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WTP Waste Feed Qualification: Glass Fabrication Unit Operation Testing Report

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EXECUTIVE SUMMARY

The waste feed qualification program is being developed to protect the Hanford Tank Waste Treatment and Immobilization Plant (WTP) design, safety basis, and technical basis by assuring waste acceptance requirements are met for each staged waste feed campaign prior to transfer from the Tank Operations Contractor to the feed receipt vessels inside the Pretreatment Facility. The *Waste Feed Qualification Program Plan* describes the three components of waste feed qualification:

1. Demonstrate compliance with the waste acceptance criteria
2. Determine waste processability
3. Test unit operations at laboratory scale

The glass fabrication unit operation is the final step in the process demonstration portion of the waste feed qualification process. This unit operation generally consists of combining each of the waste feed streams (high-level waste (HLW) and low-activity waste (LAW)) with Glass Forming Chemicals (GFCs), fabricating glass coupons, performing chemical composition analysis before and after glass fabrication, measuring hydrogen generation rate either before or after glass former addition, measuring rheological properties before and after glass former addition, and visual observation of the resulting glass coupons. Critical aspects of this unit operation are mixing and sampling of the waste and melter feeds to ensure representative samples are obtained as well as ensuring the fabrication process for the glass coupon is adequate.

Testing was performed using a range of simulants (LAW and HLW simulants) and these simulants were mixed with high and low bounding amounts of GFCs to evaluate the mixing, sampling, and glass preparation steps in shielded cells using laboratory techniques. The tests were performed with off-the-shelf equipment at the Savannah River National Laboratory (SRNL) that is similar to equipment used in the SRNL work during qualification of waste feed for the Defense Waste Processing Facility (DWPF) and other waste treatment facilities at the Savannah River Site. It is not expected that the exact equipment used during this testing will be used during the waste feed qualification testing for WTP, but functionally similar equipment will be used such that the techniques demonstrated would be applicable. For example, the mixing apparatus could use any suitable mixer capable of being remoted and achieving similar mixing speeds to those tested.

Conclusions

The mixing and sampling apparatus was shown to be acceptable to mix the GFCs with the LAW and HLW wastes and to collect representative samples. The techniques used to prepare the glass coupons were acceptable for the expected range of LAW and HLW feeds. These conclusions are based on meeting the requirements for these tasks as outlined in the Task Technical and Quality Assurance Plan (TTQAP):

Simulant (TTQAP Section 4.1)

1. *SRNL will recommend to WTP the simulant(s) to be used for this testing*
    - The simulant used was specified and procured by WTP following SRNL recommendation. The HLW-High Bound simulant used during the testing was prepared by SRNL.

Mixing (TTQAP Section 4.2)

1. *SRNL will identify and design a mixing system to blend the waste sample with GFCs.*
    - A mixing system was designed. This design was reviewed by WTP.

2. *SRNL will demonstrate that the mixing system can blend the waste sample with GFCs to allow representative sampling*.
    - The mixing system performance was demonstrated by the preparation of four simulated melter feed slurries. The system demonstrated the capability to blend the LAW and HLW simulants with the appropriate glass forming chemicals and sugar. Representative samples were pulled from the mixing vessel.
3. *SRNL will determine the number of samples required and the accepted tolerances needed to verify sample representativeness*.
    - Four sample replicates are recommended for waste qualification testing, based on the repeatability of the samples during this demonstration including statistical analysis.
    - The relative standard deviation for the replicates should be within 15% for major components for the samples to be deemed representative.
4. *If not demonstrated by experience, SRNL will perform an assessment of the remotability of the specified mixing system*.
    - The mixing system selected has been used extensively in the SRNL Shielded Cells facility for DWPF waste qualification testing.

Physical Property Measurements (TTQAP Section 4.3)

1. *SRNL will perform rheological property measurements before and after GFC additions*.
    - Rheological property measurements were successfully performed for simulant and melter feed samples at ambient temperature (25 degrees Celsius) as well as at an elevated temperature (40 degrees Celsius) for the melter feed samples.
2. *SRNL will perform dilutions to the waste sample or melter feeds if the rheological properties are outside design limits*.
    - Dilutions were not required to adjust samples to be within the design limits because samples did not exceed the rheological properties limit.
3. *SRNL will perform physical property measurements of the melter feed slurries to include: density, weight percent solids (total, dissolved, and undissolved), and supernate density*.
    - The specified measurements were successfully performed. Dissolved solids measurements were performed on some samples. For some samples insufficient sample volume remained after composition analysis. However, sufficient data was collected to ensure accuracy of analytical methods and average results were obtained for each test.
4. *SRNL will provide the specifics of the equipment needed to perform the rheological property measurements*.
    - The equipment and sample techniques used during the testing are specified in Section 1.3 and 1.4 of this report.

Glass Preparation (TTQAP Section 4.4)

1. *SRNL will provide work instructions to support conversion of the melter feed to a product*.
    - Work instructions are provided in Appendix F.
2. *SRNL will specify heat up rates and hold times*.
    - It was determined that the samples can be placed into a furnace at temperature as no controlled ramp rate was needed to prevent foaming. The lack of a need for a controlled ramp to temperature was successfully demonstrated.
    - A hold time of 60 to 65 minutes was determined during proof of concept testing. This hold time was successfully demonstrated.

Sample Analysis (TTQAP Section 4.5)

1. *SRNL will perform ICP-AES measurements of the prepared glass and melter feed slurries*.
    - SRNL successfully performed the compositional analysis of melter feed and glass samples using inductively coupled plasma-atomic emission spectroscopy (ICP-AES). Digestion methods are specified.
2. *SRNL will perform visual observations of the simulated LAW and HLW waste glasses prepared during the testing*.
    - Visual examinations were successfully performed of all glass samples to check for any nucleation or surface variations.

Hydrogen Generation Rates (TTQAP Section 4.6)

1. *SRNL will consider the sample size needed for the hydrogen generation rate (HGR) measurement during the melter feed preparation*.
    - The sampling plan included samples for HGR measurements.

Lessons Learned during Testing

The results indicated that the melter feed slurries with higher yield stresses were more easily sampled in a representative manner and the thinner feeds resulted in more difficulty in collecting representative samples. The testing was performed with mixing to achieve a “slight vortex” based on past testing with samples that indicated that this mixing requirement is sufficient to collect representative samples. Note that excessive vortex with mixing can cause air entrainment in viscous samples. Entrained air can impact density and rheological property measurements if the air remains trapped in the slurry once mixing is stopped. To reduce the variability in sample results noted during this testing for samples that are less viscous, increase mixing speed toward the maximum speed possible to produce a more vigorous mixing regime, while also minimizing sample splatter. For less viscous samples, air entrainment is not a significant issue, as these slurries typically do not trap enough air to effect property measurements. It should be noted that the melter feed water content is typically minimized as much as possible such that less viscous melter feeds would not be expected.

The time allowed to vitrify melter feed samples during the testing was 60 - 65 minutes. The demonstrated techniques for converting melter feed to glass product were successful based on results of these studies with the LAW-Low Bound (LAW-LB), HLW-High Bound (HLW-HB), and HLW-Low Bound (HLW-LB) melter feeds and can be easily translated for glass fabrication in a shielded cells environment. However, greater compositional variability was observed in LAW-LB and HLW-LB tests with the glass sample data versus the melter feed simulant results, which may be indicative of insufficient homogenization during melting. Melter feeds were not agitated during the drying process and particle settling likely occurred, especially in those melter feeds exhibiting a low yield stress. If issues with homogenization are noted during waste feed qualification, then increasing the melting time could lead to a more homogenous glass product and less variability in the glass composition results. Periodically mixing the melter feed during drying would also improve homogenization.

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LIST OF ABBREVIATIONS

ACTL	Aiken County Technology Laboratory
ARG	Analytical Reference Glass
ASTM	ASTM International
DWPF	Defense Waste Processing Facility
GFCs	Glass Forming Chemicals
HB	High Bound
HGR	Hydrogen Generation Rate
HGRMA	Hydrogen Generation Rate Measurement Apparatus
HLW	High Level Waste
ICP-AES	Inductively Coupled Plasma - Atomic Emission Spectroscopy
ID	Identification
ITS	Immobilization Technology Section (L29 Manual)
LAW	Low Activity Waste
LB	Low Bound
LRM	Low-Activity Waste Reference Material
LTD	Less than Detectable (used when result is below Method Detection Limit)
M&TE	Measuring & Test Equipment
NA	Not Applicable
NIST	National Institute of Standards and Technology
NM	Not Measured
PI	Principal Investigator
PSAL	Process Science Analytical Laboratory
RPM	Revolutions Per Minute
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
TTQAP	Task Technical and Quality Assurance Plan
WCP	Waste Compliance Plan
WTP	Hanford Tank Waste Treatment and Immobilization Plant

1.0 Introduction

1.1 Background

The waste feed qualification program is being developed to protect the Hanford Tank Waste Treatment and Immobilization Plant (WTP) design, safety basis, and technical basis by assuring waste acceptance requirements are met for each staged waste feed campaign prior to transfer from the Tank Operations Contractor to the feed receipt vessels inside the Pretreatment Facility. The *Waste Feed Qualification Program Plan*[1] describes the three components of waste feed qualification:

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The glass fabrication unit operation is the final step in the process demonstration portion of the waste feed qualification process. This unit operation generally consists of combining each of the waste feed streams (high-level waste (HLW) and low-activity waste (LAW)) with glass forming chemicals (GFCs), fabricating glass coupons, performing chemical composition analysis before and after glass fabrication, measuring hydrogen generation rate either before or after glass former addition, measuring rheological properties before and after glass former addition, and visual observation of the resulting glass coupons. Critical aspects of this unit operation are mixing and sampling of the waste and melter feeds to ensure representative samples are obtained from which processing decisions are based.

The planned approach for WTP operation to produce immobilized LAW and HLW glass products are described below.

1.1.1 LAW Glass Production

The LAW feed is received in the concentrate receipt vessels where it is sampled and analyzed to determine a recipe for GFC additions in order to produce a qualified immobilized LAW glass. This single sampling event in the LAW Facility produces two data sets. The data are identified as LAW 1a and 1b.[2] The first data set (LAW 1a) releases a hold point within the process. The second data set (LAW 1b) provides information for regulatory reporting. After the compositional analyses are complete and predictions (using glass formulation algorithms) on glass composition are made, the glass formers (e.g., silica, alumina, boric acid, calcium silicate, and sugar) are added to the waste feed in the melter feed preparation vessels. The melter feed (waste plus glass forming chemicals) is re-sampled for analyses. This sampling event in the LAW Facility is identified as LAW 6.[2] This final sample verifies that the correct glass former mixture has been added to the LAW – melter feed preparation vessels and that the melter feed will make a glass product that meets processing and product quality requirements.[3] In the LAW Facility, this sampling event is not a process hold point.

After GFC addition, the slurry of waste feed and GPFs are transferred to the LAW melter feed vessels in a manner to provide a continuous feed to each of the two LAW melters.

1.1.2 HLW Glass Production

The HLW feed from Pretreatment is received in the HLW – melter feed preparation vessels where it is sampled and analyzed. This sampling event in the HLW Facility is identified as HLW 2a.[2] From this analysis, the predictions for GFC addition are made (using glass formulation algorithms) The GFCs are then added to the waste feed in the melter feed preparation vessels, and the contents are again sampled and analyzed. This next sampling event and subsequent analysis generates two data sets. These data sets are identified as HLW 2b and 2c.[2] The first data set (from HLW 2b) is used to release a process hold point for verifying glass former addition, while the second data set (from HLW 2c) is used to confirm the composition for product compliance.[4]

After verification of GFC addition, the slurry of waste feed and glass formers is transferred to the HLW melter feed vessels in a manner to provide a continuous feed to the HLW melter.

1.1.3 Waste Feed Qualification Support and Recommendations from Literature Review

The waste feed qualification efforts will parallel those required during facility operations, to the extent practical. However, sampling times and analytical methods may be exceptions. At this point in the waste feed qualification process, it is assumed that pretreated feed (e.g. feed that has undergone a series of processing steps) meeting the LAW and HLW Vitrification facility's requirements, is available for the LAW and HLW glass fabrication unit operations.

Based on the associated literature review for the glass fabrication unit operations[5], the following apparatus and measurements were identified and recommended to support waste feed qualification activities associated with the glass fabrication unit operations testing:

1.1.3.1 Preparation and Mixing of Slurry Samples

A high speed, low shear remotable mixer such as the Resodyn LabRAM or similar is to be used to mix the sample before and after glass former addition to ensure homogeneity. Representative samples are to be obtained in order to support composition analysis, rheology measurements, and hydrogen generation rate (HGR) measurements.

1.1.3.2 Rheology Measurement

A remotable Haake M5/RV30 rotoviscometer or similar should be used to perform rheology measurements on the waste feed sample before and after glass former addition as well as after any dilutions are performed.

1.1.3.3 Glass Fabrication

A laboratory furnace such as a CM bottom loaded, elevator furnace (Model 1708 BL) or similar is to be used to fabricate the glass coupons. Platinum or platinum-alloy crucibles (100 or 250 milliliters with reinforced rims) should be used in fabricating the glass coupons.

1.1.3.4 Composition Analysis

Compositional analysis of waste feed sample is required to identify types and quantities of GFCs to be added. Compositional analysis of waste feed sample after addition of glass former materials is also required for verification.

1.1.3.5 Hydrogen Generation Rate Measurement

HGR of the waste feed sample will also be measured (either before or after addition of GFCs). Details associated with this measurement are provided in a related task.[6,7]

1.1.3.6 Observations

Visual observation of glass coupons is performed to provide a qualitative assessment that a glass product can be made (LAW and HLW glasses).

1.2 Simulants

The experimental program required simulants of the LAW and HLW wastes for use in the testing as well as procurement of the glass forming chemicals expected to be used for each formulation tested. Simulants were provided by WTP for this testing based on SRNL recommendation from previous developmental work.[8,9] The simulant recipes are provided in Appendix A.

Issues were noted with the rheological properties of the vendor provided HLW-HB simulant. As a result, SRNL prepared the HLW simulant recipe using chemicals remaining from the simulant development program. This HLW simulant was prepared with the same recipe used by the vendor. The difference noted in the rheological properties was determined to be the substitution of the ferric oxide by the vendor with ferric oxide having a different particle size (the ferric oxide specified is no longer commercially available). This is a reoccurring issue observed by WTP due to the non-availability of the Prince 5001 iron oxide, which is less than 325 mesh particle size. Rheological property results are shown in Section 2.5.6.3 The same substitution was made in the ferric oxide used in the LAW GFCs, but the LAW GFCs were used as provided since the LAW recipes were not expected to bound the upper rheological properties anticipated during the tests.

1.3 Equipment

As stated above, the fabrication of the glass coupon is expected to utilize off-the-shelf equipment and that remoting of this equipment (weigh scales, furnaces, etc.) has been performed at the Savannah River Site (SRS) and other sites since the beginning of the use of remote cells. Therefore, remotability of the equipment was not demonstrated during the task and the testing was not always performed with the exact equipment expected to be used in the cells. However, the equipment did represent equipment similar to that currently used in the SRNL Shielded Cells for waste qualification at SRS and the techniques utilized are applicable to shielded cells work.

1.3.1 Mixing Stand

The mixing and sampling stand were assembled from parts on hand at the Aiken County Technology Laboratory (ACTL). The parts and components used on the stand have all been used in the SRNL Shielded Cells for various activities involved in the SRS Defense Waste Processing Facility (DWPF) qualification runs. It should be noted that the remotability of the Resodyn LabRAM system has been demonstrated by the vendor. However, a simpler mixing system was used for this testing after reviewing the necessary mixing requirements. The mixing apparatus used was a Cole-Parmer Stir-Pak mixer as shown in Figure 1, as specified in the TTQAP.[10]

During the simulant testing, an optical tachometer was used to determine the agitator speed, but this measurement is not expected to be necessary during actual waste feed qualification. A 2-liter Nalgene bottle was utilized as the mixing vessel to ensure sufficient mixing prior to sample collection. The impeller was a stainless steel, 2-inch diameter, Lightnin A-200 pitched turbine, as shown in Figure 2. The diameter of the Nalgene 2-liter wide mouth bottle is large enough to allow this impeller to fit through the lid.

The sampler consisted of a dip leg attached to a Masterflex pump as shown in Figure 3. A modular drive separates the controller from the pump head, the pump drive shown in Figure 3 is not modular as the controller is integrated into the pump drive for pumps typically used at SRNL for non-rad testing. A modular pump separates the controller from the drive head, but otherwise functions in an identical manner to the drive unit to be used during simulant testing. A modular drive would allow the pump controls to be easily remoted.

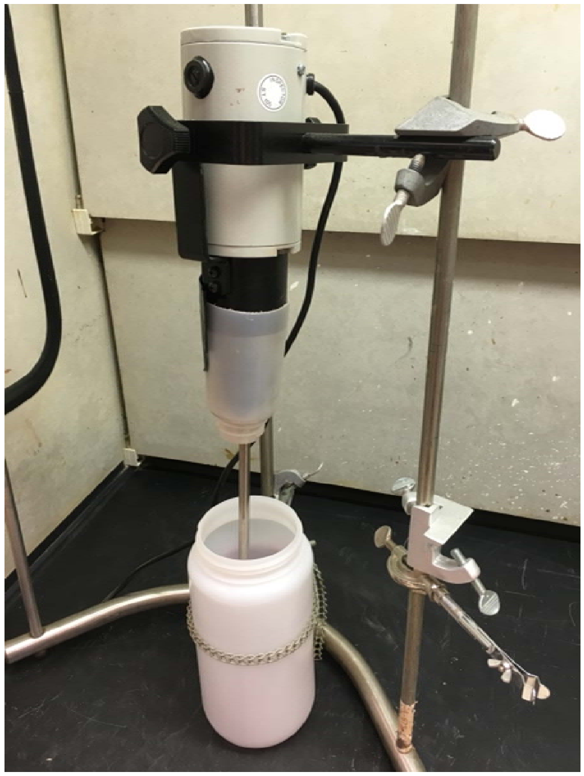
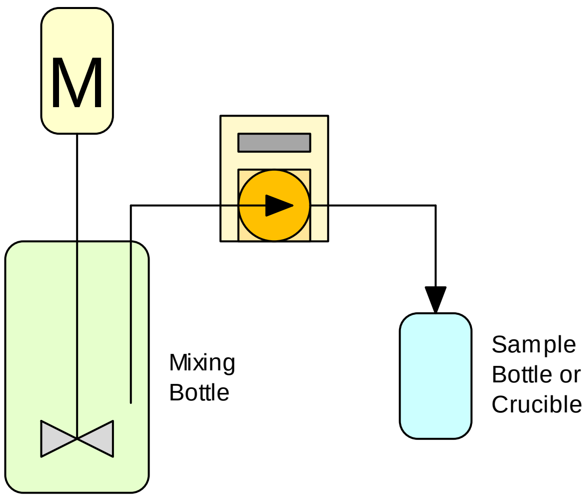


Figure 1. Mixer Used in Glass Fabrication Unit Operations Demonstration

Figure 2. Lightnin A-200 Impeller Used in Glass Fabrication Unit Operations Demonstration



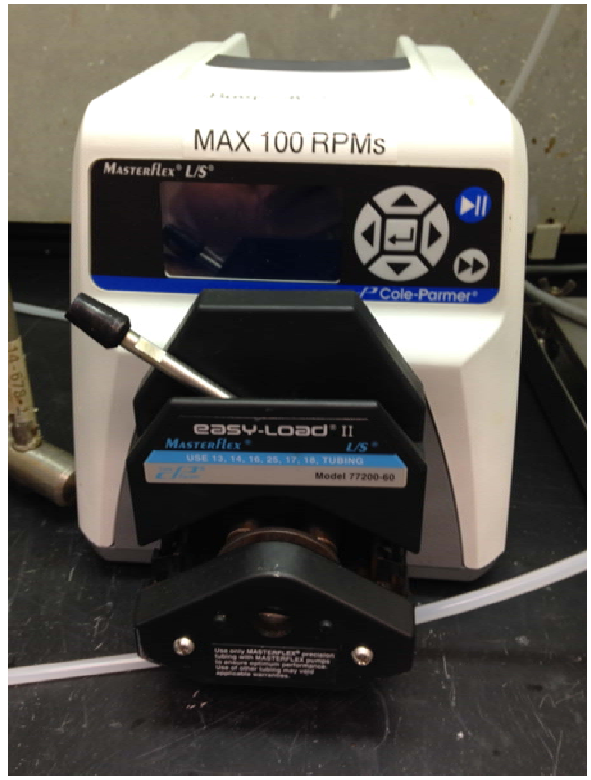


Figure 3. Sampler Diagram and Masterflex Pump/Drive/Head Used in Glass Fabrication Unit Operations Demonstration

The mixing and sampling stand consisted of the following parts:

- Mixer Stand – generic stainless steel
  - Base and 1 rod: Cole-Parmer T-04552-80
  - Two extra rods: Cole-Parmer T-04552-85

- Cole-Parmer Stir-Pak Heavy-Duty Mixer Head and Controller (0-900 Revolutions per Minute)
  - Controller: Cole-Parmer T-50007-00
  - Mixer Head: Cole-Parmer T-50007-20

- Mixing Shaft – generic stainless steel shaft. 3/8 inch diameter, 18 inch length. Bottom of shaft turned down to 5/16 inch to allow mixer impeller to be mounted
  - Cole-Parmer T-04552-35

- Mixer Impeller - Lightnin A-200 2 inch diameter impeller
  - Cole-Parmer T-04561-60

- Sampling Pump – Masterflex modular drive L/S pump w/ Easy Load II head and Tygon-EFL size 17 tubing
  - Pump drive: Cole-Parmer T-07557-10
  - Pump Head: Cole-Parmer T-77201-60
  - Pump Tubing: Cole-Parmer T-06440-17

- Sampler Dip Tube – ¼ inch thin wall stainless steel tubing (0.030 inch wall thickness)

- Mixing Vessel – 2-liter wide-mouth poly bottle, Nalgene

1.3.2 Glass Fabrication Equipment

Glass fabrication was demonstrated using available crucibles, crucible lids, and furnaces. Details for these items are shown below:

- Crucibles
  - Alloy – 95% platinum - 5% gold
  - Volume – 100 milliliters

- Crucible lids
  - Alloy – 90% platinum – 10% rhodium

- Lindberg/Blue M 1700 Degrees Celsius Box Furnaces
  - Model Numbers - BF51634PBC-1 and BF51664PBC

1.4 Experimental Method

The Task Technical and Quality Assurance Plan[10] specified testing of these specific procedure steps (as defined by the current waste feed qualification program) to convert both LAW and HLW waste feed qualification samples to glass products:

- Feed stream mixing and sampling
- Characterization of the melter feed slurry
- Rheology measurements before and after glass former addition
- Use of current glass formulation algorithms to determine the type and quantity of glass former additions
- Conversion of the melter feed to a glass product
- Analysis of the glass product

Demonstration of the HGR measurement on melter feed was performed under a separate task.[11] The methods for preparation of required simulants, melter feed preparation, melter feed rheological and composition measurements, glass preparation, glass composition, and microscopy are described below.

The glass formulation algorithm was not used during this testing as the simulants and GFC recipes were obtained from recommendations relating to previous simulant development work.[9]

The experimental methods are generally described below; the actual process steps used are shown in Appendix B. All data from the runs was collected and maintained in an electronic laboratory notebook.[12]

1.4.1 Melter Feed Slurry Preparation

The required amount of each simulant was weighed into a 2-liter polyethylene bottle and the bottle was mounted on the mixing apparatus. Agitation was initiated and adjusted to achieve a slight vortex, then the required amounts of GFCs and sugar were slowly added with the addition taking approximately 5 minutes. Agitator speed was adjusted to maintain the slight vortex, and the melter feed slurry was mixed for 30 minutes. Samples were then collected using a dip tube and peristaltic pump into appropriately size polyethylene bottles. Four samples were taken for chemical composition, four samples were taken for rheological property measurement and chemical composition, one sample was taken for HGR measurement, and eight samples were taken for glass fabrication. In addition, the remaining heel in the mixing vessel was sent for analysis.

1.4.2 Glass Crucibles and Furnace Techniques

Eight subsamples of each melter feed were collected for vitrification ((LAW-LB (MFP-1a series), HLW-LB (MFP-3a series), and HLW-HB (MFP-4a series)) in small polyethylene bottles.[A] Each sample bottle was thoroughly mixed and the contents were poured into 100 milliliter, 95% platinum-5% gold alloy crucibles. Residual solids were rinsed into the crucible with 10 grams of tap water. The melter feed samples were dried at 115 degrees Celsius ± 5 degrees Celsius for a minimum of 12 hours to remove any free water. Each crucible was covered with a loose-fitting lid and placed into a high temperature furnace at 1,150 degrees Celsius.[13] After an isothermal hold at 1,150 degrees Celsius ± 10 degrees Celsius for 60 - 65 minutes, the crucibles were removed from the furnace and placed on a stainless steel plate, where the melt was allowed to cool to ambient temperature. The resulting glasses were removed from the crucible, visually inspected, and submitted for chemical composition analysis.

1.5 Analytical Methods

Slurry samples were analyzed for physical and chemical properties as described below. Glass samples were analyzed for chemical composition by Inductively Coupled Plasm-Atomic Emission Spectroscopy (ICP-AES). Standard glasses (low-activity test reference material (LRM), DWPF Waste Compliance Plan WCP) Batch 1, and Analytical Reference Glass-1 (ARG-1))[14-16] were included with each set of eight glass samples per melter feed composition and also analyzed in duplicate.

1.5.1 Rheological Properties

Rheological properties were measured with a Haake RS-6000 rheometer[17] using the Haake Z41 concentric cylinder geometry. This instrument was used because the sample size required by the concentric cylinder geometry installed on the M5/RV30 available at ACTL was much larger than desired. The use of the rheometer varies little in how samples are loaded/unloaded between the two rheometers and geometries are available for the M5/RV30 rheometer that allow the smaller sample size used in the testing to be utilized during the waste feed qualification.

Samples run at elevated (40 degrees Celsius) temperature were placed in a shaker bath to warm the samples to the measurement temperature prior to transferring the sample to the rheometer. The temperature cup of the rheometer is temperature controlled and was also heated to 40 degrees Celsius prior to introducing the sample. This technique allows the measurement to be performed immediately after transfer to the rheometer and avoids settling of the sample prior to the measurement.

1.5.2 Ion Chromatography

Selected anions were measured using a Dionex DX-500 ion chromatograph.[18] Samples were prepared by performing a weighted 100X dilution, then filtering the resulting supernate with a 0.45 micron syringe filter.

1.5.3 Sample Preparation for ICP-AES measurements

Slurry samples were first calcined at 1,100 degrees Celsius and then mechanically ground and sieved to -100 mesh. The ground samples were then prepared via two different fusion techniques; a lithium tetra-borate/lithium nitrate fusion[19] and sodium peroxide/sodium hydroxide fusion.[20]

[A] Vitrification of the LAW-HB melter feed was attempted during proof of concept testing, but could not be melted.

The glass samples were mechanically ground in an agate mortar and pestle, and then sieved to -100 mesh. The ground samples were then prepared via two different fusion techniques; a lithium metaborate fusion[21] and sodium peroxide/sodium hydroxide fusion.[20]

For the lithium tetra-borate/lithium nitrate fusion[19], 0.1 grams of the sample was mixed with 1.0 grams of the lithium tetra-borate/lithium nitrate and heated to 1,000 degrees Celsius for a minimum of 15 minutes. After the sample cooled, the sample was dissolved in a 4 weight percent nitric acid (HNO_3) solution and diluted with water to a total volume of 100 milliliters. The resulting solution was further diluted by 10X.

For the sodium peroxide/sodium hydroxide fusion[20], 0.15 grams of the sample was mixed with 1 gram of sodium hydroxide (NaOH), 1.5 grams of sodium peroxide (Na_2O_2) and heated to 600 degrees Celsius for a minimum of 15 minutes. After the sample cooled, it was reacted with water, dissolved with 20 milliliters of concentrated hydrochloric acid (HCl), and diluted to a total volume of 250 milliliters. The resulting solution was further diluted by 10X prior to analysis.

For the lithium metaborate fusion[21], 0.1 grams of the sample was mixed with 0.3 grams of lithium metaborate and heated to 900 degrees Celsius for a minimum of 15 minutes. The sample was then dissolved in a 4 weight percent nitric acid (HNO_3) solution and diluted with water to a total volume of 100 milliliters. The resulting solution was further diluted by 10X.

1.5.4 ICP-AES Measurements

All of the prepared solutions were analyzed with an ICP-AES.[22] The ICP-AES was calibrated before each run, verified after every ten samples, and at the end of the sample series with National Institute of Standards and Technology (NIST) traceable standards to ensure that the calibration did not drift throughout the sample measurements. Each sample was analyzed in duplicate.

1.5.5 Weight Percent Solids

The weight percent total solids and calcine solids are analyzed as part of the preparation process for the ICP-AES analysis.[23] Approximately 10 grams of slurry are added to a platinum crucible and dried at 110 degrees Celsius. The dry weight is recorded to determine the weight percent total solids, followed by soluble solids on a syringe-filtered sample. Dissolved and undissolved (insoluble as reported by PSAL) solids are calculated from the total and soluble solids measurements[9]. The sample is then calcined at 1,100 degrees Celsius and reweighed to determine the percent calcine solids.

1.5.6 Density

Density is measured on liquids using an Anton Parr 4500 or 5500 density meter and on slurries using an Anton Parr 4500. Although an instrument using a similar analytical method as these density meters has been used for supernate density in the SRNL Shielded Cells, it is more likely that density will be measured by weighing a known volume of sample using a pipet or density cup to obtain the known volume during qualification testing with the actual waste samples.[24]

1.6 Quality Assurance

This work was performed according to requirements in the Task Technical and Quality Assurance Plan for Glass Fabrication Unit Operation During Waste Feed Qualification at the Hanford Tank Waste Treatment and Immobilization Plant, SRNL-RP-2013-00808, Revision 0.[10] The task activities are described in Section 4.0.

Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report

Design Checklist contained in WSRC-IM-2002-00011, Rev. 2, and maintained as an SRNL project record.

2.0 Results and Discussion

2.1 Scoping Tests

Scoping tests were performed to allow initial assessments of mixing, sampling, and glass preparation methods. These tests were qualitative in nature; therefore, quantitative analysis was not performed.

Mixing tests were performed to show that the LAW and HLW samples to be used during the testing could be blended with the agitator and impeller chosen. This testing indicated that a small vortex could be maintained on the slurries in the mixing bottle. Sampling from the mixing bottle was performed to ensure that the sampler could pull variable sized samples and that the sample lines used would not readily plug during sampling.

Glass was prepared from the HLW–HB melter feed blend to assess whether a controlled ramp to temperature was needed during the testing and what hold times should be used. Scoping tests with the HLW-HB melter feed indicated that foaming during vitrification was not excessive; therefore, insertion of the glass sample into a furnace already at temperature was feasible. A one hour isothermal hold resulted in glass that was visually crystal free and appeared homogenous. Therefore, a hold time of one hour and insertion into a furnace at temperature was specified for the testing. This method is consistent with previous experience with DWPF glass preparation for waste feed qualification work. Since the experimental work on this task was completed, foaming was noted during preparation of glass for DWPF qualification testing. The amount of glass prepared during each melt was reduced to mitigate the foaming issue versus incorporation of a temperature ramp during heat-up.

2.2 Melter Feed Slurry Preparation and Sampling

2.2.1 LAW-Low Bound Test

Simulant totaling 1,225 grams[25] was added to the mixing stand and mixed at 360 revolutions per minute to obtain a slight vortex. After 442 grams[25] of GFCs and 38.35 grams[25] of sugar were added to the vessel, the speed was increased to 390 revolutions per minute to maintain the vortex. Collecting the specified samples took approximately 30 minutes. The initial 125 gram samples were slightly above the targeted amounts, but the volume pulled for the 125 milliliter samples was adjusted and the final samples hit the weight targets, as shown in Table 1. The seven gram difference between the total amount added to the vessel and the total amount of sample collected reflects losses during rinsing of the sample line and dip leg.

In order to sub-sample sufficient amounts, the targeted amounts were held to the minimums specified by the laboratory for the required analysis. A portion of the melter feed slurry samples did not have sufficient material to perform the soluble/insoluble solids analyses. However, all samples had sufficient volume to perform compositional and total solids characterization.

2.2.2 LAW-High Bound Test

Simulant totaling 629.9 grams[25] was added to the mixing stand and mixed at 340 revolutions per minute to obtain a slight vortex. After 1,057.8 grams[25] of GFCs and 19.73[25] grams of sugar were added to the vessel, the speed was increased to 530 revolutions per minute to maintain the vortex. Collecting the specified samples took approximately 20 minutes. Targeted sample amounts along with actual amounts pulled are shown in Table 2. The 29 gram difference between the total amount added to the vessel and the total sample amount collected reflects losses during rinsing of the sample line and dip leg, as shown in Table 2.

2.2.3 HLW-Low Bound Test

Simulant totaling 1,225 grams[25] was added to the mixing stand and mixed at 430 revolutions per minute to obtain a slight vortex. After 472.3 grams[25] of GFCs and 4.13[25] grams of sugar were added to the vessel, the speed was maintained at 430 revolutions per minute to maintain the vortex. Collecting the specified samples took approximately 10 minutes. A portion of the samples did not hit target weights as accurately as desired, mainly due to an incorrect assumption on density, as shown in Table 3. A significant number of samples were lower than the target amount by more than 10%. The eight gram difference between the total amount added to the vessel and the total sample amount collected reflects losses during rinsing of the sample line and dip leg.

2.2.4 HLW-High Bound Tests

Two replicates were performed with the HLW High Bound composition. Glass fabrication and analysis was only performed on the initial replicate, but slurry composition analysis was performed on both sets.

In the first test, HLW simulant totaling 879.9 grams[25] was added to the mixing stand and mixed at 860 revolutions per minute to obtain a slight vortex. After 815.5 grams[25] of GFCs and 6.31 grams[25] of sugar were added to the vessel, the speed was maintained at 860 revolutions per minute to maintain the vortex, but was reduced to 770 revolutions per minute prior to taking samples. Collecting the samples specified took approximately 20 minutes. The 30 gram difference between the total amount added to the vessel and the total sample amount collected reflects losses during rinsing of the sample line and dip leg, as shown in Table 4.

In the second test, HLW simulant totaling 880.1 grams[25] was added to the mixing stand and mixed at 525 revolutions per minute to obtain a slight vortex. After 815.4 grams[25] of GFCs and 6.31 grams[25] of sugar were added to the vessel, the speed was increased to 1,045 revolutions per minute[B], but it was not possible to maintain a small vortex. Movement of the sample surface was noted, but this motion was not sufficient to create a vortex. Incorporation of the sugar into the slurry was slow; the mixing bottle position was adjusted to help incorporate the sugar. The mixer speed was reduced to 800 revolutions per minute prior to taking the last two samples to avoid excessive splatter. Collecting the samples specified took approximately 20 minutes. The difference between the total amount added to the vessel and the total collected reflects losses during rinsing of the sample line and dip leg, as shown in Table 5.

[B] The mixer is an analog mixer controlled by a variable voltage supply. The measured value of 1,045 RPM is above the 900 RPM maximum speed specified for the mixer. The speed rating is simply an estimate based on an applied voltage (likely 110 volts). The Variac may have applied 120 volts which results in a higher speed than the 900 RPM specified.

Table 1. Samples Taken during the LAW-Low Bound Test

Samples	Target (grams)	Tare (grams)	Full (grams)	Sample Weight (grams)	Delta (grams)
MFP-1a-23	30	11.530	42.698	31.168	1.168
MFP-1a-42	50	14.544	65.291	50.747	0.747
MFP-1a-14	125	24.842	167.560	142.718	17.718
MFP-1a-48	50	14.519	66.269	51.7503	1.7503
MFP-1a-47	50	14.493	66.963	52.470	2.470
MFP-1a-12	125	25.009	154.430	129.421	4.421
MFP-1a-43	50	14.525	66.057	51.532	1.532
MFP-1a-24	30	11.565	41.914	30.349	0.349
MFP-1a-11	125	24.811	152.09	127.279	2.279
MFP-1a-31	250	37.904	288.252	250.348	0.348
MFP-1a-21	30	11.522	42.242	30.720	0.720
MFP-1a-46	50	14.486	66.428	51.942	1.942
MFP-1a-44	50	14.544	65.326	50.782	0.782
MFP-1a-13	125	25.087	150.658	125.571	0.571
MFP-1a-41	50	14.522	65.449	50.927	0.927
MFP-1a-22	30	11.531	41.929	30.398	0.398
MFP-1a-45	50	14.570	65.140	50.570	0.570
MFP-1a-51	Heel	207.6	597.2	389.6	-
Total	1,705	-	-	1,698	-7

Table 2. Samples Taken during LAW-High Bound Test

Samples	Target (grams)	Tare (grams)	Full (grams)	Sample Weight (grams)	Delta (grams)
MFP-2a-12	125	24.247	157.215	132.968	7.968
MFP-2a-21	30	11.618	49.723	38.105	8.105
MFP-2a-13	125	24.938	149.626	124.689	-0.312
MFP-2a-45	50	14.533	62.269	47.736	-2.264
MFP-2a-44	50	14.520	64.496	49.976	-0.024
MFP-2a-43	50	14.500	64.697	50.197	0.197
MFP-2a-23	30	11.566	45.226	33.660	3.660
MFP-2a-48	50	14.480	65.930	51.450	1.450
MFP-2a-42	50	14.509	68.743	54.234	4.234
MFP-2a-31	250	37.818	292.029	254.211	4.211
MFP-2a-14	125	25.062	154.157	129.095	4.095
MFP-2a-11	125	24.921	148.463	123.542	-1.458
MFP-2a-22	30	11.599	47.815	36.216	6.216
MFP-2a-46	50	15.522	65.390	49.868	-0.132
MFP-2a-47	50	14.518	65.565	51.047	1.047
MFP-2a-24	30	11.644	46.252	34.608	4.608
MFP-2a-41	50	15.505	68.923	53.418	3.418
MFP-2a-51	Heel	208	572	364	-
Total	1,707	-	-	1,679	-29

Table 3. Samples Taken during HLW-Low Bound Test

Samples	Target (grams)	Tare (grams)	Full (grams)	Sample Weight (grams)	Delta (grams)
MFP-3a-45	50	14.517	49.521	35.003	-14.997
MFP-3a-21	30	11.623	43.355	31.733	1.733
MFP-3a-11	125	25.004	132.573	107.569	-17.431
MFP-3a-46	50	14.945	58.628	43.683	-6.317
MFP-3a-24	30	11.580	45.060	33.481	3.481
MFP-3a-48	50	14.475	49.655	35.180	-14.820
MFP-3a-42	50	14.507	62.916	48.409	-1.591
MFP-3a-13	125	24.891	128.688	103.797	-21.203
MFP-3a-12	125	25.034	122.036	97.001	-27.999
MFP-3a-44	50	14.523	45.059	30.537	-19.464
MFP-3a-47	50	14.487	50.529	36.042	-13.958
MFP-3a-14	125	24.891	120.761	95.870	-29.130
MFP-3a-41	50	14.463	48.508	34.045	-15.956
MFP-3a-23	30	11.480	41.291	29.812	-0.188
MFP-3a-43	50	14.440	47.230	32.789	-17.211
MFP-3a-22	30	11.535	41.310	29.775	-0.225
MFP-3a-31	250	38.100	300.466	262.366	12.366
MFP-3a-51	Heel	208.8	815.0	606.2	-
Total	1,701	-	-	1,693	-8

Table 4. Samples Taken during HLW-High Bound Test

Samples	Target (grams)	Tare (grams)	Full (grams)	Sample Weight (grams)	Delta (grams)
MFP-4a-44	50	14.529	68.217	53.689	3.6889
MFP-4a-48	50	14.533	63.152	48.619	-1.381
MFP-4a-13	125	25.165	151.645	126.480	1.480
MFP-4a-12	125	24.840	152.691	127.851	2.851
MFP-4a-22	30	11.566	41.994	30.427	0.427
MFP-4a-45	50	14.527	67.238	52.711	2.711
MFP-4a-23	30	11.579	43.782	32.203	2.203
MFP-4a-24	30	11.612	42.728	31.116	1.116
MFP-4a-41	50	14.489	65.762	51.273	1.273
MFP-4a-14	125	24.973	149.619	124.646	-0.354
MFP-4a-43	50	14.527	64.597	50.070	0.070
MFP-4a-11	125	25.052	155.513	130.461	5.461
MFP-4a-21	30	11.634	42.163	30.529	0.529
MFP-4a-47	50	14.474	65.559	51.085	1.085
MFP-4a-46	50	14.473	65.980	51.507	1.507
MFP-4a-31	250	37.894	289.904	252.010	2.010
MFP-4a-42	50	14.511	65.132	50.621	0.621
MFP-4a-51	Heel	207.8	584.7	376.9	-
Total	1,702	-	-	1,672.198	-30

Table 5. Samples Taken during HLW-High Bound Test Repeat

Samples	Target (grams)	Tare (grams)	Full (grams)	Sample Weight (Grams)	Delta (grams)
MFP-4b-44	50	14.463	37.122	22.659	-27.341
MFP-4b-48	50	14.543	68.539	53.996	3.996
MFP-4b-13	125	24.943	150.182	125.239	0.239
MFP-4b-12	125	25.077	150.097	125.020	0.020
MFP-4b-22	30	11.594	47.925	36.331	6.331
MFP-4b-45	50	14.506	66.794	52.288	2.288
MFP-4b-23	30	11.660	46.692	35.032	5.032
MFP-4b-24	30	11.619	47.007	35.389	5.389
MFP-4b-41	50	14.522	59.144	44.622	-5.378
MFP-4b-14	125	24.896	153.779	128.883	3.883
MFP-4b-43	50	14.514	67.773	53.259	3.259
MFP-4b-11	125	25.001	150.568	125.567	0.567
MFP-4b-21	30	11.623	48.725	37.102	7.102
MFP-4b-47	50	14.512	69.740	55.228	5.228
MFP-4b-46	50	14.581	62.336	47.755	-2.245
MFP-4b-31	250	37.850	285.717	247.867	-2.133
MFP-4b-42	50	14.508	73.0767	58.569	8.569
MFP-4b-51	Heel	206.7	543.4	336.7	-
Total	1,702	-	-	1,621	-80

2.3 Glass Fabrication Results

2.3.1 Glass Melt Observations:

Photographs of each of the as-fabricated glasses are shown in Figure 4 through Figure 6. All of the HLW-HB and HLW-LB glasses were black and shiny and appeared to be homogenous throughout with the unaided eye. Yellow spots were observed on the crucible wall of samples MFP-3a-41, MFP-3a-46, and MFP-3a-48, which is indicative of sulfur volatility. The LAW-LB glasses were amber in color and transparent, except for MFP-1a-48, which was much darker. Isolated regions of cloudiness were also observed in the LAW-LB glasses that could be related to insufficient homogenization during melting.

Note the LAW-HB glass fabrication results are not shown in any of the pictures. This particular simulant was intended to be a medium-rheology material for glass fabrication mixing and sampling testing. The chemistry of this simulant is 3 molar (M) sodium (Na), which is not conducive to making glass, primarily because of low Na_2O as well as boron B_2O_3 content. The LAW-HB GFCs were originally formulated for use with a 10.5 molar (M) sodium (Na) LAW simulant and therefore not suited to conversion to glass in these studies. This was confirmed during some of the scoping studies when the LAW-HB simulant did not fully melt after an isothermal hold at 1,150 degrees Celsius for one hour, nor after a subsequent isothermal hold at 1,300 degrees Celsius for an additional one hour.

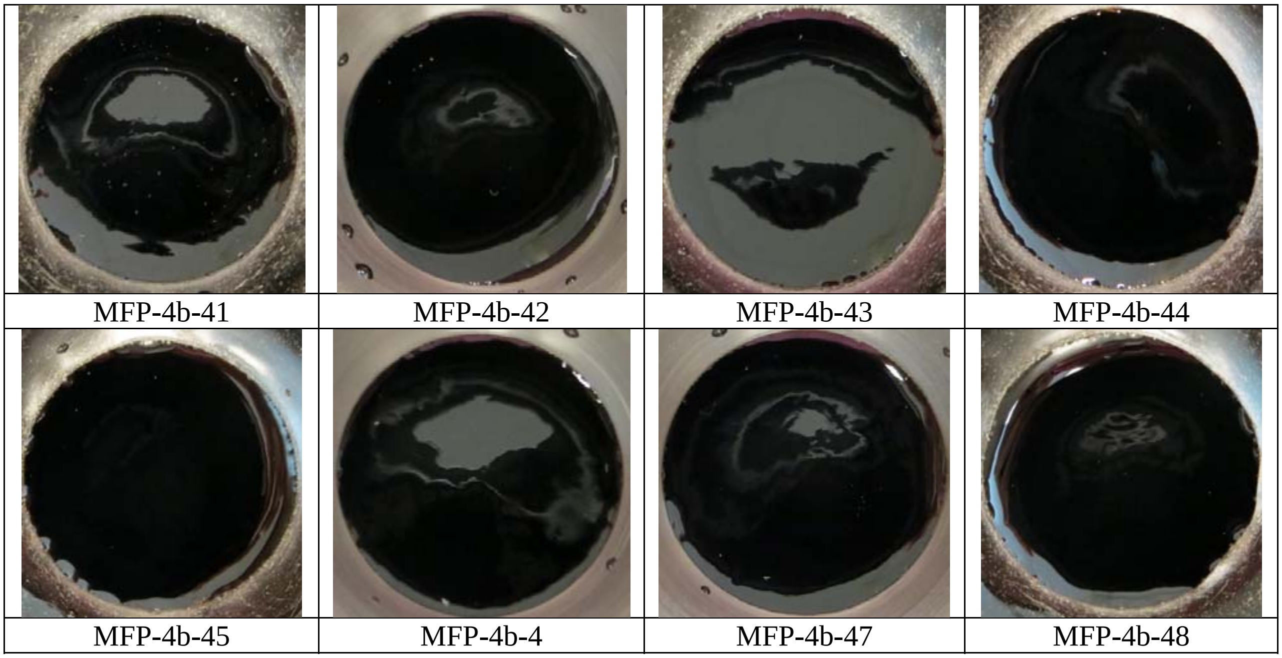


Figure 4. Photographs of the as-fabricated HLW-HB glasses.

Note: Any pink coloration is due to the reflection off of the laboratory coat.

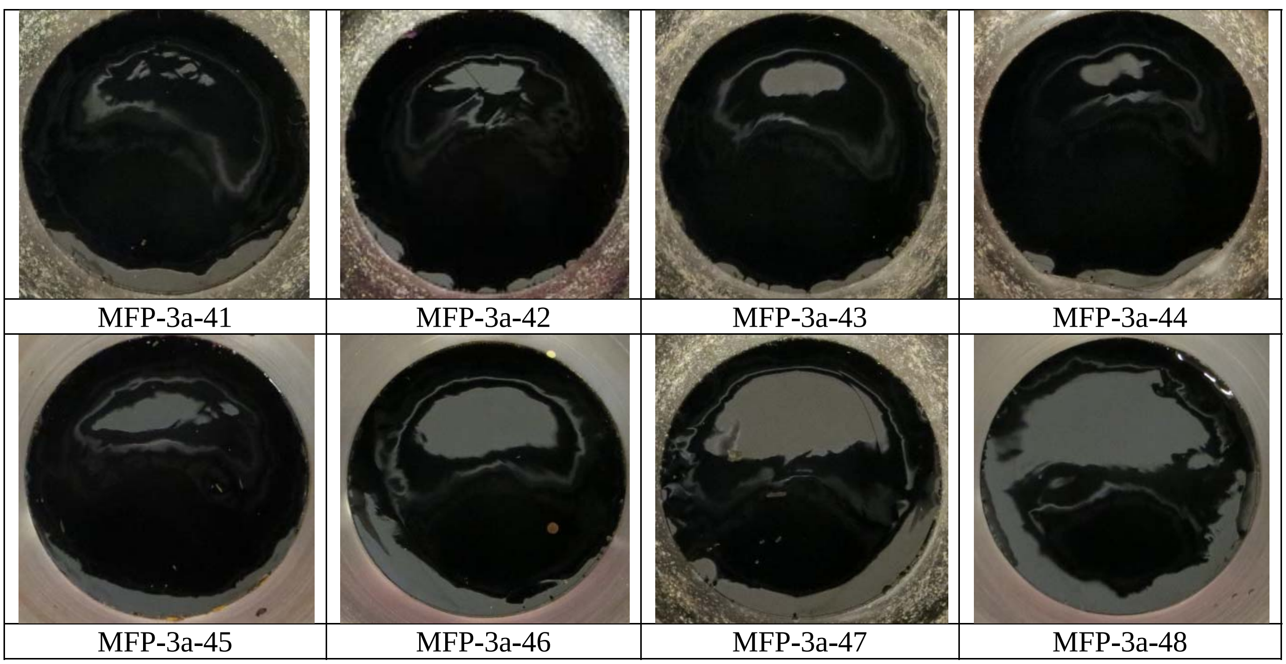


Figure 5. Photographs of the as-fabricated HLW-LB glasses.

Note: Any pink coloration is due to the reflection off of the laboratory coat.

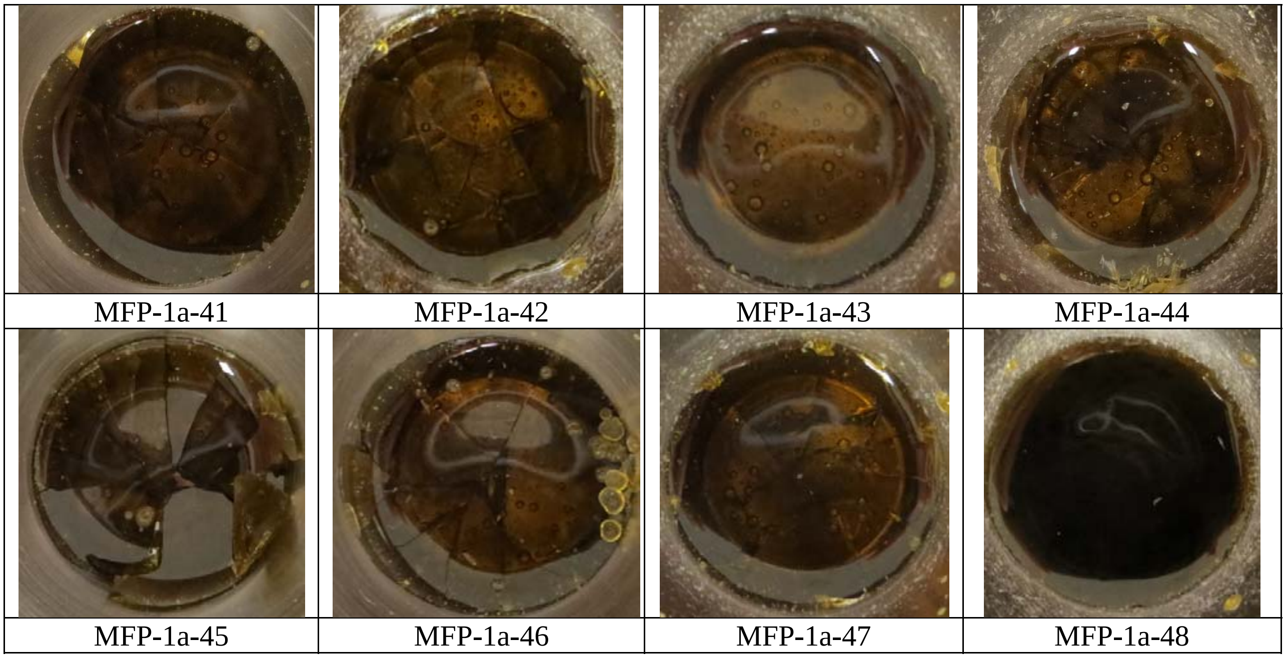


Figure 6. Photographs of the as-fabricated LAW-LB glasses.

2.3.2 Glass Fabrication Results

As is evident in the photographs of HLW-LB, HLW-HB, and LAW-LB, all of the glasses produced from the melted compositions are visually free of unmelted material and crystallization. The demonstrated techniques used for converting HLW and LAW melter feeds to glass product were successful and could be easily translated for glass fabrication in a shielded cells environment for the waste feed qualification process as shown in Appendix D. Although the one hour isothermal hold time was adequate to prepare glass that was free of unreacted feed and contained no crystallization, it is possible that longer durations could have resulted in a more uniform glass composition for feeds that had a low yield stress. Since the melter feeds were not mixed during the drying process, some segregation of certain melter feed components could have occurred due to settling, which would have been exacerbated in the melter feeds exhibiting a low yield stress (as indicated by the rheology results of the LAW-LB melter feed). Periodically mixing the melter feed during drying would also improve homogenization.

2.4 Melter Feed Slurry and Glass Analytical Results

The melter feed slurries and fabricated glass coupons were analyzed for elemental composition. Three glass standards (WCP Batch 1[16], ARG-1[14], and LRM[15]) were included with each analytical block of glasses only. Melter feed slurries were also analyzed for anions concentrations, solids content, density, and rheological properties. All measured data is provided in Appendix C. Elemental results were converted to oxides on a weight percent basis using the gravimetric factors shown in Table 6.[C] A statistical evaluation of the results is further discussed in Section 2.5.

[C] The oxide values for copper used CuO for the references glasses and Cu_2O for the melter feed slurries and glasses.

Table 6. Gravimetric Factors for Conversion of Elemental to Oxide Compositions

Oxide	Gravimetric Factor
Al_2O_3	1.89
B_2O_3	3.22
CaO	1.40
Cr_2O_3	1.46
CuO	1.25
Cu_2O	1.13
Fe_2O_3	1.43
K_2O	1.20
Li_2O	2.15
MgO	1.66
Na_2O	1.35
NiO	1.27
P_2O_5	2.29
PbO	1.08
SO_4	3.0
SiO_2	2.14
TiO_2	1.67
ZnO	1.24
ZrO_2	1.35

2.4.1 Evaluation of the Analytical Results of the Glass Standards

Table 7 through Table 9 show comparisons of the published values of the WCP Batch 1[16], ARG-1[14], and LRM[15] glass standards to the measured values. A percent (%) difference between the measured and published value greater than 10% is shown in red.

Table 7. Comparison of the Published and Measured Batch-1 Standard Glass Results

Analytical Block		Oxide	Al_2O_3	B_2O_3	CaO	Cr_2O_3	CuO	Fe_2O_3
		Published Value	***4.88***	***7.78***	***1.22***	***0.11***	***0.40***	***12.84***
LAW-LB	**MFP-1a**	Average	4.91	8.31	1.16	0.10	0.38	12.45
		% Difference	0.5	6.8	-5.0	-12.9	-4.0	-3.0
		wt% Difference	0.03	0.53	-0.06	-0.01	-0.02	-0.39
HLW-HB	**MFP-4b**	Average	4.63	7.96	1.12	0.09	0.38	12.46
		% Difference	-5.0	2.4	-8.0	-14.1	-6.1	-2.9
		wt% Difference	-0.2	0.2	-0.1	0.0	0.0	-0.4
HLW-LB	**MFP-3a**	Average	4.87	8.61	1.20	0.09	0.37	12.38
		% Difference	-0.2	10.6	-1.7	-14.7	-6.4	-3.6
		wt% Difference	-0.01	0.83	-0.02	-0.02	-0.03	-0.46

Analytical Block		Oxide	K_2O	Li_2O	MgO	Na_2O	NiO	SiO_2
		Published Value	***3.33***	***4.43***	***1.42***	***9.00***	***0.75***	***50.20***
LAW-LB	**MFP-1a**	Average	3.46	4.48	1.33	8.73	0.69	50.2
		% Difference	3.9	1.2	-6.3	-3.0	-7.4	0.1
		wt% Difference	0.13	0.05	-0.09	-0.27	-0.06	0.0
HLW-HB	**MFP-4b**	Average	3.36	4.38	1.31	8.99	---	50.0
		% Difference	1.0	-1.1	-7.9	-0.1	---	-0.3
		wt% Difference	0.0	-0.1	-0.1	0.0	---	-0.2
HLW-LB	**MFP-3a**	Average	3.34	4.64	1.30	8.67	0.68	49.1
		% Difference	0.4	4.7	-8.1	-3.6	-9.0	-2.1
		wt% Difference	0.01	0.21	-0.12	-0.33	-0.07	-1.05

Analytical Block		Oxide	TiO_2	ZrO_2
		Published Value	**0.68**	***0.10***
LAW-LB	**MFP-1a**	Average	0.64	0.09
		% Difference	-5.3	-8.8
		wt% Difference	-0.04	-0.01
HLW-HB	**MFP-4b**	Average	0.63	0.09
		% Difference	-7.3	-14.1
		wt% Difference	0.0	0.0
HLW-LB	**MFP-3a**	Average	0.63	0.05
		% Difference	-7.3	-49.8
		wt% Difference	-0.05	-0.05

Table 8. Comparison of the Published and Measured ARG-1 Glass Standard Results

Analytical Block		Oxide	Al_2O_3	B_2O_3	CaO	Cr_2O_3	CuO	Fe_2O_3
		Published Value	***4.73***	***8.67***	***1.43***	***0.093***	***0.004***	***14.0***
LAW-LB	**MFP-1a**	Average	4.89	9.28	1.38	0.09	<0.01	13.53
		% Difference	3.4	7.1	-3.7	-1.8	---	-3.3
		wt% Difference	0.16	0.61	-0.05	0.00	---	-0.47
HLW-HB	**MFP-4b**	Average	4.53	8.77	1.34	0.09	<0.01	13.46
		% Difference	-4.2	1.2	-6.0	-3.5	---	-3.8
		wt% Difference	-0.20	0.10	-0.09	0.00	---	-0.54
HLW-LB	**MFP-3a**	Average	4.84	9.48	1.41	0.09	<0.01	13.50
		% Difference	2.2	9.4	-1.3	-5.1	---	-3.6
		wt% Difference	0.11	0.81	-0.02	0.00	---	-0.50

Analytical Block		Oxide	K_2O	Li_2O	MgO	Na_2O	NiO	P_2O_5
		Published Value	***2.71***	***3.21***	***0.86***	***11.5***	***1.05***	***0.22***
LAW-LB	**MFP-1a**	Average	2.77	3.20	0.84	11.29	0.97	0.25
		% Difference	2.3	-0.4	-2.7	-1.9	-7.7	13.4
		wt% Difference	0.06	-0.01	-0.02	-0.21	-0.08	0.03
HLW-HB	**MFP-4b**	Average	2.68	3.03	0.81	11.66	---	0.24
		% Difference	-1.2	-5.5	-5.5	1.4	---	8.4
		wt% Difference	-0.03	-0.18	-0.05	0.16	---	0.02
HLW-LB	**MFP-3a**	Average	2.71	3.34	0.81	11.15	0.95	0.24
		% Difference	0.1	4.2	-5.8	-3.1	-9.4	9.3
		wt% Difference	0.00	0.13	-0.05	-0.35	-0.10	0.02

Analytical Block		Oxide	SiO_2	TiO_2	ZnO	ZrO_2
		Published Value	***47.9***	***1.15***	***0.02***	***0.13***
LAW-LB	**MFP-1a**	Average	47.4	1.11	0.02	0.14
		% Difference	-1.0	-3.7	22.7	7.9
		wt% Difference	-0.5	-0.04	0.00	0.01
HLW-HB	**MFP-4b**	Average	47.1	1.07	0.03	0.13
		% Difference	-1.6	-6.6	25.9	3.0
		wt% Difference	-0.8	-0.08	0.01	0.00
HLW-LB	**MFP-3a**	Average	46.8	1.07	0.02	0.10
		% Difference	-2.3	-6.6	22.2	-25.6
		wt% Difference	-1.1	-0.08	0.00	-0.03

Table 9. Comparison of the Published and Measured LRM Glass Standard Results

Analytical Block		Oxide	Al_2O_3	B_2O_3	CaO	Cr_2O_3	Fe_2O_3	K_2O
		Published Value	**9.51**	**7.85**	**0.54**	**0.19**	**1.38**	**1.48**
LAW-LB	MFP-1a	Average	10.41	8.77	0.51	0.19	1.47	1.51
		% Difference	9.5	11.8	-6.4	-0.4	6.9	2.2
		wt% Difference	0.9	0.9	0.0	0.0	0.1	0.0
HLW-HB	MFP-4b	Average	10.23	8.24	0.47	0.19	1.41	1.44
		% Difference	7.6	5.0	-12.9	-1.6	2.4	-2.6
		wt% Difference	0.7	0.4	-0.1	0.0	0.0	0.0
HLW-LB	MFP-3a	Average	10.42	8.85	0.53	0.18	1.40	1.42
		% Difference	9.6	12.8	-1.4	-4.2	1.3	-3.8
		wt% Difference	0.91	1.00	-0.01	-0.01	0.02	-0.06

Analytical Block		Oxide	Li_2O	MgO	Na_2O	NiO	P_2O_5	PbO
		Published Value	**0.11**	**0.1**	**20.03**	**0.19**	**0.54**	**0.1**
LAW-LB	MFP-1a	Average	<0.22	0.10	21.5	0.18	0.45	0.09
		% Difference	---	-2.6	7.1	-6.6	-17.3	-7.0
		wt% Difference	---	0.0	1.4	0.0	-0.1	0.0
HLW-HB	MFP-4b	Average	<0.22	0.10	21.9	---	0.45	0.09
		% Difference	---	-2.3	9.4	---	-16.1	-9.3
		wt% Difference	---	0.0	1.9	---	-0.1	0.0
HLW-LB	MFP-3a	Average	<0.22	0.09	20.6	0.18	0.43	0.09
		% Difference	---	-6.4	2.8	-6.2	-19.7	-8.9
		wt% Difference	---	-0.01	0.6	-0.01	-0.11	-0.01

Analytical Block		Oxide	SO_3	SiO_2	TiO_2	ZrO_2
		Published Value	**0.3**	**54.2**	**0.1**	**0.93**
LAW-LB	MFP-1a	Average	0.21	54.6	0.10	0.90
		% Difference	-28.9	0.8	2.0	-3.6
		wt% Difference	-0.1	0.4	0.0	0.0
HLW-HB	MFP-4b	Average	0.21	53.9	0.10	0.89
		% Difference	-31.1	-0.6	-1.1	-4.1
		wt% Difference	-0.1	-0.3	0.0	0.0
HLW-LB	MFP-3a	Average	0.21	52.7	<0.17	0.83
		% Difference	-30.6	-2.7	---	-10.7
		wt% Difference	-0.09	-1.5	---	-0.10

In general, the measured concentrations of the major oxides (target concentrations greater than 0.5 weight percent) are less than 10% different from the published values. Some exceptions include:

- B_2O_3 - one measurement from the WCP Batch 1 standard (10.6%) and two measurements from the LRM standard (11.8% and 12.8%)
- CaO – one measurement from the LRM standard (-12.9%)
- P_2O_5 – all three measurements from the LRM standard (-17.3%, -16.1%, and -19.7%)
- ZrO_2 – one measurement from the LRM standard (-10.7%)

The B_2O_3 measurements for all three standards are biased high, which suggests that the values for the glass samples could also be high as compared to the target values. While there are also differences (> 10%) noted for CaO, P_2O_5, and ZrO_2 in the LRM standard, the trends are not consistent with the results for the other standards and should not impact the results of the sample glasses. Differences greater than 10% are also observed for some of the oxide components with target concentrations less than 0.5 weight percent; however, the corresponding differences on an oxide weight percent basis are generally less than or equal to 0.1 weight percent, which are not expected to have any impact on the conclusions of this study.

2.4.2 Melter Feed Slurry Results

A comparison of the target[D] and measured compositions are shown in Table 10 through Table 14 using averages of the eight replicates samples. Results from each of the replicates is shown in Appendix C. Given the scope of the task was to show that the mixing/sampling apparatus and glass fabrication methods could handle a range of rheological properties and simulant types, it was important to have simulants with the particle size that was specified in the development recipes.[9] The new HLW-HB simulant was prepared using chemicals available at SRNL, which were procured for the earlier developmental work. The target composition was identical to the composition specified by WTP. The rheological properties of the SRNL prepared HLW waste simulant met the rheological property targets, although some differences in the measured composition versus the targets were noted. The measured compositions of the simulants were used to calculate the target compositions of the melter feed slurries after addition of the GFCs.

[D] Target values were calculated from the measured simulant composition.

Table 10. Averaged Results from LAW-Low Bound Feed Preparation (weight percent oxide basis)

MFP-1a LAW Low Bound Compositions		Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	P_2O_5	SO_3	SiO_2	TiO_2	ZnO	ZrO_2
Simulant	Target	10.78	---	---	---	15.55	---	71.76	0.41	1.39	0.12	---	---	---
	Measured by vendor	6.32	---	0.01	---	15.38	---	78.14	---	---	0.13	---	0.01	---
	Measured by SRNL	6.06	---	LTD	---	15.79	---	75.97	0.6	1.58	LTD	---	---	---
GFCs	Target	5.9	12.96	2.38	7.15	---	2.33	---	---	---	58.3	2.76	3.94	4.0
	Target*	**5.95**	**9.66**	**1.77**	**5.33**	**4.05**	**1.74**	**19.51**	**0.15**	**0.41**	**43.45**	**2.06**	**2.94**	**2.98**
Melter Feed	Measured	5.43	9.61	1.91	4.64	3.90	1.22	19.36	LTD	0.40	44.14	1.76	2.93	2.53
Glass	Measured	6.13	11.65	1.98	3.79	4.27	0.75	20.8	LTD	0.37	43.7	1.69	3.02	2.60

*Target composition based on measured simulant composition and target GFCs composition. LTD = Less than detectable

Table 11. Averaged Results from LAW-High Bound Feed Preparation (weight percent oxide basis)

MFP-2a LAW High Bound Compositions		Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	P_2O_5	SO_3	SiO_2	TiO_2	ZnO	ZrO_2
Simulant	Target	10.78	---	---	---	15.55	---	71.76	0.41	1.39	0.12	---	---	---
	Measured by vendor	6.32	---	0.01	---	15.38	---	78.14	---	---	0.13	---	0.01	---
	Measured by SRNL	6.06	---	LTD	---	15.79	---	75.97	0.6	1.58	LTD	---	---	---
GFCs	Target	6.6	2.58	3.0	8.0	---	2.61	---	---	---	65.23	3.09	4.41	4.48
	Target*	**6.57**	**2.41**	**2.81**	**7.79**	**1.01**	**2.44**	**4.88**	**0.04**	**0.1**	**61.04**	**2.89**	**4.13**	**4.19**
Melter Feed	Measured	6.10	3.04	2.67	7.81	1.18	1.85	4.45	0.00	0.00	62.49	2.88	4.22	4.06

*Target composition based on measured simulant composition and target GFCs composition. LTD = Less than detectable

Table 12. Averaged Results from HLW-Low Bound Feed Preparation (weight percent oxide basis)

MFP-3a HLW Low Bound Compositions		Al_2O_3	B_2O_3	Fe_2O_3	K_2O	Li_2O	Na_2O	P_2O_5	SO_3	SiO_2	ZnO	ZrO_2
Simulant	Target	27.72	0.03	42.5	0.260	---	11.2	1.12	0.22	4.10	---	12.91
	Measured by SRNL	24.74	LTD	41.82	0.47	LTD	10.70	1.75	0.60	4.37	LTD	11.11
GFCs	Target	---	15.37	---	---	5.57	12.45	---	---	63.68	2.93	---
Target*		**7.27**	**11.05**	**12.29**	**0.14**	**4.01**	**12.10**	**0.51**	**0.18**	**47.07**	**2.11**	**3.27**
Melter Feed	Measured	8.2	10.8	12.50	0.2	3.7	12.4	0.4	LTD	48.1	2.0	3.4
Glass	Measured	8.60	11.31	12.39	0.14	4.19	10.82	0.38	0.15	45.4	1.95	3.80

*Target composition based on measured simulant composition and target GFCs composition. LTD = Less than detectable

Table 13. Averaged Results from HLW-High Bound Feed Preparation (weight percent oxide basis)

MFP-4a HLW High Bound Compositions		Al_2O_3	B_2O_3	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	P_2O_5	SO_3	SiO_2	ZnO	ZrO_2
Simulant	Target	30.5	0.01	46.8	0.080	---	---	3.49	0.350	0.07	4.5	---	14.2
	Measured by SRNL	32.15	LTD	37.13	0.41	LTD	0.55	3.82	0.66	LTD	10.52	LTD	12.34
GFCs	Target	---	15.37	---	---	5.57	---	12.45	---	---	63.68	2.93	---
Target*		**10.00**	**10.68**	**11.54**	**0.13**	**3.87**	**0.17**	**9.84**	**0.21**	**0.00**	**47.50**	**2.04**	**3.84**
Melter Feed	Measured	9.04	10.8	12.77	0.0	3.7	0.0	10.4	0.0	0.0	48.5	1.9	3.5

*Target composition based on measured simulant composition and target GFCs composition. LTD = Less than detectable

Table 14. Averaged Results from HLW-High Bound Feed Preparation Repeat (weight percent oxide basis)

MFP-4b HLW High Bound Compositions		Al_2O_3	B_2O_3	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	P_2O_5	SO_3	SiO_2	ZnO	ZrO_2
Simulant	Target	30.5	0.01	46.8	0.080	---	---	3.49	0.350	0.07	4.5	---	14.2
	Measured by SRNL	32.15	LTD	37.13	0.41	LTD	0.55	3.82	0.66	LTD	10.52	LTD	12.34
GFCs	Target	---	15.37	---	---	5.57	---	12.45	---	---	63.68	2.93	---
Target*		**10.00**	**10.68**	**11.54**	**0.13**	**3.87**	**0.17**	**9.84**	**0.21**	**0.00**	**47.50**	**2.04**	**3.84**
Melter Feed	Measured	9.12	11.56	11.00	0.15	3.79	0.00	9.75	0.00	0.00	47.26	1.99	3.66
Glass	Measured	9.58	11.23	10.68	0.12	3.79	0.17	9.91	LTD	0.06	47.2	1.95	3.75

*Target composition based on measured simulant composition and target GFCs composition. LTD = Less than detectable

2.5 Statistical Evaluation of Results

The analysis of the data from the testing included determination of the standard deviation, relative standard deviation, data range, and a statistical review of the data to determine if the mixing and sampling performed resulted in representative samples from the prepared melter feed. The analysis was performed using JMP Pro Version 11.2.1[26] and includes evaluation of both the melter feed slurry and glass analysis.

The following items apply to the statistical discussions:

1) The sample preparation and analysis error is included in the standard deviation and other statistical regressions.
2) The data should be taken in aggregate and evaluation of selected species should be performed with the overall analysis taken into account.
3) The evaluation of the sample analysis accuracy shows the ability of the laboratory sample analysis methods to measure the sample solutions after all sample preparation is complete. Therefore, the error in this analysis is typically significantly less than the overall sample error. However, this does not mean that the remainder of the error is attributed to the mixing and sampling as errors of the sample preparation process are not included in the sample method error determined.
4) Errors for minor species are frequently much higher than for major components. Elements with concentrations less than 2 weight percent on an oxide basis can show significant scatter. These elements were not included in evaluations to determine adequacy of mixing and sampling.

2.5.1 LAW-Low Bound Chemical Composition Results

The major oxide components in the LAW-LB tests were Al_2O_3, B_2O_3, Fe_2O_3, K_2O, Na_2O, SiO_2, TiO_2, ZnO, and ZrO_2. Sample results were generally consistent and most results for a given oxide were within 10% of the average value as shown in Figure 7 through Figure 15. Note that results are not shown in the order sampled. All other oxide component charts are shown in the Appendix E. The consistency of the results indicated good mixing and representative sampling, but selected species (B, Fe, Ti, and Zr) indicated an offset from the target value calculated from the measured simulant composition and GFC additions and iron exhibited more scatter in the data than others species.

2.5.1.1 High Offset from Targeted Value

The four oxides that deviated from the targeted composition during the LAW-LB testing were B_2O_3, Fe_2O_3, TiO_2, and ZrO_2. Fe_2O_3 shows the most significant deviation with the glass samples with an offset by almost 30%.

The average measured value for B_2O_3 in the glass was not within 20% of the targeted value as shown in Figure 8. Issues with the analysis of B_2O_3 were noted with the glass standards as well as with samples of the GFC material and LAW-HB sample set, so the difference with B_2O_3 is likely due to laboratory analysis rather than mixing or sampling issues.

Results for Fe_2O_3 in the glass were 29% below the target value as shown in Figure 9, but melter feed slurry results did not mirror this result with the average only 13% below average. The measured Fe_2O_3 values for samples MFP-1a-48 and MFP-1a-23 are significantly different from the other samples in the data set, as shown in Figure 9 for MFP-1a-48. Sample MFP-1a-23 was the first sample taken while MFP-1a-48 was the fourth sample taken from the bottle and the samples on either side do not show the same aberrant results. It is not certain whether the outlying results are the results of errors that occurred during sampling, glass preparation, or during sample analysis.

The other oxide components that were consistently more than 10% below target in the glass samples were TiO_2 and ZrO_2, as shown in Figure 13 and Figure 15. The heel in the melter feed preparation vessel remaining after all the samples were collected was also submitted to the lab to determine if any species that settled faster were elevated in the heel. While the heel sample for Fe_2O_3 was slightly more than 10% above the average value, the heel samples for TiO_2 and ZrO_2 were not more than 10% higher than the average. These results indicate that the Fe_2O_3, TiO_2, and ZrO_2 were not excessively sampled in an unrepresentative manner during the tests as even a small error accumulated over the greater than 75% of the batch that was sampled prior to the heel would require a substantial difference in the heel to compensate. For example, if the samples collected were only 90% of the actual value, then the heel would be 33% over the targeted value to compensate. Since the heel sample is not above the target, then the error is not the result of improper mixing/sampling.

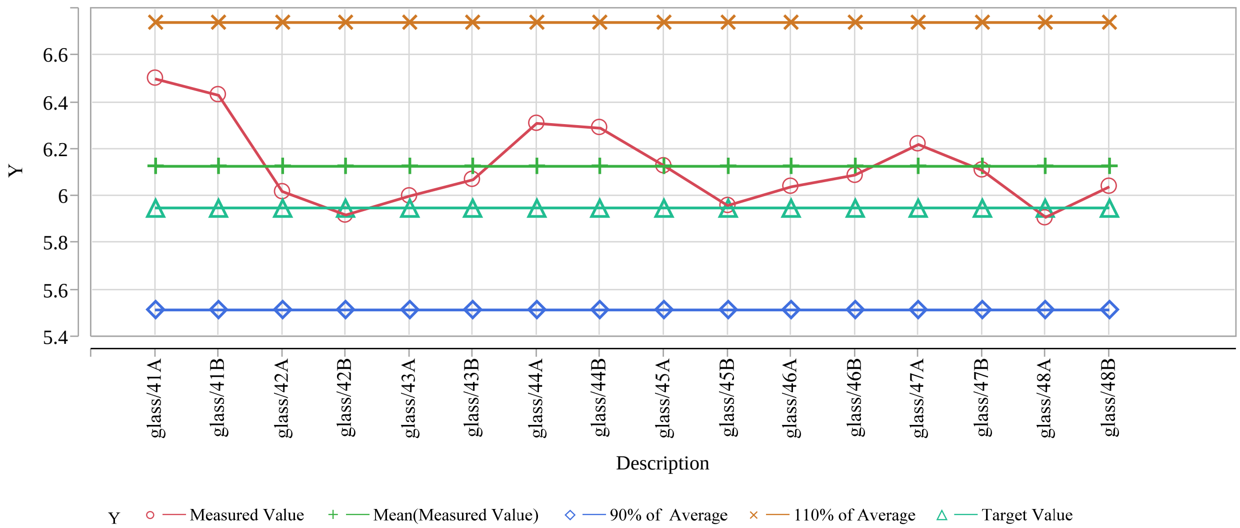


Figure 7. Al_2O_3 Results (weight percent oxide) for LAW-Low Bound Glass Samples

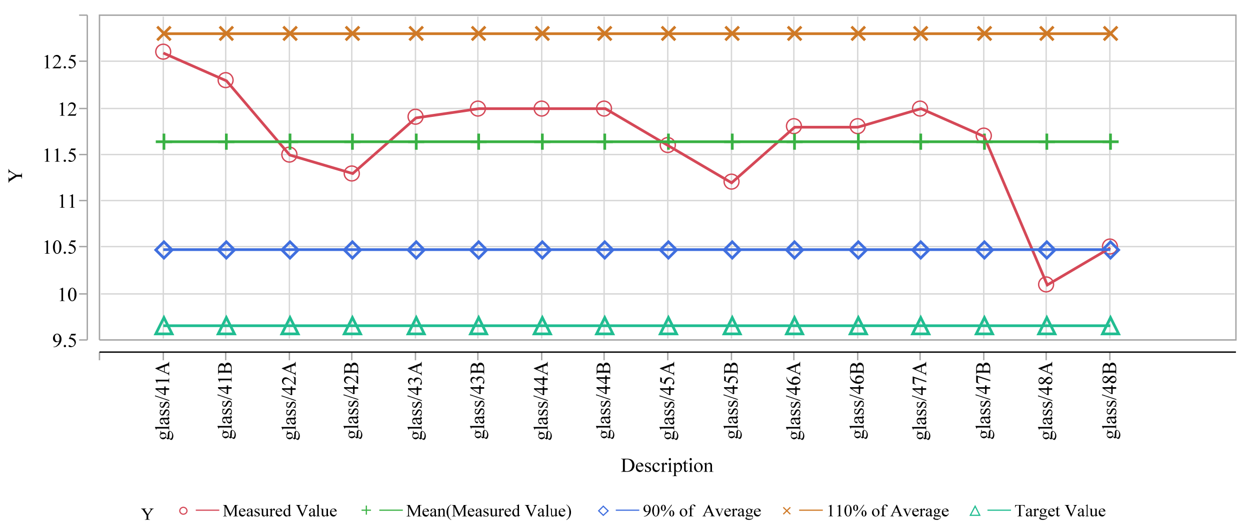


Figure 8. B_2O_3 Results (weight percent oxide) for LAW-Low Bound Glass Samples

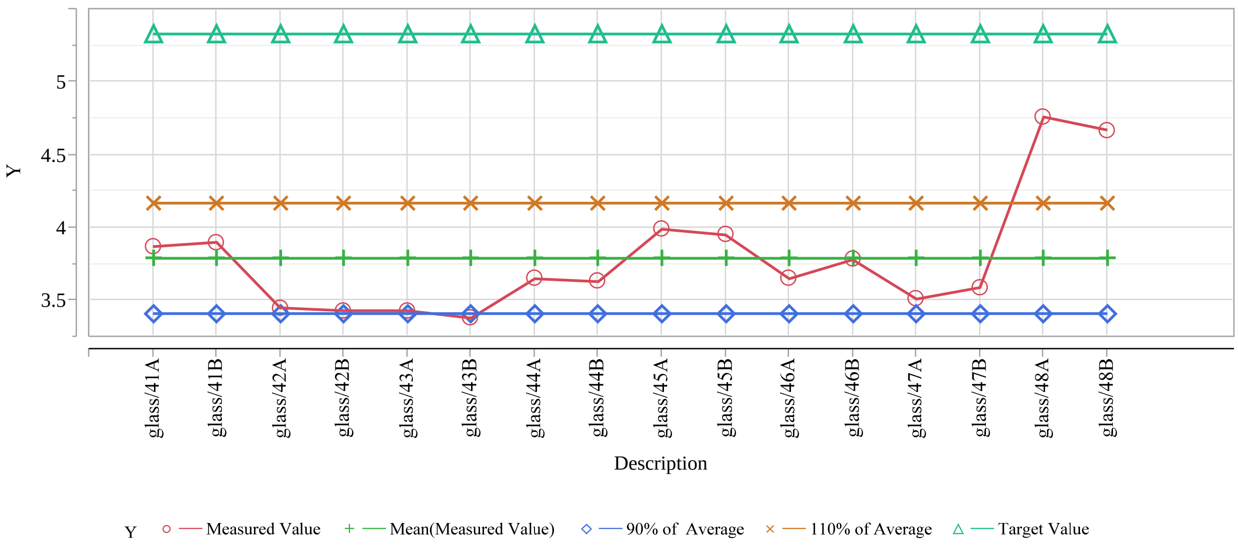


Figure 9. Fe_2O_3 Results (weight percent oxide) for LAW-Low Bound Glass Samples

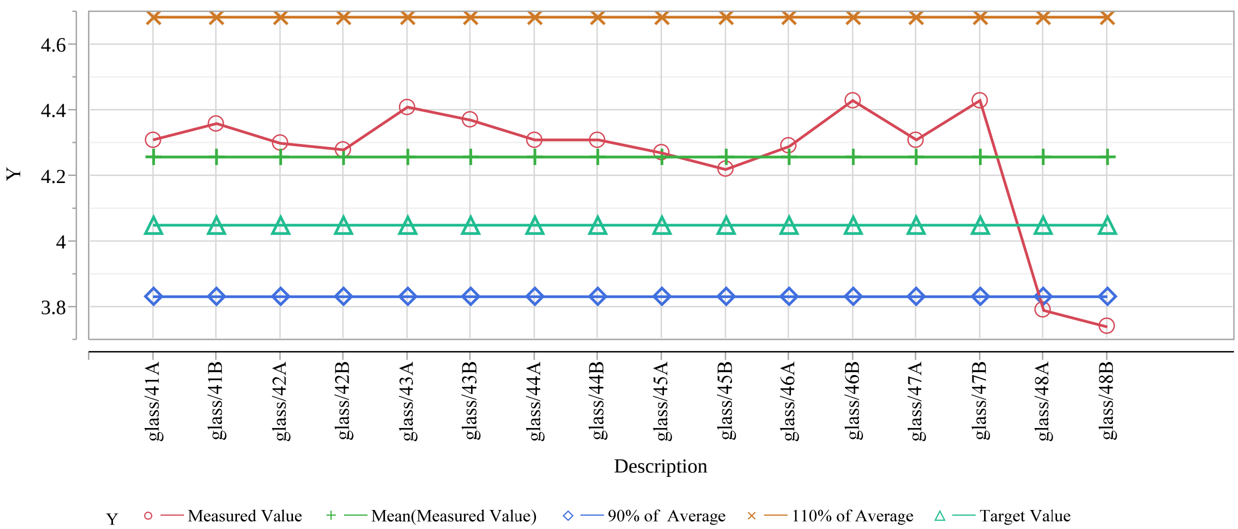


Figure 10. K_2O Results (weight percent oxide) for LAW-Low Bound Glass Samples

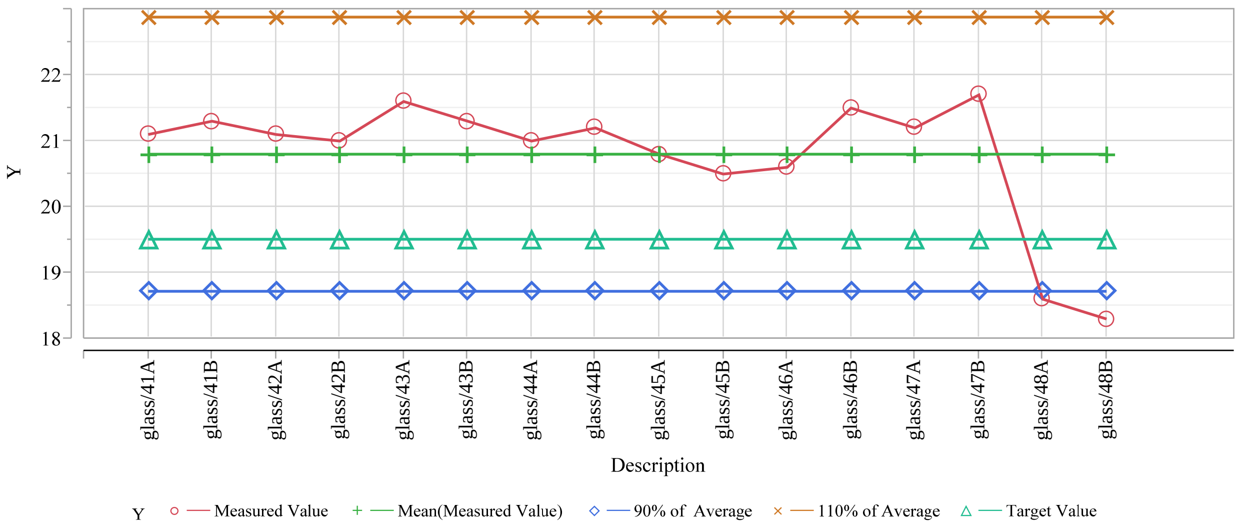


Figure 11. Na_2O Results (weight percent oxide) for LAW-Low Bound Glass Samples

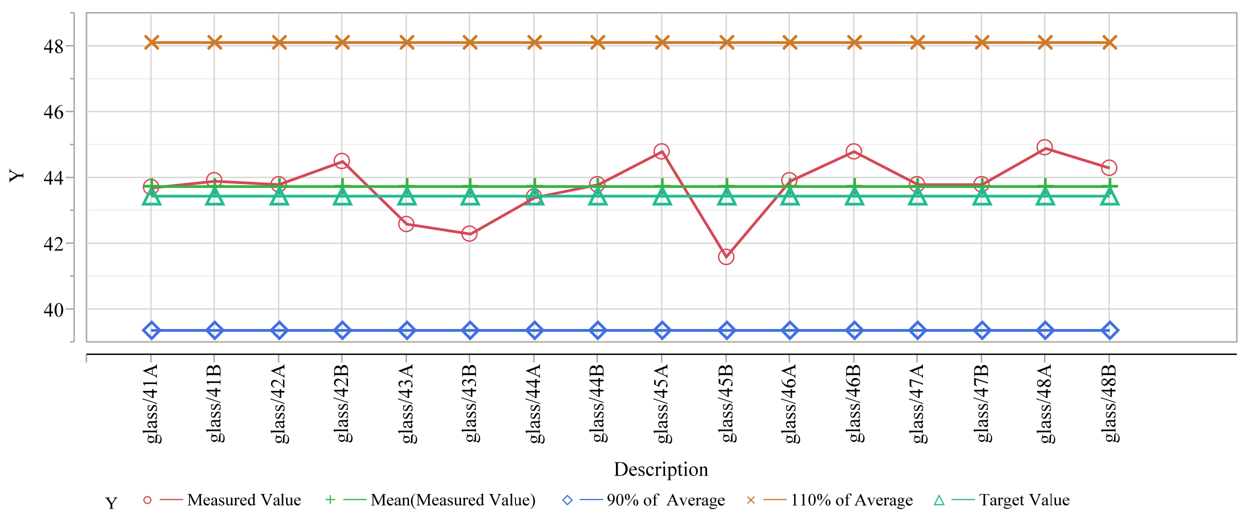


Figure 12. SiO_2 Results (weight percent oxide) for LAW-Low Bound Glass Samples

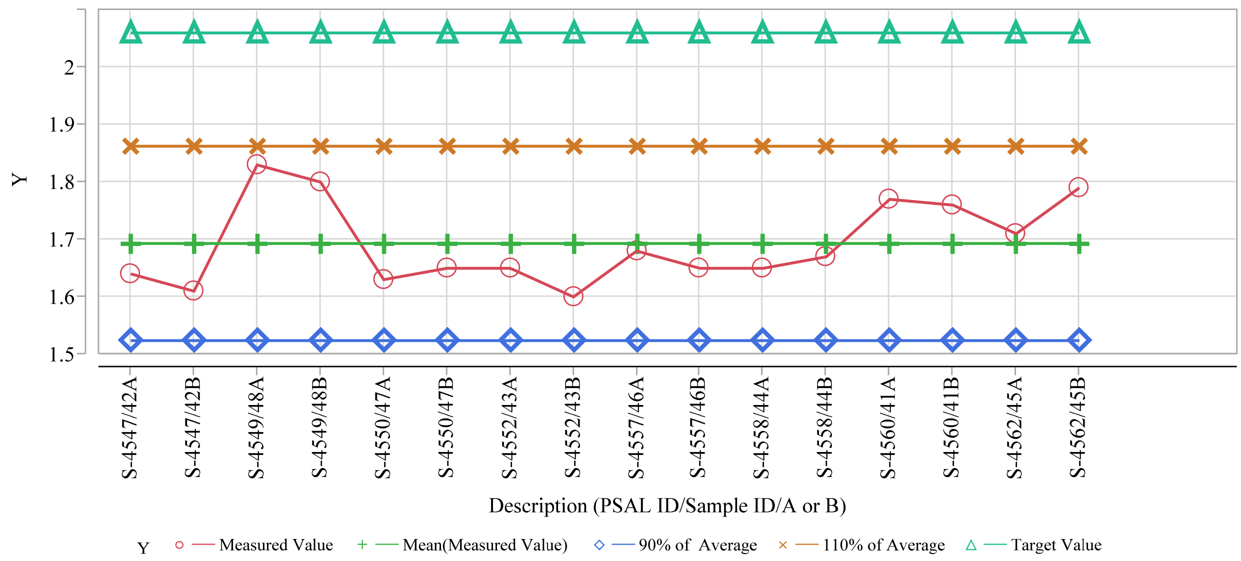


Figure 13. TiO_2 Results (weight percent oxide) for LAW-Low Bound Glass Samples

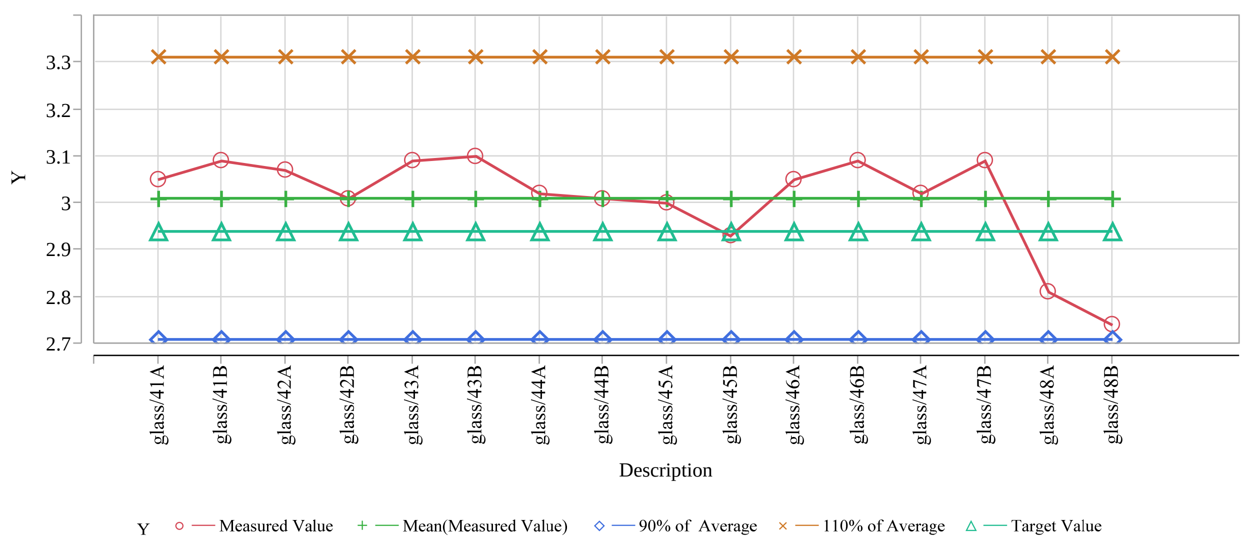


Figure 14. ZnO Results (weight percent oxide) for LAW-Low Bound Glass Samples

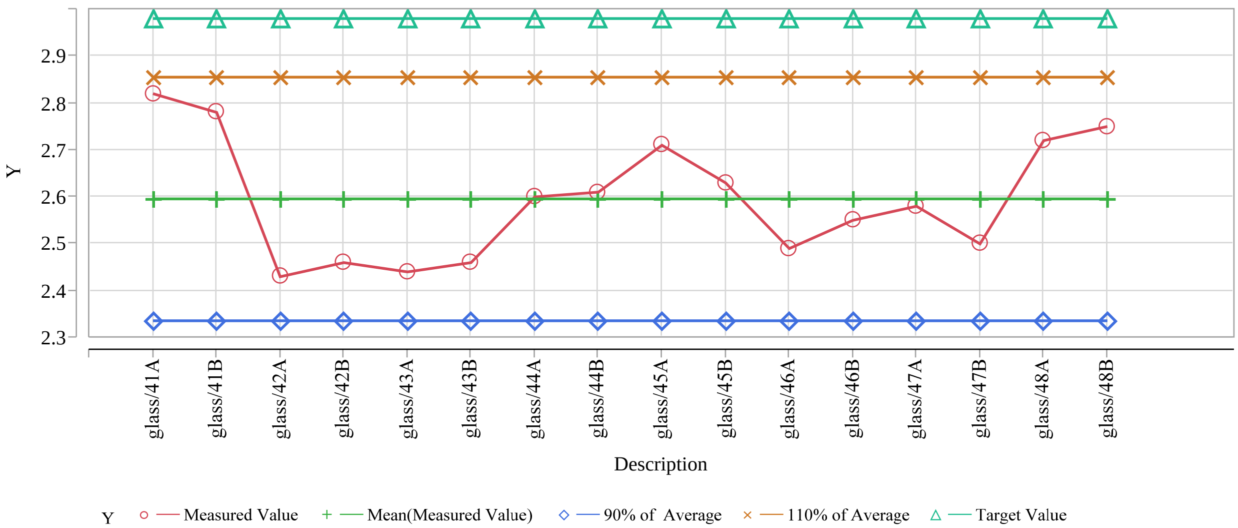


Figure 15. ZrO_2 Results (weight percent oxide) for LAW-Low Bound Glass Samples

2.5.1.2 Higher Scatter in Ferric Oxide Results

The melter feed Fe2O3 concentration had significantly more scatter than the other major species. When the melter feed slurry is plotted in order of sample taken as shown in Figure 16, it appears that the initial samples were lower in Fe_2O_3 than later samples. Given that the samples were taken near the bottom of the vessel, it is not certain that preferential settling of the Fe_2O_3 could have caused this type of result. The concentrations of ZrO_2 show a similar trend, but to a much lesser extent and selected species such as CaO and Na_2O show trends in the opposite direction. However, the other major oxides did not show a similar trend and none of the trends discussed above indicated significant R^2 values. The initial sample point from the test could be an outlier and without that sample point, the trend is much less apparent and the R^2 value for the trends is dramatically reduced, as shown in Figure 17. In addition, similar trends are not noted in the glass samples, as shown in Figure 18, therefore it is likely that the initial data (MFP-1a-23) is an outlier and that the apparent trend in the Fe_2O_3 data is not significant.

One other item of note is that the type of Fe_2O_3 used by the vendor did not match the particle size of the Fe_2O_3 specified in the GFC recipe. The ferric oxide specified was no longer commercially available. Therefore, ferric oxide with a larger particle size was substituted. The ferric oxide particle size impacts the settling rate of the iron (Fe) in the slurry as well as the rheological properties of the melter feed. The magnitude of these impacts was not evaluated as part of this study.

