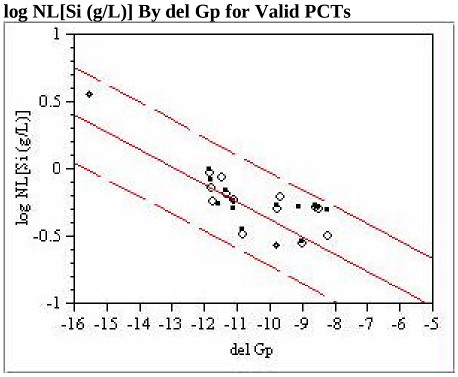
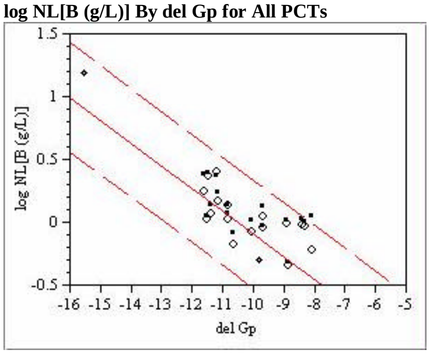
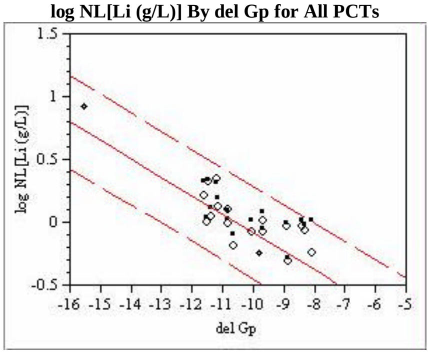


**Exhibit A.13: Durability Model Predictions versus PCT Results**
**Based Upon Bias-Corrected, Measured Glass Compositions***(continued)*

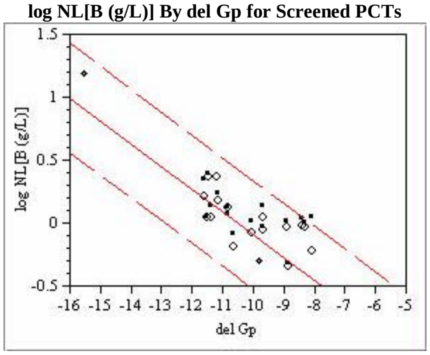
**log NL[B (g/L)] By del Gp for All PCTs**



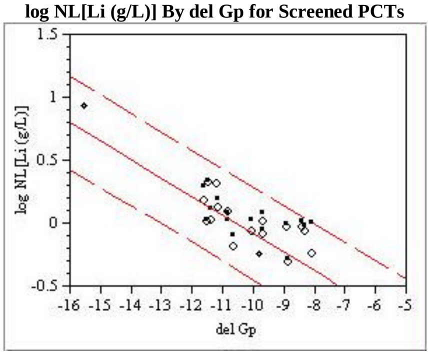

**log NL[Li (g/L)] By del Gp for All PCTs**



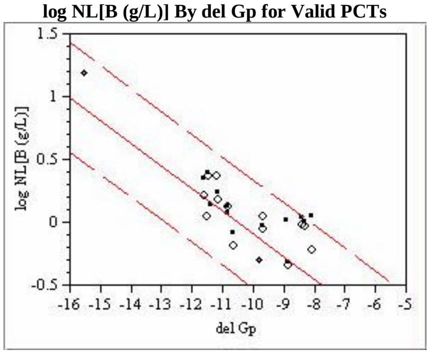

**log NL[B (g/L)] By del Gp for Screened PCTs**




**log NL[Li (g/L)] By del Gp for Screened PCTs**




**log NL[B (g/L)] By del Gp for Valid PCTs**




**log NL[Li (g/L)] By del Gp for Valid PCTs**

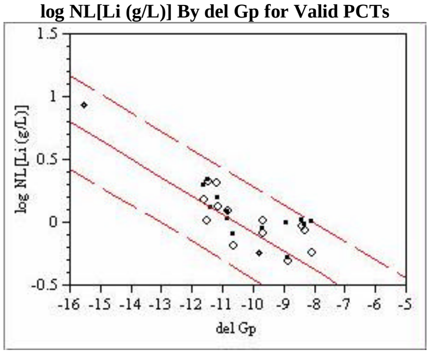
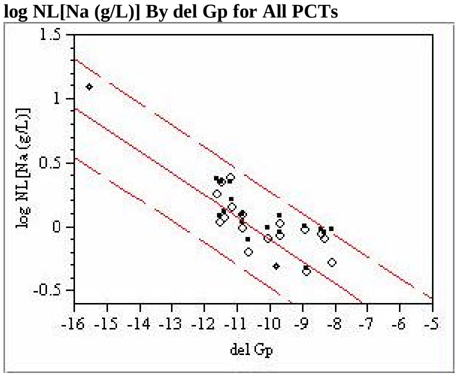
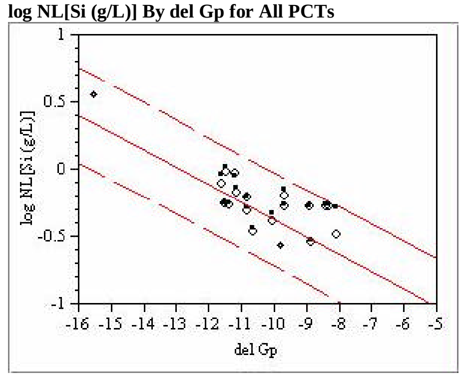


**Exhibit A.13: Durability Model Predictions versus PCT Results**
**Based Upon Bias-Corrected, Measured Glass Compositions***(continued)*

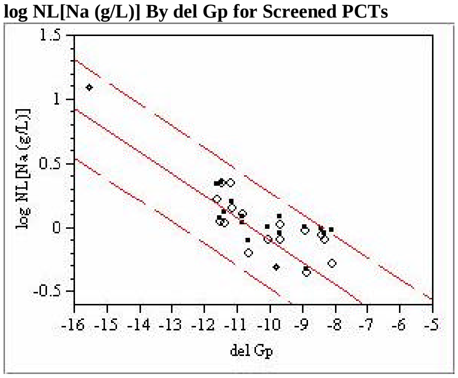
**log NL[Na (g/L)] By del Gp for All PCTs**