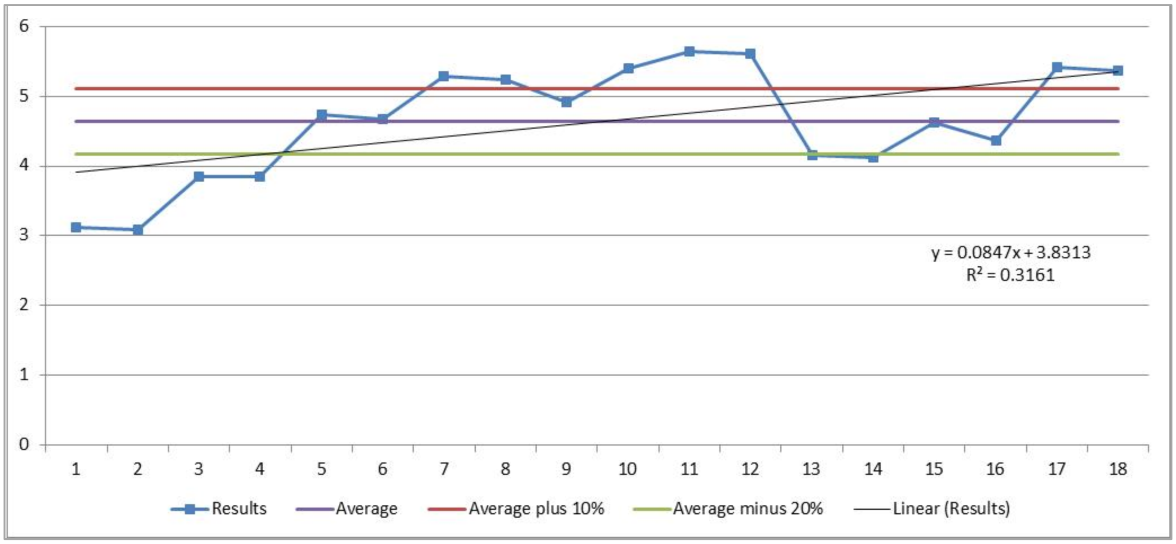


Figure 16. Fe_2O_3 Concentration in Order Sampled for MFP-1a Melter Feed Slurry

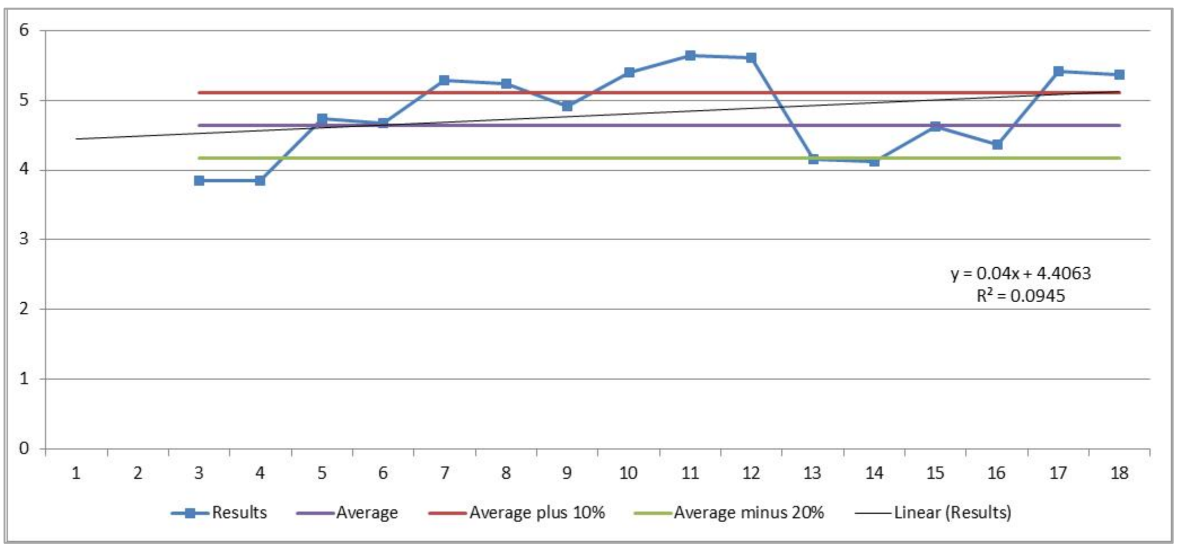


Figure 17. Fe_2O_3 Concentration in Order Sampled for MFP-1a Melter Feed Slurry with Initial Sample Removed

Figure 18. LAW-Low Bound Melter Feed and Glass Fe_2O_3 Results

2.5.2 LAW-High Bound Results

This simulant only underwent testing of the melter feed preparation process; it was not converted to glass. The major oxide components for this recipe included Al_2O_3, B_2O_3, CaO, Fe_2O_3, MgO, Na_2O, SiO_2, TiO_2, ZnO and ZrO_2. With the exception of B_2O_3 and MgO, the average result for all major oxides agreed with the target value within 10%. In addition to the overall agreement with the target values, the range of the measured values ((maximum-minimum)/average) were within 10% for all major oxides except B_2O_3 and MgO, as shown in Figure 19 through Figure 22 for selected species Issues with the analysis of B_2O_3 were discussed during the LAW-LB results in Section 2.5.1.

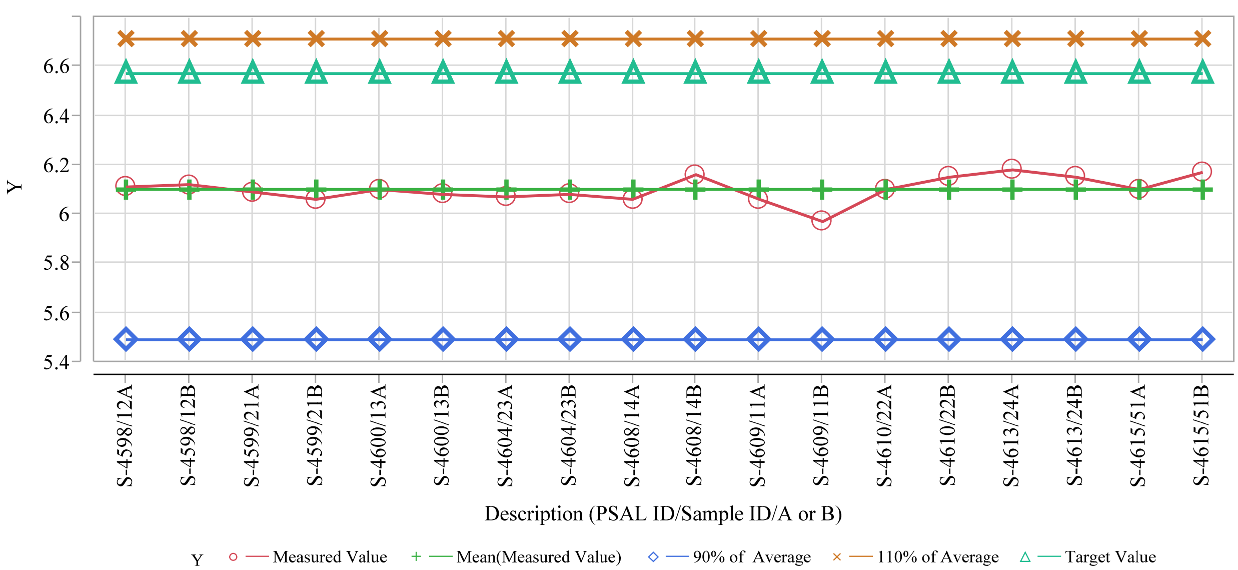


Figure 19. Al_2O_3 Results (weight percent oxide) for LAW-High Bound Melter Feed Samples

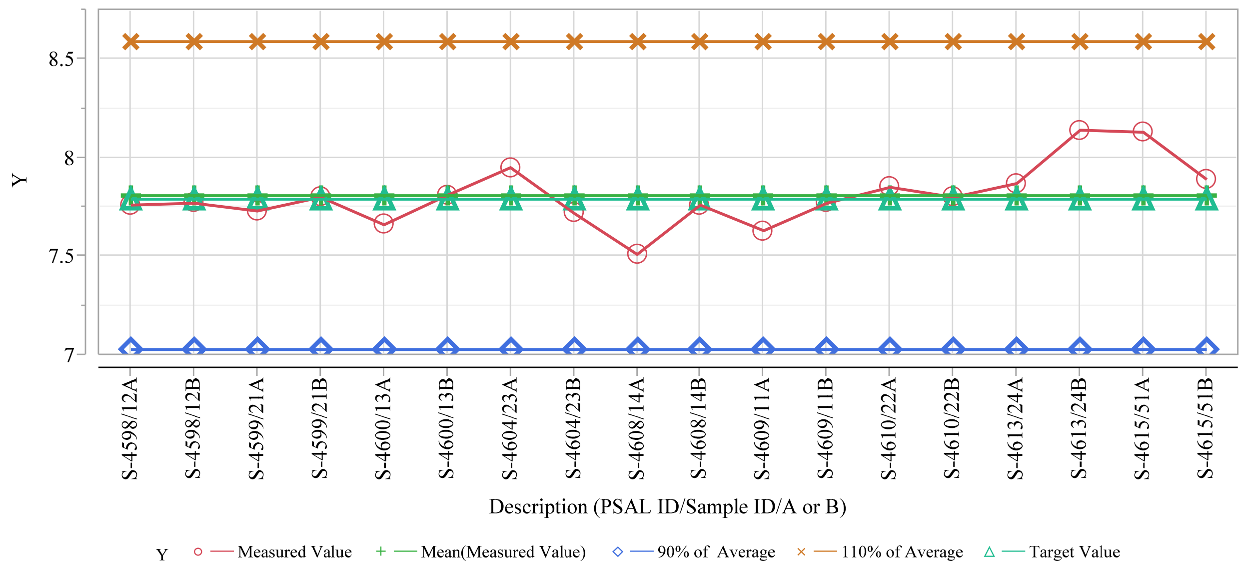


Figure 20. Fe_2O_3 Results (weight percent oxide) for LAW-High Bound Melter Feed Samples

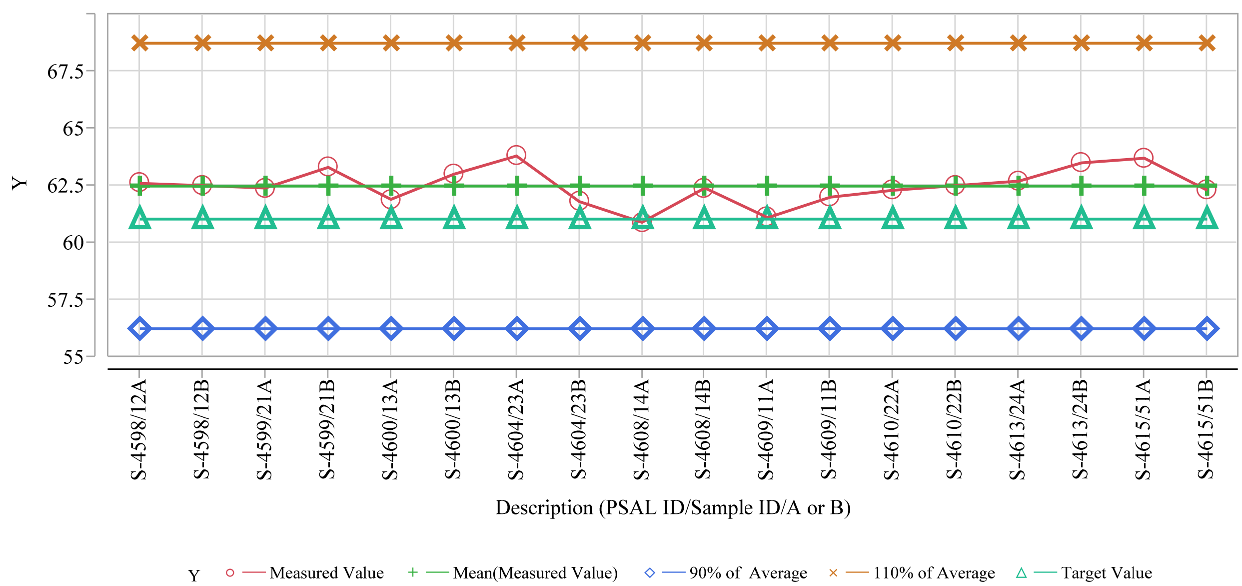


Figure 21. SiO_2 Results (weight percent oxide) for LAW-High Bound Melter Feed Samples

MgO in the melter feed was 17% below target and the range of the data was 28%, as shown in Figure 22. The greater scatter noted in the data did not follow a trend and appears to be the result of greater difficulty in sample analysis. MgO showed a large amount of variability in the LAW–LB data set as well. The low concentration of MgO in the slurry could be leading to the increased variability for this analyte.

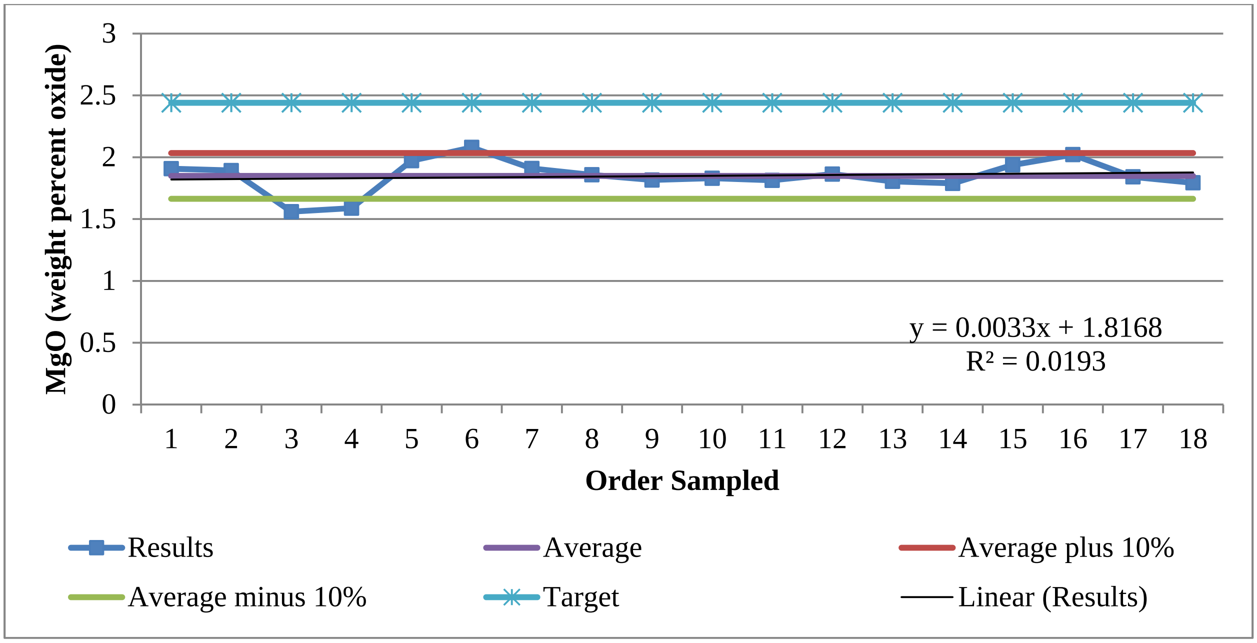


Figure 22. LAW-High Bound Melter Feed MgO Results (weight percent oxide)

2.5.3 HLW-Low Bound Results

The major oxide components present in the HLW-LB tests were Al_2O_3, B_2O_3, Fe_2O_3, Li_2O, Na_2O, SiO_2, ZnO, and ZrO_2. All major species for the HLW-LB tests were within 20% and most were within 10% of the target values, as shown in Figure 23 through Figure 26. Aluminum oxide was the only major species that was significantly (>15%) above the targeted value. A review of the data indicated that the measured value for the HLW-LB simulant was 10% lower than the targeted value for the simulant and that the measured composition for aluminum in the melter feed and glass results match the expected values from the targeted simulant composition. Therefore, it is likely that the differences noted in the aluminum oxide concentrations are in part due to the analysis of the simulant.

The range for the melter feed slurries was less than 10% for all major elements except B_2O_3, shown above in Table 12. As discussed above, issues with the analysis of boron (B) were noted during most of the testing. Glass analysis showed more variability, with most oxides having a range of 10-15%, indicating slightly more scatter in the data than the melter feed samples.

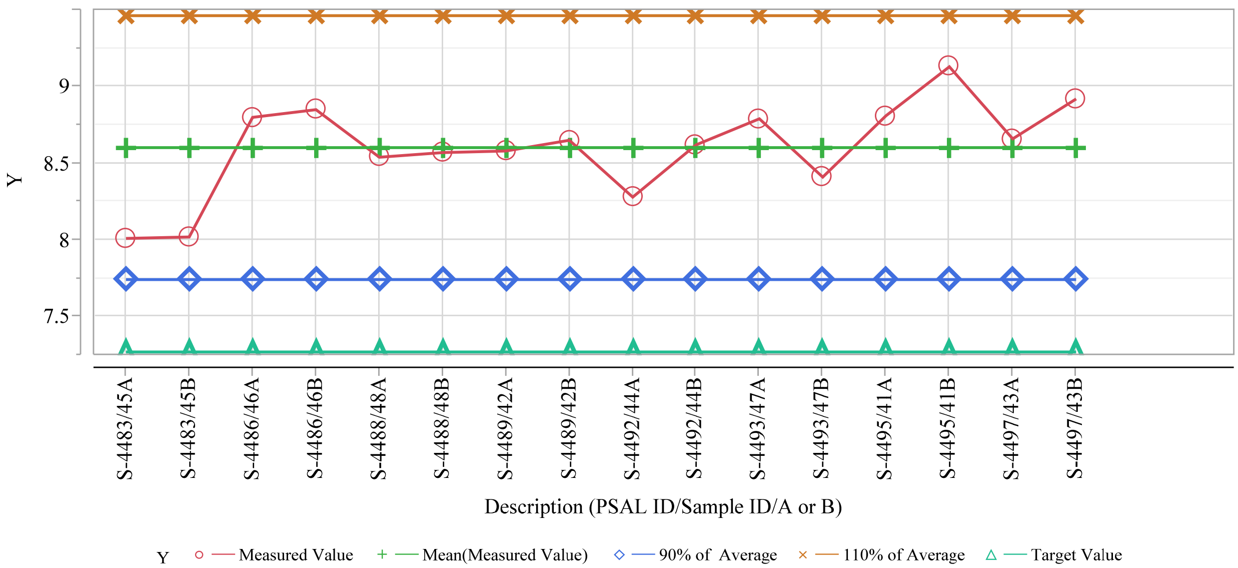


Figure 23. Al_2O_3 Results (weight percent oxide) for HLW-Low Bound Glass Samples

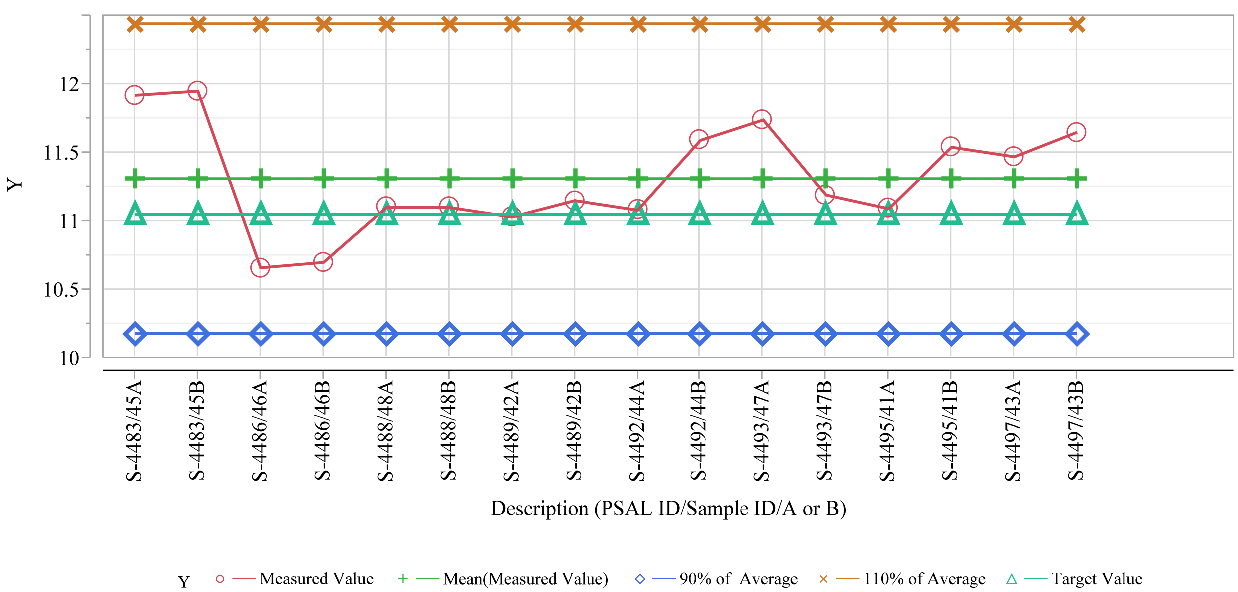


Figure 24. B_2O_3 Results (weight percent oxide) for HLW-Low Bound Glass Samples

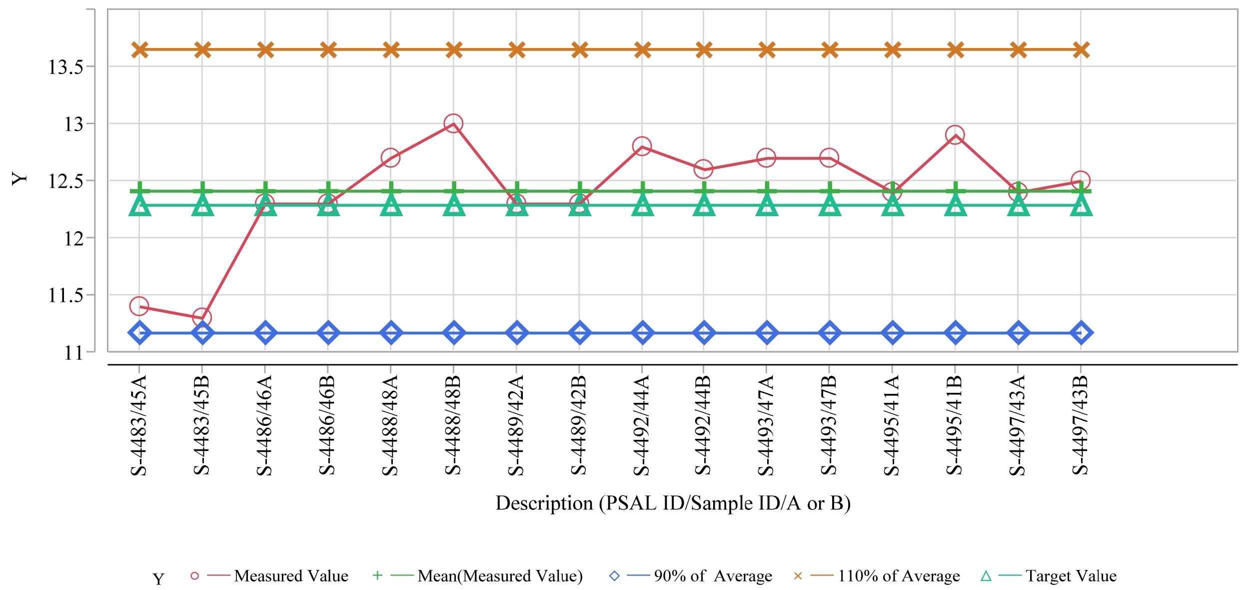


Figure 25. Fe_2O_3 Results (weight percent oxide) for HLW-Low Bound Glass Samples

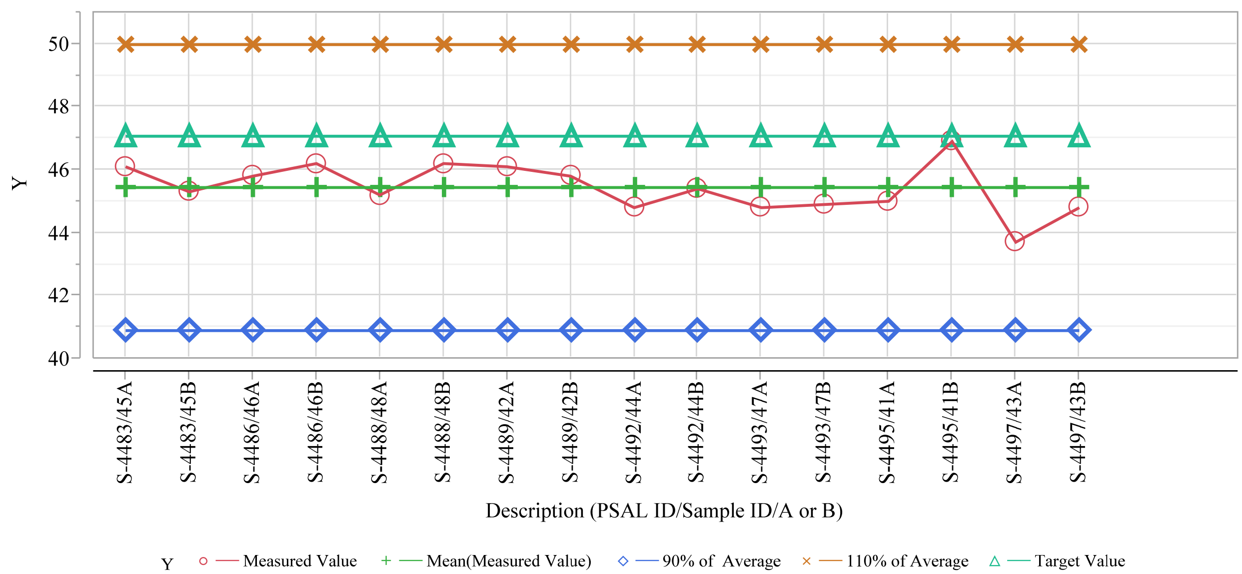


Figure 26. SiO_2 Results (weight percent oxide) for HLW-Low Bound Glass Samples

2.5.4 HLW-High Bound Results

The major oxides in the HLW–HB tests were Al_2O_3, B_2O_3, Fe_2O_3, Li_2O, Na_2O, SiO_2, ZnO, and ZrO_2. All major species for the HLW–HB tests were within 10% of the target values as shown in Figure 27 through Figure 30. The range for the melter feed slurries and glass analysis was less than 10% for all major elements except B_2O_3. As discussed in previous sections, issues with the analysis of B_2O_3 were noted during most of the testing.

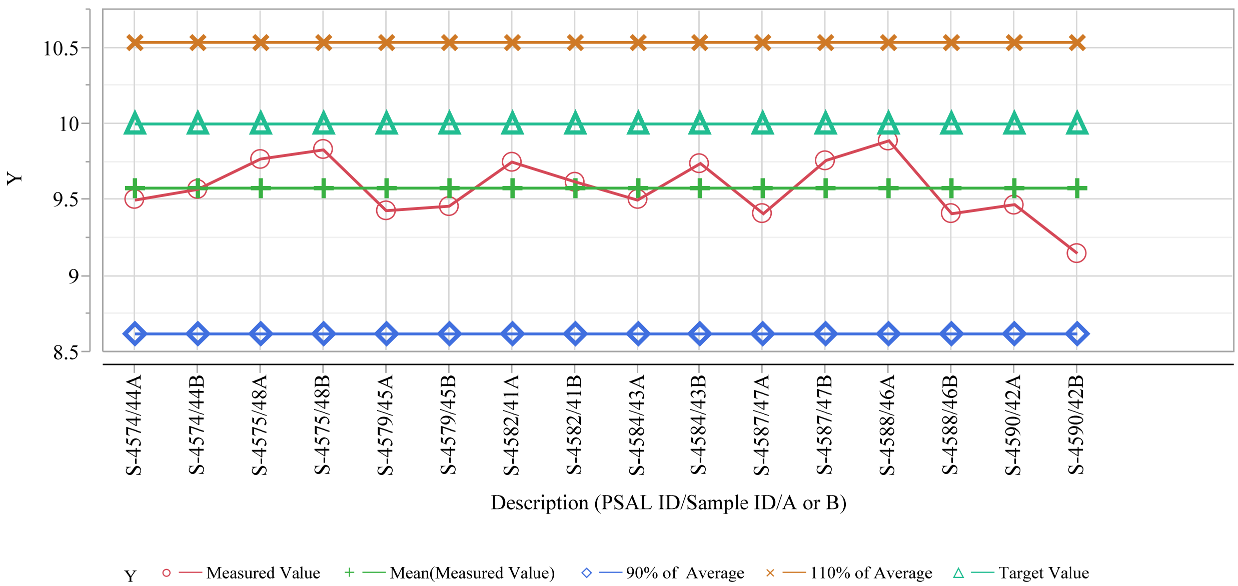


Figure 27. Al_2O_3 Results (weight percent oxide) for HLW-High Bound Glass Samples

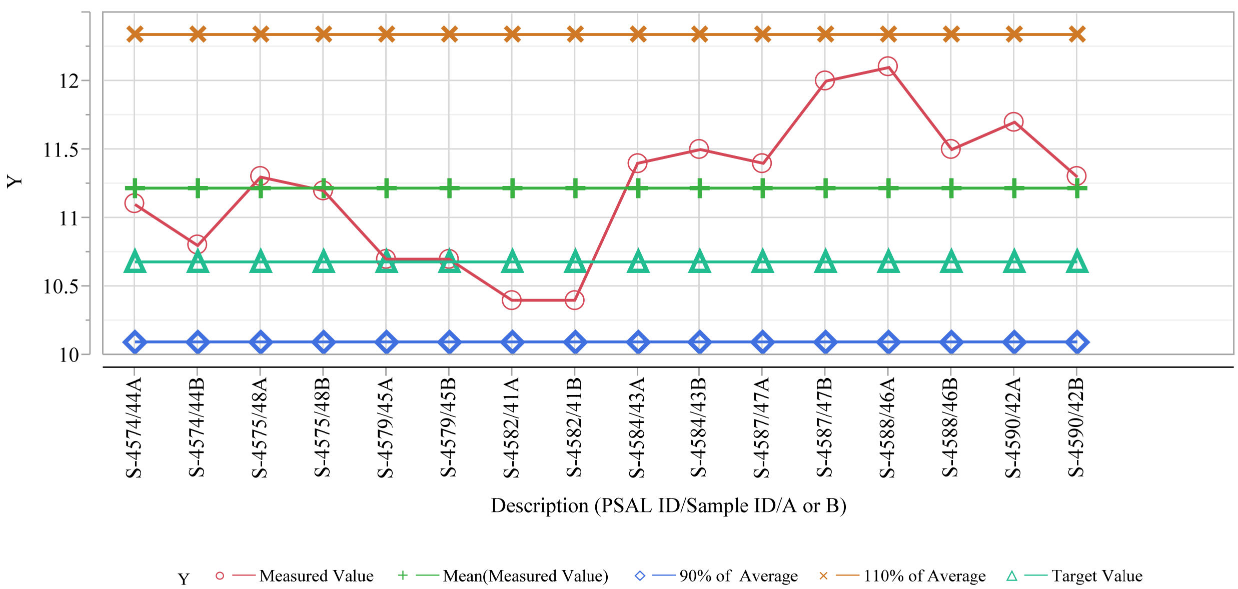


Figure 28. B_2O_3 Results (weight percent oxide) for HLW-High Bound Glass Samples

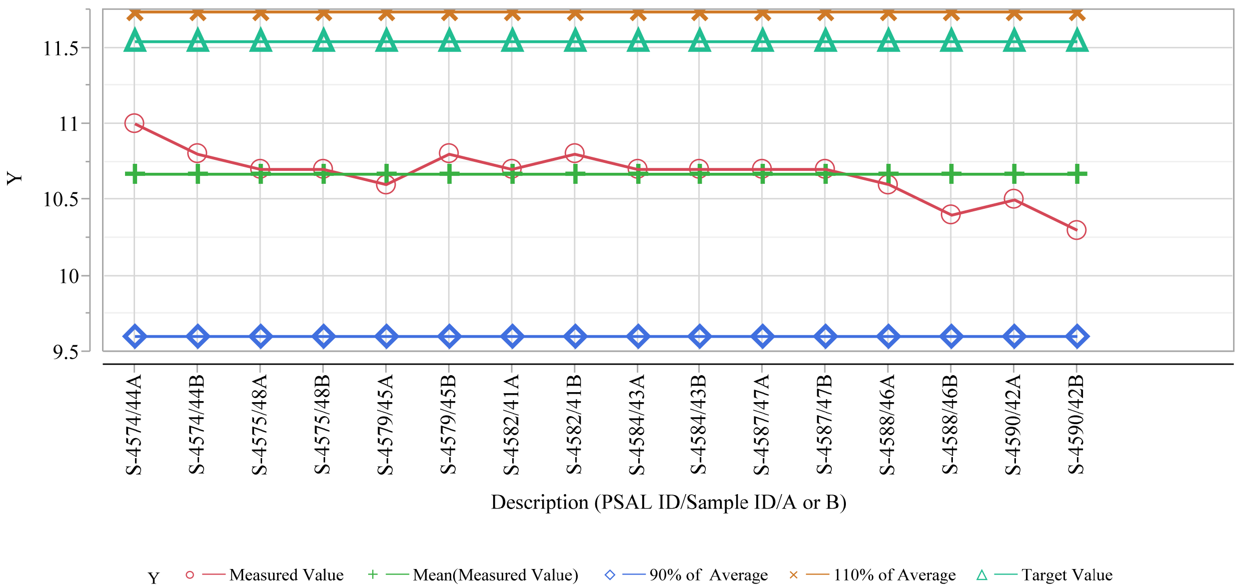


Figure 29. Fe_2O_3 Results (weight percent oxide) for HLW-High Bound Glass Samples

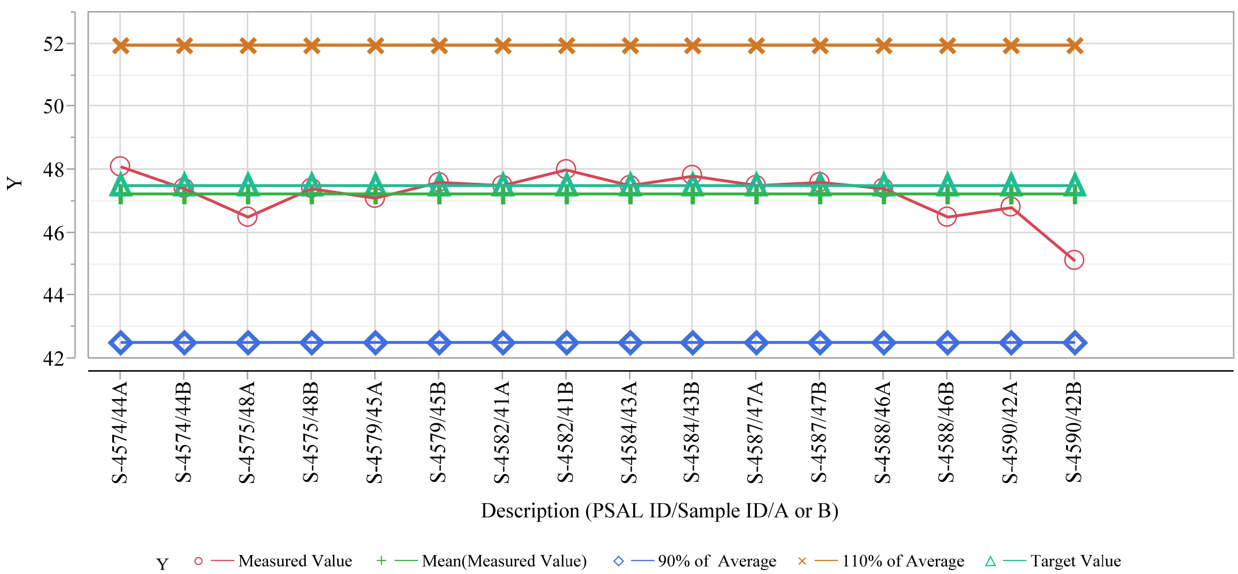


Figure 30. SiO_2 Results (weight percent oxide) for HLW-High Bound Glass Samples

2.5.5 Anion Results

Anion data was very consistent with all samples within 10% of the average value, as shown in Figure 31 through Figure 33 for selected species for the LAW–LB melter feeds. This result was expected since soluble species would not be significantly impacted by the typical mixing and sampling issues that could occur when mixing slurries.

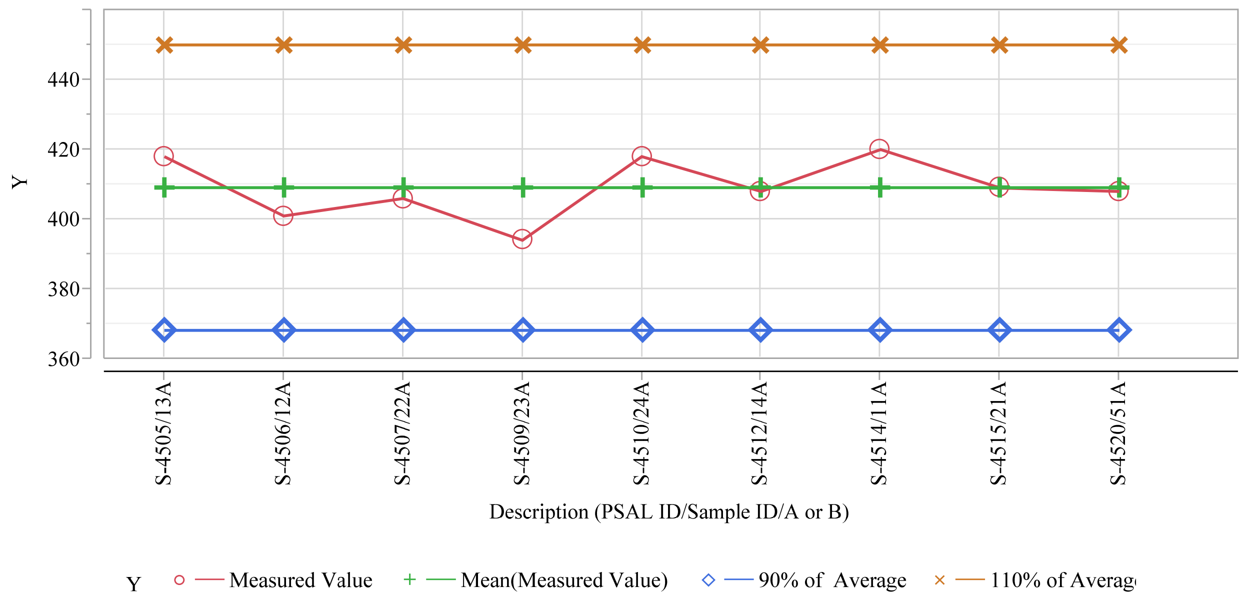


Figure 31. Nitrite Results (milligrams/kilogram) from LAW-Low Bound Tests

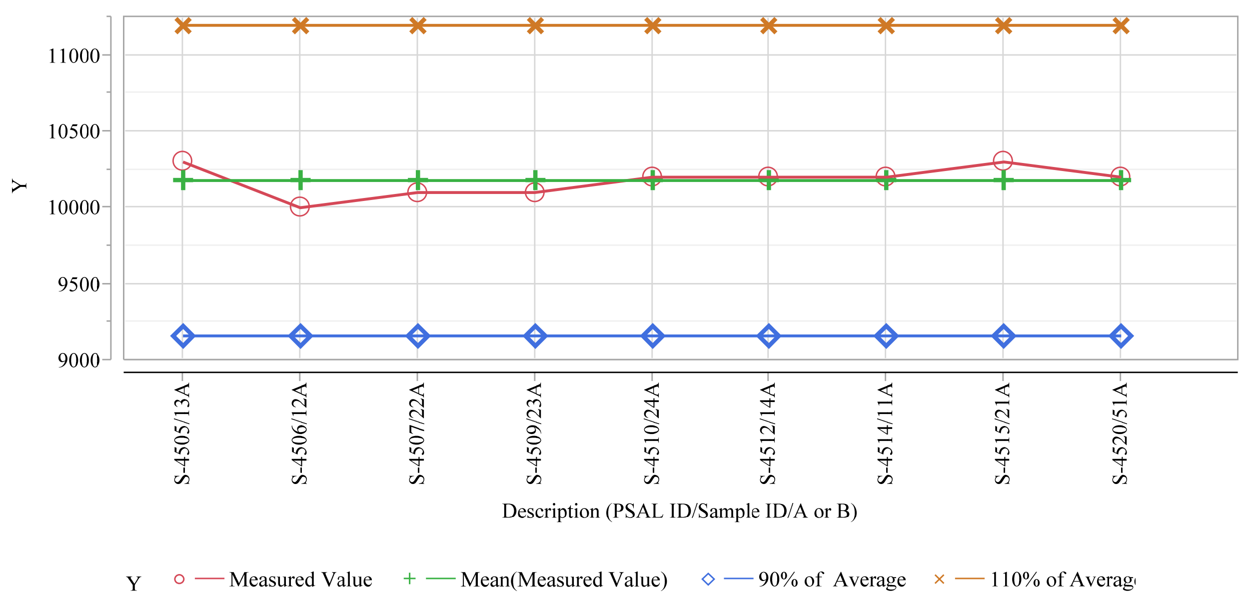


Figure 32. Nitrate Results (milligrams/kilogram) from LAW-Low Bound Tests

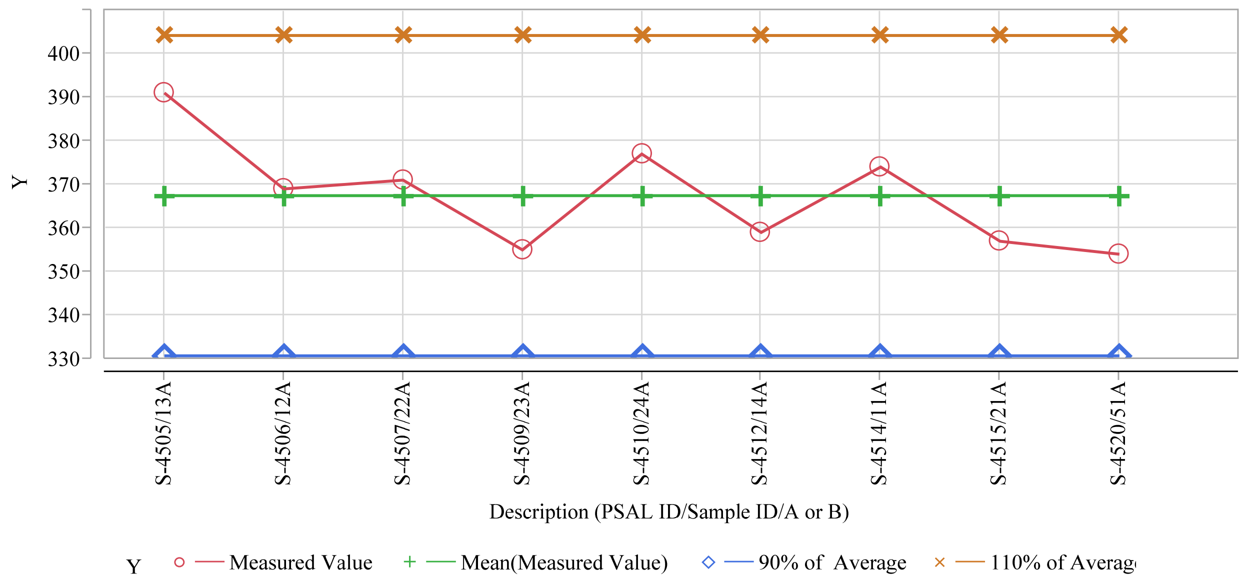


Figure 33. Sulfate Results (milligrams/kilogram) from LAW-Low Bound Tests

2.5.6 Physical Property Results

Physical property measurements of the melter feed slurries included solids, density and rheological property measurements. Results from all physical property measurements indicated good repeatability and consistent results that were within ten percent of the average value for all data sets.

2.5.6.1 Solids Results

Review of the melter feed slurry solids concentrations results did not indicate any issues with mixing and sampling, with nearly all values within 10% of the average value as shown in Figure 34 through Figure 37 for the LAW-LB test. Note that results are not shown in order of sampling. Solids data from other testing showed significantly less variability than the low bound melter feeds, indicating no issues with measurement of total, undissolved, dissolved, or calcine solids during the testing. Note that selected sample did not have enough material to perform the dissolved solids analysis which also did not allow an undissolved solids value to be calculated. However, as shown by the excellent agreement in sample results from the testing, additional samples are not needed to confirm the ability to measure the solids from the melter feed samples.

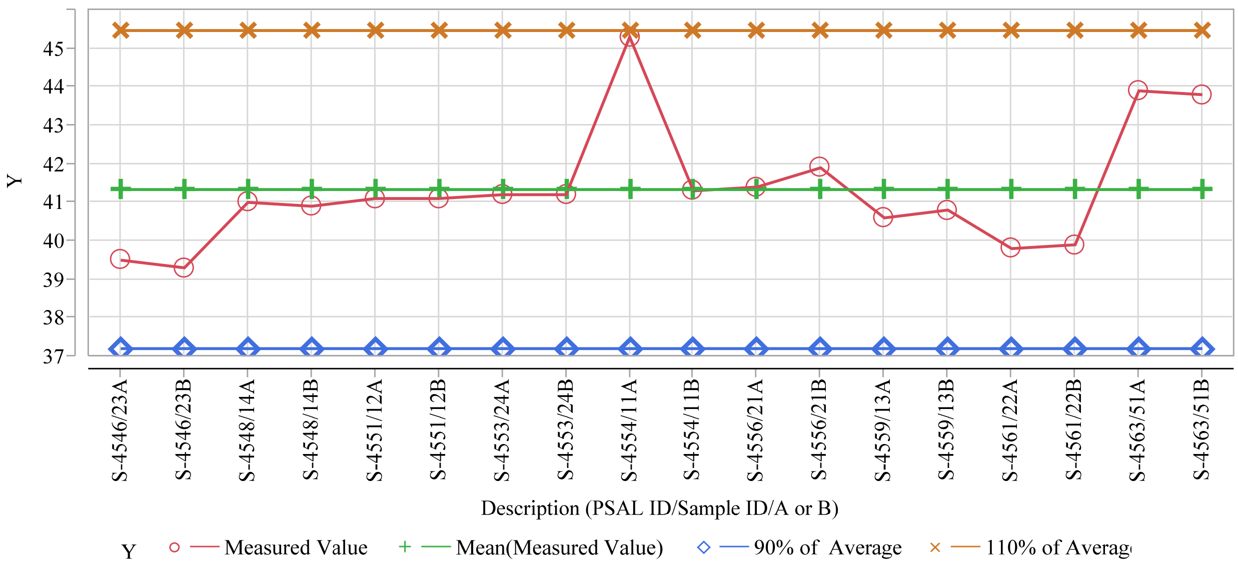


Figure 34. Total Solids (weight percent) from LAW-Low Bound Melter Feeds

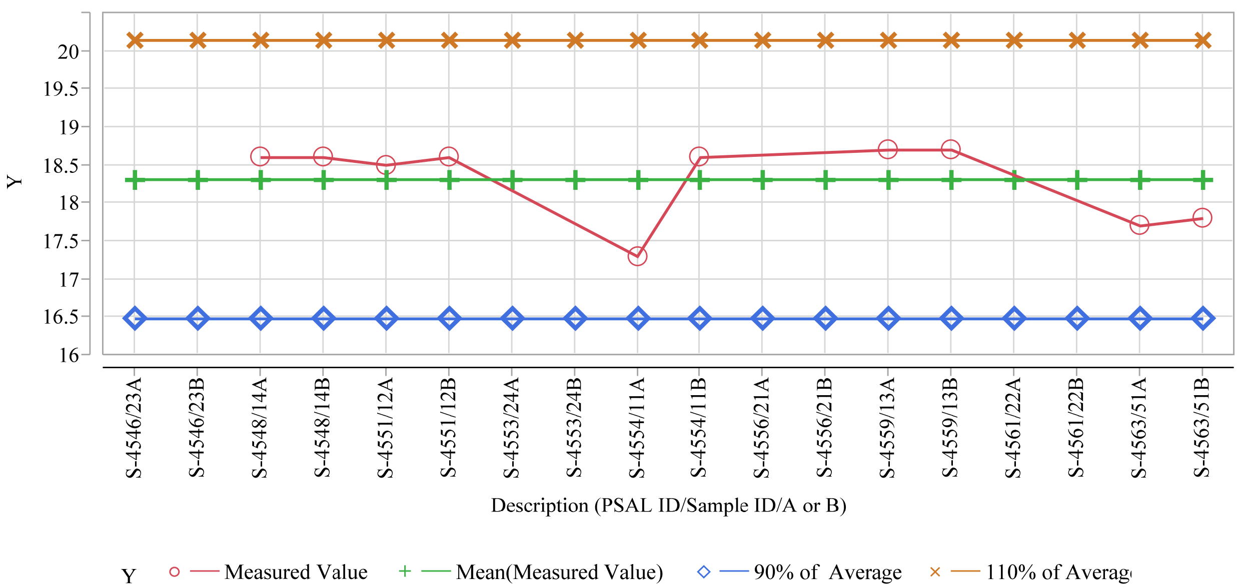


Figure 35. Dissolved Solids (weight percent) from LAW-Low Bound Melter Feed

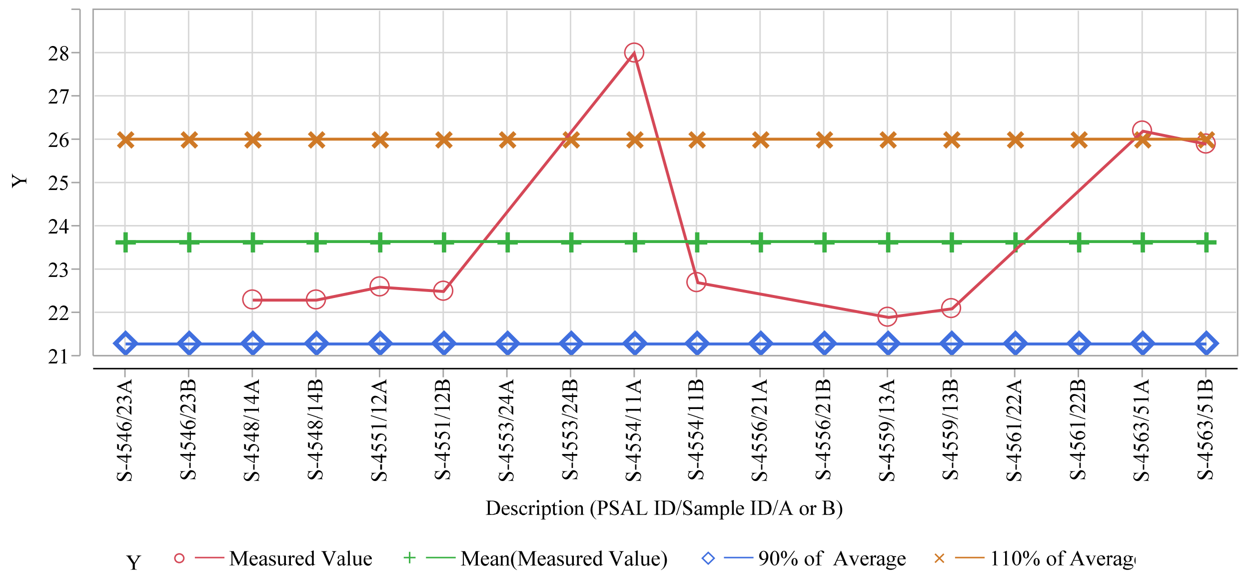


Figure 36. Undissolved Solids (weight percent) from LAW-Low Bound Melter Feed

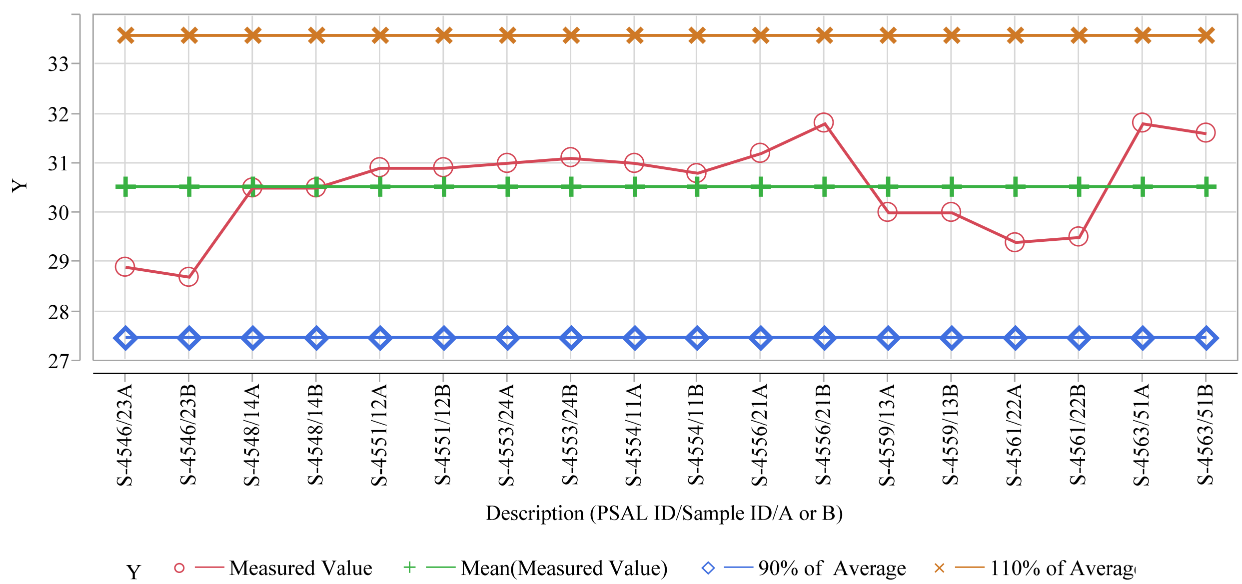


Figure 37. Calcine Solids Results (weight percent oxide) from LAW-Low Bound Melter Feed

2.5.6.2 Density Results

As with the solids results, very little variation was noted in the density results from the testing, as shown in Figure 38 for the LAW–LB melter feed, and no issues were noted in performing this measurement during the testing.

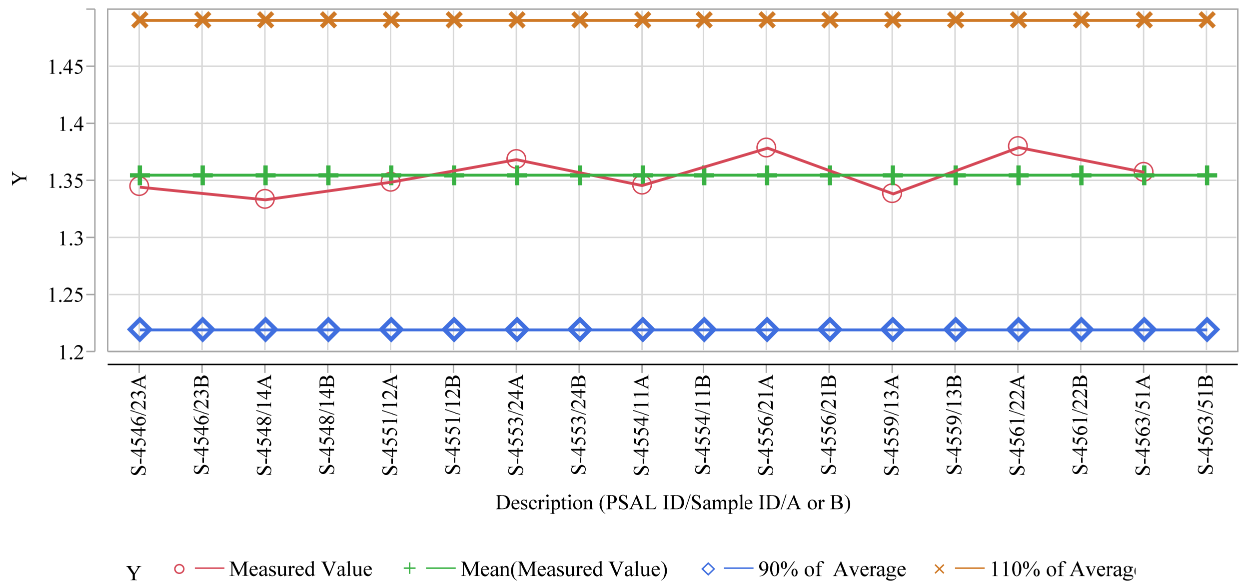


Figure 38. Density (kilograms/Liter) for LAW-Low Bound Melter Feed

2.5.6.3 Melter Feed Simulant Rheological Property Results

Rheological property measurements were performed for two replicates for both the simulants and the melter feeds, with results shown in Table 15. The melter feed samples were measured at ambient (25 degrees Celsius) and at elevated temperatures (40 degrees Celsius). Replicates typically showed excellent agreement with the calculated yield stress and viscosity (or plastic viscosity) results within 10% of the average and most samples within 5% of the average. Some common responses were noted in the flow curves, such as Taylor vortices and occasional binding between the bob and cup due to large solids.

Taylor vortices were noted in essentially all the flow curve measurements and is the point where secondary flow patterns start to form between the rotating bob and stationary cup. The Taylor vortices is identified by an inflection of the flow curve as noted at shear rates of approximately 400 to 450/seconds on the LAW–HB graphs. The LAW-LB and HLW–LB samples began to exhibit these features at very low shear rates (< 100/seconds). When Taylor vortices are noted, the data past the inflection point is excluded from the regression of the data. Taylor vortices can be minimized by decreasing the size of the gap in the concentric cylinder geometry by increasing the size of the bob, but increased binding (as described below) could occur. Taylor vortices can also be mitigated by decreasing the upper shear rate range, but this approach simply reduces the available data in a similar manner to removing the affected data from the regression.

Binding of the rotating bob with the stationary cup can occur due to large particles that can bridge the gap between the two surfaces. This binding is noted by spikes (large increases in the shear stress) in the data, as shown in the rheogram for the HLW–LB simulant. Like Taylor vortices, the data points where binding occurs were removed from the data regression.

Unlike the Taylor vortices and the spikes due to binding, the misshapen down curve noted in the LAW-HB down curve for the 40 degrees Celsius measurement does not have a known cause. The replicate sample did not show the same behavior and no issues were noted in the "Up" curve. Therefore, the data from the "Up" curve was used to regress this curve. Repeating this measurement would be recommended for a sample during waste feed qualification if any issues with the reliability of the "Up" curve data were noted.

The flow curves can be regressed using both the "Up" curve and the "Down" generated during the measurement. The "Up" curve represents data from the start of the measurement and the shear rate is linearly increased until the maximum shear rate is obtained, held at this maximum shear rate, while the "Down" curve represents data collected as the rheometer linearly decreases the shear rate back to zero. Due to the presence of Taylor vortices, only the "Up" curves were regressed to generate the yield stress and plastic viscosity during this testing.

The targeted yield stress for the HLW-HB was 30 Pascals, the actual results are ~11% above this value. This difference is within sample error; therefore no adjustments were deemed necessary to adjust the rheological properties of this feed. Both the LAW-LB and HLW-LB melter feed slurries exhibited very low yield stresses, a condition that is not expected for melter feed slurries although a lower yield stress limit does not exist. Water in the melter feed reduces melt rate and a low yield stress can lead to settling of the GFCs in the feed lines[27]; therefore, it is expected that the targeted solids content of the feed slurry would be increased if the melter feed had a low yield stress. The yield stress (essential zero Pascals) of these two melter feed slurries represents a bounding test for the suspension of solids during mixing and sampling, as well as potentially allowing significant stratification during sample drying for glass preparation and sample analysis.

Table 15. Melter Feed Slurry Rheological Property Results Summary

Product	Sample ID	Yield Stress (Pascals)	Plastic Viscosity (centipoise)	R^2
HLW-HB-25°C	4577	33.3	68.6	0.99
	4585	33.3	68.0	0.99
	Average	33.3	68.3	
HLW-LB-25°C	4491	0.4	6.3	0.99
	4485	0.4	6.6	0.98
	Average	0.4	6.4	
LAW-HB-25°C	4598	5.8	43.0	1.00
	4609	7.0	42.3	1.00
	Average	6.4	42.7	
LAW-LW-25°C	4551	0.0	5.2	0.97
	4554	0.0	5.4	0.98
	Average	0.0	5.3	
HLW-HB-40°C	4577	31.4	48.8	0.99
	4585	31.7	51.1	0.99
	Average	31.6	49.9	
HLW-LB-40°C	4491	0.3	5.3	0.99
	4485	0.3	5.2	0.99
	Average	0.3	5.2	
LAW-HB-40°C	4598	4.1	30.5	1.00
	4609	4.4	31.1	1.00
	Average	4.3	30.8	
LAW-LW-40°C	4551	0.0	3.7	0.98
	4554	0.0	3.7	0.99
	Average	0.0	3.7	

As shown in Table 15, samples at elevated temperature only exhibited a slight decrease in yield stress, but plastic viscosity was significantly reduced versus the lower temperature data for the HLW-HB and LAW–HB samples. An example flow curve is shown in Figure 39; additional rheograms and discussions of the features noted in the rheograms is in Appendix E.

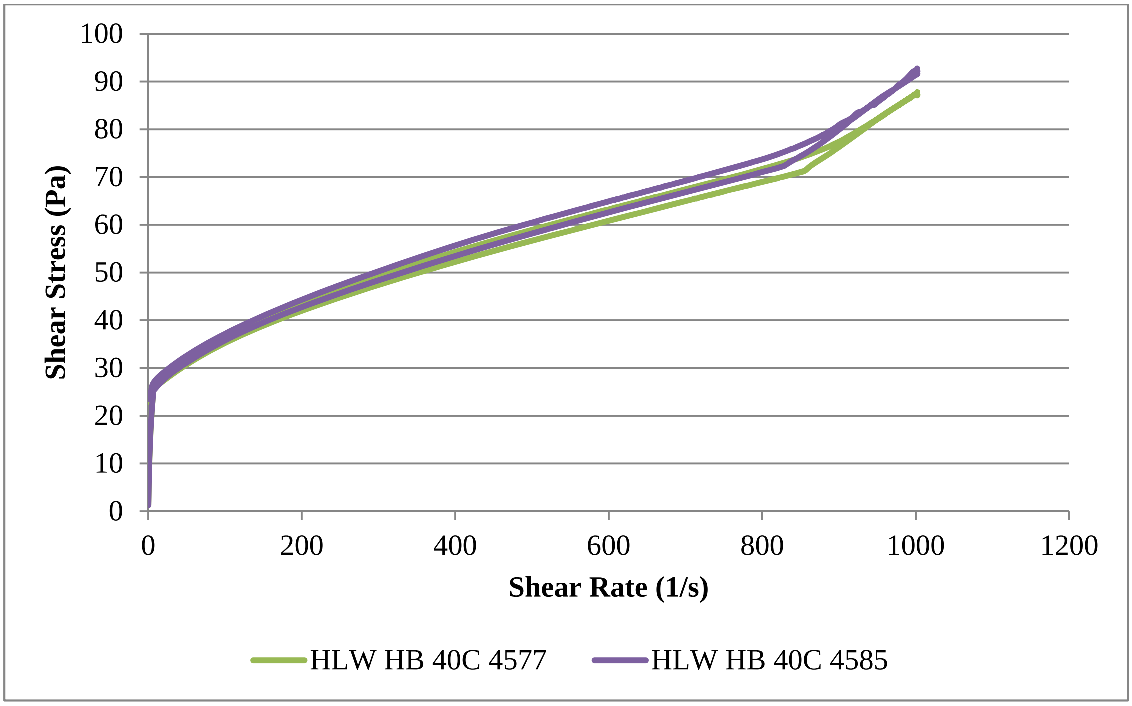


Figure 39. Rheogram for HLW-High Bound Melter Feed at 25 Degrees Celsius

2.5.6.4 Simulant Rheological Property Results

Bingham Plastic properties of the simulants were calculated from measured flow curves prior to addition of GFCs, as shown in Table 16.

As noted above, Taylor vortices were present in most rheograms. Oscillations were noted in the rheogram for the LAW simulant as the result of the extremely low yield stress and viscosity of this sample and could be due to slight eccentricity of the bob/cup.

As expected, the results indicated that the LAW simulant was Newtonian (Newtonian is assumed when the yield stress is less than one Pascal). The HLW simulants prepared by the vendor were lower than expected, as discussed in Section 1.2. The results for SRNL prepared HLW–HB simulant were much higher and replicate makeups showed good agreement.

Table 16. Rheological Property Results Summary for Simulants

Simulant	Yield Stress (Pascals)	Plastic Viscosity (centipoise)
LAW Simulant	0.0	2.68
HLW-LB Simulant	0.0	6.52
Vendor HLW-HB Simulant	3.1	5.3
ACTL HLW-HB Simulant Batch 1	14.3	11.4
ACTL HLW-HB Simulant Batch 2	13.8	11.8

2.6 Evaluation of Number of Samples Needed and Tolerance to Determine if Sample Set is Representative

The statistical regression indicated that four replicates with a bound of 15% on the relative standard deviation for major species (>5 weight percent on an oxide basis) would be expected to allow analysis of the composition of the melter feed slurries given the analytical and sampling error noted in this testing.

Four replicates are recommended to allow for adequate regression of the data to allow any outliers to be identified as well as provide the ability to determine standard deviation calculations if one measurement is discarded. Four replicates also matches the standard practice used in performing feed qualification testing for DWPF.

2.7 Lessons Learned

The results indicated that the melter feed slurries with higher yield stresses were more easily sampled in a representative manner and the thinner feeds resulted in more difficulty in collecting representative samples. The testing was performed with mixing to achieve a “slight vortex” based on past testing with samples that indicated that this mixing requirement is sufficient to collect representative samples. Note that excessive vortex with mixing can cause air entrainment in viscous samples. Entrained air can impact density and rheological property measurements if the air remains trapped in the slurry once mixing is stopped. To reduce the variability in sample results noted during this testing for samples that are less viscous, increase mixing speed toward the maximum speed possible to produce a more vigorous mixing regime, while also minimizing sample splatter. For less viscous samples, air entrainment is not a significant issue as these slurries do not trap large amounts of air. It should be noted that the melter feed water content is typically minimized as much as possible such that less viscous melter feeds would not be expected.

The time allowed to vitrify melter feed samples during the testing was 60 - 65 minutes. The demonstrated techniques for converting melter feed to glass product were successful based on results of these studies with the LAW-LB, HLW-HB, and HLW-LB melter feeds and can be easily translated for glass fabrication in a shielded cells environment. However, greater compositional variability was observed in LAW-LB and HLW-LB tests with the glass sample data versus the melter feed simulant results, which may be indicative of insufficient homogenization during melting. Melter feeds were not agitated during the drying process and particle settling likely occurred, especially in those melter feeds exhibiting a low yield stress. If issues with homogenization are noted during waste feed qualification, then increasing the melting time could lead to a more homogenous glass product and less variability in the glass composition results. Periodically mixing the melter feed during drying would also improve homogenization.

The Prince 5001 iron oxide specified for the glass forming chemicals is no longer commercially available. Substitution of available iron oxides led to a change in the rheological properties of the melter feed slurries during this study.

3.0 Conclusions

The mixing and sampling apparatus was shown to be acceptable to mix the GFCs with the LAW and HLW wastes and to collect representative samples. The techniques used to prepare the glass coupons were acceptable for the expected range of LAW and HLW feeds. These conclusions are based meeting the requirements for these tasks as outlined in the TTQAP[10]:

3.1 Simulant (TTQAP Section 4.1)

SRNL will recommend to WTP the simulant(s) to be used for this testing

- The simulant used was specified and procured by WTP following SRNL recommendation. The HLW-HB simulant used during the testing was prepared by SRNL.

3.2 Mixing (TTQAP Section 4.2)

SRNL will identify and design a mixing system to blend the waste sample with GFCs.

- A mixing system was designed. This design was reviewed by WTP.

SRNL will demonstrate that the mixing system can blend the waste sample with GFCs to allow representative sampling.

- The mixing system performance was demonstrated by the preparation of four simulated melter feed slurries. The system demonstrated the capability to blend the LAW and HLW simulants with the appropriate glass forming chemicals and sugar. Representative samples were pulled from the mixing vessel.

SRNL will determine the number of samples required and the accepted tolerances needed to verify sample representativeness.

- Four sample replicates are recommended for waste qualification testing, based on the repeatability of the samples during this demonstration including statistical analysis.
- The relative standard deviation for the replicates should be within 15% for major components for the samples to be deemed representative.

If not demonstrated by experience, SRNL will perform an assessment of the remotability of the specified mixing system.

- The mixing system selected has been used extensively in the SRNL Shielded Cells facility for DWPF waste qualification testing.

3.3 Physical Property Measurements (TTQAP Section 4.3)

SRNL will perform rheological property measurements before and after GFC additions.

- Rheological property measurements were successfully performed for simulant and melter feed samples at ambient temperature (25 degrees Celsius) as well as at an elevated temperature (40 degrees Celsius) for the melter feed samples.

SRNL will perform dilutions to the waste sample or melter feeds if the rheological properties are outside design limits.

- Dilutions were not required to adjust samples to be within the design limits because samples did not exceed the limits for rheological properties.

SRNL will perform physical property measurements of the melter feed slurries to include: density, weight percent solids (total, dissolved, and undissolved), and supernate density.

- The specified measurements were successfully performed. Dissolved solids measurements were performed on some samples. For some samples, insufficient sample volume remained after compositional analysis. However, sufficient data was collected to ensure accuracy of the analytical methods and average results were obtained for each test.

SRNL will provide the specifics of the equipment needed to perform the rheological property measurements.

- The equipment and sample techniques used during the testing are specified in Section 1.3 and 1.4 of this report.

3.4 Glass Preparation (TTQAP Section 4.4)

SRNL will provide work instructions to support conversion of the melter feed to a product.

- Work instructions are provided in Appendix F.

SRNL will specify heat up rates and hold times.

- It was determined that the samples can be placed into a furnace at temperature as no ramp rate was needed to prevent foaming. The lack of a need for a ramp to temperature was successfully demonstrated.
- A hold time of 60 to 65 minutes was determined during proof of concept testing. This hold time was successfully demonstrated to produce acceptable results.

3.5 Sample Analysis (TTQAP Section 4.5)

SRNL will perform ICP-AES measurements of the prepared glass and melter feed slurries.

- SRNL successfully performed the compositional analysis of melter feed and glass samples using ICP-AES. Digestion methods are specified.

SRNL will perform visual observations of the simulated LAW and HLW waste glasses prepared during the testing.

- Visual examinations were successfully performed of all glass samples to check for any nucleations or surface variations.

3.6 Hydrogen Generation Rates (TTQAP Section 4.6)

SRNL will consider the sample size needed for HGR measurement during the melter feed preparation.

- The sampling plan included samples for HGR measurements.

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Appendix A. Simulant Recipes

LAW Simulant

The LAW simulant is a ~ 3 molar (M) sodium (Na) simulant that will be used to prepare both the low bound and high bound LAW melter feeds. This recipe was specified by WTP and prepared by NOAH Technologies Corporation. Note that preparation steps (such as addition order, wait times, etc.) and specific item number have been removed from the recipe as shown in Table A- 1.

Table A- 1. Recipe for LAW Simulant

Formula	Molecular Weight	grams/Liter
H_2O	18.0153	111.94
$NaCH_3COO\ (H_2O)_3$	136.0796	2.02
$Na_2C_2O_4$	133.9985	1.43
$Al(NO_3)_3$ (59.86% Solution)	212.9962	97.28
NaCl	58.44277	1.43
$NaH_2PO_4 \cdot H_2O$	137.9923	1.03
Na_2SO_4	142.0421	3.18
$NaNO_3$	84.99467	36
KNO_3	101.1032	12.01
NaOH (50.20% Solution)	39.99711	142.47
Na_2SiO_3	122.0632	0.32
HCOONa	68.00721	0.97
$NaNO_2$	68.99527	29.27
Na_2CO_3	105.9884	12.02
K_2CO_3	138.2055	21.31
H_2O	18.0153	684.9
Total		1157.58

HLW-Low Bound Simulant

The HLW-LB simulant was specified by WTP and prepared by NOAH Technologies Corporation. Note that preparation steps (such as addition order, wait times, etc.) have been removed from the recipe and that the specific form of the compound (particle size, etc.) has been omitted from Table A- 2.

Table A- 2. Recipe for HLW-Low Bound Simulant

Formula	Molecular Weight	grams/Liter
H_3BO_3	61.83302	0.084
NaCl	58.44277	0.187
NaF	41.98817	0.139
Na_2SO_4	142.0421	0.576
NaOH (50.2 % Solution)	39.99711	12.266
$Na_3PO_4 \cdot (H_2O)_{12}$	380.1241	8.942
$Na_2C_2O_4$	133.9985	0.128
Na_2CO_3	105.9884	6.377
$NaNO_3$	84.99467	0.483
KNO_2	85.1038	0.704
$NaNO_2$	68.99527	1.192
Fe_2O_3	159.6882	63.41
$Al(OH)_3$	78.00356	63.27
SiO_2	60.0843	6.12
$Zr(OH)_4$	159.2534	24.89

To the above, 26.025 grams/liter of the Cesium ion exchange (IX) Concentrate[8] was added to complete the recipe.

HLW-High Bound Simulant

The HLW–HB simulant was specified by WTP and prepared by NOAH Technologies Corporation. Note that preparation steps (such as addition order, wait times, etc.) have been removed from the recipe and that the specific form of the compound (particle size, etc.) has been omitted from Table A- 3.

Table A- 3. Recipe for HLW-High Bound Simulant

Formula	Molecular Weight	grams/Liter
H_3BO_3	61.83302	0.073
$NaCl$	58.44277	0.162
NaF	41.98817	0.121
Na_2SO_4	142.0421	0.498
$NaOH$	39.99711	10.604
$Na_3PO_4 \cdot (H_2O)_{12}$	380.1241	7.73
$Na_2C_2O_4$	133.9985	0.11
Na_2CO_3	105.9884	5.513
$NaNO_3$	84.99467	0.417
KNO_2	85.1038	0.609
$NaNO_2$	68.99527	1.031
Fe_2O_3	159.6882	192.79
$Al(OH)_3$	78.00356	192.38
SiO_2	60.0843	18.61
$Zr(OH)_4$	159.2534	75.66

To the above, 72.55 grams/liter of the Cesium ion exchange (IX) Concentrate[8] was added to complete the recipe.

The rheological properties of the NOAH provided HLW–HB simulant did not meet the targeted yield stress for the HLW-HB melter feed. As a result, SRNL prepared this simulant recipe using chemicals remaining from the development program for the recipes used by WTP to prepare the HLW simulants using the same recipe as above.

LAW-Low Bound GFCs

The recipe for the LAW–LB Melter Feed specifies that the following GFCs be added to one liter of LAW simulant. Note that the GFCs were blended in the ratio below by NOAH Technologies Corporation. Therefore, 419 grams of the blended GFCs were added to a liter of LAW simulant during the testing, as shown in Table A- 4.

Table A- 4. Recipe for LAW-Low Bound GFCs

Formula	Molecular Weight	grams/Liter
Al_2SiO_5	162.0456	35.67
H_3BO_3	61.83302	87.65
$CaSiO_3$	116.1617	21.16
Fe_2O_3	159.6882	27.21
Mg_2SiO_4	140.6931	15.5
SiO_2	60.0843	183.63
TiO_2	79.8658	10.52
ZnO	81.40839	14.99
$ZrSiO_4$	183.3071	22.67
Total		419

LAW-High Bound GFCs

The recipe for the LAW-HB Melter Feed specifies that the following GFCs be added to one liter of LAW simulant. Note that the GFCs were blended in the ratio below by NOAH Technologies Corporation. Therefore, 1,949.62 grams of the blended GFCs were added to a liter of LAW simulant during the testing, as shown in Table A- 5.

Table A- 5. Recipe for LAW-High Bound GFCs

Formula	Molecular Weight	grams/Liter
Al_2SiO_5	162.0456	200.45
H_3BO_3	61.83302	87.65
$CaSiO_3$	116.1617	118.89
Fe_2O_3	159.6882	152.88
Mg_2SiO_4	140.6931	87.09
SiO_2	60.0843	1031.93
TiO_2	79.8658	59.11
ZnO	81.40839	84.23
$ZrSiO_4$	183.3071	127.39
Total		1,949.62

HLW-Low Bound GFCs

The recipe for the HLW–LB Melter Feed specifies that the following GFCs be added to one liter of HLW–LB simulant. Note that the GFCs were blended in the ratio below by NOAH Technologies Corporation. Therefore, 429.74 grams of the blended GFCs were added to a liter of HLW-LB simulant during the testing, as shown in Table A- 6.

Table A- 6. Recipe for HLW-Low Bound GFCs

Formula	MW (grams)	g/L
$Na_2B_4O_7 \cdot (H_2O)_{10}$	381.3721	136.98
Li_2CO_3	73.8909	44.86
Na_2CO_3	105.9884	31.17
SiO_2	60.0843	207.2
ZnO	81.40839	9.53
Total		429.74

HLW-High Bound GFCs

The recipe for the HLW–HB Melter Feed specifies that the following GFCs be added to one liter of HLW–HB simulant. Note that the GFCs were blended in the ratio below by NOAH Technologies Corporation. Therefore, 1,202.7 grams of the blended GFCs were added to a liter of HLW-HB simulant during the testing. Note that the GFC total amount is changed versus the HLW-LB melter feed, but the GFC formula is otherwise unchanged. Thus, the same blend of GFCs from NOAH Technologies Corporation was used for both HLW melter feeds, as shown in Table A- 7.

Table A- 7. Recipe for HLW High Bound GFCs

Formula	MW (grams)	g/L
$Na_2B_4O_7 \cdot (H_2O)_{10}$	381.3721	383.38
Li_2CO_3	73.8909	125.54
Na_2CO_3	105.9884	87.22
SiO_2	60.0843	579.9
ZnO	81.40839	26.66
Total		1202.7

Appendix B. Experimental Steps

The experiments were performed using standard SRNL procedures for glass preparation and analytical methods with written Research and Development Directions used for guidance and documented in the SRNL Electronic Notebook. The amounts of simulant, GFC addition, and sugar added for each test are shown in Table B- 1.

Table B- 1. Test Matrix for Simulant Tests

Test ID	Simulant	Estimated Simulant Amount (grams)	GFC Type	Estimated GFC Amount (grams)	Sugar Amount (grams)
LAW – Low Bound	LAW	1,225	LAW Low Bound	442.0	38.35
LAW – High Bound	LAW	630	LAW High Bound	1,057.7	19.73
HLW – Low Bound	HLW-L	1,225	HLW	472.3	4.13
HLW – High Bound	HLW-H	880	HLW	815.5	6.31

The following steps were used to perform the experiments:

1. Ensure mixing apparatus is assembled as directed by PI.
2. Ensure scales to be used are checked prior to use. Record M&TE ID of scales used.
3. Verify calibration of optical tachometer is current. Record M&TE ID of tachometer used.
4. Utilize poly bottle specified by PI for blending simulant with GFCs.
5. Add required amount of simulant to mixing bottle.
6. Place bottle under mixing stand and secure as specified by PI.
7. Ensure mixer impeller is within ½ inch (± ¼ inch) of the bottom of the bottle. Record observations and measurements made to confirm impeller position.
8. Begin mixing and adjust mixer speed to obtain a slight vortex. If a slight vortex cannot be achieved, notify PI.
9. Measure required mixer speed with optical tachometer. Record speed.
10. Weigh out required amounts of specified GFCs.
11. Slowly add GFCs to mixing bottle (addition should take approximately 5 minutes).
    a. Adjust addition rate to avoid buildup of a layer of GFCs on surface.
    b. Adjust agitation rate during addition to maintain a slight vortex. If a slight vortex cannot be achieved, notify PI.
12. Once all GFCs are added, measure required mixer speed with optical tachometer. Record speed and time addition was completed. Add specified amount of sugar to the slurry.
    a. Adjust addition rate to avoid buildup of a layer of sugar on surface.
    b. Adjust agitation rate during addition to maintain a slight vortex. If a slight vortex cannot be achieved, notify PI.
    c. Once the sugar is added, measure required mixer speed with optical tachometer. Record speed and time addition was completed.
13. Allow slurry to mix for at least 30 minutes or as specified by PI. Record time that mixing was completed.

14. Insert sampler tube into mixing bottle to within ½ inch (± ¼ inch) of the impeller location. No tolerance on radial position. Record observations and measurements made to confirm sampler position.
15. Collect samples from vessel as shown below in Table B- 2.
    a. Sample bottles/crucibles shall be pre-labeled as specified by sample data sheet and weighed prior to use. Weight/scale M&TE information shall be recorded on data sheet. Samples collected should be a minimum of the amount specified in Table B- 2 and not more than 10 grams over the specified amount.
    b. Samples must be taken in the order specified by the sample data sheet.
    c. Turn on sample pump at least 50 milliliters/minute to recirculate slurry back into mixing vessel
    d. Once sample pump has recirculated slurry for at least 5 minutes, samples may be taken.
    e. Turn pump Off and place sample line outlet into sample bottle/crucible
    f. Turn on sample pump at 50 to 100 milliliters/minute to pump sample into bottle/crucible.
    g. Turn off sample pump when amount required has been delivered into bottle/crucible.
    h. Weigh sample bottle/crucible and record full weight/scale used.
    i. Repeat steps 15e through 15h for each sample to be taken.
    j. The heel from each test will be retained in the mixing vessel and submitted for solids and compositional analysis.
16. The HGR measurement will be performed by a separate task.
17. Only two replicates of the rheological property measurement are needed, but chemical analysis and other physical properties will be performed on all four replicates collected for rheological property/composition measurements. Additional rheological property measurements could be performed on the two remaining samples after dilution to a lower solids target if specified by PI.
    a. Rheological property measurements will utilize ASTM C1752-11.[28] Procedure ITS-0086[29] for performing rheological property measurements in the SRNL Shielded Cells will be used to guide the work while Procedure ITS-0073[17] will be the governing document for performing the measurements at ACTL. Measurements will be performed at 25 and 40 degrees Celsius per the guidelines provided by WTP.[30]
18. SRNL procedure ITS-003 will be used for glass preparation.[13] Glass will be prepared in 100 milliliter platinum alloy crucibles. Crucibles will be cleaned per SRNL procedure ITS-0054 after each use.[31] If the samples are taken from the mixing vessel directly into the crucible during subsampling (step 15 above), then skip to step 18.f.
    a. Shake melter feed until thoroughly mixed if the glass preparation samples are not taken directly into the platinum crucibles from the mixing vessel. Ensure that there is no material left on the bottom of the bottle.
    b. Pour the melter feed into the crucible.
    c. Rinse the melter feed sample bottle with 10 grams (±1 gram) water and empty the contents into the crucible. The total volume in the crucible should not exceed 1/2 inch below the lip of the crucible. Record weights of bottle before and after water rinse addition and again after rinse water is emptied into crucible.
    d. Ensure that no particles remain in the melter feed sample bottle.
    e. Tare the balance and weigh the filled crucible. Record weight.

f. Ensure that the drying oven has been at 115 degrees Celsius (±5 degrees Celsius) for at least one hour. Record M&TE information for the thermocouple and logger.
g. Place the crucible into a drying oven set to 115 degrees Celsius (±5 degrees Celsius).
h. Dry the sample for at least 12 hours.
i. Remove the crucible and allow to cool. There should be no visual indication of free liquid in the sample.
j. Weigh the crucible. Record weight and balance M&TE information.
k. Ensure that the high temperature furnace has been at 1150 degrees Celsius (±10 degrees Celsius) for at least one hour.
l. Place the crucible into the furnace with a lid.
m. Record the start time for the sample heating when the temperature of the furnace has returned to 1150 degrees Celsius (±10 degrees Celsius).
n. Remove the crucible from the furnace after at least 60 minutes (not to exceed 65 minutes) has elapsed and place the crucible on a stainless steel plate to cool.
o. Record the time at which the crucible was removed and MS&E information from furnace.

19. When the glass has cooled, record visual observation of the glass surface.
    a. If foaming occurred during melting, then crucibles may need to be re-inserted into a furnace at room temperature and ramped to 1150 degrees Celsius at a rate to be determined during testing.
20. Gently tap the crucible with a plastic faced mallet to loosen the glass from the crucible.
21. Place the glass from the crucible in a thick mil plastic bag.
22. Fracture the glass with a hammer.
23. Record visual observations of bulk glass.
24. Collect a glass sample from each crucible.
    a. Samples will be uniquely labeled per guidance from the analytical plan.
25. Housekeep work area.
26. All melter feed and glass samples will be uniquely labeled and submitted to PSAL and AD for analysis per the analytical plan. Once sample results are received, the PI will compile the data from each run and a statistical regression performed to validate that the subsamples collected from the mixing vessel were each representative of the vessel contents. A final report will be issued documenting the results of the testing.

Samples Taken During Testing

Table B- 2 lists the samples taken during each test. Test MFP4a was repeated, the sample numbers from that test used the prefix MFP4b. Nine samples of the melter feed slurry were taken during the testing because the heel remaining after the other samples were collected was also analyzed.

Table B- 2. Sample Order for Glass Fabrication Testing

Test ID	Sample ID	Intended Sample Type	Sample Amount
LAW-Low Bound	MFP-1a-23	composition	30 grams
	MFP-1a-42	glass	50 grams
	MFP-1a-14	composition & rheology	125 grams
	MFP-1a-48	glass	50 grams
	MFP-1a-47	glass	50 grams
	MFP-1a-12	composition & rheology	125 grams
	MFP-1a-43	glass	50 grams
	MFP-1a-24	composition	30 grams
	MFP-1a-11	composition & rheology	125 grams
	MFP-1a-31	HGR	250 grams
	MFP-1a-21	composition	30 grams
	MFP-1a-46	glass	50 grams
	MFP-1a-44	glass	50 grams
	MFP-1a-13	composition & rheology	125 grams
	MFP-1a-41	glass	50 grams
	MFP-1a-22	composition	30 grams
	MFP-1a-45	glass	50 grams
	MFP-1a-51	heel	to be determined
LAW-High Bound	Sample ID	**Intended Sample Type**	**Sample Amount**
	MFP-2a-12	composition & rheology	125 grams
	MFP-2a-21	composition	30 grams
	MFP-2a-13	composition & rheology	125 grams
	MFP-2a-45	glass	50 grams
	MFP-2a-44	glass	50 grams
	MFP-2a-43	glass	50 grams
	MFP-2a-23	composition	30 grams
	MFP-2a-48	glass	50 grams
	MFP-2a-42	glass	50 grams
	MFP-2a-31	HGR	250 grams
	MFP-2a-14	composition & rheology	125 grams
	MFP-2a-11	composition & rheology	125 grams
	MFP-2a-22	composition	30 grams
	MFP-2a-46	glass	50 grams
	MFP-2a-47	glass	50 grams
	MFP-2a-24	composition	30 grams
	MFP-2a-41	glass	50 grams
	MFP-2a-51	heel	to be determined

Table B- 2. Sample Order for Glass Fabrication Testing, Continued

	Sample ID	Intended Sample Type	Sample Amount
HLW-Low Bound	MFP-3a-45	glass	50 grams
	MFP-3a-21	composition	30 grams
	MFP-3a-11	composition & rheology	125 grams
	MFP-3a-46	glass	50 grams
	MFP-3a-24	composition	30 grams
	MFP-3a-48	glass	50 grams
	MFP-3a-42	glass	50 grams
	MFP-3a-13	composition & rheology	125 grams
	MFP-3a-12	composition & rheology	125 grams
	MFP-3a-44	glass	50 grams
	MFP-3a-47	glass	50 grams
	MFP-3a-14	composition & rheology	125 grams
	MFP-3a-41	glass	50 grams
	MFP-3a-23	composition	30 grams
	MFP-3a-43	glass	50 grams
	MFP-3a-22	composition	30 grams
	MFP-3a-31	HGR	250 grams
	MFP-3a-51	heel	to be determined
	Sample ID	**Intended Sample Type**	**Sample Amount**
HLW-High Bound	MFP-4a-44	glass	50 grams
	MFP-4a-48	glass	50 grams
	MFP-4a-13	composition & rheology	125 grams
	MFP-4a-12	composition & rheology	125 grams
	MFP-4a-22	composition	30 grams
	MFP-4a-45	glass	50 grams
	MFP-4a-23	composition	30 grams
	MFP-4a-24	composition	30 grams
	MFP-4a-41	glass	50 grams
	MFP-4a-14	composition & rheology	125 grams
	MFP-4a-43	glass	50 grams
	MFP-4a-11	composition & rheology	125 grams
	MFP-4a-21	composition	30 grams
	MFP-4a-47	glass	50 grams
	MFP-4a-46	glass	50 grams
	MFP-4a-31	HGR	250 grams
	MFP-4a-42	glass	50 grams
	MFP-4a-51	heel	to be determined

Appendix C. **Melter Feed Sample Results**

Table C- 1. LAW-Low Bound Melter Feed Slurry Elemental Results (Weight percent – calcined at 1100 degrees Celsius)

Sample ID	Lab ID	Al	B	Ca	Fe	K	Mg	Na	S	Si	Ti	Zn	Zr
MFP-1a-23 (A)	S-4546	2.93	3.34	1.47	2.19	3.52	0.151	15.5	0.151	20.7	0.897	2.54	1.64
MFP-1a-23 (B)	S-4546	2.91	3.17	1.45	2.16	3.52	0.151	15.5	0.152	20.7	0.888	2.51	1.64
MFP-1a-14 (A)	S-4548	2.89	3.03	1.37	2.69	3.22	0.707	14.5	0.137	21.2	0.968	2.41	1.71
MFP-1a-14 (B)	S-4548	2.89	3.01	1.40	2.69	3.36	0.705	14.5	0.133	21.3	0.965	2.39	1.71
MFP-1a-12 (A)	S-4551	2.81	2.90	1.39	3.31	3.20	1.02	13.7	0.129	20.3	1.07	2.35	1.85
MFP-1a-12 (B)	S-4551	2.82	2.82	1.34	3.26	3.10	1.02	13.7	0.126	20.4	1.06	2.29	1.82
MFP-1a-24 (A)	S-4553	2.87	2.92	1.37	3.70	3.26	0.670	14.0	0.136	20.6	1.16	2.32	2.04
MFP-1a-24 (B)	S-4553	2.84	2.89	1.32	3.66	3.09	0.672	13.9	0.135	20.4	1.15	2.30	2.03
MFP-1a-11 (A)	S-4554	2.87	2.94	1.40	3.43	3.28	0.798	14.2	0.132	20.8	1.07	2.35	1.93
MFP-1a-11 (B)	S-4554	2.88	2.92	1.34	3.78	3.14	0.798	14.2	0.131	20.9	1.06	2.35	1.89
MFP-1a-21 (A)	S-4556	2.88	2.86	1.31	3.95	3.15	1.16	13.8	0.120	20.7	1.18	2.26	2.03
MFP-1a-21 (B)	S-4556	2.88	2.83	1.29	3.92	3.11	1.15	13.9	0.125	20.7	1.17	2.26	2.02
MFP-1a-13 (A)	S-4559	2.89	3.00	1.39	2.91	3.30	0.567	14.7	0.135	20.6	1.01	2.39	1.79
MFP-1a-13 (B)	S-4559	2.90	3.03	1.35	2.88	3.26	0.559	14.8	0.139	20.7	1.01	2.39	1.78
MFP-1a-22 (A)	S-4561	2.93	3.19	1.40	3.23	3.39	0.413	15.2	0.147	20.2	1.04	2.49	1.95
MFP-1a-22 (B)	S-4561	2.92	3.16	1.41	3.05	3.50	0.415	15.1	0.138	20.1	1.03	2.46	1.89
MFP-1a-51 (A)	S-4563	2.81	2.85	1.28	3.78	3.09	1.15	13.4	0.121	20.4	1.14	2.25	1.99
MFP-1a-51 (B)	S-4563	2.80	2.82	1.28	3.76	3.05	1.16	13.4	0.121	20.5	1.13	2.24	1.98
Average	----	2.87	2.98	1.36	3.24	3.25	0.74	14.34	0.13	20.63	1.05	2.36	1.87
Standard Deviation	----	0.04	0.15	0.05	0.56	0.15	0.33	0.68	0.01	0.31	0.09	0.09	0.14
Percent Relative Standard Deviation	----	1.41	4.99	3.99	17.35	4.70	44.60	4.71	7.05	1.48	8.40	3.87	7.29
Maximum	----	2.93	3.34	1.47	3.95	3.52	1.16	15.50	0.15	21.27	1.18	2.54	2.04
Minimum	----	2.80	2.82	1.28	2.16	3.05	0.15	13.42	0.12	20.14	0.89	2.24	1.64
Range	----	0.13	0.52	0.19	1.78	0.48	1.01	2.08	0.03	1.13	0.29	0.30	0.40
Range (%)	----	4.42	17.52	13.87	55.00	14.61	136.67	14.50	23.48	5.47	27.35	12.82	21.46

Below detection limit (<0.1 weight percent): Cr, Cu, Li, P

Table C- 2. LAW-Low Bound Melter Feed Slurry Oxide Results (weight percent - calcined at 1100 degrees Celsius)

Sample ID	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SO_4	SiO_2	TiO_2	ZnO	ZrO_2	Totals
MFP-1a-23 (A)	5.53	10.8	2.05	3.13	4.23	0.250	20.9	0.452	44.4	1.50	3.15	2.21	98.6
MFP-1a-23 (B)	5.50	10.2	2.03	3.10	4.22	0.251	20.9	0.455	44.2	1.48	3.11	2.21	97.7
MFP-1a-14 (A)	5.45	9.76	1.92	3.85	3.86	1.17	19.6	0.412	45.4	1.62	2.99	2.31	98.4
MFP-1a-14 (B)	5.46	9.70	1.96	3.85	4.04	1.17	19.6	0.398	45.5	1.61	2.96	2.31	98.6
MFP-1a-12 (A)	5.31	9.35	1.94	4.74	3.85	1.70	18.4	0.388	43.5	1.79	2.91	2.50	96.4
MFP-1a-12 (B)	5.34	9.09	1.87	4.67	3.73	1.69	18.6	0.378	43.6	1.77	2.84	2.46	96.0
MFP-1a-24 (A)	5.43	9.40	1.92	5.28	3.91	1.11	18.9	0.407	44.1	1.94	2.88	2.76	98.0
MFP-1a-24 (B)	5.37	9.30	1.85	5.24	3.71	1.12	18.8	0.405	43.6	1.92	2.85	2.74	96.9
MFP-1a-11 (A)	5.42	9.46	1.96	4.91	3.94	1.32	19.1	0.397	44.5	1.79	2.91	2.61	98.4
MFP-1a-11 (B)	5.43	9.41	1.87	5.40	3.77	1.32	19.2	0.393	44.8	1.76	2.91	2.56	98.8
MFP-1a-21 (A)	5.44	9.21	1.84	5.65	3.78	1.92	18.7	0.360	44.3	1.96	2.80	2.74	98.7
MFP-1a-21 (B)	5.43	9.13	1.81	5.60	3.74	1.92	18.7	0.375	44.3	1.95	2.80	2.73	98.5
MFP-1a-13 (A)	5.46	9.68	1.95	4.16	3.95	0.941	19.9	0.406	44.1	1.69	2.97	2.41	97.6
MFP-1a-13 (B)	5.49	9.77	1.89	4.12	3.91	0.928	20.0	0.417	44.2	1.68	2.96	2.41	97.8
MFP-1a-22 (A)	5.53	10.3	1.96	4.62	4.07	0.686	20.5	0.441	43.3	1.74	3.08	2.64	98.8
MFP-1a-22 (B)	5.51	10.2	1.97	4.37	4.19	0.688	20.4	0.415	43.1	1.72	3.05	2.55	98.1
MFP-1a-51 (A)	5.31	9.17	1.79	5.41	3.70	1.92	18.1	0.364	43.7	1.90	2.79	2.69	96.8
MFP-1a-51 (B)	5.29	9.08	1.79	5.37	3.66	1.92	18.1	0.363	43.8	1.89	2.78	2.68	96.8
Average	5.43	9.61	1.91	4.64	3.90	1.22	19.36	0.40	44.14	1.76	2.93	2.53	----
Standard Deviation	0.08	0.48	0.08	0.80	0.18	0.55	0.91	0.03	0.66	0.15	0.11	0.18	----
Percent Relative Standard Deviation	1.41	4.99	3.99	17.35	4.70	44.60	4.71	7.05	1.48	8.40	3.87	7.29	----
Maximum	5.53	10.76	2.05	5.65	4.23	1.92	20.92	0.45	45.51	1.96	3.15	2.76	----
Minimum	5.29	9.08	1.79	3.10	3.66	0.25	18.11	0.36	43.10	1.48	2.78	2.21	----
Range	0.24	1.68	0.27	2.55	0.57	1.67	2.81	0.09	2.41	0.48	0.38	0.54	----
Range (%)	4.42	17.52	13.87	55.00	14.61	136.67	14.50	23.48	5.47	27.35	12.82	21.46	----

Table C- 3. LAW-Low Bound Melter Feed Slurry Solids and Density Results

Sample ID	Lab ID	Total Solids (weight percent)	Undissolved Solids (weight percent)	Dissolved Solids (weight percent)	Weight Percent Calcined	Density (kilograms/liter)
MFP-1a-23 (A)	S-4546	39.5%	IS	IS	28.9%	1.3446
MFP-1a-23 (B)	S-4546	39.3%	IS	IS	28.7%	
MFP-1a-14 (A)	S-4548	41.0%	22.3%	18.6%	30.5%	1.3335
MFP-1a-14 (B)	S-4548	40.9%	22.3%	18.6%	30.5%	
MFP-1a-12 (A)	S-4551	41.1%	22.6%	18.5%	30.9%	1.3490
MFP-1a-12 (B)	S-4551	41.1%	22.5%	18.6%	30.9%	
MFP-1a-24 (A)	S-4553	41.2%	IS	IS	31.0%	1.3687
MFP-1a-24 (B)	S-4553	41.2%	IS	IS	31.1%	
MFP-1a-11 (A)	S-4554	45.3%	28.0%	17.3%	31.0%	1.3461
MFP-1a-11 (B)	S-4554	41.3%	22.7%	18.6%	30.8%	
MFP-1a-21 (A)	S-4556	41.4%	IS	IS	31.2%	1.3789
MFP-1a-21 (B)	S-4556	41.9%	IS	IS	31.8%	
MFP-1a-13 (A)	S-4559	40.6%	21.9%	18.7%	30.0%	1.3388
MFP-1a-13 (B)	S-4559	40.8%	22.1%	18.7%	30.0%	
MFP-1a-22 (A)	S-4561	39.8%	IS	IS	29.4%	1.3794
MFP-1a-22 (B)	S-4561	39.9%	IS	IS	29.5%	
MFP-1a-51 (A)	S-4563	43.9%	26.2%	17.7%	31.8%	1.3576
MFP-1a-51 (B)	S-4563	43.8%	25.9%	17.8%	31.6%	
Average	----	41%	24%	18%	31%	1.36
Standard Deviation	----	2%	2%	1%	1%	0.02
Percent Relative Standard Deviation	----	3.78	9.20	2.77	3.06	1.25
Maximum	----	45%	28%	19%	32%	1.38
Minimum	----	39%	22%	17%	29%	1.33
Range	----	0.06	0.06	0.01	0.03	0.05
Range (%)	----	14.32	27.92	8.38	10.16	3.39

IS = Insufficient sample

Table C- 4. LAW-Low Bound Melter Feed Slurry Anion Results (milligram/Kilogram – water dilutions)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	SO_4	C_2O_4	HCO_2	PO_4
MFP-1a-23 (A)	S-4546	144	558	12,100	41,700	1,390	575	444	<500
MFP-1a-14 (A)	S-4548	140	524	11,900	39,100	1,300	526	428	<500
MFP-1a-12 (A)	S-4551	186	546	12,000	39,500	1,310	543	371	<500
MFP-1a-24 (A)	S-4553	130	506	11,300	39,500	1,300	514	403	<500
MFP-1a-11 (A)	S-4554	140	537	11,500	39,600	1,340	546	421	<500
MFP-1a-21 (A)	S-4556	136	527	11,100	39,100	1,310	537	410	<500
MFP-1a-13 (A)	S-4559	135	526	11,000	39,000	1,310	537	410	<500
MFP-1a-22 (A)	S-4561	140	543	11,400	40,600	1,360	560	425	<500
MFP-1a-51 (A)	S-4563	140	541	12,200	39,700	1,310	530	429	<500
Values below calibration curve									
Average		143.4	534.2	11,611	39,755.6	1,325.6	540.9	415.7	----
Standard Deviation		16.5	15.2	448.5	871.9	31.3	18.2	20.8	----
Percent Relative Standard Deviation		11.47	2.85	3.86	2.19	2.36	3.37	5.01	----
Maximum		186	558	12,200	41,700	1,390	575	444	0
Minimum		130	506	11,000	39,000	1,300	514	371	0
Range		56.00	52.00	1,200.00	2,700.00	90.00	61.00	73.00	0.00
Range (%)		39.04	9.73	10.33	6.79	6.79	11.28	17.56	----

Table C- 5. LAW-High Bound Melter Feed Slurry Elemental Results (weight percent - calcined at 1100 degrees Celsius)

Sample ID	Lab ID	Al	B	Ca	Fe	K	Mg	Na	Si	Ti	Zn	Zr
MFP-2a-12 (A)	S-4598	3.23	1.15	1.93	5.43	0.987	1.15	3.27	29.2	1.70	3.43	2.95
MFP-2a-12 (B)	S-4598	3.24	1.04	1.91	5.43	0.999	1.14	3.30	29.2	1.71	3.44	2.98
MFP-2a-21 (A)	S-4599	3.22	0.987	1.91	5.41	1.01	0.939	3.35	29.2	1.72	3.45	2.99
MFP-2a-21 (B)	S-4599	3.21	1.02	1.92	5.45	1.01	0.957	3.34	29.6	1.71	3.48	3.03
MFP-2a-13 (A)	S-4600	3.23	0.969	1.90	5.36	1.07	1.19	3.31	28.9	1.70	3.38	2.97
MFP-2a-13 (B)	S-4600	3.22	1.01	1.96	5.46	1.02	1.25	3.30	29.5	1.70	3.42	3.01
MFP-2a-23 (A)	S-4604	3.21	1.05	1.95	5.56	1.01	1.15	3.27	29.8	1.71	3.44	3.05
MFP-2a-23 (B)	S-4604	3.22	0.959	1.90	5.40	1.01	1.12	3.29	28.9	1.71	3.40	2.96
MFP-2a-14 (A)	S-4608	3.21	0.913	1.86	5.25	0.972	1.09	3.35	28.5	1.70	3.30	2.92
MFP-2a-14 (B)	S-4608	3.26	0.904	1.92	5.43	1.00	1.10	3.40	29.2	1.73	3.36	3.00
MFP-2a-11 (A)	S-4609	3.20	0.808	1.89	5.34	0.960	1.09	3.24	28.6	1.71	3.30	2.95
MFP-2a-11 (B)	S-4609	3.16	0.832	1.92	5.43	0.946	1.12	3.19	29.0	1.70	3.37	3.01
MFP-2a-22 (A)	S-4610	3.23	0.885	1.88	5.49	0.970	1.09	3.32	29.1	1.74	3.40	3.02
MFP-2a-22 (B)	S-4610	3.25	0.936	1.93	5.45	0.958	1.08	3.34	29.2	1.76	3.39	3.02
MFP-2a-24 (A)	S-4613	3.27	0.892	1.92	5.51	0.956	1.17	3.20	29.3	1.76	3.38	3.03
MFP-2a-24 (B)	S-4613	3.25	0.900	1.90	5.69	0.962	1.22	3.34	29.7	1.75	3.41	3.09
MFP-2a-51 (A)	S-4615	3.23	0.907	1.91	5.68	0.945	1.11	3.22	29.8	1.75	3.45	3.08
MFP-2a-51 (B)	S-4615	3.26	0.813	1.89	5.52	0.965	1.08	3.25	29.1	1.77	3.42	3.02
Average		3.23	0.94	1.91	5.46	0.99	1.11	3.29	29.20	1.73	3.40	3.01
Standard Deviation		0.03	0.09	0.02	0.11	0.03	0.08	0.06	0.37	0.02	0.05	0.05
Percent Relative Standard Deviation		0.83	9.54	1.29	1.97	3.35	6.92	1.68	1.26	1.39	1.45	1.51
Maximum		3.27	1.15	1.96	5.69	1.07	1.25	3.40	29.81	1.77	3.48	3.09
Minimum		3.16	0.81	1.86	5.25	0.94	0.94	3.19	28.47	1.70	3.30	2.92
Range		0.11	0.35	0.11	0.44	0.13	0.31	0.20	1.33	0.07	0.18	0.17
Range (%)		3.52	36.57	5.60	8.00	13.03	28.12	6.18	4.56	4.01	5.42	5.72

Below detection limit (<0.1 weight percent): Cr, Cu, Li, P, S

Table C- 6. LAW-High Bound Melter Feed Slurry Oxide Results (weight percent - calcined at 1100 degrees Celsius)

Sample ID	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SiO_2	TiO_2	ZnO	ZrO_2	Totals
MFP-2a-12 (A)	6.11	3.71	2.70	7.76	1.18	1.91	4.42	62.6	2.84	4.26	3.98	101.5
MFP-2a-12 (B)	6.12	3.35	2.67	7.77	1.20	1.89	4.46	62.5	2.85	4.27	4.02	101.1
MFP-2a-21 (A)	6.09	3.18	2.67	7.73	1.21	1.56	4.52	62.4	2.87	4.28	4.04	100.6
MFP-2a-21 (B)	6.06	3.28	2.68	7.80	1.21	1.59	4.50	63.3	2.86	4.32	4.10	101.7
MFP-2a-13 (A)	6.10	3.12	2.66	7.66	1.29	1.97	4.47	61.9	2.84	4.20	4.01	100.2
MFP-2a-13 (B)	6.08	3.27	2.75	7.81	1.23	2.08	4.46	63.0	2.85	4.24	4.07	101.9
MFP-2a-23 (A)	6.07	3.38	2.73	7.95	1.21	1.91	4.41	63.8	2.85	4.27	4.11	102.7
MFP-2a-23 (B)	6.08	3.09	2.67	7.72	1.21	1.86	4.44	61.8	2.86	4.22	4.00	99.9
MFP-2a-14 (A)	6.06	2.94	2.60	7.51	1.17	1.82	4.52	60.9	2.84	4.09	3.95	98.4
MFP-2a-14 (B)	6.16	2.91	2.68	7.76	1.20	1.83	4.59	62.4	2.89	4.17	4.05	100.7
MFP-2a-11 (A)	6.06	2.60	2.65	7.63	1.15	1.81	4.38	61.1	2.86	4.09	3.98	98.3
MFP-2a-11 (B)	5.97	2.68	2.68	7.77	1.14	1.86	4.31	62.0	2.84	4.18	4.06	99.5
MFP-2a-22 (A)	6.10	2.85	2.63	7.85	1.16	1.80	4.48	62.3	2.91	4.21	4.08	100.4
MFP-2a-22 (B)	6.15	3.01	2.70	7.80	1.15	1.79	4.51	62.5	2.93	4.21	4.07	100.9
MFP-2a-24 (A)	6.18	2.87	2.68	7.87	1.15	1.94	4.33	62.7	2.94	4.19	4.09	100.9
MFP-2a-24 (B)	6.15	2.90	2.65	8.14	1.15	2.02	4.50	63.5	2.92	4.23	4.18	102.3
MFP-2a-51 (A)	6.10	2.92	2.67	8.13	1.13	1.84	4.35	63.7	2.93	4.28	4.16	102.2
MFP-2a-51 (B)	6.17	2.62	2.65	7.89	1.16	1.79	4.38	62.3	2.95	4.24	4.08	100.2
Average	6.10	3.04	2.67	7.81	1.18	1.85	4.45	62.49	2.88	4.22	4.06	----
Standard Deviation	0.05	0.29	0.03	0.15	0.04	0.13	0.07	0.79	0.04	0.06	0.06	----
Percent Relative Standard Deviation	0.83	9.54	1.29	1.97	3.35	6.92	1.68	1.26	1.39	1.45	1.51	----
Maximum	6.18	3.71	2.75	8.14	1.29	2.08	4.59	63.79	2.95	4.32	4.18	----
Minimum	5.97	2.60	2.60	7.51	1.13	1.56	4.31	60.94	2.84	4.09	3.95	----
Range	0.21	1.11	0.15	0.62	0.15	0.52	0.27	2.85	0.12	0.23	0.23	----
Range (%)	3.52	36.57	5.60	8.00	13.03	28.12	6.18	4.56	4.01	5.42	5.72	----

Table C- 7. LAW-High Bound Melter Feed Slurry Solids and Density Results

Sample ID	Total Solids (weight percent)	Undissolved Solids (weight percent)	Dissolved Solids (weight percent)	Calcined Solids (weight percent)	Density (kilograms/liter)
MFP-2a-12 (A)	69.0%	58.7%	10.3%	64.6%	1.9049
MFP-2a-12 (B)	68.9%	58.6%	10.3%	64.5%	
MFP-2a-21 (A)	69.1%	IS	IS	64.7%	1.8786
MFP-2a-21 (B)	69.1%	IS	IS	64.7%	
MFP-2a-13 (A)	68.9%	58.5%	10.4%	64.5%	1.8712
MFP-2a-13 (B)	68.9%	58.8%	10.1%	64.5%	
MFP-2a-23 (A)	69.2%	IS	IS	64.7%	1.9760
MFP-2a-23 (B)	68.9%	IS	IS	64.5%	
MFP-2a-14 (A)	68.9%	58.6%	10.3%	64.6%	1.8689
MFP-2a-14 (B)	69.0%	58.9%	10.1%	64.5%	
MFP-2a-11 (A)	69.0%	58.9%	10.1%	64.6%	1.8974
MFP-2a-11 (B)	69.0%	58.9%	10.0%	64.6%	
MFP-2a-22 (A)	69.2%	IS	IS	64.8%	1.8994
MFP-2a-22 (B)	69.2%	IS	IS	64.8%	
MFP-2a-24 (A)	69.3%	IS	IS	64.9%	1.8946
MFP-2a-24 (B)	69.3%	IS	IS	64.9%	
MFP-2a-51 (A)	69.1%	59.1%	10.0%	64.8%	1.8804
MFP-2a-51 (B)	69.2%	59.2%	10.0%	64.8%	
Average	69%	59%	10%	65%	1.90
Standard Deviation	0.14%	0.22%	0.15%	0.14%	0.03
Percent Relative Standard Deviation	0.20	0.38	1.47	0.21	1.71
Maximum	69%	59%	10%	65%	1.98
Minimum	69%	58%	10%	64%	1.87
Range	0.00	0.01	0.00	0.00	0.11
Range (%)	0.63	1.23	3.83	0.67	5.65

IS = Insufficient Sample

Table C- 8. LAW-High Bound Melter Feed Slurry Anion Results (milligrams/Kilogram – water dilutions)

Sample ID	F	Cl	NO_2	NO_3	SO_4	C_2O_4	HCO_2	PO_4
MFP-2a-12 (A)	78.6	263	6,890	19,500	650	356	238	<500
MFP-2a-21 (A)	84.8	283	7,510	21,100	701	368	254	<500
MFP-2a-13 (A)	77.4	267	6,950	19,700	673	335	234	<500
MFP-2a-23 (A)	77.7	271	7,020	19,900	671	322	241	<500
MFP-2a-14 (A)	75.6	268	6,890	19,500	667	314	230	<500
MFP-2a-11 (A)	77.4	268	7,010	19,700	663	331	238	<500
MFP-2a-22 (A)	78.1	268	7,090	19,800	660	341	239	<500
MFP-2a-24 (A)	77.8	268	7,080	19,800	660	345	235	<500
MFP-2a-51 (A)	77.4	273	7,070	20,000	677	340	236	<500
Values below calibration curve								
Average	78.3	269.9	7,056.7	1,9888.9	669.1	339.1	238.3	----
Standard Deviation	2.6	5.6	186.3	483.3	14.5	16.5	6.7	----
Percent Relative Standard Deviation	3.28	2.08	2.64	2.43	2.16	4.85	2.81	----
Maximum	84.8	283	7510	21,100	701	368	254	0
Minimum	75.6	263	6890	19,500	650	314	230	0
Range	9.20	20.00	620.00	1,600.00	51.00	54.00	24.00	0.00
Range (%)	11.75	7.41	8.79	8.04	7.62	15.92	10.07	----

Table C- 9. HLW-Low Bound Melter Feed Slurry Elemental Results (weight percent - calcined at 1100 degrees Celsius)

Sample ID	Lab ID	Al	B	Fe	K	Li	Na	P	Si	Zn	Zr
MFP-3a-21 (A)	S-4484	4.31	2.70	9.39	0.157	1.83	8.60	0.173	23.7	1.76	2.67
MFP-3a-21 (B)	S-4484	4.33	2.74	9.68	0.160	1.84	8.74	0.171	23.2	1.66	2.65
MFP-3a-11 (A)	S-4485	4.27	3.77	8.19	0.142	1.61	9.34	0.158	22.3	1.52	2.40
MFP-3a-11 (B)	S-4485	4.25	3.77	8.14	0.144	1.60	9.13	0.157	22.3	1.49	2.37
MFP-3a-24 (A)	S-4487	4.38	2.89	9.06	0.159	1.76	8.53	0.169	22.8	1.61	2.60
MFP-3a-24 (B)	S-4487	4.51	2.87	8.93	0.153	1.75	8.80	0.168	23.5	1.65	2.56
MFP-3a-13 (A)	S-4490	4.28	3.55	8.64	0.143	1.69	9.47	0.163	22.6	1.60	2.49
MFP-3a-13 (B)	S-4490	4.26	3.54	8.75	0.144	1.72	9.39	0.166	22.5	1.58	2.53
MFP-3a-12 (A)	S-4491	4.20	3.33	8.85	0.147	1.74	9.30	0.160	22.3	1.61	2.53
MFP-3a-12 (B)	S-4491	4.22	3.43	8.90	0.146	1.76	9.37	0.164	22.4	1.61	2.56
MFP-3a-14 (A)	S-4494	4.37	3.59	8.55	0.152	1.68	9.35	0.155	22.1	1.55	2.47
MFP-3a-14 (B)	S-4494	4.34	3.57	8.65	0.151	1.69	9.32	0.155	21.9	1.55	2.49
MFP-3a-23 (A)	S-4496	4.45	2.91	8.81	0.158	1.73	8.82	0.170	22.9	1.62	2.52
MFP-3a-23 (B)	S-4496	4.50	2.92	8.80	0.159	1.72	8.89	0.170	23.1	1.66	2.54
MFP-3a-22 (A)	S-4498	4.41	3.03	9.00	0.154	1.76	8.88	0.171	22.6	1.64	2.58
MFP-3a-22 (B)	S-4498	4.42	3.00	8.85	0.154	1.76	8.90	0.167	22.6	1.64	2.53
MFP-3a-51 (A)	S-4500	4.25	4.49	7.99	0.141	1.77	9.98	0.150	21.0	1.53	2.32
MFP-3a-51 (B)	S-4500	4.21	4.29	8.12	0.137	1.62	9.89	0.151	20.8	1.52	2.34
Average	----	4.33	3.36	8.74	0.15	1.72	9.15	0.16	22.46	1.60	2.51
Standard Deviation	----	0.10	0.52	0.44	0.01	0.07	0.41	0.01	0.74	0.06	0.10
Percent Relative Standard Deviation	----	2.25	15.45	4.99	4.85	3.80	4.50	4.54	3.32	4.05	3.97
Maximum	----	4.51	4.49	9.68	0.16	1.84	9.98	0.17	23.73	1.76	2.67
Minimum	----	4.20	2.70	7.99	0.14	1.60	8.53	0.15	20.78	1.49	2.32
Range	----	0.31	1.79	1.69	0.02	0.24	1.45	0.02	2.94	0.26	0.35
Range (%)	----	7.14	53.39	19.32	15.55	13.63	15.87	14.47	13.10	16.44	14.10

Below detection limit (< 0.1 weight percent): Ca, Cr, Cu, Mg, S, Ti

Table C- 10. HLW-Low Bound Melter Feed Slurry Oxide Results (weight percent - calcined at 1100 degrees Celsius)

Sample ID	Al_2O_3	B_2O_3	Fe_2O_3	K_2O	Li_2O	Na_2O	P_2O_5	SiO_2	ZnO	ZrO_2	Totals
MFP-3a-21 (A)	8.15	8.70	13.4	0.189	3.93	11.6	0.397	50.8	2.18	3.61	103
MFP-3a-21 (B)	8.18	8.81	13.8	0.193	3.95	11.8	0.391	49.6	2.06	3.58	102
MFP-3a-11 (A)	8.08	12.1	11.7	0.170	3.47	12.6	0.361	47.8	1.88	3.24	101
MFP-3a-11 (B)	8.04	12.2	11.6	0.173	3.44	12.3	0.359	47.7	1.85	3.20	101
MFP-3a-24 (A)	8.28	9.31	13.0	0.191	3.79	11.5	0.386	48.7	2.00	3.51	101
MFP-3a-24 (B)	8.53	9.25	12.8	0.183	3.77	11.9	0.384	50.2	2.04	3.46	102
MFP-3a-13 (A)	8.10	11.4	12.3	0.172	3.63	12.8	0.372	48.3	1.98	3.36	103
MFP-3a-13 (B)	8.05	11.4	12.5	0.173	3.69	12.7	0.380	48.1	1.96	3.41	102
MFP-3a-12 (A)	7.94	10.7	12.7	0.176	3.73	12.6	0.367	47.7	2.00	3.41	101
MFP-3a-12 (B)	7.98	11.0	12.7	0.176	3.78	12.6	0.376	47.8	1.99	3.46	102
MFP-3a-14 (A)	8.26	11.6	12.2	0.182	3.62	12.6	0.354	47.2	1.92	3.33	101
MFP-3a-14 (B)	8.21	11.5	12.4	0.181	3.64	12.6	0.355	46.9	1.92	3.36	101
MFP-3a-23 (A)	8.42	9.38	12.6	0.190	3.71	11.9	0.389	49.0	2.01	3.41	101
MFP-3a-23 (B)	8.50	9.41	12.6	0.191	3.70	12.0	0.389	49.4	2.05	3.42	102
MFP-3a-22 (A)	8.33	9.75	12.9	0.185	3.78	12.0	0.391	48.3	2.03	3.49	101
MFP-3a-22 (B)	8.35	9.67	12.7	0.185	3.77	12.0	0.384	48.5	2.04	3.42	101
MFP-3a-51 (A)	8.03	14.5	11.4	0.170	3.80	13.5	0.343	44.8	1.90	3.13	102
MFP-3a-51 (B)	7.96	13.8	11.6	0.165	3.48	13.3	0.347	44.5	1.89	3.15	100
Average	8.19	10.81	12.50	0.18	3.71	12.35	0.37	48.07	1.98	3.39	----
Standard Deviation	0.18	1.67	0.62	0.01	0.14	0.56	0.02	1.59	0.08	0.13	----
Percent Relative Standard Deviation	2.25	15.45	4.99	4.85	3.80	4.50	4.54	3.32	4.05	3.97	----
Maximum	8.53	14.47	13.84	0.19	3.95	13.47	0.40	50.77	2.18	3.61	----
Minimum	7.94	8.70	11.43	0.16	3.44	11.51	0.34	44.48	1.85	3.13	----
Range	0.58	5.77	2.41	0.03	0.51	1.96	0.05	6.30	0.33	0.48	----
Range (%)	7.14	53.39	19.32	15.55	13.63	15.87	14.47	13.10	16.44	14.10	----

Table C- 11. HLW-Low Bound Melter Feed Slurry Solids and Density Results

Sample ID	Lab ID	Total Solids (weight percent)	Undissolved Solids (weight percent)	Dissolved Solids (weight percent)	Calcined Solids (weight percent)	Density (kilograms/liter)
MFP-3a-21 (A)	S-4484	35.3%	IS	IS	29.6%	1.3491
MFP-3a-21 (B)	S-4484	35.2%	IS	IS	29.5%	
MFP-3a-11 (A)	S-4485	37.9%	30.8%	7.05%	31.8%	1.3426
MFP-3a-11 (B)	S-4485	37.5%	30.5%	7.03%	31.6%	
MFP-3a-24 (A)	S-4487	35.7%	IS	IS	29.9%	1.3574
MFP-3a-24 (B)	S-4487	36.2%	IS	IS	30.3%	
MFP-3a-13 (A)	S-4490	36.7%	29.7%	7.05%	30.8%	1.3318
MFP-3a-13 (B)	S-4490	36.2%	29.0%	7.23%	30.4%	
MFP-3a-12 (A)	S-4491	35.9%	28.7%	7.27%	30.1%	1.3284
MFP-3a-12 (B)	S-4491	35.9%	28.7%	7.19%	30.1%	
MFP-3a-14 (A)	S-4494	36.8%	29.7%	7.07%	30.8%	1.3446
MFP-3a-14 (B)	S-4494	36.3%	29.1%	7.17%	30.4%	
MFP-3a-23 (A)	S-4496	35.9%	IS	IS	30.1%	1.3488
MFP-3a-23 (B)	S-4496	35.8%	IS	IS	30.0%	
MFP-3a-22 (A)	S-4498	35.7%	IS	IS	29.9%	1.3592
MFP-3a-22 (B)	S-4498	35.7%	IS	IS	29.9%	
MFP-3a-51 (A)	S-4500	37.3%	30.3%	7.00%	31.2%	1.3332
MFP-3a-51 (B)	S-4500	37.8%	30.8%	6.93%	31.6%	
Average	----	36%	30%	7%	30%	1.3439
Standard Deviation	----	1%	1%	0%	1%	0.01
Percent Relative Standard Deviation	----	2.26	2.85	1.55	2.34	0.82
Maximum	----	38%	31%	7%	32%	1.36
Minimum	----	35%	29%	7%	29%	1.33
Range	----	0.03	0.02	0.00	0.02	0.03
Range (%)	----	7.30	7.61	4.95	7.85	2.29

IS = Insufficient Sample

Table C- 12. HLW-Low Bound Melter Feed Slurry Anion Results (milligrams/Kilogram – water dilutions)

Sample ID	Cl	NO_2	NO_3	SO_4	C_2O_4	PO_4
MFP-3a-21 (A)	94.1	754	5,810	377	110	871
MFP-3a-11 (A)	99.5	784	6,303	397	113	980
MFP-3a-24 (A)	95.9	757	5,830	411	176	925
MFP-3a-13 (A)	93.1	738	5,770	399	107	863
MFP-3a-12 (A)	103	799	6,180	403	117	845
MFP-3a-14 (A)	97.6	758	5,880	382	134	906
MFP-3a-23 (A)	102	797	6,160	399	112	860
MFP-3a-22 (A)	100	774	6,000	389	110	832
MFP-3a-51 (A)	90.1	707	5,470	354	97.8	774
Values below calibration curve						
Average	97.3	763.1	5,933.7	390.1	119.6	872.9
Standard Deviation	4.3	29.4	255.8	17.1	23.2	58.9
Percent Relative Standard Deviation	4.43	3.85	4.31	4.39	19.41	6.75
Maximum	103	799	6303	411	176	980
Minimum	90.1	707	5470	354	97.8	774
Range	12.90	92.00	833.00	57.00	78.20	206.00
Range (%)	13.26	12.06	14.04	14.61	65.36	23.60

Below Detection Limit (<500 parts per million): fluorine (F), formate

Table C- 13. HLW-High Bound Melter Feed Slurry Elemental Results (weight percent - calcined at 1100 degrees Celsius)

Sample ID	Lab ID	Al	B	Fe	Li	Na	Si	Zn	Zr
MFP-4a-13 (A)	S-4505	4.92	3.32	8.80	1.73	7.80	23.3	1.57	2.59
MFP-4a-13 (B)	S-4505	4.90	3.24	8.82	1.73	7.74	23.2	1.55	2.61
MFP-4a-12 (A)	S-4506	4.89	3.29	8.89	1.74	7.72	23.1	1.57	2.64
MFP-4a-12 (B)	S-4506	4.82	3.24	8.92	1.75	7.60	22.7	1.56	2.65
MFP-4a-22 (A)	S-4507	4.80	3.34	8.83	1.74	7.70	22.7	1.56	2.65
MFP-4a-22 (B)	S-4507	4.81	3.28	9.05	1.73	7.69	22.7	1.55	2.60
MFP-4a-23 (A)	S-4509	4.77	3.35	8.91	1.73	7.76	22.7	1.56	2.63
MFP-4a-23 (B)	S-4509	4.74	3.34	8.81	1.72	7.72	22.6	1.54	2.60
MFP-4a-24 (A)	S-4510	4.73	3.43	8.77	1.71	7.78	22.4	1.53	2.60
MFP-4a-24 (B)	S-4510	4.74	3.45	8.85	1.72	7.78	22.5	1.55	2.62
MFP-4a-14 (A)	S-4512	4.75	3.34	8.82	1.71	7.63	22.5	1.51	2.57
MFP-4a-14 (B)	S-4512	4.71	3.36	8.97	1.74	7.57	22.4	1.56	2.62
MFP-4a-11 (A)	S-4514	4.72	3.20	9.45	1.70	7.57	22.3	1.50	2.52
MFP-4a-11 (B)	S-4514	4.75	3.39	8.94	1.73	7.62	22.5	1.56	2.61
MFP-4a-21 (A)	S-4515	4.69	3.51	8.77	1.71	7.73	22.2	1.52	2.58
MFP-4a-21 (B)	S-4515	4.77	3.55	8.83	1.71	7.91	22.6	1.53	2.58
MFP-4a-51 (A)	S-4520	4.81	3.42	8.88	1.72	7.83	22.8	1.53	2.61
MFP-4a-51 (B)	S-4520	4.80	3.35	9.38	1.70	7.78	22.7	1.53	2.58
Average	----	4.78	3.35	8.93	1.72	7.72	22.65	1.54	2.60
Standard Deviation	----	0.07	0.09	0.19	0.02	0.09	0.29	0.02	0.03
Percent Relative Standard Deviation	----	1.40	2.76	2.16	0.88	1.22	1.30	1.25	1.23
Maximum	----	4.92	3.55	9.45	1.75	7.91	23.26	1.57	2.65
Minimum	----	4.69	3.20	8.77	1.70	7.57	22.20	1.50	2.52
Range	----	0.23	0.35	0.68	0.05	0.35	1.06	0.07	0.13
Range (%)	----	4.91	10.49	7.67	2.99	4.48	4.68	4.55	5.13

Below Detection Limit (< 0.1 weight percent): Ca, Cr, Cu, K, Mg, P, S, Ti

Table C- 14. HLW-High Bound Melter Feed Slurry Oxide Results (weight percent - calcined at 1100 degrees Celsius)

Sample ID	Al_2O_3	B_2O_3	Fe_2O_3	Li_2O	Na_2O	SiO_2	ZnO	ZrO_2	Totals
MFP-4a-13 (A)	9.30	10.7	12.6	3.73	10.5	49.8	1.94	3.49	102
MFP-4a-13 (B)	9.26	10.4	12.6	3.73	10.4	49.6	1.92	3.52	102
MFP-4a-12 (A)	9.24	10.6	12.7	3.75	10.4	49.5	1.95	3.57	102
MFP-4a-12 (B)	9.11	10.4	12.8	3.76	10.3	48.6	1.94	3.58	100
MFP-4a-22 (A)	9.07	10.8	12.6	3.75	10.4	48.6	1.93	3.58	101
MFP-4a-22 (B)	9.09	10.6	12.9	3.72	10.4	48.6	1.93	3.51	101
MFP-4a-23 (A)	9.01	10.8	12.7	3.72	10.5	48.5	1.94	3.54	101
MFP-4a-23 (B)	8.96	10.7	12.6	3.69	10.4	48.3	1.91	3.52	100
MFP-4a-24 (A)	8.94	11.1	12.5	3.68	10.5	47.9	1.90	3.51	100
MFP-4a-24 (B)	8.95	11.1	12.7	3.70	10.5	48.1	1.92	3.53	100
MFP-4a-14 (A)	8.98	10.8	12.6	3.68	10.3	48.1	1.88	3.47	99.8
MFP-4a-14 (B)	8.90	10.8	12.8	3.74	10.2	47.9	1.93	3.54	99.9
MFP-4a-11 (A)	8.92	10.3	13.5	3.66	10.2	47.8	1.87	3.40	99.7
MFP-4a-11 (B)	8.98	10.9	12.8	3.72	10.3	48.0	1.93	3.53	100
MFP-4a-21 (A)	8.86	11.3	12.5	3.67	10.4	47.5	1.88	3.48	99.7
MFP-4a-21 (B)	9.02	11.4	12.6	3.67	10.7	48.3	1.90	3.48	101
MFP-4a-51 (A)	9.10	11.0	12.7	3.70	10.6	48.8	1.90	3.53	101
MFP-4a-51 (B)	9.07	10.8	13.4	3.65	10.5	48.5	1.90	3.49	101
Average	9.04	10.80	12.77	3.71	10.42	48.47	1.91	3.52	----
Standard Deviation	0.13	0.30	0.28	0.03	0.13	0.63	0.02	0.04	----
Percent Relative Standard Deviation	1.40	2.76	2.16	0.88	1.22	1.30	1.25	1.23	----
Maximum	9.30	11.43	13.51	3.76	10.68	49.78	1.95	3.58	----
Minimum	8.86	10.30	12.54	3.65	10.21	47.51	1.87	3.40	----
Range	0.44	1.13	0.98	0.11	0.47	2.27	0.09	0.18	----
Range (%)	4.91	10.49	7.67	2.99	4.48	4.68	4.55	5.13	----

Table C- 15. HLW-High Bound Melter Feed Slurry Solids and Density Results

Sample ID	Lab ID	Total Solids (weight percent)	Undissolved Solids (weight percent)	Dissolved Solids (weight percent)	Calcined Solids (weight percent)	Density (kilograms/liter)
MFP-4a-13 (A)	S-4505	61.5%	53.4%	8.04%	51.6%	1.5960
MFP-4a-13 (B)	S-4505	61.5%	53.0%	8.48%	51.6%	
MFP-4a-12 (A)	S-4506	61.4%	53.3%	8.14%	51.5%	1.6755
MFP-4a-12 (B)	S-4506	61.4%	53.4%	8.02%	51.6%	
MFP-4a-22 (A)	S-4507	66.3%	IS	IS	51.5%	1.6723
MFP-4a-22 (B)	S-4507	61.9%	IS	IS	51.6%	
MFP-4a-23 (A)	S-4509	71.0%	IS	IS	51.5%	1.6822
MFP-4a-23 (B)	S-4509	61.6%	IS	IS	51.6%	
MFP-4a-24 (A)	S-4510	66.5%	IS	IS	51.7%	1.6782
MFP-4a-24 (B)	S-4510	66.2%	IS	IS	51.7%	
MFP-4a-14 (A)	S-4512	61.5%	53.4%	8.09%	51.6%	1.6916
MFP-4a-14 (B)	S-4512	61.7%	53.6%	8.01%	51.6%	
MFP-4a-11 (A)	S-4514	61.6%	53.7%	7.87%	51.6%	1.6147
MFP-4a-11 (B)	S-4514	61.6%	53.6%	7.99%	51.6%	
MFP-4a-21 (A)	S-4515	61.6%	IS	IS	51.6%	1.6736
MFP-4a-21 (B)	S-4515	72.7%	IS	IS	51.7%	
MFP-4a-51 (A)	S-4520	62.0%	54.0%	7.94%	51.8%	1.5972
MFP-4a-51 (B)	S-4520	61.8%	53.8%	7.98%	51.9%	
Average	----	64%	54%	8%	52%	1.6535
Standard Deviation	----	4%	0%	0%	0%	0.04
Percent Relative Standard Deviation	----	5.56	0.56	2.05	0.17	2.35
Maximum	----	73%	54%	8%	52%	1.69
Minimum	----	61%	53%	8%	52%	1.60
Range	----	0.11	0.01	0.01	0.00	0.10
Range (%)	----	17.83	1.97	7.66	0.59	5.78

IS = Insufficient Sample

Table C- 16. HLW-High Bound Melter Feed Slurry Anion Results (milligrams/Kilogram – water dilutions)

Sample ID	Lab ID	Cl	NO_2	NO_3	SO_4	C_2O_4
MFP-4a-13 (A)	S-4505	85.9	418	10,300	391	269
MFP-4a-12 (A)	S-4506	90.3	401	10,000	369	224
MFP-4a-22 (A)	S-4507	91.6	406	10,100	371	207
MFP-4a-23 (A)	S-4509	87	394	10,100	355	214
MFP-4a-24 (A)	S-4510	96.5	418	10,200	377	179
MFP-4a-14 (A)	S-4512	90.1	408	10,200	359	167
MFP-4a-11 (A)	S-4514	96.6	420	10,200	374	146
MFP-4a-21 (A)	S-4515	87	409	10,300	357	187
MFP-4a-51 (A)	S-4520	97.8	408	10,200	354	187
Values below calibration curve						
Average	----	91.4	409.1	10,177.8	367.4	197.8
Standard Deviation	----	4.6	8.5	97.2	12.4	35.9
Percent Relative Standard Deviation	----	4.98	2.09	0.95	3.36	18.16
Maximum	----	97.8	420	10,300	391	269
Minimum	----	85.9	394	10,000	354	146
Range	----	11.90	26.00	300.00	37.00	123.00
Range (%)	----	13.02	6.36	2.95	10.07	62.19

Below Detection Limits (< 500 parts per million): fluorine (F), Formate, Phosphate

Table C- 17. HLW-High Bound Melter Feed Slurry Repeat Elemental Results (weight percent - calcined at 1100 degrees Celsius)

Sample ID	Lab ID	Al	B	Fe	K	Li	Na	Si	Zn	Zr
MFP-4b-13 (A)	S-4576	4.94	3.60	7.91	0.122	1.81	7.33	22.6	1.65	2.76
MFP-4b-13 (B)	S-4576	4.92	3.61	7.82	0.116	1.80	7.30	22.4	1.63	2.76
MFP-4b-12 (A)	S-4577	4.86	3.64	7.71	0.115	1.78	7.25	22.1	1.60	2.72
MFP-4b-12 (B)	S-4577	4.87	3.67	7.75	0.126	1.79	7.24	22.1	1.63	2.74
MFP-4b-22 (A)	S-4578	4.88	3.65	7.75	0.124	1.78	7.25	22.2	1.62	2.74
MFP-4b-22 (B)	S-4578	4.87	3.63	7.73	0.126	1.77	7.17	22.2	1.62	2.73
MFP-4b-23 (A)	S-4580	4.97	3.51	7.92	0.131	1.80	6.99	22.8	1.66	2.80
MFP-4b-23 (B)	S-4580	4.90	3.47	7.78	0.127	1.77	7.21	22.4	1.62	2.76
MFP-4b-24 (A)	S-4581	4.80	3.47	7.62	0.127	1.76	7.16	22.0	1.58	2.71
MFP-4b-24 (B)	S-4581	4.76	3.42	7.55	0.122	1.77	7.22	21.8	1.59	2.67
MFP-4b-14 (A)	S-4583	4.80	3.48	7.78	0.119	1.76	7.14	21.8	1.60	2.70
MFP-4b-14 (B)	S-4583	4.91	3.55	7.78	0.118	1.79	7.14	22.5	1.64	2.77
MFP-4b-11 (A)	S-4585	4.73	3.66	7.54	0.120	1.72	7.34	21.7	1.57	2.66
MFP-4b-11 (B)	S-4585	4.71	3.68	7.48	0.118	1.72	7.25	21.6	1.56	2.65
MFP-4b-21 (A)	S-4586	4.67	3.71	7.46	0.122	1.72	7.33	21.5	1.57	2.62
MFP-4b-21 (B)	S-4586	4.75	3.72	7.60	0.119	1.73	7.11	21.9	1.58	2.67
MFP-4b-51 (A)	S-4591	4.76	3.51	7.60	0.126	1.73	7.39	21.8	1.58	2.68
MFP-4b-51 (B)	S-4591	4.82	3.61	7.70	0.119	1.76	7.21	22.2	1.59	2.71
Average	----	4.83	3.59	7.69	0.12	1.76	7.22	22.08	1.61	2.71
Standard Deviation	----	0.09	0.09	0.14	0.00	0.03	0.10	0.36	0.03	0.05
Percent Relative Standard Deviation	----	1.77	2.56	1.77	3.58	1.66	1.35	1.64	1.84	1.82
Maximum	----	4.97	3.72	7.92	0.13	1.81	7.39	22.78	1.66	2.80
Minimum	----	4.67	3.42	7.46	0.12	1.72	6.99	21.48	1.56	2.62
Range	----	0.30	0.31	0.47	0.02	0.09	0.40	1.30	0.09	0.18
Range (%)	----	6.23	8.54	6.05	12.55	5.00	5.52	5.90	5.65	6.69

Below detection limit (< 0.1 weight percent): Ca, Cr, Cu, Mg, P, S, Ti

Table C- 18. HLW-High Bound Melter Feed Slurry Repeat Oxide Results (weight percent - calcined at 1100 degrees Celsius)

Sample ID	Al_2O_3	B_2O_3	Fe_2O_3	K_2O	Li_2O	Na_2O	SiO_2	ZnO	ZrO_2	Totals
MFP-4b-13 (A)	9.33	11.6	11.3	0.146	3.89	9.89	48.4	2.05	3.73	100
MFP-4b-13 (B)	9.30	11.6	11.2	0.139	3.88	9.86	47.9	2.02	3.73	99.6
MFP-4b-12 (A)	9.18	11.7	11.0	0.138	3.83	9.79	47.3	1.98	3.67	98.6
MFP-4b-12 (B)	9.20	11.8	11.1	0.151	3.84	9.77	47.3	2.02	3.70	98.9
MFP-4b-22 (A)	9.22	11.8	11.1	0.149	3.82	9.78	47.6	2.01	3.69	99.1
MFP-4b-22 (B)	9.20	11.7	11.1	0.152	3.80	9.68	47.4	2.01	3.68	98.7
MFP-4b-23 (A)	9.39	11.3	11.3	0.157	3.87	9.44	48.8	2.05	3.78	100
MFP-4b-23 (B)	9.26	11.2	11.1	0.153	3.80	9.74	48.0	2.01	3.73	99.0
MFP-4b-24 (A)	9.07	11.2	10.9	0.153	3.77	9.66	47.1	1.95	3.66	97.5
MFP-4b-24 (B)	8.99	11.0	10.8	0.147	3.81	9.74	46.6	1.97	3.60	96.7
MFP-4b-14 (A)	9.07	11.2	11.1	0.142	3.78	9.65	46.6	1.98	3.64	97.2
MFP-4b-14 (B)	9.27	11.4	11.1	0.142	3.85	9.64	48.1	2.04	3.74	99.3
MFP-4b-11 (A)	8.93	11.8	10.8	0.144	3.70	9.91	46.4	1.95	3.59	97.2
MFP-4b-11 (B)	8.91	11.8	10.7	0.142	3.70	9.79	46.3	1.94	3.57	96.9
MFP-4b-21 (A)	8.82	11.9	10.7	0.146	3.70	9.90	46.0	1.94	3.53	96.6
MFP-4b-21 (B)	8.98	12.0	10.9	0.143	3.71	9.60	46.8	1.96	3.60	97.6
MFP-4b-51 (A)	8.99	11.3	10.9	0.151	3.72	10.0	46.7	1.96	3.62	97.2
MFP-4b-51 (B)	9.10	11.6	11.0	0.143	3.79	9.74	47.5	1.97	3.66	98.5
Average	9.12	11.56	11.00	0.15	3.79	9.75	47.26	1.99	3.66	----
Standard Deviation	0.16	0.30	0.19	0.01	0.06	0.13	0.78	0.04	0.07	----
Percent Relative Standard Deviation	1.77	2.56	1.77	3.58	1.66	1.35	1.64	1.84	1.82	----
Maximum	9.39	11.98	11.33	0.16	3.89	9.98	48.76	2.05	3.78	----
Minimum	8.82	11.00	10.66	0.14	3.70	9.44	45.97	1.94	3.53	----
Range	0.57	0.99	0.67	0.02	0.19	0.54	2.79	0.11	0.25	----
Range (%)	6.23	8.54	6.05	12.55	5.00	5.52	5.90	5.65	6.69	----

Table C- 19. HLW-High Bound Melter Feed Slurry Repeat Solids and Density Results

Sample	Total Solids (weight percent)	Undissolved Solids (weight percent)	Dissolved Solids (weight percent)	Calcined Solids (weight percent)	Density (kilograms/liter)
MFP-4b-13 (A)	61.4%	53.3%	8.14%	51.7%	1.6387
MFP-4b-13 (B)	61.4%	53.2%	8.16%	51.7%	
MFP-4b-12 (A)	61.4%	53.2%	8.22%	51.7%	1.6388
MFP-4b-12 (B)	61.4%	53.3%	8.17%	51.7%	
MFP-4b-22 (A)	61.2%	IS	IS	51.5%	1.6357
MFP-4b-22 (B)	61.5%	IS	IS	51.8%	
MFP-4b-23 (A)	61.5%	IS	IS	51.7%	1.635
MFP-4b-23 (B)	61.5%	IS	IS	51.8%	
MFP-4b-24 (A)	61.5%	IS	IS	51.8%	1.6389
MFP-4b-24 (B)	61.5%	IS	IS	51.8%	
MFP-4b-14 (A)	61.4%	53.0%	8.36%	51.7%	1.6359
MFP-4b-14 (B)	61.6%	53.4%	8.23%	51.7%	
MFP-4b-11 (A)	63.3%	55.3%	7.97%	51.7%	1.6807
MFP-4b-11 (B)	61.5%	53.2%	8.25%	51.7%	
MFP-4b-21 (A)	61.6%	IS	IS	51.9%	1.6345
MFP-4b-21 (B)	61.5%	IS	IS	51.9%	
MFP-4b-51 (A)	67.3%	59.8%	7.45%	51.9%	1.6576
MFP-4b-51 (B)	61.8%	53.5%	8.30%	51.9%	
Average	62%	54%	8%	52%	1.6503
Standard Deviation	1%	2%	0%	0%	0.019
Percent Relative Standard Deviation	2.28	3.91	3.19	0.18	1.155
Maximum	67%	60%	8%	52%	1.681
Minimum	61%	53%	7%	52%	1.636
Range	0.06	0.07	0.01	0.00	0.045
Range (%)	9.82	12.82	12.21	0.77	2.751

IS – Insufficient Sample

Table C- 20. HLW-High Bound Melter Feed Slurry Repeat Anion Results (milligrams/Kilogram – water dilutions)

Sample ID	Cl	NO_2	NO_3	SO_4	C_2O_4
MFP-4b-13 (A)	93.9	275	10,400	383	414
MFP-4b-12 (A)	90.4	267	10,100	362	320
MFP-4b-22 (A)	107	281	10,500	376	357
MFP-4b-23 (A)	93.8	276	10,300	371	254
MFP-4b-24 (A)	96.7	279	10,400	378	251
MFP-4b-14 (A)	96.1	277	10,300	376	244
MFP-4b-11 (A)	90.6	274	10,200	360	297
MFP-4b-21 (A)	93	277	10,400	361	232
MFP-4b-51 (A)	97.2	281	10,500	370	221
Values below calibration curve					
Average	95.4	276.3	10,344.4	370.8	287.8
Standard Deviation	5.0	4.3	133.3	8.3	65.0
Percent Relative Standard Deviation	5.22	1.55	1.29	2.23	22.60
Maximum	107	281	10,500	383	414
Minimum	90.4	267	10,100	360	221
Range	16.60	14.00	400.00	23.00	193.00
Range (%)	17.40	5.07	3.87	6.20	67.07

Below Detection Limit (< 500 parts per million): fluorine (F), Formate, Phosphate

Appendix D. Glass Sample Results

Table D- 1. LAW-Low Bound Glass Elemental Results (elemental weight percent)

Sample ID	Lab ID	Al	B	Ca	Fe	K	Mg	Na	S	Si	Ti	Zn	Zr
MFP-1a-42 (A)	S-4547	3.18	3.58	1.42	2.41	3.59	0.326	15.6	0.147	20.5	0.981	2.47	1.80
MFP-1a-42 (B)	S-4547	3.13	3.51	1.41	2.40	3.57	0.324	15.5	0.151	20.8	0.964	2.43	1.82
MFP-1a-48 (A)	S-4549	3.13	3.12	1.30	3.33	3.16	1.26	13.8	0.131	21.0	1.09	2.27	2.01
MFP-1a-48 (B)	S-4549	3.19	3.26	1.28	3.27	3.11	1.23	13.5	0.128	20.7	1.07	2.21	2.04
MFP-1a-47 (A)	S-4550	3.29	3.72	1.42	2.46	3.59	0.357	15.7	0.152	20.5	0.974	2.44	1.91
MFP-1a-47 (B)	S-4550	3.23	3.65	1.46	2.51	3.69	0.362	16.1	0.155	20.5	0.986	2.49	1.85
MFP-1a-43 (A)	S-4552	3.17	3.70	1.44	2.40	3.68	0.281	16.0	0.157	19.9	0.986	2.49	1.81
MFP-1a-43 (B)	S-4552	3.21	3.72	1.43	2.36	3.64	0.271	15.8	0.155	19.8	0.956	2.50	1.82
MFP-1a-46 (A)	S-4557	3.19	3.66	1.40	2.55	3.57	0.358	15.2	0.153	20.5	1.008	2.46	1.85
MFP-1a-46 (B)	S-4557	3.22	3.65	1.47	2.64	3.69	0.351	15.9	0.151	20.9	0.985	2.49	1.89
MFP-1a-44 (A)	S-4558	3.34	3.73	1.42	2.55	3.59	0.348	15.5	0.148	20.3	0.991	2.44	1.93
MFP-1a-44 (B)	S-4558	3.33	3.74	1.43	2.54	3.59	0.350	15.7	0.146	20.5	1.00	2.43	1.93
MFP-1a-41 (A)	S-4560	3.44	3.91	1.42	2.70	3.60	0.364	15.7	0.158	20.4	1.06	2.46	2.09
MFP-1a-41 (B)	S-4560	3.40	3.82	1.44	2.72	3.63	0.359	15.8	0.155	20.5	1.05	2.49	2.06
MFP-1a-45 (A)	S-4562	3.24	3.60	1.42	2.79	3.56	0.332	15.4	0.145	20.9	1.02	2.42	2.01
MFP-1a-45 (B)	S-4562	3.15	3.49	1.42	2.76	3.52	0.348	15.2	0.149	19.4	1.07	2.36	1.95
Average	----	**3.24**	**3.62**	**1.41**	**2.65**	**3.55**	**0.45**	**15.4**	**0.15**	**20.44**	**1.01**	**2.43**	**1.92**
Standard Deviation	----	0.09	0.2	0.05	0.29	0.17	0.31	0.72	0.01	0.43	0.04	0.08	0.1
%RSD	----	2.89	5.48	3.64	10.84	4.73	68.95	4.7	5.72	2.08	4.31	3.4	4.95
Maximum	----	3.44	3.91	1.47	3.33	3.69	1.26	16.06	0.16	20.99	1.09	2.5	2.09
Minimum	----	3.13	3.12	1.28	2.36	3.11	0.27	13.54	0.13	19.44	0.96	2.21	1.8
Range	----	0.31	0.79	0.2	0.97	0.58	0.99	2.52	0.03	1.55	0.14	0.29	0.29
Range (%)	----	9.54	21.77	13.89	36.51	16.35	219.04	16.37	19.92	7.56	13.56	11.82	14.90

Below detection limit (<0.1 weight percent): Cr, Cu, Li, Ni, P, and Pb

Table D- 2. Elemental Results of the Glass Standards Included with the LAW-Low Bound Glasses (elemental weight percent)

Sample ID	Al	B	Ca	Cr	Cu	Fe	K	Li	Mg	Na	Ni	P	Pb	S	Si	Ti	Zn	Zr
Batch-1 (A)	2.57	2.58	0.818	0.065	0.301	8.62	2.85	2.07	0.787	6.42	0.538	<0.100	<0.010	0.016	23.2	0.380	<0.010	0.069
Batch-1 (B)	2.62	2.58	0.839	0.067	0.312	8.80	2.89	2.09	0.818	6.53	0.553	<0.100	<0.010	0.016	23.8	0.393	<0.010	0.065
ARG-1 (A)	2.60	2.91	0.995	0.064	<0.010	9.53	2.32	1.48	0.508	8.42	0.771	0.109	<0.010	0.028	22.3	0.667	0.020	0.102
ARG-1 (B)	2.58	2.86	0.974	0.061	<0.010	9.40	2.28	1.48	0.502	8.33	0.752	0.109	<0.010	0.031	22.0	0.660	0.019	0.106
LRM (A)	5.52	2.71	0.359	0.129	<0.010	0.990	1.26	<0.100	0.058	15.9	0.140	0.196	0.086	0.086	25.5	0.061	<0.010	0.667
LRM (B)	5.50	2.74	0.364	0.130	<0.010	1.07	1.26	<0.100	0.059	15.9	0.139	0.193	0.087	0.085	25.5	0.061	<0.010	0.660

Table D- 3. LAW-Low Bound Glass Oxide Results (weight percent)

Sample ID	Lab ID	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	SO_4	SiO_2	TiO_2	ZnO	ZrO_2
MFP-1a-42 (A)	S-4547	6.02	11.5	1.99	3.45	4.30	0.541	21.1	0.442	43.8	1.64	3.07	2.43
MFP-1a-42 (B)	S-4547	5.92	11.3	1.98	3.43	4.28	0.538	21.0	0.454	44.5	1.61	3.01	2.46
MFP-1a-48 (A)	S-4549	5.91	10.1	1.82	4.76	3.79	2.09	18.6	0.392	44.9	1.83	2.81	2.72
MFP-1a-48 (B)	S-4549	6.04	10.5	1.79	4.67	3.74	2.04	18.3	0.384	44.3	1.80	2.74	2.75
MFP-1a-47 (A)	S-4550	6.22	12.0	1.98	3.51	4.31	0.593	21.2	0.456	43.8	1.63	3.02	2.58
MFP-1a-47 (B)	S-4550	6.11	11.7	2.05	3.59	4.43	0.601	21.7	0.466	43.8	1.65	3.09	2.50
MFP-1a-43 (A)	S-4552	6.00	11.9	2.02	3.43	4.41	0.467	21.6	0.471	42.6	1.65	3.09	2.44
MFP-1a-43 (B)	S-4552	6.07	12.0	2.00	3.38	4.37	0.450	21.3	0.464	42.3	1.60	3.10	2.46
MFP-1a-46 (A)	S-4557	6.04	11.8	1.96	3.65	4.29	0.594	20.6	0.460	43.9	1.68	3.05	2.49
MFP-1a-46 (B)	S-4557	6.09	11.8	2.06	3.78	4.43	0.583	21.5	0.452	44.8	1.65	3.09	2.55
MFP-1a-44 (A)	S-4558	6.31	12.0	1.99	3.65	4.31	0.577	21.0	0.443	43.4	1.65	3.02	2.60
MFP-1a-44 (B)	S-4558	6.29	12.0	2.00	3.63	4.31	0.581	21.2	0.439	43.8	1.67	3.01	2.61
MFP-1a-41 (A)	S-4560	6.50	12.6	1.99	3.87	4.31	0.605	21.1	0.473	43.7	1.77	3.05	2.82
MFP-1a-41 (B)	S-4560	6.43	12.3	2.01	3.90	4.36	0.595	21.3	0.465	43.9	1.76	3.09	2.78
MFP-1a-45 (A)	S-4562	6.13	11.6	1.98	3.99	4.27	0.551	20.8	0.436	44.8	1.71	3.00	2.71
MFP-1a-45 (B)	S-4562	5.96	11.2	1.99	3.95	4.22	0.577	20.5	0.446	41.6	1.79	2.93	2.63
Average	----	6.13	11.65	1.98	3.79	4.26	0.75	20.80	0.45	43.74	1.69	3.01	2.60
St. Deviation	----	0.18	0.64	0.07	0.41	0.20	0.52	0.98	0.03	0.91	0.07	0.10	0.13
Percent Relative Standard Deviation	----	2.89	5.48	3.64	10.84	4.73	68.95	4.70	5.72	2.08	4.31	3.40	4.95
Maximum	----	6.50	12.59	2.06	4.76	4.43	2.09	21.68	0.47	44.91	1.83	3.10	2.82
Minimum	----	5.91	10.05	1.79	3.38	3.74	0.45	18.28	0.38	41.61	1.60	2.74	2.43
Range	----	0.58	2.54	0.27	1.38	0.70	1.64	3.40	0.09	3.31	0.23	0.36	0.39
Range (%)	----	9.54	21.77	13.89	36.51	16.35	219.04	16.37	19.92	7.56	13.56	11.82	14.90

Table D- 4. HLW-Low Bound Glass Elemental Results (elemental weight percent)

Sample ID	Lab ID	Al	B	Ca	Cu	Fe	K	Li	Na	P	S	Si	Zn	Zr
MFP-3a-45 (A)	S-4483	4.24	3.70	0.033	0.009	7.95	0.107	1.78	7.90	0.150	0.050	21.5	1.50	2.58
MFP-3a-45 (B)	S-4483	4.25	3.71	0.035	0.010	7.87	0.103	1.78	7.81	0.150	0.055	21.2	1.47	2.59
MFP-3a-46 (A)	S-4486	4.66	3.31	0.028	0.010	8.59	0.115	1.87	7.86	0.169	0.065	21.4	1.55	2.72
MFP-3a-46 (B)	S-4486	4.68	3.32	0.028	0.011	8.61	0.117	1.88	7.82	0.162	0.062	21.6	1.55	2.79
MFP-3a-48 (A)	S-4488	4.52	3.45	0.027	0.013	8.87	0.124	2.02	8.06	0.169	0.063	21.1	1.60	2.95
MFP-3a-48 (B)	S-4488	4.53	3.45	0.025	0.015	9.08	0.122	2.02	8.25	0.165	0.065	21.6	1.65	2.91
MFP-3a-42 (A)	S-4489	4.54	3.43	0.021	0.011	8.62	0.116	1.92	7.91	0.163	0.059	21.5	1.55	2.73
MFP-3a-42 (B)	S-4489	4.58	3.46	0.021	0.012	8.58	0.115	1.94	7.90	0.163	0.062	21.4	1.54	2.82
MFP-3a-44 (A)	S-4492	4.38	3.44	0.025	0.013	8.92	0.119	1.91	8.23	0.168	0.061	20.9	1.60	2.71
MFP-3a-44 (B)	S-4492	4.56	3.60	0.036	0.012	8.81	0.121	1.99	8.21	0.166	0.063	21.2	1.58	2.78
MFP-3a-47 (A)	S-4493	4.65	3.64	0.022	0.011	8.90	0.119	2.05	8.17	0.168	0.059	20.9	1.59	2.91
MFP-3a-47 (B)	S-4493	4.45	3.47	0.023	0.012	8.87	0.126	1.96	8.13	0.170	0.062	21.0	1.59	2.83
MFP-3a-41 (A)	S-4495	4.66	3.45	0.026	0.013	8.65	0.122	1.97	7.82	0.177	0.066	21.0	1.55	2.89
MFP-3a-41 (B)	S-4495	4.83	3.58	0.028	0.011	9.01	0.120	2.03	8.16	0.175	0.062	21.9	1.61	2.96
MFP-3a-43 (A)	S-4497	4.58	3.56	0.026	0.010	8.64	0.119	1.97	8.00	0.163	0.060	20.4	1.54	2.87
MFP-3a-43 (B)	S-4497	4.72	3.62	0.040	0.011	8.73	0.134	2.02	8.21	0.166	0.058	21.0	1.58	2.95
Average	----	**4.55**	**3.51**	**0.03**	**0.01**	**8.67**	**0.12**	**1.95**	**8.03**	**0.17**	**0.06**	**21.24**	**1.56**	**2.81**
Standard Deviation	----	0.16	0.12	0.01	0	0.34	0.01	0.08	0.17	0.01	0	0.36	0.04	0.12
Percent Relative Standard Deviation	----	3.54	3.49	20.4	12.6	3.87	6.03	4.34	2.08	4.31	6.59	1.69	2.74	4.28
Maximum	----	4.83	3.71	0.04	0.01	9.08	0.13	2.05	8.25	0.18	0.07	21.92	1.65	2.96
Minimum	----	4.24	3.31	0.02	0.01	7.87	0.1	1.78	7.81	0.15	0.05	20.43	1.47	2.58
Range	----	0.59	0.4	0.02	0.01	1.21	0.03	0.27	0.45	0.03	0.02	1.49	0.17	0.38
Range (%)	----	12.98	11.41	71.31	51.16	13.98	26.07	14.06	5.55	16.22	25.55	7.01	11.15	13.47

Below detection limit (<0.1 weight percent): Cr, Mg, Ni, Pb, and Ti

Table D- 5. Elemental Results of the Glass Standards Included with the HLW-Low Bound Glasses (elemental weight percent)

Sample ID	Al	B	Ca	Cr	Cu	Fe	K	Li	Mg	Na	Ni	P	Pb	S	Si	Ti	Zn	Zr
Batch-1 (A)	2.57	2.72	0.841	0.064	0.295	8.54	2.72	2.16	0.778	6.35	0.528	<0.100	<0.010	0.018	22.6	0.375	<0.010	0.040
Batch-1 (B)	2.59	2.63	0.872	0.065	0.303	8.78	2.83	2.15	0.795	6.52	0.545	<0.100	<0.010	0.017	23.4	0.381	<0.010	0.034
ARG-1 (A)	2.56	2.91	1.02	0.062	<0.010	9.49	2.27	1.55	0.491	8.31	0.754	0.105	<0.010	0.034	21.9	0.646	0.020	0.070
ARG-1 (B)	2.56	2.98	0.998	0.059	<0.010	9.40	2.24	1.56	0.486	8.22	0.740	0.105	<0.010	0.029	21.9	0.641	0.019	0.073
LRM (A)	5.56	2.78	0.382	0.125	<0.010	0.982	1.19	<0.100	0.056	15.3	0.140	0.193	0.085	0.082	24.9	<0.100	<0.010	0.624
LRM (B)	5.47	2.72	0.380	0.124	<0.010	0.974	1.17	<0.100	0.056	15.2	0.140	0.186	0.084	0.084	24.5	<0.100	<0.010	0.606

Table D- 6. HLW-Low Bound Glass Oxide Results (weight percent)

Sample ID	Lab ID	Al_2O_3	B_2O_3	CaO	Cu_2O	Fe_2O_3	K_2O	Li_2O	Na_2O	P_2O_5	SO_4	SiO_2	ZnO	ZrO_2
MFP-3a-45 (A)	S-4483	8.01	11.92	0.046	0.010	11.4	0.128	3.83	10.7	0.344	0.151	46.1	1.86	3.48
MFP-3a-45 (B)	S-4483	8.02	11.95	0.049	0.011	11.3	0.124	3.83	10.5	0.344	0.164	45.3	1.83	3.50
MFP-3a-46 (A)	S-4486	8.80	10.66	0.039	0.011	12.3	0.138	4.01	10.6	0.386	0.194	45.8	1.92	3.67
MFP-3a-46 (B)	S-4486	8.85	10.70	0.040	0.013	12.3	0.140	4.04	10.6	0.371	0.186	46.2	1.93	3.76
MFP-3a-48 (A)	S-4488	8.54	11.10	0.038	0.014	12.7	0.149	4.35	10.9	0.388	0.190	45.2	1.98	3.98
MFP-3a-48 (B)	S-4488	8.57	11.10	0.034	0.017	13.0	0.146	4.35	11.1	0.377	0.196	46.2	2.04	3.93
MFP-3a-42 (A)	S-4489	8.58	11.03	0.029	0.013	12.3	0.139	4.12	10.7	0.374	0.177	46.1	1.92	3.68
MFP-3a-42 (B)	S-4489	8.65	11.15	0.030	0.014	12.3	0.138	4.17	10.7	0.373	0.185	45.8	1.92	3.81
MFP-3a-44 (A)	S-4492	8.28	11.08	0.035	0.015	12.8	0.143	4.11	11.1	0.384	0.182	44.8	1.98	3.66
MFP-3a-44 (B)	S-4492	8.62	11.59	0.050	0.014	12.6	0.146	4.29	11.1	0.381	0.188	45.4	1.95	3.76
MFP-3a-47 (A)	S-4493	8.79	11.74	0.031	0.013	12.7	0.143	4.42	11.0	0.385	0.177	44.8	1.97	3.93
MFP-3a-47 (B)	S-4493	8.41	11.19	0.032	0.013	12.7	0.151	4.22	11.0	0.388	0.186	44.9	1.97	3.82
MFP-3a-41 (A)	S-4495	8.81	11.09	0.036	0.014	12.4	0.146	4.24	10.6	0.405	0.197	45.0	1.92	3.90
MFP-3a-41 (B)	S-4495	9.13	11.54	0.039	0.012	12.9	0.144	4.37	11.0	0.400	0.187	46.9	1.99	4.00
MFP-3a-43 (A)	S-4497	8.66	11.47	0.037	0.012	12.4	0.142	4.24	10.8	0.373	0.181	43.7	1.91	3.87
MFP-3a-43 (B)	S-4497	8.92	11.65	0.056	0.012	12.5	0.161	4.34	11.1	0.380	0.174	44.8	1.96	3.98
Average	----	8.60	11.31	0.04	0.01	12.40	0.14	4.18	10.84	0.38	0.18	45.45	1.94	3.80
St. Deviation	----	0.30	0.39	0.01	0.00	0.48	0.01	0.18	0.23	0.02	0.01	0.77	0.05	0.16
Percent Relative Standard Deviation	----	3.54	3.49	20.40	12.60	3.87	6.03	4.34	2.08	4.31	6.59	1.69	2.74	4.28
Maximum	----	9.13	11.95	0.06	0.02	12.98	0.16	4.42	11.14	0.41	0.20	46.91	2.04	4.00
Minimum	----	8.01	10.66	0.03	0.01	11.25	0.12	3.83	10.54	0.34	0.15	43.73	1.83	3.48
Range	----	1.12	1.29	0.03	0.01	1.73	0.04	0.59	0.60	0.06	0.05	3.19	0.22	0.51
Range (%)	----	12.98	11.41	71.31	51.16	13.98	26.07	14.06	5.55	16.22	25.55	7.01	11.15	13.47

Table D- 7. HLW-High Bound Glass Elemental Results (elemental weight percent)

Sample ID	Lab ID	Al	B	Ca	Fe	K	Li	Mg	Na	S	Si	Ti	Zn	Zr
MFP-4b-44 (A)	S-4574	5.02	3.44	0.080	7.68	0.103	1.75	0.108	7.43	0.023	22.5	0.021	1.62	2.72
MFP-4b-44 (B)	S-4574	5.07	3.37	0.080	7.53	0.100	1.77	0.106	7.33	0.020	22.2	0.021	1.58	2.76
MFP-4b-48 (A)	S-4575	5.17	3.52	0.080	7.52	0.101	1.79	0.104	7.22	0.024	21.7	0.021	1.58	2.83
MFP-4b-48 (B)	S-4575	5.20	3.48	0.080	7.46	0.103	1.80	0.106	7.30	0.022	22.2	0.022	1.57	2.84
MFP-4b-45 (A)	S-4579	4.99	3.32	0.078	7.43	0.098	1.73	0.105	7.16	0.023	22.0	0.021	1.55	2.73
MFP-4b-45 (B)	S-4579	5.01	3.32	0.082	7.54	0.100	1.74	0.107	7.41	0.020	22.2	0.021	1.59	2.74
MFP-4b-41 (A)	S-4582	5.16	3.24	0.081	7.50	0.099	1.79	0.106	7.09	0.024	22.2	0.021	1.58	2.84
MFP-4b-41 (B)	S-4582	5.09	3.23	0.080	7.57	0.101	1.77	0.107	7.15	0.021	22.4	0.021	1.58	2.81
MFP-4b-43 (A)	S-4584	5.02	3.55	0.080	7.49	0.102	1.75	0.107	7.33	0.023	22.2	0.022	1.58	2.75
MFP-4b-43 (B)	S-4584	5.16	3.58	0.079	7.49	0.099	1.79	0.105	7.33	0.021	22.3	0.021	1.59	2.82
MFP-4b-47 (A)	S-4587	4.98	3.54	0.081	7.50	0.099	1.73	0.105	7.54	0.025	22.2	0.021	1.57	2.73
MFP-4b-47 (B)	S-4587	5.16	3.73	0.079	7.48	0.098	1.79	0.105	7.47	0.019	22.3	0.021	1.57	2.81
MFP-4b-46 (A)	S-4588	5.23	3.76	0.079	7.45	0.101	1.83	0.105	7.55	0.026	22.2	0.021	1.56	2.87
MFP-4b-46 (B)	S-4588	4.98	3.56	0.078	7.30	0.100	1.74	0.104	7.33	0.026	21.7	0.021	1.54	2.73
MFP-4b-42 (A)	S-4590	5.01	3.63	0.081	7.34	0.103	1.74	0.106	7.52	0.022	21.8	0.022	1.55	2.76
MFP-4b-42 (B)	S-4590	4.84	3.52	0.085	7.20	0.099	1.68	0.101	7.40	0.020	21.1	0.020	1.52	2.66
Average	----	5.07	3.49	0.08	7.47	0.10	1.76	0.11	7.35	0.02	22.07	0.02	1.57	2.77
St. Deviation	----	0.11	0.16	0.00	0.11	0.00	0.04	0.00	0.14	0.00	0.34	0.00	0.02	0.06
Percent Relative Standard Deviation	----	2.08	4.54	2.01	1.50	1.60	2.11	1.40	1.90	9.87	1.53	1.82	1.42	2.07
Maximum	----	5.23	3.76	0.08	7.68	0.10	1.83	0.11	7.55	0.03	22.47	0.02	1.62	2.87
Minimum	----	4.84	3.23	0.08	7.20	0.10	1.68	0.10	7.09	0.02	21.10	0.02	1.52	2.66
Range	----	0.39	0.53	0.01	0.49	0.01	0.15	0.01	0.45	0.01	1.37	0.00	0.10	0.21
Range (%)	----	7.77	15.28	8.53	6.55	5.02	8.64	6.00	6.19	30.76	6.20	7.10	6.09	7.51

Below detection limit (<0.1 weight percent): Cr, Cu, P, and Pb

Table D- 8. Elemental Results of the Glass Standards Included with the HLW-High Bound Glasses (elemental weight percent)

Sample ID	Al	B	Ca	Cr	Cu	Fe	K	Li	Mg	Na	P	Pb	S	Si	Ti	Zn	Zr
Batch-1 (A)	2.42	2.47	0.791	0.064	0.296	8.59	2.74	2.02	0.788	6.56	<0.100	<0.100	0.015	23	0.375	<0.010	0.066
Batch-1 (B)	2.48	2.47	0.813	0.065	0.304	8.85	2.85	2.05	0.79	6.78	<0.100	<0.100	0.01	23.7	0.381	<0.010	0.061
ARG-1 (A)	2.38	2.65	0.969	0.063	<0.010	9.46	2.23	1.39	0.492	8.72	0.103	<0.100	0.024	22.1	0.646	0.021	0.097
ARG-1 (B)	2.42	2.8	0.952	0.06	<0.010	9.37	2.21	1.42	0.488	8.58	0.105	<0.100	0.025	21.9	0.641	0.02	0.101
LRM (A)	5.26	2.47	0.333	0.128	<0.010	0.984	1.19	<0.100	0.059	16.1	0.199	0.084	0.084	25.1	0.059	<0.010	0.661
LRM (B)	5.57	2.65	0.339	0.128	<0.010	0.992	1.2	<0.100	0.059	16.4	0.197	0.084	0.081	25.3	0.059	<0.010	0.66

Table D- 9. HLW-High Bound Glass Oxide Results (weight percent)

Sample ID	Lab ID	Al_2O_3	B_2O_3	CaO	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SO_4	SiO_2	TiO_2	ZnO	ZrO_2
MFP-4b-44 (A)	S-4574	9.50	11.1	0.112	11.0	0.123	3.77	0.179	10.0	0.070	48.1	0.036	2.00	3.67
MFP-4b-44 (B)	S-4574	9.57	10.8	0.113	10.8	0.120	3.80	0.176	9.89	0.060	47.4	0.035	1.96	3.73
MFP-4b-48 (A)	S-4575	9.77	11.3	0.113	10.7	0.121	3.85	0.173	9.74	0.073	46.5	0.035	1.96	3.82
MFP-4b-48 (B)	S-4575	9.83	11.2	0.112	10.7	0.124	3.87	0.175	9.86	0.066	47.4	0.036	1.94	3.84
MFP-4b-45 (A)	S-4579	9.43	10.7	0.109	10.6	0.118	3.72	0.175	9.67	0.070	47.1	0.034	1.93	3.68
MFP-4b-45 (B)	S-4579	9.46	10.7	0.114	10.8	0.120	3.73	0.178	10.0	0.059	47.6	0.035	1.97	3.70
MFP-4b-41 (A)	S-4582	9.75	10.4	0.113	10.7	0.119	3.84	0.175	9.58	0.073	47.5	0.035	1.95	3.83
MFP-4b-41 (B)	S-4582	9.62	10.4	0.112	10.8	0.121	3.81	0.177	9.65	0.062	48.0	0.036	1.95	3.79
MFP-4b-43 (A)	S-4584	9.50	11.4	0.112	10.7	0.122	3.77	0.177	9.90	0.069	47.5	0.037	1.96	3.71
MFP-4b-43 (B)	S-4584	9.74	11.5	0.110	10.7	0.119	3.85	0.174	9.90	0.064	47.8	0.035	1.98	3.81
MFP-4b-47 (A)	S-4587	9.41	11.4	0.114	10.7	0.119	3.72	0.175	10.2	0.075	47.5	0.035	1.95	3.68
MFP-4b-47 (B)	S-4587	9.76	12.0	0.110	10.7	0.118	3.86	0.174	10.1	0.056	47.6	0.035	1.95	3.79
MFP-4b-46 (A)	S-4588	9.89	12.1	0.111	10.6	0.122	3.93	0.175	10.2	0.077	47.4	0.036	1.94	3.87
MFP-4b-46 (B)	S-4588	9.41	11.5	0.109	10.4	0.120	3.75	0.173	9.90	0.077	46.5	0.035	1.91	3.69
MFP-4b-42 (A)	S-4590	9.47	11.7	0.113	10.5	0.124	3.73	0.176	10.2	0.066	46.8	0.036	1.92	3.72
MFP-4b-42 (B)	S-4590	9.15	11.3	0.119	10.3	0.119	3.60	0.168	10.0	0.060	45.1	0.034	1.89	3.59
Average	----	9.58	11.23	0.11	10.68	0.12	3.79	0.18	9.92	0.07	47.23	0.04	1.95	3.74
St. Deviation	----	0.20	0.51	0.00	0.16	0.00	0.08	0.00	0.19	0.01	0.72	0.00	0.03	0.08
Percent Relative Standard Deviation	----	2.08	4.54	2.01	1.50	1.60	2.11	1.40	1.90	9.87	1.53	1.82	1.42	2.07
Maximum	----	9.89	12.11	0.12	10.99	0.12	3.93	0.18	10.19	0.08	48.08	0.04	2.00	3.87
Minimum	----	9.15	10.40	0.11	10.29	0.12	3.60	0.17	9.58	0.06	45.15	0.03	1.89	3.59
Range	----	0.74	1.72	0.01	0.70	0.01	0.33	0.01	0.61	0.02	2.93	0.00	0.12	0.28
Range (%)	----	7.77	15.28	8.53	6.55	5.02	8.64	6.00	6.19	30.76	6.20	7.10	6.09	7.51

Appendix E. Rheological Property Measurements

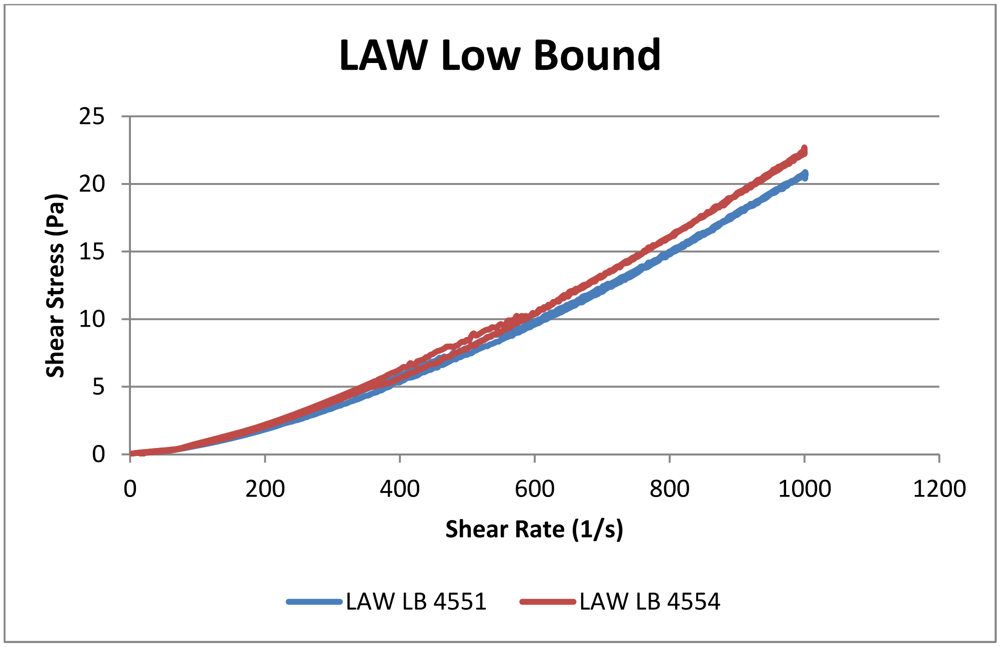


Figure E- 1. LAW-Low Bound Rheogram – 25 degrees Celsius

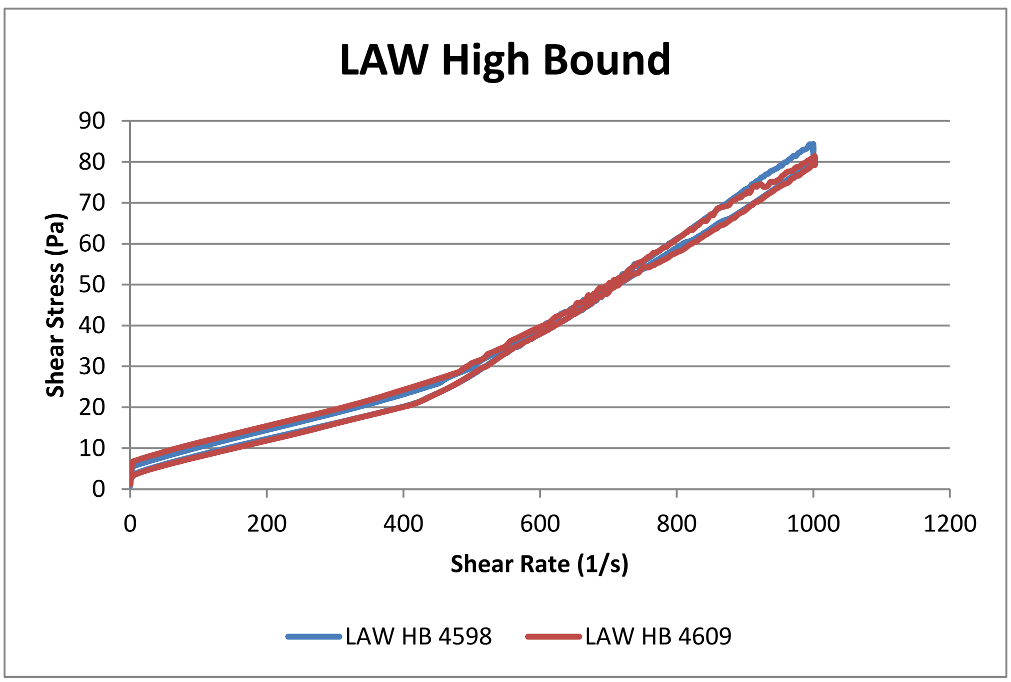


Figure E- 2. LAW-High Bound Rheogram – 25 degrees Celsius

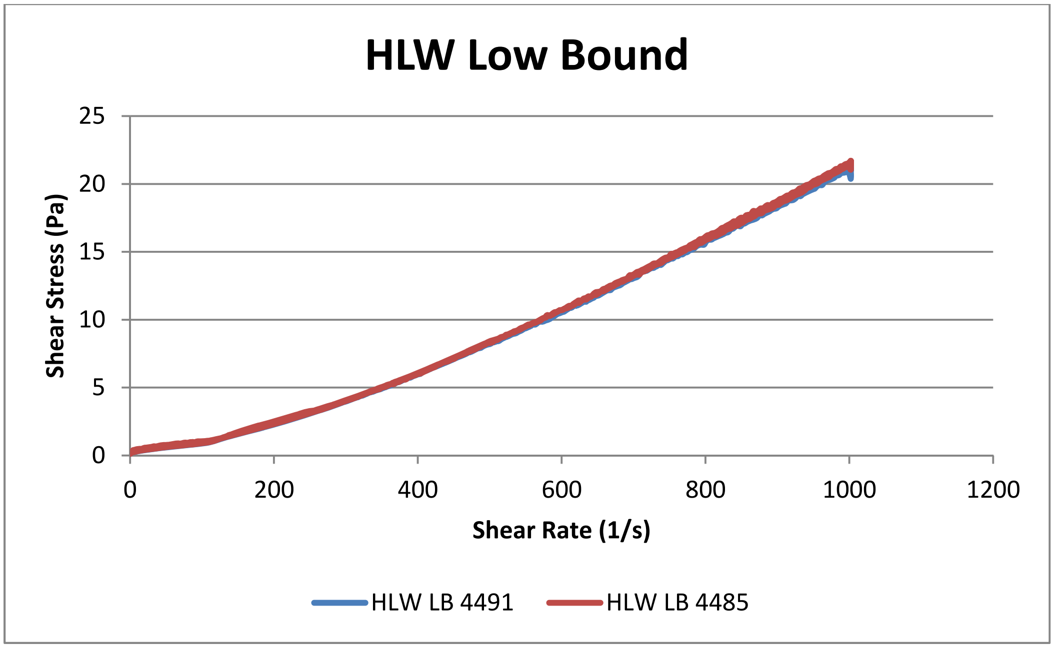


Figure E- 3. HLW-Low Bound Rheogram – 25 degrees Celsius

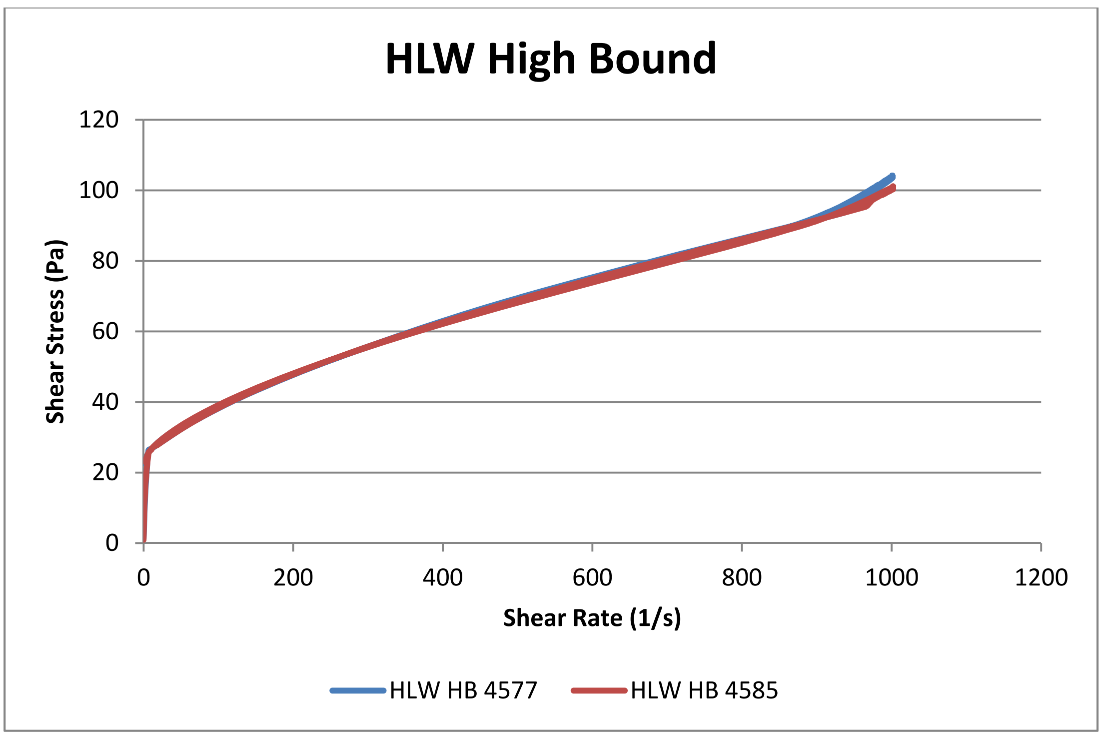


Figure E- 4. HLW-High Bound Rheogram – 25 degrees Celsius

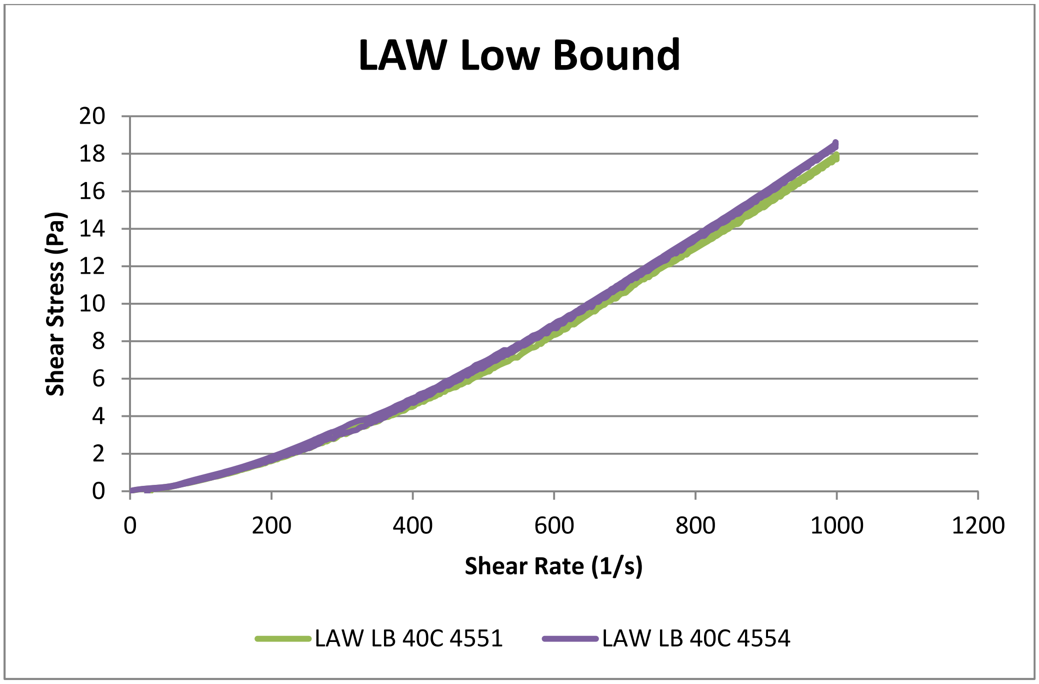


Figure E- 5. LAW-Low Bound Rheogram – 40 degrees Celsius

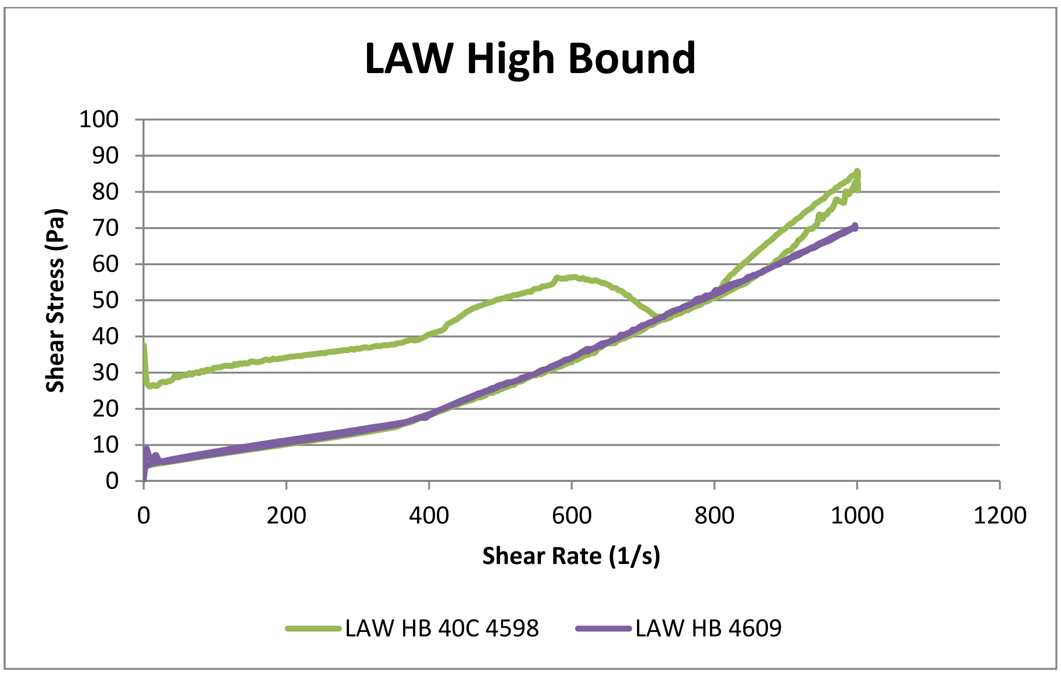


Figure E- 6. LAW-High Bound Rheogram – 40 degrees Celsius

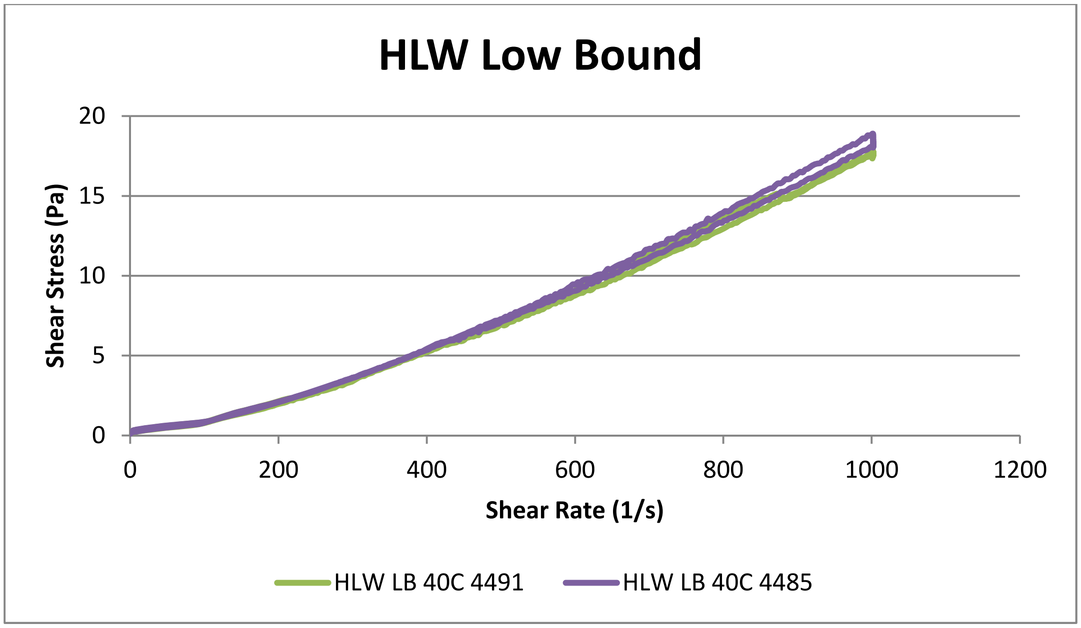


Figure E- 7. HLW-Low Bound Rheogram – 40 degrees Celsius

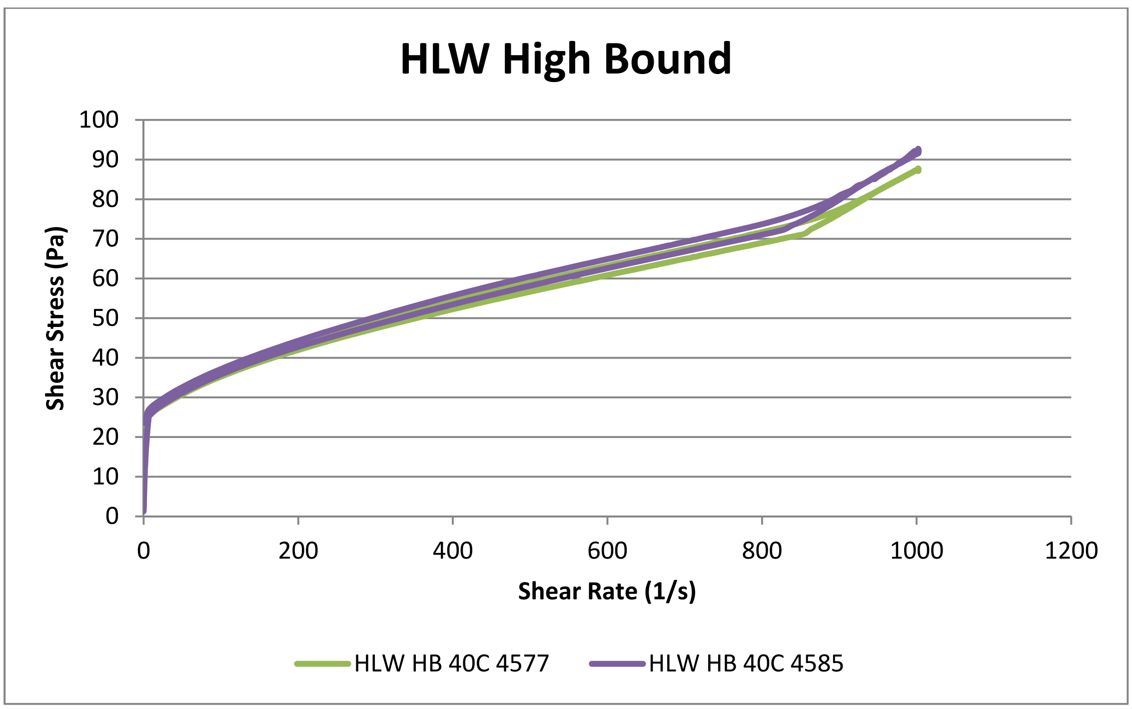


Figure E- 8. HLW-High Bound Rheogram – 40 degrees Celsius

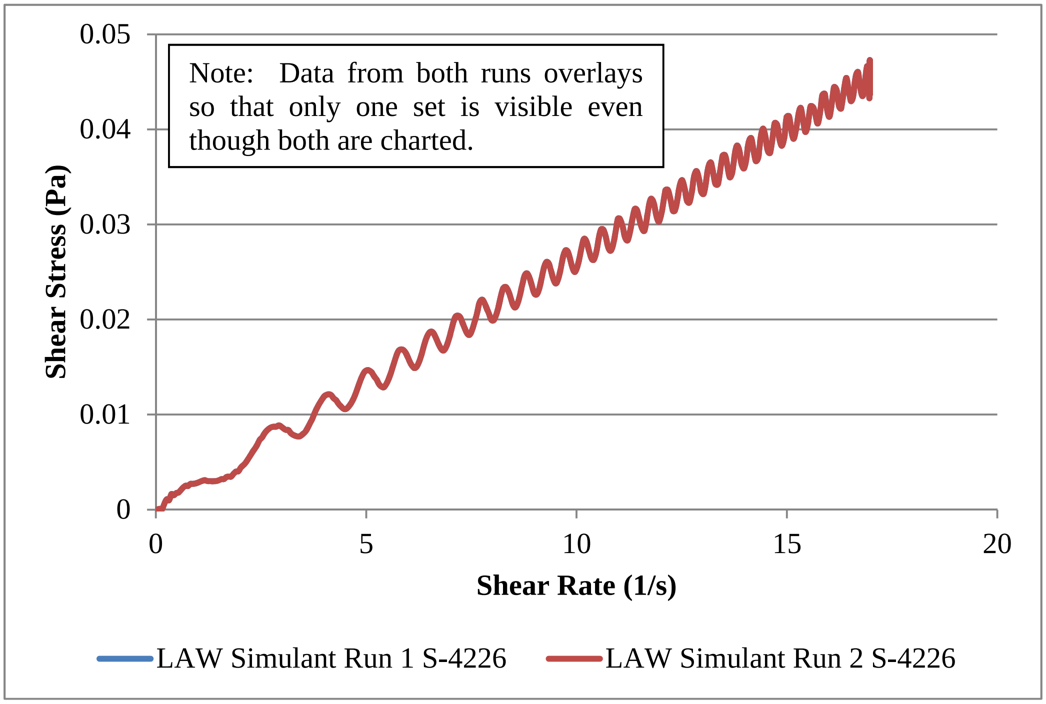


Figure E- 9. LAW Simulant Rheogram

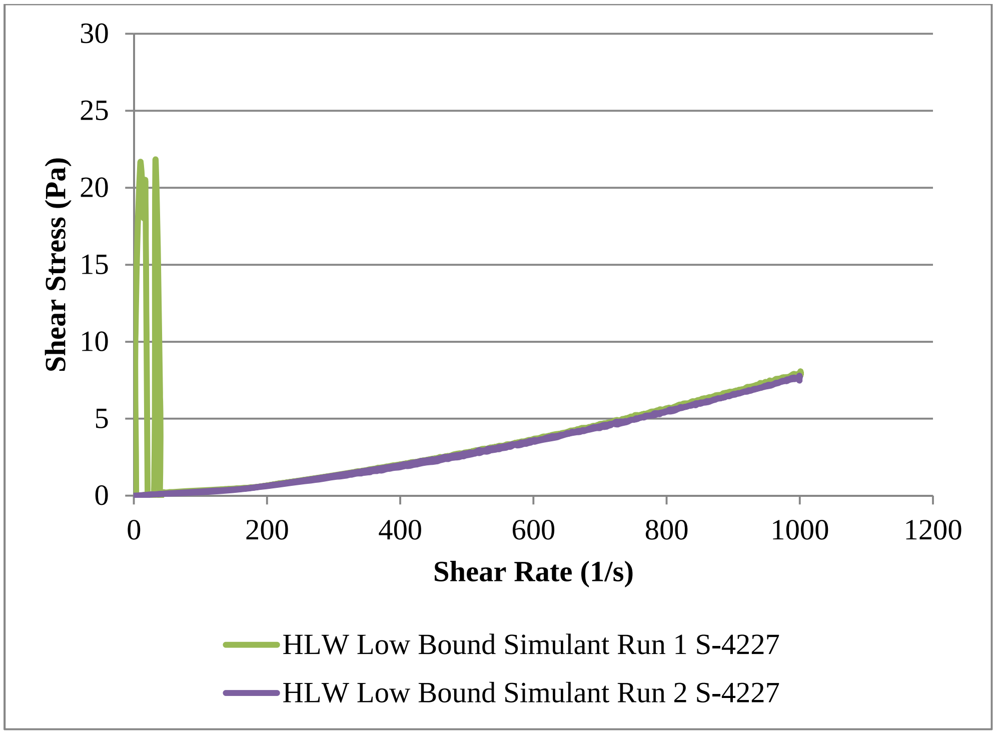


Figure E- 10. HLW-LB Simulant Rheogram

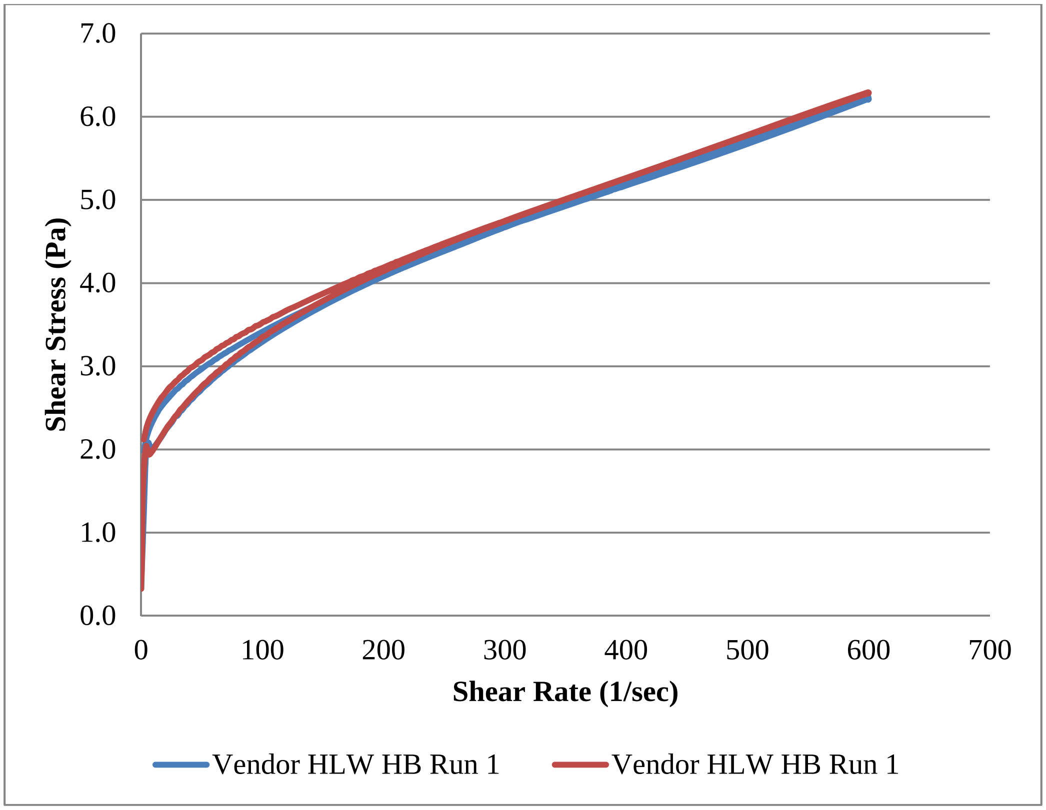


Figure E- 11. Vendor Prepared HLW-High Bound Simulant Rheogram

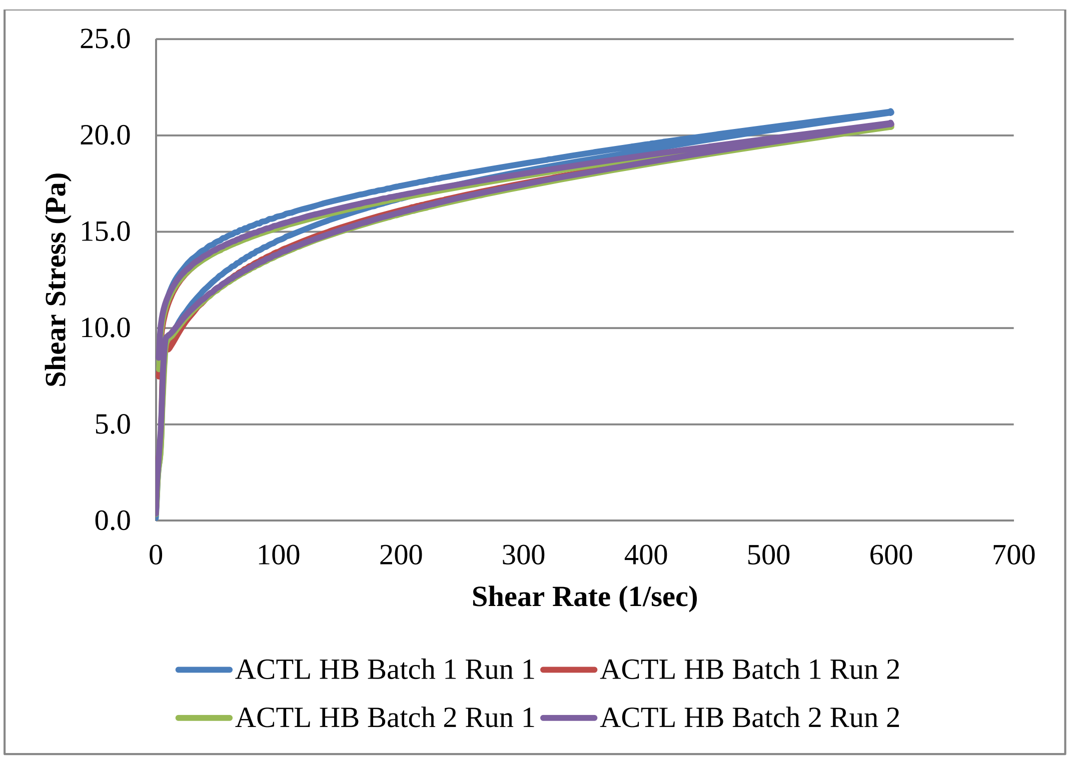


Figure E- 12. ACTL Prepared HLW-High Bound Simulant Rheogram

Appendix F. Example Work Instructions

These work instructions were developed based on the methods used during this testing. Some sections will need to be adjusted to account for facility specific requirements and practices (such as the recommended PPE).