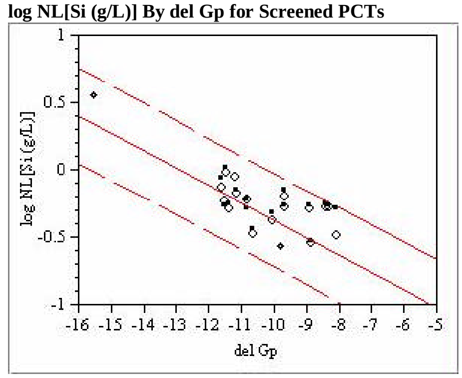

**log NL[Si (g/L)] By del Gp for All PCTs**



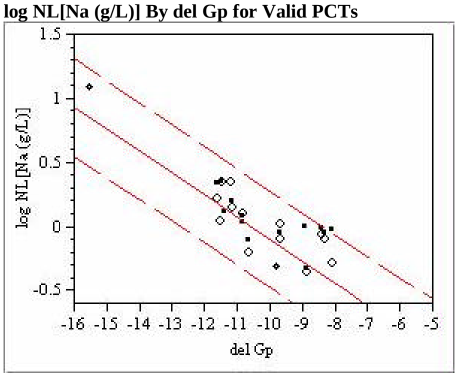

**log NL[Na (g/L)] By del Gp for Screened PCTs**




**log NL[Si (g/L)] By del Gp for Screened PCTs**




**log NL[Na (g/L)] By del Gp for Valid PCTs**




**log NL[Si (g/L)] By del Gp for Valid PCTs**

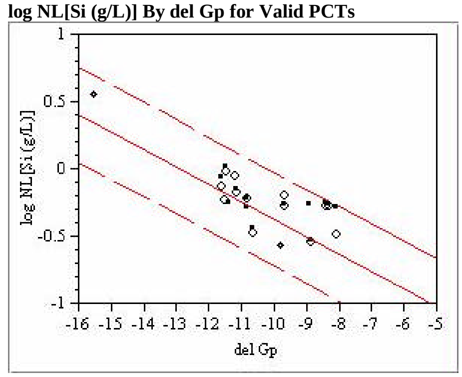
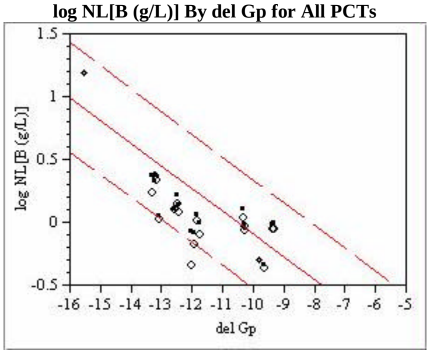
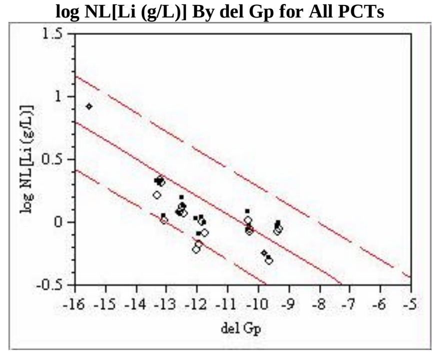


**Exhibit A.13: Durability Model Predictions versus PCT Results**
**Based Upon Targeted Glass Compositions***(continued)*

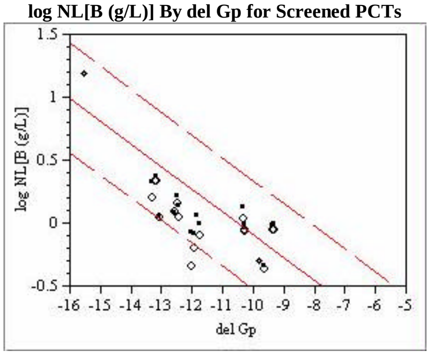
**log NL[B (g/L)] By del Gp for All PCTs**



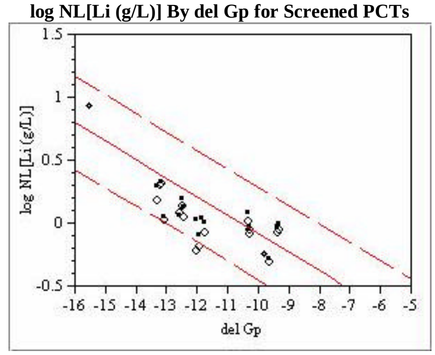

**log NL[Li (g/L)] By del Gp for All PCTs**



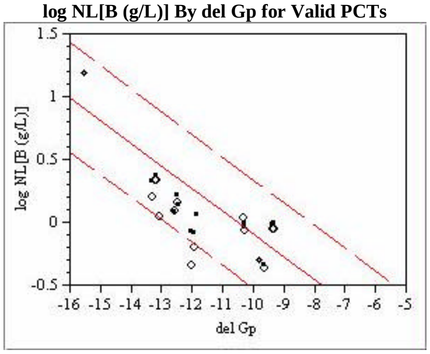

**log NL[B (g/L)] By del Gp for Screened PCTs**




**log NL[Li (g/L)] By del Gp for Screened PCTs**




**log NL[B (g/L)] By del Gp for Valid PCTs**




**log NL[Li (g/L)] By del Gp for Valid PCTs**

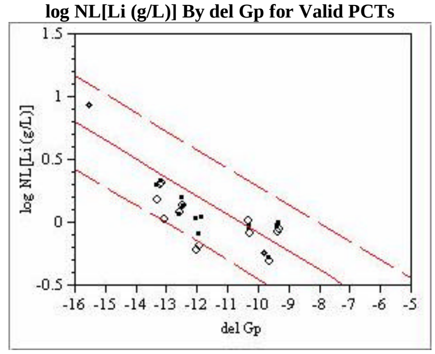
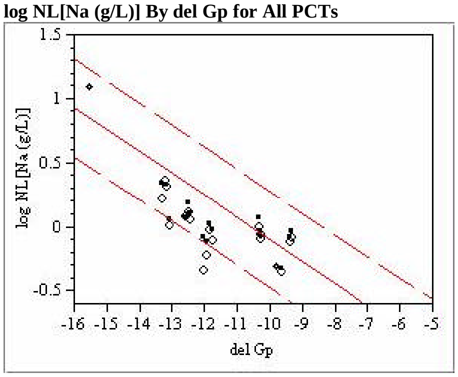
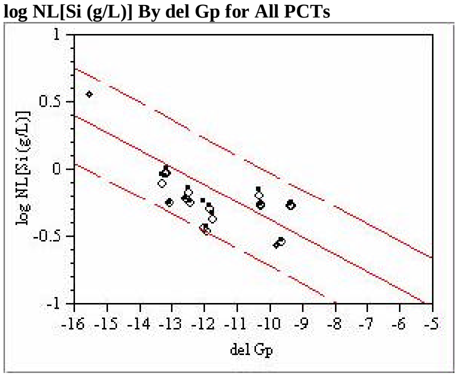


**Exhibit A.13: Durability Model Predictions versus PCT Results**
**Based Upon Targeted Glass Compositions***(continued)*

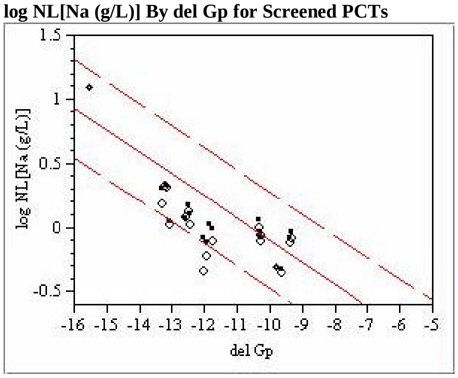
**log NL[Na (g/L)] By del Gp for All PCTs**



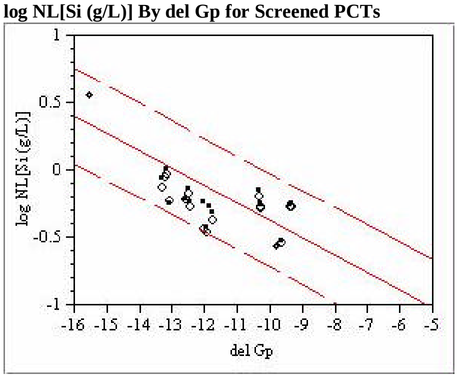

**log NL[Si (g/L)] By del Gp for All PCTs**



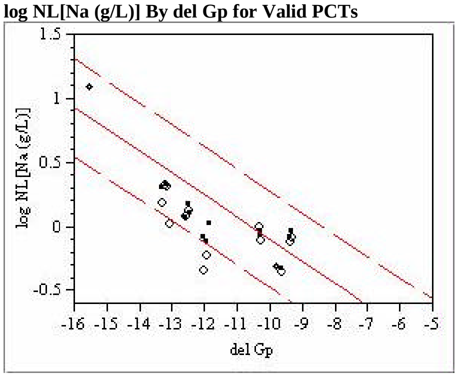

**log NL[Na (g/L)] By del Gp for Screened PCTs**




**log NL[Si (g/L)] By del Gp for Screened PCTs**




**log NL[Na (g/L)] By del Gp for Valid PCTs**




**log NL[Si (g/L)] By del Gp for Valid PCTs**

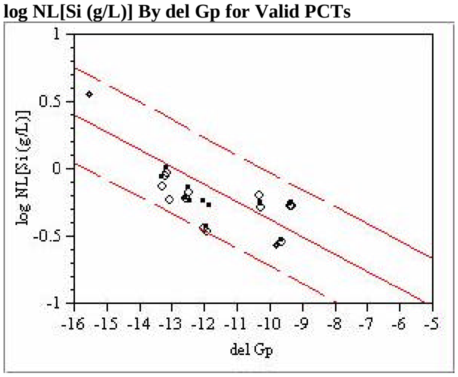
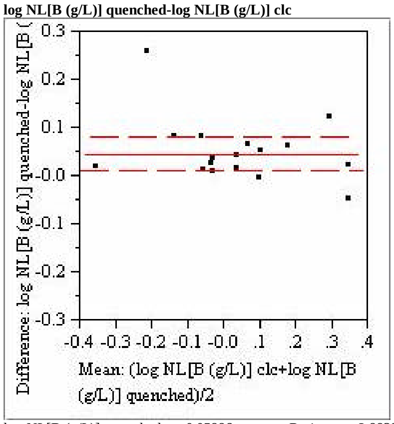


**Exhibit A.14: Paired Comparisons of Quenched versus Centerline Cooled PCTs Using All of the Leachate Concentrations, Using Only Those Screened For Water Loss Problems, and Using Only Valid PCTs**

## All of the PCT Results

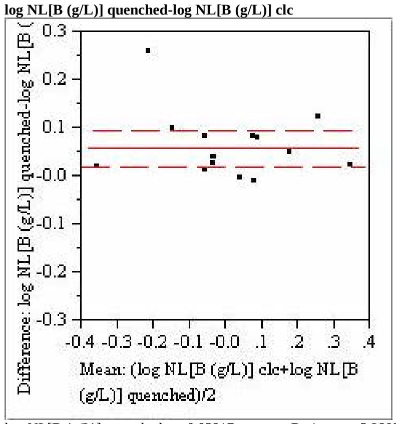
**Difference:**
**log NL[B (g/L)] quenched-log NL[B (g/L)] clc**




| | | | |
|---|---|---|---|
| log NL[B (g/L)] quenched | 0.05886 | t-Ratio | 2.883982 |
| log NL[B (g/L)] clc | 0.0126 | DF | 16 |
| Mean Difference | 0.04627 | Prob > \|t\| | 0.0108 |
| Std Error | 0.01604 | Prob > t | 0.0054 |
| Upper95% | 0.08027 | Prob < t | 0.9946 |
| Lower95% | 0.01226 | | |
| N | 17 | | |
| Correlation | 0.94532 | | |

## Only Results for PCTs Passing Water Loss (i.e. Screened)

**Difference:**
**log NL[B (g/L)] quenched-log NL[B (g/L)] clc**

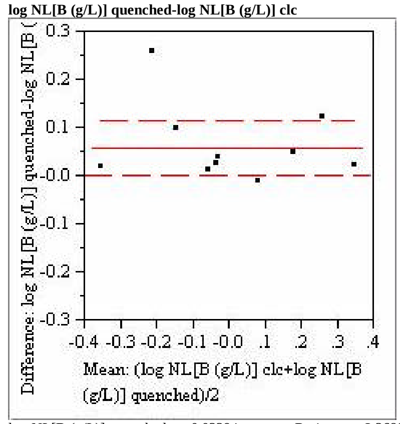



| | | | |
|---|---|---|---|
| log NL[B (g/L)] quenched | 0.03917 | t-Ratio | 3.280505 |
| log NL[B (g/L)] clc | -0.0176 | DF | 14 |
| Mean Difference | 0.05682 | Prob > \|t\| | 0.0055 |
| Std Error | 0.01732 | Prob > t | 0.0027 |
| Upper95% | 0.09397 | Prob < t | 0.9973 |
| Lower95% | 0.01967 | | |
| N | 15 | | |
| Correlation | 0.93404 | | |

## Valid PCTs Only

**(i.e., those with at least 2 of the triplicates OK).**

**Difference:**
**log NL[B (g/L)] quenched-log NL[B (g/L)] clc**

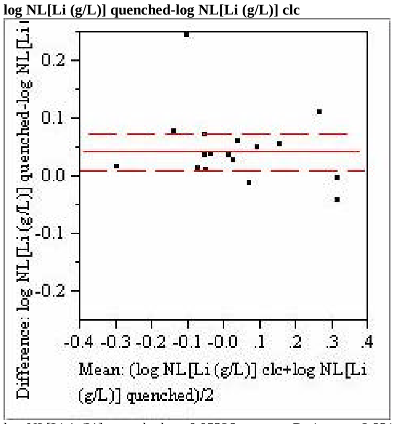



| | | | |
|---|---|---|---|
| log NL[B (g/L)] quenched | 0.03394 | t-Ratio | 2.36807 |
| log NL[B (g/L)] clc | -0.0255 | DF | 9 |
| Mean Difference | 0.05942 | Prob > \|t\| | 0.0420 |
| Std Error | 0.02509 | Prob > t | 0.0210 |
| Upper95% | 0.11619 | Prob < t | 0.9790 |
| Lower95% | 0.00266 | | |
| N | 10 | | |
| Correlation | 0.93846 | | |

**Exhibit A.14: Paired Comparisons of Quenched versus Centerline Cooled PCTs Using All of the Leachate Concentrations and Using Only Those Screened For Water Loss Problems**
***(continued)***

## All of the PCT Results

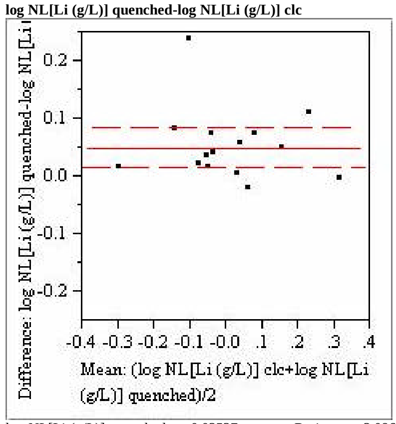
**Difference:**
**log NL[Li (g/L)] quenched-log NL[Li (g/L)] clc**




| | | | |
|---|---|---|---|
| log NL[Li (g/L)] quenched | 0.05326 | t-Ratio | 2.831674 |
| log NL[Li (g/L)] clc | 0.01041 | DF | 16 |
| Mean Difference | 0.04285 | Prob > \|t\| | 0.0120 |
| Std Error | 0.01513 | Prob > t | 0.0060 |
| Upper95% | 0.07493 | Prob < t | 0.9940 |
| Lower95% | 0.01077 | | |
| N | 17 | | |
| Correlation | 0.9337 | | |