1.0 INTRODUCTION

1.1 Purpose

This procedure provides direction for preparation of LAW and HLW melter feeds, sub-sampling of the melter feeds, and fabrication of glass from the melter feed samples.

1.2 Scope

This procedure applies to personnel preparing glass for qualification of LAW or HLW feeds to the WTP.

2.0 GENERAL INFORMATION

2.1 Definitions / Abbreviations / Acronyms

- **LAW** – Low Activity Waste
- **HGR** – Hydrogen Generation Rate
- **HLW** – High Level Waste
- **GFC** – Glass Forming Chemical
- **PI** – Principal Investigator
- **WTP** – Waste Treatment Plant
- **M&TE** – Measurement and Testing Equipment

2.2 Responsibilities

Based on chemical analysis of the waste sample, the PI shall specify the amount of waste, GFCs, and sugar to be added in the work control document(s), using the approved algorithm for the waste type.

3.0 PRECAUTIONS AND LIMITATIONS

3.1 Safety

- Care should be taken not to touch the heating elements in the furnace as elements are fragile and may fracture (if applicable).
- Crucibles will be hot upon removal from the furnace and should be handled with extreme care.
- If glass preparation will be performed in a fume hood:
  - Appropriate PPE should be worn when working with waste and GFCs; including gloves, safety glasses, laboratory coats, and any other PPE required by the facility.

- o Rotating equipment should be guarded to preclude incidental contact.
- o Appropriate PPE should be worn when putting in/removing crucibles from a furnace; including but not limited to heat resistant gloves, apron, and face shield. UV/IR shielded glasses should also be worn.
- o The buddy system should be utilized when putting in/removing crucibles from a furnace.
- If glass preparation will be performed in a shielded cell:
- o Follow all safety precautions specified by the facility.

4.0 PREREQUISITES

4.1 Equipment

- **ENSURE** the mixing apparatus is assembled as directed by the PI.
- **USE** the sample bottle specified by the PI for blending simulant or waste with GFCs.
- **ENSURE** that the pre-batched raw materials are thoroughly mixed prior to melting.
- **ENSURE** all ovens/furnaces used have equilibrated at their set-point temperature for at least 1 hour prior to use.
- **ENSURE** all M&TE to be used is within calibration and **RECORD** M&TE information.
- **ENSURE** work control document(s) have been prepared that specify the amount of GFCs required.
- **ENSURE** each 100 mL 95% Pt/5% Au crucible is uniquely identified.
- **ENSURE** the work control document(s) contain a sampling plan that specifies the following for each sample to be taken:
  - o **Identification (ID)**
  - o **Type**
  - o **Amount**
  - o **Handling Hazards**
  - o **Disposal Path**

5.0 PERFORMANCE

All additions should be within 10% of the specified amount for the simulant and 1% of the specified amount for the GFC addition. Samples of each melter feed will be pulled for physical property measurements (including rheological properties), chemical analysis and Hydrogen Generation Rate (HGR) measurements in addition to the fabrication of glass from the melter feed. Each glass will be visually inspected and analyzed for chemical composition.

5.1 Batching/Mixing

1. **TARE** the mixing bottle prior to use and **RECORD** mass.
2. Following the work control document(s), **ADD** the required amount of simulant or waste to the mixing bottle.
3. **PLACE** the mixing bottle under the mixing stand and secure it as specified by the PI.

4. **ENSURE** the mixer impeller is within 1/2”($\pm$ 1/4”) of the bottom of the mixing bottle, or as specified by the PI. **RECORD** observations and measurements made to confirm this position.

5. **START** mixing and **ADJUST** the mixer speed to maximum speed possible without excessive splatter. If a slight vortex is not noted at the maximum speed possible, notify the PI.

6. Following the work control document(s), **WEIGH** out, **RECORD,** and **MIX** the required amount of GFCs.

7. **SLOWLY ADD** the GFCs to the mixing bottle so that the GFCs can be incorporated into the slurry. **ADJUST** the addition rate as needed to avoid a buildup of GFCs on the surface. If a slight vortex cannot be maintained, **INCREASE** the mixing speed as performed in Step 5.1.5.

8. **RECORD** the time at which all of the specified GFCs have been added.

9. **ADD** the specified amount of sugar to the slurry. **ADJUST** the addition rate as needed to avoid a buildup of sugar on the surface. If a slight vortex cannot be maintained, **INCREASE** the mixing speed as performed in Step 5.1.5.

10. **RECORD** the time at which all of the specified sugar has been added.

11. **MIX** the slurry for at least 30 minutes, or as specified by the PI, prior to sampling.

12. **RECORD** the time that mixing was completed.

5.2 Sampling

1. **ENSURE** mixing/sample apparatus is assembled per the work control document(s) or as specified by PI.

NOTE: All sample bottles should be labelled, tared, and placed in the shielded cell/hood prior to starting sampling.

2. **LABEL** the sample containers/crucibles as specified in the work control document(s).

NOTE: Slurry can be added directly to a 100 mL 95% Pt/5% Au crucible if drying will be performed immediately afterwards.3. **WEIGH** sample containers and/or crucibles as needed based on the sampling plan specified in the work control document(s).

4. **RECORD** the sample container/crucible ID and mass to the nearest 0.001 g for each sample container/crucible to be used.

5. **INSERT** the sampler tube into the mixing bottle so that it is 1/2”($\pm$ 1/4”) above the impeller, or as specified by the PI. observations and measurements made to confirm this position.

6. **START** the sample pump at a flow rate of at least 50 mL/min, or as specified by PI, to recirculate slurry back into the mixing bottle.

7. **RECIRCULATE** the slurry for at least 5 minutes.

8. **STOP** the sample pump and place the discharge line into the sample bottle/crucible.

9. **START** the sample pump at a rate of 50 to 100 mL/min, or as specified by PI, to pump the sample into the bottle/crucible.

10. **STOP** the sample pump when the required amount of sample has been delivered to the sample bottle/crucible.

11. **PLACE** the discharge line back into the mixing bottle and **RESTART** pump at a flow rate of at least 50 mL/min, or as specified by PI, to recirculate slurry back into the mixing bottle.

12. **WEIGH** and **RECORD** the mass of the filled sample bottle/crucible.

13. **REPEAT** Steps 5.2.1 through 5.2.12 for each sample to be taken.

14. **SUBMIT** samples for HGR, chemical composition, and physical property analysis as specified in the sample plan or as specified by the PI.

15. **HOUSEKEEP** work area.

5.3 Drying Samples to be Vitrified

NOTE: **RECORD** mass of the empty crucible(s).

1. If the slurry sample was pulled into a sample container, **POUR** the slurry sample into a marked 100 mL 95% Pt/5% Au crucible(s).

2. **RECORD** the crucible ID used for the sample.

CAUTION: The total volume of material in the crucible should not exceed ¾ inch below the lip of the crucible.

3. **ADD** water as needed to rinse the sample bottle(s), and **POUR** this into the sample crucible.

4. **RECORD** the crucible ID.

5. If working in the shielded cells, **LOCATE** the crucible holder, and **PLACE** the crucible(s) in this holder.

6. **SET** a drying oven to 115^{o}C, or as specified by PI, and allow it to stabilize at this temperature ($\pm$5^{o}C) for at least one hour.

7. **PLACE** the crucible holder into the drying oven and **RECORD** the time.

8. When there is no visual indication of free liquid in the sample(s), **REMOVE** the crucible/holder from the drying oven, and **RECORD** the time.

9. **REMOVE** the crucible from the holder (if applicable), and **PLACE** it in a desiccator for at least 15 minutes.

10. **WEIGH** the crucible, and **RECORD** the mass to the nearest 0.001 g.

11. **PLACE** a Pt/Rh lid on each crucible, and **SUBMIT** the dried slurry material for vitrification.

5.4 Vitrification

1. **SET** a high temperature furnace to 1150^{o}C, or as specified by the PI, and allow it to stabilize at this temperature ($\pm$10^{o}C) for at least one hour.

2. If working in the shielded cells, **PLACE** the crucible with lid (containing the dried slurry material) in a holder.
3. **PLACE** the holder/crucible into the furnace and **RECORD** the time when the furnace temperature has returned to 1150°C (±10°C), or as specified by the PI.
4. After at least 60-65 minutes at 1150°C (±10°C), or as specified by the PI, **REMOVE** the holder/crucible(s) from the furnace and **PLACE** the crucible on a piece of refractory brick.
5. **RECORD** the time, and **ALLOW** the melt(s) to cool to ambient temperature.
6. After the melt has cooled, **RECORD** visual observations pertaining to the glass surface.

> **NOTE**: Information that may be of interest includes: homogeneity, color, streaks, undissolved solids, the presence of bubbles, surface coating, phase separation, deposits on the interior crucible wall above the melt line, and the presence of crystals.

7. **WEIGH** and **RECORD** the mass of the crucible.
8. If necessary, gently **TAP** the crucible with a plastic faced mallet to loosen the glass from the crucible.
9. Carefully **FRACTURE** the glass.
10. **RECORD** visual observations pertaining to the bulk glass (see note above).
11. **COLLECT** a glass sample, and submit it for analysis (as directed by the PI).
12. **REPEAT** Steps 5.4.1 through 5.4.12 for all dried slurry samples.
13. **HOUSEKEEP** work area.

Appendix G. Statistical Regressions

Exhibit G1 provides a plot of the data generated by this testing. The plots are arranged by analyte (also showing the unit of measure) and the information on each plot is grouped on the x-axis by the test and type of material analyzed and the sample identifier (ID) used by PSAL with the sample number. Thus, the results on these plots for each test are intended to be presented in the order that the samples were taken. For those samples analyzed in duplicate, both of the measured results appear above the sample ID.

For those samples that were analyzed only once, there is no opportunity to separate out the sample-to-sample variation from the analytical variation for those results. The sources of variation are confounded. Exhibit G2 provides descriptive statistics for the results from the measurements of these analytes, and included is an estimate of the “combined” variation for the analytes that fall into this category. Table G-1 provides a summary of this variation.

Table G- 1. Summary Statistics (including the Percent Relative Standard Deviation (%RSD)) for Analytes with Samples Measured Only Once

Test	Type	Analyte	Unit of Measure	Number of Samples	Average Measured Value	Standard Deviation	%RSD
HLW HB (a)	anion	C2O4	mg/kg	9	197.8	35.92	18.2
HLW HB (a)	anion	Cl	mg/kg	9	91.4	4.55	5.0
HLW HB (a)	anion	F	mg/kg	9	500.0	0.00	0.0
HLW HB (a)	anion	HCO2	mg/kg	9	500.0	0.00	0.0
HLW HB (a)	anion	NO2	mg/kg	9	409.1	8.54	2.1
HLW HB (a)	anion	NO3	mg/kg	9	10177.8	97.18	1.0
HLW HB (a)	anion	PO4	mg/kg	9	500.0	0.00	0.0
HLW HB (a)	anion	SO4	mg/kg	9	367.4	12.35	3.4
HLW HB (b)	anion	C2O4	mg/kg	9	287.8	65.03	22.6
HLW HB (b)	anion	Cl	mg/kg	9	95.4	4.98	5.2
HLW HB (b)	anion	F	mg/kg	9	500.0	0.00	0.0
HLW HB (b)	anion	HCO2	mg/kg	9	500.0	0.00	0.0
HLW HB (b)	anion	NO2	mg/kg	9	276.3	4.27	1.5
HLW HB (b)	anion	NO3	mg/kg	9	10344.4	133.33	1.3
HLW HB (b)	anion	PO4	mg/kg	9	500.0	0.00	0.0
HLW HB (b)	anion	SO4	mg/kg	9	370.8	8.26	2.2
HLW LB	anion	C2O4	mg/kg	9	119.6	23.22	19.4
HLW LB	anion	Cl	mg/kg	9	97.3	4.31	4.4
HLW LB	anion	F	mg/kg	9	500.0	0.00	0.0
HLW LB	anion	HCO2	mg/kg	9	500.0	0.00	0.0
HLW LB	anion	NO2	mg/kg	9	763.1	29.40	3.9
HLW LB	anion	NO3	mg/kg	9	5933.7	255.79	4.3
HLW LB	anion	PO4	mg/kg	9	872.9	58.93	6.8
HLW LB	anion	SO4	mg/kg	9	390.1	17.14	4.4
LAW HB	anion	C2O4	mg/kg	9	339.1	16.45	4.9
LAW HB	anion	Cl	mg/kg	9	269.9	5.62	2.1
LAW HB	anion	F	mg/kg	9	78.3	2.57	3.3
LAW HB	anion	HCO2	mg/kg	9	238.3	6.69	2.8
LAW HB	anion	NO2	mg/kg	9	7056.7	186.35	2.6
LAW HB	anion	NO3	mg/kg	9	19888.9	483.33	2.4
LAW HB	anion	PO4	mg/kg	9	500.0	0.00	0.0
LAW HB	anion	SO4	mg/kg	9	669.1	14.45	2.2
LAW LB	anion	C2O4	mg/kg	9	540.9	18.21	3.4
LAW LB	anion	Cl	mg/kg	9	534.2	15.23	2.9
LAW LB	anion	F	mg/kg	9	143.4	16.46	11.5
LAW LB	anion	HCO2	mg/kg	9	415.7	20.82	5.0
LAW LB	anion	NO2	mg/kg	9	11611.1	448.45	3.9
LAW LB	anion	NO3	mg/kg	9	39755.6	871.94	2.2
LAW LB	anion	PO4	mg/kg	9	500.0	0.00	0.0
LAW LB	anion	SO4	mg/kg	9	1325.6	31.27	2.4

All measurements for the shaded averages were below detection limits.

For those samples that were analyzed in duplicate, Exhibit G3 provides the results of a statistical analysis of a random effects model designed to estimate the two sources of variation for these analytes: sample-to-sample and analytical. Table G- 2 summarizes the results for the average measurements from Exhibit G3.

Table G- 2. Averages by Test, Type of Analyte, and Analyte with 95% Confidence Intervals for the Mean

Test	Type	Analyte	Target Value	Unit of Measure	Average	Lower 95%	Upper 95%
HLW HB (a)	physical property	Density	.	g/mL	1.65	1.62	1.68
HLW HB (a)	physical property	Insoluble Solids	.	Wt%	53.52	53.18	53.86
HLW HB (a)	physical property	Soluble Solids	.	wt%	8.05	7.90	8.20
HLW HB (a)	physical property	Total Solids	.	wt%	63.54	61.67	65.42
HLW HB (a)	physical property	Wt% Calcine	.	wt%	51.63	51.55	51.70
HLW HB (a)	slurry	Al2O3	10	wt%	9.04	8.95	9.14
HLW HB (a)	slurry	B2O3	10.68	wt%	10.81	10.59	11.02
HLW HB (a)	slurry	Fe2O3	11.54	wt%	12.76	12.60	12.92
HLW HB (a)	slurry	Li2O	3.87	wt%	3.71	3.68	3.73
HLW HB (a)	slurry	Na2O	9.84	wt%	10.42	10.33	10.50
HLW HB (a)	slurry	SiO2	47.5	wt%	48.47	48.00	48.94
HLW HB (a)	slurry	ZnO	2.04	wt%	1.92	1.90	1.93
HLW HB (a)	slurry	ZrO2	3.84	wt%	3.52	3.49	3.54
HLW HB (b)	glass	Al2O3	10	wt%	9.58	9.45	9.70
HLW HB (b)	glass	B2O3	10.68	wt%	11.22	10.80	11.63
HLW HB (b)	glass	CaO	0.12	wt%	0.11	0.11	0.11
HLW HB (b)	glass	Fe2O3	11.54	wt%	10.67	10.54	10.80
HLW HB (b)	glass	K2O	0.13	wt%	0.12	0.12	0.12
HLW HB (b)	glass	Li2O	3.87	wt%	3.79	3.73	3.84
HLW HB (b)	glass	MgO	0.17	wt%	0.18	0.17	0.18
HLW HB (b)	glass	Na2O	9.84	wt%	9.92	9.78	10.07
HLW HB (b)	glass	SiO2	47.5	wt%	47.24	46.73	47.75
HLW HB (b)	glass	SO4	0	wt%	0.07	0.06	0.07
HLW HB (b)	glass	TiO2	0	wt%	0.04	0.03	0.04
HLW HB (b)	glass	ZnO	2.04	wt%	1.95	1.93	1.97
HLW HB (b)	glass	ZrO2	3.84	wt%	3.75	3.69	3.80
HLW HB (b)	physical property	Density	.	g/mL	1.64	1.63	1.66
HLW HB (b)	physical property	Insoluble Solids	.	wt%	54.12	52.28	55.96
HLW HB (b)	physical property	Soluble Solids	.	wt%	8.14	7.96	8.32
HLW HB (b)	physical property	Total Solids	.	wt%	61.91	61.11	62.71
HLW HB (b)	physical property	Wt% Calcine	.	wt%	51.76	51.69	51.83
HLW HB (b)	slurry	Al2O3	10	wt%	9.12	9.00	9.24
HLW HB (b)	slurry	B2O3	10.68	wt%	11.55	11.33	11.77
HLW HB (b)	slurry	Fe2O3	11.54	wt%	11.01	10.87	11.14
HLW HB (b)	slurry	K2O	0.13	wt%	0.15	0.14	0.15
HLW HB (b)	slurry	Li2O	3.87	wt%	3.79	3.74	3.84
HLW HB (b)	slurry	Na2O	9.84	wt%	9.75	9.68	9.83
HLW HB (b)	slurry	SiO2	47.5	wt%	47.27	46.73	47.80
HLW HB (b)	slurry	ZnO	2.04	wt%	1.99	1.96	2.02
HLW HB (b)	slurry	ZrO2	3.84	wt%	3.66	3.61	3.71
HLW LB	glass	Al2O3	7.27	wt%	8.60	8.36	8.85
HLW LB	glass	B2O3	11.05	wt%	11.31	11.00	11.62
HLW LB	glass	CaO	0	wt%	0.04	0.03	0.04
HLW LB	glass	Cu2O	0	wt%	0.01	0.01	0.01
HLW LB	glass	Fe2O3	12.29	wt%	12.41	12.02	12.81
HLW LB	glass	K2O	0.14	wt%	0.14	0.14	0.15
HLW LB	glass	Li2O	4.01	wt%	4.18	4.03	4.33
HLW LB	glass	Na2O	12.1	wt%	10.84	10.68	11.01
HLW LB	glass	P2O5	0.51	wt%	0.38	0.36	0.39
HLW LB	glass	SiO2	47.07	wt%	45.44	44.90	45.97
HLW LB	glass	SO4	0.18	wt%	0.18	0.17	0.19
HLW LB	glass	ZnO	2.11	wt%	1.94	1.90	1.98
HLW LB	glass	ZrO2	3.27	wt%	3.80	3.66	3.93
HLW LB	physical property	Density	.	g/mL	1.34	1.34	1.35
HLW LB	physical property	Insoluble Solids	.	wt%	29.73	28.69	30.77
HLW LB	physical property	Soluble Solids	.	wt%	7.11	6.97	7.25
HLW LB	physical property	Total Solids	.	wt%	36.32	35.68	36.96
HLW LB	physical property	Wt% Calcine	.	wt%	30.44	29.90	30.99

Table G- 2. Averages by Test, Type of Analyte, and Analyte with 95% Confidence Intervals for the Mean (continued)

Test	Type	Analyte	Target Value	Unit of Measure	Average	Lower 95%	Upper 95%
HLW LB	slurry	Al2O3	7.27	wt%	8.19	8.05	8.33
HLW LB	slurry	B2O3	11.05	wt%	10.80	9.48	12.13
HLW LB	slurry	Fe2O3	12.29	wt%	12.49	12.00	12.99
HLW LB	slurry	K2O	0.14	wt%	0.18	0.17	0.19
HLW LB	slurry	Li2O	4.01	wt%	3.70	3.60	3.81
HLW LB	slurry	Na2O	12.1	wt%	12.35	11.92	12.78
HLW LB	slurry	P2O5	0.51	wt%	0.37	0.36	0.39
HLW LB	slurry	SiO2	47.07	wt%	48.07	46.83	49.31
HLW LB	slurry	TiO2	0	wt%	0.02	-0.03	0.07
HLW LB	slurry	ZnO	2.11	wt%	1.98	1.92	2.04
HLW LB	slurry	ZrO2	3.27	wt%	3.39	3.28	3.49
LAW HB	physical property	Density	.	g/mL	1.90	1.87	1.92
LAW HB	physical property	Insoluble Solids	.	wt%	58.82	58.56	59.08
LAW HB	physical property	Soluble Solids	.	wt%	10.16	10.00	10.32
LAW HB	physical property	Total Solids	.	wt%	69.07	68.96	69.17
LAW HB	physical property	Wt% Calcine	.	wt%	64.67	64.56	64.77
LAW HB	slurry	Al2O3	6.57	wt%	6.10	6.07	6.13
LAW HB	slurry	B2O3	2.41	wt%	3.04	2.82	3.25
LAW HB	slurry	CaO	2.81	wt%	2.67	2.66	2.69
LAW HB	slurry	Fe2O3	7.79	wt%	7.81	7.71	7.91
LAW HB	slurry	K2O	1.01	wt%	1.18	1.15	1.21
LAW HB	slurry	MgO	2.44	wt%	1.85	1.75	1.95
LAW HB	slurry	Na2O	4.88	wt%	4.45	4.39	4.50
LAW HB	slurry	SiO2	61.04	wt%	62.48	62.06	62.91
LAW HB	slurry	TiO2	2.89	wt%	2.88	2.85	2.91
LAW HB	slurry	ZnO	4.13	wt%	4.22	4.18	4.26
LAW HB	slurry	ZrO2	4.19	wt%	4.06	4.02	4.09
LAW LB	glass	Al2O3	5.95	wt%	6.13	5.98	6.27
LAW LB	glass	B2O3	9.66	wt%	11.64	11.11	12.18
LAW LB	glass	CaO	1.77	wt%	1.98	1.92	2.03
LAW LB	glass	Fe2O3	5.33	wt%	3.79	3.44	4.14
LAW LB	glass	K2O	4.05	wt%	4.26	4.09	4.43
LAW LB	glass	MgO	1.74	wt%	0.75	0.30	1.20
LAW LB	glass	Na2O	19.51	wt%	20.80	19.98	21.62
LAW LB	glass	SiO2	43.45	wt%	43.74	43.17	44.31
LAW LB	glass	SO4	0.41	wt%	0.45	0.42	0.47
LAW LB	glass	TiO2	2.06	wt%	1.69	1.63	1.75
LAW LB	glass	ZnO	2.94	wt%	3.01	2.92	3.10
LAW LB	glass	ZrO2	2.98	wt%	2.60	2.49	2.70
LAW LB	physical property	Density	.	g/mL	1.36	1.34	1.37
LAW LB	physical property	Insoluble Solids	.	wt%	23.65	21.29	26.01
LAW LB	physical property	Soluble Solids	.	wt%	18.31	17.78	18.84
LAW LB	physical property	Total Solids	.	wt%	41.33	40.22	42.45
LAW LB	physical property	Wt% Calcine	.	wt%	30.53	29.80	31.27
LAW LB	slurry	Al2O3	5.95	wt%	5.43	5.37	5.49
LAW LB	slurry	B2O3	9.66	wt%	9.61	9.24	9.99
LAW LB	slurry	CaO	1.77	wt%	1.91	1.85	1.97
LAW LB	slurry	Fe2O3	5.33	wt%	4.64	4.01	5.27
LAW LB	slurry	K2O	4.05	wt%	3.90	3.77	4.04
LAW LB	slurry	MgO	1.74	wt%	1.22	0.79	1.66
LAW LB	slurry	Na2O	19.51	wt%	19.36	18.63	20.08
LAW LB	slurry	SiO2	43.45	wt%	44.13	43.63	44.64
LAW LB	slurry	SO4	0.41	wt%	0.40	0.38	0.42
LAW LB	slurry	TiO2	2.06	wt%	1.76	1.64	1.88
LAW LB	slurry	ZnO	2.94	wt%	2.93	2.84	3.02
LAW LB	slurry	ZrO2	2.98	wt%	2.53	2.38	2.68

An additional insight that is provided by the results from Exhibit G3 are estimates of the variance components: sample (which includes sampling and sample preparation) and analytical. Table G- 3 provides a summary of these results.

Table G- 3.Estimates of Components of Variation by Test, Type of Analyte, and Analyte

Test	Type	Analyte	Target Value	Unit of Measure	Analytical Std Dev	Sample Std Dev	Total Std Dev
HLW HB (a)	physical property	Insoluble Solids	.	wt%	0.161	0.245	0.294
HLW HB (a)	physical property	Soluble Solids	.	wt%	0.170	0.022	0.172
HLW HB (a)	physical property	Total Solids	.	wt%	3.583	0.000	3.583
HLW HB (a)	physical property	Wt% Calcine	.	wt%	0.053	0.090	0.104
HLW HB (a)	slurry	Al2O3	10	wt%	0.057	0.115	0.129
HLW HB (a)	slurry	B2O3	10.68	wt%	0.181	0.244	0.304
HLW HB (a)	slurry	Fe2O3	11.54	wt%	0.256	0.103	0.276
HLW HB (a)	slurry	Li2O	3.87	wt%	0.026	0.022	0.034
HLW HB (a)	slurry	Na2O	9.84	wt%	0.091	0.095	0.131
HLW HB (a)	slurry	SiO2	47.5	wt%	0.311	0.571	0.650
HLW HB (a)	slurry	ZnO	2.04	wt%	0.021	0.010	0.024
HLW HB (a)	slurry	ZrO2	3.84	wt%	0.041	0.016	0.044
HLW HB (b)	glass	Al2O3	10	wt%	0.184	0.077	0.199
HLW HB (b)	glass	B2O3	10.68	wt%	0.249	0.463	0.525
HLW HB (b)	glass	CaO	0.12	wt%	0.002	0.001	0.002
HLW HB (b)	glass	Fe2O3	11.54	wt%	0.103	0.135	0.170
HLW HB (b)	glass	K2O	0.13	wt%	0.002	0.000	0.002
HLW HB (b)	glass	Li2O	3.87	wt%	0.070	0.041	0.081
HLW HB (b)	glass	MgO	0.17	wt%	0.003	0.000	0.003
HLW HB (b)	glass	Na2O	9.84	wt%	0.132	0.149	0.200
HLW HB (b)	glass	SiO2	47.5	wt%	0.592	0.448	0.742
HLW HB (b)	glass	SO4	0	wt%	0.007	0.000	0.007
HLW HB (b)	glass	TiO2	0	wt%	0.001	0.000	0.001
HLW HB (b)	glass	ZnO	2.04	wt%	0.019	0.019	0.027
HLW HB (b)	glass	ZrO2	3.84	wt%	0.070	0.036	0.078
HLW HB (b)	physical property	Insoluble Solids	.	wt%	2.104	0.000	2.104
HLW HB (b)	physical property	Soluble Solids	.	wt%	0.279	0.000	0.279
HLW HB (b)	physical property	Total Solids	.	wt%	1.367	0.388	1.421
HLW HB (b)	physical property	Wt% Calcine	.	wt%	0.075	0.075	0.106
HLW HB (b)	slurry	Al2O3	10	wt%	0.076	0.148	0.166
HLW HB (b)	slurry	B2O3	10.68	wt%	0.108	0.279	0.299
HLW HB (b)	slurry	Fe2O3	11.54	wt%	0.085	0.167	0.187
HLW HB (b)	slurry	K2O	0.13	wt%	0.004	0.003	0.005
HLW HB (b)	slurry	Li2O	3.87	wt%	0.031	0.058	0.066
HLW HB (b)	slurry	Na2O	9.84	wt%	0.125	0.048	0.133
HLW HB (b)	slurry	SiO2	47.5	wt%	0.512	0.599	0.788
HLW HB (b)	slurry	ZnO	2.04	wt%	0.022	0.031	0.038
HLW HB (b)	slurry	ZrO2	3.84	wt%	0.037	0.059	0.069
HLW LB	glass	Al2O3	7.27	wt%	0.166	0.266	0.313
HLW LB	glass	B2O3	11.05	wt%	0.226	0.336	0.405
HLW LB	glass	CaO	0	wt%	0.006	0.005	0.008
HLW LB	glass	Cu2O	0	wt%	0.001	0.001	0.002
HLW LB	glass	Fe2O3	12.29	wt%	0.158	0.460	0.486
HLW LB	glass	K2O	0.14	wt%	0.005	0.007	0.009
HLW LB	glass	Li2O	4.01	wt%	0.080	0.170	0.188
HLW LB	glass	Na2O	12.1	wt%	0.144	0.167	0.220
HLW LB	glass	P2O5	0.51	wt%	0.005	0.016	0.017
HLW LB	glass	SiO2	47.07	wt%	0.665	0.431	0.793
HLW LB	glass	SO4	0.18	wt%	0.006	0.011	0.012
HLW LB	glass	ZnO	2.11	wt%	0.028	0.044	0.052
HLW LB	glass	ZrO2	3.27	wt%	0.067	0.154	0.168
HLW LB	physical property	Insoluble Solids	.	wt%	0.345	0.805	0.876
HLW LB	physical property	Soluble Solids	.	wt%	0.071	0.102	0.124

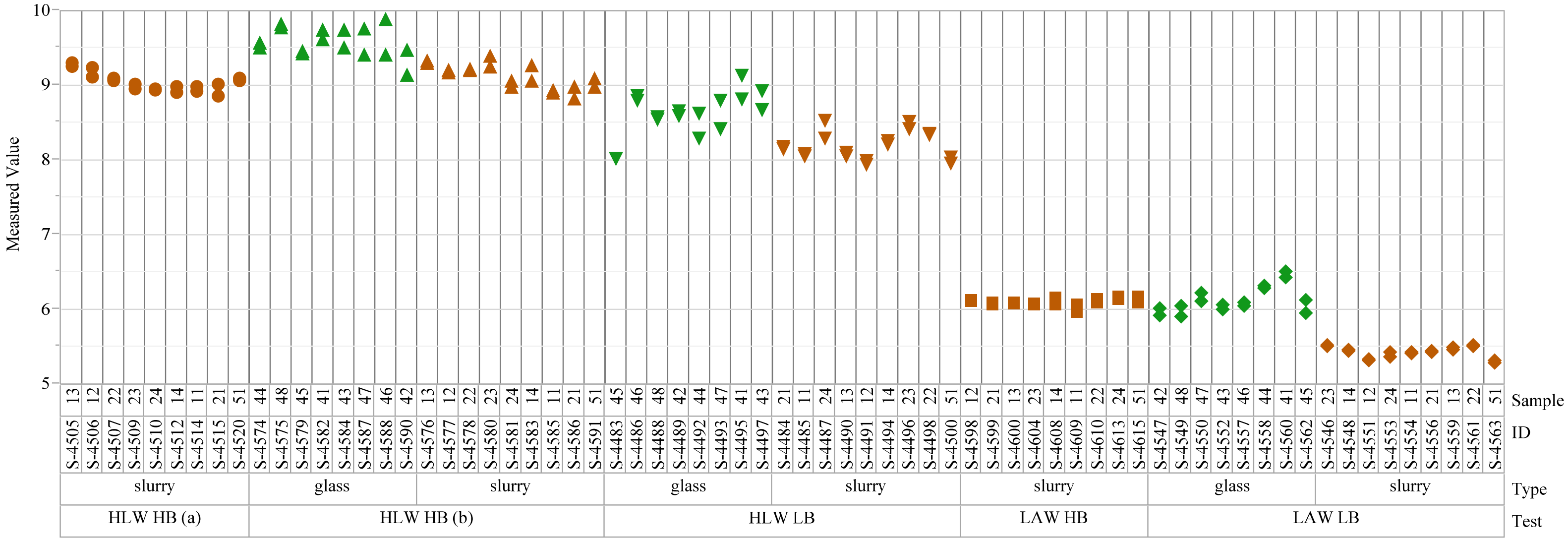
Table G- 3.Estimates of Components of Variation by Test, Type of Analyte, and Analyte (continued)

Test	Type	Analyte	Target Value	Unit of Measure	Analytical Std Dev	Sample Std Dev	Total Std Dev
HLW LB	physical property	Total Solids	.	wt%	0.256	0.813	0.852
HLW LB	physical property	Wt% Calcine	.	wt%	0.197	0.696	0.723
HLW LB	slurry	Al2O3	7.27	wt%	0.068	0.176	0.188
HLW LB	slurry	B2O3	11.05	wt%	0.186	1.713	1.723
HLW LB	slurry	Fe2O3	12.29	wt%	0.143	0.632	0.649
HLW LB	slurry	K2O	0.14	wt%	0.003	0.009	0.009
HLW LB	slurry	Li2O	4.01	wt%	0.078	0.121	0.145
HLW LB	slurry	Na2O	12.1	wt%	0.139	0.553	0.570
HLW LB	slurry	P2O5	0.51	wt%	0.004	0.017	0.017
HLW LB	slurry	SiO2	47.07	wt%	0.479	1.576	1.647
HLW LB	slurry	TiO2	0	wt%	0.005	0.062	0.062
HLW LB	slurry	ZnO	2.11	wt%	0.033	0.076	0.083
HLW LB	slurry	ZrO2	3.27	wt%	0.030	0.136	0.139
LAW HB	physical property	Insoluble Solids	.	wt%	0.141	0.186	0.233
LAW HB	physical property	Soluble Solids	.	wt%	0.118	0.099	0.154
LAW HB	physical property	Total Solids	.	wt%	0.082	0.119	0.144
LAW HB	physical property	Wt% Calcine	.	wt%	0.058	0.133	0.145
LAW HB	slurry	Al2O3	6.57	wt%	0.039	0.033	0.051
LAW HB	slurry	B2O3	2.41	wt%	0.143	0.259	0.296
LAW HB	slurry	CaO	2.81	wt%	0.038	0.000	0.038
LAW HB	slurry	Fe2O3	7.79	wt%	0.128	0.091	0.157
LAW HB	slurry	K2O	1.01	wt%	0.018	0.037	0.041
LAW HB	slurry	MgO	2.44	wt%	0.039	0.125	0.131
LAW HB	slurry	Na2O	4.88	wt%	0.049	0.058	0.076
LAW HB	slurry	SiO2	61.04	wt%	0.807	0.000	0.807
LAW HB	slurry	TiO2	2.89	wt%	0.016	0.037	0.041
LAW HB	slurry	ZnO	4.13	wt%	0.036	0.051	0.063
LAW HB	slurry	ZrO2	4.19	wt%	0.054	0.030	0.061
LAW LB	glass	Al2O3	5.95	wt%	0.071	0.167	0.181
LAW LB	glass	B2O3	9.66	wt%	0.185	0.626	0.653
LAW LB	glass	CaO	1.77	wt%	0.033	0.066	0.074
LAW LB	glass	Fe2O3	5.33	wt%	0.048	0.422	0.425
LAW LB	glass	K2O	4.05	wt%	0.052	0.201	0.208
LAW LB	glass	MgO	1.74	wt%	0.015	0.534	0.534
LAW LB	glass	Na2O	19.51	wt%	0.298	0.960	1.005
LAW LB	glass	SiO2	43.45	wt%	0.873	0.292	0.920
LAW LB	glass	SO4	0.41	wt%	0.006	0.026	0.026
LAW LB	glass	TiO2	2.06	wt%	0.028	0.070	0.076
LAW LB	glass	ZnO	2.94	wt%	0.037	0.100	0.106
LAW LB	glass	ZrO2	2.98	wt%	0.036	0.128	0.133
LAW LB	physical property	Insoluble Solids	.	wt%	1.680	1.480	2.239
LAW LB	physical property	Soluble Solids	.	wt%	0.414	0.314	0.519
LAW LB	physical property	Total Solids	.	wt%	0.953	1.286	1.601
LAW LB	physical property	Wt% Calcine	.	wt%	0.167	0.948	0.962
LAW LB	slurry	Al2O3	5.95	wt%	0.020	0.075	0.078
LAW LB	slurry	B2O3	9.66	wt%	0.163	0.475	0.502
LAW LB	slurry	CaO	1.77	wt%	0.037	0.069	0.078
LAW LB	slurry	Fe2O3	5.33	wt%	0.132	0.817	0.827
LAW LB	slurry	K2O	4.05	wt%	0.087	0.167	0.188
LAW LB	slurry	MgO	1.74	wt%	0.005	0.563	0.563
LAW LB	slurry	Na2O	19.51	wt%	0.067	0.936	0.939
LAW LB	slurry	SiO2	43.45	wt%	0.160	0.651	0.671
LAW LB	slurry	SO4	0.41	wt%	0.009	0.028	0.029
LAW LB	slurry	TiO2	2.06	wt%	0.013	0.152	0.153
LAW LB	slurry	ZnO	2.94	wt%	0.023	0.115	0.117
LAW LB	slurry	ZrO2	2.98	wt%	0.027	0.189	0.191

Finally, Exhibit G4 provides a plot of the measurements with reference lines at ±10% of the average values of the measurements. These graphs are shown to provide an opportunity for an assessment of these results from a practical perspective.

Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=Al2O3, Unit of Measure=wt%



Analyte=B2O3, Unit of Measure=wt%

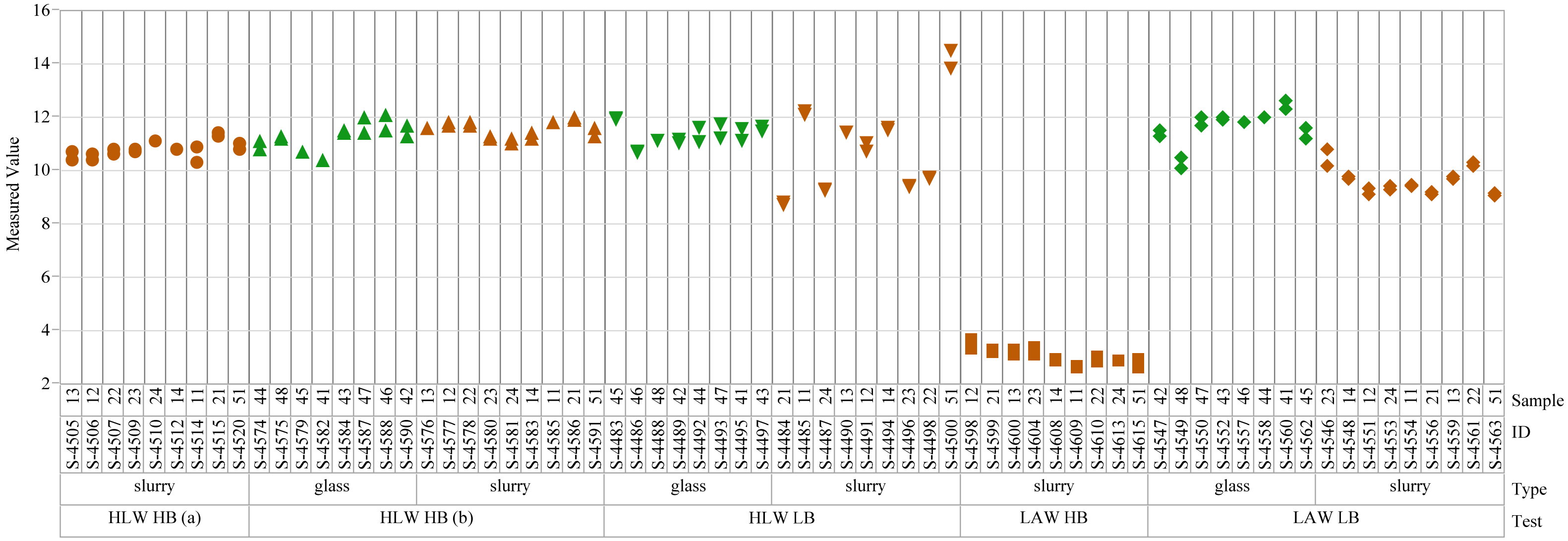
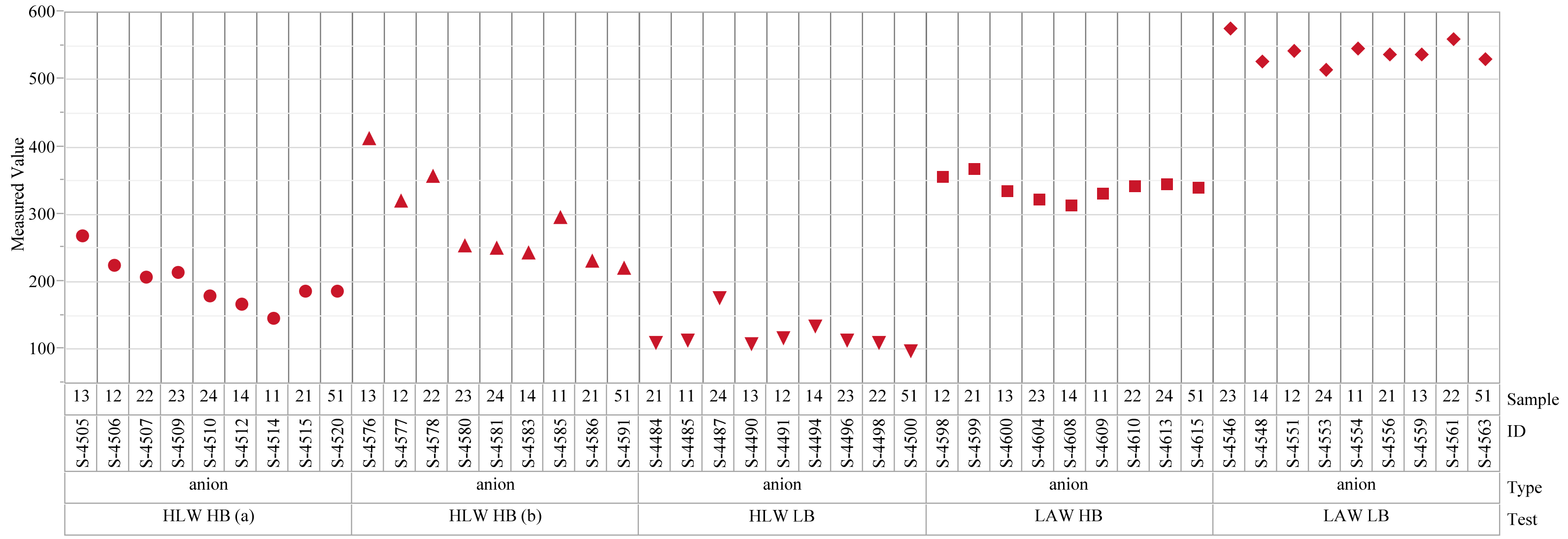


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=C2O4, Unit of Measure=mg/kg



Analyte=CaO, Unit of Measure=wt%

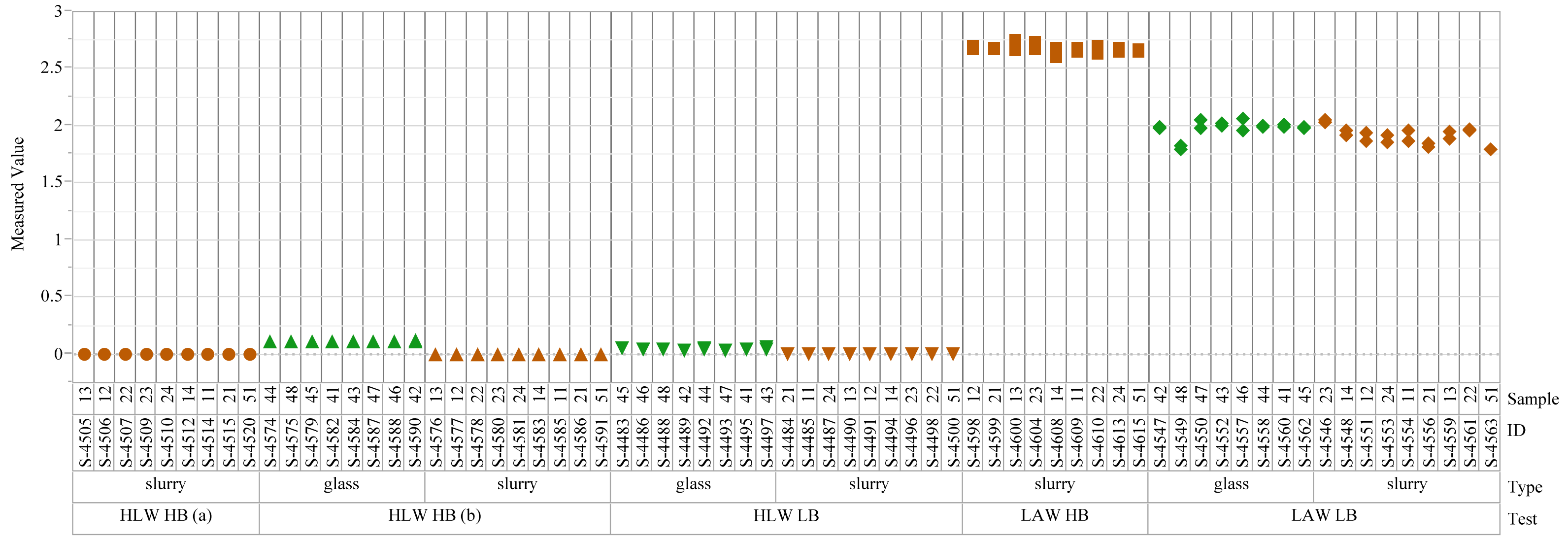
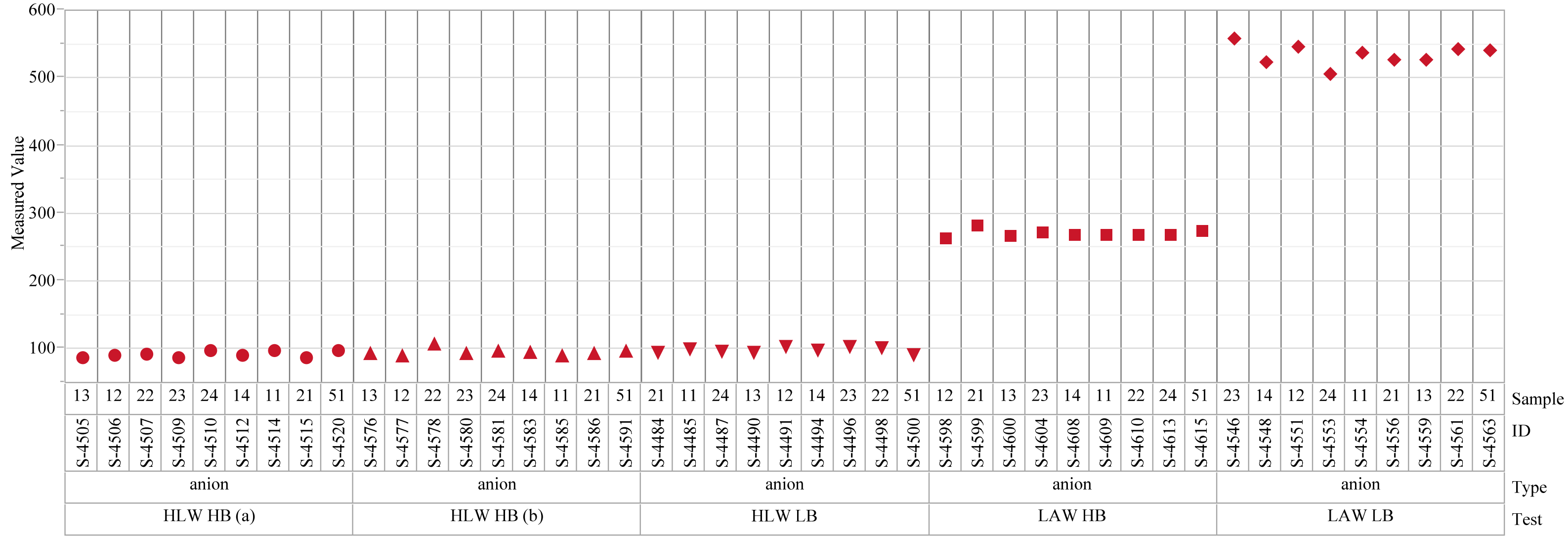


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=Cl, Unit of Measure=mg/kg



Analyte=Cu2O, Unit of Measure=wt%

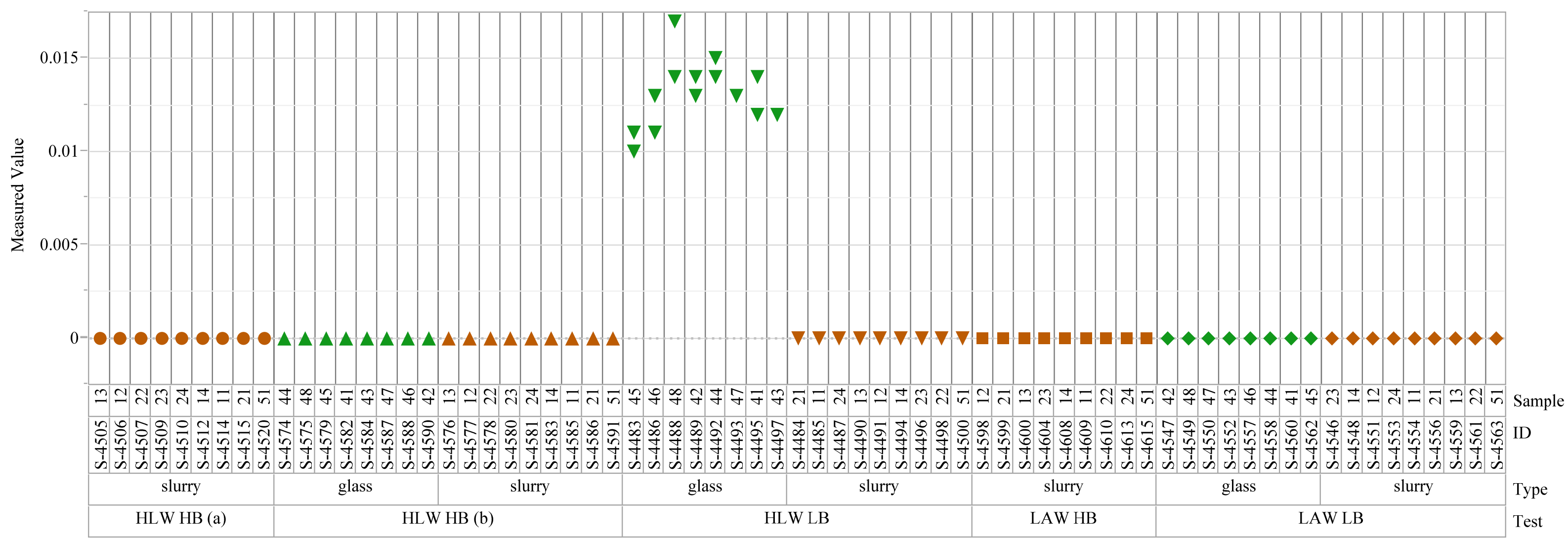
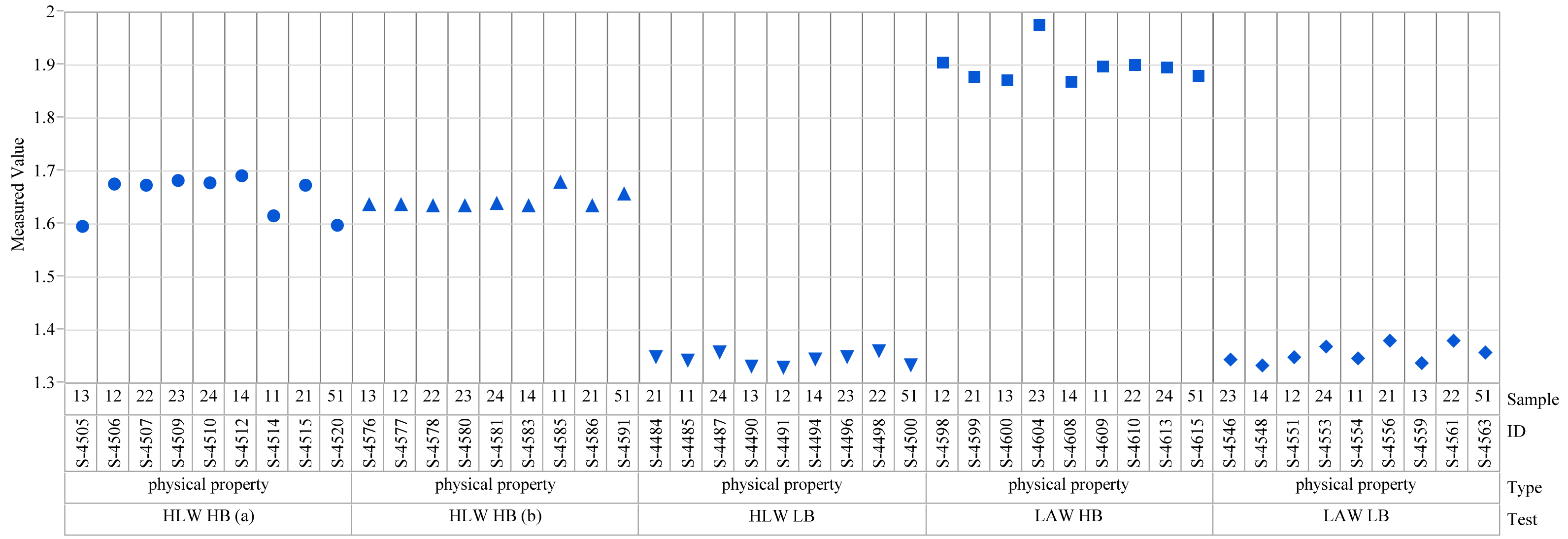


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=Density, Unit of Measure=g/mL



Analyte=F, Unit of Measure=mg/kg

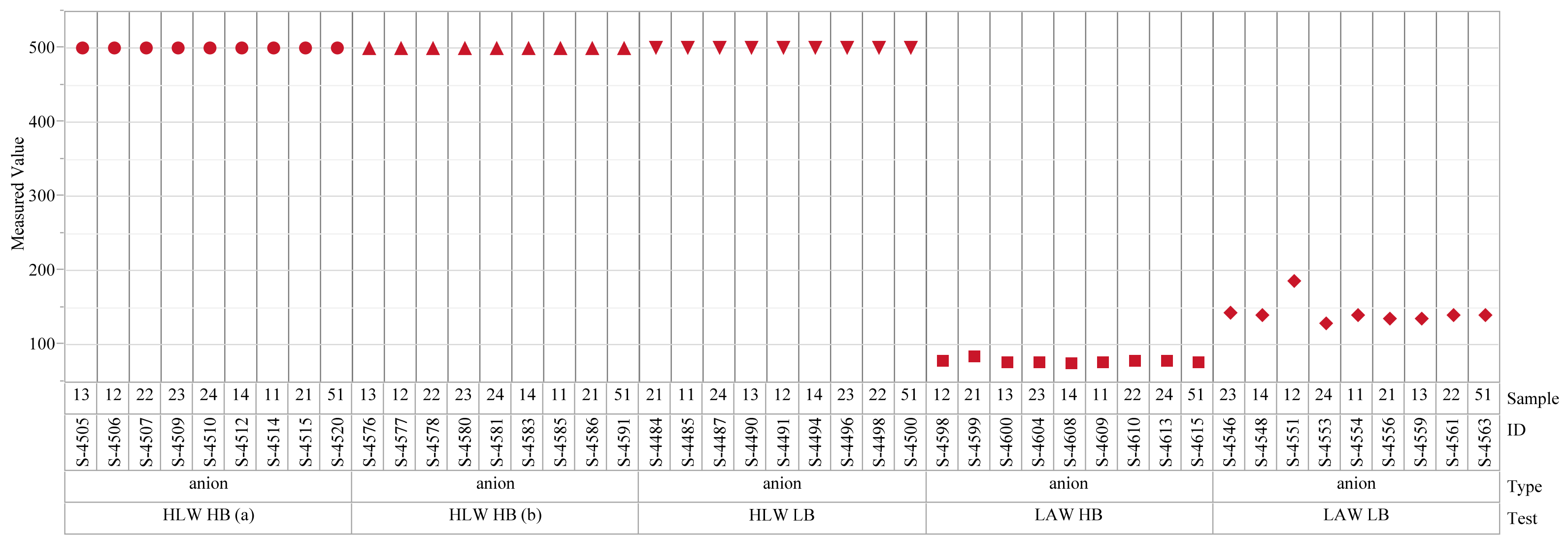
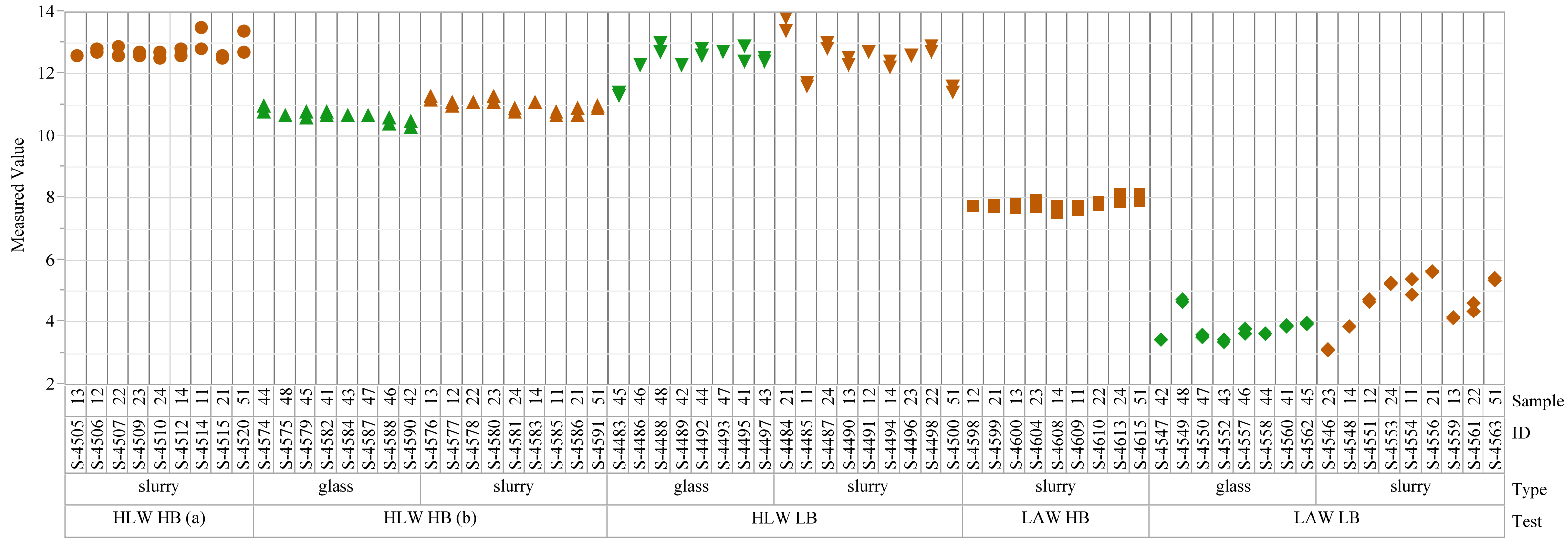


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=Fe2O3, Unit of Measure=wt%



Analyte=HCO2, Unit of Measure=mg/kg

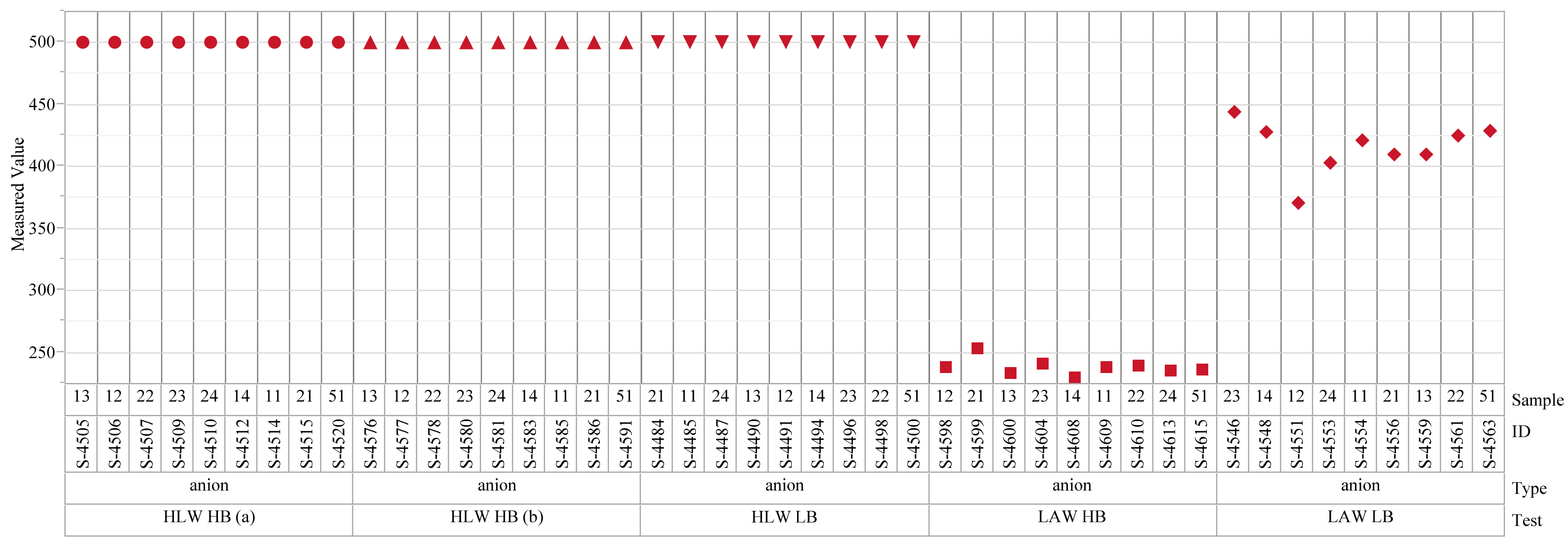
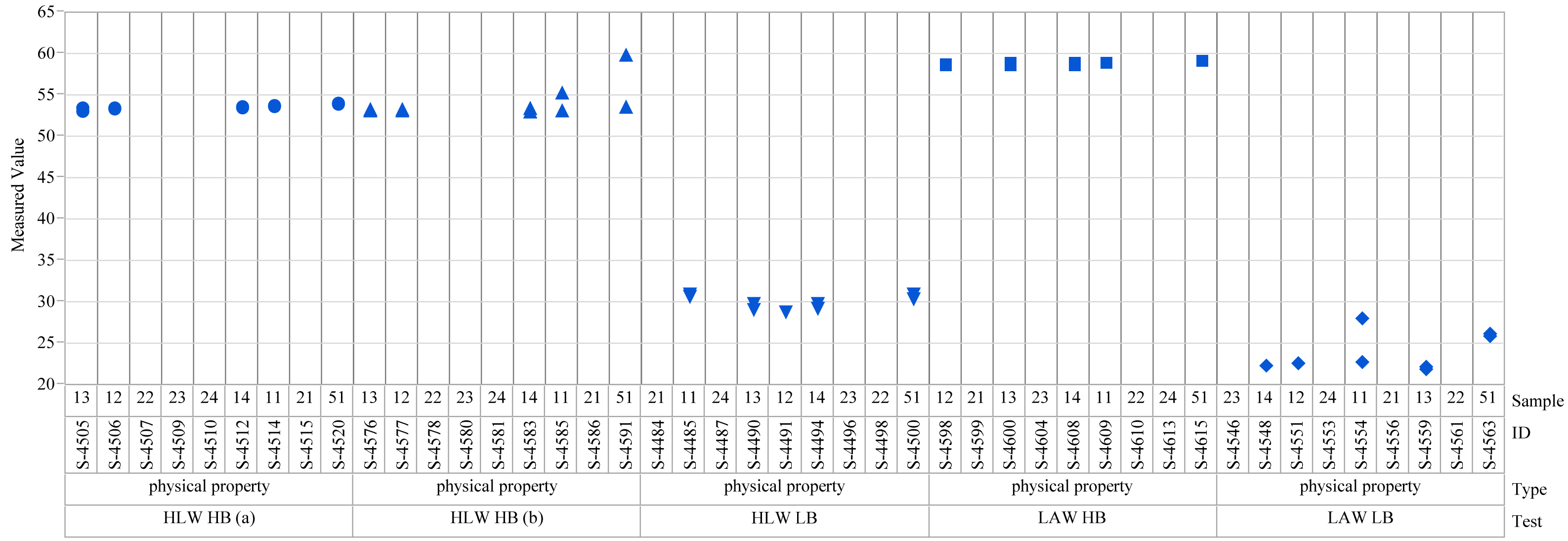


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=Insoluble Solids, Unit of Measure=wt%



Analyte=K2O, Unit of Measure=wt%

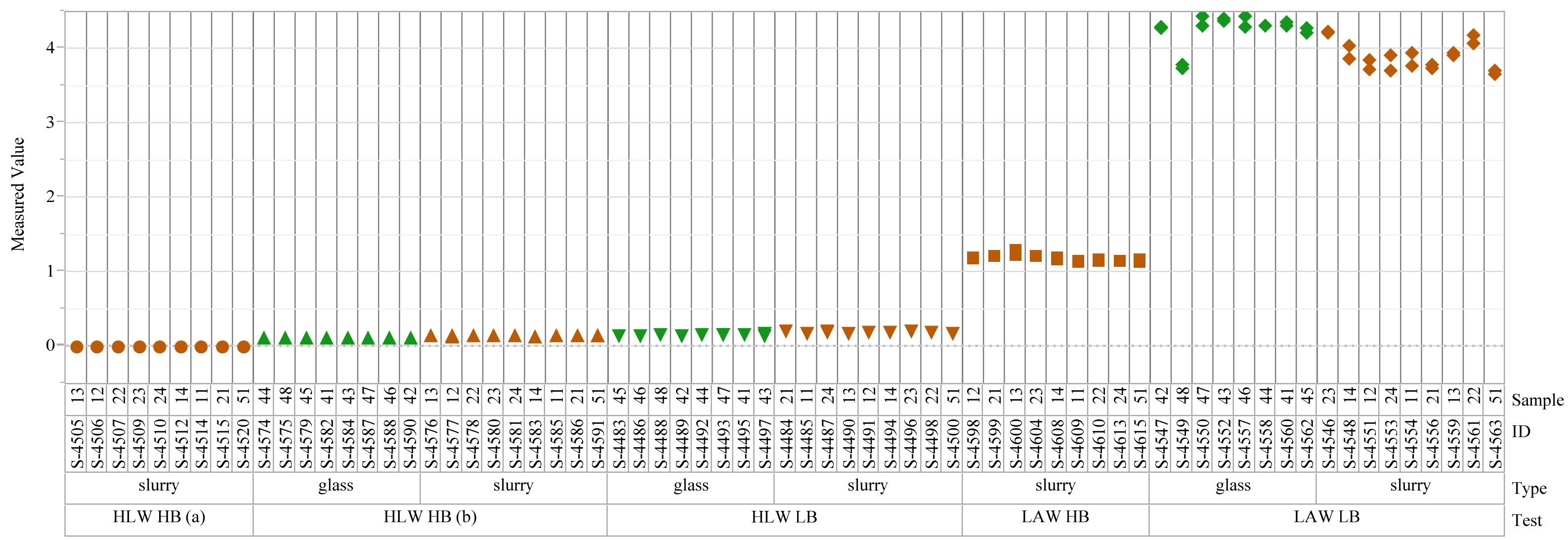
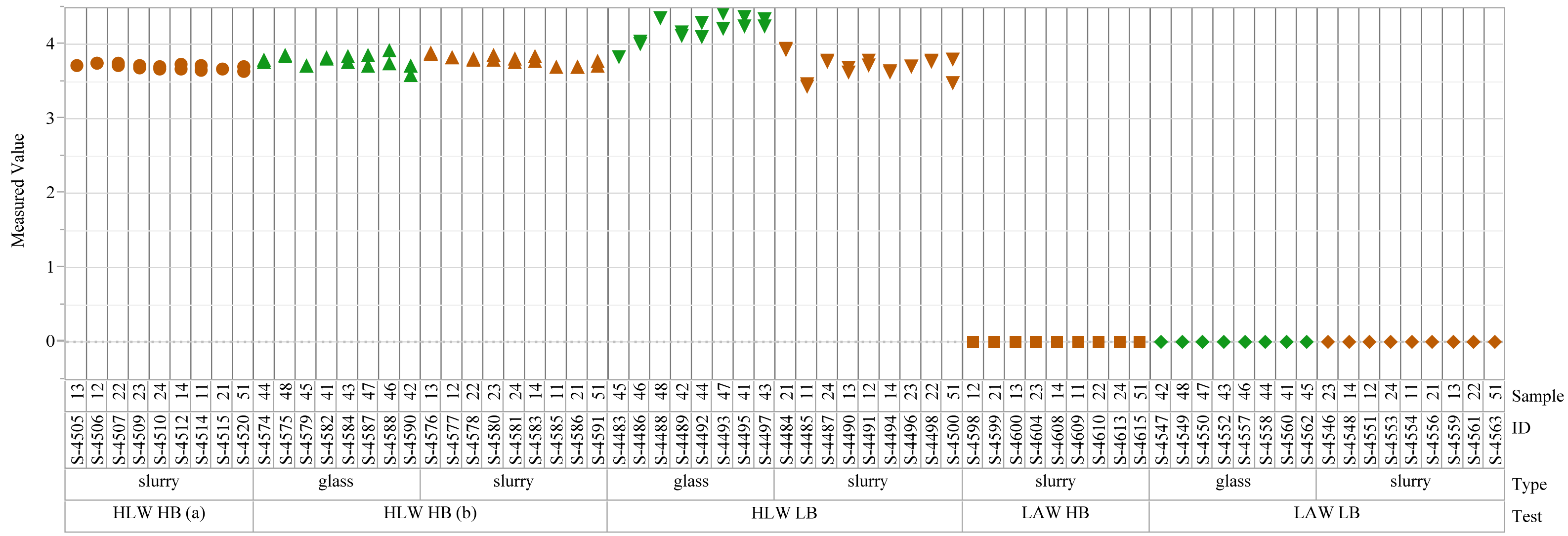


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=Li2O, Unit of Measure=wt%



Analyte=MgO, Unit of Measure=wt%

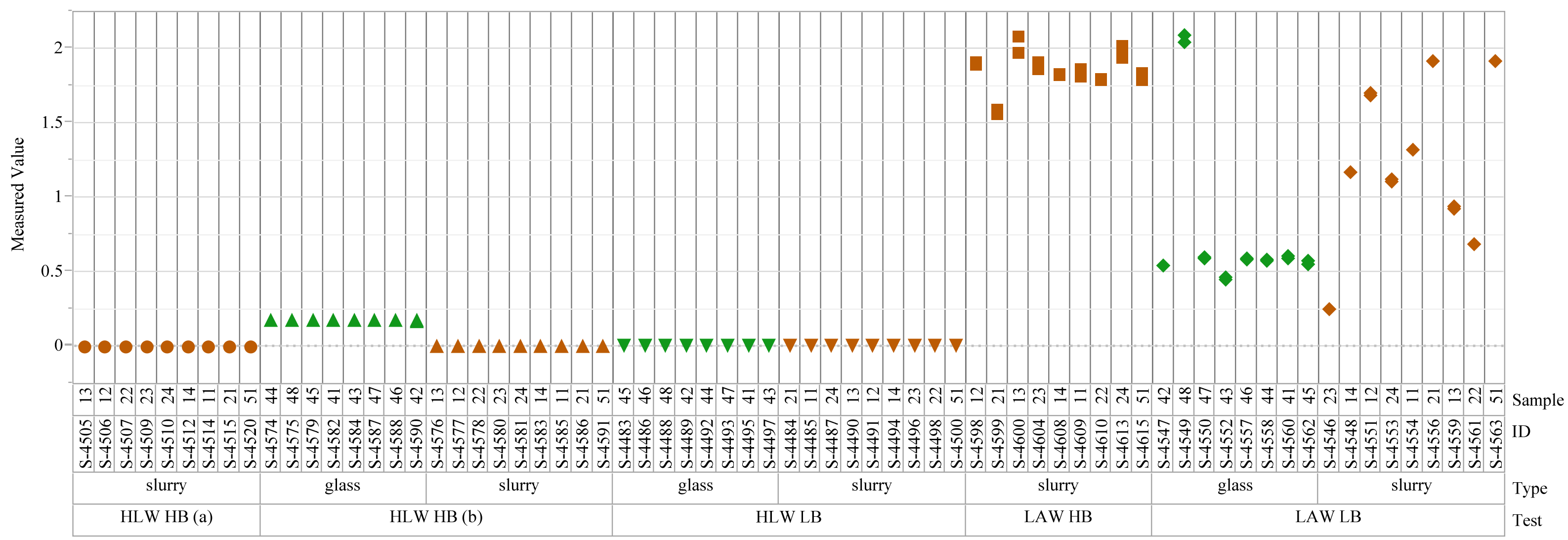
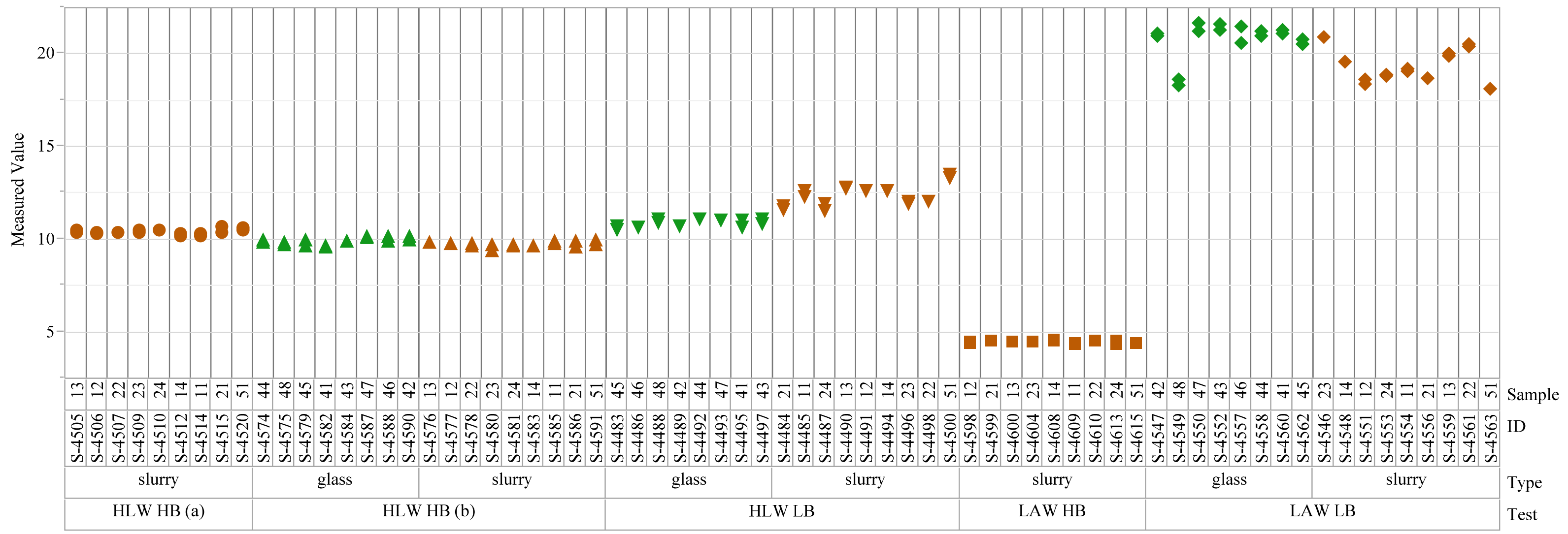


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=Na2O, Unit of Measure=wt%



Analyte=NO2, Unit of Measure=mg/kg

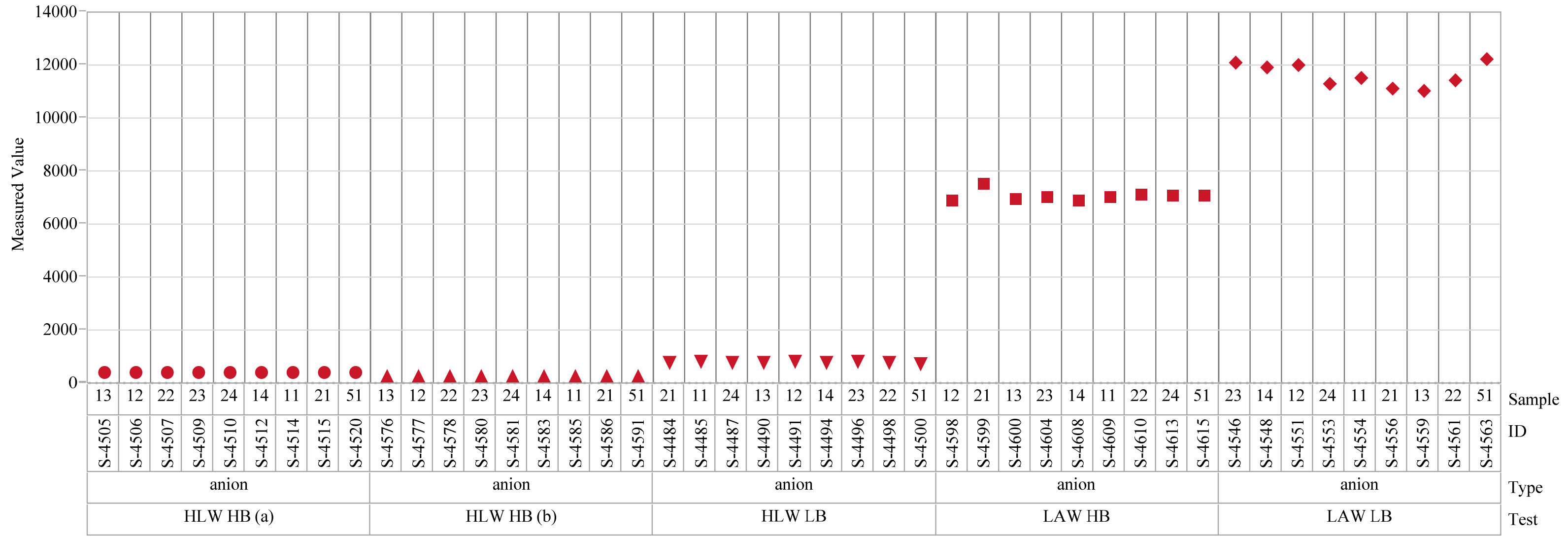
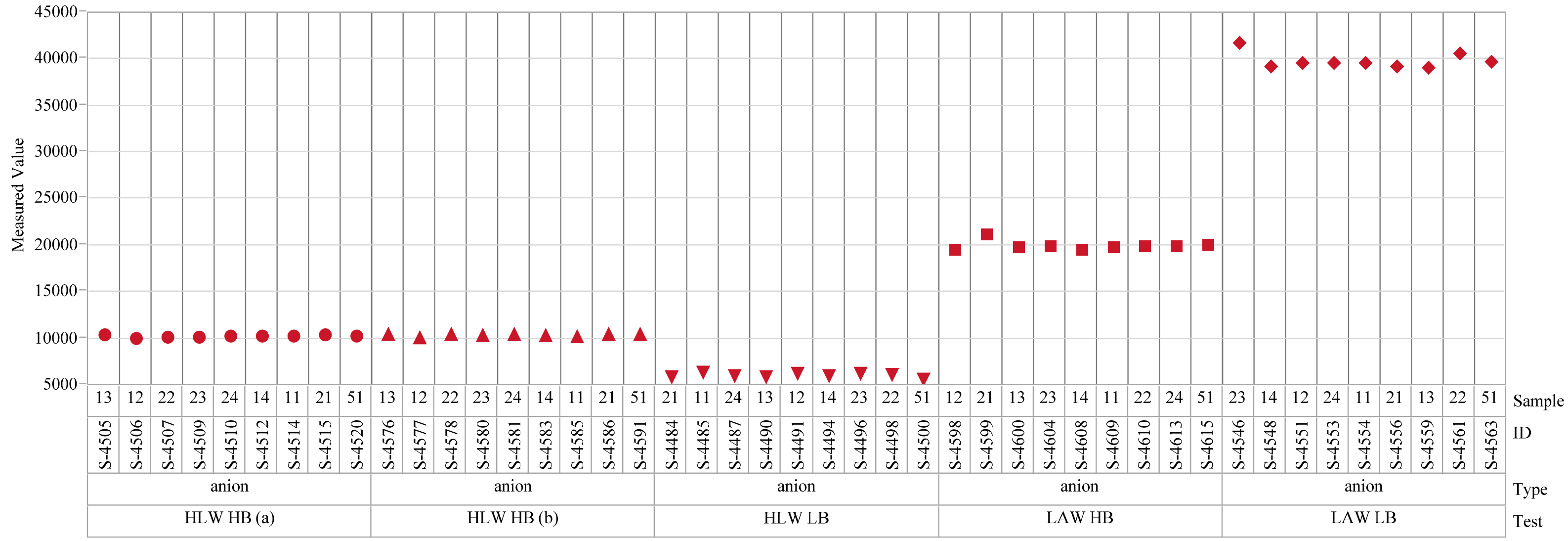


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=NO3, Unit of Measure=mg/kg



Analyte=P2O5, Unit of Measure=wt%

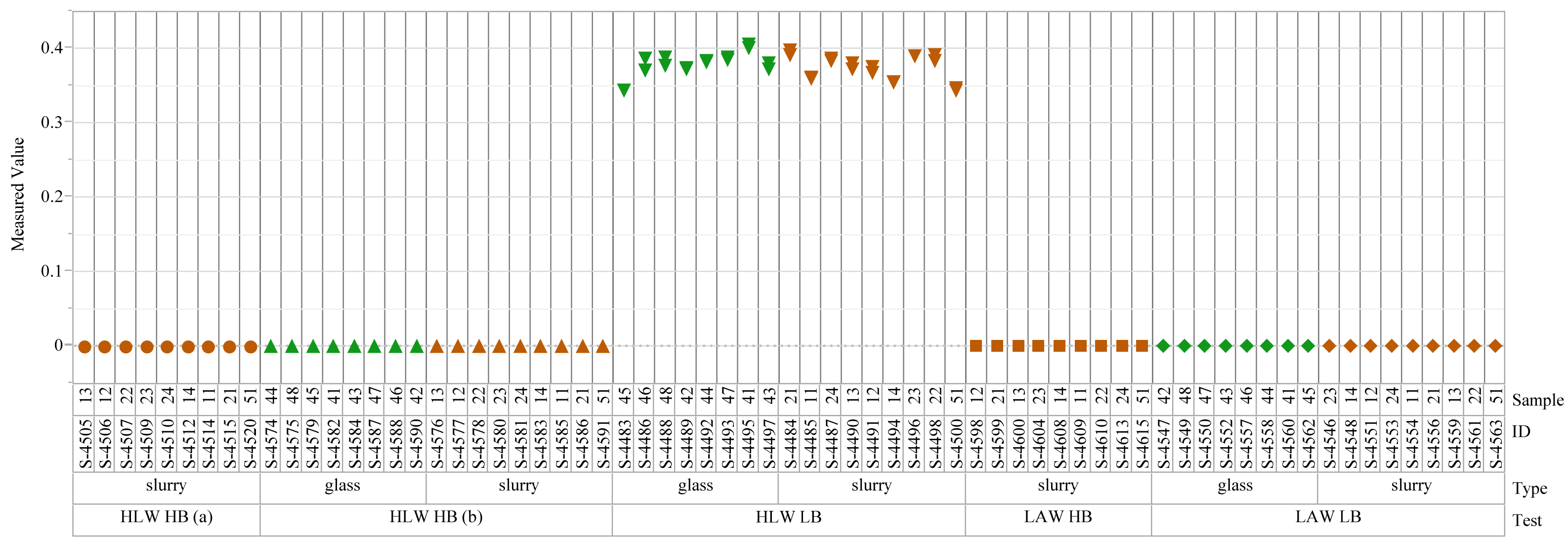
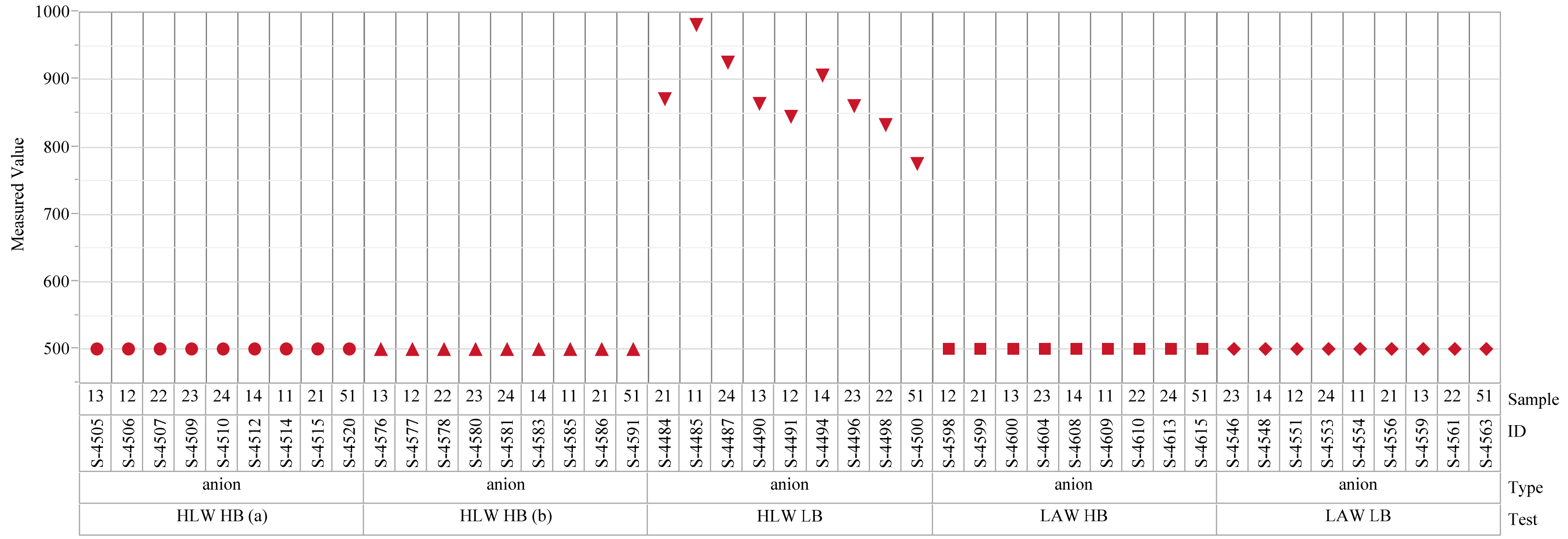