## Only Results for PCTs Passing Water Loss (i.e. Screened)

**Difference:**
**log NL[Li (g/L)] quenched-log NL[Li (g/L)] clc**

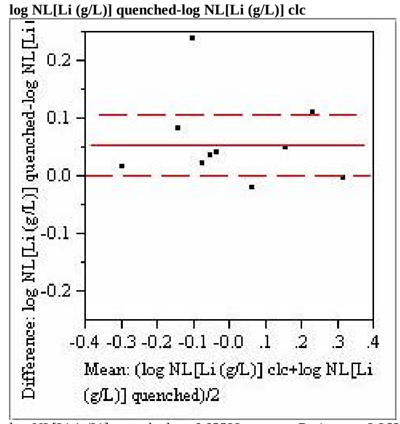



| | | | |
|---|---|---|---|
| log NL[Li (g/L)] quenched | 0.03537 | t-Ratio | 3.086592 |
| log NL[Li (g/L)] clc | -0.0145 | DF | 14 |
| Mean Difference | 0.04984 | Prob > \|t\| | 0.0080 |
| Std Error | 0.01615 | Prob > t | 0.0040 |
| Upper95% | 0.08447 | Prob < t | 0.9960 |
| Lower95% | 0.01521 | | |
| N | 15 | | |
| Correlation | 0.91985 | | |

## Valid PCTs Only

**(i.e., those with at least 2 of the triplicates OK).**

**Difference:**
**log NL[Li (g/L)] quenched-log NL[Li (g/L)] clc**

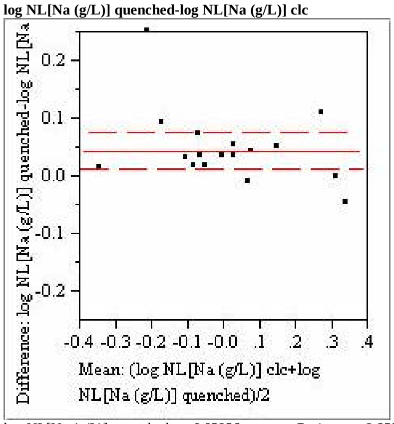



| | | | |
|---|---|---|---|
| log NL[Li (g/L)] quenched | 0.03522 | t-Ratio | 2.268857 |
| log NL[Li (g/L)] clc | -0.0182 | DF | 9 |
| Mean Difference | 0.05347 | Prob > \|t\| | 0.0495 |
| Std Error | 0.02356 | Prob > t | 0.0247 |
| Upper95% | 0.10677 | Prob < t | 0.9753 |
| Lower95% | 0.00016 | | |
| N | 10 | | |
| Correlation | 0.92417 | | |

**Exhibit A.14: Paired Comparisons of Quenched versus Centerline Cooled PCTs**
**Using All of the Leachate Concentrations and Using Only Those Screened For Water Loss Problems**
***(continued)***

## All of the PCT Results

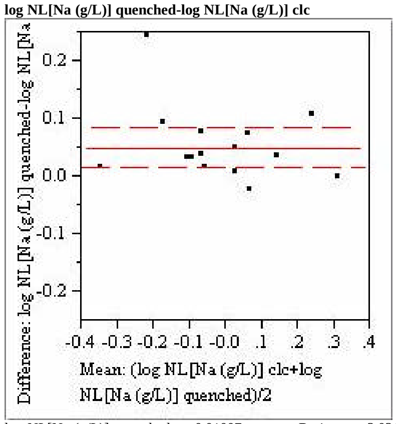
**Difference:**
**log NL[Na (g/L)] quenched-log NL[Na (g/L)] clc**




| | | | |
|---|---|---|---|
| log NL[Na (g/L)] quenched | 0.03236 | t-Ratio | 2.85998 |
| log NL[Na (g/L)] clc | -0.012 | DF | 16 |
| Mean Difference | 0.04441 | Prob > \|t\| | 0.0113 |
| Std Error | 0.01553 | Prob > t | 0.0057 |
| Upper95% | 0.07732 | Prob < t | 0.9943 |
| Lower95% | 0.01149 | | |
| N | 17 | | |
| Correlation | 0.94867 | | |

## Only Results for PCTs Passing Water Loss (i.e. Screened)

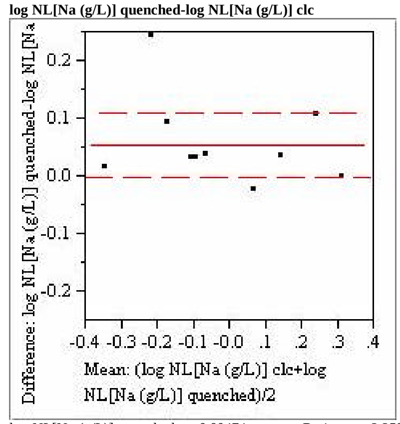
**Difference:**
**log NL[Na (g/L)] quenched-log NL[Na (g/L)] clc**




| | | | |
|---|---|---|---|
| log NL[Na (g/L)] quenched | 0.01007 | t-Ratio | 3.031363 |
| log NL[Na (g/L)] clc | -0.0399 | DF | 14 |
| Mean Difference | 0.04994 | Prob > \|t\| | 0.0090 |
| Std Error | 0.01647 | Prob > t | 0.0045 |
| Upper95% | 0.08527 | Prob < t | 0.9955 |
| Lower95% | 0.01461 | | |
| N | 15 | | |
| Correlation | 0.93724 | | |

## Valid PCTs Only
**(i.e., those with at least 2 of the triplicates OK).**

**Difference:**
**log NL[Na (g/L)] quenched-log NL[Na (g/L)] clc**

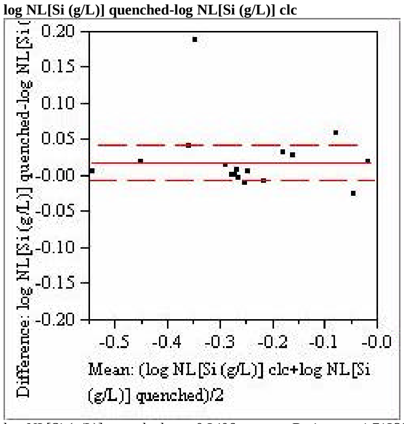



| | | | |
|---|---|---|---|
| log NL[Na (g/L)] quenched | 0.00474 | t-Ratio | 2.259991 |
| log NL[Na (g/L)] clc | -0.0497 | DF | 9 |
| Mean Difference | 0.05446 | Prob > \|t\| | 0.0502 |
| Std Error | 0.0241 | Prob > t | 0.0251 |
| Upper95% | 0.10897 | Prob < t | 0.9749 |
| Lower95% | -5.3e-5 | | |
| N | 10 | | |
| Correlation | 0.94069 | | |

**Exhibit A.14: Paired Comparisons of Quenched versus Centerline Cooled PCTs**
**Using All of the Leachate Concentrations and Using Only Those Screened For Water Loss Problems**
***(continued)***

## All of the PCT Results

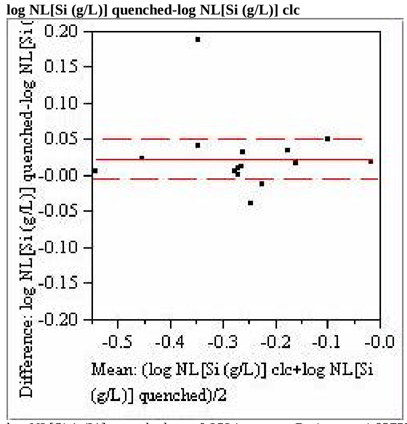
**Difference:**
**log NL[Si (g/L)] quenched-log NL[Si (g/L)] clc**




| | | | |
|---|---|---|---|
| log NL[Si (g/L)] quenched | -0.2406 | t-Ratio | 1.712305 |
| log NL[Si (g/L)] clc | -0.2604 | DF | 16 |
| Mean Difference | 0.01972 | Prob > \|t\| | 0.1061 |
| Std Error | 0.01152 | Prob > t | 0.0531 |
| Upper95% | 0.04413 | Prob < t | 0.9469 |
| Lower95% | -0.0047 | | |
| N | 17 | | |
| Correlation | 0.94088 | | |

## Only Results for PCTs Passing Water Loss (i.e. Screened)

**Difference:**
**log NL[Si (g/L)] quenched-log NL[Si (g/L)] clc**

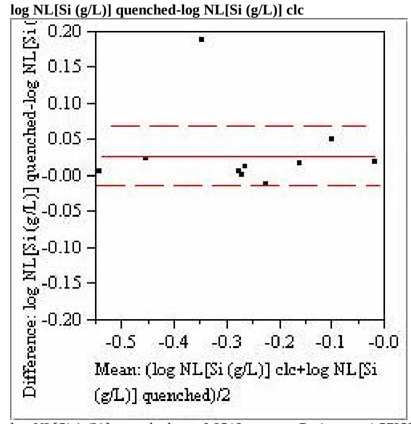



| | | | |
|---|---|---|---|
| log NL[Si (g/L)] quenched | -0.2524 | t-Ratio | 1.837579 |
| log NL[Si (g/L)] clc | -0.276 | DF | 14 |
| Mean Difference | 0.02361 | Prob > \|t\| | 0.0874 |
| Std Error | 0.01285 | Prob > t | 0.0437 |
| Upper95% | 0.05116 | Prob < t | 0.9563 |
| Lower95% | -0.0039 | | |
| N | 15 | | |
| Correlation | 0.92956 | | |

## Valid PCTs Only

**(i.e., those with at least 2 of the triplicates OK).**

**Difference:**
**log NL[Si (g/L)] quenched-log NL[Si (g/L)] clc**




| | | | |
|---|---|---|---|
| log NL[Si (g/L)] quenched | -0.2519 | t-Ratio | 1.572331 |
| log NL[Si (g/L)] clc | -0.2805 | DF | 9 |
| Mean Difference | 0.02855 | Prob > \|t\| | 0.1503 |
| Std Error | 0.01816 | Prob > t | 0.0752 |
| Upper95% | 0.06963 | Prob < t | 0.9248 |
| Lower95% | -0.0125 | | |
| N | 10 | | |
| Correlation | 0.9353 | | |

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# Attachment I.

Edwards, T. B., "An Analytical Plan for the SRTC Mobile Laboratory to Follow in Measuring the Chemical Composition of the PHA Glasses of the FY01 Study (U), SRT-SCS-2001-00001, January 4, 2001.

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WESTINGHOUSE SAVANNAH RIVER COMPANY
**INTEROFFICE MEMORANDUM**

**SRT-SCS-2001-00001**

January 4, 2001

To: J. R. Harbour, 773-43A (wi)

cc: R. A. Baker, 773-42A (es)
D. R. Best, 773-41A (wo)
K. G. Brown, 773-43A (wi)
E. W. Holtzscheiter, 773-A (es)
S. L. Marra, 704-T (wi)
R. C. Tuckfield, 773-42A (wi)
R. J. Workman, 773-A (wi)

wi - with sample identifiers
wo - without sample identifiers
es - executive summary only

From: T. B. Edwards, 773-42A (5-5148)
Statistical Consulting Section

R. A. Baker, Technical Reviewer ____________ Date

R. C. Tuckfield, Manager ____________ Date
Statistical Consulting Section

# An Analytical Plan for the SRTC Mobile Laboratory to Follow in Measuring the Chemical Compositions of the PHA Glasses of the FY01 Study (U)

# *EXECUTIVE SUMMARY*

A task technical and quality assurance plan and an analytical plan have been prepared to direct activities associated with the FY01 PHA glass studies for the Salt Processing Program. Seventeen PHA glasses were fabricated as part of this study. The chemical compositions of these 17 glasses are to be determined by the SRTC Mobile Laboratory (SRTC-ML). This memorandum provides an analytical plan for the SRTC-ML to follow in measuring the chemical compositions of these 17 PHA glasses.

# INTRODUCTION

A task technical and quality assurance (TT&QA) plan [1] and an analytical plan [2] have been prepared to direct activities associated with the FY01 PHA glass studies for the Salt Processing Program. Seventeen glasses have been fabricated as part of the PHA study [3]. The compositions of these 17 glasses are to be determined by the SRTC Mobile Laboratory (SRTC-ML). This memorandum provides an analytical plan for the SRTC-ML to follow in measuring the compositions of these 17 PHA glasses.

# DISCUSSION

Table 1 provides the naming conventions for the 17 samples that are to be used by the SRTC-ML in conducting the compositional analyses and in reporting the measurements.[1]

**Table 1: Unique Sample ID's for the 17 Glasses**

| Original ID | Lab ID |
|---|---|
| pha01 | T14 |
| pha02 | T11 |
| pha03 | T05 |
| pha04 | T03 |
| pha05 | T01 |
| pha06 | T17 |
| pha07 | T13 |
| pha08 | T10 |
| pha09 | T04 |
| pha10 | T09 |
| pha11 | T02 |
| pha12 | T16 |
| pha13 | T08 |
| pha14 | T06 |
| pha15 | T15 |
| pha16 | T12 |
| pha17 | T07 |

## PREPARATION OF THE SAMPLES

The analytical procedures used by the SRTC-ML to determine cation concentrations for a glass sample include steps for sample preparation and for calibration of the Inductively Coupled Plasma (ICP) – Emission Spectrometer. These procedural steps are of primary concern in the development of this analytical plan.

The primary dissolution methods that are to be used by the SRTC-ML to complete this compositional study are lithium metaborate (LM) and peroxide fusion (pf). A third dissolution method (microwave fusion, mf) is to be used if necessary to assure

1 Renaming these samples ensures that they will be processed as blind samples. This table is complete only for those on the distribution list with a "wi" following their names.

complete sample dissolution. All three dissolution methods are considered in this analytical plan.

The cation concentrations are to be measured (as weight percents) for the submitted samples prepared using one or more of the dissolution methods for the following elements: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), potassium (K), lithium (Li), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), silicon (Si), titanium (Ti), uranium (U), and zirconium (Zr).

Each of the 17 samples submitted to the SRTC-ML is to be prepared twice by each of the dissolution methods utilized, and the prepared samples are to be read twice by Inductively Coupled Plasma – Emission Spectroscopy, with the instrument being calibrated before each of these two readings (for each of the prepared samples). This will lead to 4 measurements for each cation of interest for each of the 17 samples submitted to the lab. Table 2 provides unique identifiers for the 34 preparations for each dissolution method and a random sequencing scheme for conducting the dissolutions.

In Table 2, the sample identifier has been modified with a suffix consisting of a two-letter indicator for the preparation method (LM for lithium metaborate, pf for peroxide fusion, and mw for microwave) and a 1-digit indicator for preparation number.