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=PO4, Unit of Measure=mg/kg



Analyte=SiO2, Unit of Measure=wt%

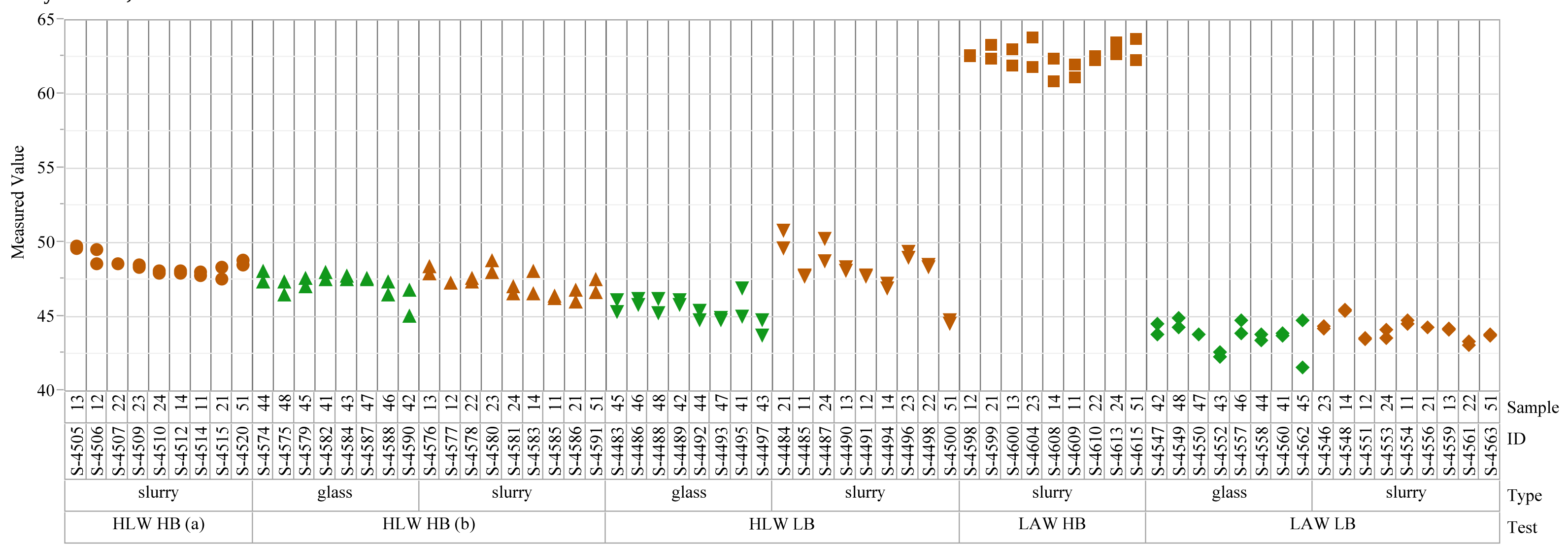
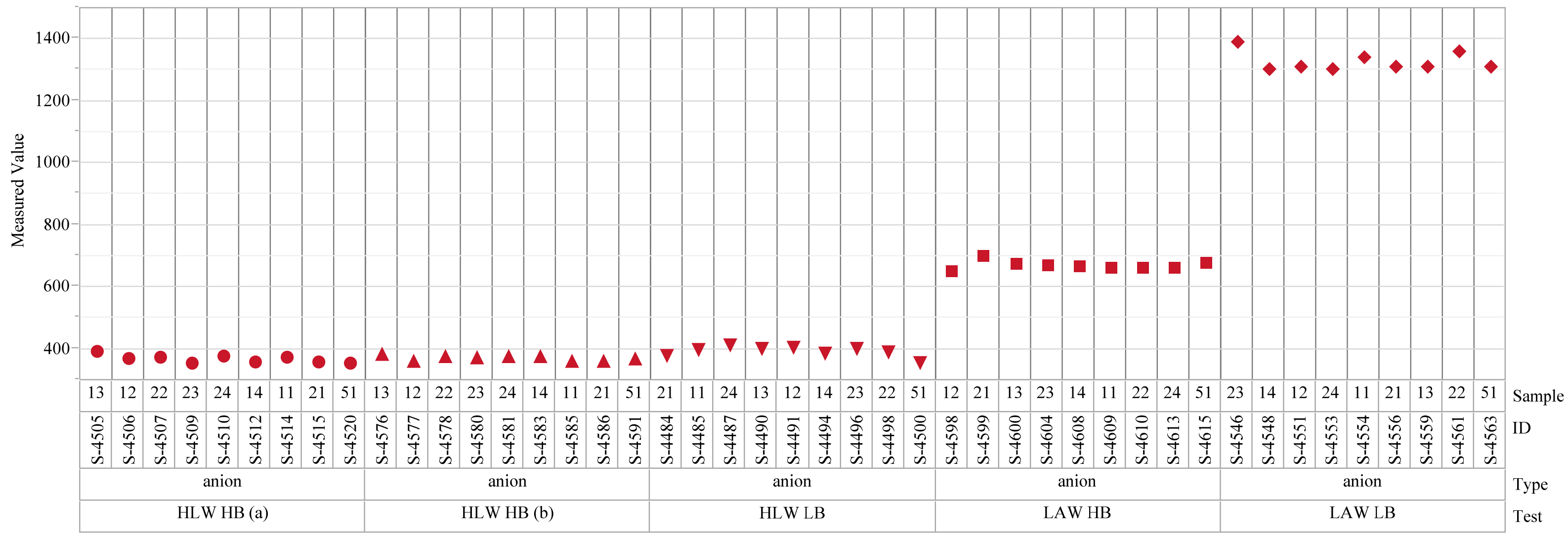


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=SO4, Unit of Measure=mg/kg



Analyte=SO4, Unit of Measure=wt%

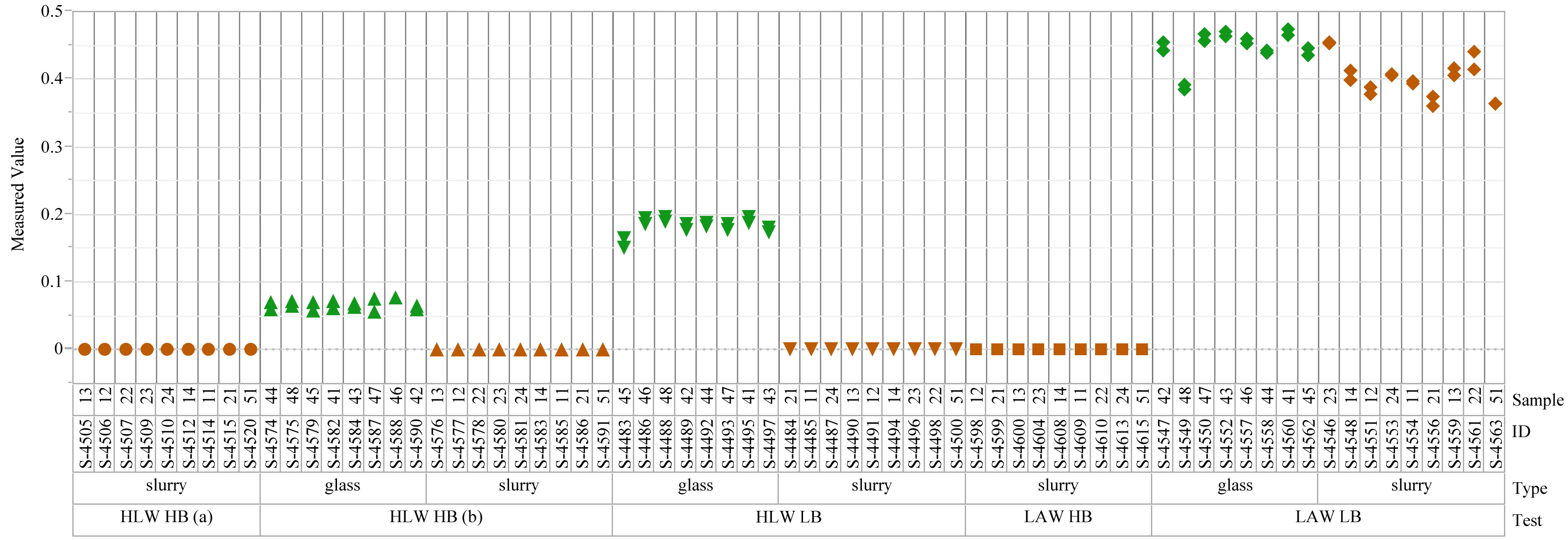
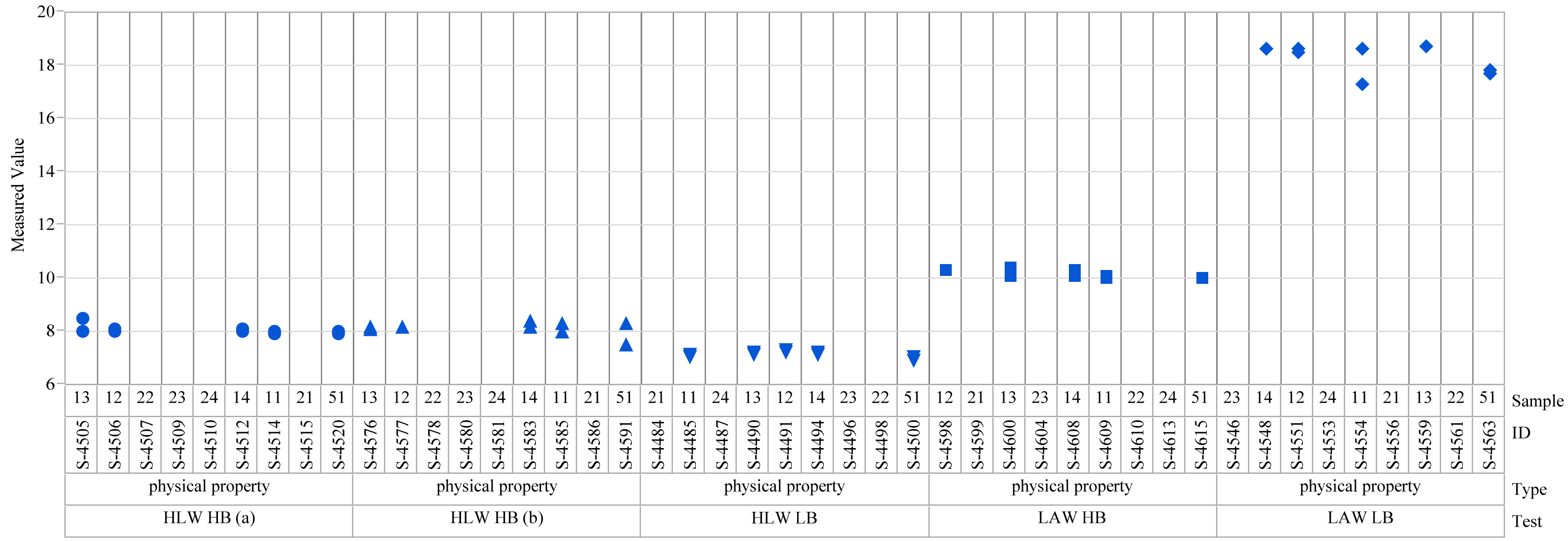


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=Soluble Solids, Unit of Measure=wt%



Analyte=TiO2, Unit of Measure=wt%

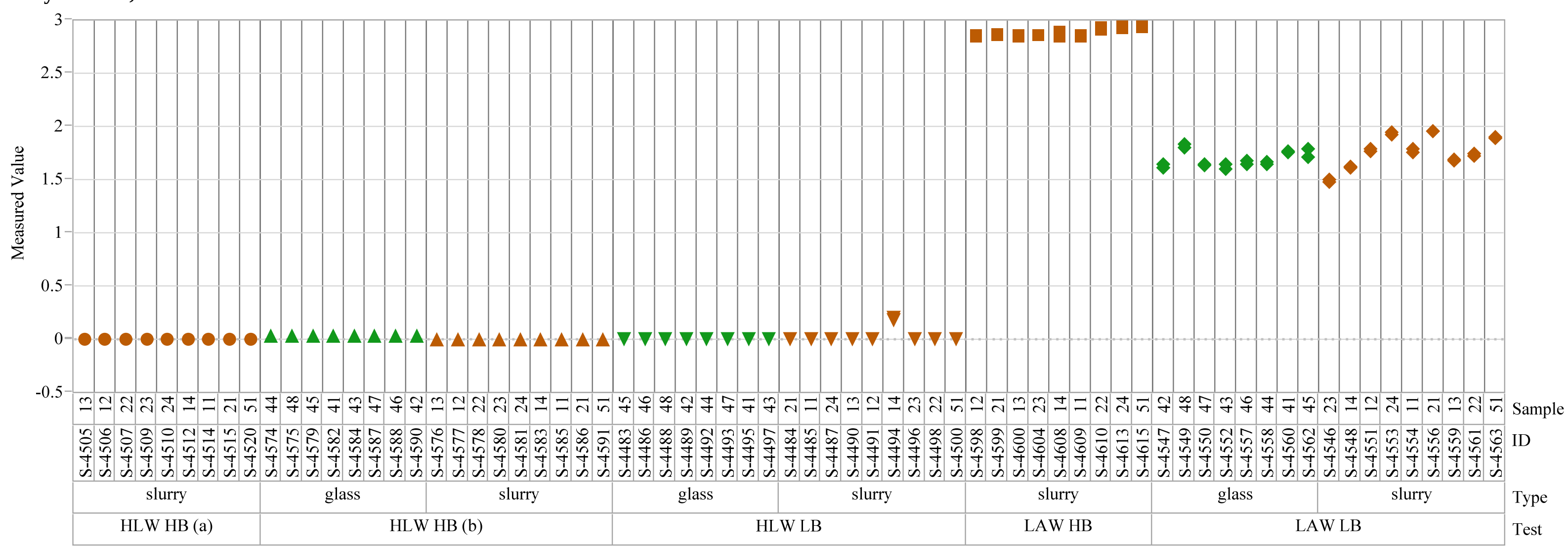
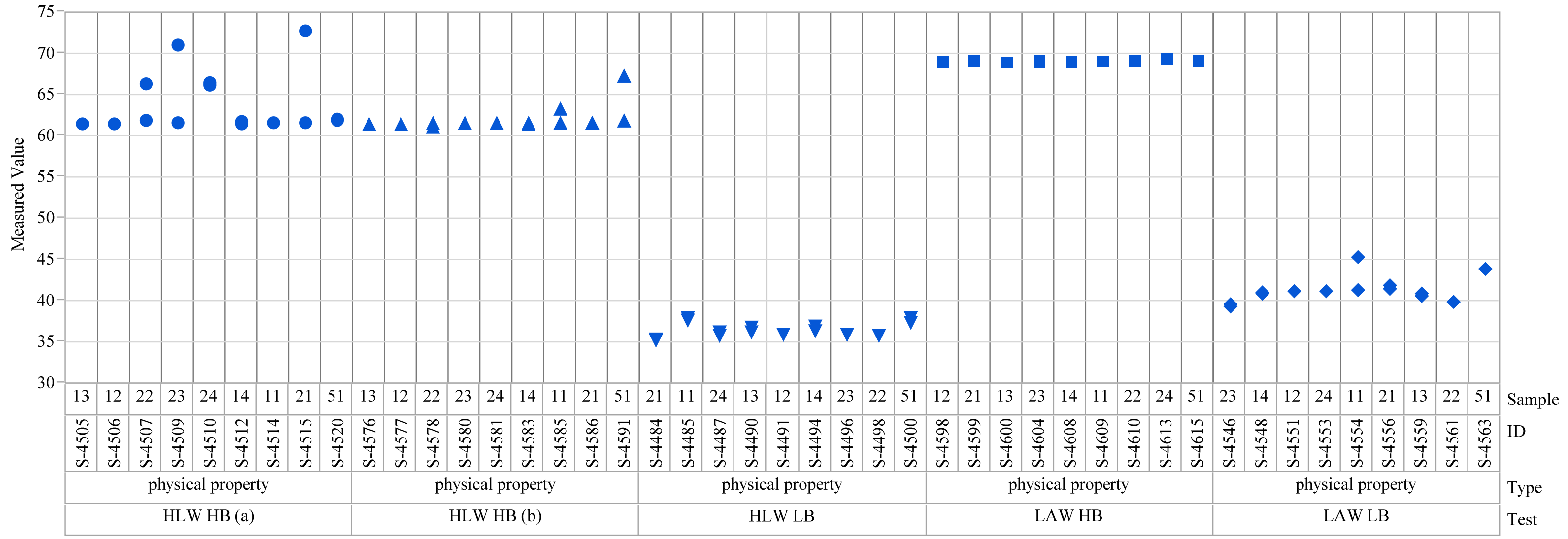


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=Total Solids, Unit of Measure=wt%



Analyte=Wt% Calcine, Unit of Measure=wt%

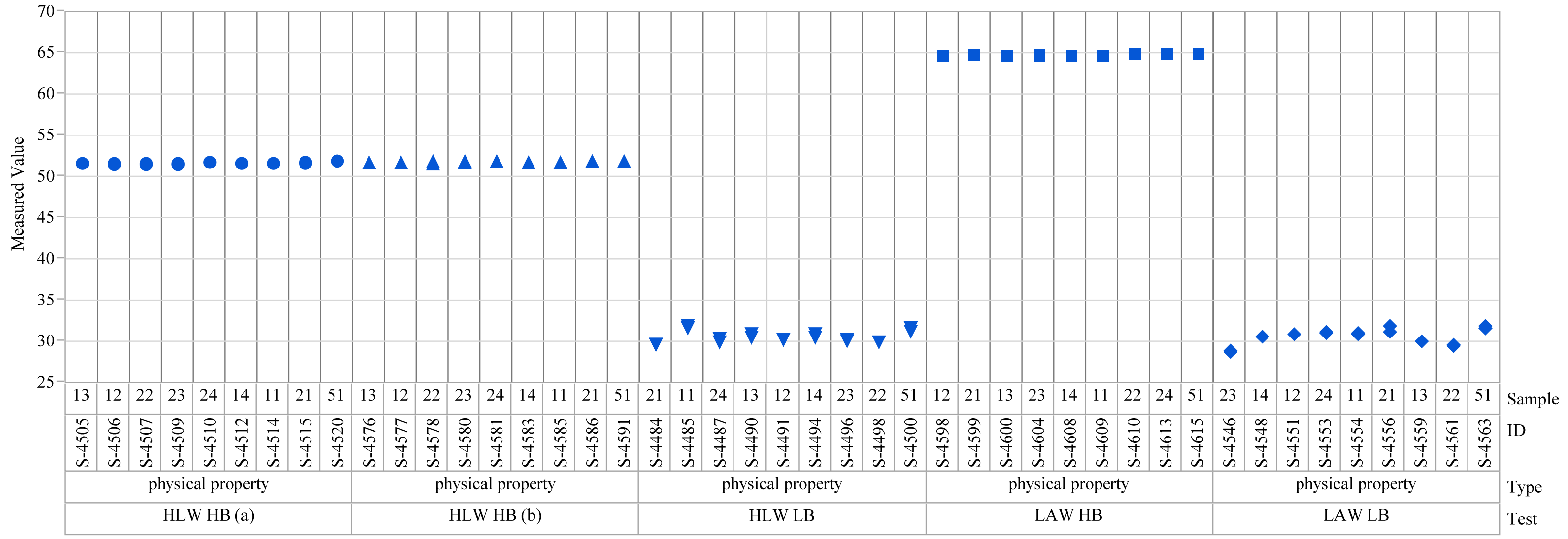
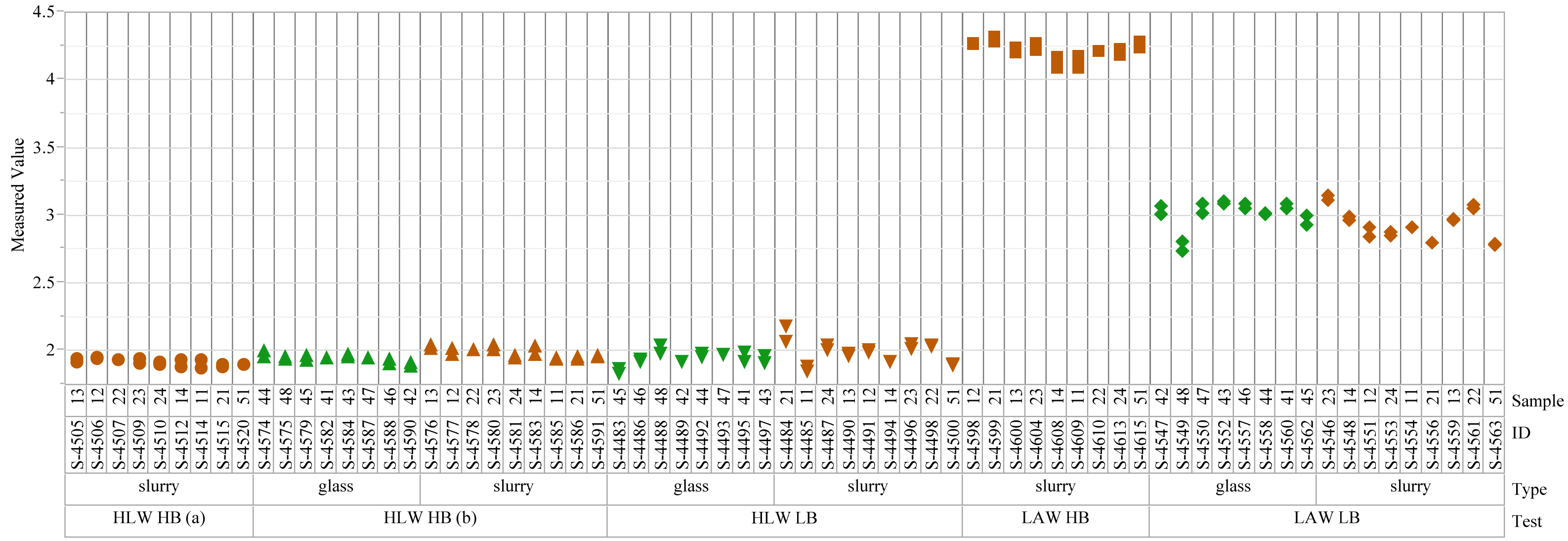


Exhibit G1. Plots of the Measurements by Analyte in Sampling Sequence Grouped by Test and Type of Analyte with Sample IDs

Analyte=ZnO, Unit of Measure=wt%



Analyte=ZrO2, Unit of Measure=wt%

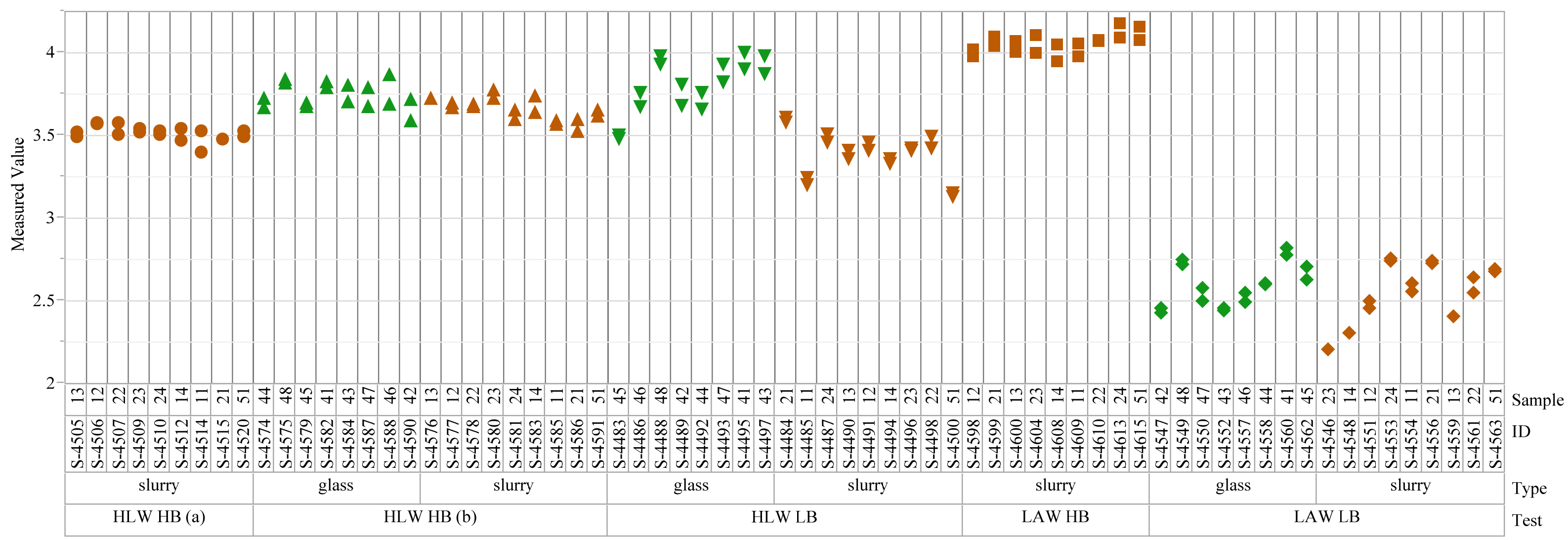


Exhibit G2. Descriptive Statistics for Analytes with Samples Measured Only Once

Distributions Test=HLW HB (a), Type=anion, Analyte=C2O4, Unit of Measure=mg/kg, Target Value=.

Measured Value

Quantiles

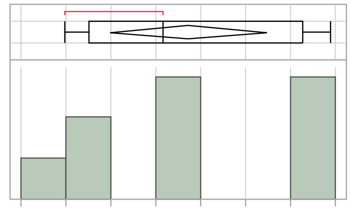
100.0%	maximum	269
99.5%		269
97.5%		269
90.0%		269
75.0%	quartile	219
50.0%	median	187
25.0%	quartile	173
10.0%		146
2.5%		146
0.5%		146
0.0%	minimum	146

Summary Statistics

Mean	197.77778
Std Dev	35.919277
Std Err Mean	11.973092
Upper 95% Mean	225.38778
Lower 95% Mean	170.16778
N	9

Distributions Test=HLW HB (a), Type=anion, Analyte=Cl, Unit of Measure= mg/kg, Target Value=.

Measured Value



Quantiles

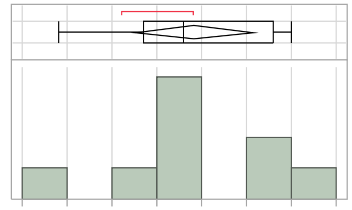
100.0%	maximum	97.8
99.5%		97.8
97.5%		97.8
90.0%		97.8
75.0%	quartile	96.55
50.0%	median	90.3
25.0%	quartile	87
10.0%		85.9
2.5%		85.9
0.5%		85.9
0.0%	minimum	85.9

Summary Statistics

Mean	91.422222
Std Dev	4.554058
Std Err Mean	1.5180193
Upper 95% Mean	94.922781
Lower 95% Mean	87.921663
N	9

Distributions Test=HLW HB (a), Type=anion, Analyte=NO2, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

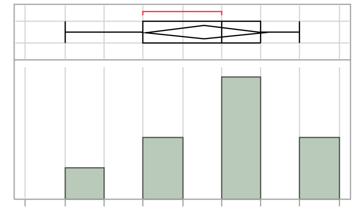
100.0%	maximum	420
99.5%		420
97.5%		420
90.0%		420
75.0%	quartile	418
50.0%	median	408
25.0%	quartile	403.5
10.0%		394
2.5%		394
0.5%		394
0.0%	minimum	394

Summary Statistics

Mean	409.11111
Std Dev	8.535872
Std Err Mean	2.8452907
Upper 95% Mean	415.67236
Lower 95% Mean	402.54986
N	9

Distributions Test=HLW HB (a), Type=anion, Analyte=NO3, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

100.0%	maximum	10300
99.5%		10300
97.5%		10300
90.0%		10300
75.0%	quartile	10250
50.0%	median	10200
25.0%	quartile	10100
10.0%		10000
2.5%		10000
0.5%		10000
0.0%	minimum	10000

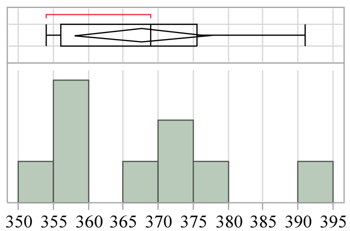
Summary Statistics

Mean	10177.778
Std Dev	97.182532
Std Err Mean	32.394177
Upper 95% Mean	10252.479
Lower 95% Mean	10103.077
N	9

Exhibit G2. Descriptive Statistics for Analytes with Samples Measured Only Once

Distributions Test=HLW HB (a), Type=anion, Analyte=SO4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

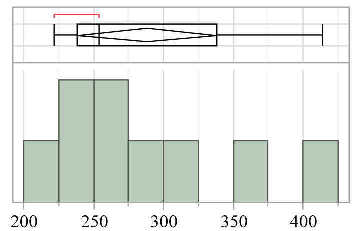
100.0%	maximum	391
99.5%		391
97.5%		391
90.0%		391
75.0%	quartile	375.5
50.0%	median	369
25.0%	quartile	356
10.0%		354
2.5%		354
0.5%		354
0.0%	minimum	354

Summary Statistics

Mean	367.44444
Std Dev	12.350214
Std Err Mean	4.1167379
Upper 95% Mean	376.93766
Lower 95% Mean	357.95123
N	9

Distributions Test=HLW HB (b), Type=anion, Analyte=C2O4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

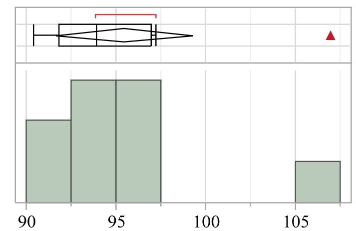
100.0%	maximum	414
99.5%		414
97.5%		414
90.0%		414
75.0%	quartile	338.5
50.0%	median	254
25.0%	quartile	238
10.0%		221
2.5%		221
0.5%		221
0.0%	minimum	221

Summary Statistics

Mean	287.77778
Std Dev	65.02649
Std Err Mean	21.675497
Upper 95% Mean	337.76156
Lower 95% Mean	237.79399
N	9

Distributions Test=HLW HB (b), Type=anion, Analyte=Cl, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

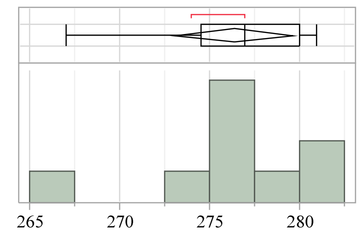
100.0%	maximum	107
99.5%		107
97.5%		107
90.0%		107
75.0%	quartile	96.95
50.0%	median	93.9
25.0%	quartile	91.8
10.0%		90.4
2.5%		90.4
0.5%		90.4
0.0%	minimum	90.4

Summary Statistics

Mean	95.411111
Std Dev	4.9823299
Std Err Mean	1.6607766
Upper 95% Mean	99.240869
Lower 95% Mean	91.581353
N	9

Distributions Test=HLW HB (b), Type=anion, Analyte=NO2, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

100.0%	maximum	281
99.5%		281
97.5%		281
90.0%		281
75.0%	quartile	280
50.0%	median	277
25.0%	quartile	274.5
10.0%		267
2.5%		267
0.5%		267
0.0%	minimum	267

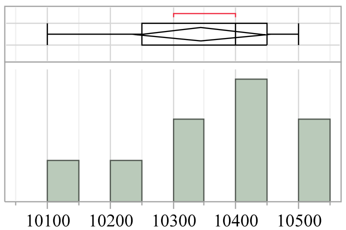
Summary Statistics

Mean	276.33333
Std Dev	4.2720019
Std Err Mean	1.4240006
Upper 95% Mean	279.61708
Lower 95% Mean	273.04958
N	9

Exhibit G2. Descriptive Statistics for Analytes with Samples Measured Only Once

Distributions Test=HLW HB (b), Type=anion, Analyte=NO3, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

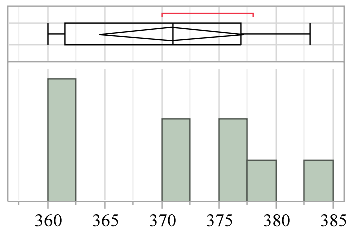
100.0%	maximum	10500
99.5%		10500
97.5%		10500
90.0%		10500
75.0%	quartile	10450
50.0%	median	10400
25.0%	quartile	10250
10.0%		10100
2.5%		10100
0.5%		10100
0.0%	minimum	10100

Summary Statistics

Mean	10344.444
Std Dev	133.33333
Std Err Mean	44.444444
Upper 95% Mean	10446.934
Lower 95% Mean	10241.955
N	9

Distributions Test=HLW HB (b), Type=anion, Analyte=SO4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

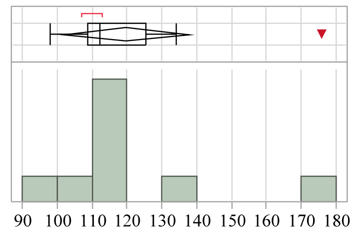
100.0%	maximum	383
99.5%		383
97.5%		383
90.0%		383
75.0%	quartile	377
50.0%	median	371
25.0%	quartile	361.5
10.0%		360
2.5%		360
0.5%		360
0.0%	minimum	360

Summary Statistics

Mean	370.77778
Std Dev	8.2579928
Std Err Mean	2.7526643
Upper 95% Mean	377.12543
Lower 95% Mean	364.43012
N	9

Distributions Test=HLW LB, Type=anion, Analyte=C2O4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

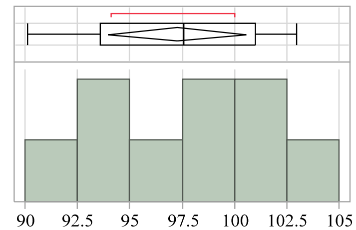
100.0%	maximum	176
99.5%		176
97.5%		176
90.0%		176
75.0%	quartile	125.5
50.0%	median	112
25.0%	quartile	108.5
10.0%		97.8
2.5%		97.8
0.5%		97.8
0.0%	minimum	97.8

Summary Statistics

Mean	119.64444
Std Dev	23.223647
Std Err Mean	7.7412157
Upper 95% Mean	137.49572
Lower 95% Mean	101.79317
N	9

Distributions Test=HLW LB, Type=anion, Analyte=Cl, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

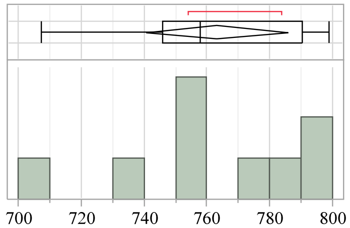
100.0%	maximum	103
99.5%		103
97.5%		103
90.0%		103
75.0%	quartile	101
50.0%	median	97.6
25.0%	quartile	93.6
10.0%		90.1
2.5%		90.1
0.5%		90.1
0.0%	minimum	90.1

Summary Statistics

Mean	97.255556
Std Dev	4.3078739
Std Err Mean	1.435958
Upper 95% Mean	100.56688
Lower 95% Mean	93.944231
N	9

Distributions Test=HLW LB, Type=anion, Analyte=NO2, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

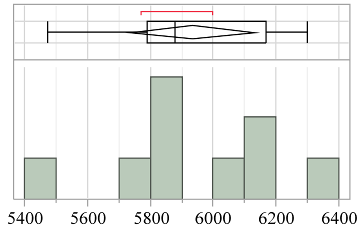
100.0%	maximum	799
99.5%		799
97.5%		799
90.0%		799
75.0%	quartile	790.5
50.0%	median	758
25.0%	quartile	746
10.0%		707
2.5%		707
0.5%		707
0.0%	minimum	707

Summary Statistics

Mean	763.11111
Std Dev	29.40427
Std Err Mean	9.8014234
Upper 95% Mean	785.71323
Lower 95% Mean	740.50899
N	9

Distributions Test=HLW LB, Type=anion, Analyte=NO3, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

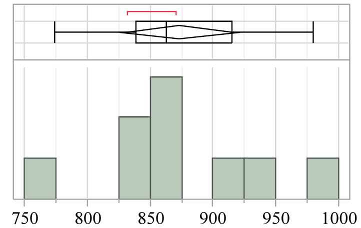
100.0%	maximum	6303
99.5%		6303
97.5%		6303
90.0%		6303
75.0%	quartile	6170
50.0%	median	5880
25.0%	quartile	5790
10.0%		5470
2.5%		5470
0.5%		5470
0.0%	minimum	5470

Summary Statistics

Mean	5933.6667
Std Dev	255.78507
Std Err Mean	85.261689
Upper 95% Mean	6130.2805
Lower 95% Mean	5737.0529
N	9

Distributions Test=HLW LB, Type=anion, Analyte=PO4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

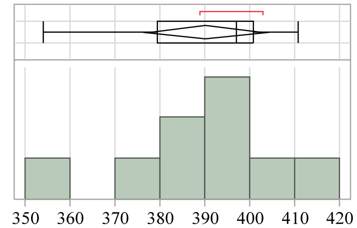
100.0%	maximum	980
99.5%		980
97.5%		980
90.0%		980
75.0%	quartile	915.5
50.0%	median	863
25.0%	quartile	838.5
10.0%		774
2.5%		774
0.5%		774
0.0%	minimum	774

Summary Statistics

Mean	872.88889
Std Dev	58.928865
Std Err Mean	19.642955
Upper 95% Mean	918.18562
Lower 95% Mean	827.59215
N	9

Distributions Test=HLW LB, Type=anion, Analyte=SO4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

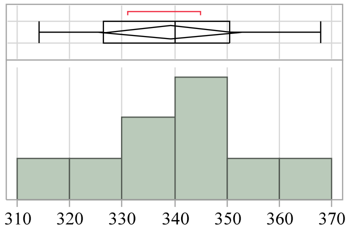
100.0%	maximum	411
99.5%		411
97.5%		411
90.0%		411
75.0%	quartile	401
50.0%	median	397
25.0%	quartile	379.5
10.0%		354
2.5%		354
0.5%		354
0.0%	minimum	354

Summary Statistics

Mean	390.11111
Std Dev	17.142378
Std Err Mean	5.7141259
Upper 95% Mean	403.28791
Lower 95% Mean	376.93431
N	9

Distributions Test=LAW HB, Type=anion, Analyte=C2O4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

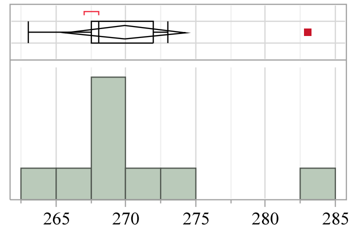
100.0%	maximum	368
99.5%		368
97.5%		368
90.0%		368
75.0%	quartile	350.5
50.0%	median	340
25.0%	quartile	326.5
10.0%		314
2.5%		314
0.5%		314
0.0%	minimum	314

Summary Statistics

Mean	339.11111
Std Dev	16.450262
Std Err Mean	5.4834206
Upper 95% Mean	351.7559
Lower 95% Mean	326.46632
N	9

Distributions Test=LAW HB, Type=anion, Analyte=Cl, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

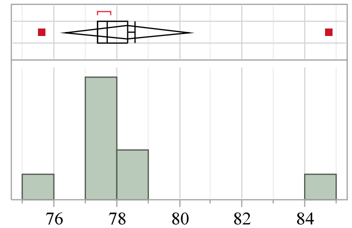
100.0%	maximum	283
99.5%		283
97.5%		283
90.0%		283
75.0%	quartile	272
50.0%	median	268
25.0%	quartile	267.5
10.0%		263
2.5%		263
0.5%		263
0.0%	minimum	263

Summary Statistics

Mean	269.88889
Std Dev	5.6223759
Std Err Mean	1.8741253
Upper 95% Mean	274.21063
Lower 95% Mean	265.56715
N	9

Distributions Test=LAW HB, Type=anion, Analyte=F, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

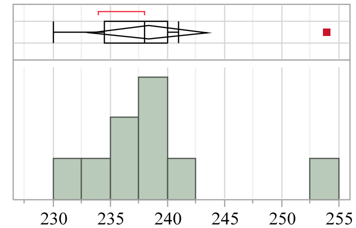
100.0%	maximum	84.8
99.5%		84.8
97.5%		84.8
90.0%		84.8
75.0%	quartile	78.35
50.0%	median	77.7
25.0%	quartile	77.4
10.0%		75.6
2.5%		75.6
0.5%		75.6
0.0%	minimum	75.6

Summary Statistics

Mean	78.311111
Std Dev	2.566829
Std Err Mean	0.8556097
Upper 95% Mean	80.284151
Lower 95% Mean	76.338072
N	9

Distributions Test=LAW HB, Type=anion, Analyte=HCO2, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

100.0%	maximum	254
99.5%		254
97.5%		254
90.0%		254
75.0%	quartile	240
50.0%	median	238
25.0%	quartile	234.5
10.0%		230
2.5%		230
0.5%		230
0.0%	minimum	230

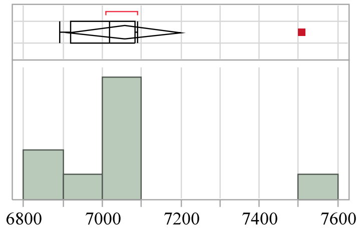
Summary Statistics

Mean	238.33333
Std Dev	6.6895441
Std Err Mean	2.229848
Upper 95% Mean	243.47537
Lower 95% Mean	233.19129
N	9

Exhibit G2. Descriptive Statistics for Analytes with Samples Measured Only Once

Distributions Test=LAW HB, Type=anion, Analyte=NO2, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

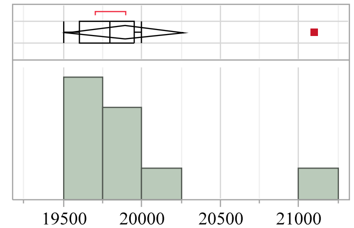
100.0%	maximum	7510
99.5%		7510
97.5%		7510
90.0%		7510
75.0%	quartile	7085
50.0%	median	7020
25.0%	quartile	6920
10.0%		6890
2.5%		6890
0.5%		6890
0.0%	minimum	6890

Summary Statistics

Mean	7056.6667
Std Dev	186.34645
Std Err Mean	62.115484
Upper 95% Mean	7199.9052
Lower 95% Mean	6913.4281
N	9

Distributions Test=LAW HB, Type=anion, Analyte=NO3, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

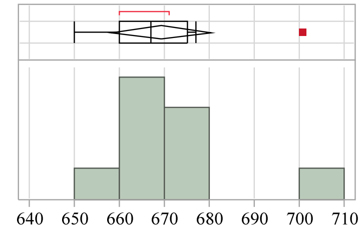
100.0%	maximum	21100
99.5%		21100
97.5%		21100
90.0%		21100
75.0%	quartile	19950
50.0%	median	19800
25.0%	quartile	19600
10.0%		19500
2.5%		19500
0.5%		19500
0.0%	minimum	19500

Summary Statistics

Mean	19888.889
Std Dev	483.33333
Std Err Mean	161.11111
Upper 95% Mean	20260.412
Lower 95% Mean	19517.366
N	9

Distributions Test=LAW HB, Type=anion, Analyte=SO4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

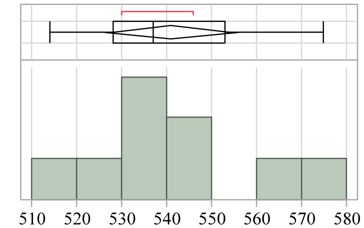
100.0%	maximum	701
99.5%		701
97.5%		701
90.0%		701
75.0%	quartile	675
50.0%	median	667
25.0%	quartile	660
10.0%		650
2.5%		650
0.5%		650
0.0%	minimum	650

Summary Statistics

Mean	669.11111
Std Dev	14.452028
Std Err Mean	4.8173426
Upper 95% Mean	680.21992
Lower 95% Mean	658.0023
N	9

Distributions Test=LAW LB, Type=anion, Analyte=C2O4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

100.0%	maximum	575
99.5%		575
97.5%		575
90.0%		575
75.0%	quartile	553
50.0%	median	537
25.0%	quartile	528
10.0%		514
2.5%		514
0.5%		514
0.0%	minimum	514

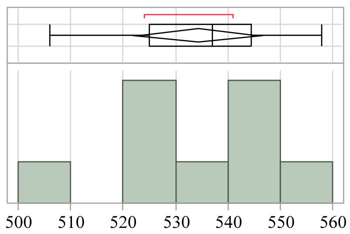
Summary Statistics

Mean	540.88889
Std Dev	18.210193
Std Err Mean	6.0700642
Upper 95% Mean	554.88648
Lower 95% Mean	526.8913
N	9

Exhibit G2. Descriptive Statistics for Analytes with Samples Measured Only Once

Distributions Test=LAW LB, Type=anion, Analyte=Cl, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

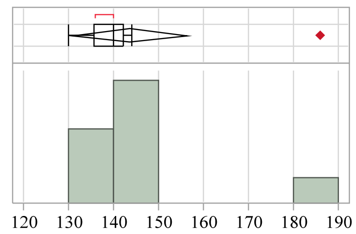
100.0%	maximum	558
99.5%		558
97.5%		558
90.0%		558
75.0%	quartile	544.5
50.0%	median	537
25.0%	quartile	525
10.0%		506
2.5%		506
0.5%		506
0.0%	minimum	506

Summary Statistics

Mean	534.22222
Std Dev	15.229722
Std Err Mean	5.0765741
Upper 95% Mean	545.92882
Lower 95% Mean	522.51562
N	9

Distributions Test=LAW LB, Type=anion, Analyte=F, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

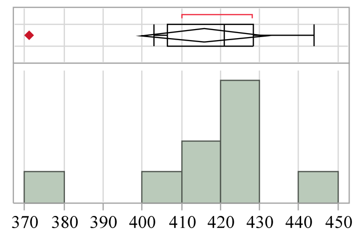
100.0%	maximum	186
99.5%		186
97.5%		186
90.0%		186
75.0%	quartile	142
50.0%	median	140
25.0%	quartile	135.5
10.0%		130
2.5%		130
0.5%		130
0.0%	minimum	130

Summary Statistics

Mean	143.44444
Std Dev	16.455327
Std Err Mean	5.4851089
Upper 95% Mean	156.09313
Lower 95% Mean	130.79576
N	9

Distributions Test=LAW LB, Type=anion, Analyte=HCO2, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

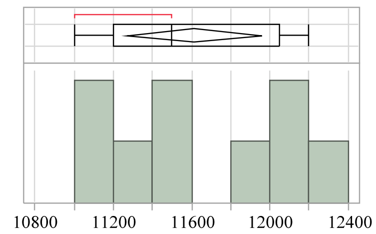
100.0%	maximum	444
99.5%		444
97.5%		444
90.0%		444
75.0%	quartile	428.5
50.0%	median	421
25.0%	quartile	406.5
10.0%		371
2.5%		371
0.5%		371
0.0%	minimum	371

Summary Statistics

Mean	415.66667
Std Dev	20.820663
Std Err Mean	6.9402209
Upper 95% Mean	431.67084
Lower 95% Mean	399.66249
N	9

Distributions Test=LAW LB, Type=anion, Analyte=NO2, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

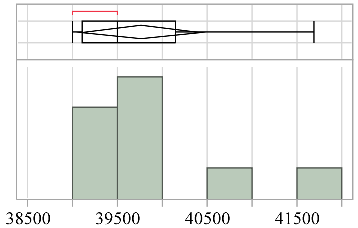
100.0%	maximum	12200
99.5%		12200
97.5%		12200
90.0%		12200
75.0%	quartile	12050
50.0%	median	11500
25.0%	quartile	11200
10.0%		11000
2.5%		11000
0.5%		11000
0.0%	minimum	11000

Summary Statistics

Mean	11611.111
Std Dev	448.45413
Std Err Mean	149.48471
Upper 95% Mean	11955.823
Lower 95% Mean	11266.399
N	9

Distributions Test=LAW LB, Type=anion, Analyte=NO3, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

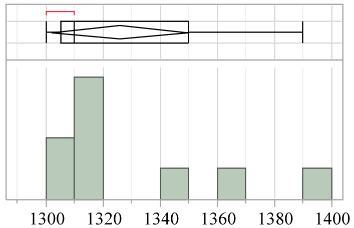
100.0%	maximum	41700
99.5%		41700
97.5%		41700
90.0%		41700
75.0%	quartile	40150
50.0%	median	39500
25.0%	quartile	39100
10.0%		39000
2.5%		39000
0.5%		39000
0.0%	minimum	39000

Summary Statistics

Mean	39755.556
Std Dev	871.93909
Std Err Mean	290.64636
Upper 95% Mean	40425.787
Lower 95% Mean	39085.324
N	9

Distributions Test=LAW LB, Type=anion, Analyte=SO4, Unit of Measure=mg/kg, Target Value=.

Measured Value



Quantiles

100.0%	maximum	1390
99.5%		1390
97.5%		1390
90.0%		1390
75.0%	quartile	1350
50.0%	median	1310
25.0%	quartile	1305
10.0%		1300
2.5%		1300
0.5%		1300
0.0%	minimum	1300

Summary Statistics

Mean	1325.5556
Std Dev	31.269438
Std Err Mean	10.423146
Upper 95% Mean	1349.5914
Lower 95% Mean	1301.5197
N	9

Exhibit G3. Estimation of Variance Components (Sample versus Analytical) for Analytes with Samples Measured Twice

Response Measured Value Test=HLW HB (a), Type=physical property, Analyte=Density, Unit of Measure=g/mL, Target Value=.
Summary of Fit

RSquare	-2.2e-16
RSquare Adj	-2.2e-16
Root Mean Square Error	0.038904
Mean of Response	1.653478
Observations (or Sum Wgts)	9

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.6534778	0.012968	8	127.50	<.0001*	1.6235735	1.6833821

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample		0.0015135	0.0007568	0.0006905	0.0055549	100.000
Total		0.0015135	0.0007568	0.0006905	0.0055549	100.000

-2 LogLikelihood =
-27.04625991
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0015135
Residual is confounded with Sample and has been removed.

Response Measured Value Test=HLW HB (a), Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.029686
RSquare Adj	0.029686
Root Mean Square Error	0.170294
Mean of Response	8.05
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	8.05	0.054772	4	146.97	<.0001*	7.8979278	8.2020722

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.0172414	0.0005	0.0140214	-0.026981	0.0279815	1.695
Residual		0.029	0.0183412	0.0112994	0.1744441	98.305
Total		0.0295	0.0140214	0.0138873	0.0995999	100.000

-2 LogLikelihood =
-3.885050144
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0295

Response Measured Value Test=HLW HB (a), Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.792657
RSquare Adj	0.792657
Root Mean Square Error	0.161245
Mean of Response	53.52
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	53.52	0.121037	4	442.18	<.0001*	53.183947	53.856053

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.3173077	0.06025	0.0524441	-0.042539	0.1630385	69.855
Residual		0.026	0.0164438	0.0101305	0.1563982	30.145
Total		0.08625	0.0524441	0.0345553	0.4707175	100.000

-2 LogLikelihood =
1.9122655837
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.08625

Response Measured Value Test=HLW HB (a), Type=physical property, Analyte=Total Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	-0.0695
RSquare Adj	-0.0695
Root Mean Square Error	3.58314
Mean of Response	63.54444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	63.544444	0.814941	8	77.97	<.0001*	61.665188	65.423701

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	-0.034449	-0.442292	4.2531405	-8.778294	7.8937104	0.000
Residual		12.838889	6.0523103	6.0743001	42.790123	100.000
Total		12.838889	6.0523103	6.0743001	42.790123	100.000

-2 LogLikelihood =
93.955322809
Note: Total is the sum of the positive variance components.
Total including negative estimates =
12.396597

Exhibit G3. Estimation of Variance Components (Sample versus Analytical) for Analytes with Samples Measured Twice

Response Measured Value Test=HLW HB (a), Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.839488
RSquare Adj	0.839488
Root Mean Square Error	0.052705
Mean of Response	51.62778
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	51.627778	0.032394	8	1593.7	<.0001*	51.553077	51.702479

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.9	0.0080556	0.0047674	-0.001288	0.0173995	74.359
Residual		0.0027778	0.0013095	0.0013142	0.0092579	25.641
Total		0.0108333	0.0047674	0.0053388	0.0326095	100.000

-2 LogLikelihood =
-33.59410576
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0108333

Response Measured Value Test=HLW HB (a), Type=slurry, Analyte=B2O3, Unit of Measure=wt%, Target Value=10.68
Summary of Fit

RSquare	0.767054
RSquare Adj	0.767054
Root Mean Square Error	0.181046
Mean of Response	10.80556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	10.805556	0.091835	8	117.66	<.0001*	10.593784	11.017327

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.815678	0.0595139	0.0387298	-0.016395	0.1354229	64.485
Residual		0.0327778	0.0154516	0.0155077	0.1092435	35.515
Total		0.0922917	0.0387298	0.0467344	0.2605017	100.000

-2 LogLikelihood =
5.2910028524
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0922917

Response Measured Value Test=HLW HB (a), Type=slurry, Analyte=Al2O3, Unit of Measure=wt%, Target Value=10
Summary of Fit

RSquare	0.881471
RSquare Adj	0.881471
Root Mean Square Error	0.056765
Mean of Response	9.042222
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	9.0422222	0.040749	8	221.90	<.0001*	8.9482545	9.1361899

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	4.137931	0.0133333	0.0075107	-0.001387	0.0280541	80.537
Residual		0.0032222	0.001519	0.0015245	0.0107392	19.463
Total		0.0165556	0.0075107	0.0080146	0.0520614	100.000

-2 LogLikelihood =
-28.58702216
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0165556

Response Measured Value Test=HLW HB (a), Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%, Target Value=11.54
Summary of Fit

RSquare	0.232306
RSquare Adj	0.232306
Root Mean Square Error	0.256038
Mean of Response	12.75556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	12.755556	0.069444	8	183.68	<.0001*	12.595416	12.915695

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.1620763	0.010625	0.0266402	-0.041589	0.0628389	13.947
Residual		0.0655556	0.0309032	0.0310155	0.218487	86.053
Total		0.0761806	0.0266402	0.0424879	0.1745137	100.000

-2 LogLikelihood =
7.0578887699
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0761806

Exhibit G3. Estimation of Variance Components (Sample versus Analytical) for Analytes with Samples Measured Twice

Response Measured Value Test=HLW HB (a), Type=slurry, Analyte=Li2O, Unit of Measure=wt%, Target Value=3.87
Summary of Fit

RSquare	0.575267
RSquare Adj	0.575267
Root Mean Square Error	0.02582
Mean of Response	3.706667
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.7066667	0.009574	8	387.15	<.0001*	3.6845884	3.728745

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.7375	0.0004917	0.0004414	-0.000373	0.0013568	42.446
Residual		0.0006667	0.0003143	0.0003154	0.0022219	57.554
Total		0.0011583	0.0004414	0.0006182	0.0029078	100.000

-2 LogLikelihood =
-65.94054153
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0011583

Response Measured Value Test=HLW HB (a), Type=slurry, Analyte=SiO2, Unit of Measure=wt%, Target Value=47.5
Summary of Fit

RSquare	0.858624
RSquare Adj	0.858624
Root Mean Square Error	0.310913
Mean of Response	48.46667
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	48.466667	0.203954	8	237.64	<.0001*	47.996348	48.936985

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	3.3728448	0.3260417	0.1885691	-0.043547	0.6956303	77.132
Residual		0.0966667	0.0455691	0.0457347	0.3221757	22.868
Total		0.4227083	0.1885691	0.2066708	1.2971912	100.000

-2 LogLikelihood =
27.791101049
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.4227083

Response Measured Value Test=HLW HB (a), Type=slurry, Analyte=Na2O, Unit of Measure=wt%, Target Value=9.84
Summary of Fit

RSquare	0.662582
RSquare Adj	0.662582
Root Mean Square Error	0.091287
Mean of Response	10.41667
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	10.416667	0.038188	8	272.77	<.0001*	10.328605	10.504729

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.075	0.0089583	0.0068501	-0.004468	0.0223844	51.807
Residual		0.0083333	0.0039284	0.0039426	0.0277738	48.193
Total		0.0172917	0.0068501	0.0090391	0.0454139	100.000

-2 LogLikelihood =
-21.07385812
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0172917

Response Measured Value Test=HLW HB (a), Type=slurry, Analyte=ZnO, Unit of Measure=wt%, Target Value=2.04
Summary of Fit

RSquare	0.28915
RSquare Adj	0.28915
Root Mean Square Error	0.021473
Mean of Response	1.915
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.915	0.006067	8	315.65	<.0001*	1.90101	1.92899

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.2183735	0.0001007	0.0001981	-0.000288	0.000489	17.923
Residual		0.0004611	0.0002174	0.0002182	0.0015368	82.077
Total		0.0005618	0.0001981	0.000312	0.0012978	100.000

-2 LogLikelihood =
-76.55848181
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0005618

Response Measured Value Test=HLW HB (a), Type=slurry, Analyte=ZrO2, Unit of Measure=wt%, Target Value=3.84
Summary of Fit

RSquare	0.21925
RSquare Adj	0.21925
Root Mean Square Error	0.040893
Mean of Response	3.515
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.515	0.010992	8	319.77	<.0001*	3.4896514	3.5403486

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.1503322	0.0002514	0.0006716	-0.001065	0.0015677	13.069
Residual		0.0016722	0.0007883	0.0007912	0.0055733	86.931
Total		0.0019236	0.0006716	0.0010737	0.0043993	100.000

-2 LogLikelihood =
-55.45394781
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0019236

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=B2O3, Unit of Measure=wt%, Target Value=10.68
Summary of Fit

RSquare	0.859926
RSquare Adj	0.859926
Root Mean Square Error	0.248747
Mean of Response	11.21875
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	11.21875	0.174984	7	64.11	<.0001*	10.804978	11.632522

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	3.4588745	0.2140179	0.1318447	-0.044393	0.4724288	77.573
Residual		0.061875	0.0309375	0.02823	0.2270923	22.427
Total		0.2758929	0.1318447	0.1294503	0.9395404	100.000

-2 LogLikelihood =
18.084907412
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.2758929

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=Al2O3, Unit of Measure=wt%, Target Value=10
Summary of Fit

RSquare	0.243758
RSquare Adj	0.243758
Root Mean Square Error	0.183576
Mean of Response	9.57875
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	9.57875	0.0533	7	179.72	<.0001*	9.4527165	9.7047835

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.1743853	0.0058768	0.0147836	-0.023098	0.0348521	14.849
Residual		0.0337	0.01685	0.0153754	0.123685	85.151
Total		0.0395768	0.0147836	0.0213444	0.0971601	100.000

-2 LogLikelihood =
-3.41876199
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0395768

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=CaO, Unit of Measure=wt%, Target Value=0.12
Summary of Fit

RSquare	0.098035
RSquare Adj	0.098035
Root Mean Square Error	0.002345
Mean of Response	0.11225
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.11225	0.00062	7	181.16	<.0001*	0.1107848	0.1137152

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.0584416	3.2143e-7	2.1415e-6	-3.876e-6	4.5187e-6	5.521
Residual		0.0000055	2.75e-6	2.5093e-6	2.0186e-5	94.479
Total		5.8214e-6	2.1415e-6	3.1646e-6	1.4055e-5	100.000

-2 LogLikelihood =
-135.5468991
Note: Total is the sum of the positive variance components.
Total including negative estimates =
5.8214e-6

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=Fe2O3, Unit of Measure=wt%, Target Value=11.54
Summary of Fit

RSquare	0.754342
RSquare Adj	0.754342
Root Mean Square Error	0.103078
Mean of Response	10.66875
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	10.66875	0.05423	7	196.73	<.0001*	10.540517	10.796983

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.7142857	0.0182143	0.0128531	-0.006977	0.0434058	63.158
Residual		0.010625	0.0053125	0.0048476	0.0389956	36.842
Total		0.0288393	0.0128531	0.0141079	0.0883821	100.000

-2 LogLikelihood =
-12.41089936
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0288393

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=Li2O, Unit of Measure=wt%, Target Value=3.87
Summary of Fit

RSquare	0.390925
RSquare Adj	0.390925
Root Mean Square Error	0.069642
Mean of Response	3.7875
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.7875	0.022698	7	166.87	<.0001*	3.7338288	3.8411712

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.3497791	0.0016964	0.0025146	-0.003232	0.006625	25.914
Residual		0.00485	0.002425	0.0022128	0.0178004	74.086
Total		0.0065464	0.0025146	0.0034792	0.0165831	100.000

-2 LogLikelihood =
-30.87832566
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0065464

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=K2O, Unit of Measure=wt%, Target Value=0.13
Summary of Fit

RSquare	-0.10967
RSquare Adj	-0.10967
Root Mean Square Error	0.002016
Mean of Response	0.120563
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.1205625	0.000477	7	252.98	<.0001*	0.1194356	0.1216894

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	-0.052747	-2.143e-7	1.4053e-6	-2.969e-6	2.54e-6	0.000
Residual		4.0625e-6	2.0313e-6	1.8535e-6	1.491e-5	100.000
Total		4.0625e-6	2.0313e-6	1.8535e-6	1.491e-5	100.000

-2 LogLikelihood =
-141.6453251
Note: Total is the sum of the positive variance components.
Total including negative estimates =
3.8482e-6

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=MgO, Unit of Measure=wt%, Target Value=0.17
Summary of Fit

RSquare	-0.07757
RSquare Adj	-0.07757
Root Mean Square Error	0.00255
Mean of Response	0.175
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.175	0.000612	7	285.77	<.0001*	0.173552	0.176448

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	-0.038462	-2.5e-7	2.283e-6	-4.725e-6	4.2246e-6	0.000
Residual		0.0000065	3.25e-6	2.9656e-6	2.3856e-5	100.000
Total		0.0000065	3.25e-6	2.9656e-6	2.3856e-5	100.000

-2 LogLikelihood =
-134.37518
Note: Total is the sum of the positive variance components.
Total including negative estimates =
6.25e-6

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=Na2O, Unit of Measure=wt%, Target Value=9.84
Summary of Fit

RSquare	0.696512
RSquare Adj	0.696512
Root Mean Square Error	0.132358
Mean of Response	9.924375
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	9.924375	0.062353	7	159.16	<.0001*	9.7769337	10.071816

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.2754192	0.0223438	0.0171925	-0.011353	0.0560405	56.052
Residual		0.0175187	0.0087594	0.0079928	0.0642969	43.948
Total		0.0398625	0.0171925	0.0198741	0.1166981	100.000

-2 LogLikelihood =
-6.45622224
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0398625

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=SO4, Unit of Measure=wt%, Target Value=0
Summary of Fit

RSquare	-0.2983
RSquare Adj	-0.2983
Root Mean Square Error	0.007128
Mean of Response	0.067313
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.0673125	0.00155	7	43.44	<.0001*	0.0636483	0.0709767

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	-0.121947	-6.196e-6	1.6334e-5	-3.821e-5	2.5818e-5	0.000
Residual		5.0812e-5	0.0000254	2.3183e-5	0.0001865	100.000
Total		5.0812e-5	0.0000254	2.3183e-5	0.0001865	100.000

-2 LogLikelihood =
-104.9267925
Note: Total is the sum of the positive variance components.
Total including negative estimates =
4.4616e-5

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=SiO2, Unit of Measure=wt%, Target Value=47.5
Summary of Fit

RSquare	0.510803
RSquare Adj	0.510803
Root Mean Square Error	0.591608
Mean of Response	47.2375
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	47.2375	0.216661	7	218.02	<.0001*	46.725178	47.749822

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.5729592	0.2005357	0.2189742	-0.228646	0.6297173	36.426
Residual		0.35	0.175	0.1596848	1.2845623	63.574
Total		0.5505357	0.2189742	0.2871627	1.4528935	100.000

-2 LogLikelihood =
34.938386079
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.5505357

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=TiO2, Unit of Measure=wt%, Target Value=0
Summary of Fit

RSquare	-0.85557
RSquare Adj	-0.85557
Root Mean Square Error	0.000901
Mean of Response	0.035313
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.0353125	0.000162	7	218.05	<.0001*	0.0349296	0.0356954

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	-0.241758	-1.964e-7	2.3203e-7	-6.512e-7	2.5834e-7	0.000
Residual		8.125e-7	4.0625e-7	3.707e-7	2.982e-6	100.000
Total		8.125e-7	4.0625e-7	3.707e-7	2.982e-6	100.000

-2 LogLikelihood =
-169.6314875
Note: Total is the sum of the positive variance components.
Total including negative estimates =
6.1607e-7

Exhibit G3. Estimation of Variance Components (Sample versus Analytical) for Analytes with Samples Measured Twice

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=ZnO, Unit of Measure=wt%, Target Value=2.04
Summary of Fit

RSquare	0.651822
RSquare Adj	0.651822
Root Mean Square Error	0.019039
Mean of Response	1.9475
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.9475	0.008345	7	233.37	<.0001*	1.9277667	1.9672333

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.0369458	0.0003759	0.0003113	-0.000234	0.000986	50.907
Residual		0.0003625	0.0001813	0.0001654	0.0013304	49.093
Total		0.0007384	0.0003113	0.0003729	0.0020968	100.000

-2 LogLikelihood =
-65.63593581
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0007384

Response Measured Value Test=HLW HB (b), Type=physical property, Analyte=Density, Unit of Measure=g/mL, Target Value=.
Summary of Fit

RSquare	0
RSquare Adj	0
Root Mean Square Error	0.015487
Mean of Response	1.643978
Observations (or Sum Wgts)	9

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.6439778	0.005162	8	318.46	<.0001*	1.6320735	1.655882

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample		0.0002398	0.0001199	0.0001094	0.0008803	100.000
Total		0.0002398	0.0001199	0.0001094	0.0008803	100.000

-2 LogLikelihood =
-41.78400222
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0002398
Residual is confounded with Sample and has been removed.

Response Measured Value Test=HLW HB (b), Type=glass, Analyte=ZrO2, Unit of Measure=wt%, Target Value=3.84
Summary of Fit

RSquare	0.333793
RSquare Adj	0.333793
Root Mean Square Error	0.069552
Mean of Response	3.745
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.745	0.021609	7	173.30	<.0001*	3.693902	3.796098

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.2722407	0.001317	0.0023345	-0.003259	0.0058925	21.399
Residual		0.0048375	0.0024188	0.0022071	0.0177545	78.601
Total		0.0061545	0.0023345	0.0032927	0.0153691	100.000

-2 LogLikelihood =
-31.58679645
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0061545

Response Measured Value Test=HLW HB (b), Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	-0.00789
RSquare Adj	-0.00789
Root Mean Square Error	2.104281
Mean of Response	54.12
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	54.12	0.662495	4	81.69	<.0001*	52.280618	55.959382

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	-0.004404	-0.0195	2.0901276	-4.116075	4.0770749	0.000
Residual		4.428	2.8005131	1.7253066	26.635816	100.000
Total		4.428	2.8005131	1.7253066	26.635816	100.000

-2 LogLikelihood =
41.199624408
Note: Total is the sum of the positive variance components.
Total including negative estimates =
4.4085

Response Measured Value Test=HLW HB (b), Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	-0.68342
RSquare Adj	-0.68342
Root Mean Square Error	0.279285
Mean of Response	8.14
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	8.14	0.065955	4	123.42	<.0001*	7.9568809	8.3231191

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	-0.221154	-0.01725	0.0290677	-0.074222	0.0397216	0.000
Residual		0.078	0.0493315	0.0303916	0.4691946	100.000
Total		0.078	0.0493315	0.0303916	0.4691946	100.000

-2 LogLikelihood =
2.5482690657
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.06075

Response Measured Value Test=HLW HB (b), Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.649258
RSquare Adj	0.649258
Root Mean Square Error	0.074536
Mean of Response	51.75556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	51.755556	0.030556	8	1693.8	<.0001*	51.685094	51.826017

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.0125	0.005625	0.0044007	-0.003	0.0142503	50.311
Residual		0.0055556	0.0026189	0.0026284	0.0185158	49.689
Total		0.0111806	0.0044007	0.005865	0.0291389	100.000

-2 LogLikelihood =
-28.29069585
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0111806

Response Measured Value Test=HLW HB (b), Type=physical property, Analyte=Total Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.131155
RSquare Adj	0.131155
Root Mean Square Error	1.36687
Mean of Response	61.90556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	61.905556	0.347156	8	178.32	<.0001*	61.105013	62.706098

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.0805456	0.1504861	0.6986015	-1.218748	1.5197198	7.454
Residual		1.8683333	0.8807408	0.8839408	6.2268795	92.546
Total		2.0188194	0.6986015	1.1318229	4.5766727	100.000

-2 LogLikelihood =
62.954959564
Note: Total is the sum of the positive variance components.
Total including negative estimates =
2.0188194

Response Measured Value Test=HLW HB (b), Type=slurry, Analyte=Al2O3, Unit of Measure=wt%, Target Value=10
Summary of Fit

RSquare	0.872722
RSquare Adj	0.872722
Root Mean Square Error	0.075682
Mean of Response	9.122778
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	9.1227778	0.052388	8	174.14	<.0001*	9.0019704	9.2435851

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	3.8124394	0.0218368	0.0124239	-0.002514	0.0461872	79.221
Residual		0.0057278	0.0027001	0.0027099	0.0190898	20.779
Total		0.0275646	0.0124239	0.0133956	0.0858582	100.000

-2 LogLikelihood =
-19.38978085
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0275646

Exhibit G3. Estimation of Variance Components (Sample versus Analytical) for Analytes with Samples Measured Twice

Response Measured Value Test=HLW HB (b), Type=slurry, Analyte=B2O3, Unit of Measure=wt%, Target Value=10.68
Summary of Fit

RSquare	0.922837
RSquare Adj	0.922837
Root Mean Square Error	0.108012
Mean of Response	11.55
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	11.55	0.096465	8	119.73	<.0001*	11.327551	11.772449

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	6.6785714	0.0779167	0.0419652	-0.004334	0.1601669	86.977
Residual		0.0116667	0.0054997	0.0055197	0.0388833	13.023
Total		0.0895833	0.0419652	0.0425449	0.2956639	100.000

-2 LogLikelihood =
-3.21906909
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0895833

Response Measured Value Test=HLW HB (b), Type=slurry, Analyte=K2O, Unit of Measure=wt%, Target Value=0.13
Summary of Fit

RSquare	0.476866
RSquare Adj	0.476866
Root Mean Square Error	0.004447
Mean of Response	0.146556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.1465556	0.001478	8	99.18	<.0001*	0.1431479	0.1499632

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.4936798	9.7639e-6	1.0876e-5	-1.155e-5	3.1081e-5	33.051
Residual		1.9778e-5	9.3233e-6	9.3572e-6	6.5916e-5	66.949
Total		2.9542e-5	1.0876e-5	1.6053e-5	7.1388e-5	100.000

-2 LogLikelihood =
-127.4974399
Note: Total is the sum of the positive variance components.
Total including negative estimates =
2.9542e-5

Response Measured Value Test=HLW HB (b), Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%, Target Value=11.54
Summary of Fit

RSquare	0.874232
RSquare Adj	0.874232
Root Mean Square Error	0.084984
Mean of Response	11.00556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	11.005556	0.059187	8	185.95	<.0001*	10.86907	11.142041

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	3.8653846	0.0279167	0.0158555	-0.00316	0.0589929	79.447
Residual		0.0072222	0.0034046	0.003417	0.0240706	20.553
Total		0.0351389	0.0158555	0.0170652	0.1096292	100.000

-2 LogLikelihood =
-15.35096425
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0351389

Response Measured Value Test=HLW HB (b), Type=slurry, Analyte=Li2O, Unit of Measure=wt%, Target Value=3.87
Summary of Fit

RSquare	0.86469
RSquare Adj	0.86469
Root Mean Square Error	0.030732
Mean of Response	3.792222
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.7922222	0.020617	8	183.93	<.0001*	3.7446784	3.839766

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	3.5507353	0.0033535	0.0019258	-0.000421	0.0071279	78.026
Residual		0.0009444	0.0004452	0.0004468	0.0031477	21.974
Total		0.0042979	0.0019258	0.0020959	0.0132731	100.000

-2 LogLikelihood =
-50.5328861
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0042979

Response Measured Value Test=HLW HB (b), Type=slurry, Analyte=Na2O, Unit of Measure=wt%, Target Value=9.84
Summary of Fit

RSquare	0.213751
RSquare Adj	0.213751
Root Mean Square Error	0.124677
Mean of Response	9.754444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	9.7544444	0.03339	8	292.14	<.0001*	9.677447	9.8314419

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.1455057	0.0022618	0.0062124	-0.009914	0.0144379	12.702
Residual		0.0155444	0.0073277	0.0073543	0.0518073	87.298
Total		0.0178062	0.0062124	0.0099424	0.0406962	100.000

-2 LogLikelihood =
-17.61119392
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0178062

Response Measured Value Test=HLW HB (b), Type=slurry, Analyte=ZnO, Unit of Measure=wt%, Target Value=2.04
Summary of Fit

RSquare	0.783794
RSquare Adj	0.783794
Root Mean Square Error	0.021985
Mean of Response	1.989444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.9894444	0.01159	8	171.65	<.0001*	1.962717	2.0161719

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.0014368	0.0009674	0.0006152	-0.000238	0.002173	66.683
Residual		0.0004833	0.0002278	0.0002287	0.0016109	33.317
Total		0.0014507	0.0006152	0.0007303	0.0041513	100.000

-2 LogLikelihood =
-65.77728662
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0014507

Response Measured Value Test=HLW HB (b), Type=slurry, Analyte=SiO2, Unit of Measure=wt%, Target Value=47.5
Summary of Fit

RSquare	0.713597
RSquare Adj	0.713597
Root Mean Square Error	0.512076
Mean of Response	47.26667
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	47.266667	0.233333	8	202.57	<.0001*	46.728599	47.804734

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.3686441	0.3588889	0.2526757	-0.136346	0.8541242	57.782
Residual		0.2622222	0.1236127	0.1240619	0.873948	42.218
Total		0.6211111	0.2526757	0.3200047	1.6850478	100.000

-2 LogLikelihood =
38.925593604
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.6211111

Response Measured Value Test=HLW HB (b), Type=slurry, Analyte=ZrO2, Unit of Measure=wt%, Target Value=3.84
Summary of Fit

RSquare	0.822777
RSquare Adj	0.822777
Root Mean Square Error	0.036515
Mean of Response	3.662222
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.6622222	0.021329	8	171.70	<.0001*	3.6130368	3.7114076

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.5708333	0.0034278	0.0020712	-0.000632	0.0074873	71.995
Residual		0.0013333	0.0006285	0.0006308	0.0044438	28.005
Total		0.0047611	0.0020712	0.002362	0.0141036	100.000

-2 LogLikelihood =
-46.88619343
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0047611

Response Measured Value Test=HLW LB, Type=glass, Analyte=Al2O3, Unit of Measure=wt%, Target Value=7.27
Summary of Fit

RSquare	0.821219
RSquare Adj	0.821219
Root Mean Square Error	0.165529
Mean of Response	8.6025
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	8.6025	0.102691	7	83.77	<.0001*	8.3596733	8.8453267

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.5789885	0.0706643	0.0456119	-0.018733	0.160062	72.059
Residual		0.0274	0.0137	0.012501	0.1005629	27.941
Total		0.0980643	0.0456119	0.0467729	0.320128	100.000

-2 LogLikelihood =
4.1067990038
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0980643

Response Measured Value Test=HLW LB, Type=glass, Analyte=CaO, Unit of Measure=wt%, Target Value=0
Summary of Fit

RSquare	0.520107
RSquare Adj	0.520107
Root Mean Square Error	0.00624
Mean of Response	0.038813
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.0388125	0.002309	7	16.81	<.0001*	0.0333534	0.0442716

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.595047	2.317e-5	2.4783e-5	-2.54e-5	7.1743e-5	37.306
Residual		3.8937e-5	1.9469e-5	1.7765e-5	0.0001429	62.694
Total		0.0000621	2.4783e-5	3.2339e-5	0.0001645	100.000

-2 LogLikelihood =
-101.4749354
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0000621

Response Measured Value Test=HLW LB, Type=glass, Analyte=B2O3, Unit of Measure=wt%, Target Value=11.05
Summary of Fit

RSquare	0.798075
RSquare Adj	0.798075
Root Mean Square Error	0.22561
Mean of Response	11.31
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	11.31	0.131421	7	86.06	<.0001*	10.999239	11.620761

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.2145664	0.1127214	0.0749439	-0.034166	0.2596089	68.892
Residual		0.0509	0.02545	0.0232227	0.1868121	31.108
Total		0.1636214	0.0749439	0.0787611	0.5218844	100.000

-2 LogLikelihood =
12.514815238
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.1636214

Response Measured Value Test=HLW LB, Type=glass, Analyte=Cu2O, Unit of Measure=wt%, Target Value=0
Summary of Fit

RSquare	0.721549
RSquare Adj	0.721549
Root Mean Square Error	0.001118
Mean of Response	0.013
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.013	0.000551	7	23.59	<.0001*	0.0116972	0.0143028

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.4428571	1.8036e-6	1.3352e-6	-8.134e-7	4.4205e-6	59.064
Residual		1.25e-6	6.25e-7	5.703e-7	4.5877e-6	40.936
Total		3.0536e-6	1.3352e-6	1.5104e-6	9.1099e-6	100.000

-2 LogLikelihood =
-149.0436126
Note: Total is the sum of the positive variance components.
Total including negative estimates =
3.0536e-6

Response Measured Value Test=HLW LB, Type=glass, Analyte=Fe2O3, Unit of Measure=wt%, Target Value=12.29
Summary of Fit

RSquare	0.93715
RSquare Adj	0.93715
Root Mean Square Error	0.158114
Mean of Response	12.4125
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	12.4125	0.167372	7	74.16	<.0001*	12.016728	12.808272

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	8.4642857	0.2116071	0.1199532	-0.023497	0.4467112	89.434
Residual		0.025	0.0125	0.0114061	0.0917545	10.566
Total		0.2366071	0.1199532	0.107012	0.8895072	100.000

-2 LogLikelihood =
10.212322173
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.2366071

Response Measured Value Test=HLW LB, Type=glass, Analyte=Li2O, Unit of Measure=wt%, Target Value=4.01
Summary of Fit

RSquare	0.888287
RSquare Adj	0.888287
Root Mean Square Error	0.080117
Mean of Response	4.183125
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	4.183125	0.063287	7	66.10	<.0001*	4.033474	4.332776

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	4.4920017	0.028833	0.0172024	-0.004883	0.0625491	81.792
Residual		0.0064187	0.0032094	0.0029285	0.023558	18.208
Total		0.0352518	0.0172024	0.016329	0.1241933	100.000

-2 LogLikelihood =
-14.28034452
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0352518

Response Measured Value Test=HLW LB, Type=glass, Analyte=K2O, Unit of Measure=wt%, Target Value=0.14
Summary of Fit

RSquare	0.745448
RSquare Adj	0.745448
Root Mean Square Error	0.005408
Mean of Response	0.142375
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.142375	0.002793	7	50.97	<.0001*	0.1357704	0.1489796

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.6336996	4.7786e-5	3.4152e-5	-1.915e-5	0.0001147	62.031
Residual		2.925e-5	1.4625e-5	1.3345e-5	0.0001074	37.969
Total		7.7036e-5	3.4152e-5	0.0000378	0.0002343	100.000

-2 LogLikelihood =
-101.0966881
Note: Total is the sum of the positive variance components.
Total including negative estimates =
7.7036e-5

Response Measured Value Test=HLW LB, Type=glass, Analyte=Na2O, Unit of Measure=wt%, Target Value=12.1
Summary of Fit

RSquare	0.708302
RSquare Adj	0.708302
Root Mean Square Error	0.143614
Mean of Response	10.84375
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	10.84375	0.069074	7	156.99	<.0001*	10.680416	11.007084

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.3506494	0.0278571	0.021044	-0.013388	0.0691026	57.459
Residual		0.020625	0.0103125	0.00941	0.0756974	42.541
Total		0.0484821	0.021044	0.0240832	0.1431762	100.000

-2 LogLikelihood =
-3.717239174
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0484821

Response Measured Value Test=HLW LB, Type=glass, Analyte=P2O5, Unit of Measure=wt%, Target Value=0.51
Summary of Fit

RSquare	0.942707
RSquare Adj	0.942707
Root Mean Square Error	0.005238
Mean of Response	0.378313
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.3783125	0.005811	7	65.10	<.0001*	0.3645718	0.3920532

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	9.3455906	0.0002564	0.0001446	-0.000027	0.0005397	90.334
Residual		2.7438e-5	1.3719e-5	1.2518e-5	0.0001007	9.666
Total		0.0002839	0.0001446	0.000128	0.0010756	100.000

-2 LogLikelihood =
-91.3520571
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0002839

Response Measured Value Test=HLW LB, Type=glass, Analyte=SO4, Unit of Measure=wt%, Target Value=0.18
Summary of Fit

RSquare	0.841812
RSquare Adj	0.841812
Root Mean Square Error	0.006119
Mean of Response	0.182188
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.1821875	0.004043	7	45.06	<.0001*	0.1726268	0.1917482

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.9933222	0.0001121	7.0529e-5	-2.617e-5	0.0002503	74.958
Residual		3.7438e-5	1.8719e-5	1.7081e-5	0.0001374	25.042
Total		0.0001495	7.0529e-5	0.0000707	0.0004989	100.000

-2 LogLikelihood =
-93.94381782
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0001495

Response Measured Value Test=HLW LB, Type=glass, Analyte=SiO2, Unit of Measure=wt%, Target Value=47.07
Summary of Fit

RSquare	0.434481
RSquare Adj	0.434481
Root Mean Square Error	0.665207
Mean of Response	45.4375
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	45.4375	0.225545	7	201.46	<.0001*	44.904171	45.970829

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.4196933	0.1857143	0.2440448	-0.292605	0.6640333	29.562
Residual		0.4425	0.22125	0.2018872	1.6240538	70.438
Total		0.6282143	0.2440448	0.3318726	1.6122004	100.000

-2 LogLikelihood =
37.377047534
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.6282143

Response Measured Value Test=HLW LB, Type=glass, Analyte=ZnO, Unit of Measure=wt%, Target Value=2.11
Summary of Fit

RSquare	0.810053
RSquare Adj	0.810053
Root Mean Square Error	0.028395
Mean of Response	1.940625
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.940625	0.017072	7	113.67	<.0001*	1.9002555	1.9809945

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.3920266	0.0019286	0.0012625	-0.000546	0.0044031	70.519
Residual		0.0008063	0.0004031	0.0003678	0.0029591	29.481
Total		0.0027348	0.0012625	0.0013103	0.0088267	100.000

-2 LogLikelihood =
-49.2202729
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0027348

Response Measured Value Test=HLW LB, Type=glass, Analyte=ZrO2, Unit of Measure=wt%, Target Value=3.27
Summary of Fit

RSquare	0.903091
RSquare Adj	0.903091
Root Mean Square Error	0.067129
Mean of Response	3.795625
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.795625	0.05702	7	66.57	<.0001*	3.6607941	3.9304559

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	5.2720428	0.0237571	0.0139486	-0.003582	0.051096	84.056
Residual		0.0045063	0.0022531	0.0020559	0.0165387	15.944
Total		0.0282634	0.0139486	0.0130005	0.1014608	100.000

-2 LogLikelihood =
-18.57039198
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0282634

Response Measured Value Test=HLW LB, Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.89858
RSquare Adj	0.89858
Root Mean Square Error	0.344964
Mean of Response	29.73
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	29.73	0.376364	4	78.99	<.0001*	28.685045	30.774955

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	5.4516807	0.64875	0.5022202	-0.335584	1.6330835	84.500
Residual		0.119	0.0752622	0.0463666	0.7158225	15.500
Total		0.76775	0.5022202	0.2919573	5.0481475	100.000

-2 LogLikelihood =
18.593075922
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.76775

Response Measured Value Test=HLW LB, Type=physical property, Analyte=Density, Unit of Measure=g/mL, Target Value=.
Summary of Fit

RSquare	1.11e-16
RSquare Adj	1.11e-16
Root Mean Square Error	0.011015
Mean of Response	1.3439
Observations (or Sum Wgts)	9

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.3439	0.003672	8	366.00	<.0001*	1.3354328	1.3523672

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample		0.0001213	6.067e-5	5.536e-5	0.0004453	100.000
Total		0.0001213	6.067e-5	5.536e-5	0.0004453	100.000

-2 LogLikelihood =
-47.23507117
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0001213
Residual is confounded with Sample and has been removed.

Response Measured Value Test=HLW LB, Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.776386
RSquare Adj	0.776386
Root Mean Square Error	0.070711
Mean of Response	7.11
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	7.11	0.05099	4	139.44	<.0001*	6.9684285	7.2515715

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.1	0.0105	0.0093274	-0.007781	0.0287813	67.742
Residual		0.005	0.0031623	0.0019482	0.0300766	32.258
Total		0.0155	0.0093274	0.0062552	0.0825404	100.000

-2 LogLikelihood =
-13.24674311
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0155

Response Measured Value Test=HLW LB, Type=physical property, Analyte=Total Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.947415
RSquare Adj	0.947415
Root Mean Square Error	0.256038
Mean of Response	36.32222
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	36.322222	0.277653	8	130.82	<.0001*	35.681954	36.962491

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	10.083686	0.6610417	0.3472537	-0.019563	1.3416463	90.978
Residual		0.0655556	0.0309032	0.0310155	0.218487	9.022
Total		0.7265972	0.3472537	0.3409083	2.4746733	100.000

-2 LogLikelihood =
29.231395306
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.7265972

Response Measured Value Test=HLW LB, Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.956926
RSquare Adj	0.956926
Root Mean Square Error	0.197203
Mean of Response	30.44444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	30.444444	0.236503	8	128.73	<.0001*	29.899068	30.989821

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	12.444643	0.4839583	0.2518682	-0.009694	0.977611	92.562
Residual		0.0388889	0.0183324	0.018399	0.1296109	7.438
Total		0.5228472	0.2518682	0.2441231	1.8035676	100.000

-2 LogLikelihood =
21.965121589
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.5228472

Response Measured Value Test=HLW LB, Type=slurry, Analyte=Al2O3, Unit of Measure=wt%, Target Value=7.27
Summary of Fit

RSquare	0.922703
RSquare Adj	0.922703
Root Mean Square Error	0.068028
Mean of Response	8.188333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	8.1883333	0.060702	8	134.89	<.0001*	8.0483545	8.3283122

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	6.6659664	0.0308486	0.0166171	-0.00172	0.0634175	86.955
Residual		0.0046278	0.0021816	0.0021895	0.0154237	13.045
Total		0.0354764	0.0166171	0.0168495	0.1170681	100.000

-2 LogLikelihood =
-18.95233153
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0354764

Response Measured Value Test=HLW LB, Type=slurry, Analyte=B2O3, Unit of Measure=wt%, Target Value=11.05
Summary of Fit

RSquare	0.993416
RSquare Adj	0.993416
Root Mean Square Error	0.186041
Mean of Response	10.80444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	10.804444	0.572814	8	18.86	<.0001*	9.4835322	12.125357

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	84.820766	2.935741	1.4765458	0.0417644	5.8297176	98.835
Residual		0.0346111	0.0163158	0.0163751	0.1153537	1.165
Total		2.9703521	1.4765458	1.3601582	10.793771	100.000

-2 LogLikelihood =
35.069933538
Note: Total is the sum of the positive variance components.
Total including negative estimates =
2.9703521

Response Measured Value Test=HLW LB, Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%, Target Value=12.29
Summary of Fit

RSquare	0.97198
RSquare Adj	0.97198
Root Mean Square Error	0.143372
Mean of Response	12.49444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	12.494444	0.21351	8	58.52	<.0001*	12.00209	12.986799

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	19.459459	0.4	0.2051961	-0.002177	0.802177	95.112
Residual		0.0205556	0.00969	0.0097252	0.0685086	4.888
Total		0.4205556	0.2051961	0.1948226	1.4812824	100.000

-2 LogLikelihood =
14.590476315
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.4205556

Response Measured Value Test=HLW LB, Type=slurry, Analyte=Li2O, Unit of Measure=wt%, Target Value=4.01
Summary of Fit

RSquare	0.81241
RSquare Adj	0.81241
Root Mean Square Error	0.078457
Mean of Response	3.704444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.7044444	0.044507	8	83.23	<.0001*	3.6018113	3.8070775

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.3962094	0.01475	0.0090312	-0.002951	0.0324508	70.555
Residual		0.0061556	0.0029018	0.0029123	0.0205156	29.445
Total		0.0209056	0.0090312	0.0104131	0.0613375	100.000

-2 LogLikelihood =
-21.35012294
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0209056

Response Measured Value Test=HLW LB, Type=slurry, Analyte=K2O, Unit of Measure=wt%, Target Value=0.14
Summary of Fit

RSquare	0.95232
RSquare Adj	0.95232
Root Mean Square Error	0.00255
Mean of Response	0.180278
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.1802778	0.002905	8	62.06	<.0001*	0.1735791	0.1869764

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	11.183761	0.0000727	0.000038	-1.79e-6	0.0001472	91.792
Residual		0.0000065	3.0641e-6	3.0753e-6	2.1664e-5	8.208
Total		0.0000792	0.000038	3.7064e-5	0.0002715	100.000

-2 LogLikelihood =
-126.6979839
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0000792

Response Measured Value Test=HLW LB, Type=slurry, Analyte=Na2O, Unit of Measure=wt%, Target Value=12.1
Summary of Fit

RSquare	0.96559
RSquare Adj	0.96559
Root Mean Square Error	0.139443
Mean of Response	12.35
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	12.35	0.187268	8	65.95	<.0001*	11.918158	12.781842

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	15.732143	0.3059028	0.157879	-0.003534	0.61534	94.023
Residual		0.0194444	0.0091662	0.0091995	0.0648055	5.977
Total		0.3253472	0.157879	0.1512257	1.1357223	100.000

-2 LogLikelihood =
11.992110558
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.3253472

Response Measured Value Test=HLW LB, Type=slurry, Analyte=P2O5, Unit of Measure=wt%, Target Value=0.51
Summary of Fit

RSquare	0.973073
RSquare Adj	0.973073
Root Mean Square Error	0.003764
Mean of Response	0.373611
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.3736111	0.005718	8	65.34	<.0001*	0.3604245	0.3867977

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	20.27402	0.0002872	0.0001472	-1.266e-6	0.0005757	95.299
Residual		1.4167e-5	6.6782e-6	6.7025e-6	4.7215e-5	4.701
Total		0.0003014	0.0001472	0.0001395	0.0010632	100.000

-2 LogLikelihood =
-108.8494346
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0003014

Response Measured Value Test=HLW LB, Type=slurry, Analyte=TiO2, Unit of Measure=wt%, Target Value=0
Summary of Fit

RSquare	0.996026
RSquare Adj	0.996026
Root Mean Square Error	0.005185
Mean of Response	0.020556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.0205556	0.020556	8	1.00	0.3466	-0.026846	0.0679568

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	140.92562	0.0037893	0.0019014	6.2659e-5	0.007516	99.295
Residual		2.6889e-5	1.2676e-5	1.2722e-5	8.9617e-5	0.705
Total		0.0038162	0.0019014	0.001745	0.013922	100.000

-2 LogLikelihood =
-82.61090523
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0038162

Response Measured Value Test=HLW LB, Type=slurry, Analyte=SiO2, Unit of Measure=wt%, Target Value=47.07
Summary of Fit

RSquare	0.950819
RSquare Adj	0.950819
Root Mean Square Error	0.479004
Mean of Response	48.07222
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	48.072222	0.537297	8	89.47	<.0001*	46.833213	49.311232

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	10.82385	2.4834722	1.3002224	-0.064917	5.0318613	91.543
Residual		0.2294444	0.1081611	0.1085541	0.7647045	8.457
Total		2.7129167	1.3002224	1.2706603	9.2816443	100.000

-2 LogLikelihood =
51.069144248
Note: Total is the sum of the positive variance components.
Total including negative estimates =
2.7129167

Response Measured Value Test=HLW LB, Type=slurry, Analyte=ZnO, Unit of Measure=wt%, Target Value=2.11
Summary of Fit

RSquare	0.907582
RSquare Adj	0.907582
Root Mean Square Error	0.03266
Mean of Response	1.983333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.9833333	0.026615	8	74.52	<.0001*	1.9219601	2.0447066

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	5.4765625	0.0058417	0.0031974	-0.000425	0.0121085	84.560
Residual		0.0010667	0.0005028	0.0005047	0.003555	15.440
Total		0.0069083	0.0031974	0.0033048	0.0223831	100.000

-2 LogLikelihood =
-45.35246099
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0069083

Response Measured Value Test=HLW LB, Type=slurry, Analyte=ZrO2, Unit of Measure=wt%, Target Value=3.27
Summary of Fit

RSquare	0.973204
RSquare Adj	0.973204
Root Mean Square Error	0.030092
Mean of Response	3.386111
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.3861111	0.045832	8	73.88	<.0001*	3.2804231	3.4917991

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	20.376534	0.0184521	0.0094548	-0.000079	0.0369832	95.322
Residual		0.0009056	0.0004269	0.0004284	0.0030181	4.678
Total		0.0193576	0.0094548	0.0089616	0.0682999	100.000

-2 LogLikelihood =
-38.12988754
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0193576

Response Measured Value Test=LAW HB, Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.741277
RSquare Adj	0.741277
Root Mean Square Error	0.141421
Mean of Response	58.82
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	58.82	0.09434	4	623.49	<.0001*	58.558071	59.081929

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.725	0.0345	0.0320956	-0.028406	0.0974061	63.303
Residual		0.02	0.0126491	0.0077927	0.1203063	36.697
Total		0.0545	0.0320956	0.0223255	0.2761584	100.000

-2 LogLikelihood =
-1.393111974
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0545

Response Measured Value Test=LAW HB, Type=physical property, Analyte=Density, Unit of Measure=g/mL, Target Value=.
Summary of Fit

RSquare	0
RSquare Adj	0
Root Mean Square Error	0.032373
Mean of Response	1.896822
Observations (or Sum Wgts)	9

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.8968222	0.010791	8	175.78	<.0001*	1.871938	1.9217064

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample		0.001048	0.000524	0.0004782	0.0038464	100.000
Total		0.001048	0.000524	0.0004782	0.0038464	100.000

-2 LogLikelihood =
-29.98656492
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.001048
Residual is confounded with Sample and has been removed.