**Table 2: Preparation Blocks**

| Lithium Metaborate | Peroxide Fusion | Microwave Fusion (if necessary) |
|---|---|---|
| T11LM1 | T11pf1 | T09mf1 |
| T10LM1 | T04pf1 | T17mf1 |
| T03LM1 | T11pf2 | T06mf1 |
| T10LM2 | T07pf1 | T09mf2 |
| T16LM1 | T12pf1 | T16mf1 |
| T16LM2 | T04pf2 | T02mf1 |
| T11LM2 | T10pf1 | T03mf1 |
| T12LM1 | T07pf2 | T17mf2 |
| T17LM1 | T05pf1 | T05mf1 |
| T13LM1 | T09pf1 | T15mf1 |
| T17LM2 | T03pf1 | T06mf2 |
| T12LM2 | T05pf2 | T08mf1 |
| T14LM1 | T13pf1 | T05mf2 |
| T01LM1 | T12pf2 | T14mf1 |
| T03LM2 | T10pf2 | T02mf2 |
| T04LM1 | T06pf1 | T16mf2 |
| T04LM2 | T08pf1 | T04mf1 |
| T05LM1 | T13pf2 | T10mf1 |
| T06LM1 | T01pf1 | T04mf2 |
| T06LM2 | T17pf1 | T15mf2 |
| T15LM1 | T03pf2 | T14mf2 |
| T13LM2 | T14pf1 | T08mf2 |
| T15LM2 | T06pf2 | T07mf1 |
| T08LM1 | T15pf1 | T11mf1 |
| T07LM1 | T09pf2 | T03mf2 |
| T08LM2 | T02pf1 | T01mf1 |
| T09LM1 | T16pf1 | T12mf1 |
| T05LM2 | T15pf2 | T11mf2 |
| T14LM2 | T08pf2 | T13mf1 |
| T02LM1 | T17pf2 | T10mf2 |

| | | |
|---|---|---|
| T02LM2 | T01pf2 | T01mf2 |
| T01LM2 | T14pf2 | T07mf2 |
| T07LM2 | T02pf2 | T13mf2 |
| T09LM2 | T16pf2 | T12mf2 |

## MEASUREMENT OF THE SAMPLES WITH THE ICP

The samples prepared by each of the dissolution methods employed are to be analyzed using ICP instrumentation calibrated for the particular preparation method. After the initial set of cation concentration measurements have been completed for a set of samples, the ICP instrumentation is to be recalibrated and a second set of concentration measurements for the appropriate cations determined.

Two additional glasses are included in this analytical plan to provide an opportunity for checking the performance of the ICP instrumentation over the course of these analyses and for possible bias-correction of the measurements of the other glasses. One of these glasses is the standard, Batch 1, whose composition is provided in Table 3.

**Table 3: Composition of Batch 1 in Weight Percent (wt%)**

| Oxide | Wt% | Oxide | Wt% |
|---|---|---|---|
| $Al_2O_3$ | 4.877 | MgO | 1.419 |
| $B_2O_3$ | 7.777 | MnO | 1.726 |
| BaO | 0.151 | $Na_2O$ | 9.003 |
| CaO | 1.220 | $Nd_2O_3$ | 0.147 |
| $Cr_2O_3$ | 0.107 | NiO | 0.751 |
| $Cs_2O$ | 0.060 | $RuO_2$ | 0.0214 |
| CuO | 0.399 | $SiO_2$ | 50.22 |
| $Fe_2O_3$ | 12.839 | $TiO_2$ | 0.677 |
| $K_2O$ | 3.327 | $ZrO_2$ | 0.098 |
| $Li_2O$ | 4.429 | | |

The second glass that will be used as a standard for these measurements is a uranium glass that is to be provided to the SRTC-ML along with other glass samples.

A randomized plan for measuring cation concentrations in the prepared samples by each dissolution method is provided in Tables 4-6. In these tables, the sample identifiers have been modified by the addition of a one-digit suffix to indicate whether the measurement is to be made during the first or second ICP calibration block for that sample.

Samples of the standards, Batch 1 and the uranium-bearing glasses, which are to be prepared using the appropriate dissolution method, have been added to Tables 4-6. The identifiers for the Batch 1 standard samples begin with the 3-letter designation "std" followed by the 2-letter dissolution indicator, then the 2-digit ICP block number, and finally, a number 1 through 3 for the three replicates of this glass per block. The identifiers for the uranium standard samples begin with the 4-letter designation "ustd" followed by the 2-letter dissolution indicator, then the 2-digit ICP block number, and finally, a number 1 through 2 for the duplicate measurements per block of this glass.

**Table 4: ICP Blocks for Samples Prepared Using Lithium Metaborate (LM) Method**

| 1-1 | 1-2 | 2-1 | 2-2 |
|---|---|---|---|
| stdLM111 | stdLM121 | stdLM211 | stdLM221 |
| T07LM11 | T14LM22 | T08LM11 | T11LM12 |
| T13LM21 | T14LM12 | T11LM21 | T02LM12 |
| T05LM21 | T16LM12 | T03LM21 | T03LM12 |
| T07LM21 | T04LM22 | T02LM21 | T08LM12 |
| T17LM11 | T01LM12 | T12LM21 | T11LM22 |
| ustdLM111 | ustdLM121 | ustdLM211 | ustdLM221 |
| T14LM11 | T05LM22 | T10LM21 | T15LM12 |
| T06LM11 | T13LM12 | T10LM11 | T12LM22 |
| T01LM21 | T07LM12 | T08LM21 | T10LM22 |
| T14LM21 | T07LM22 | T12LM11 | T08LM22 |
| stdLM112 | stdLM122 | stdLM212 | stdLM222 |
| T06LM21 | T17LM12 | T15LM11 | T15LM22 |
| T04LM11 | T16LM22 | T02LM11 | T02LM22 |
| T05LM11 | T06LM22 | T15LM21 | T12LM12 |
| T16LM11 | T01LM22 | T03LM11 | T03LM22 |
| ustdLM112 | ustdLM122 | ustdLM212 | ustdLM222 |
| T01LM11 | T06LM12 | T09LM11 | T09LM12 |
| T16LM21 | T17LM22 | T09LM21 | T09LM22 |
| T13LM11 | T04LM12 | T11LM11 | T10LM12 |
| T17LM21 | T05LM12 | stdLM213 | stdLM223 |
| T04LM21 | T13LM22 | | |
| stdLM113 | stdLM123 | | |

**Table 5: ICP Blocks for Samples Prepared Using Peroxide Fusion (pf) Method**

| 1-1 | 1-2 | 2-1 | 2-2 |
|---|---|---|---|
| stdpf111 | stdpf121 | stdpf211 | stdpf221 |
| T05pf11 | T17pf12 | T08pf21 | T02pf22 |
| T11pf21 | T06pf12 | T15pf11 | T02pf12 |
| T17pf21 | T10pf22 | T03pf11 | T07pf22 |
| T13pf11 | T05pf12 | T07pf21 | T12pf12 |
| T16pf21 | T09pf12 | T02pf21 | T08pf12 |
| ustdpf111 | ustdpf121 | ustdpf211 | ustdpf221 |
| T17pf11 | T09pf22 | T04pf11 | T15pf22 |
| T01pf21 | T17pf22 | T14pf11 | T08pf22 |
| T05pf21 | T11pf22 | T02pf11 | T12pf22 |
| T09pf21 | T05pf22 | T15pf21 | T04pf22 |
| stdpf112 | stdpf122 | stdpf212 | stdpf222 |
| T06pf21 | T10pf12 | T07pf11 | T03pf12 |
| T16pf11 | T16pf12 | T12pf21 | T14pf22 |
| T13pf21 | T01pf22 | T04pf21 | T07pf12 |
| T11pf11 | T06pf22 | T08pf11 | T14pf12 |
| ustdpf112 | ustdpf122 | ustdpf212 | ustdpf222 |
| T10pf11 | T01pf12 | T03pf21 | T15pf12 |
| T10pf21 | T13pf22 | T12pf11 | T04pf12 |
| T06pf11 | T16pf22 | T14pf21 | T03pf22 |
| T01pf11 | T13pf12 | stdpf213 | stdpf223 |
| T09pf11 | T11pf12 | | |
| stdpf113 | stdpf123 | | |

**Table 6: ICP Blocks for Samples Prepared Using Microwave Fusion (mf) Method (if needed)**

| 1-1 | 1-2 | 2-1 | 2-2 |
|---|---|---|---|
| stdmf111 | stdmf121 | stdmf211 | stdmf221 |
| T05mf11 | T02mf22 | T14mf11 | T12mf22 |
| T17mf11 | T01mf12 | T15mf11 | T10mf12 |
| T03mf11 | T01mf22 | T11mf21 | T06mf12 |
| T02mf11 | T04mf12 | T13mf21 | T12mf12 |
| T01mf11 | T05mf12 | T06mf21 | T13mf12 |

| | | | |
|---|---|---|---|
| ustdmf111 | ustdmf121 | ustdmf211 | ustdmf221 |
| T09mf21 | T08mf22 | T10mf21 | T14mf22 |
| T04mf11 | T17mf12 | T16mf11 | T15mf22 |
| T17mf21 | T05mf22 | T15mf21 | T14mf12 |
| T02mf21 | T03mf12 | T16mf21 | T11mf22 |
| stdmf112 | stdmf122 | stdmf212 | stdmf222 |
| T08mf11 | T09mf22 | T12mf11 | T11mf12 |
| T05mf21 | T04mf22 | T11mf11 | T16mf12 |
| T07mf21 | T07mf12 | T10mf11 | T10mf22 |
| T01mf21 | T08mf12 | T12mf21 | T16mf22 |
| ustdmf112 | ustdmf122 | ustdmf212 | ustdmf222 |
| T09mf11 | T17mf22 | T06mf11 | T06mf22 |
| T08mf21 | T03mf22 | T14mf21 | T13mf22 |
| T03mf21 | T07mf22 | T13mf11 | T15mf12 |
| T07mf11 | T02mf12 | stdmf213 | stdmf223 |
| T04mf21 | T09mf12 | | |
| stdmf113 | stdmf123 | | |

# *CONCLUDING COMMENTS*

This memorandum provides an analytical plan for the SRTC-ML to follow in measuring the chemical compositions of 17 PHA glasses. The analytical plan identifies several ICP calibration blocks in Tables 4-6 as well as preparation blocks in Table 2. The sequencing of the activities associated with each of the steps in the analytical procedures has been randomized. The size of each of the blocks is such that it should be completed in a single work shift.

If for some reason the measurements are not conducted in the sequences presented in this memorandum, the actual order used should be recorded along with any explanative comments.

The analytical plan provided in the preceding tables should be modified by the personnel of SRTC-ML to include any calibration check standards and/or other standards that are part of their routine operating procedures.

# *REFERENCES*

[1] Harbour, J. R. and T. B. Edwards, "Task Technical & QA Plan: Impact of Cooling Rates on the Durabilities of CST and PHA Glasses", WSRC-RP-2000-00996, Revision 0, December 2000.

[2] Harbour, J. R. and T. B. Edwards, "Analytical Study Plan: Impact of Cooling Rates on the Durabilities of CST and PHA Glasses", WSRC-RP-2001-00080, Revision 0, January 3, 2001.

[3] Edwards, T. B., "Selecting Test Compositions for the FY01 Glass Studies of the Salt Processing Program," SRT-SCS-2000-00069, December 15, 2000.

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## Attachment II.

Edwards, T. B., "An Analytical Plan for the SRTC Mobile Laboratory to Follow in Measuring PCT Solutions for the PHA Glasses of the SDP FY01 Study (U), SRT-SCS-2001-00005, January 12, 2001.

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WESTINGHOUSE SAVANNAH RIVER COMPANY
**INTEROFFICE MEMORANDUM**

**SRT-SCS-2001-00005**

January 12, 2001

To: J. R. Harbour, 773-43A (wi)

cc: R. A. Baker, 773-42A (es)
D. R. Best, 773-41A (wo)
K. G. Brown, 773-43A (wi)
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R. J. Workman, 773-A (wi)

wi - with sample identifiers
wo - without sample identifiers
es - executive summary only

From: T. B. Edwards, 773-42A (5-5148)
Statistical Consulting Section

R. A. Baker, Technical Reviewer Date

R. C. Tuckfield, Manager Date
Statistical Consulting Section

# An Analytical Plan for the SRTC Mobile Laboratory to Follow in Measuring PCT Solutions for the PHA Glasses of the SDP FY01 Study (U)

## *EXECUTIVE SUMMARY*

The Immobilization Technology Section currently is conducting a study of the impact of cooling rate on glass durability as part of the Salt Disposition Program (SDP). The Product Consistency Test, or PCT, is used as a measure of glass durability, and its requirements are described in ASTM C1285-97 (Method A). Each PCT results in a leachate solution whose elemental concentrations must be measured to complete the determination of glass durability. In addition to the test glasses, PCTs are usually conducted on samples of Approved Reference Material (ARM) glass and samples of Environmental Assessment (EA) glass. One or more reagent blank samples are also included in these tests.

This memorandum addresses the PCTs that are being conducted for the seventeen Precipitate Hydrolysis Aqueous (PHA) glasses supporting the PHA portion of the SDP glass study. The glasses were cooled by both quenching and centerline cooling, yielding thirty-four glasses that are to be subjected to the PCT.

The Savannah River Technology Center-Mobile Laboratory (SRTC-ML) is to measure elemental concentrations of the resulting leachate solutions. This memorandum provides an analytical plan for the SRTC-ML to follow in measuring the compositions of the leachate solutions resulting from the PCT procedures for these PHA glasses.

# *INTRODUCTION*

In support of the Salt Disposition Program (SDP), the Immobilization Technology Section currently is conducting a study [1] of the impact of cooling rate on glass durabilities. The Product Consistency Test, or PCT, is used as a measure of glass durability, and its requirements are described in ASTM C1285-97 (Method A) [2].

Seventeen Precipitate Hydrolysis Aqueous (PHA) glasses were batched and fabricated as part of the SDP glass study. Each of the seventeen glasses was both quenched and centerline cooled. This resulted in 34 PHA glasses for which PCTs are to be conducted.

The Savannah River Technology Center Mobile Laboratory (SRTC-ML) is to measure the compositions of the leachate solutions resulting from the PCTs for these glasses, and this memorandum provides an analytical plan for the SRTC-ML to follow in conducting the measurements.

# *DISCUSSION*

Thirty-four glasses from the PHA portion of the SDP glass study are to be subjected to the PCT. Each of the tests is to be conducted in triplicate. In addition to the test glasses, triplicate PCTs are to be conducted on a sample of the Approved Reference Material (ARM) glass and a sample of the Environmental Assessment (EA) glass. Two reagent blank samples are also to be included in these tests. Thus, a total of 110 samples are required to complete these PCTs.

The leachates from these tests will be diluted by adding 6 mL of 0.4 $HNO_3$ to 4 mL of the leachate (a 4:10, volume to volume, v:v, dilution) before being submitted to the Mobile Laboratory. The EA leachates will be further diluted (1:10, v:v) with deionized water prior to submission to the Mobile Lab in order to prevent problems with the nebulizer.