Response Measured Value Test=LAW HB, Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.542142
RSquare Adj	0.542142
Root Mean Square Error	0.118322
Mean of Response	10.16
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	10.16	0.057879	4	175.54	<.0001*	9.9993016	10.320698

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.6964286	0.00975	0.0126444	-0.015033	0.0345326	41.053
Residual		0.014	0.0088544	0.0054549	0.0842144	58.947
Total		0.02375	0.0126444	0.0104094	0.0976352	100.000

-2 LogLikelihood =
-7.084850417
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.02375

Exhibit G3. Estimation of Variance Components (Sample versus Analytical) for Analytes with Samples Measured Twice

Response Measured Value Test=LAW HB, Type=physical property, Analyte=Total Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.793651
RSquare Adj	0.793651
Root Mean Square Error	0.08165
Mean of Response	69.06667
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	69.066667	0.044096	8	1566.3	<.0001*	68.964981	69.168352

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.125	0.0141667	0.00889	-0.003257	0.0315907	68.000
Residual		0.0066667	0.0031427	0.0031541	0.022219	32.000
Total		0.0208333	0.00889	0.0104502	0.0601179	100.000

-2 LogLikelihood =
-20.7806935
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0208333

Response Measured Value Test=LAW HB, Type=slurry, Analyte=Al2O3, Unit of Measure=wt%, Target Value=6.57
Summary of Fit

RSquare	0.565211
RSquare Adj	0.565211
Root Mean Square Error	0.03937
Mean of Response	6.100556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	6.1005556	0.01442	8	423.05	<.0001*	6.0673021	6.133809

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.7074373	0.0010965	0.0010046	-0.000872	0.0030654	41.433
Residual		0.00155	0.0007307	0.0007333	0.0051659	58.567
Total		0.0026465	0.0010046	0.0014154	0.006614	100.000

-2 LogLikelihood =
-51.79404531
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0026465

Response Measured Value Test=LAW HB, Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.905018
RSquare Adj	0.905018
Root Mean Square Error	0.057735
Mean of Response	64.66667
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	64.666667	0.046398	8	1393.7	<.0001*	64.559673	64.773661

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	5.3125	0.0177083	0.0097193	-0.001341	0.0367578	84.158
Residual		0.0033333	0.0015713	0.0015771	0.0111095	15.842
Total		0.0210417	0.0097193	0.0100779	0.0679692	100.000

-2 LogLikelihood =
-26.20475658
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0210417

Response Measured Value Test=LAW HB, Type=slurry, Analyte=B2O3, Unit of Measure=wt%, Target Value=2.41
Summary of Fit

RSquare	0.854976
RSquare Adj	0.854976
Root Mean Square Error	0.143372
Mean of Response	3.037778
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.0377778	0.09283	8	32.72	<.0001*	2.823711	3.2518445

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	3.2730405	0.0672792	0.03908	-0.009316	0.1438745	76.597
Residual		0.0205556	0.00969	0.0097252	0.0685086	23.403
Total		0.0878347	0.03908	0.0430103	0.2685324	100.000

-2 LogLikelihood =
1.2639002869
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0878347

Exhibit G3. Estimation of Variance Components (Sample versus Analytical) for Analytes with Samples Measured Twice

Response Measured Value Test=LAW HB, Type=slurry, Analyte=CaO, Unit of Measure=wt%, Target Value=2.81
Summary of Fit

RSquare	-0.68373
RSquare Adj	-0.68373
Root Mean Square Error	0.038152
Mean of Response	2.673333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	2.6733333	0.006821	8	391.92	<.0001*	2.6576038	2.6890629

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	-0.212309	-0.000309	0.0004019	-0.001097	0.0004787	0.000
Residual		0.0014556	0.0006862	0.0006886	0.0048512	100.000
Total		0.0014556	0.0006862	0.0006886	0.0048512	100.000

-2 LogLikelihood =
-64.3377411
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0011465

Response Measured Value Test=LAW HB, Type=slurry, Analyte=K2O, Unit of Measure=wt%, Target Value=1.01
Summary of Fit

RSquare	0.879874
RSquare Adj	0.879874
Root Mean Square Error	0.018257
Mean of Response	1.183333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.1833333	0.013017	8	90.91	<.0001*	1.1533159	1.2133508

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	4.075	0.0013583	0.0007665	-0.000144	0.0028607	80.296
Residual		0.0003333	0.0001571	0.0001577	0.001111	19.704
Total		0.0016917	0.0007665	0.0008195	0.0053104	100.000

-2 LogLikelihood =
-67.26393573
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0016917

Response Measured Value Test=LAW HB, Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%, Target Value=7.79
Summary of Fit

RSquare	0.479687
RSquare Adj	0.479687
Root Mean Square Error	0.128128
Mean of Response	7.808333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	7.8083333	0.042696	8	182.88	<.0001*	7.709877	7.9067896

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.4993655	0.0081979	0.0090699	-0.009579	0.0259747	33.305
Residual		0.0164167	0.0077389	0.007767	0.0547143	66.695
Total		0.0246146	0.0090699	0.0133693	0.0595368	100.000

-2 LogLikelihood =
-13.18640782
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0246146

Response Measured Value Test=LAW HB, Type=slurry, Analyte=MgO, Unit of Measure=wt%, Target Value=2.44
Summary of Fit

RSquare	0.948438
RSquare Adj	0.948438
Root Mean Square Error	0.039087
Mean of Response	1.848333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.8483333	0.042809	8	43.18	<.0001*	1.7496148	1.9470518

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	10.295909	0.0157299	0.0082547	-0.000449	0.0319088	91.147
Residual		0.0015278	0.0007202	0.0007228	0.0050919	8.853
Total		0.0172576	0.0082547	0.0080928	0.0588565	100.000

-2 LogLikelihood =
-34.51420002
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0172576

Response Measured Value Test=LAW HB, Type=slurry, Analyte=Na2O, Unit of Measure=wt%, Target Value=4.88
Summary of Fit

RSquare	0.719648
RSquare Adj	0.719648
Root Mean Square Error	0.04916
Mean of Response	4.446111
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	4.4461111	0.02265	8	196.29	<.0001*	4.3938792	4.498343

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.4106322	0.003409	0.0023779	-0.001252	0.0080696	58.517
Residual		0.0024167	0.0011392	0.0011434	0.0080544	41.483
Total		0.0058257	0.0023779	0.0029959	0.0158711	100.000

-2 LogLikelihood =
-40.57229096
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0058257

Response Measured Value Test=LAW HB, Type=slurry, Analyte=TiO2, Unit of Measure=wt%, Target Value=2.89
Summary of Fit

RSquare	0.908849
RSquare Adj	0.908849
Root Mean Square Error	0.015811
Mean of Response	2.879444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	2.8794444	0.012976	8	221.91	<.0001*	2.8495228	2.9093661

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	5.5611111	0.0013903	0.0007599	-9.915e-5	0.0028797	84.759
Residual		0.00025	0.0001179	0.0001183	0.0008332	15.241
Total		0.0016403	0.0007599	0.0007842	0.0053225	100.000

-2 LogLikelihood =
-69.90423947
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0016403

Response Measured Value Test=LAW HB, Type=slurry, Analyte=SiO2, Unit of Measure=wt%, Target Value=61.04
Summary of Fit

RSquare	-0.05602
RSquare Adj	-0.05602
Root Mean Square Error	0.807259
Mean of Response	62.48333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	62.483333	0.184842	8	338.04	<.0001*	62.057086	62.90958

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	-0.028133	-0.018333	0.2173288	-0.44429	0.4076233	0.000
Residual		0.6516667	0.3071986	0.3083148	2.1719089	100.000
Total		0.6516667	0.3071986	0.3083148	2.1719089	100.000

-2 LogLikelihood =
43.39121894
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.6333333

Response Measured Value Test=LAW HB, Type=slurry, Analyte=ZnO, Unit of Measure=wt%, Target Value=4.13
Summary of Fit

RSquare	0.784162
RSquare Adj	0.784162
Root Mean Square Error	0.036132
Mean of Response	4.219444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	4.2194444	0.019066	8	221.31	<.0001*	4.1754787	4.2634102

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	2.0058511	0.0026187	0.0016645	-0.000644	0.005881	66.732
Residual		0.0013056	0.0006154	0.0006177	0.0043512	33.268
Total		0.0039243	0.0016645	0.0019753	0.0112331	100.000

-2 LogLikelihood =
-48.87066575
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0039243

Response Measured Value Test=LAW HB, Type=slurry, Analyte=ZrO2, Unit of Measure=wt%, Target Value=4.19
Summary of Fit

RSquare	0.365979
RSquare Adj	0.365979
Root Mean Square Error	0.053697
Mean of Response	4.057222
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	4.0572222	0.016118	8	251.72	<.0001*	4.0200534	4.0943911

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.3109345	0.0008965	0.0013523	-0.001754	0.0035469	23.719
Residual		0.0028833	0.0013592	0.0013642	0.0096097	76.281
Total		0.0037799	0.0013523	0.0020842	0.008862	100.000

-2 LogLikelihood =
-44.42682491
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0037799

Response Measured Value Test=LAW LB, Type=glass, Analyte=B2O3, Unit of Measure=wt%, Target Value=9.66
Summary of Fit

RSquare	0.952476
RSquare Adj	0.952476
Root Mean Square Error	0.185405
Mean of Response	11.64375
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	11.64375	0.226076	7	51.50	<.0001*	11.109165	12.178335

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	11.394805	0.3916964	0.2187265	-0.037	0.8203926	91.932
Residual		0.034375	0.0171875	0.0156833	0.1261624	8.068
Total		0.4260714	0.2187265	0.1911765	1.6377134	100.000

-2 LogLikelihood =
16.969101503
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.4260714

Response Measured Value Test=LAW LB, Type=glass, Analyte=Al2O3, Unit of Measure=wt%, Target Value=5.95
Summary of Fit

RSquare	0.907058
RSquare Adj	0.907058
Root Mean Square Error	0.070975
Mean of Response	6.1275
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	6.1275	0.061586	7	99.49	<.0001*	5.9818718	6.2731282

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	5.523396	0.0278241	0.0162678	-0.00406	0.0597083	84.671
Residual		0.0050375	0.0025188	0.0022983	0.0184885	15.329
Total		0.0328616	0.0162678	0.0150867	0.1185783	100.000

-2 LogLikelihood =
-16.6003468
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0328616

Response Measured Value Test=LAW LB, Type=glass, Analyte=CaO, Unit of Measure=wt%, Target Value=1.77
Summary of Fit

RSquare	0.879549
RSquare Adj	0.879549
Root Mean Square Error	0.0325
Mean of Response	1.975625
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.975625	0.024702	7	79.98	<.0001*	1.9172129	2.0340371

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	4.1217244	0.0043536	0.0026227	-0.000787	0.009494	80.475
Residual		0.0010563	0.0005281	0.0004819	0.0038766	19.525
Total		0.0054098	0.0026227	0.002516	0.0188554	100.000

-2 LogLikelihood =
-41.88730549
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0054098

Response Measured Value Test=LAW LB, Type=glass, Analyte=Fe2O3, Unit of Measure=wt%, Target Value=5.33
Summary of Fit

RSquare	0.992594
RSquare Adj	0.992594
Root Mean Square Error	0.048218
Mean of Response	3.79
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.79	0.149613	7	25.33	<.0001*	3.4362224	4.1437776

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	76.519969	0.1779089	0.0957195	-0.009698	0.3655156	98.710
Residual		0.002325	0.0011625	0.0010608	0.0085332	1.290
Total		0.1802339	0.0957195	0.0791214	0.7374732	100.000

-2 LogLikelihood =
-10.35930051
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.1802339

Response Measured Value Test=LAW LB, Type=glass, Analyte=MgO, Unit of Measure=wt%, Target Value=1.74
Summary of Fit

RSquare	0.999527
RSquare Adj	0.999527
Root Mean Square Error	0.01536
Mean of Response	0.748938
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.7489375	0.188714	7	3.97	0.0054*	0.3026998	1.1951752

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1207.0394	0.2847858	0.1522875	-0.013692	0.5832639	99.917
Residual		0.0002359	0.000118	0.0001076	0.0008659	0.083
Total		0.2850218	0.1522875	0.1246313	1.1797203	100.000

-2 LogLikelihood =
-25.41199945
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.2850218

Response Measured Value Test=LAW LB, Type=glass, Analyte=K2O, Unit of Measure=wt%, Target Value=4.05
Summary of Fit

RSquare	0.963226
RSquare Adj	0.963226
Root Mean Square Error	0.052142
Mean of Response	4.258125
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	4.258125	0.072364	7	58.84	<.0001*	4.0870113	4.4292387

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	14.908703	0.040533	0.0224027	-0.003376	0.0844416	93.714
Residual		0.0027188	0.0013594	0.0012404	0.0099783	6.286
Total		0.0432518	0.0224027	0.0192964	0.1689489	100.000

-2 LogLikelihood =
-19.2764437
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0432518

Response Measured Value Test=LAW LB, Type=glass, Analyte=Na2O, Unit of Measure=wt%, Target Value=19.51
Summary of Fit

RSquare	0.948137
RSquare Adj	0.948137
Root Mean Square Error	0.297909
Mean of Response	20.8
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	20.8	0.347568	7	59.84	<.0001*	19.978132	21.621868

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	10.389336	0.9220536	0.5170541	-0.091354	1.9354609	91.220
Residual		0.08875	0.044375	0.0404915	0.3257283	8.780
Total		1.0108036	0.5170541	0.4545755	3.8606007	100.000

-2 LogLikelihood =
30.578284965
Note: Total is the sum of the positive variance components.
Total including negative estimates =
1.0108036

Response Measured Value Test=LAW LB, Type=glass, Analyte=P2O5, Unit of Measure=wt%, Target Value=0.15
Summary of Fit

RSquare	.
RSquare Adj	.
Root Mean Square Error	0
Mean of Response	0
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0	.	0	.	.	.	.

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0	0	0	0	0	0.000
Residual		0	0	.	.	0.000
Total		0	0	.	.	100.000

-2 LogLikelihood =
.
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0

Response Measured Value Test=LAW LB, Type=glass, Analyte=SO4, Unit of Measure=wt%, Target Value=0.41
Summary of Fit

RSquare	0.968482
RSquare Adj	0.968482
Root Mean Square Error	0.006129
Mean of Response	0.446438
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.4464375	0.009193	7	48.56	<.0001*	0.4246993	0.4681757

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	17.499406	0.0006573	0.0003615	-5.123e-5	0.0013659	94.594
Residual		3.7563e-5	1.8781e-5	1.7138e-5	0.0001379	5.406
Total		0.0006949	0.0003615	0.0003091	0.0027363	100.000

-2 LogLikelihood =
-82.417419
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0006949

Response Measured Value Test=LAW LB, Type=glass, Analyte=SiO2, Unit of Measure=wt%, Target Value=43.45
Summary of Fit

RSquare	0.171561
RSquare Adj	0.171561
Root Mean Square Error	0.872855
Mean of Response	43.74375
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	43.74375	0.241357	7	181.24	<.0001*	43.173031	44.314469

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.1116841	0.0850893	0.3135762	-0.529509	0.6996874	10.046
Residual		0.761875	0.3809375	0.3475995	2.7962169	89.954
Total		0.8469643	0.3135762	0.4588946	2.0591767	100.000

-2 LogLikelihood =
42.672407587
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.8469643

Response Measured Value Test=LAW LB, Type=glass, Analyte=TiO2, Unit of Measure=wt%, Target Value=2.06
Summary of Fit

RSquare	0.917622
RSquare Adj	0.917622
Root Mean Square Error	0.027951
Mean of Response	1.693125
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.693125	0.02579	7	65.65	<.0001*	1.6321414	1.7541086

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	6.3108571	0.0049304	0.0028509	-0.000657	0.010518	86.322
Residual		0.0007813	0.0003906	0.0003564	0.0028673	13.678
Total		0.0057116	0.0028509	0.0026087	0.0209008	100.000

-2 LogLikelihood =
-43.69682953
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0057116

Exhibit G3. Estimation of Variance Components (Sample versus Analytical) for Analytes with Samples Measured Twice

Response Measured Value Test=LAW LB, Type=glass, Analyte=ZnO, Unit of Measure=wt%, Target Value=2.94
Summary of Fit

RSquare	0.928455
RSquare Adj	0.928455
Root Mean Square Error	0.036827
Mean of Response	3.010625
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.010625	0.036504	7	82.47	<.0001*	2.924307	3.096943

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	7.3601053	0.0099821	0.0057082	-0.001206	0.0211701	88.038
Residual		0.0013563	0.0006781	0.0006188	0.0049777	11.962
Total		0.0113384	0.0057082	0.0051508	0.0421095	100.000

-2 LogLikelihood =
-34.42010108
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0113384

Response Measured Value Test=LAW LB, Type=physical property, Analyte=Density, Unit of Measure=g/mL, Target Value=.
Summary of Fit

RSquare	0
RSquare Adj	0
Root Mean Square Error	0.016988
Mean of Response	1.355178
Observations (or Sum Wgts)	9

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.3551778	0.005663	8	239.31	<.0001*	1.3421195	1.3682361

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample		0.0002886	0.0001443	0.0001317	0.0010592	100.000
Total		0.0002886	0.0001443	0.0001317	0.0010592	100.000

-2 LogLikelihood =
-40.30352558
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0002886
Residual is confounded with Sample and has been removed.

Response Measured Value Test=LAW LB, Type=glass, Analyte=ZrO2, Unit of Measure=wt%, Target Value=2.98
Summary of Fit

RSquare	0.957945
RSquare Adj	0.957945
Root Mean Square Error	0.03562
Mean of Response	2.595625
Observations (or Sum Wgts)	16

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	2.595625	0.046199	7	56.18	<.0001*	2.4863825	2.7048675

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	12.957776	0.0164402	0.0091322	-0.001459	0.034339	92.836
Residual		0.0012687	0.0006344	0.0005789	0.0046565	7.164
Total		0.0177089	0.0091322	0.007923	0.0686249	100.000

-2 LogLikelihood =
-31.65617207
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0177089

Response Measured Value Test=LAW LB, Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.568064
RSquare Adj	0.568064
Root Mean Square Error	1.680179
Mean of Response	23.65
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	23.65	0.848675	4	27.87	<.0001*	21.293699	26.006301

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.7756819	2.18975	2.6984132	-3.099043	7.4785426	43.684
Residual		2.823	1.785422	1.0999414	16.981235	56.316
Total		5.01275	2.6984132	2.181234	21.048699	100.000

-2 LogLikelihood =
40.930192189
Note: Total is the sum of the positive variance components.
Total including negative estimates =
5.01275

Response Measured Value Test=LAW LB, Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.496606
RSquare Adj	0.496606
Root Mean Square Error	0.413521
Mean of Response	18.31
Observations (or Sum Wgts)	10

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	18.31	0.191964	4	95.38	<.0001*	17.777024	18.842976

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	0.5774854	0.09875	0.1410607	-0.177724	0.375224	36.608
Residual		0.171	0.1081499	0.0666277	1.0286189	63.392
Total		0.26975	0.1410607	0.1196103	1.0722811	100.000

-2 LogLikelihood =
15.019761809
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.26975

Response Measured Value Test=LAW LB, Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.982926
RSquare Adj	0.982926
Root Mean Square Error	0.166667
Mean of Response	30.53333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	30.533333	0.318307	8	95.92	<.0001*	29.799316	31.267351

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	32.3275	0.8979861	0.4559845	0.0042729	1.7916993	96.999
Residual		0.0277778	0.0130946	0.0131421	0.0925792	3.001
Total		0.9257639	0.4559845	0.4263539	3.312346	100.000

-2 LogLikelihood =
23.689770007
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.9257639

Response Measured Value Test=LAW LB, Type=physical property, Analyte=Total Solids, Unit of Measure=wt%, Target Value=.
Summary of Fit

RSquare	0.767354
RSquare Adj	0.767354
Root Mean Square Error	0.953357
Mean of Response	41.33333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	41.333333	0.483908	8	85.42	<.0001*	40.21744	42.449227

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	1.8187653	1.6530556	1.0753057	-0.454505	3.760616	64.523
Residual		0.9088889	0.4284543	0.430011	3.0291926	35.477
Total		2.5619444	1.0753057	1.2971766	7.233055	100.000

-2 LogLikelihood =
61.783686778
Note: Total is the sum of the positive variance components.
Total including negative estimates =
2.5619444

Response Measured Value Test=LAW LB, Type=slurry, Analyte=Al2O3, Unit of Measure=wt%, Target Value=5.95
Summary of Fit

RSquare	0.96079
RSquare Adj	0.96079
Root Mean Square Error	0.020276
Mean of Response	5.427778
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	5.4277778	0.025497	8	212.88	<.0001*	5.3689825	5.4865731

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	13.731419	0.0056451	0.002927	-9.158e-5	0.0113819	93.212
Residual		0.0004111	0.0001938	0.0001945	0.0013702	6.788
Total		0.0060563	0.002927	0.0028221	0.0210015	100.000

-2 LogLikelihood =
-54.61992333
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0060563

Response Measured Value Test=LAW LB, Type=slurry, Analyte=B2O3, Unit of Measure=wt%, Target Value=9.66
Summary of Fit

RSquare	0.938375
RSquare Adj	0.938375
Root Mean Square Error	0.162669
Mean of Response	9.611667
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	9.6116667	0.162807	8	59.04	<.0001*	9.2362321	9.9871012

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	8.5153527	0.2253257	0.1194411	-0.008775	0.4594259	89.491
Residual		0.0264611	0.0124739	0.0125192	0.088191	10.509
Total		0.2517868	0.1194411	0.1186716	0.8474788	100.000

-2 LogLikelihood =
12.52554599
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.2517868

Response Measured Value Test=LAW LB, Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%, Target Value=5.33
Summary of Fit

RSquare	0.985448
RSquare Adj	0.985448
Root Mean Square Error	0.132434
Mean of Response	4.637222
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	4.6372222	0.274045	8	16.92	<.0001*	4.0052729	5.2691716

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	38.037615	0.6671375	0.3379788	0.0047113	1.3295637	97.438
Residual		0.0175389	0.0082679	0.008298	0.0584545	2.562
Total		0.6846764	0.3379788	0.3148918	2.4587906	100.000

-2 LogLikelihood =
17.155848611
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.6846764

Response Measured Value Test=LAW LB, Type=slurry, Analyte=CaO, Unit of Measure=wt%, Target Value=1.77
Summary of Fit

RSquare	0.861982
RSquare Adj	0.861982
Root Mean Square Error	0.036893
Mean of Response	1.909444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.9094444	0.024501	8	77.93	<.0001*	1.8529446	1.9659443

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	3.4693878	0.0047222	0.0027204	-0.00061	0.0100541	77.626
Residual		0.0013611	0.0006416	0.000644	0.0045364	22.374
Total		0.0060833	0.0027204	0.00297	0.0187336	100.000

-2 LogLikelihood =
-44.48236238
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0060833

Response Measured Value Test=LAW LB, Type=slurry, Analyte=K2O, Unit of Measure=wt%, Target Value=4.05
Summary of Fit

RSquare	0.869417
RSquare Adj	0.869417
Root Mean Square Error	0.086603
Mean of Response	3.903333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	3.9033333	0.059167	8	65.97	<.0001*	3.7668948	4.0397719

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	3.7008333	0.0277562	0.015852	-0.003313	0.0588256	78.727
Residual		0.0075	0.0035355	0.0035484	0.0249964	21.273
Total		0.0352562	0.015852	0.0171581	0.1094277	100.000

-2 LogLikelihood =
-15.01676572
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0352562

Response Measured Value Test=LAW LB, Type=slurry, Analyte=MgO, Unit of Measure=wt%, Target Value=1.74
Summary of Fit

RSquare	0.999963
RSquare Adj	0.999963
Root Mean Square Error	0.004558
Mean of Response	1.223556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.2235556	0.187623	8	6.52	0.0002*	0.7908967	1.6562144

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	15247.556	0.3168103	0.1584104	0.0063317	0.6272889	99.993
Residual		2.0778e-5	9.7947e-6	9.8303e-6	6.9249e-5	0.007
Total		0.3168311	0.1584104	0.1445547	1.1627612	100.000

-2 LogLikelihood =
-49.55053319
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.3168311

Response Measured Value Test=LAW LB, Type=slurry, Analyte=SiO2, Unit of Measure=wt%, Target Value=43.45
Summary of Fit

RSquare	0.967316
RSquare Adj	0.967316
Root Mean Square Error	0.159861
Mean of Response	44.13333
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	44.133333	0.220322	8	200.31	<.0001*	43.625271	44.641396

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	16.595109	0.4240972	0.2185205	-0.004195	0.8523896	94.317
Residual		0.0255556	0.012047	0.0120908	0.0851729	5.683
Total		0.4496528	0.2185205	0.2088154	1.5734253	100.000

-2 LogLikelihood =
17.052489077
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.4496528

Response Measured Value Test=LAW LB, Type=slurry, Analyte=Na2O, Unit of Measure=wt%, Target Value=19.51
Summary of Fit

RSquare	0.997158
RSquare Adj	0.997158
Root Mean Square Error	0.066667
Mean of Response	19.35556
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	19.355556	0.312522	8	61.93	<.0001*	18.634879	20.076232

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	197.28125	0.8768056	0.4395151	0.0153717	1.7382394	99.496
Residual		0.0044444	0.0020951	0.0021027	0.0148127	0.504
Total		0.88125	0.4395151	0.4027	3.2204087	100.000

-2 LogLikelihood =
6.9030454703
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.88125

Response Measured Value Test=LAW LB, Type=slurry, Analyte=SO4, Unit of Measure=wt%, Target Value=0.41
Summary of Fit

RSquare	0.948871
RSquare Adj	0.948871
Root Mean Square Error	0.008654
Mean of Response	0.401444
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	0.4014444	0.009518	8	42.18	<.0001*	0.3794949	0.423394

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	10.388168	0.000778	0.0004081	-2.187e-5	0.0015778	91.219
Residual		7.4889e-5	0.0000353	3.5431e-5	0.0002496	8.781
Total		0.0008528	0.0004081	0.0003998	0.0029103	100.000

-2 LogLikelihood =
-85.71071278
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0008528

Response Measured Value Test=LAW LB, Type=slurry, Analyte=TiO2, Unit of Measure=wt%, Target Value=2.06
Summary of Fit

RSquare	0.99611
RSquare Adj	0.99611
Root Mean Square Error	0.012693
Mean of Response	1.761667
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	1.7616667	0.050854	8	34.64	<.0001*	1.6443975	1.8789358

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	143.96552	0.0231944	0.0116376	0.0003852	0.0460036	99.310
Residual		0.0001611	7.5949e-5	7.6224e-5	0.000537	0.690
Total		0.0233556	0.0116376	0.0106789	0.0852146	100.000

-2 LogLikelihood =
-52.00429101
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0233556

Response Measured Value Test=LAW LB, Type=slurry, Analyte=ZrO2, Unit of Measure=wt%, Target Value=2.98
Summary of Fit

RSquare	0.988968
RSquare Adj	0.988968
Root Mean Square Error	0.026667
Mean of Response	2.528889
Observations (or Sum Wgts)	18

Parameter Estimates

Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	2.5288889	0.063398	8	39.89	<.0001*	2.3826931	2.6750846

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	50.369141	0.0358181	0.0180876	0.000367	0.0712691	98.053
Residual		0.0007111	0.0003352	0.0003364	0.00237	1.947
Total		0.0365292	0.0180876	0.016768	0.1318645	100.000

-2 LogLikelihood =
-35.11408067
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0365292

Response Measured Value Test=LAW LB, Type=slurry, Analyte=ZnO, Unit of Measure=wt%, Target Value=2.94
Summary of Fit

RSquare	0.978147
RSquare Adj	0.978147
Root Mean Square Error	0.022852
Mean of Response	2.93
Observations (or Sum Wgts)	18

Parameter Estimates

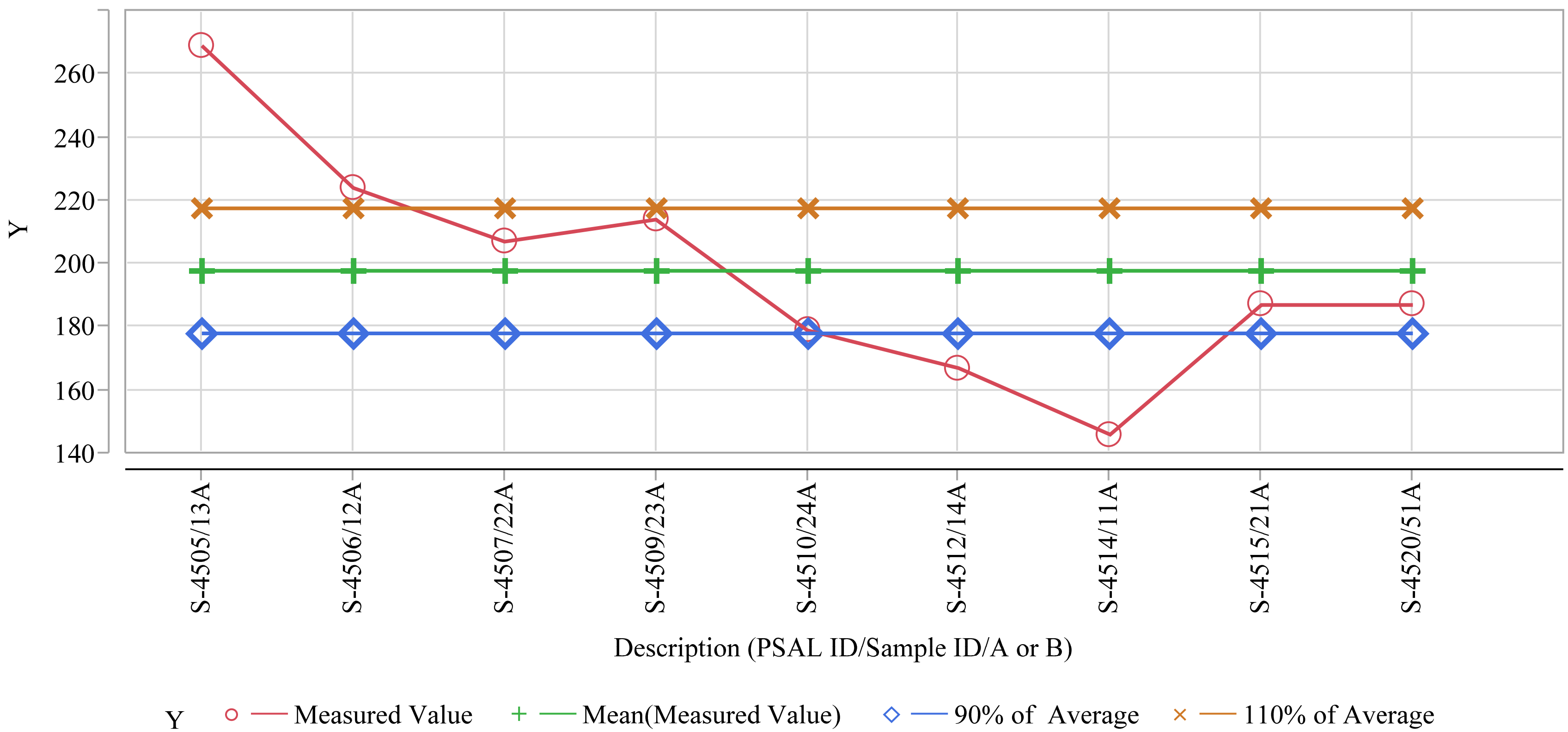
Term	Estimate	Std Error	DFDen	t Ratio	Prob>|t|	Lower 95%	Upper 95%
Intercept	2.93	0.038559	8	75.99	<.0001*	2.8410825	3.0189175

REML Variance Component Estimates

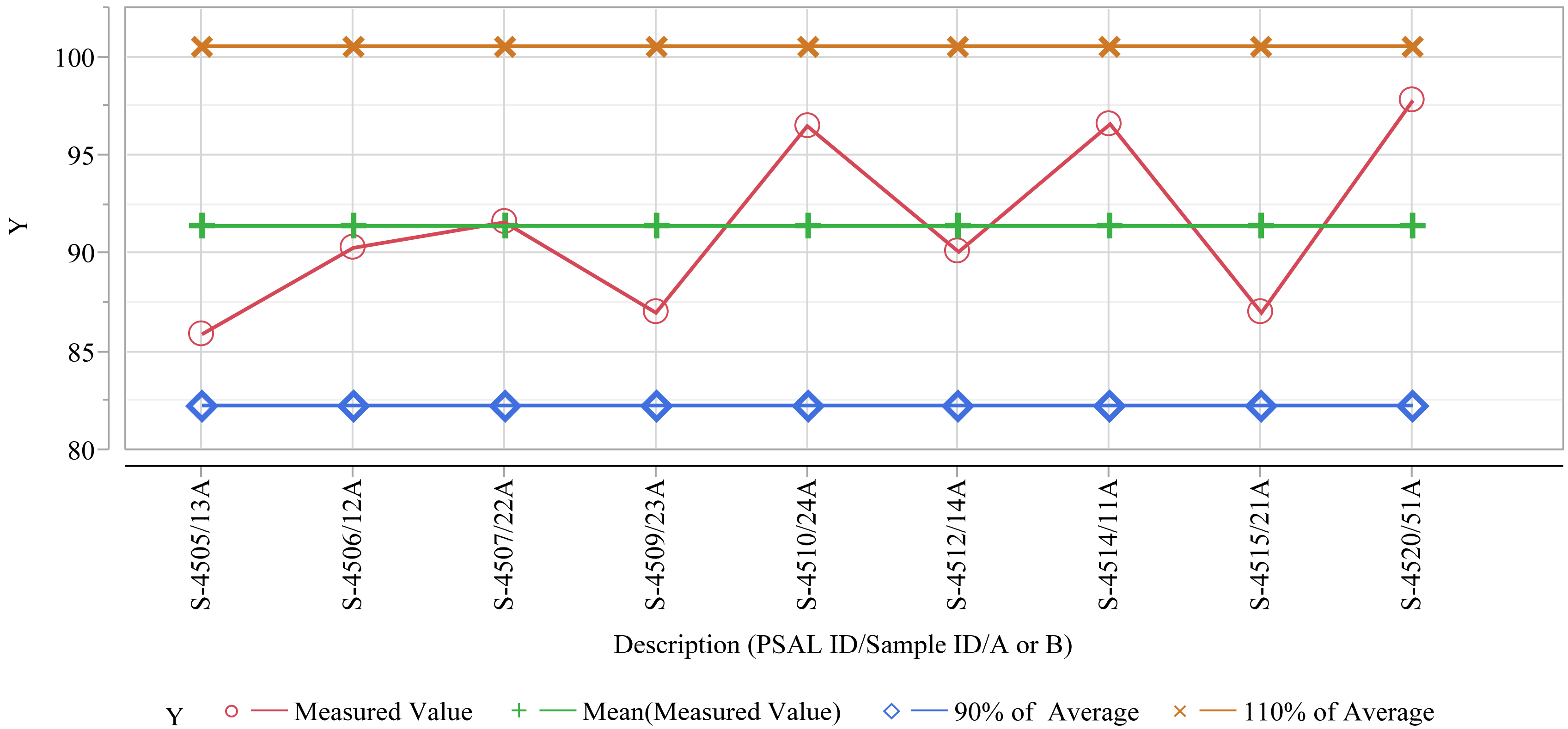
Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Sample	25.12367	0.0131201	0.0066918	4.5359e-6	0.0262357	96.172
Residual		0.0005222	0.0002462	0.0002471	0.0017405	3.828
Total		0.0136424	0.0066918	0.0062991	0.0484755	100.000

-2 LogLikelihood =
-45.84850324
Note: Total is the sum of the positive variance components.
Total including negative estimates =
0.0136424

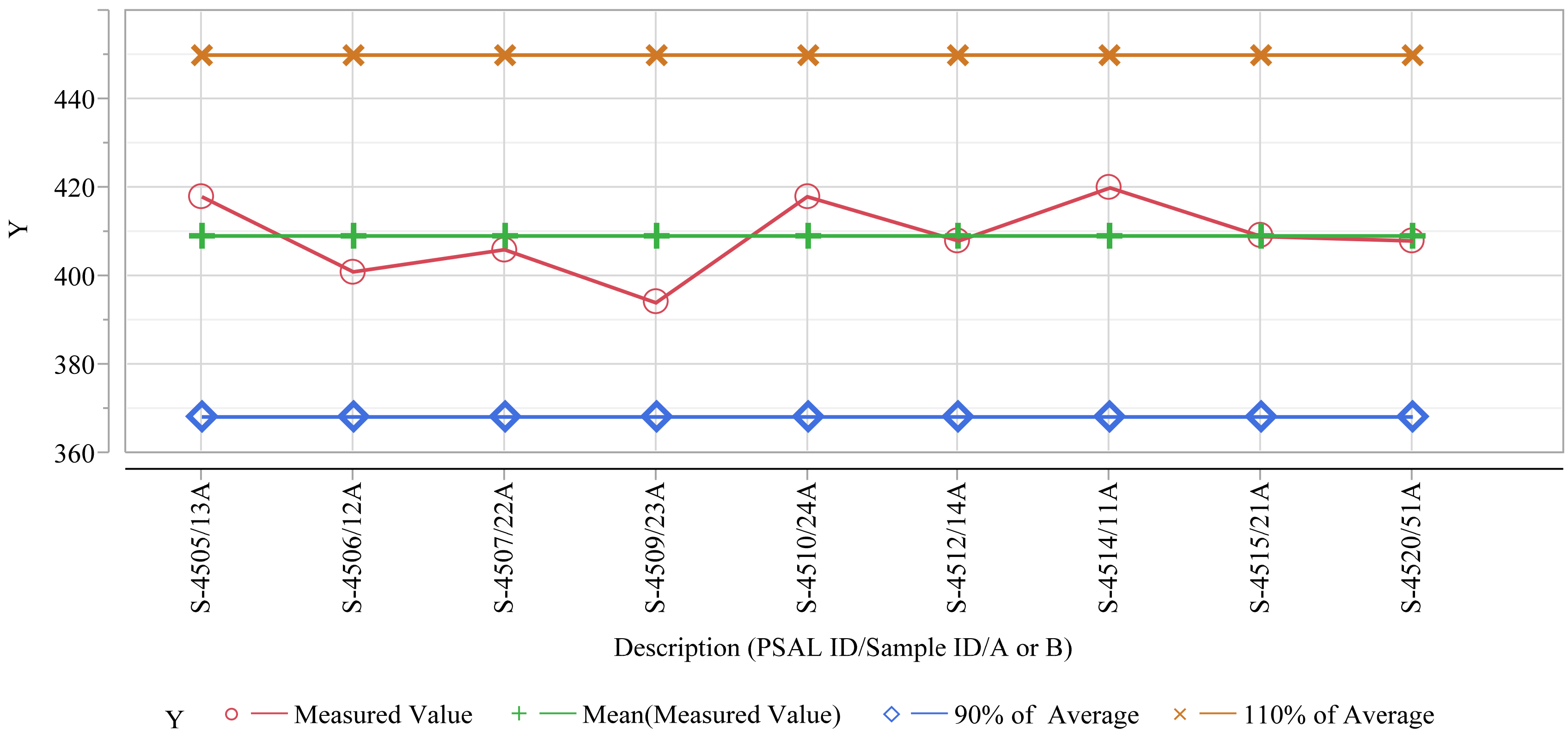
Overlay Plot Test=HLW HB (a), Type=anion, Analyte=C2O4, Unit of Measure=mg/kg



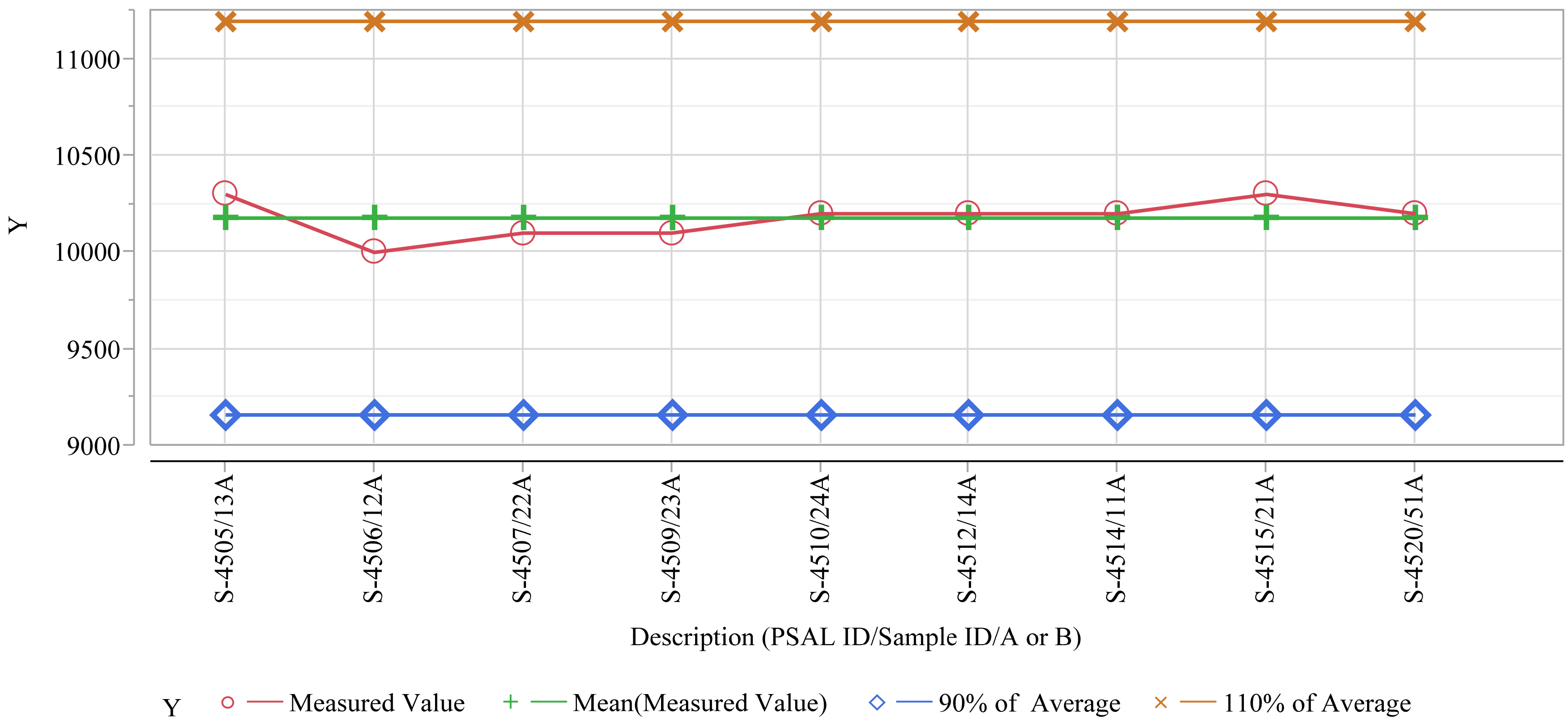
Overlay Plot Test=HLW HB (a), Type=anion, Analyte=Cl, Unit of Measure=mg/kg



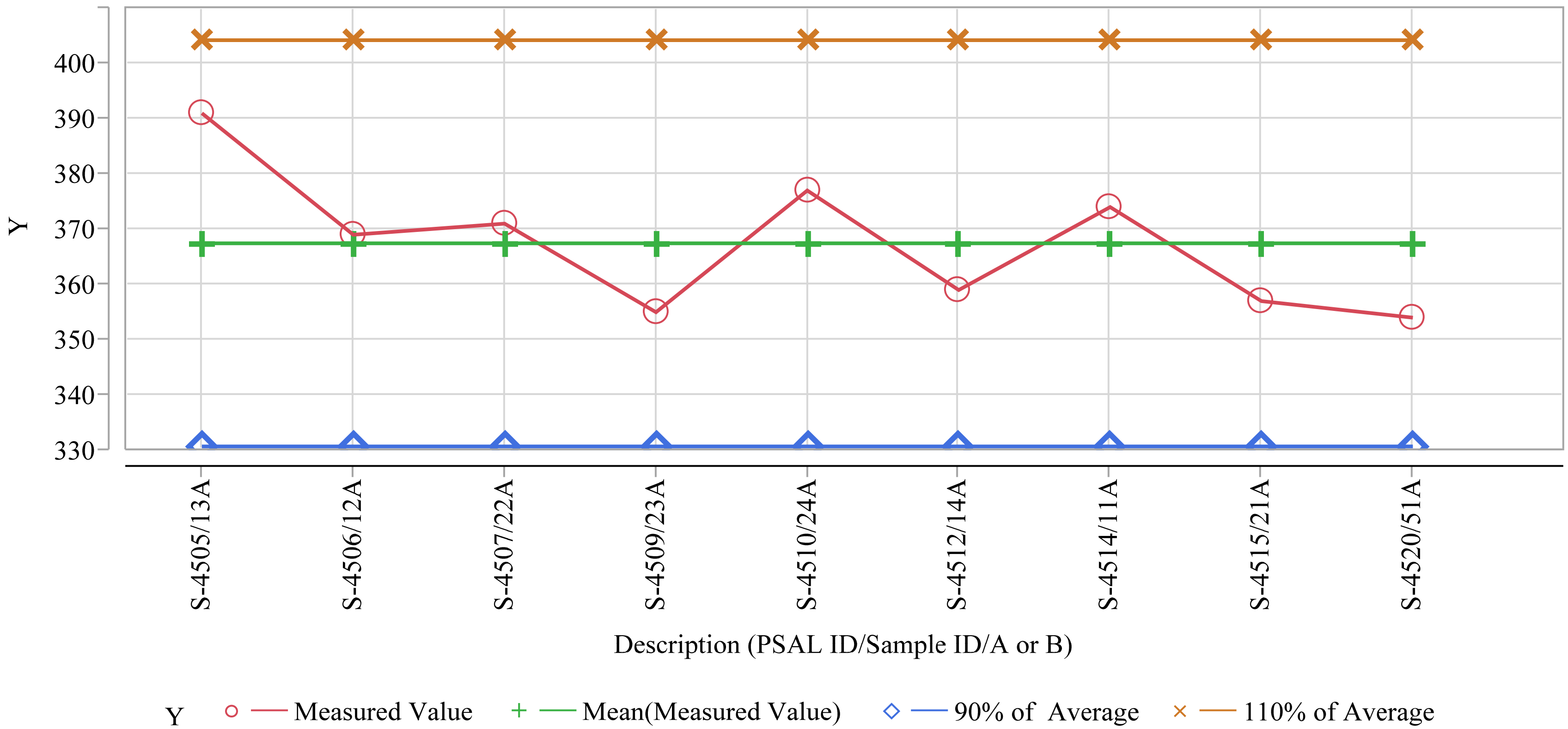
Overlay Plot Test=HLW HB (a), Type=anion, Analyte=NO2, Unit of Measure=mg/kg



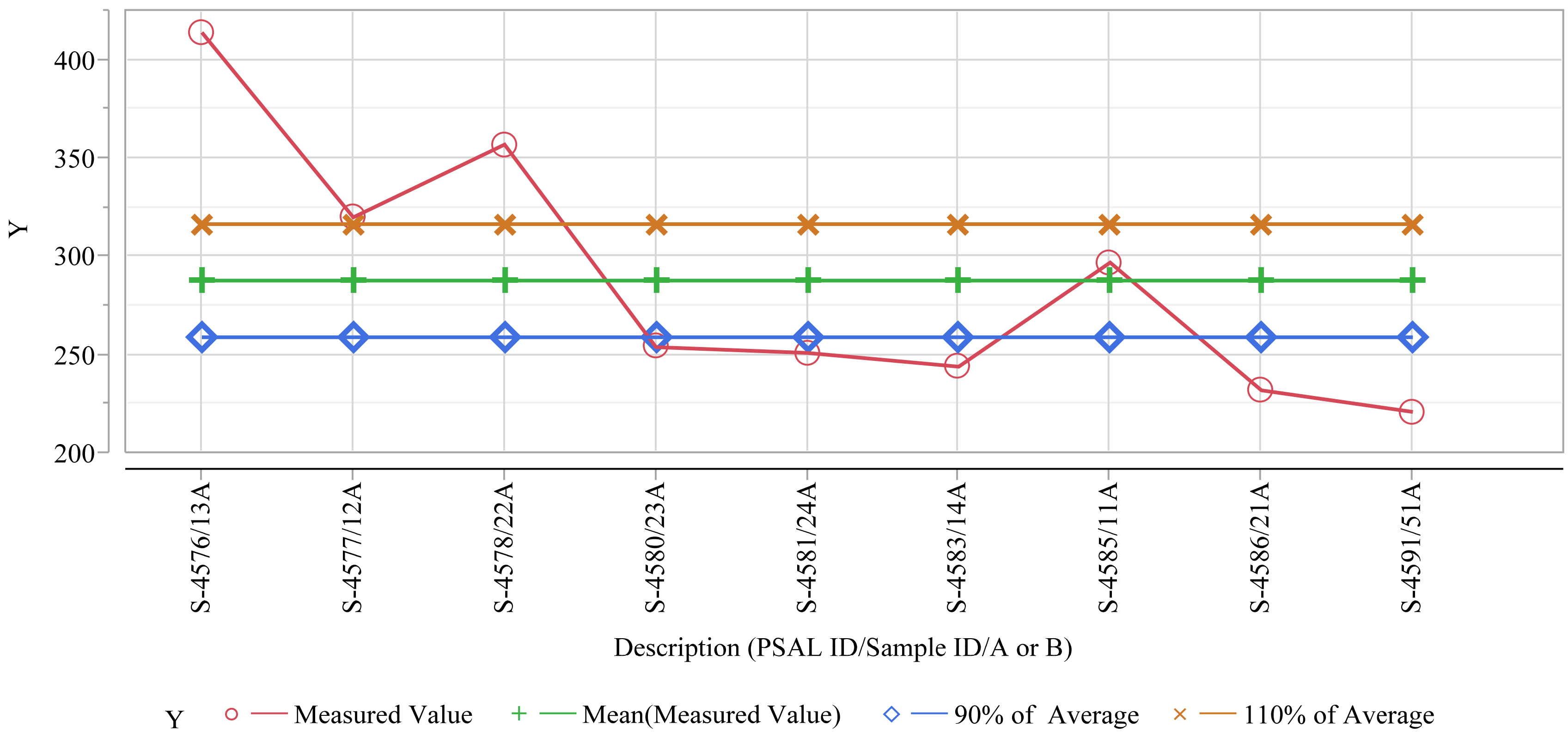
Overlay Plot Test=HLW HB (a), Type=anion, Analyte=NO_3, Unit of Measure=mg/kg



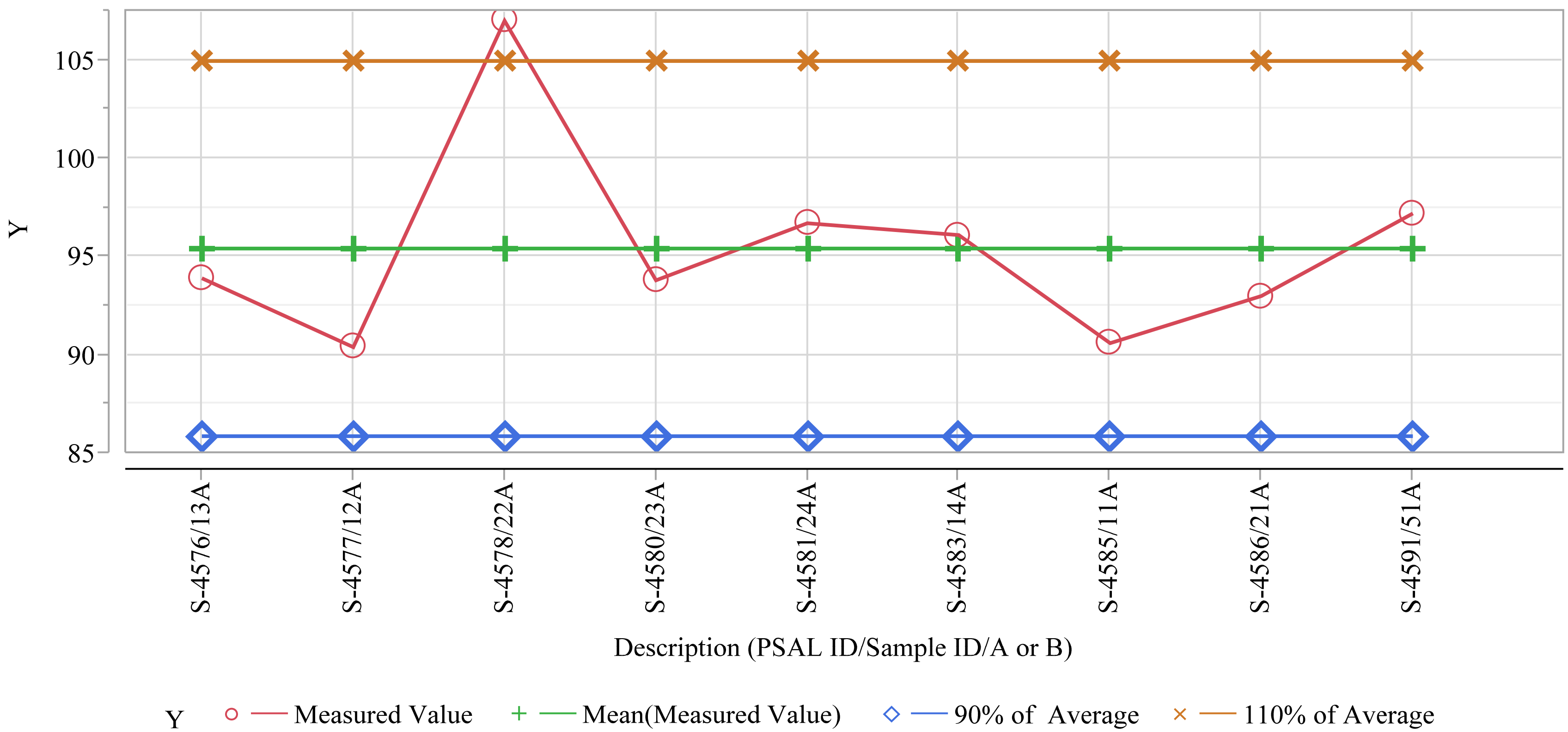
Overlay Plot Test=HLW HB (a), Type=anion, Analyte=SO_4, Unit of Measure=mg/kg



Overlay Plot Test=HLW HB (b), Type=anion, Analyte=C2O4, Unit of Measure=mg/kg



Overlay Plot Test=HLW HB (b), Type=anion, Analyte=Cl, Unit of Measure=mg/kg



Overlay Plot Test=HLW HB (b), Type=anion, Analyte=NO2, Unit of Measure=mg/kg

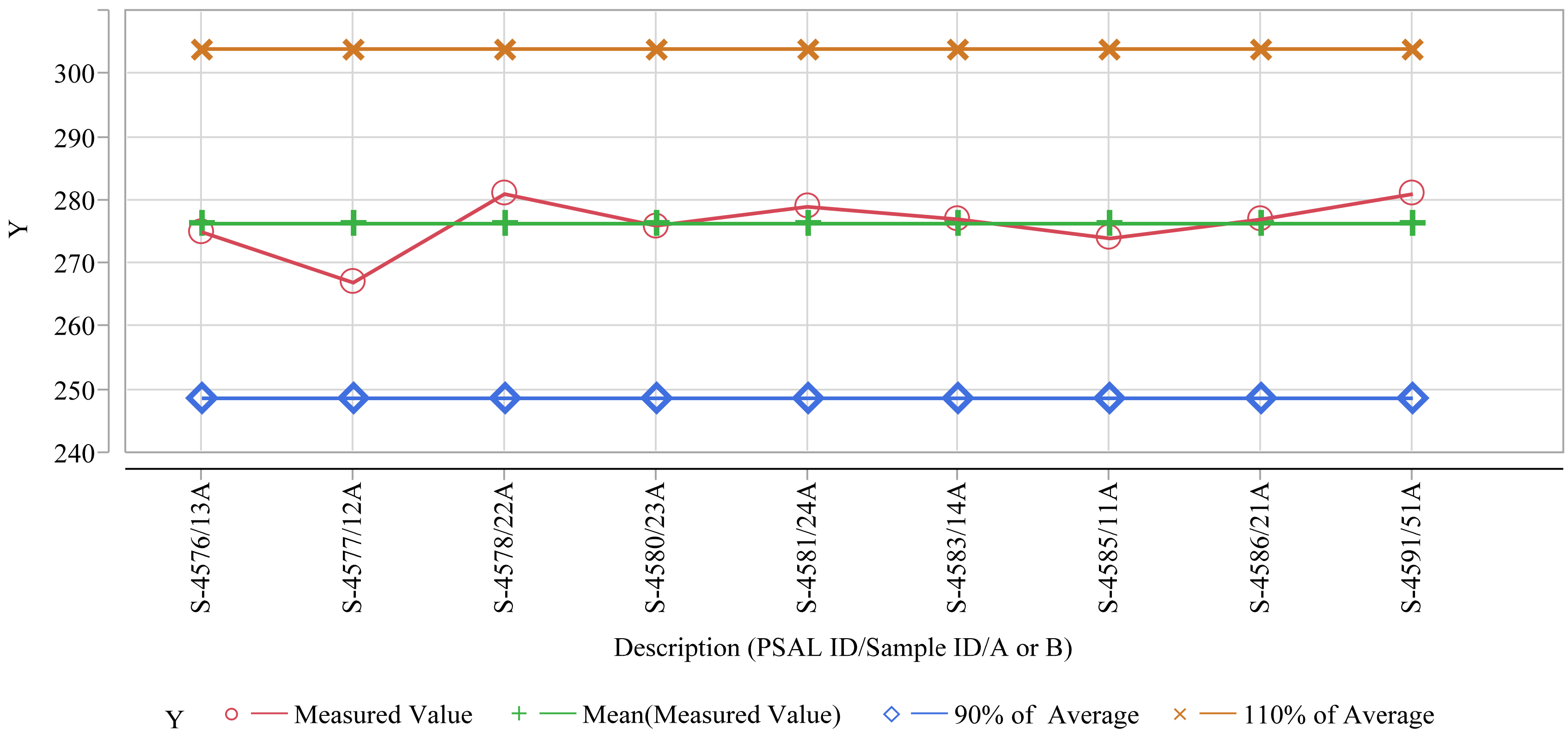
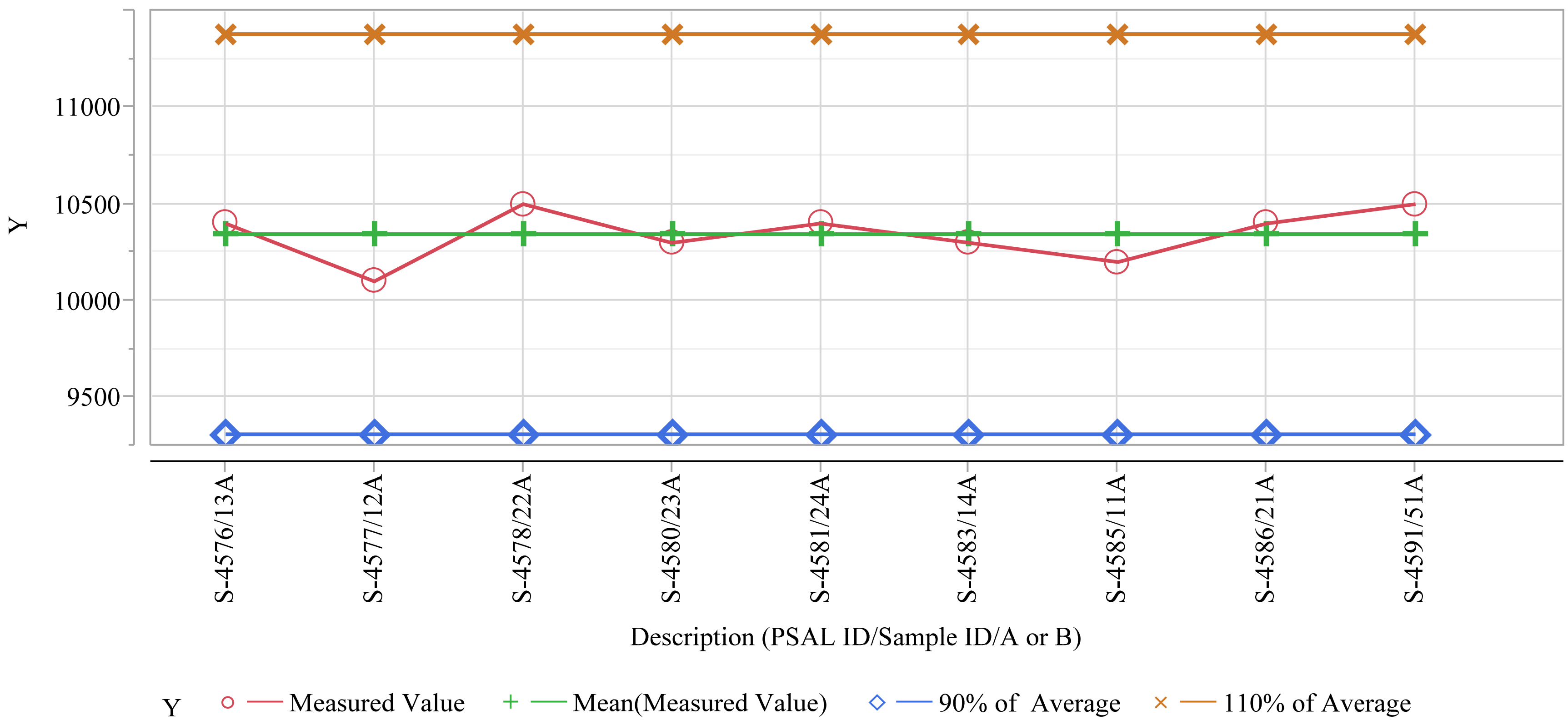
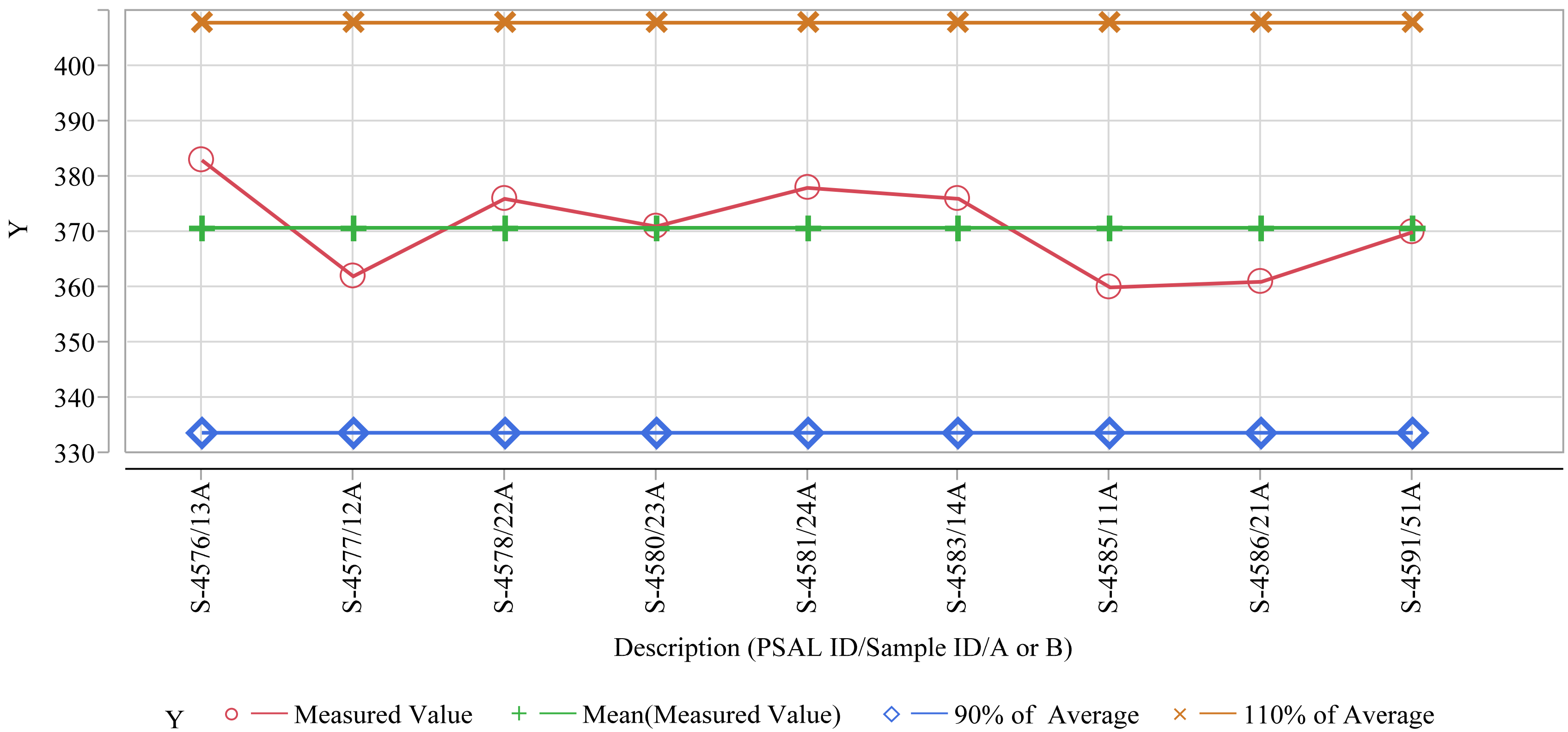


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

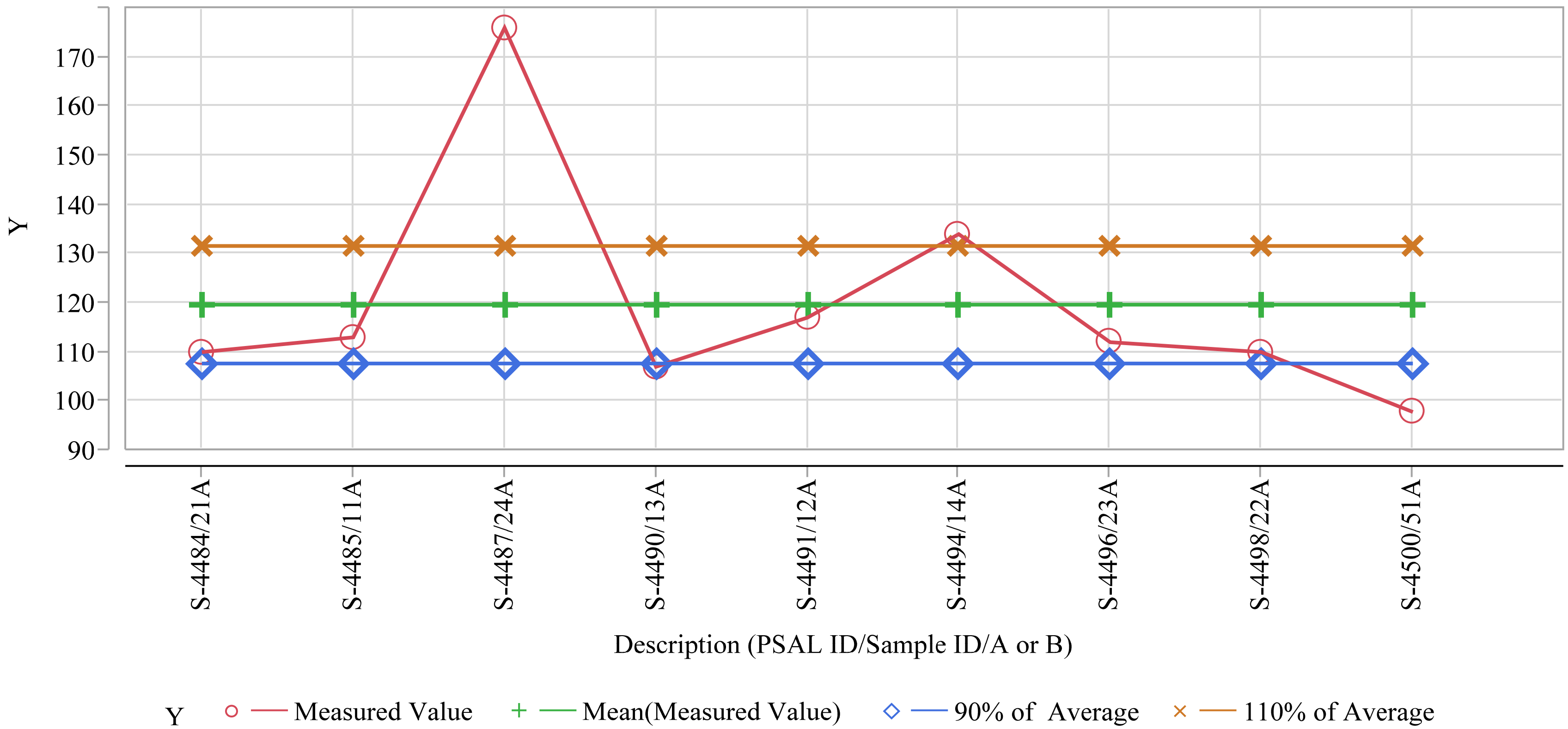
Overlay Plot Test=HLW HB (b), Type=anion, Analyte=NO3, Unit of Measure=mg/kg



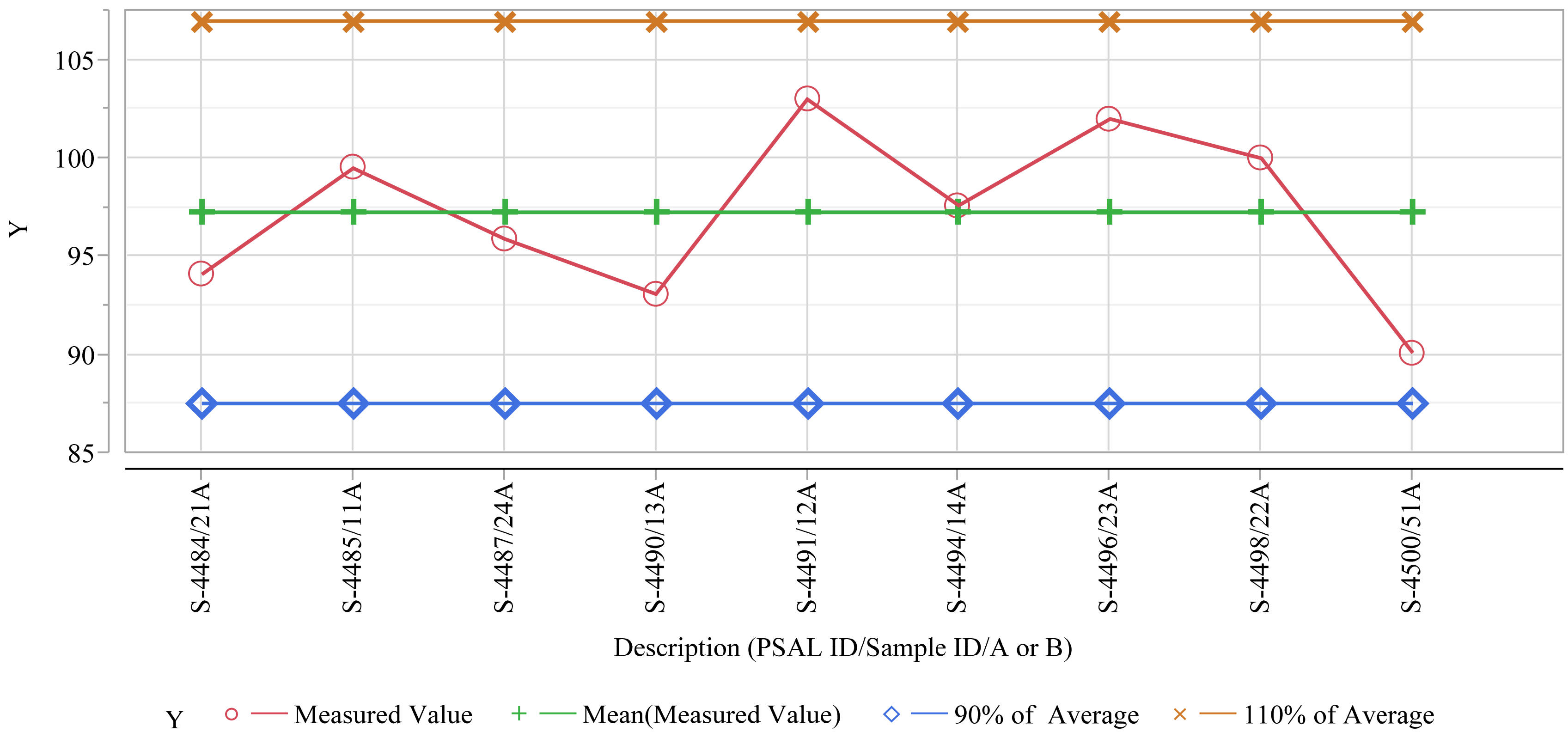
Overlay Plot Test=HLW HB (b), Type=anion, Analyte=SO4, Unit of Measure=mg/kg



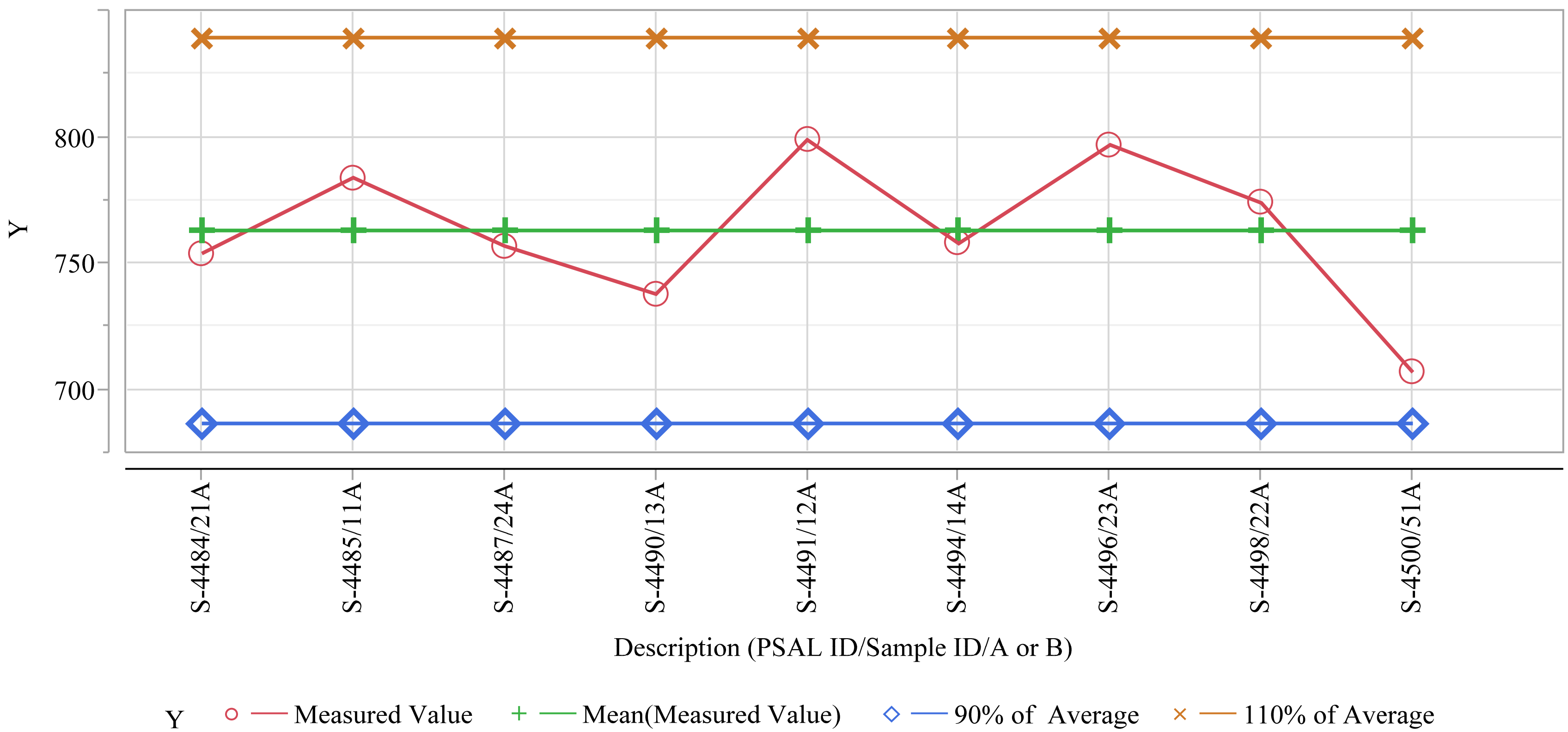
Overlay Plot Test=HLW LB, Type=anion, Analyte=C2O4, Unit of Measure=mg/kg



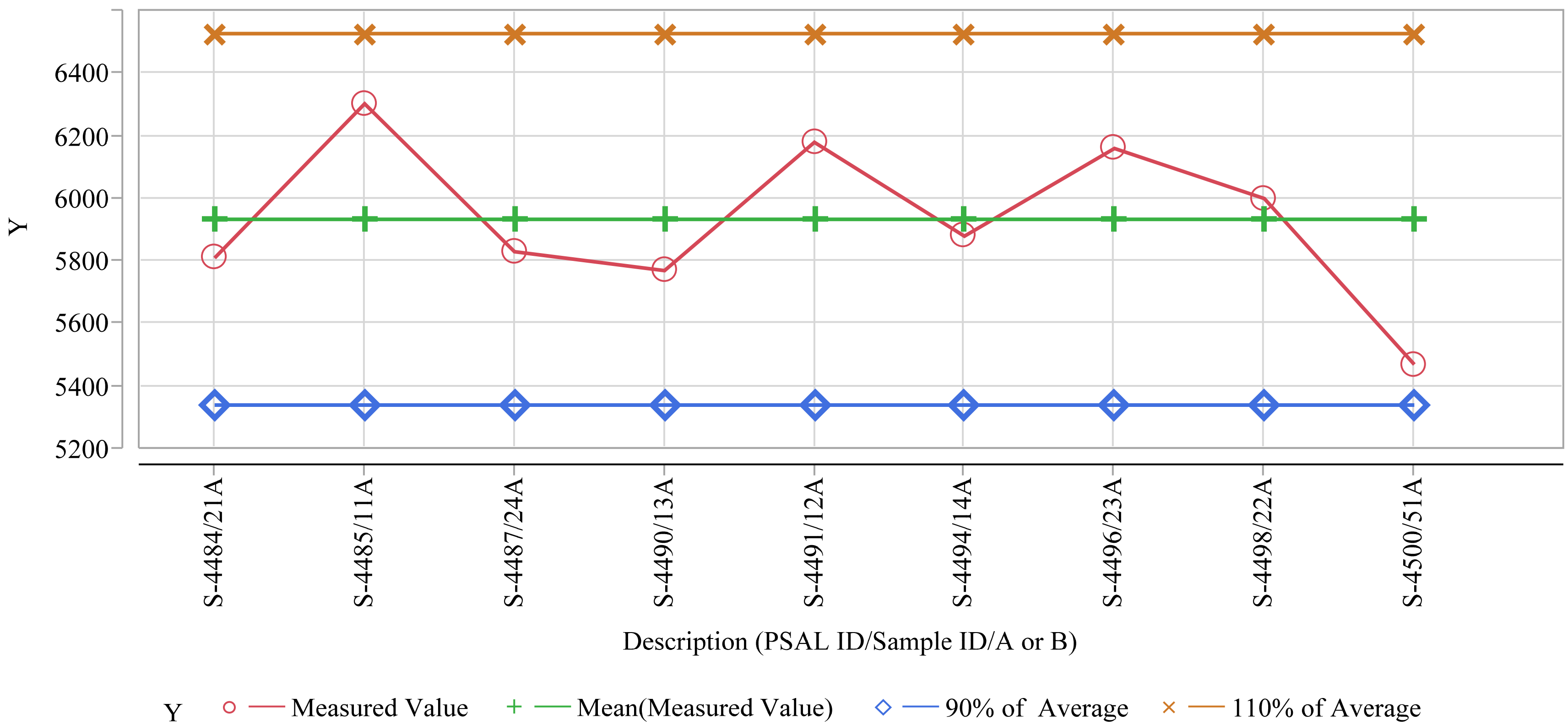
Overlay Plot Test=HLW LB, Type=anion, Analyte=Cl, Unit of Measure=mg/kg



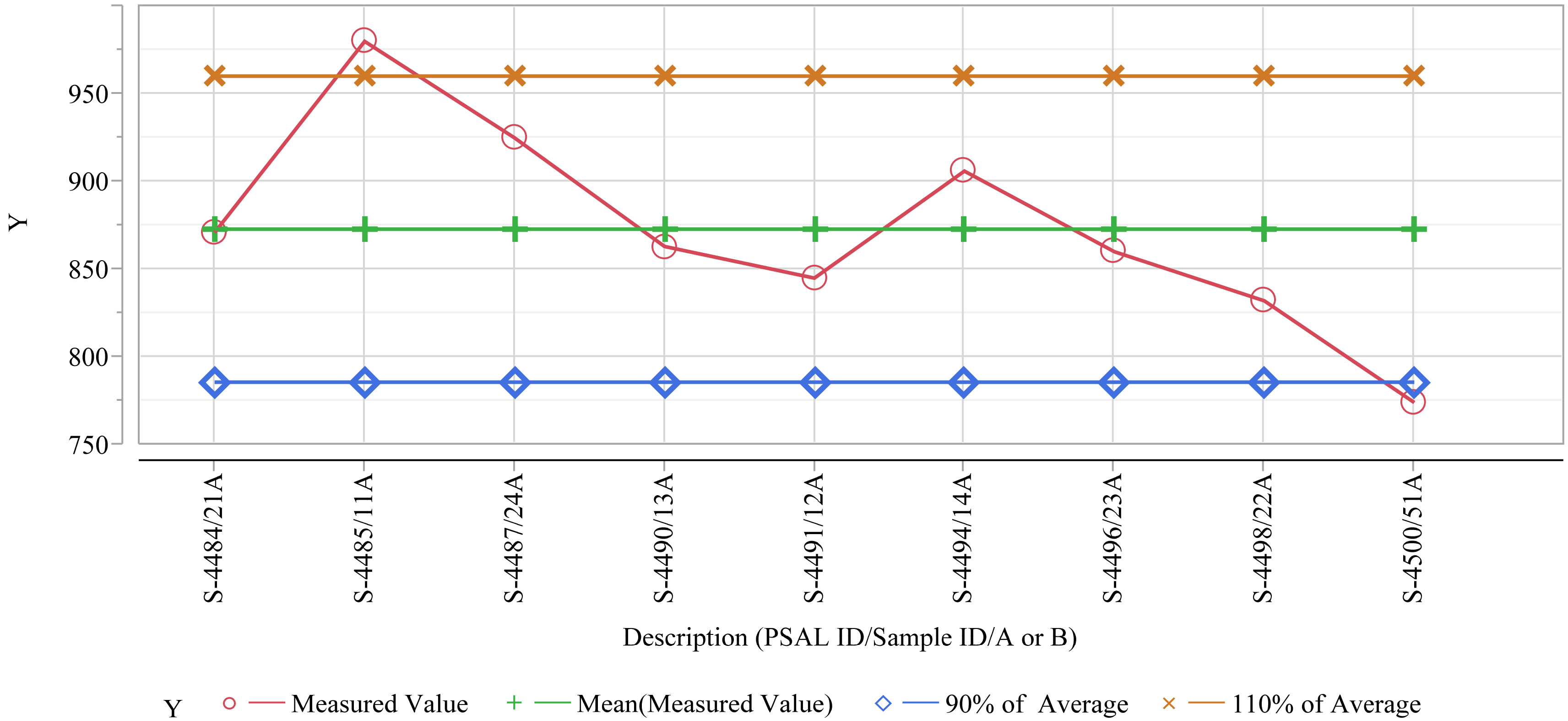
Overlay Plot Test=HLW LB, Type=anion, Analyte=NO2, Unit of Measure=mg/kg



Overlay Plot Test=HLW LB, Type=anion, Analyte=NO3, Unit of Measure=mg/kg



Overlay Plot Test=HLW LB, Type=anion, Analyte=PO4, Unit of Measure=mg/kg



Overlay Plot Test=HLW LB, Type=anion, Analyte=SO4, Unit of Measure=mg/kg

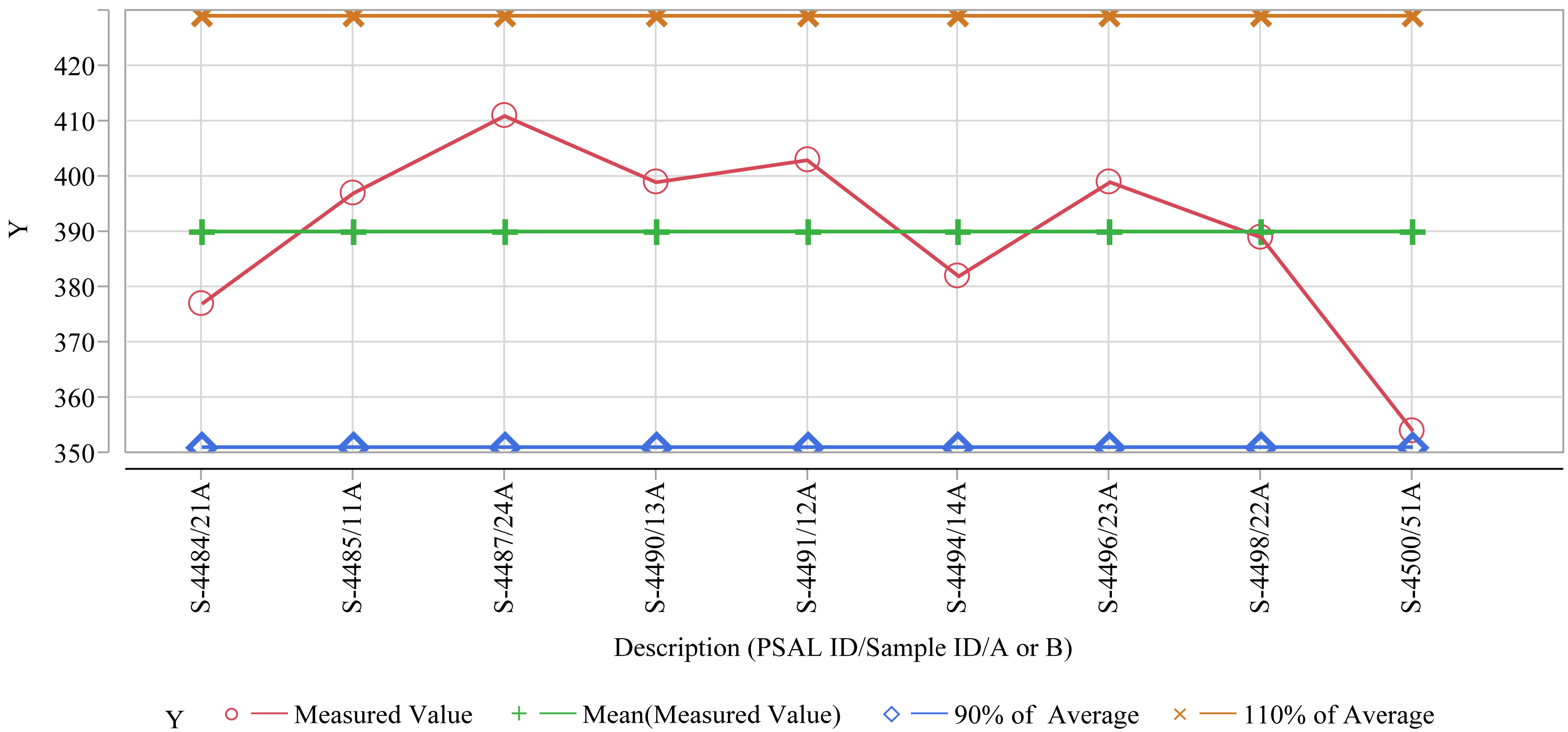
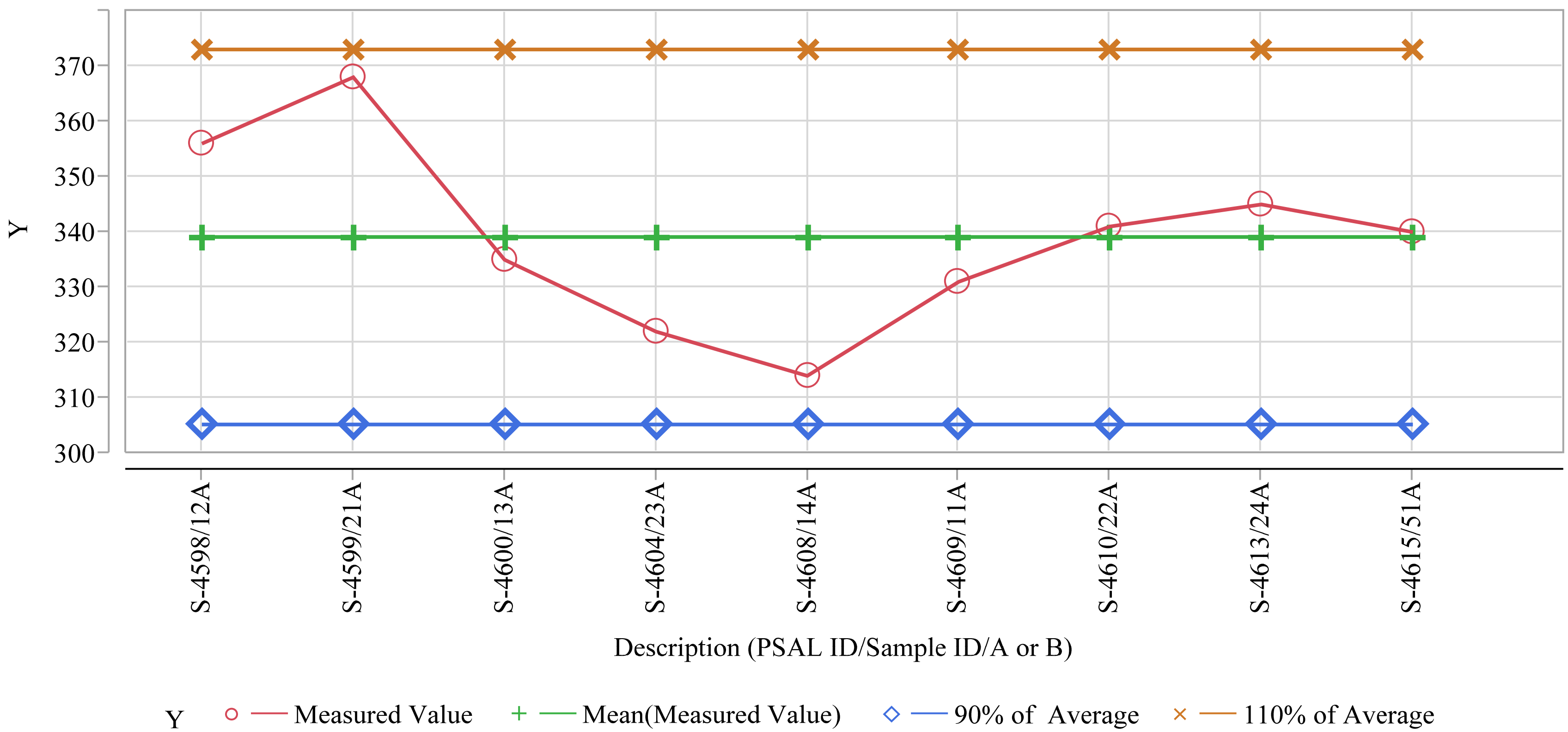
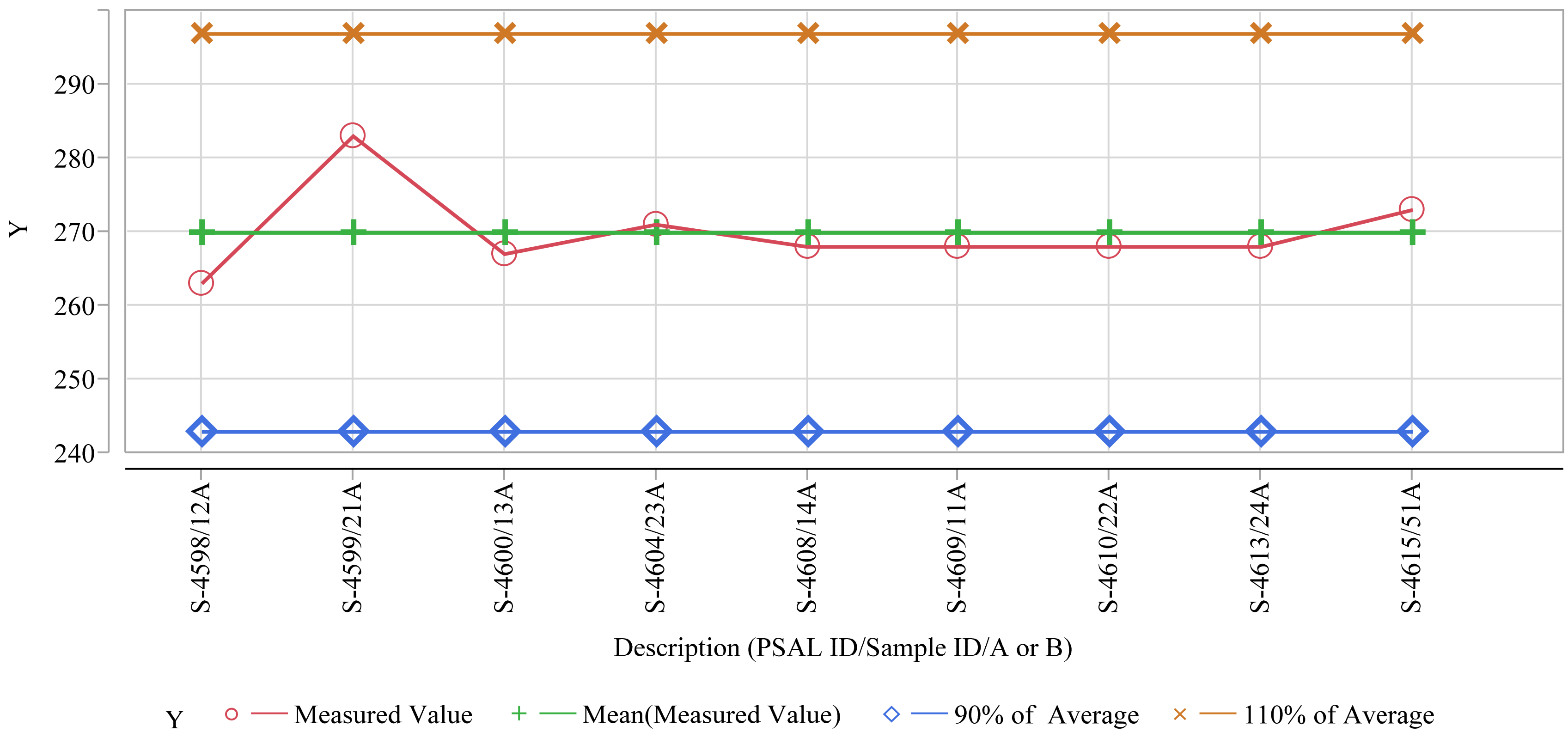