Table 1 enumerates the PHA glasses and presents identifying codes, ab001 through ab110, for their PCTs as well as for the standards: EA, ARM, and blanks. The glass identifiers in Table 1 indicate glasses that were centerline cooled via a "clc" suffix. The naming convention of Table 1 is to be used by the SRTC-ML in analyzing these solutions and reporting the relevant concentration measurements.[1]

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1 Renaming these samples ensures that they will be processed as blind samples by the SRTC-ML. This table is complete only for those on the distribution list with a "wi" following their names.

**Table 1: Solution Identifiers**

| Original Sample | Solution Identifier | Original Sample | Solution Identifier | Original Sample | Solution Identifier | Original Sample | Solution Identifier | Original Sample | Solution Identifier |
|---|---|---|---|---|---|---|---|---|---|
| pha01 | ab056 | pha04clc | ab013 | pha08 | ab091 | pha12 | ab082 | pha15clc | ab093 |
| pha01 | ab098 | pha04clc | ab106 | pha08clc | ab104 | pha12 | ab006 | pha15clc | ab002 |
| pha01 | ab041 | pha05 | ab085 | pha08clc | ab016 | pha12 | ab049 | pha16 | ab064 |
| pha01clc | ab108 | pha05 | ab109 | pha08clc | ab100 | pha12clc | ab055 | pha16 | ab105 |
| pha01clc | ab030 | pha05 | ab068 | pha09 | ab001 | pha12clc | ab097 | pha16 | ab076 |
| pha01clc | ab080 | pha05clc | ab037 | pha09 | ab034 | pha12clc | ab099 | pha16clc | ab052 |
| pha02 | ab066 | pha05clc | ab038 | pha09 | ab005 | pha13 | ab039 | pha16clc | ab065 |
| pha02 | ab040 | pha05clc | ab063 | pha09clc | ab057 | pha13 | ab073 | pha16clc | ab032 |
| pha02 | ab004 | pha06 | ab075 | pha09clc | ab078 | pha13 | ab019 | pha17 | ab045 |
| pha02clc | ab060 | pha06 | ab061 | pha09clc | ab107 | pha13clc | ab089 | pha17 | ab003 |
| pha02clc | ab050 | pha06 | ab026 | pha10 | ab070 | pha13clc | ab028 | pha17 | ab090 |
| pha02clc | ab017 | pha06clc | ab012 | pha10 | ab029 | pha13clc | ab024 | pha17clc | ab067 |
| pha03 | ab110 | pha06clc | ab023 | pha10 | ab095 | pha14 | ab087 | pha17clc | ab015 |
| pha03 | ab020 | pha06clc | ab018 | pha10clc | ab044 | pha14 | ab101 | pha17clc | ab010 |
| pha03 | ab043 | pha07 | ab086 | pha10clc | ab053 | pha14 | ab096 | EA | ab047 |
| pha03clc | ab069 | pha07 | ab025 | pha10clc | ab062 | pha14clc | ab036 | EA | ab014 |
| pha03clc | ab048 | pha07 | ab011 | pha11 | ab088 | pha14clc | ab072 | EA | ab092 |
| pha03clc | ab083 | pha07clc | ab042 | pha11 | ab084 | pha14clc | ab094 | ARM | ab031 |
| pha04 | ab035 | pha07clc | ab027 | pha11 | ab077 | pha15 | ab008 | ARM | ab102 |
| pha04 | ab058 | pha07clc | ab033 | pha11clc | ab059 | pha15 | ab074 | ARM | ab007 |
| pha04 | ab021 | pha08 | ab022 | pha11clc | ab054 | pha15 | ab079 | blank | ab046 |
| pha04clc | ab081 | pha08 | ab051 | pha11clc | ab009 | pha15clc | ab103 | blank | ab071 |

## *ANALYTICAL PLAN*

The analytical plan for the Mobile Lab is provided in this section. Each of the solution samples submitted to the SRTC-ML is to be analyzed only once for each of the following: boron (B), lithium (Li), sodium (Na), and silicon (Si). These measurements are to be made in parts per million (ppm). The analytical procedure used by the SRTC-ML to determine the relevant concentrations involves an Inductively Coupled Plasma (ICP) – Emission Spectrometer. The PCT solutions (as identified in Table 1) are grouped in six ICP blocks for processing by the Mobile Lab in Table 2. Each block will probably require a different calibration of the ICP.

**Table 2: ICP Calibration Blocks for Leachate Measurements**

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| std-b1-1 | std-b2-1 | std-b3-1 | std-b4-1 | std-b5-1 | std-b6-1 |
| ab059 | ab053 | ab083 | ab103 | ab023 | ab021 |
| ab108 | ab003 | ab009 | ab035 | ab027 | ab106 |
| ab064 | ab065 | ab099 | ab089 | ab028 | ab005 |
| ab085 | ab054 | ab077 | ab075 | ab025 | ab002 |
| ab069 | ab084 | ab041 | ab086 | ab102 | ab107 |
| ab044 | ab105 | ab100 | ab008 | ab078 | ab017 |
| ab082 | ab097 | ab068 | ab042 | ab014 | ab007 |
| ab052 | ab038 | ab080 | ab031 | ab093 | ab018 |
| ab067 | ab109 | ab090 | ab001 | ab058 | ab019 |
| std-b1-2 | std-b2-2 | std-b3-2 | std-b4-2 | std-b5-2 | std-b6-2 |
| ab104 | ab048 | ab076 | ab066 | ab040 | ab071 |
| ab045 | ab015 | ab062 | ab012 | ab072 | ab094 |
| ab037 | ab098 | ab032 | ab047 | ab013 | ab033 |
| ab070 | ab016 | ab063 | ab081 | ab101 | ab092 |
| ab046 | ab030 | ab091 | ab057 | ab034 | ab096 |
| ab055 | ab006 | ab095 | ab036 | ab050 | ab026 |
| ab110 | ab051 | ab010 | ab039 | ab061 | ab079 |
| ab088 | ab029 | ab049 | ab060 | ab073 | ab024 |
| ab022 | ab020 | ab043 | ab087 | ab074 | ab004 |
| ab056 | std-b2-3 | std-b3-3 | std-b4-3 | std-b5-3 | ab011 |
| std-b1-3 | | | | | std-b6-3 |

A multi-element solution standard (denoted by "std-bi-j" where i=1, 2, 3, 4, 5, and 6 represents the block number and j=1, 2, 3 represents the position in the block) was added at the beginning, middle, and end of each of the six blocks. This standard may be useful in checking and correcting for bias in the concentration measurements resulting from the ICP calibrations.

## *CONCLUDING COMMENTS*

In summary, this analytical plan identifies six ICP calibration blocks in Table 2 that are to be used by the SRTC-ML in conducting the boron (B), lithium (Li), sodium (Na), and silicon (Si) concentration measurements for the PCT study of the PHA test glasses. The sequencing of the activities associated with each of these steps in the analytical procedures has been randomized. The size of the blocks was selected so that each block could be completed in a single work shift. If for some reason the measurements are not conducted in the sequence presented in this memorandum, the actual order used should be recorded along with any explanative comments.

The analytical plan indicated in the preceding tables should be modified by the personnel of SRTC-ML to include any calibration check standards and/or other standards that are part of the standard operating procedures.

## *REFERENCES*

[1] Harbour, J. R. and T. B. Edwards, "Task Technical and QA Plan: Impact of Cooling Rate on the Durabilities of CST and PHA Glasses," WSRC-RP-2000-00996, December 11, 2000.

[2] ASTM C1285-97, "Standard Test Methods for Determining Chemical Durability of Nuclear Waste Glasses: The Product Consistency Test (PCT)," 1997.

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