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

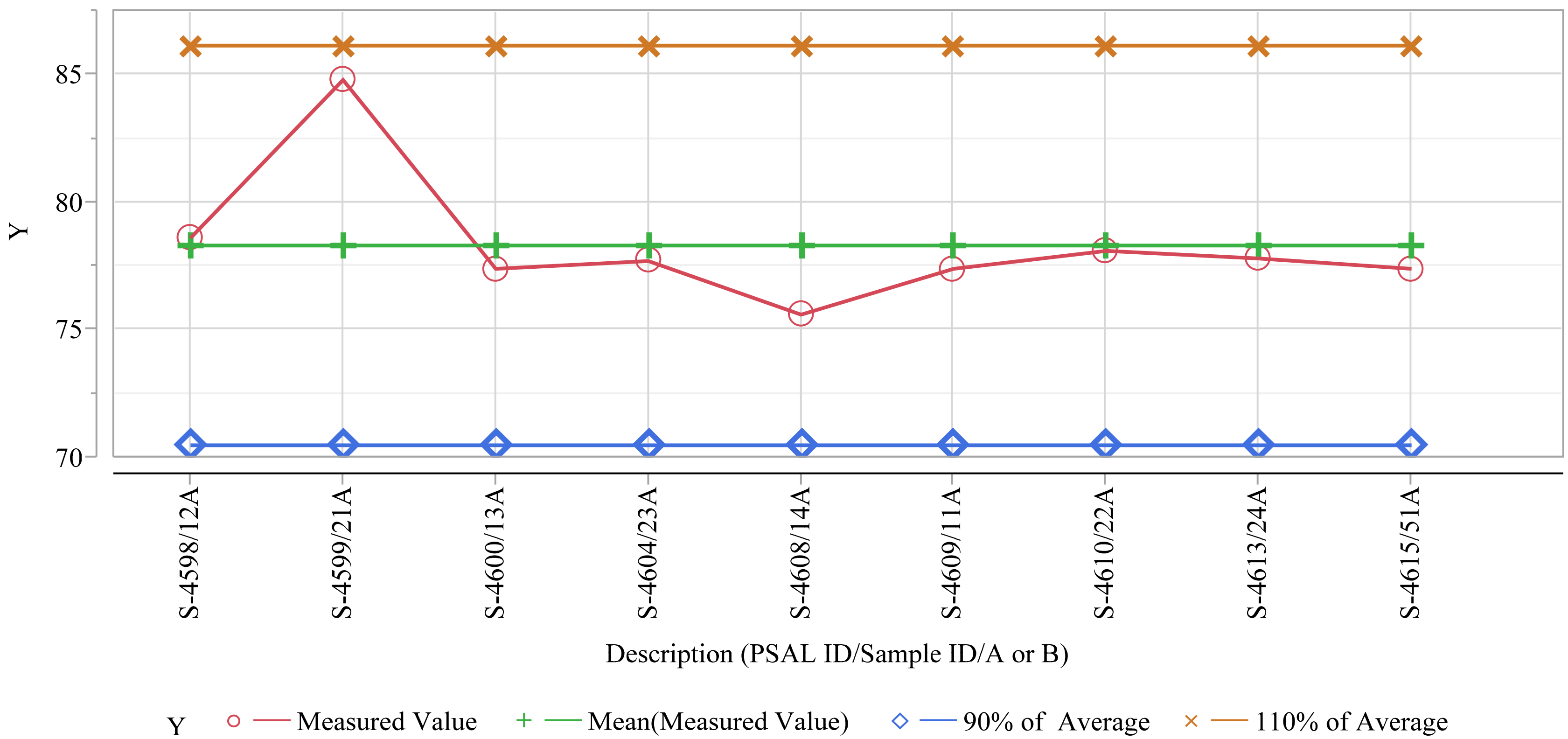
Overlay Plot Test=LAW HB, Type=anion, Analyte=C2O4, Unit of Measure=mg/kg



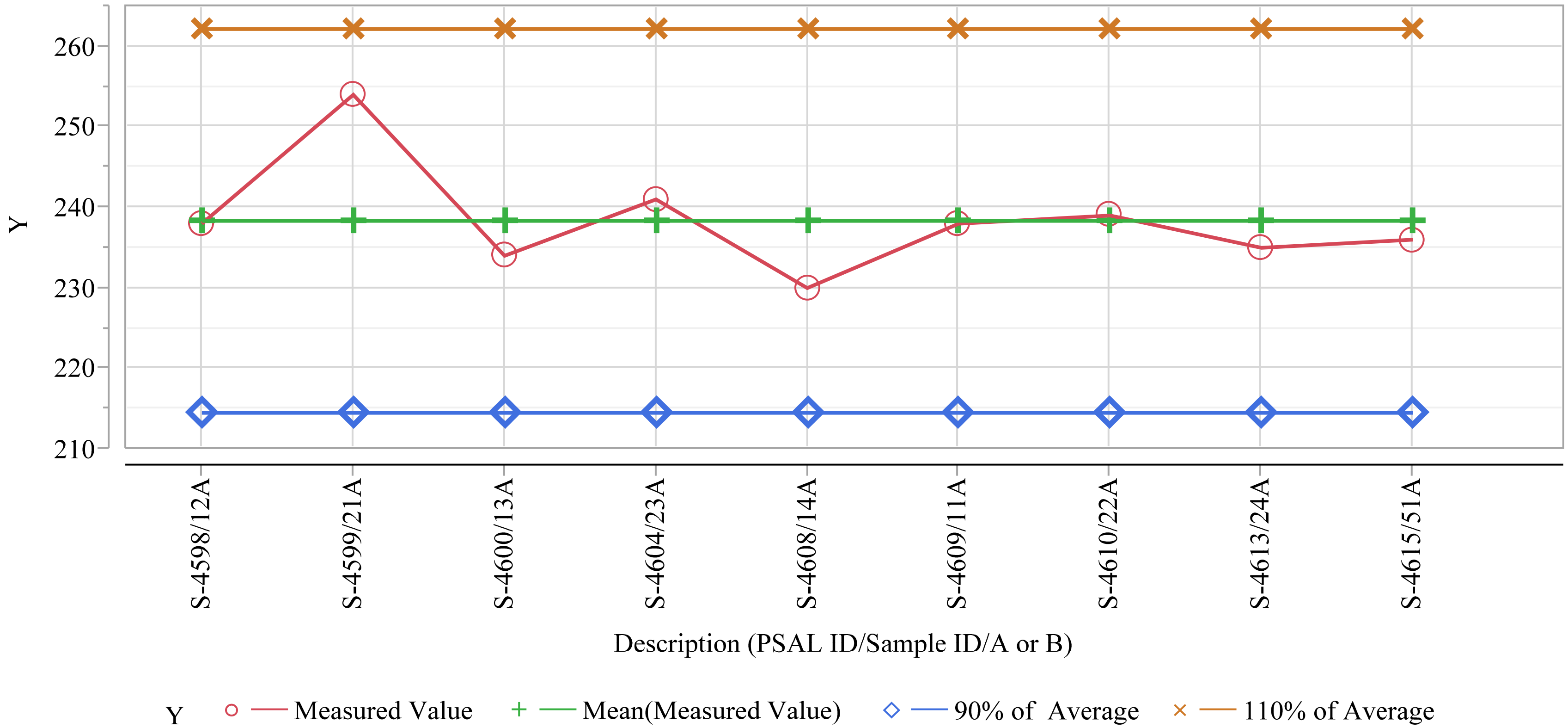
Overlay Plot Test=LAW HB, Type=anion, Analyte=Cl, Unit of Measure=mg/kg



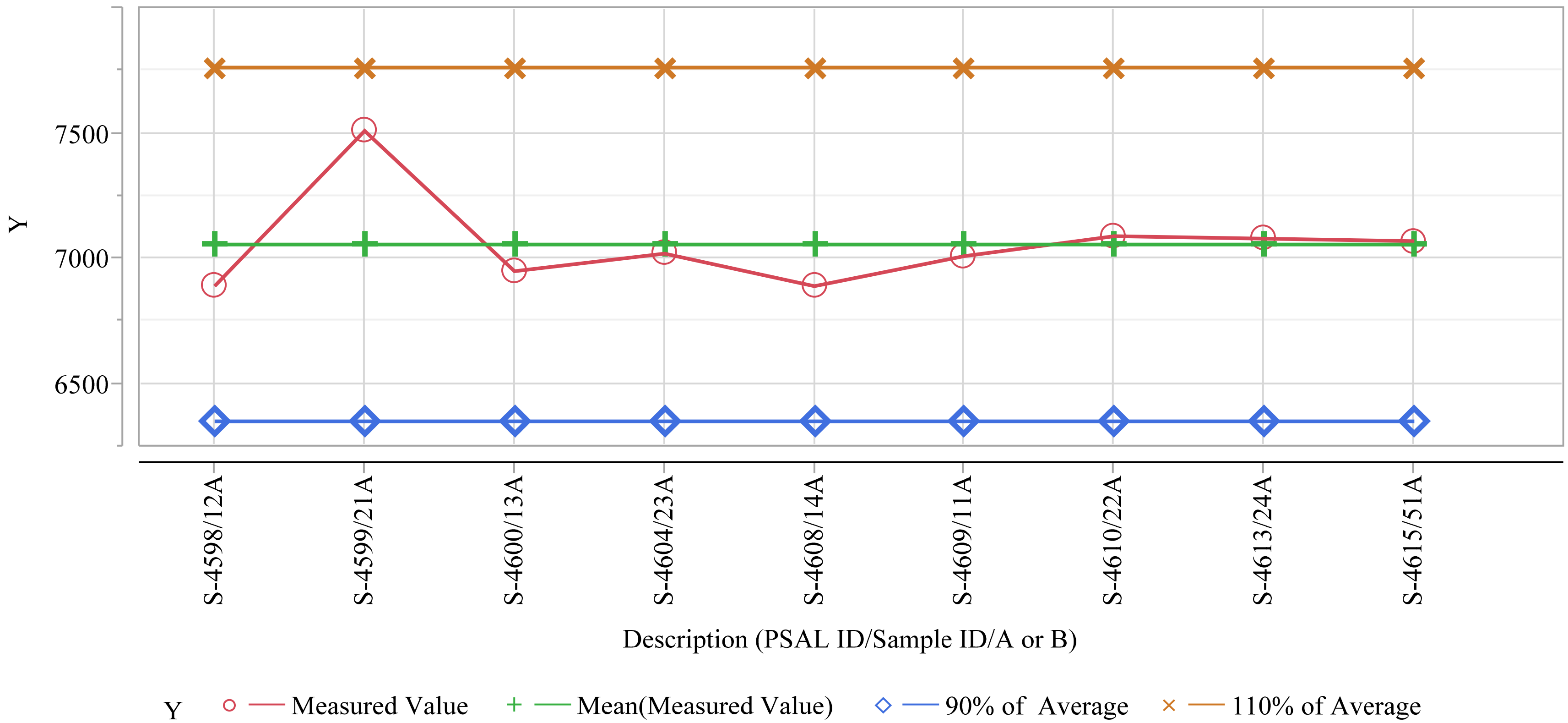
Overlay Plot Test=LAW HB, Type=anion, Analyte=F, Unit of Measure=mg/kg



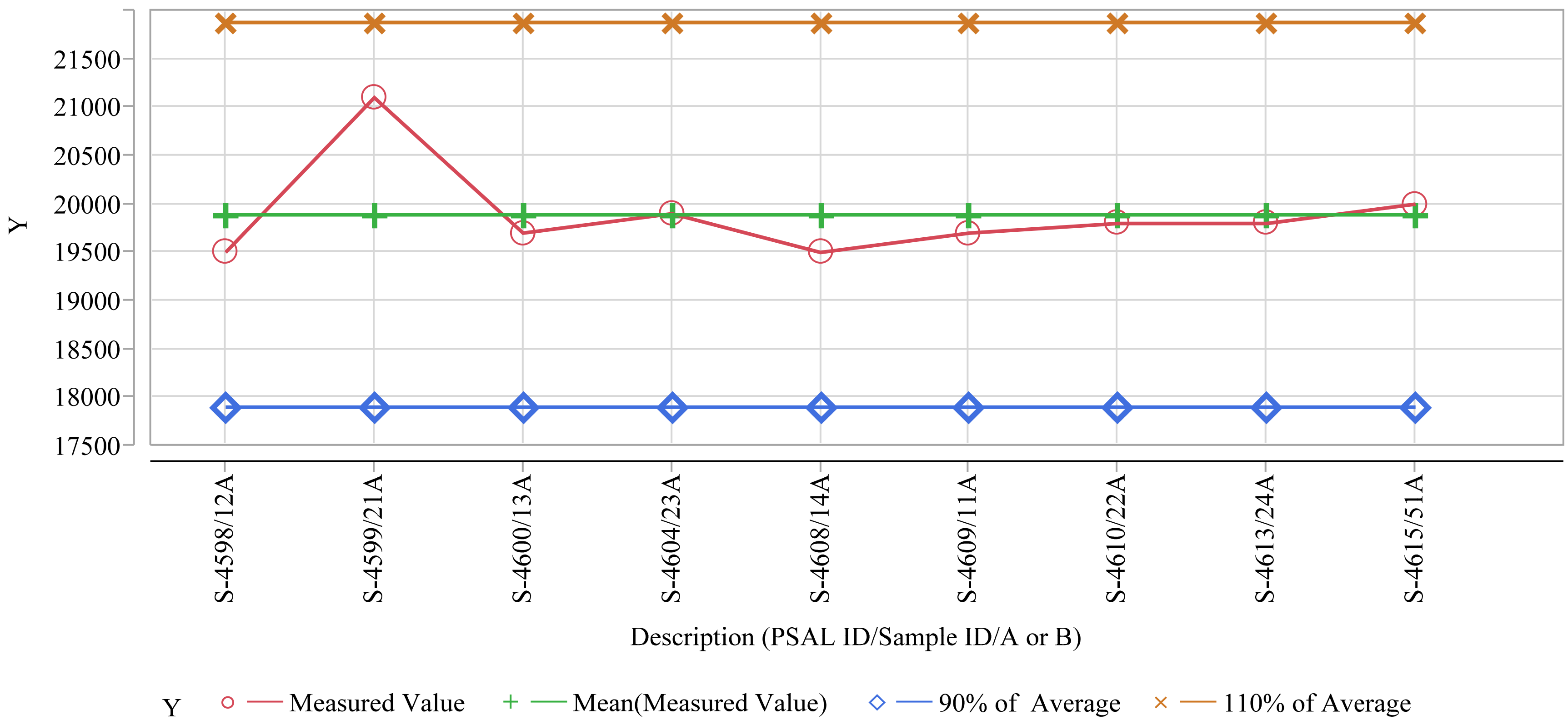
Overlay Plot Test=LAW HB, Type=anion, Analyte=HCO2, Unit of Measure=mg/kg



Overlay Plot Test=LAW HB, Type=anion, Analyte=NO2, Unit of Measure=mg/kg



Overlay Plot Test=LAW HB, Type=anion, Analyte=NO3, Unit of Measure=mg/kg



Overlay Plot Test=LAW HB, Type=anion, Analyte=SO4, Unit of Measure=mg/kg

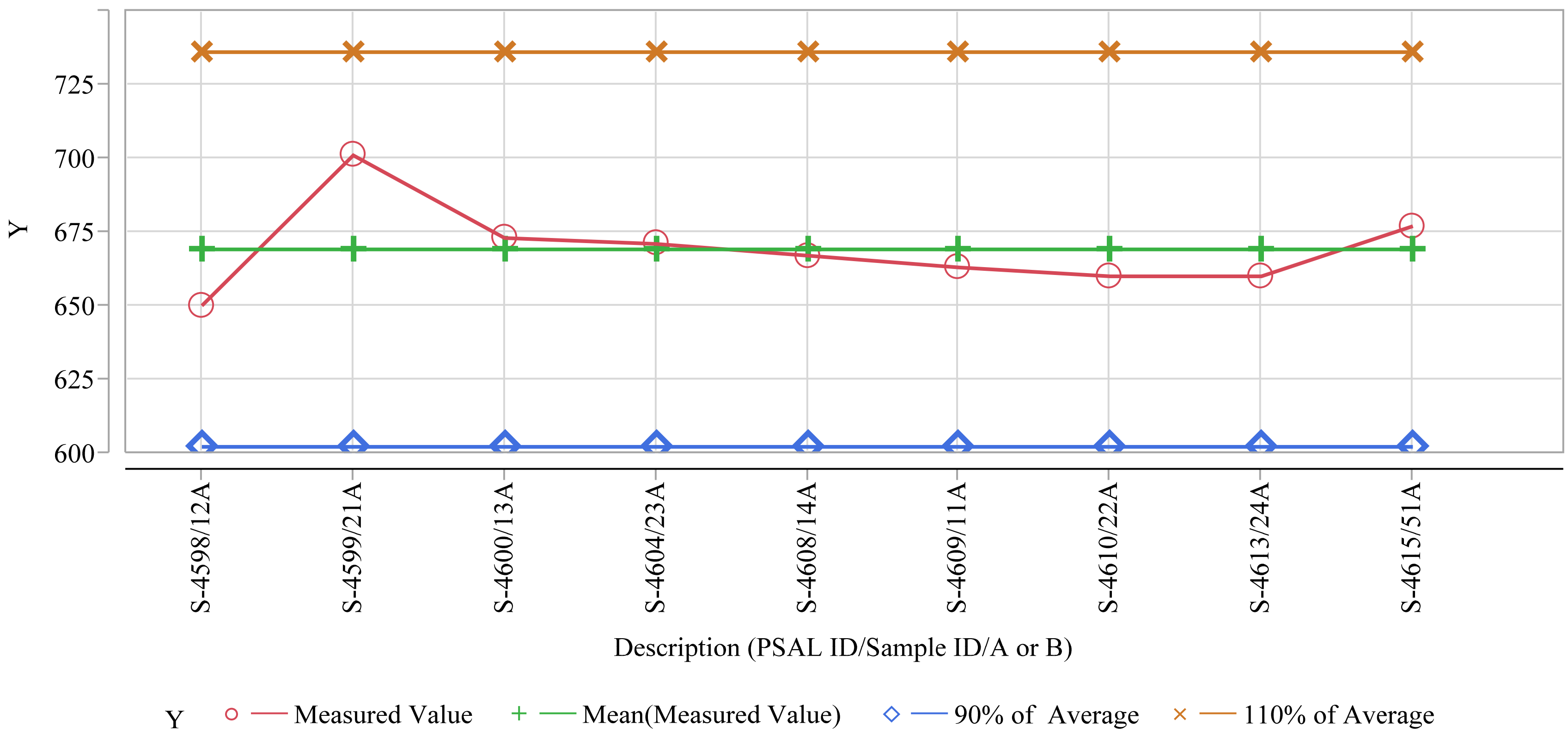


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

Overlay Plot Test=LAW LB, Type=anion, Analyte=C2O4, Unit of Measure=mg/kg

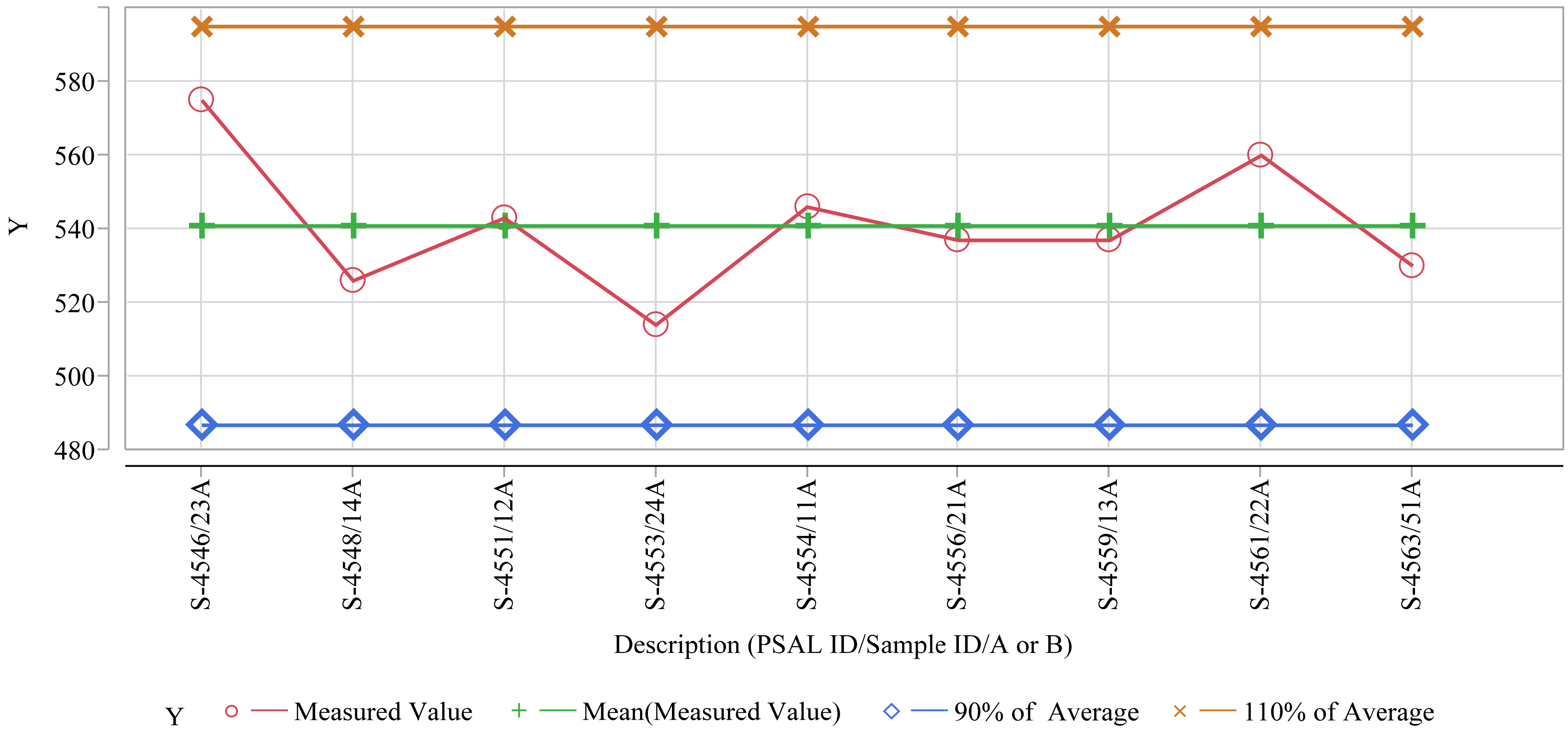
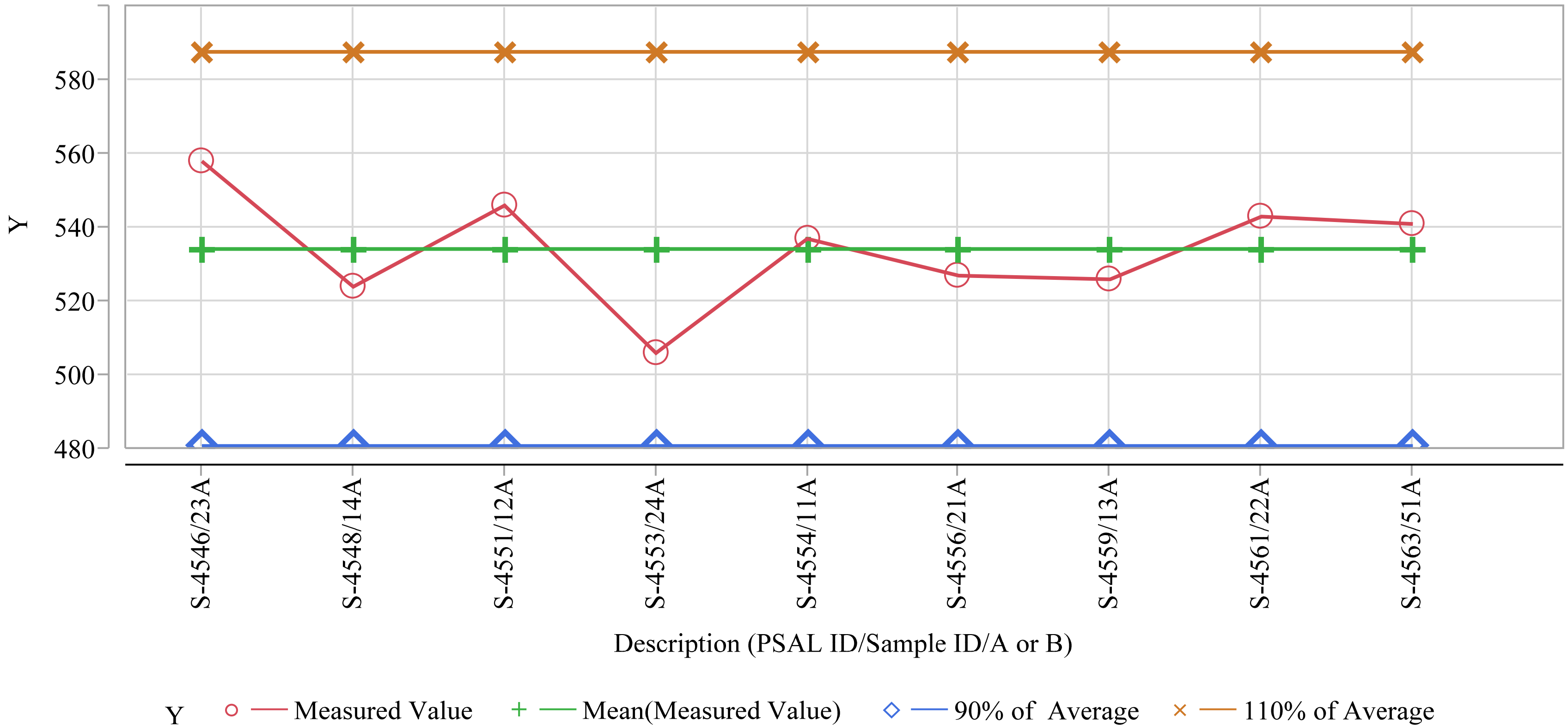
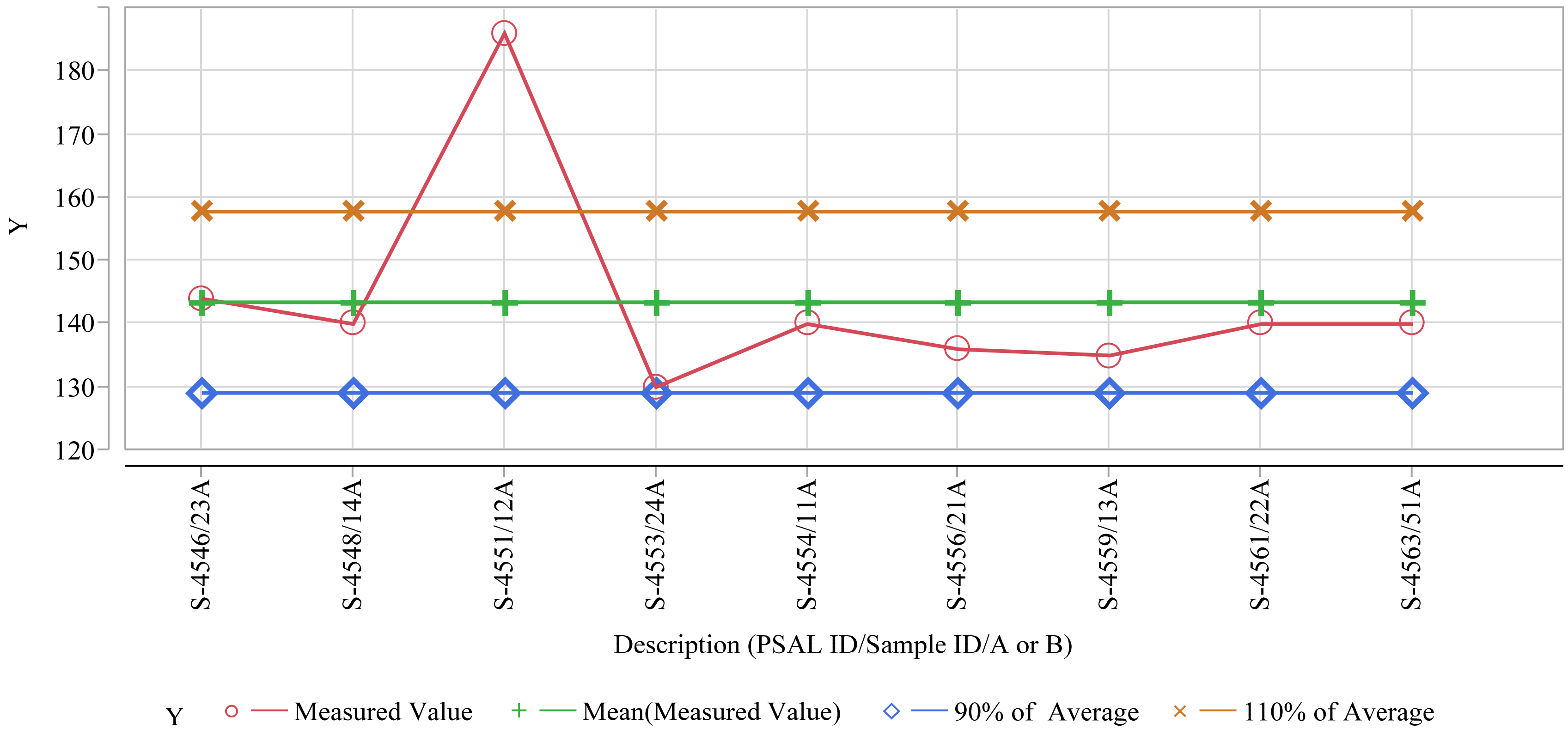


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

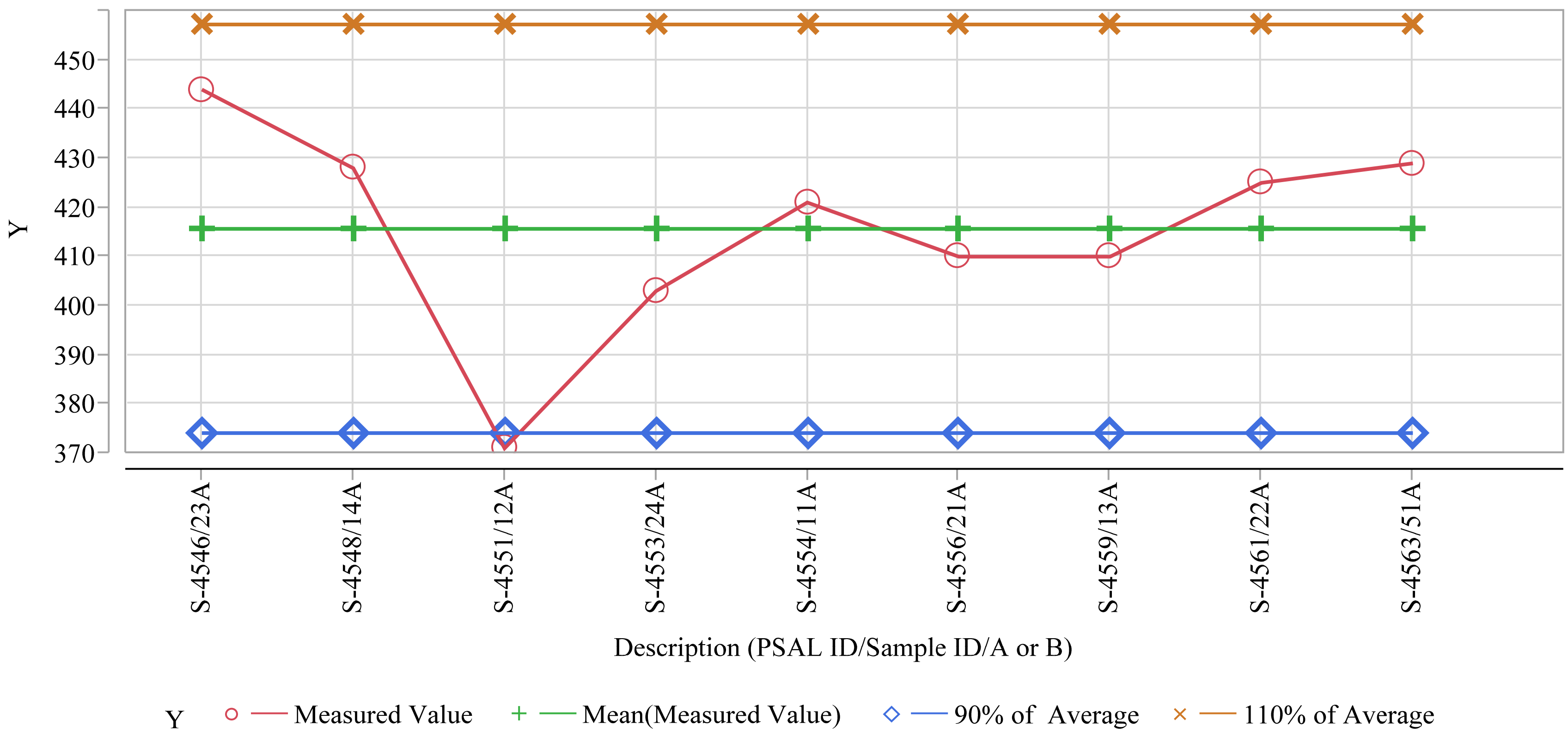
Overlay Plot Test=LAW LB, Type=anion, Analyte=Cl, Unit of Measure=mg/kg



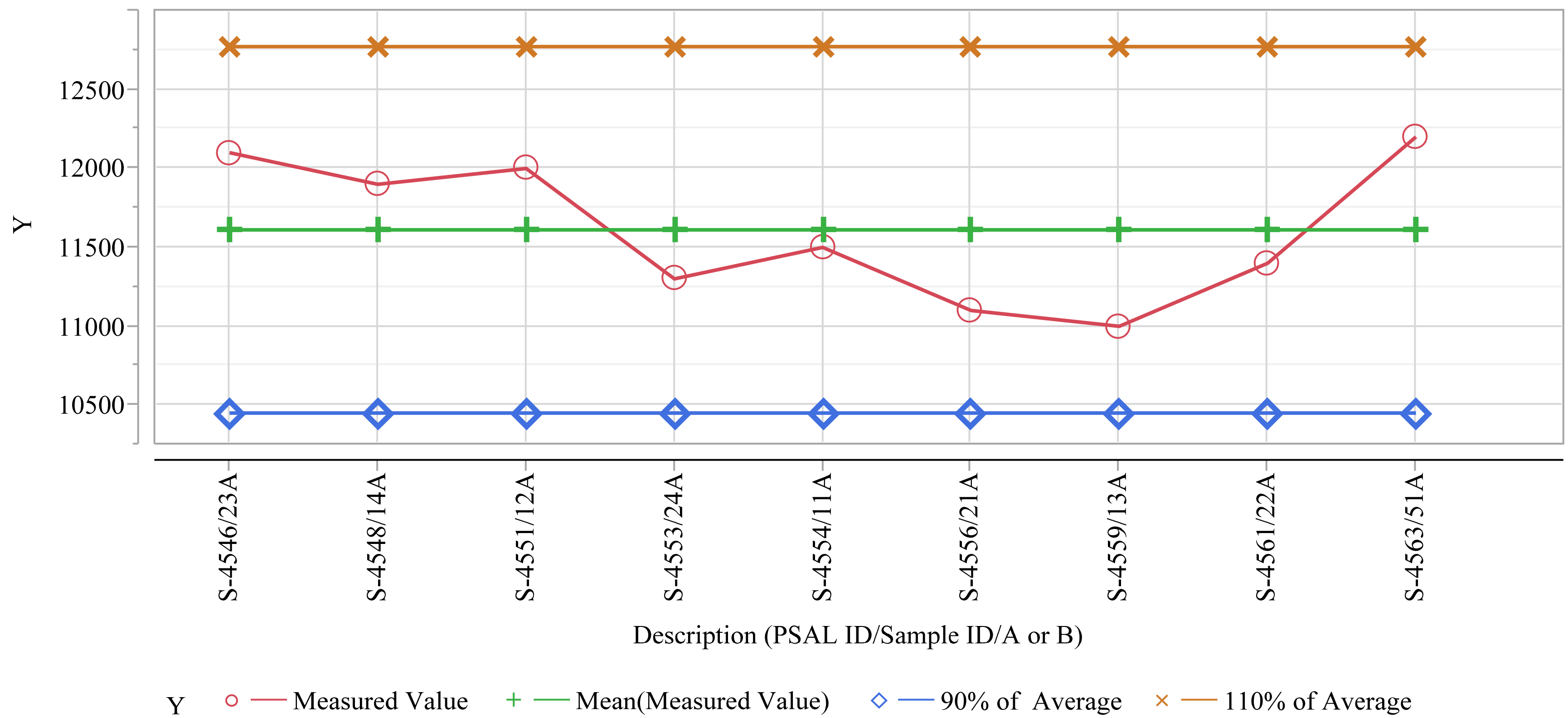
Overlay Plot Test=LAW LB, Type=anion, Analyte=F, Unit of Measure=mg/kg



Overlay Plot Test=LAW LB, Type=anion, Analyte=HCO2, Unit of Measure=mg/kg



Overlay Plot Test=LAW LB, Type=anion, Analyte=NO2, Unit of Measure=mg/kg



Overlay Plot Test=LAW LB, Type=anion, Analyte=NO3, Unit of Measure=mg/kg

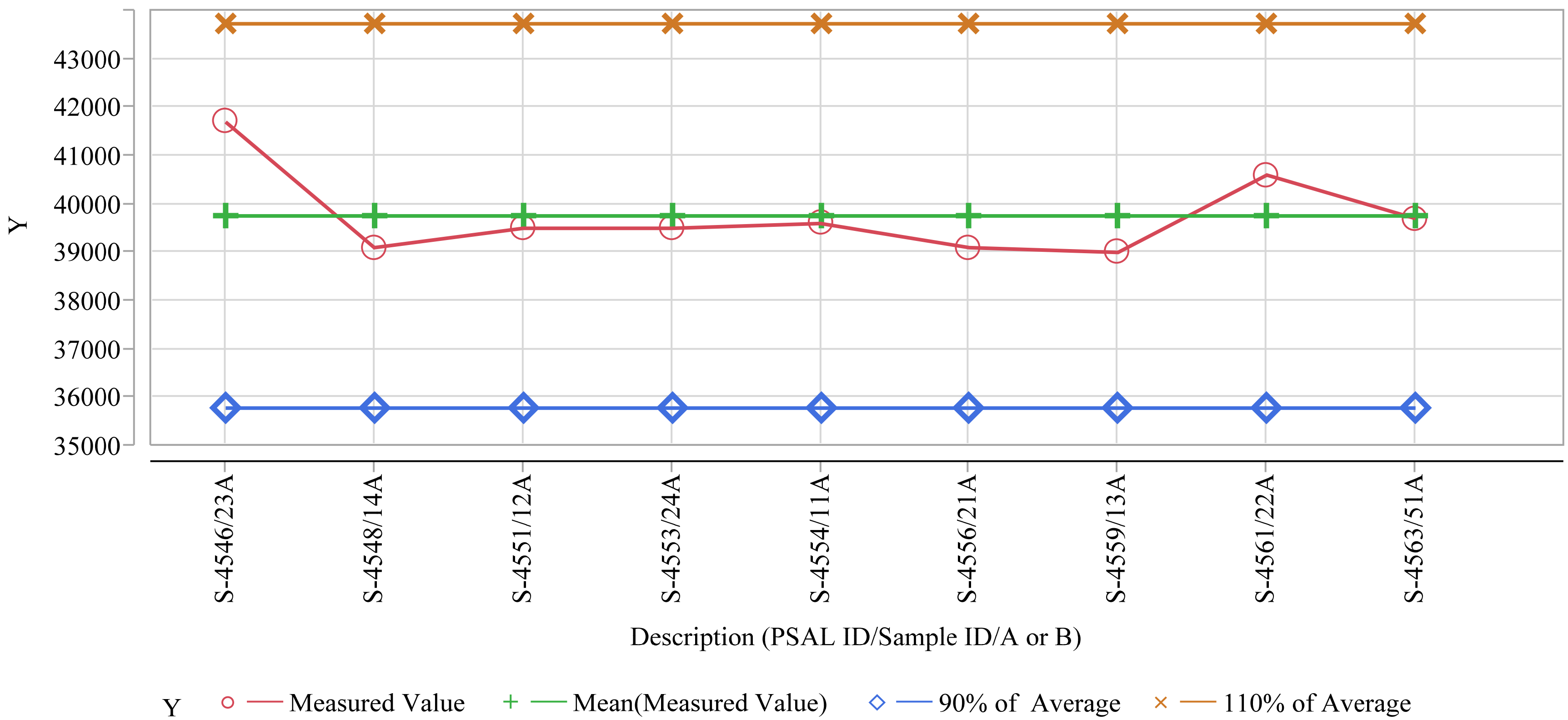
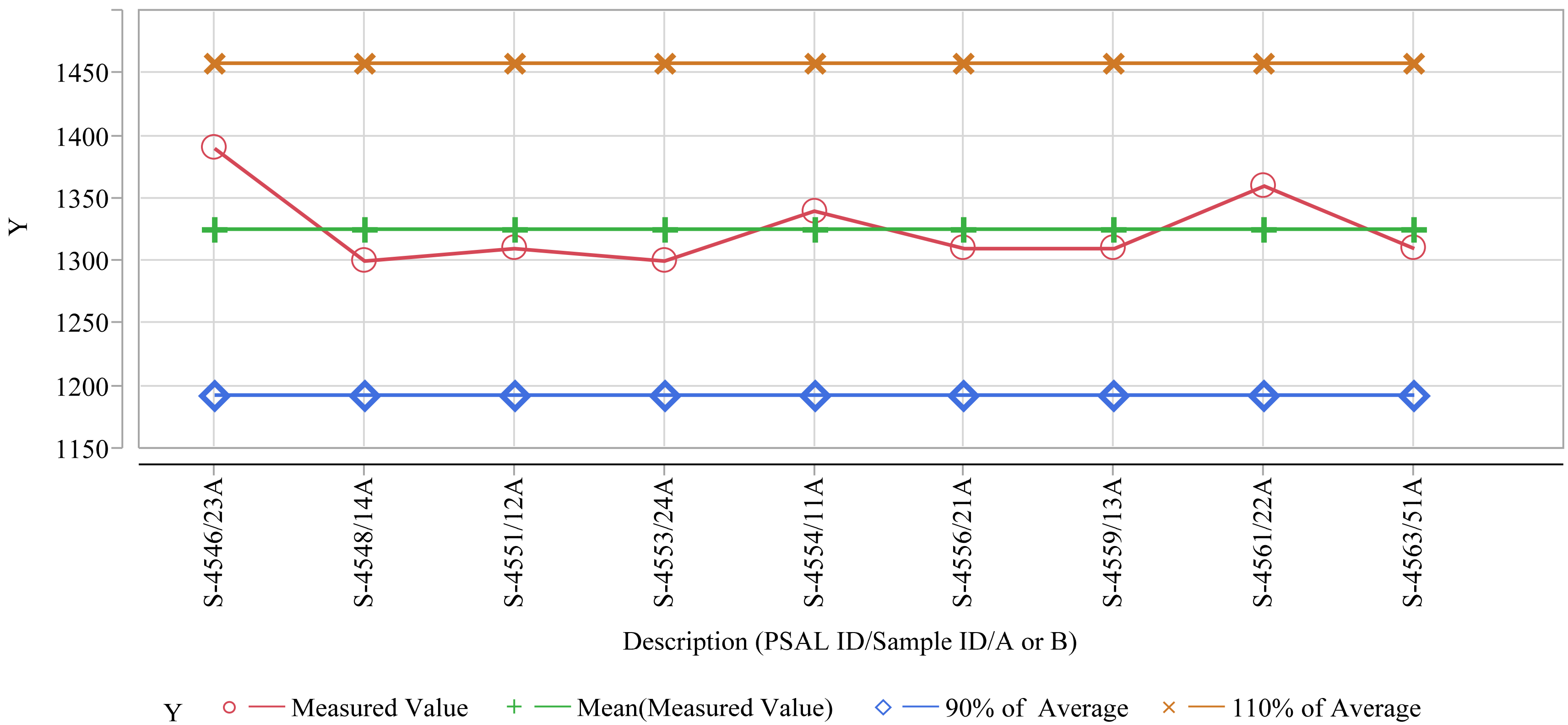
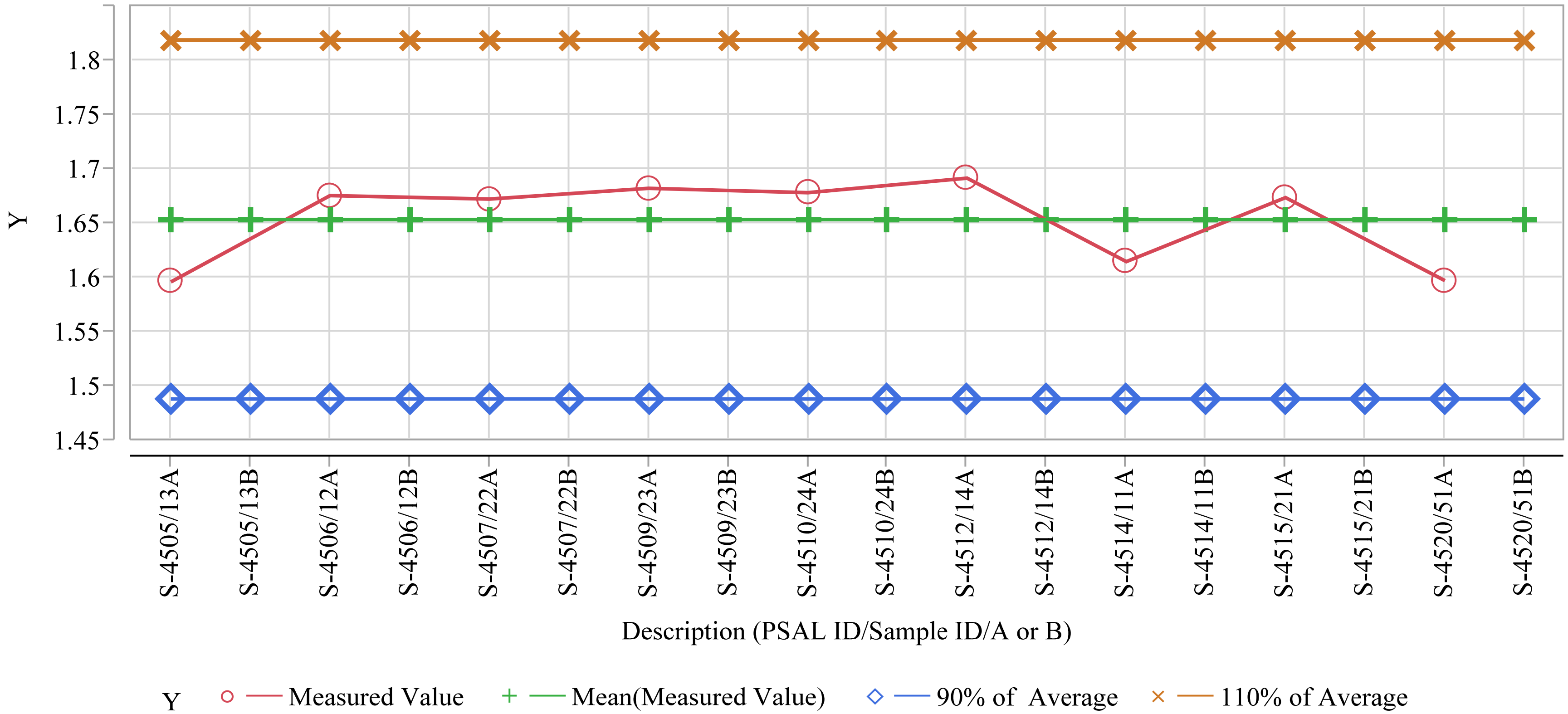


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

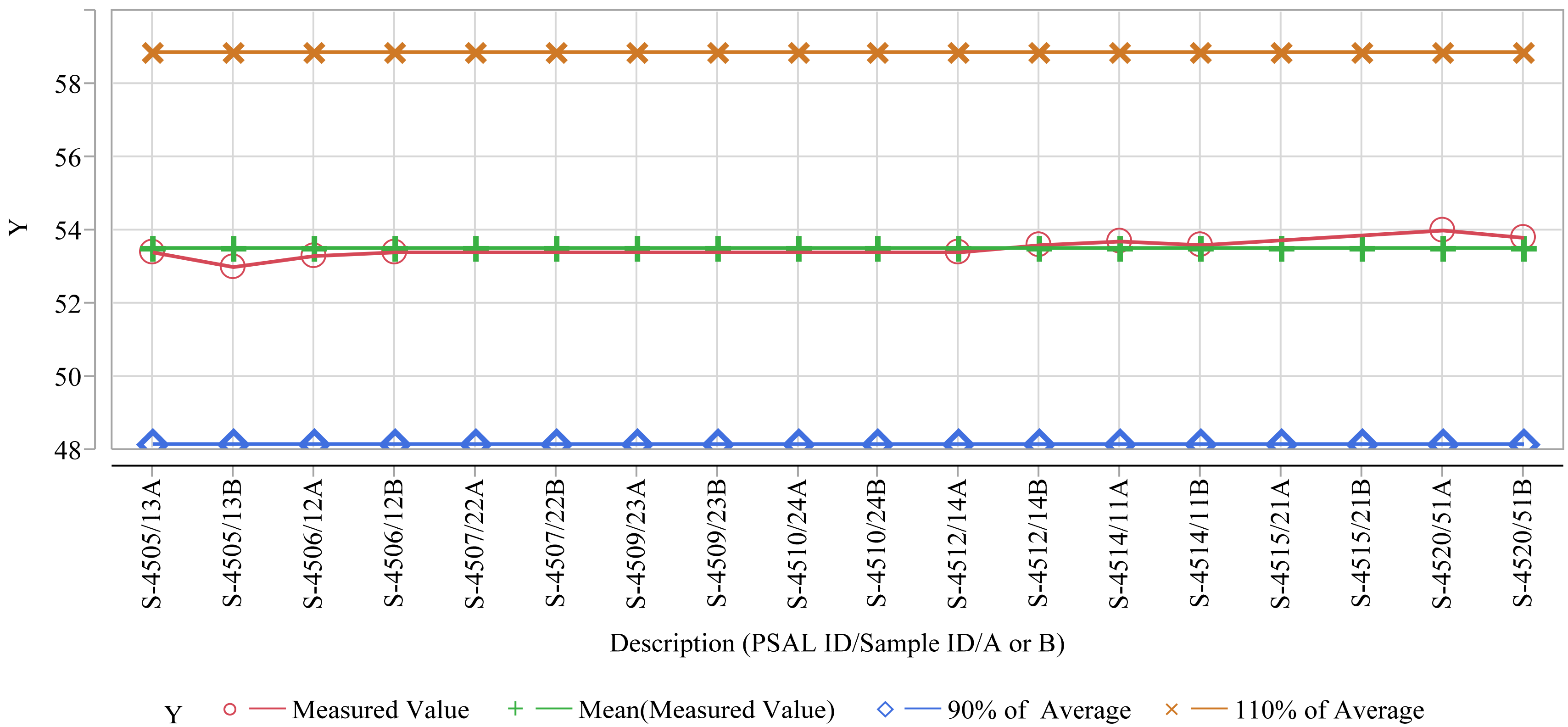
Overlay Plot Test=LAW LB, Type=anion, Analyte=SO4, Unit of Measure=mg/kg



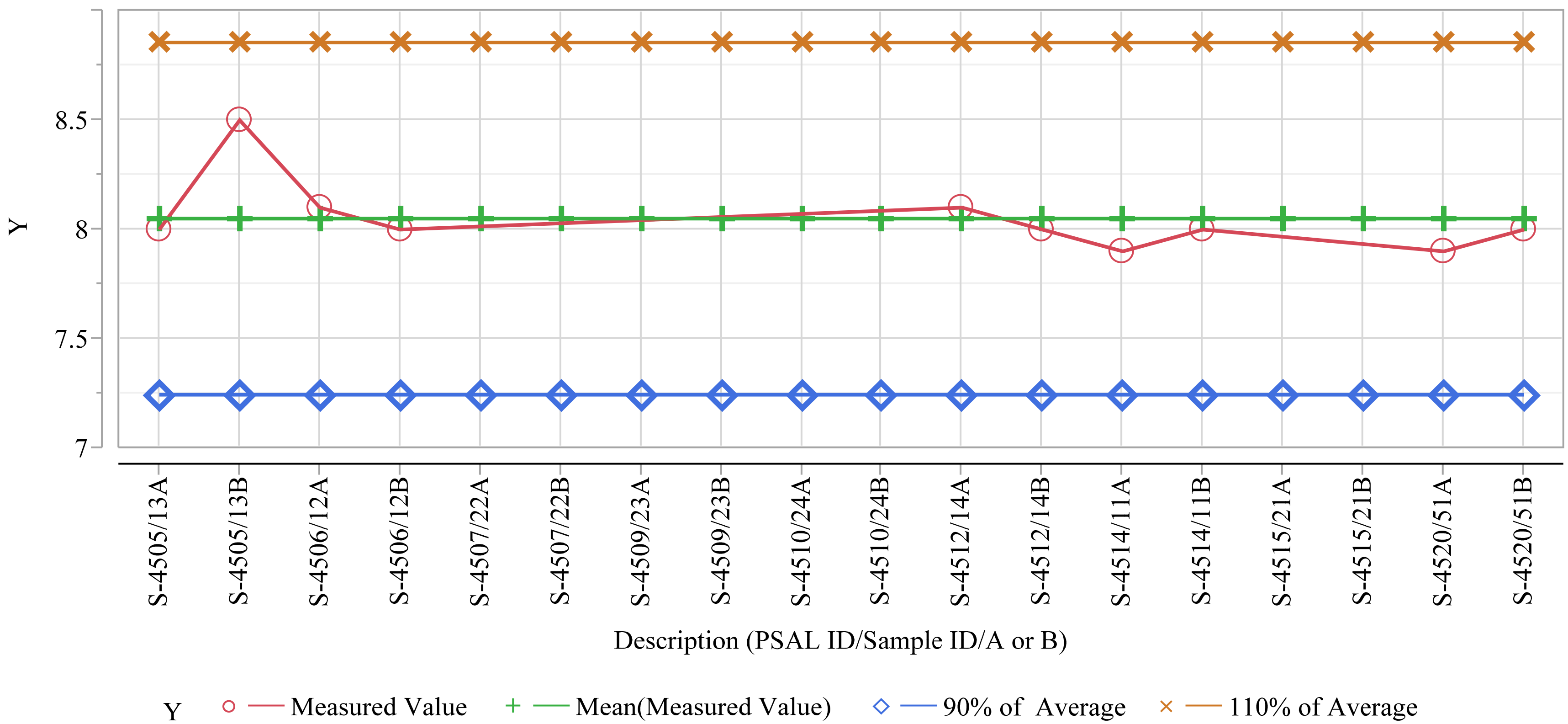
Overlay Plot Test=HLW HB (a), Type=physical property, Analyte=Density, Unit of Measure=g/mL



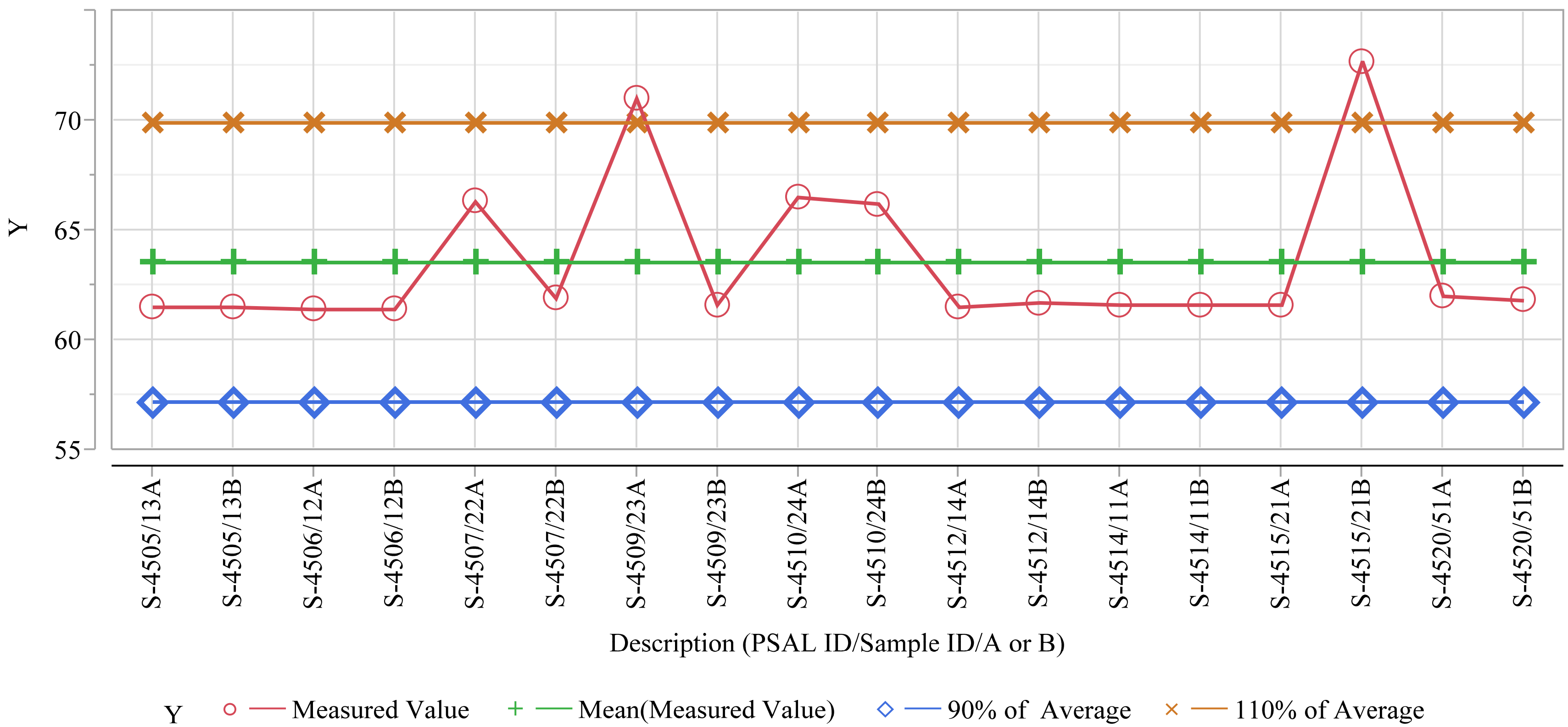
Overlay Plot Test=HLW HB (a), Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%



Overlay Plot Test=HLW HB (a), Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%



Overlay Plot Test=HLW HB (a), Type=physical property, Analyte=Total Solids, Unit of Measure=wt%



Overlay Plot Test=HLW HB (a), Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%

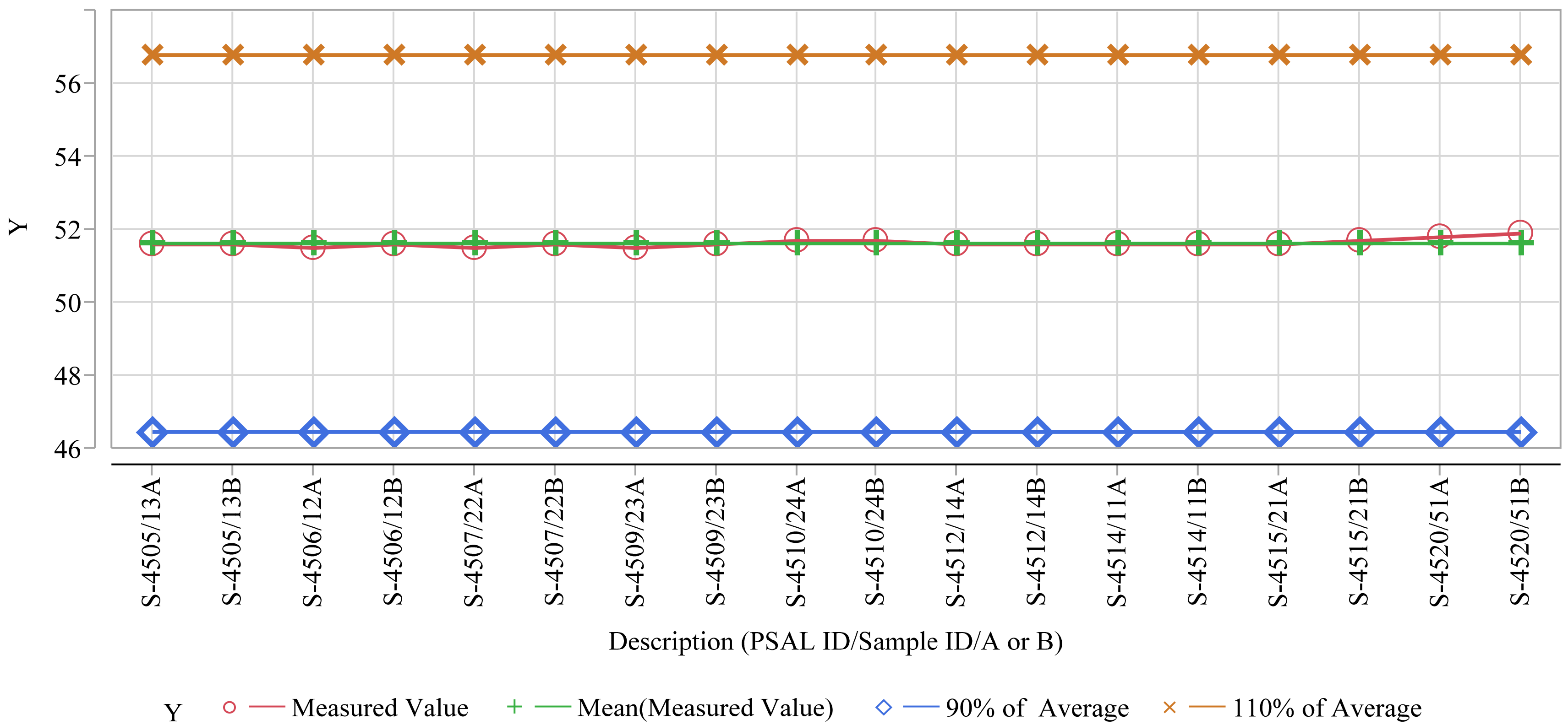
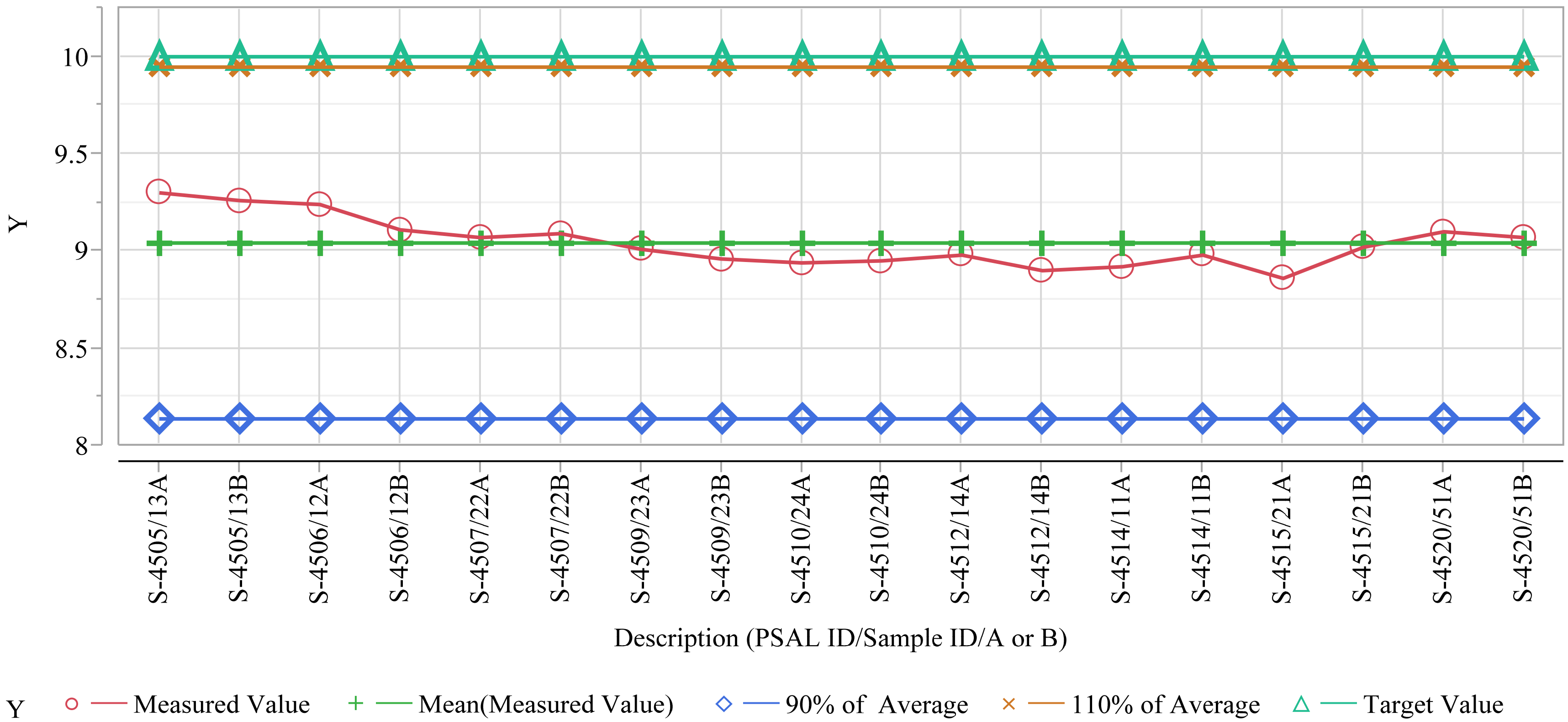
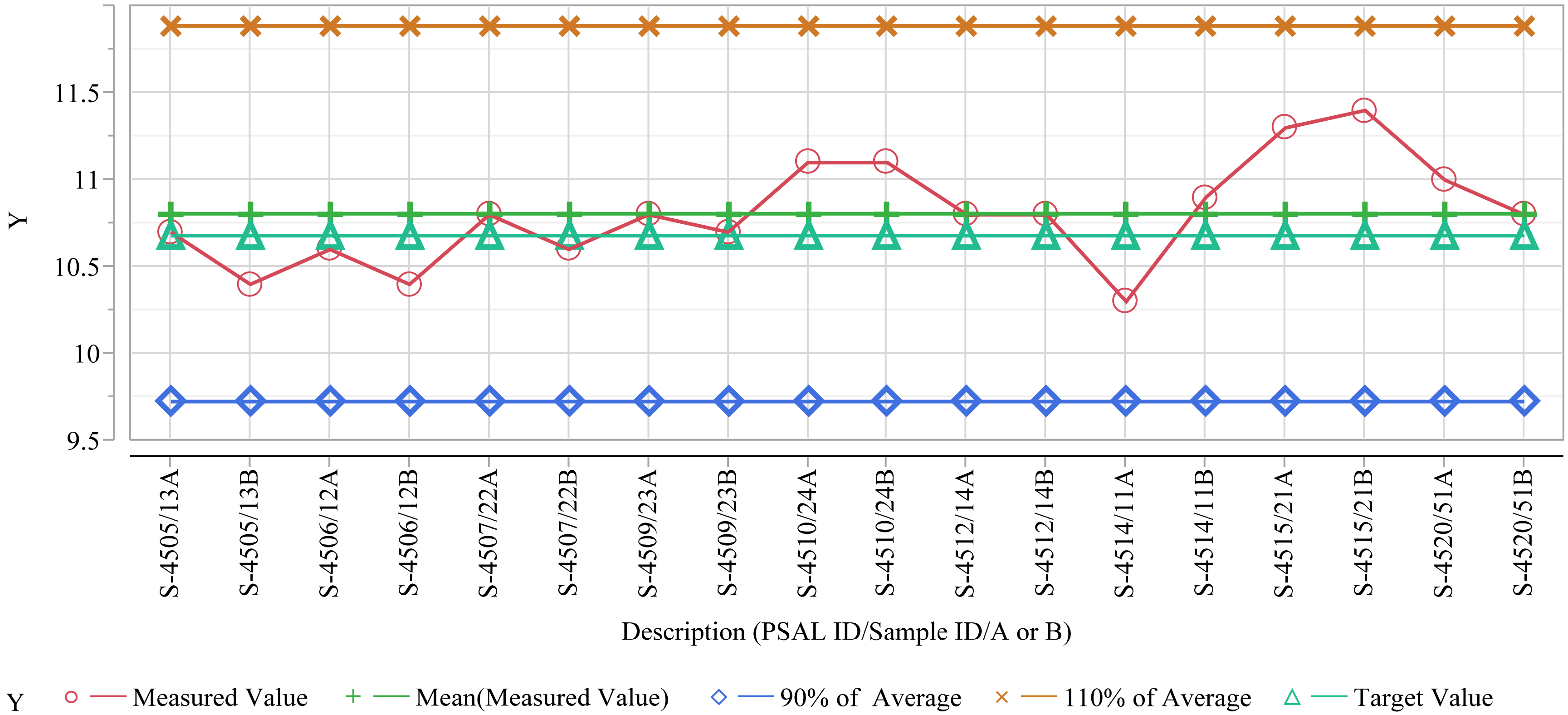


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

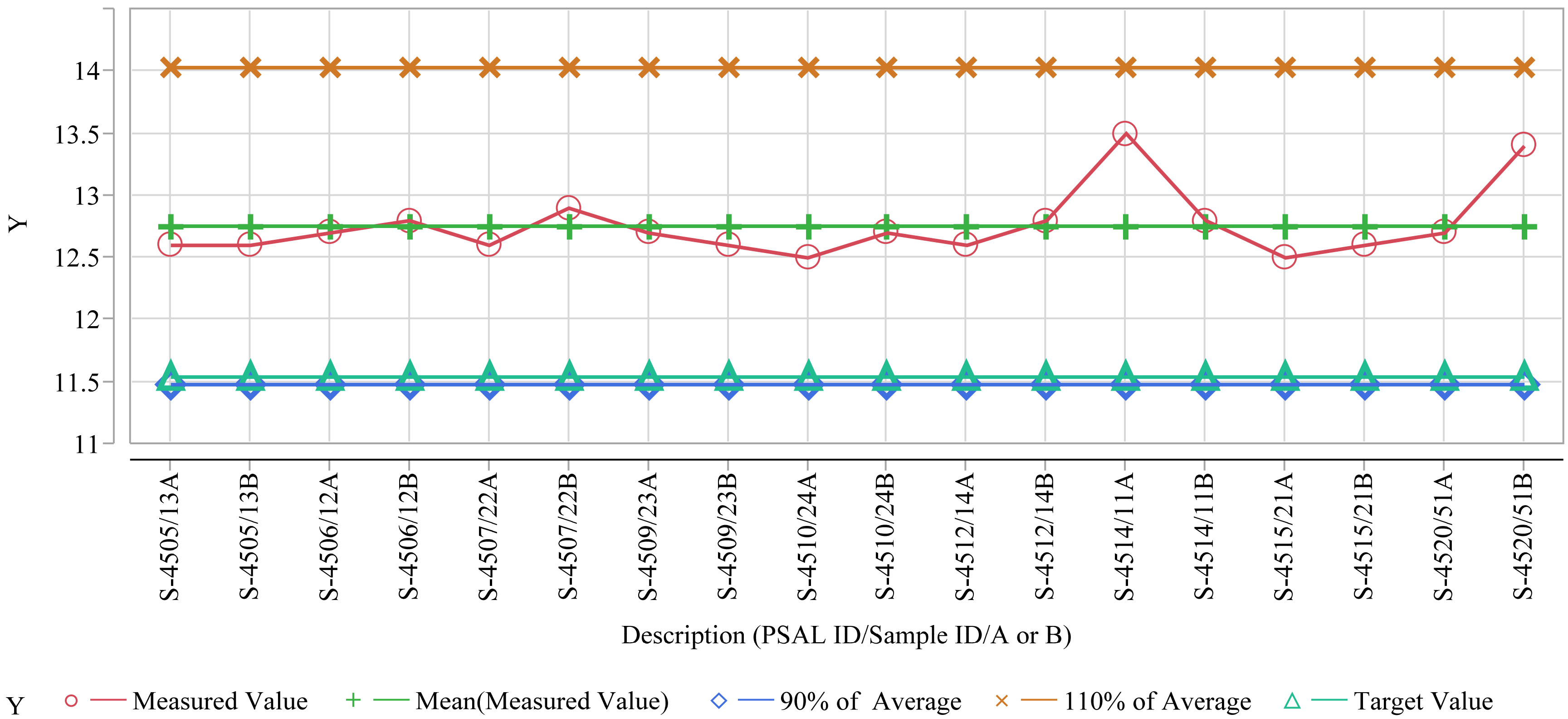
Overlay Plot Test=HLW HB (a), Type=slurry, Analyte=Al2O3, Unit of Measure=wt%



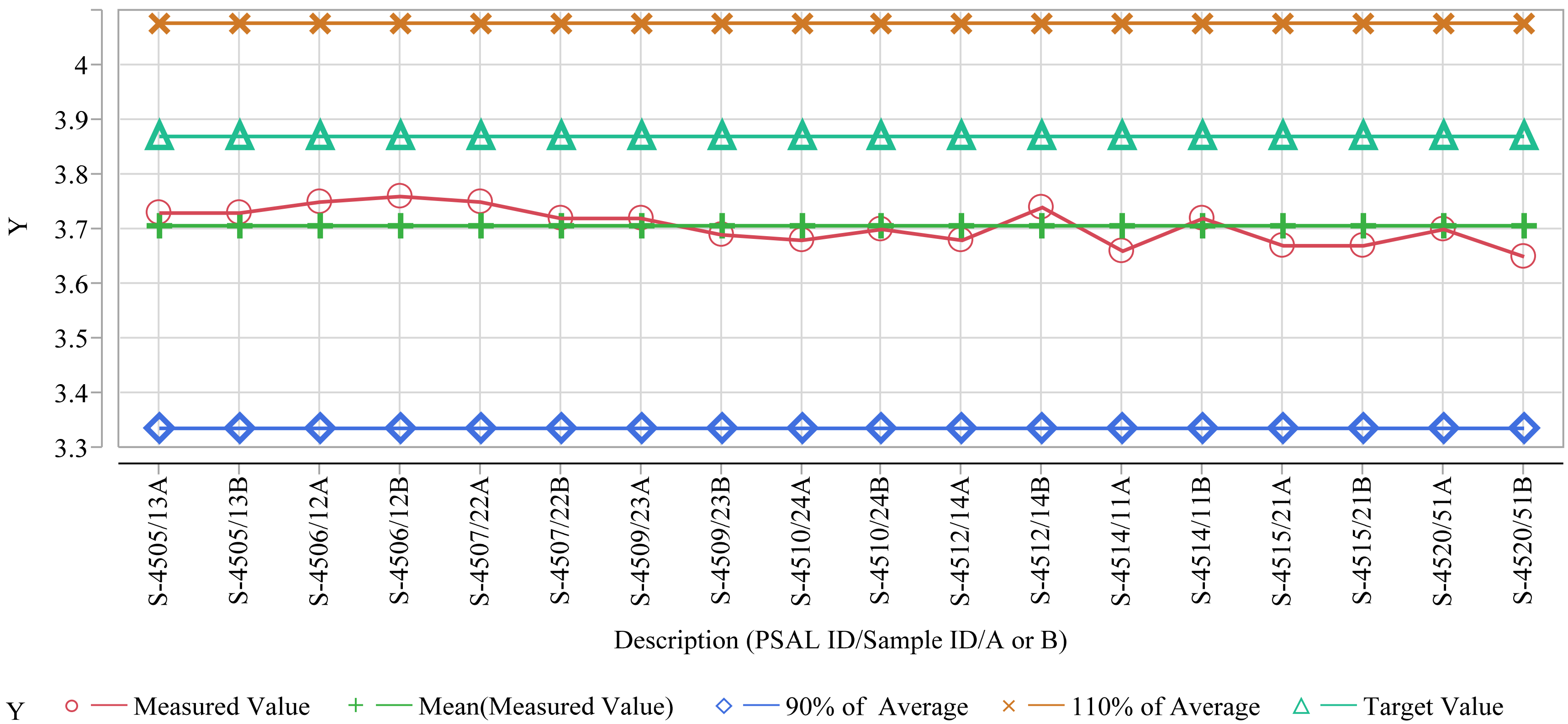
Overlay Plot Test=HLW HB (a), Type=slurry, Analyte=B2O3, Unit of Measure=wt%



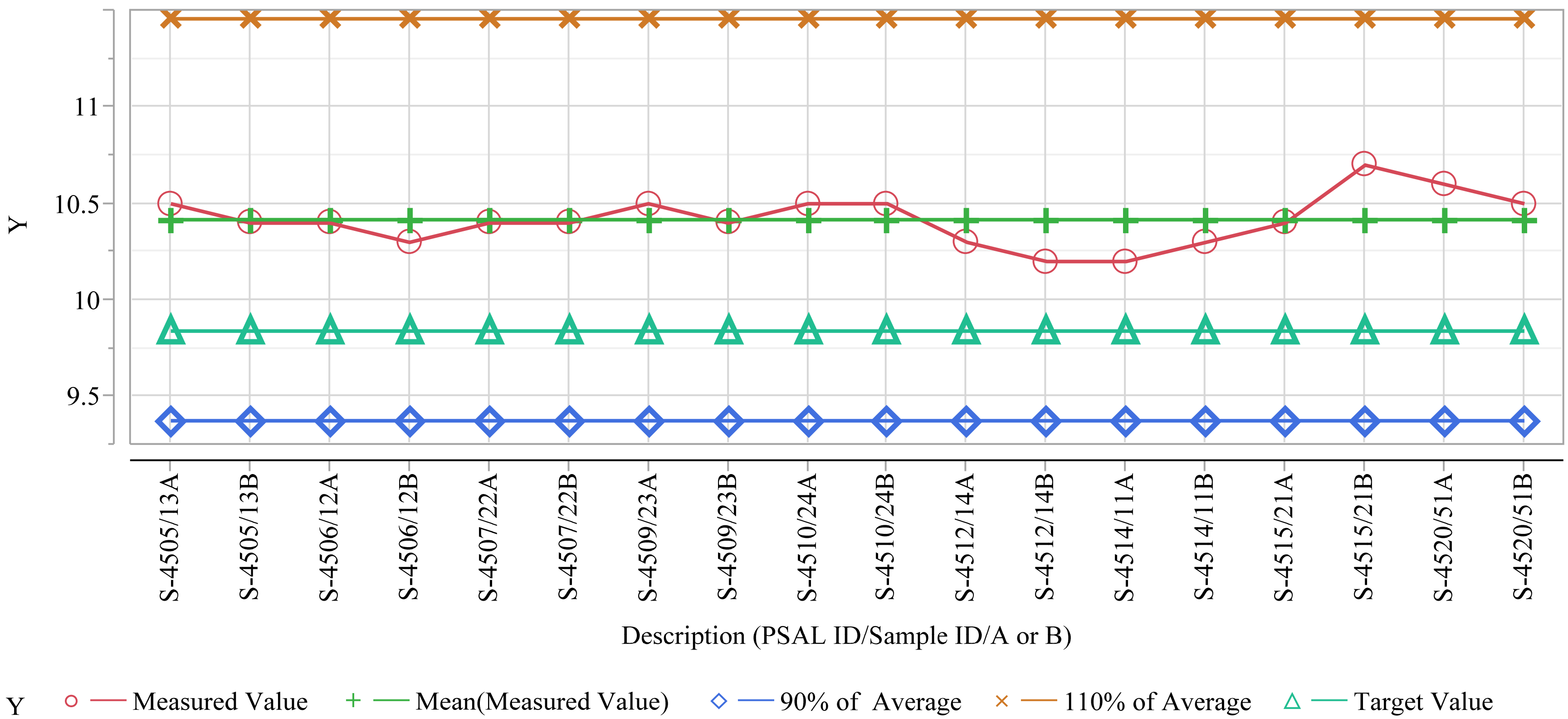
Overlay Plot Test=HLW HB (a), Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%



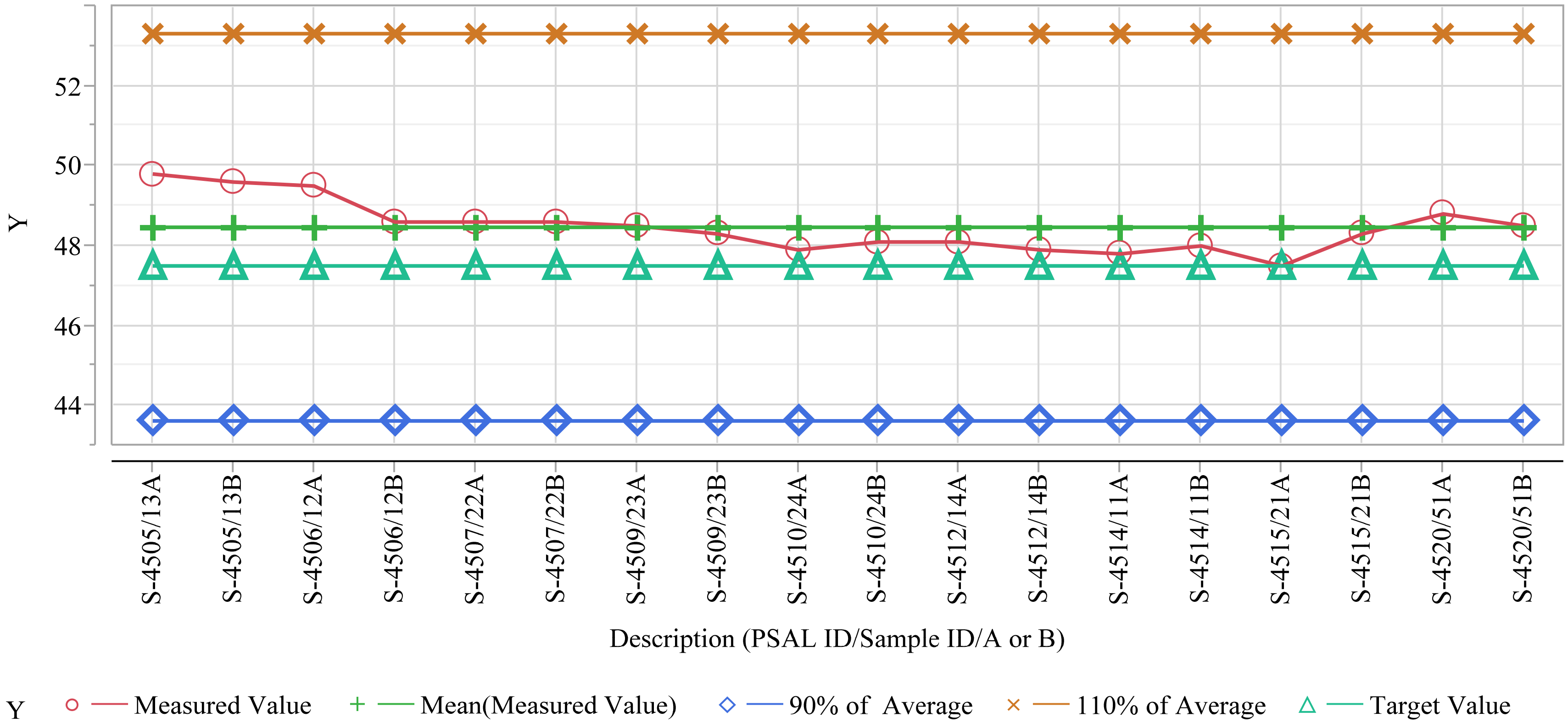
Overlay Plot Test=HLW HB (a), Type=slurry, Analyte=Li2O, Unit of Measure=wt%



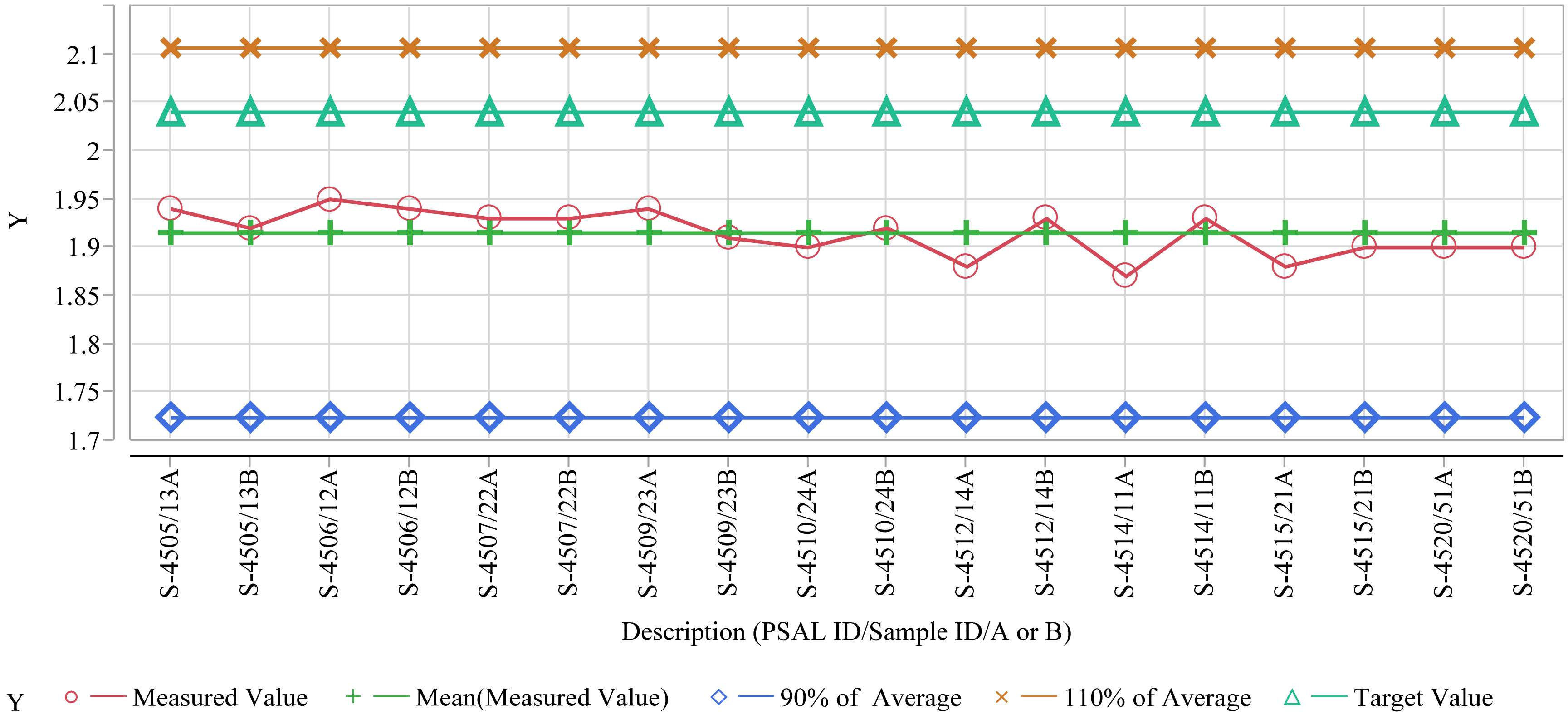
Overlay Plot Test=HLW HB (a), Type=slurry, Analyte=Na2O, Unit of Measure=wt%



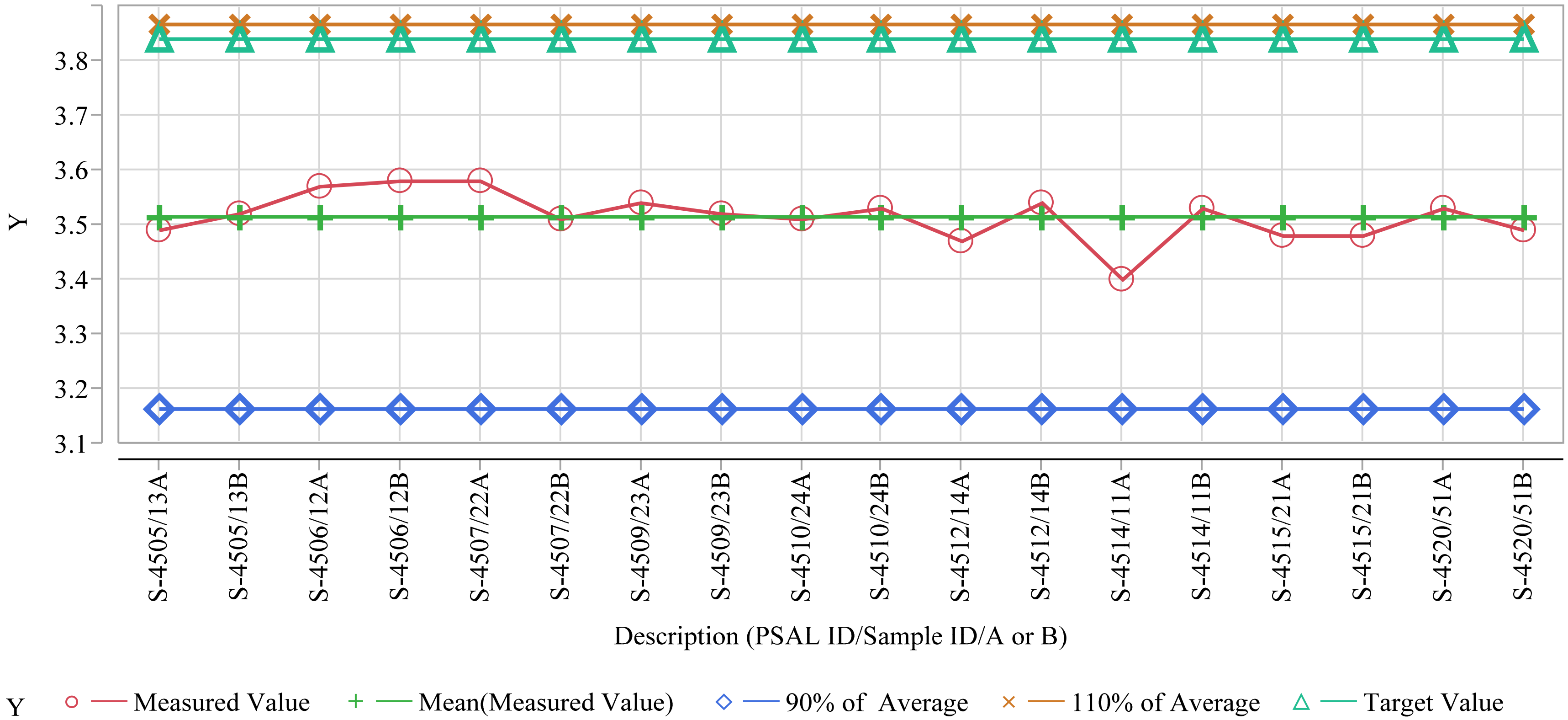
Overlay Plot Test=HLW HB (a), Type=slurry, Analyte=SiO2, Unit of Measure=wt%



Overlay Plot Test=HLW HB (a), Type=slurry, Analyte=ZnO, Unit of Measure=wt%



Overlay Plot Test=HLW HB (a), Type=slurry, Analyte=ZrO2, Unit of Measure=wt%



Overlay Plot Test=HLW HB (b), Type=glass, Analyte=Al2O3, Unit of Measure=wt%

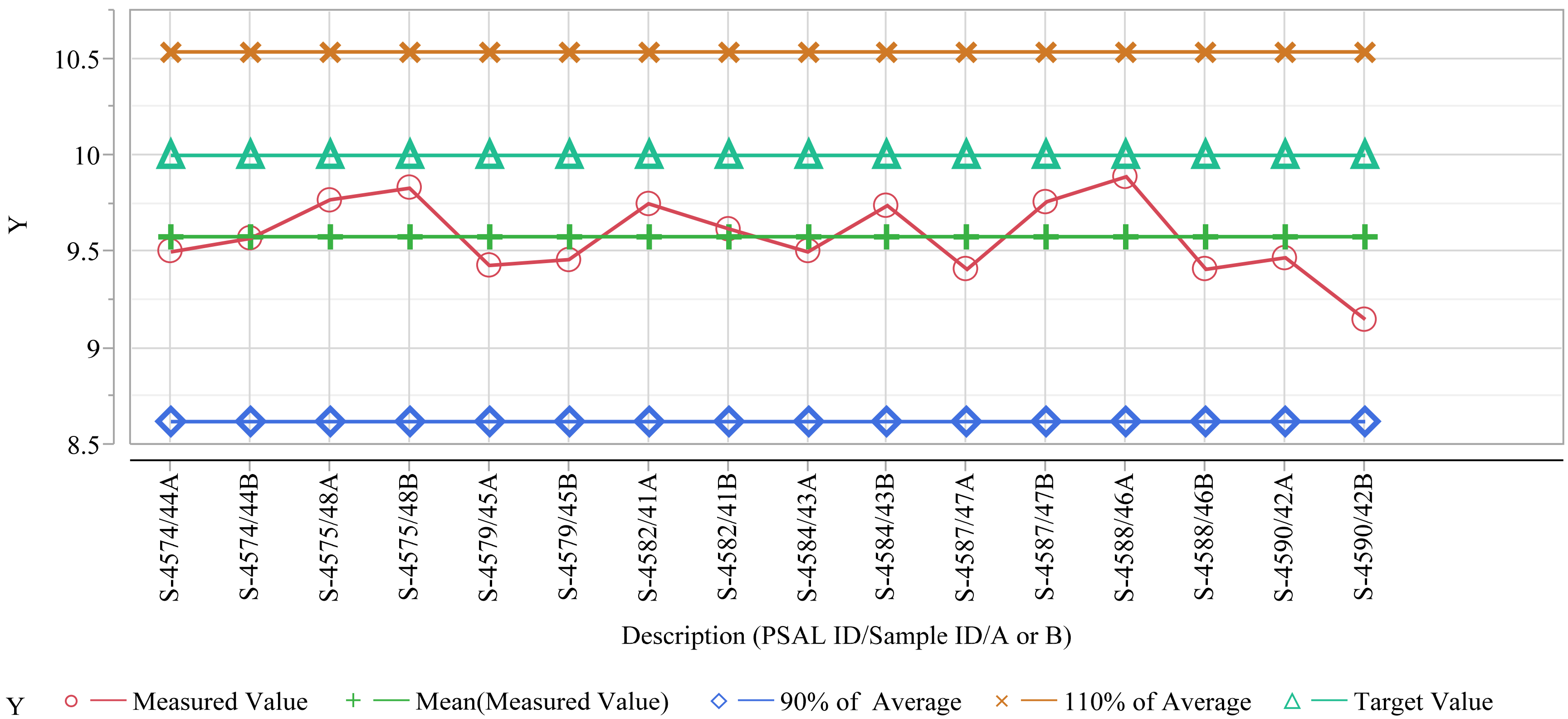
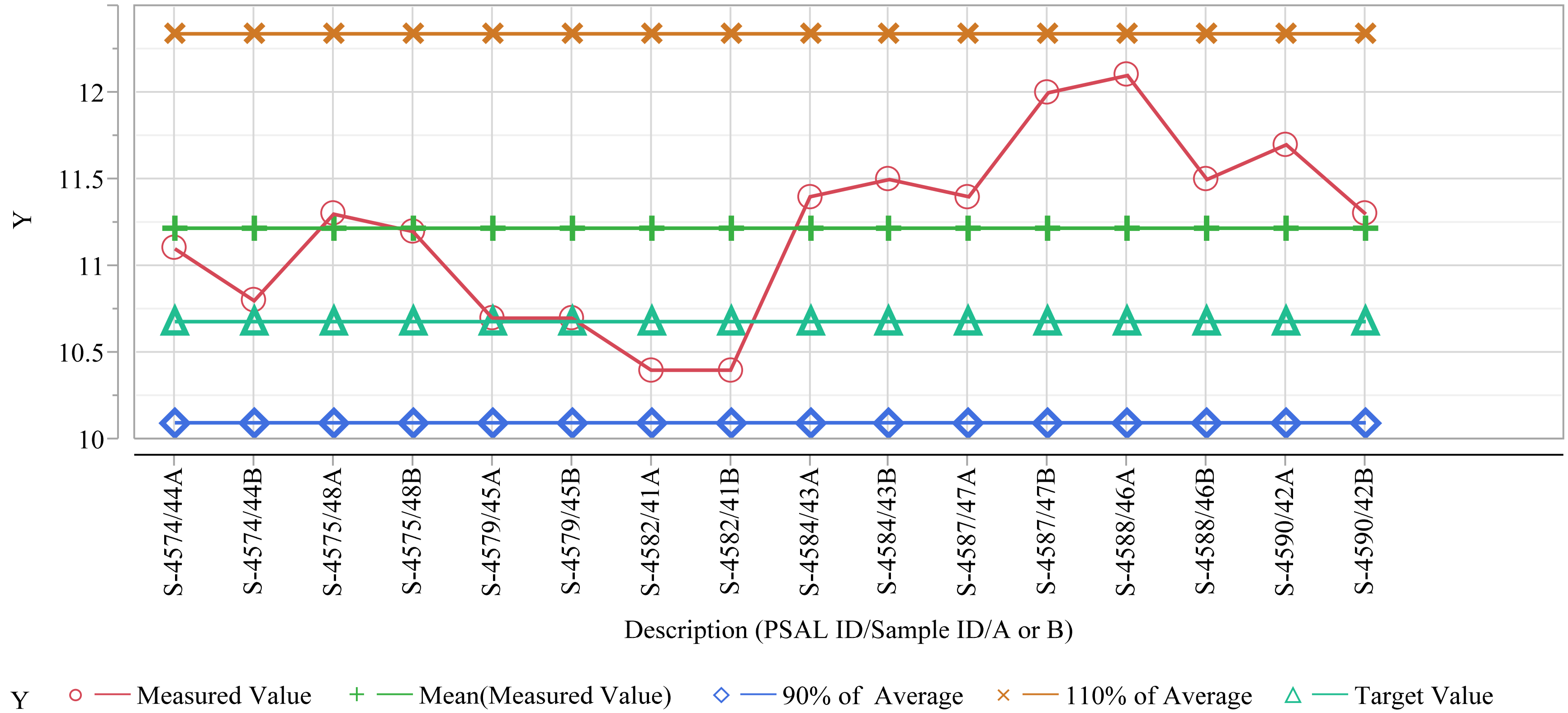
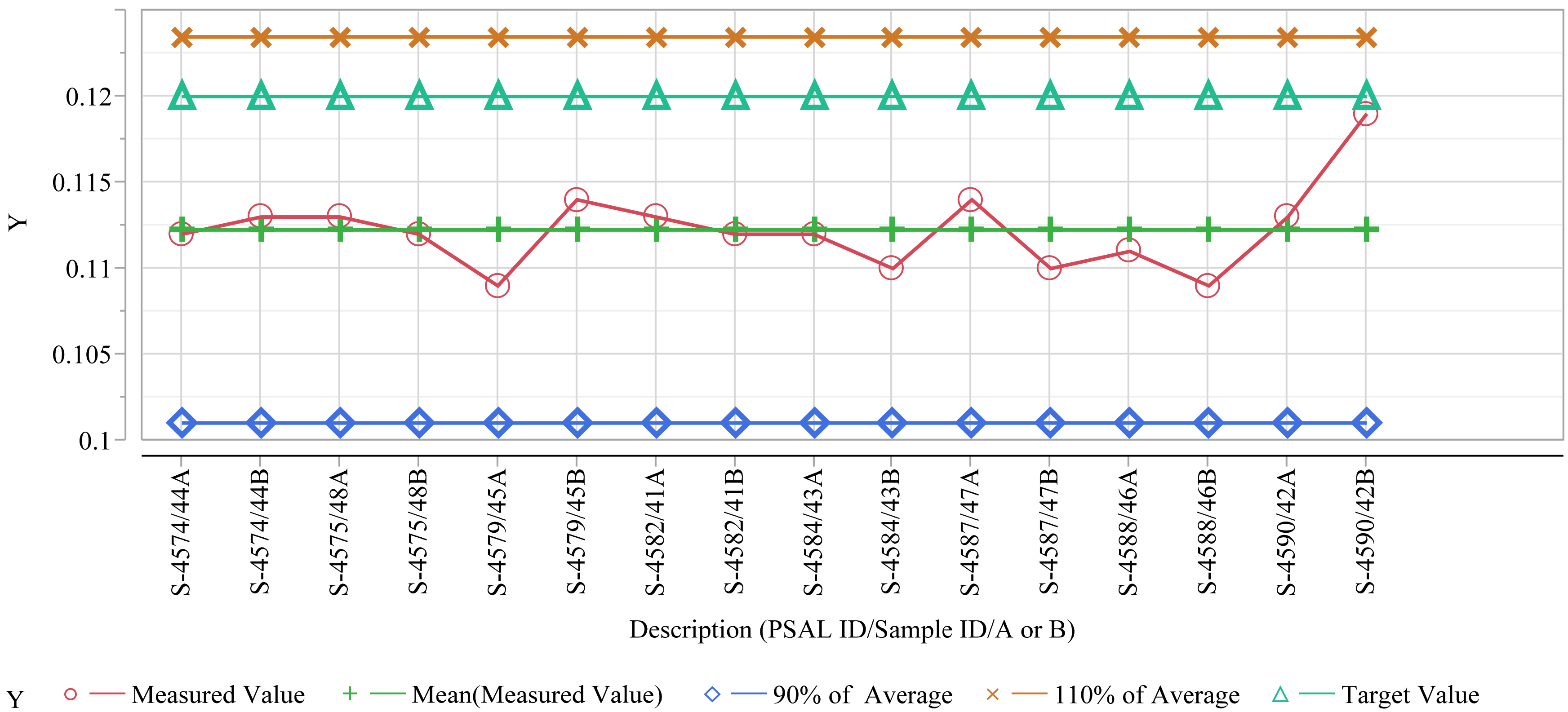


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

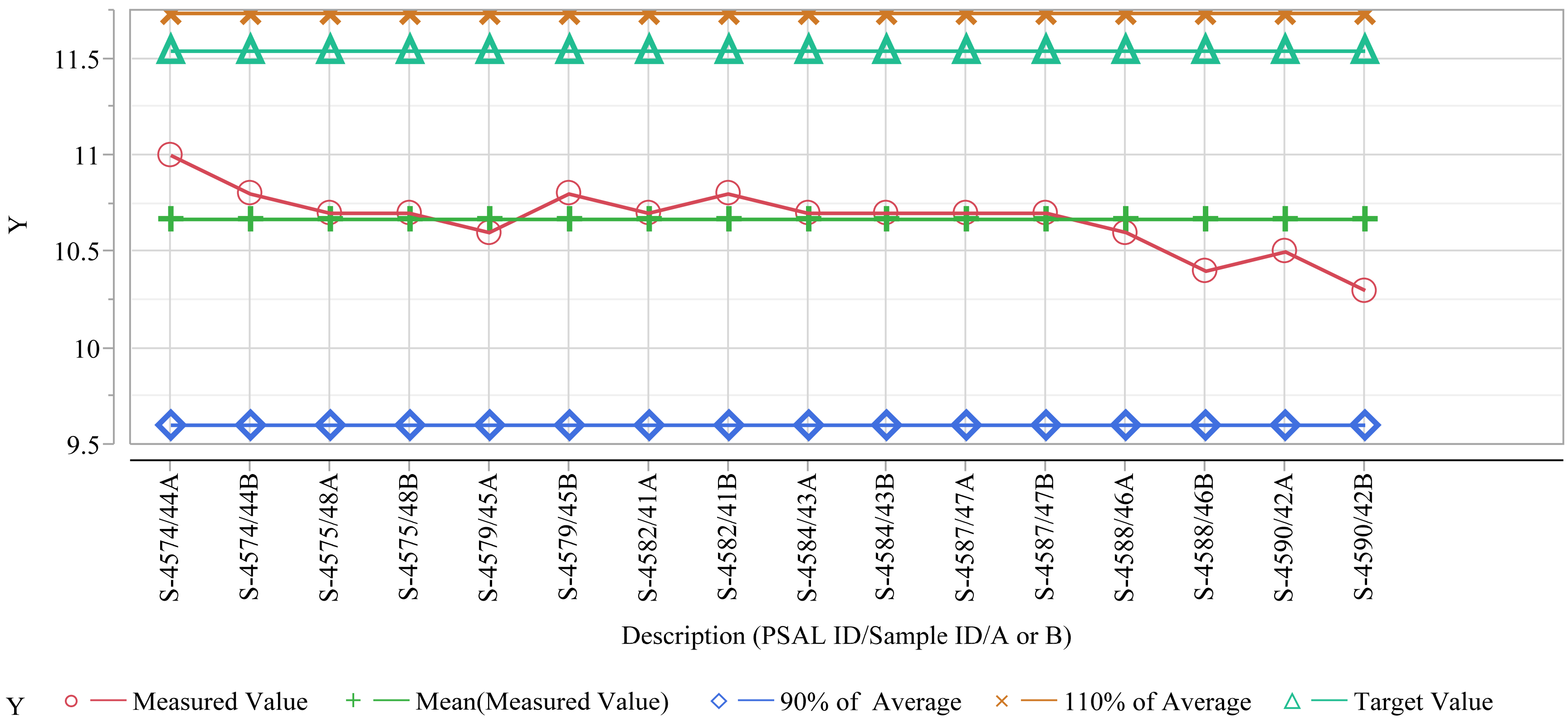
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=B2O3, Unit of Measure=wt%



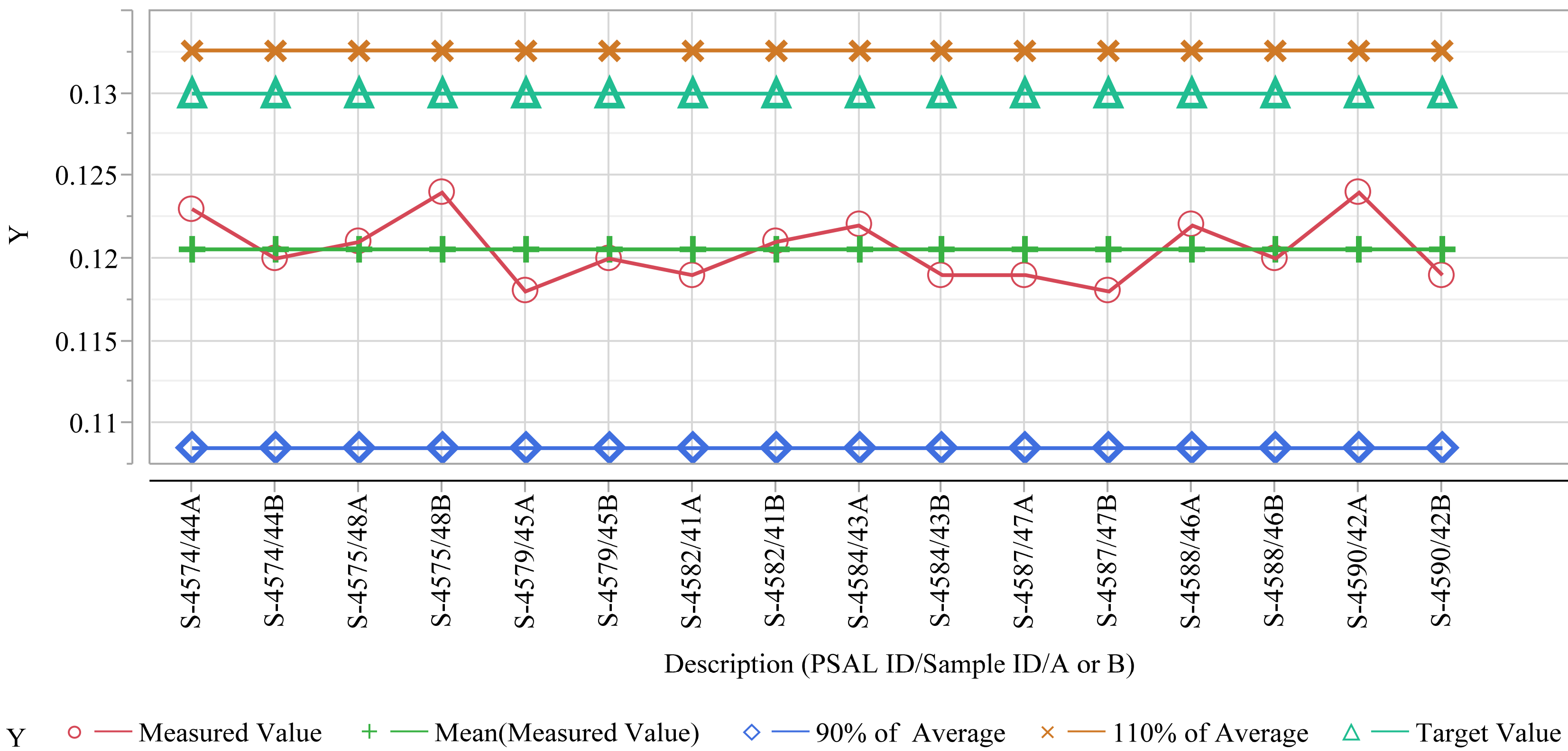
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=CaO, Unit of Measure=wt%



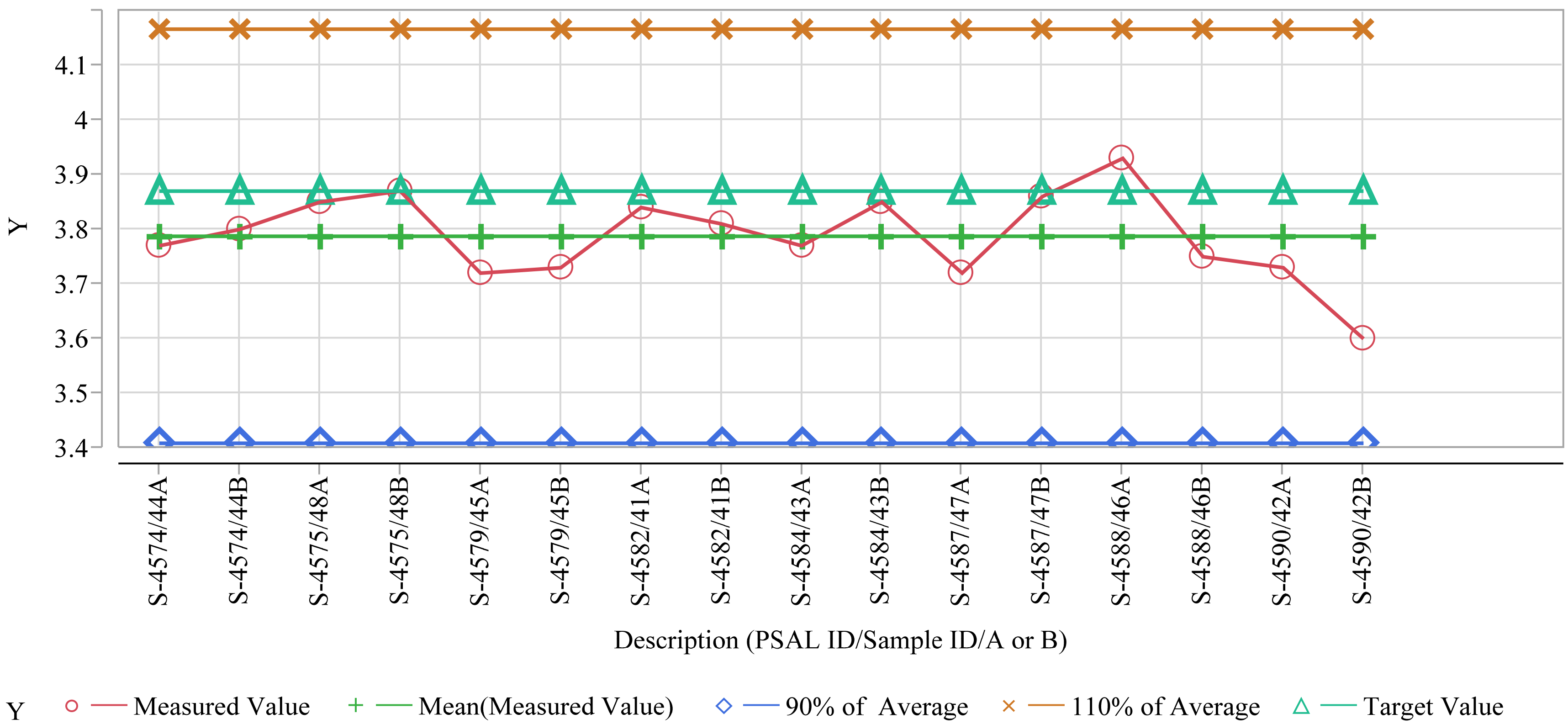
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=Fe2O3, Unit of Measure=wt%



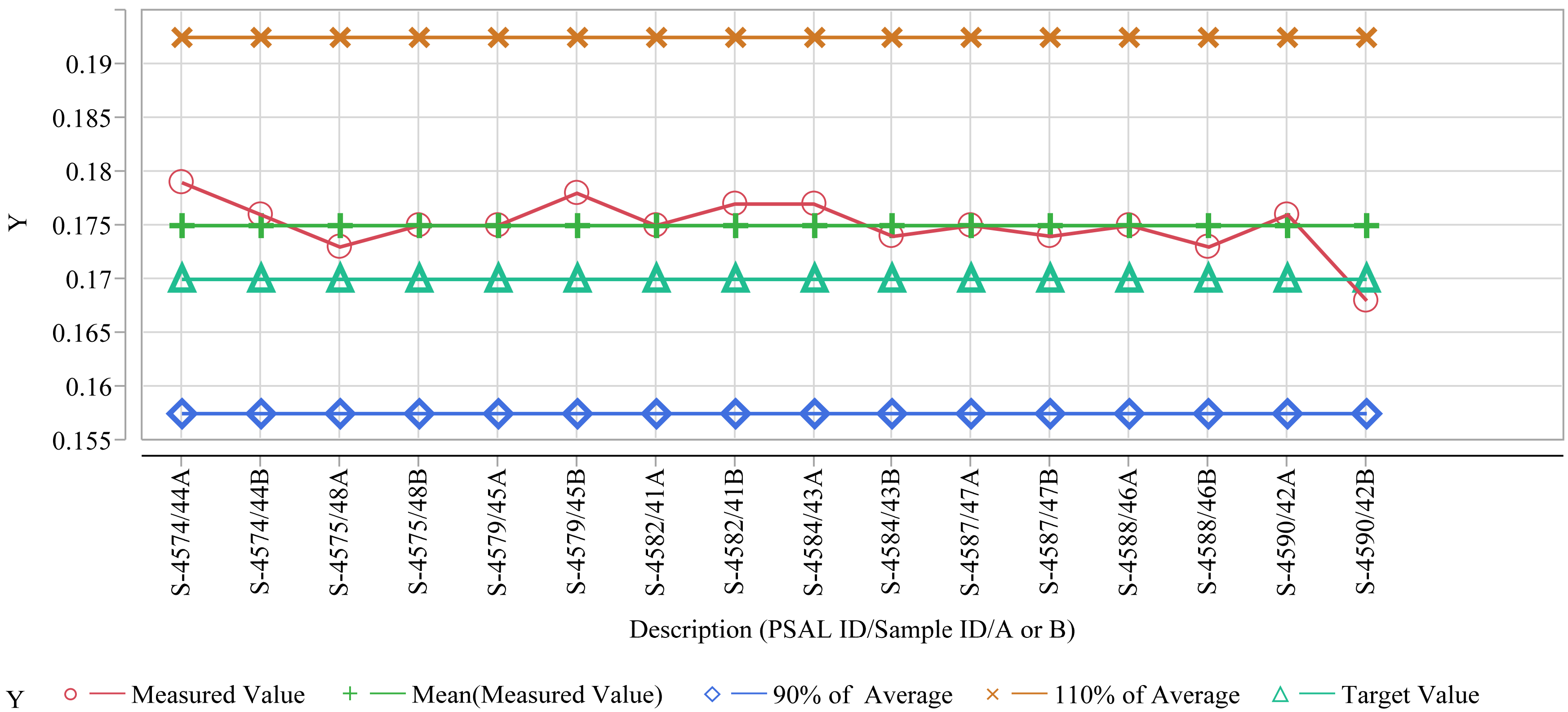
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=K2O, Unit of Measure=wt%



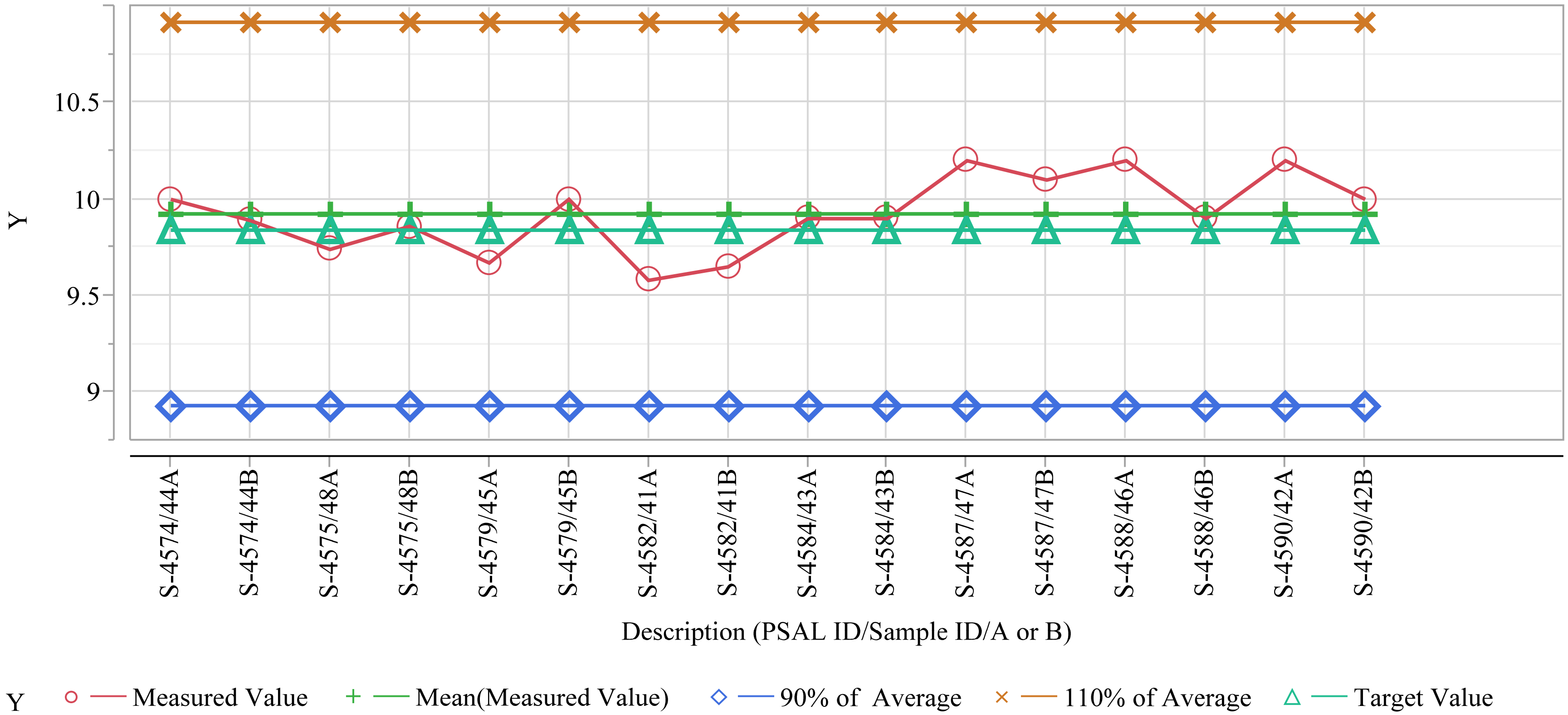
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=Li2O, Unit of Measure=wt%



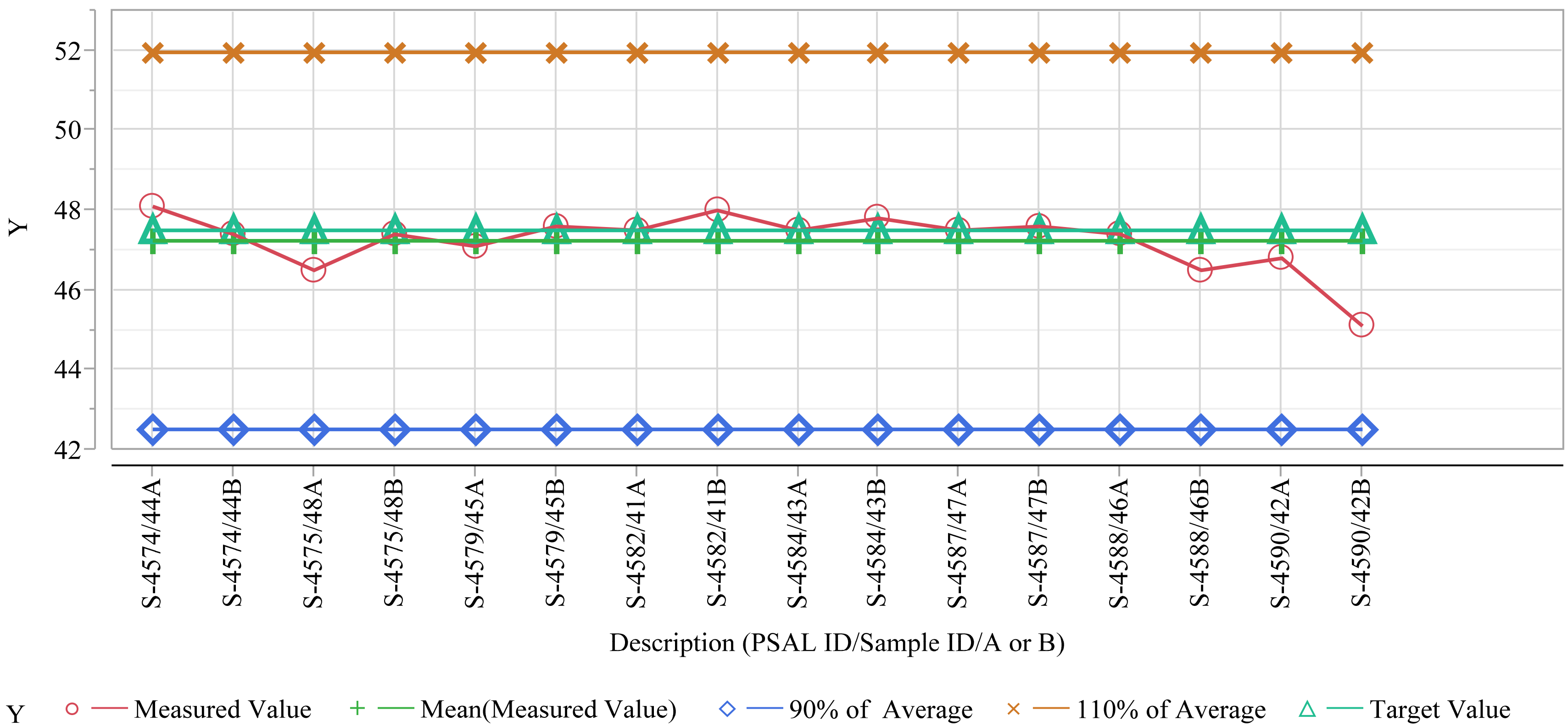
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=MgO, Unit of Measure=wt%



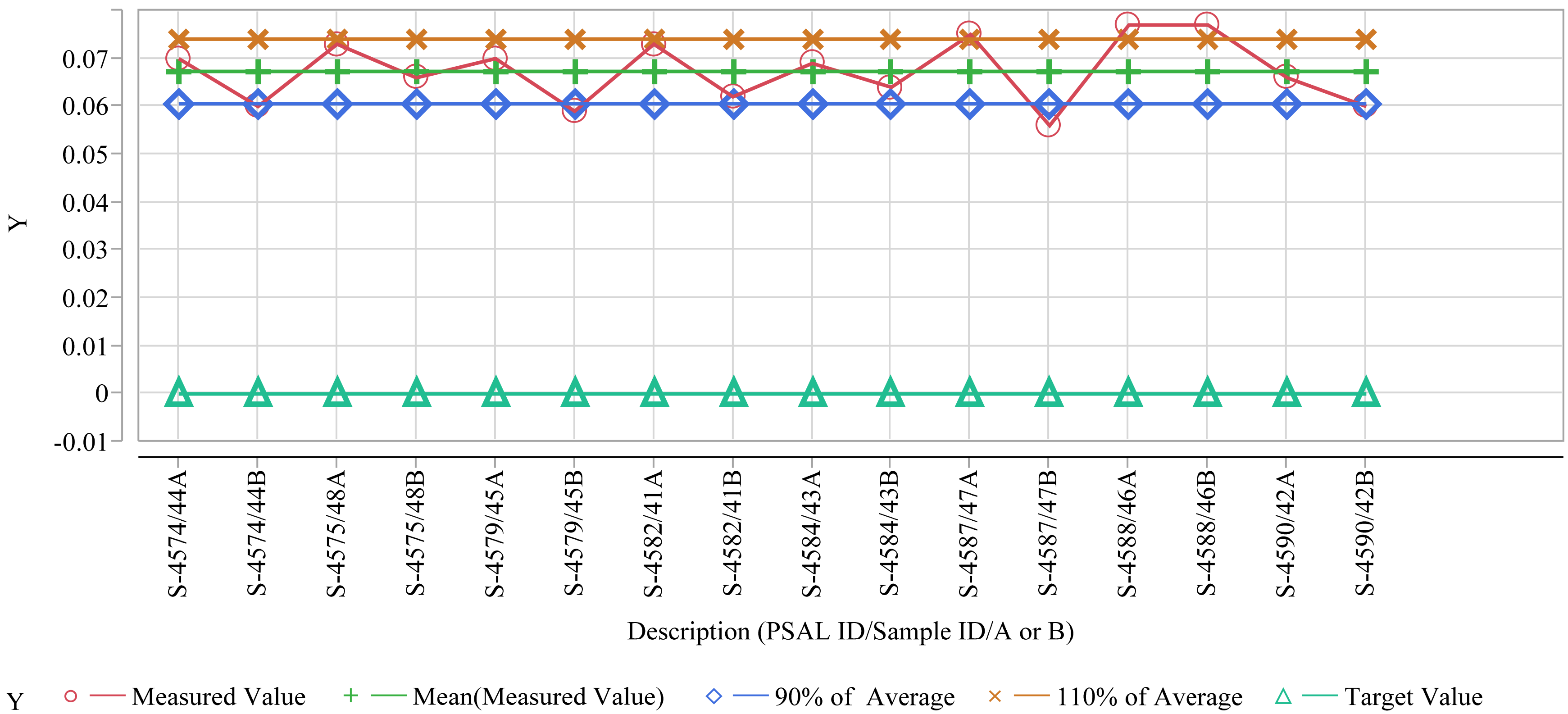
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=Na2O, Unit of Measure=wt%



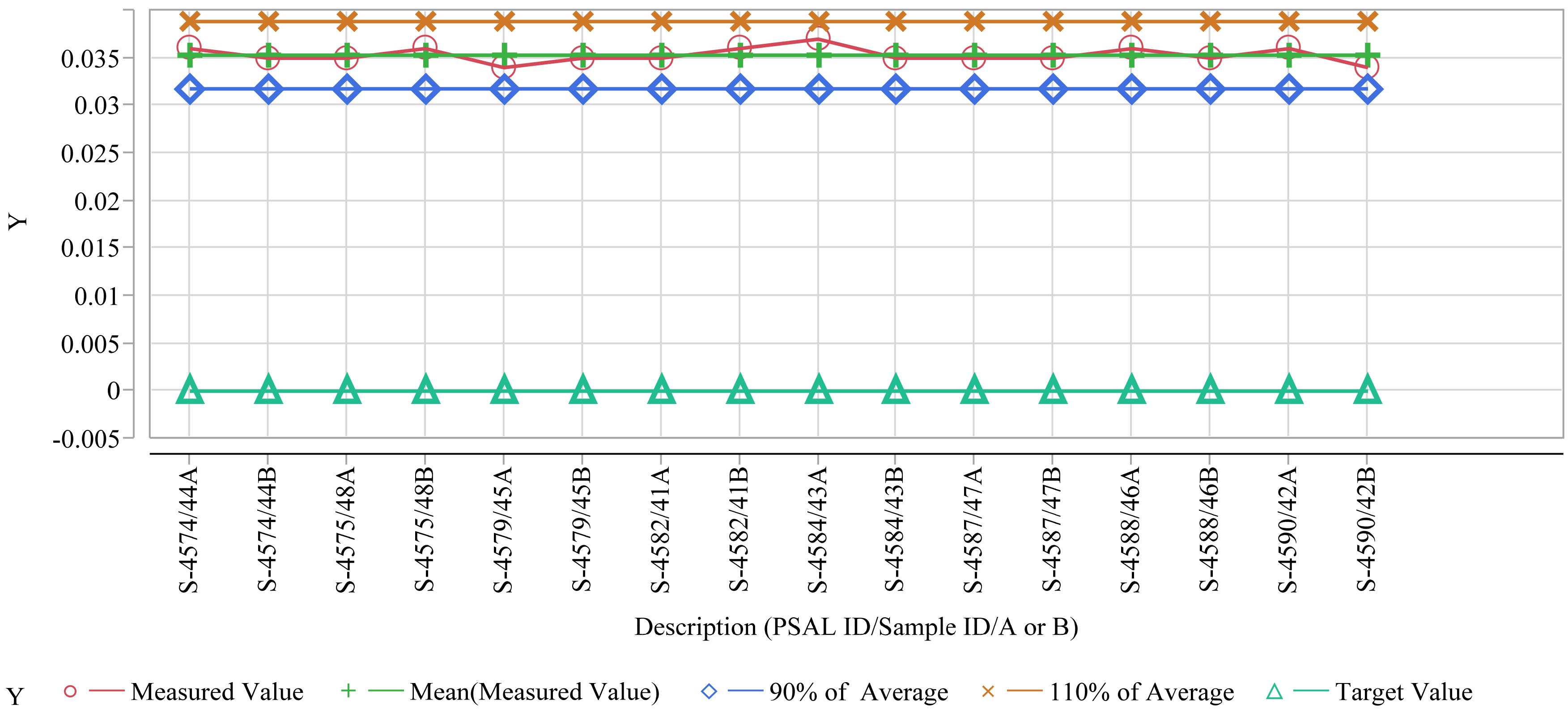
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=SiO2, Unit of Measure=wt%



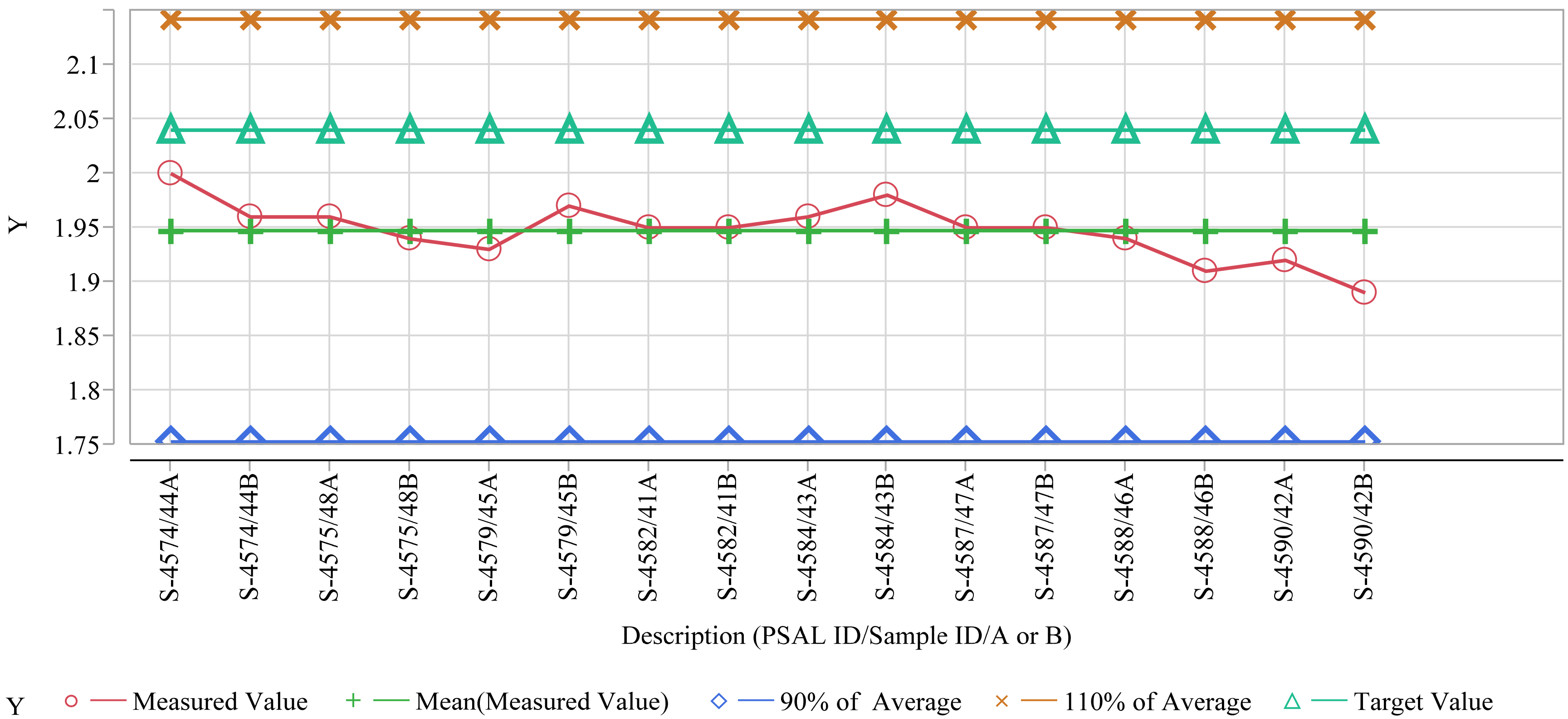
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=SO4, Unit of Measure=wt%



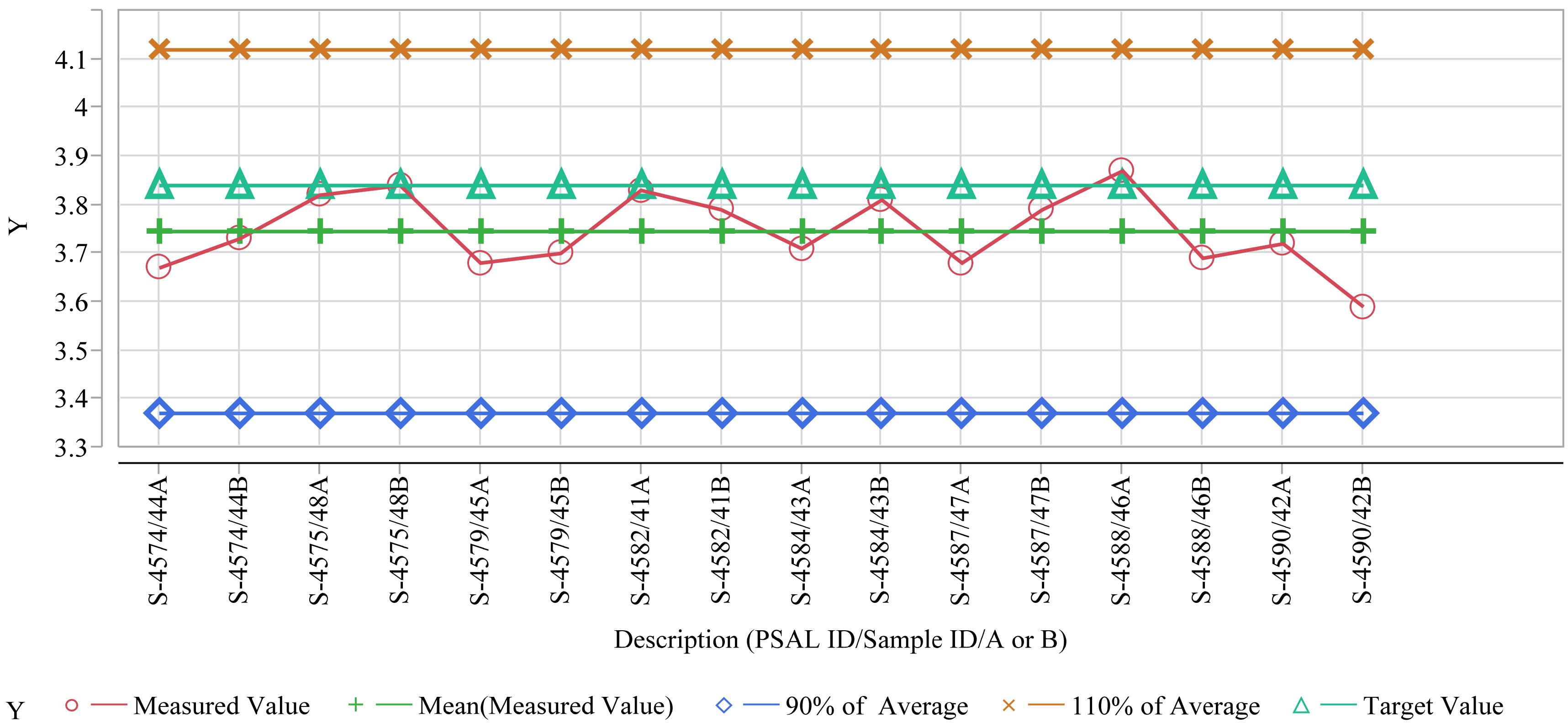
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=TiO2, Unit of Measure=wt%



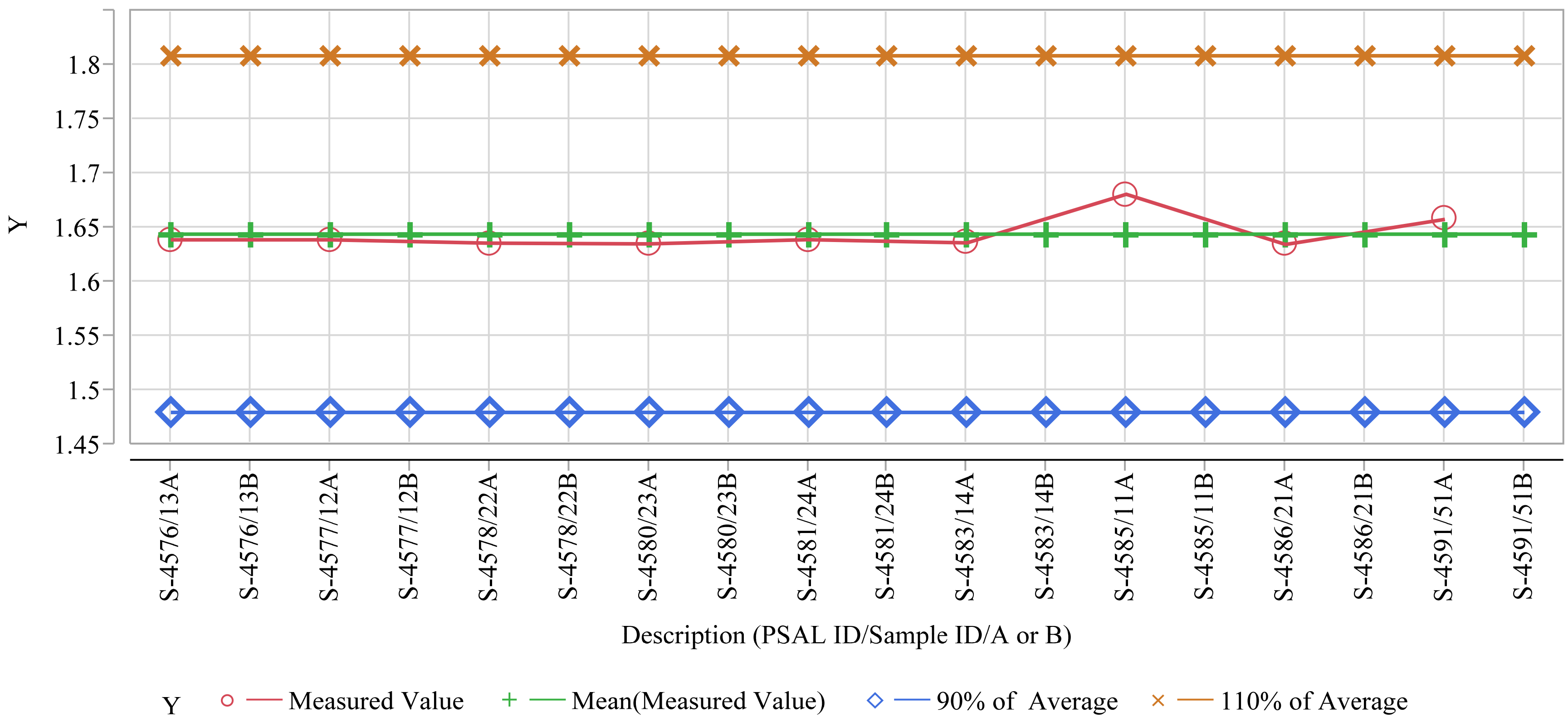
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=ZnO, Unit of Measure=wt%



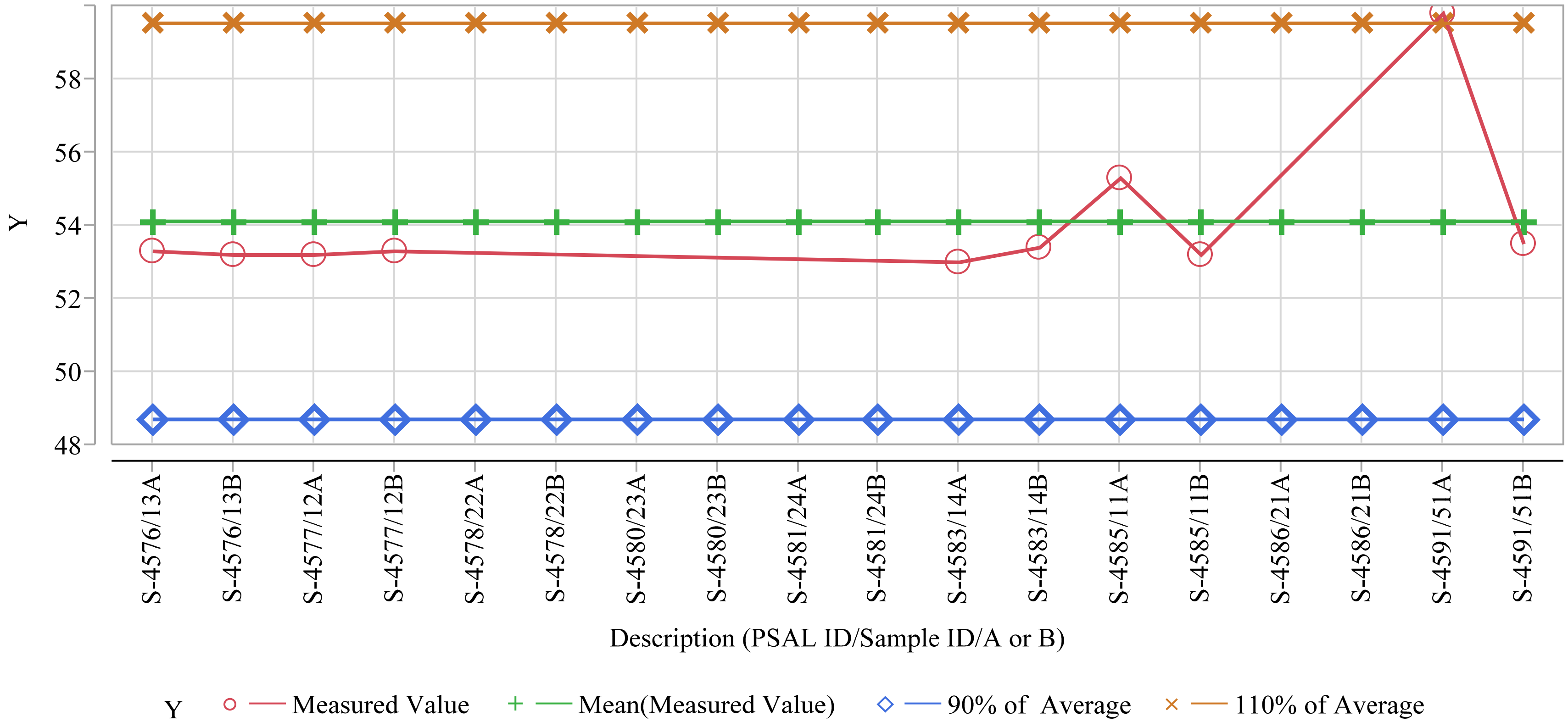
Overlay Plot Test=HLW HB (b), Type=glass, Analyte=ZrO2, Unit of Measure=wt%



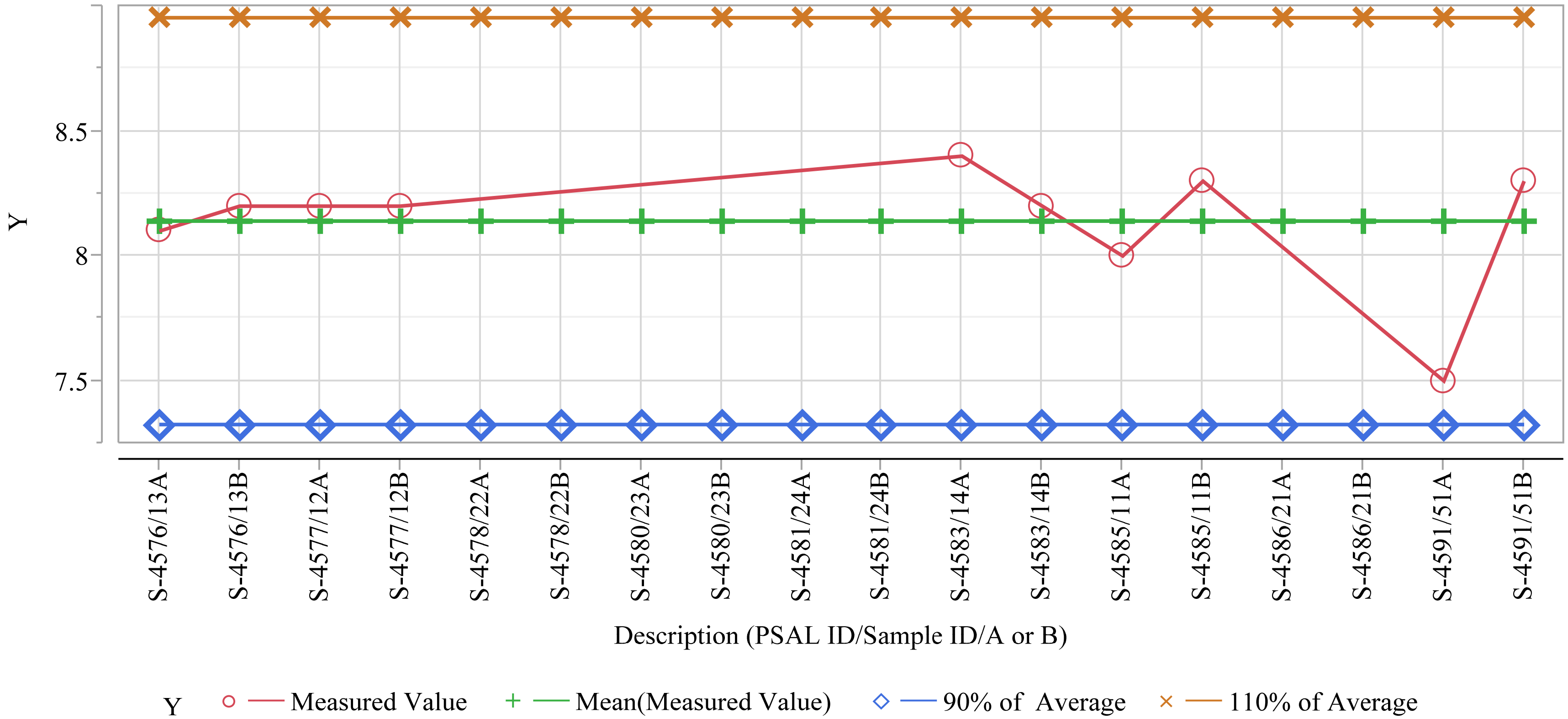
Overlay Plot Test=HLW HB (b), Type=physical property, Analyte=Density, Unit of Measure=g/mL



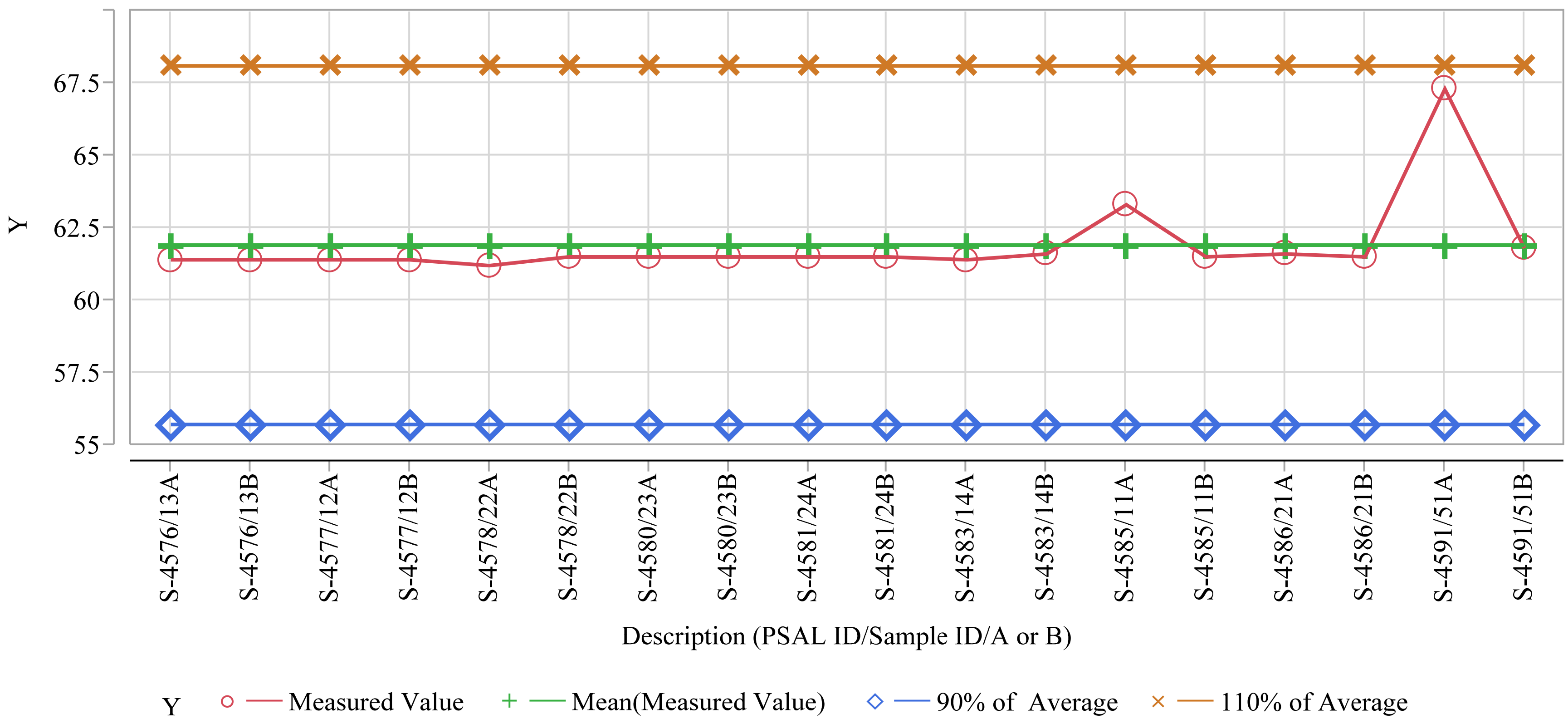
Overlay Plot Test=HLW HB (b), Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%



Overlay Plot Test=HLW HB (b), Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%



Overlay Plot Test=HLW HB (b), Type=physical property, Analyte=Total Solids, Unit of Measure=wt%



Overlay Plot Test=HLW HB (b), Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%

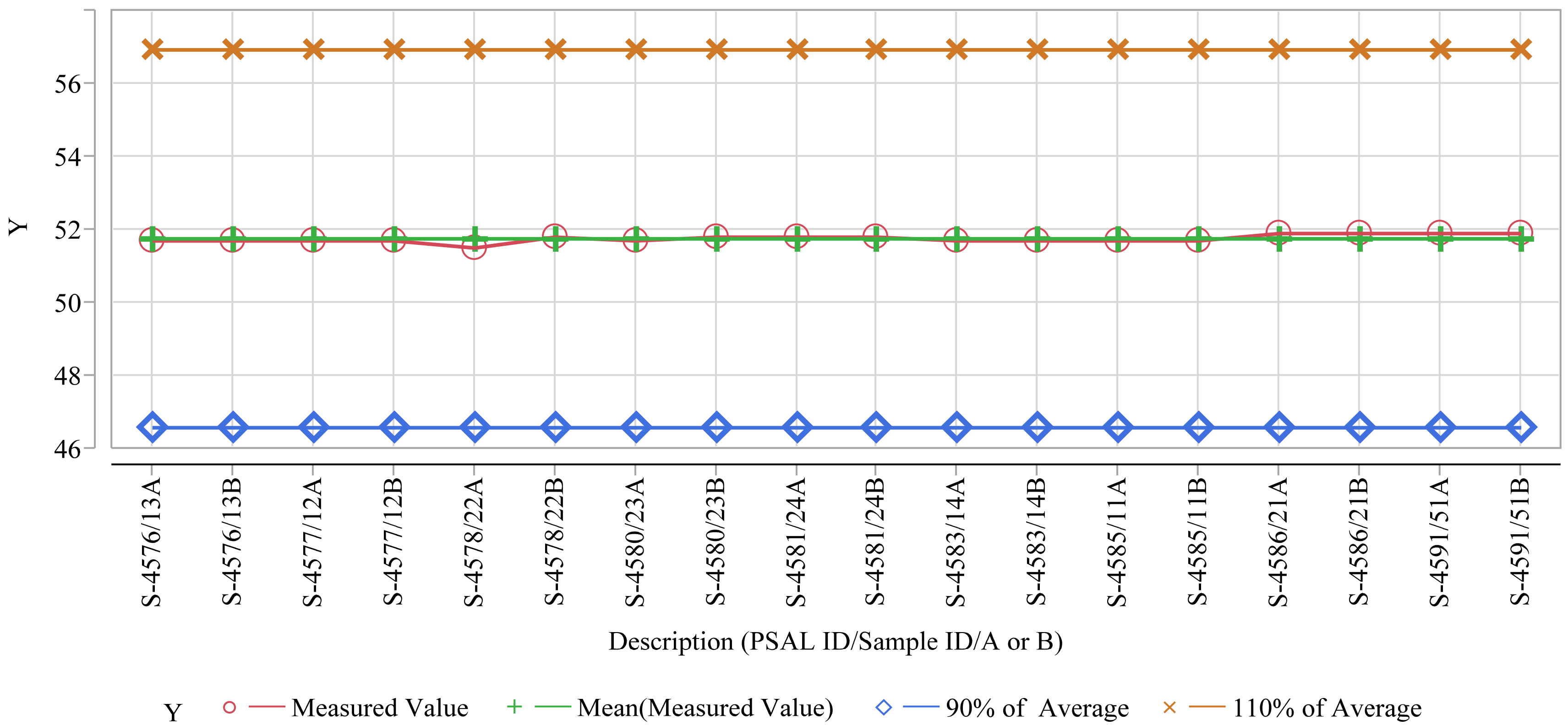


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

Overlay Plot Test=HLW HB (b), Type=slurry, Analyte=Al2O3, Unit of Measure=wt%

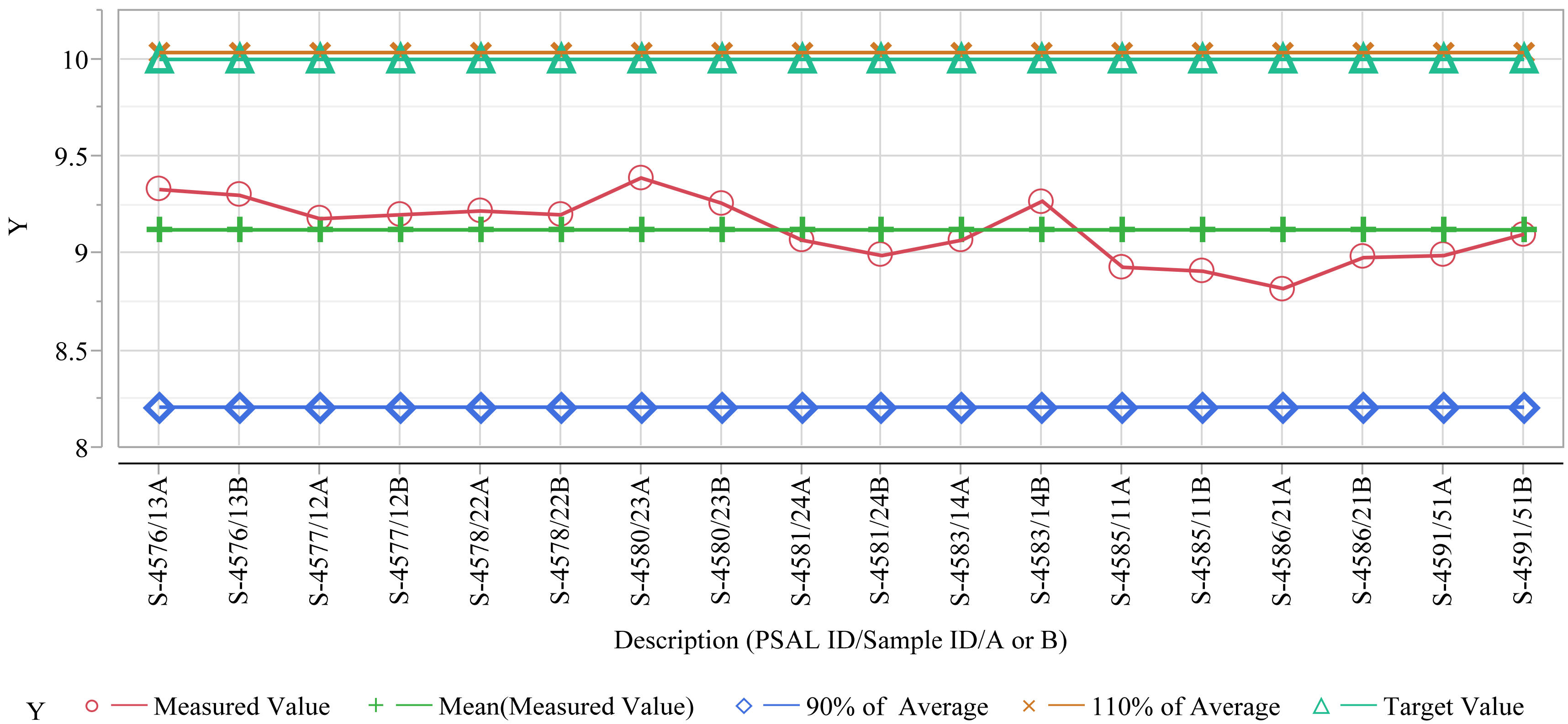
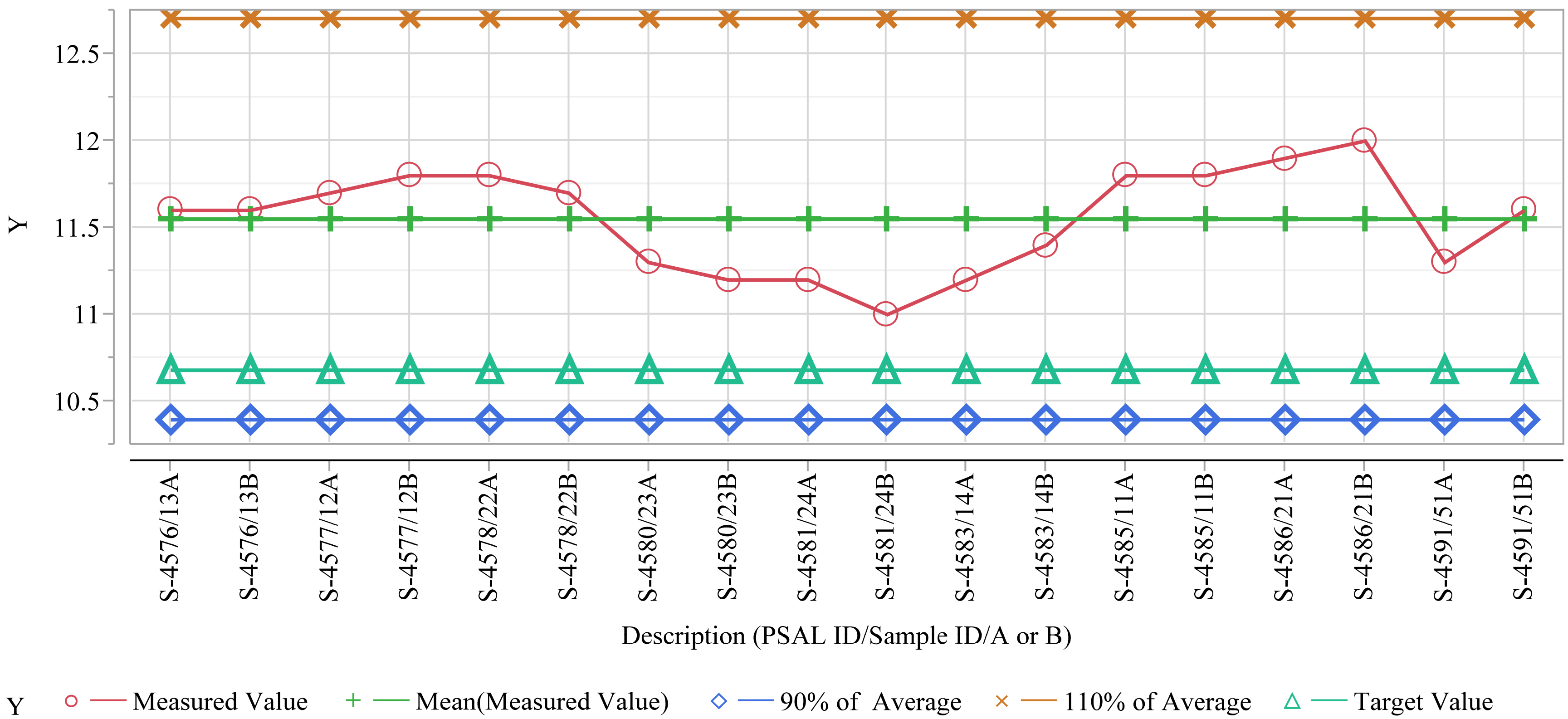
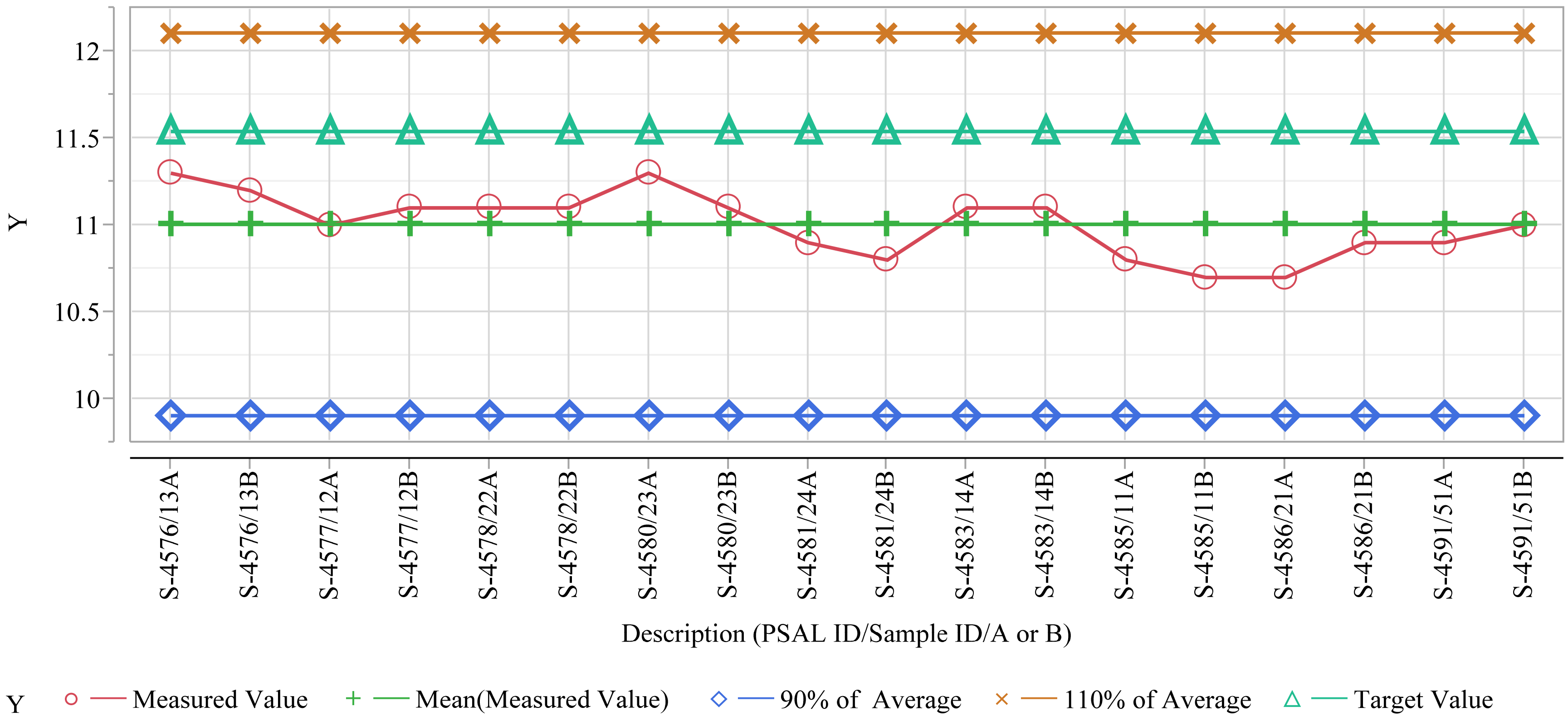


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

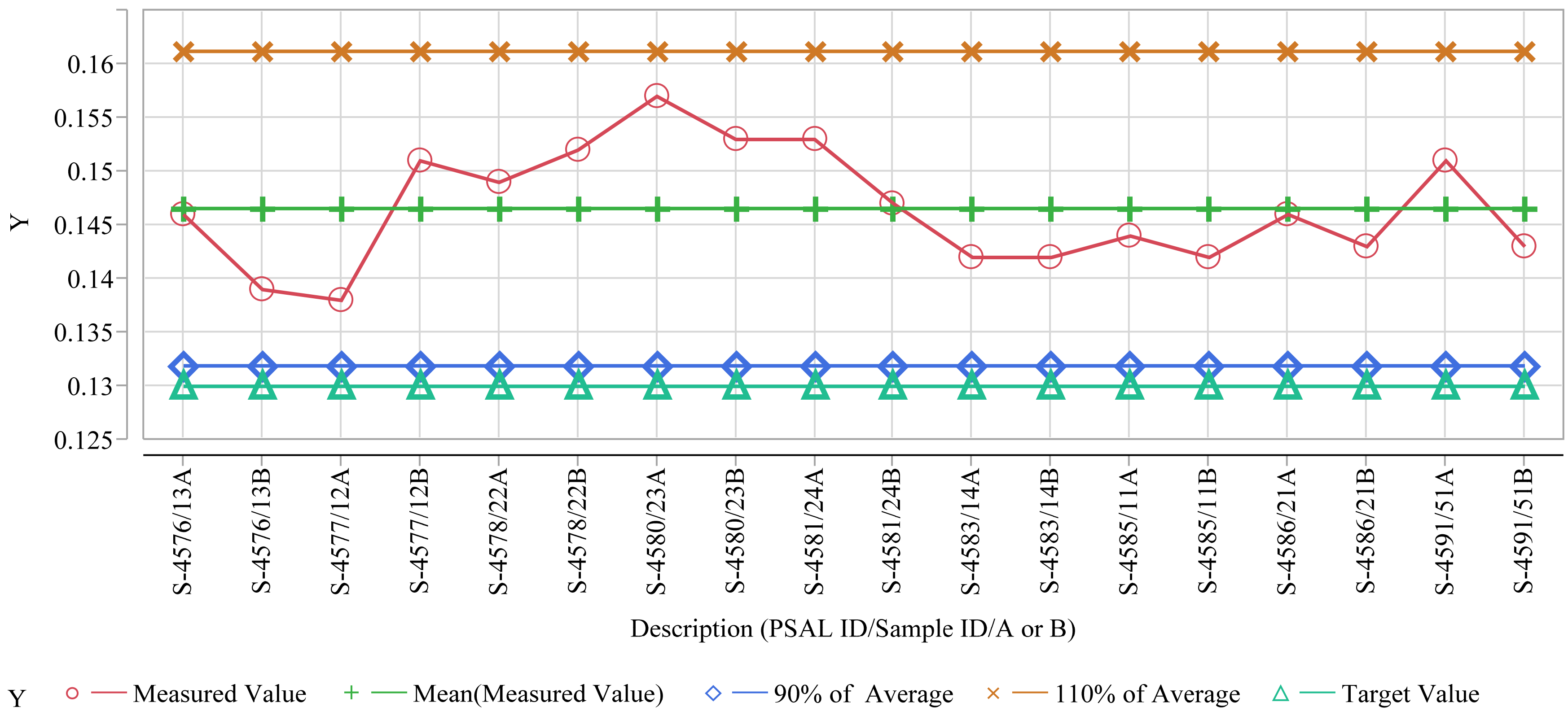
Overlay Plot Test=HLW HB (b), Type=slurry, Analyte=B2O3, Unit of Measure=wt%



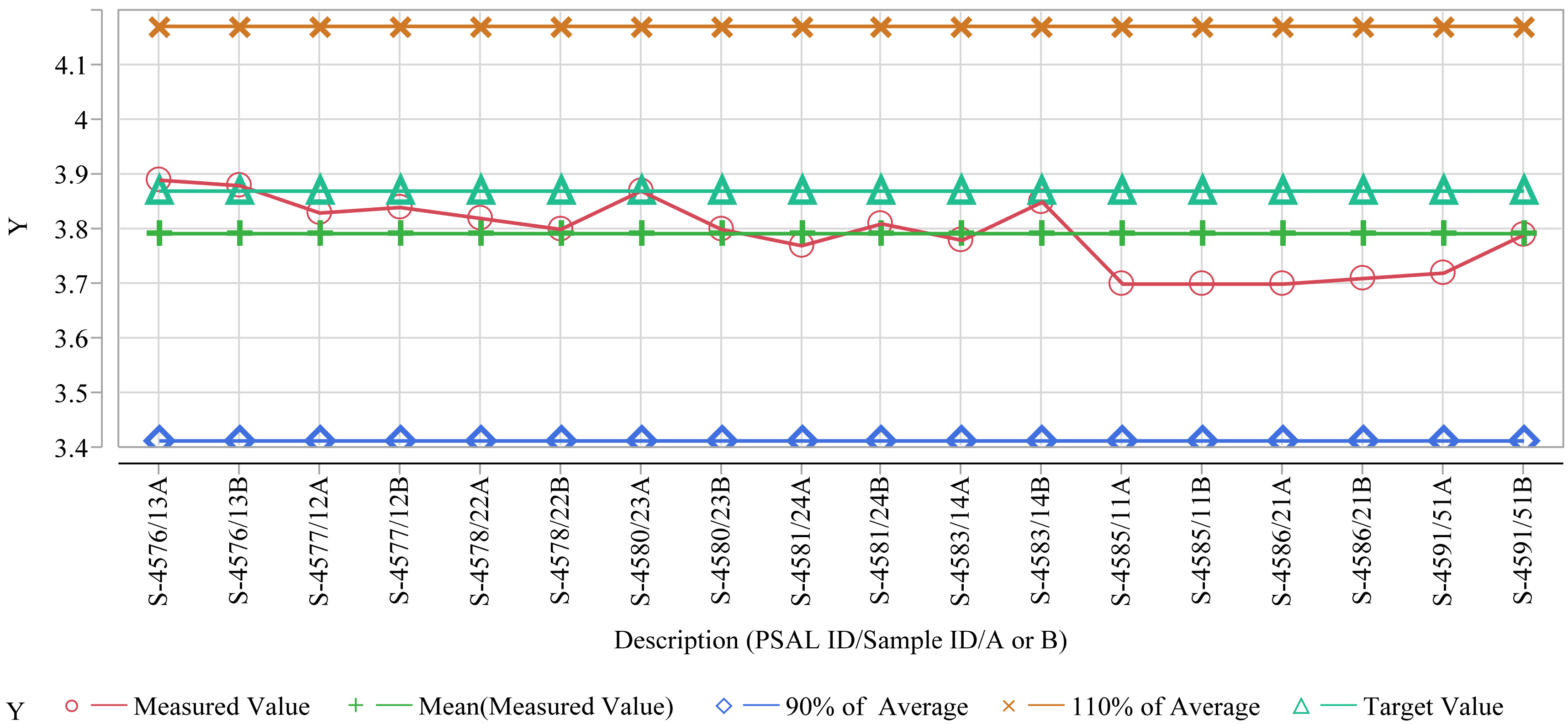
Overlay Plot Test=HLW HB (b), Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%



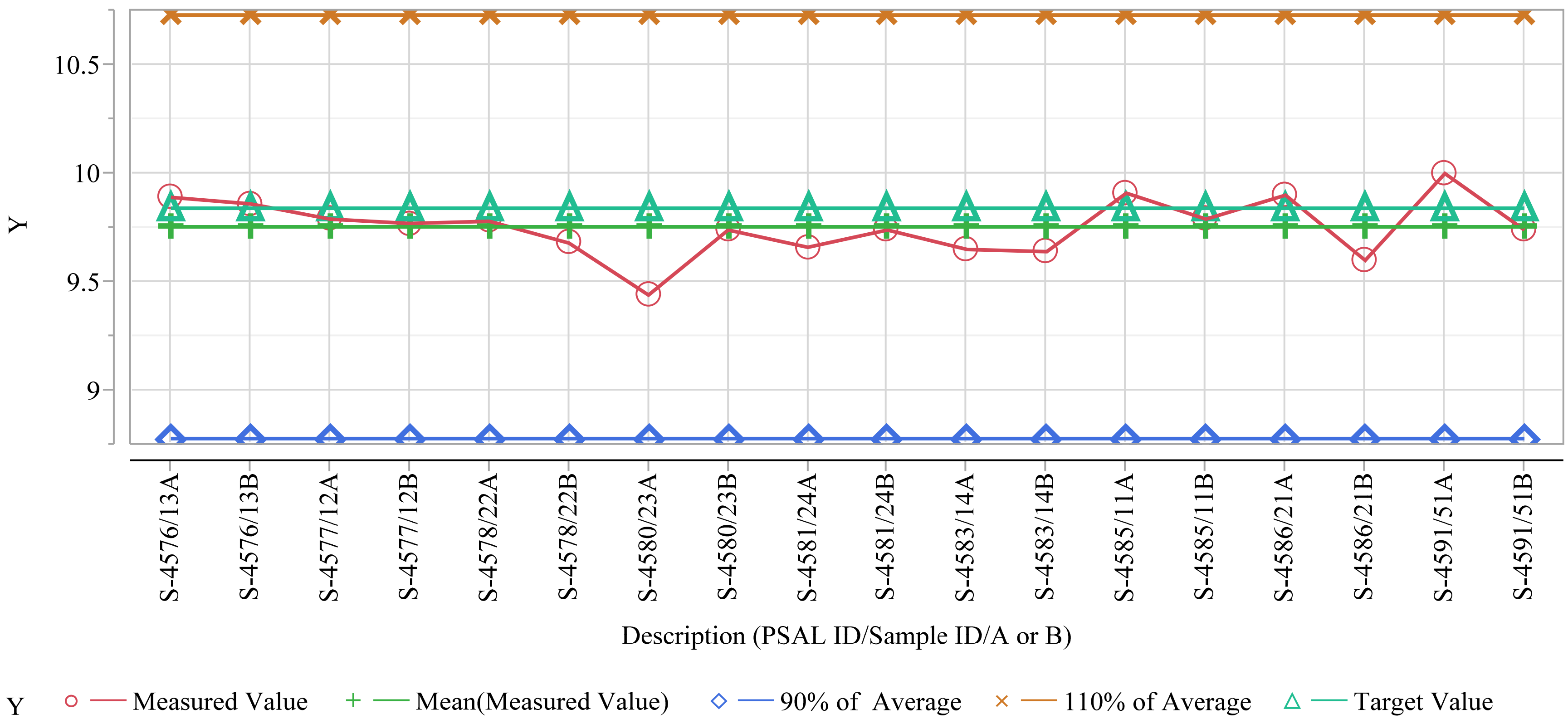
Overlay Plot Test=HLW HB (b), Type=slurry, Analyte=K2O, Unit of Measure=wt%



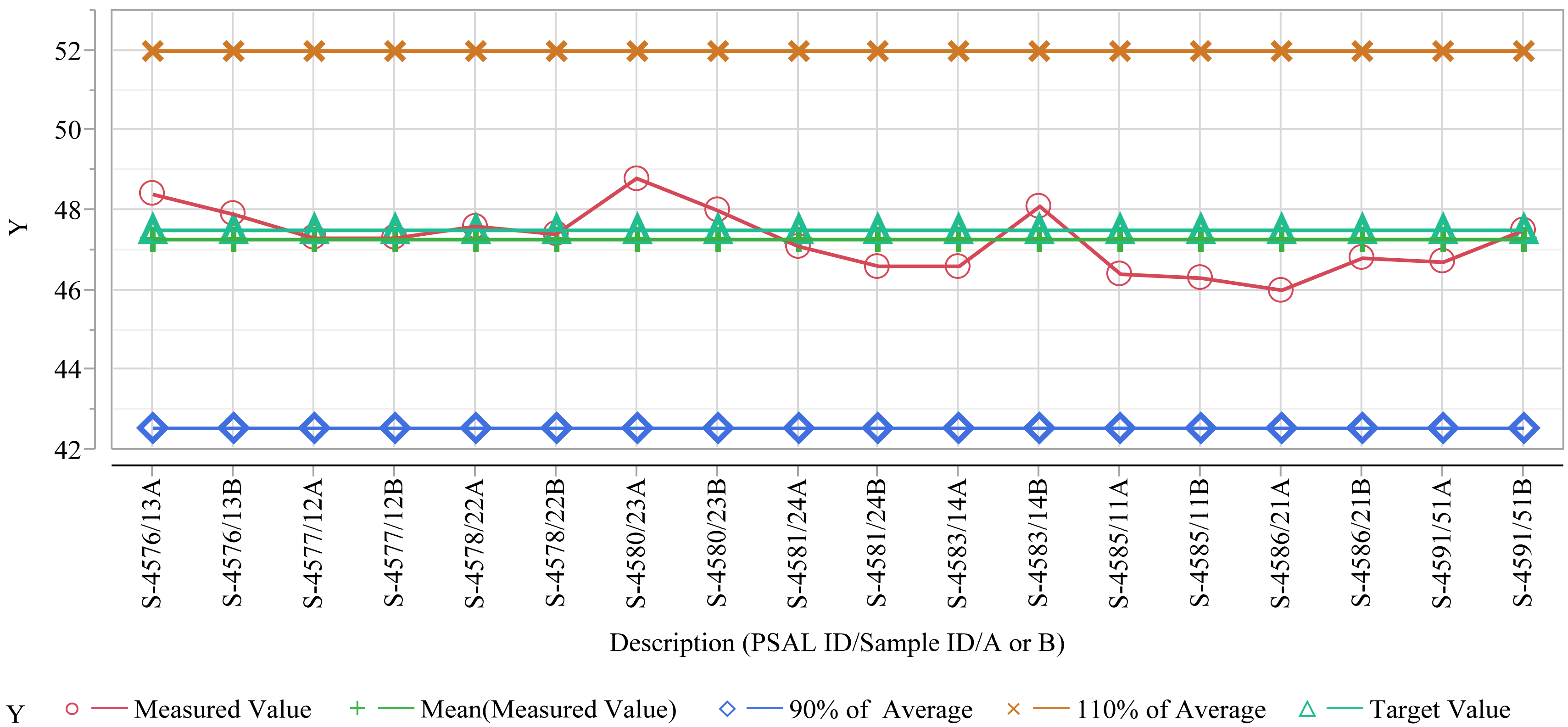
Overlay Plot Test=HLW HB (b), Type=slurry, Analyte=Li2O, Unit of Measure=wt%



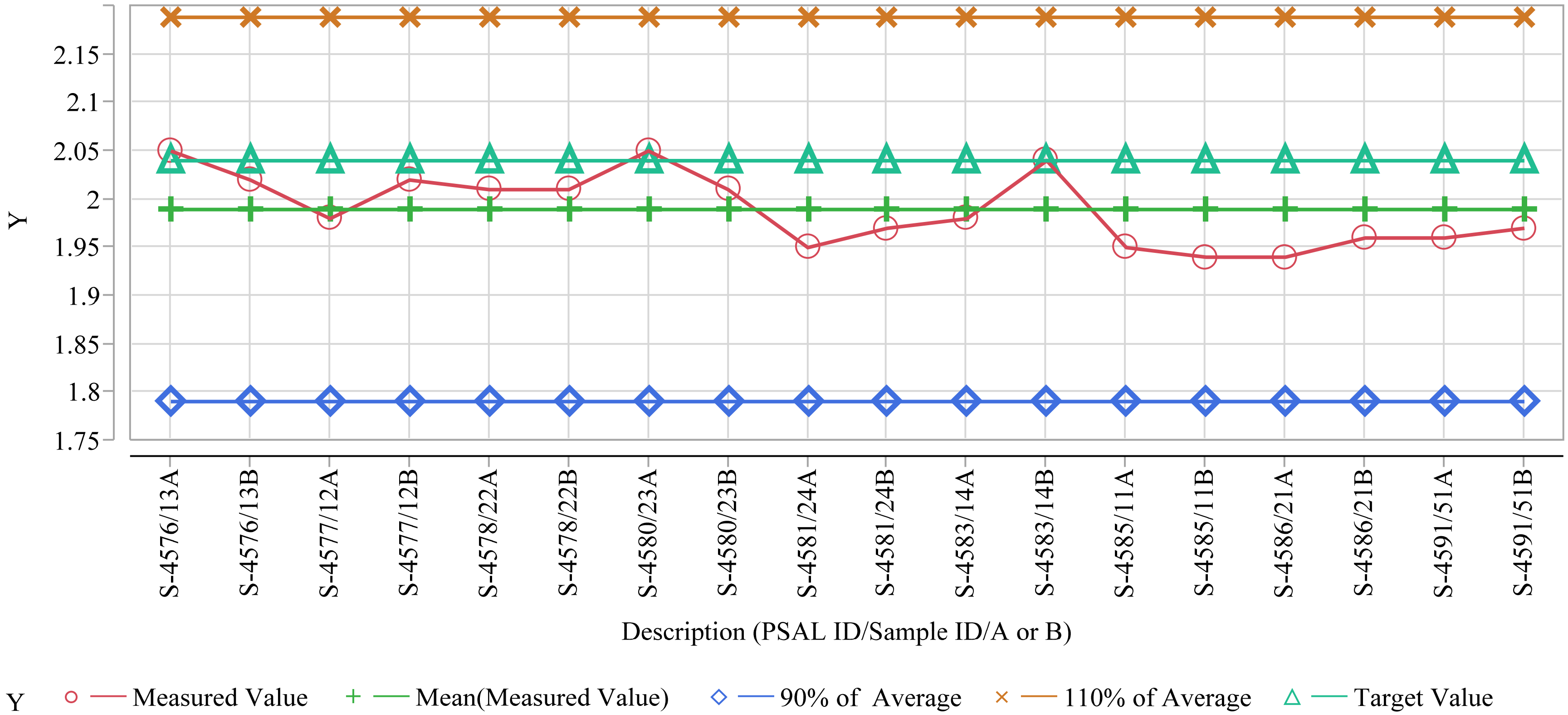
Overlay Plot Test=HLW HB (b), Type=slurry, Analyte=Na2O, Unit of Measure=wt%



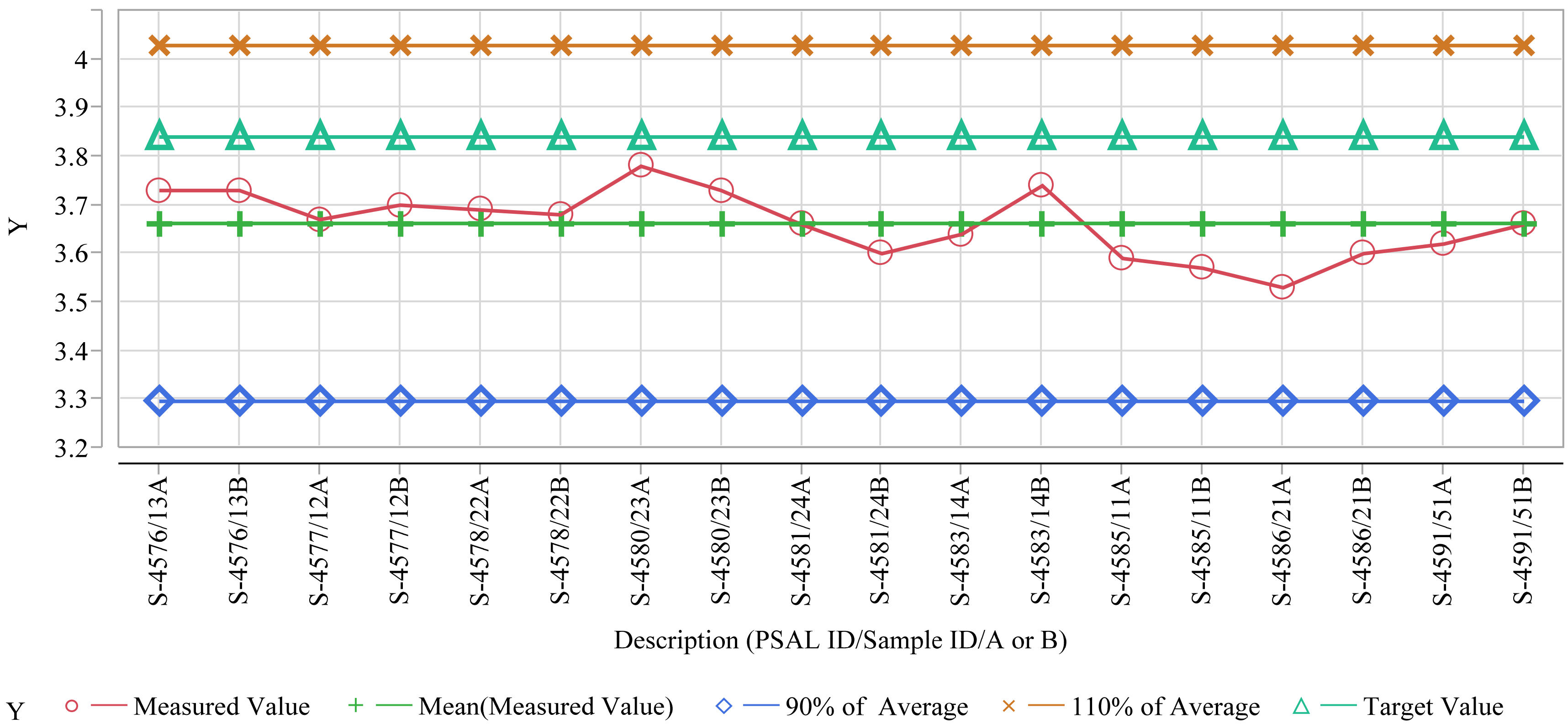
Overlay Plot Test=HLW HB (b), Type=slurry, Analyte=SiO2, Unit of Measure=wt%



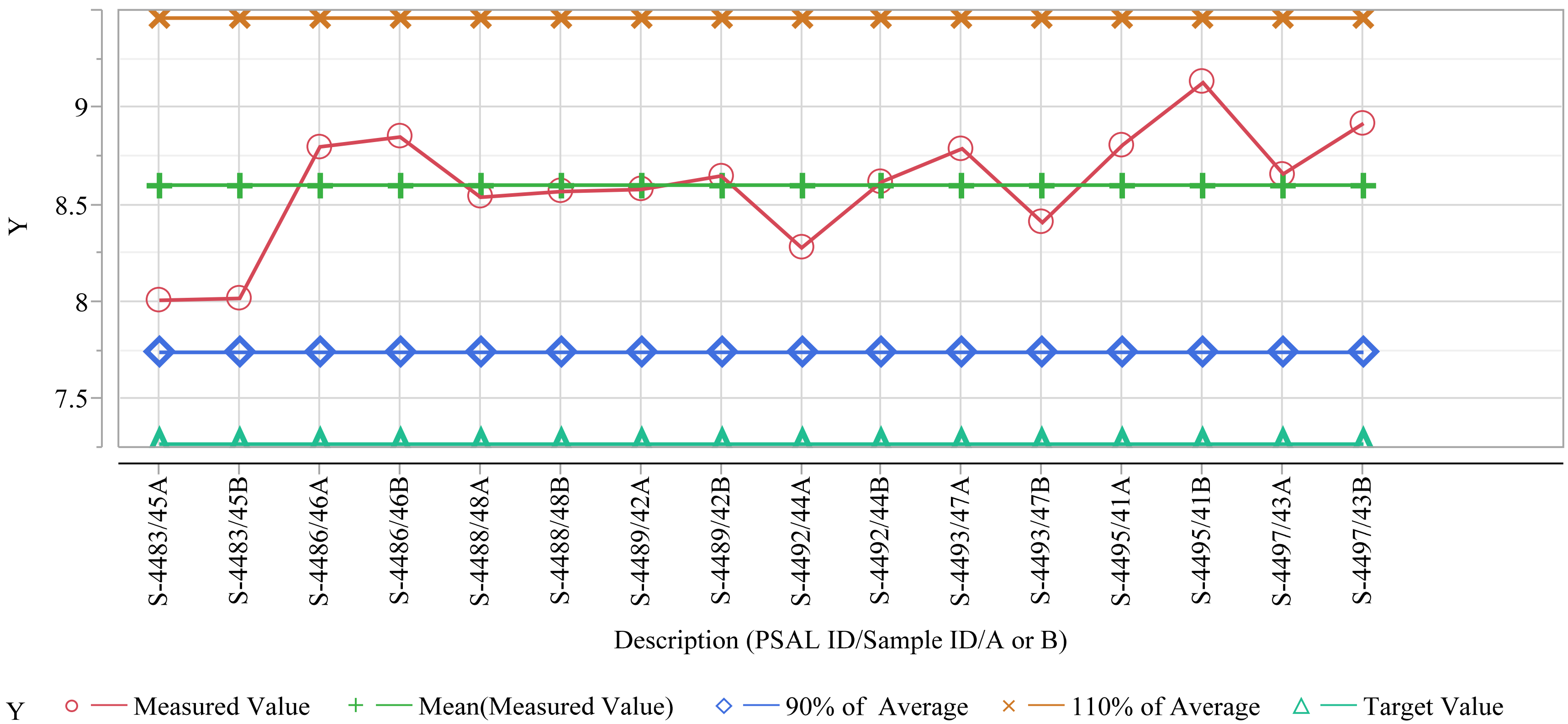
Overlay Plot Test=HLW HB (b), Type=slurry, Analyte=ZnO, Unit of Measure=wt%



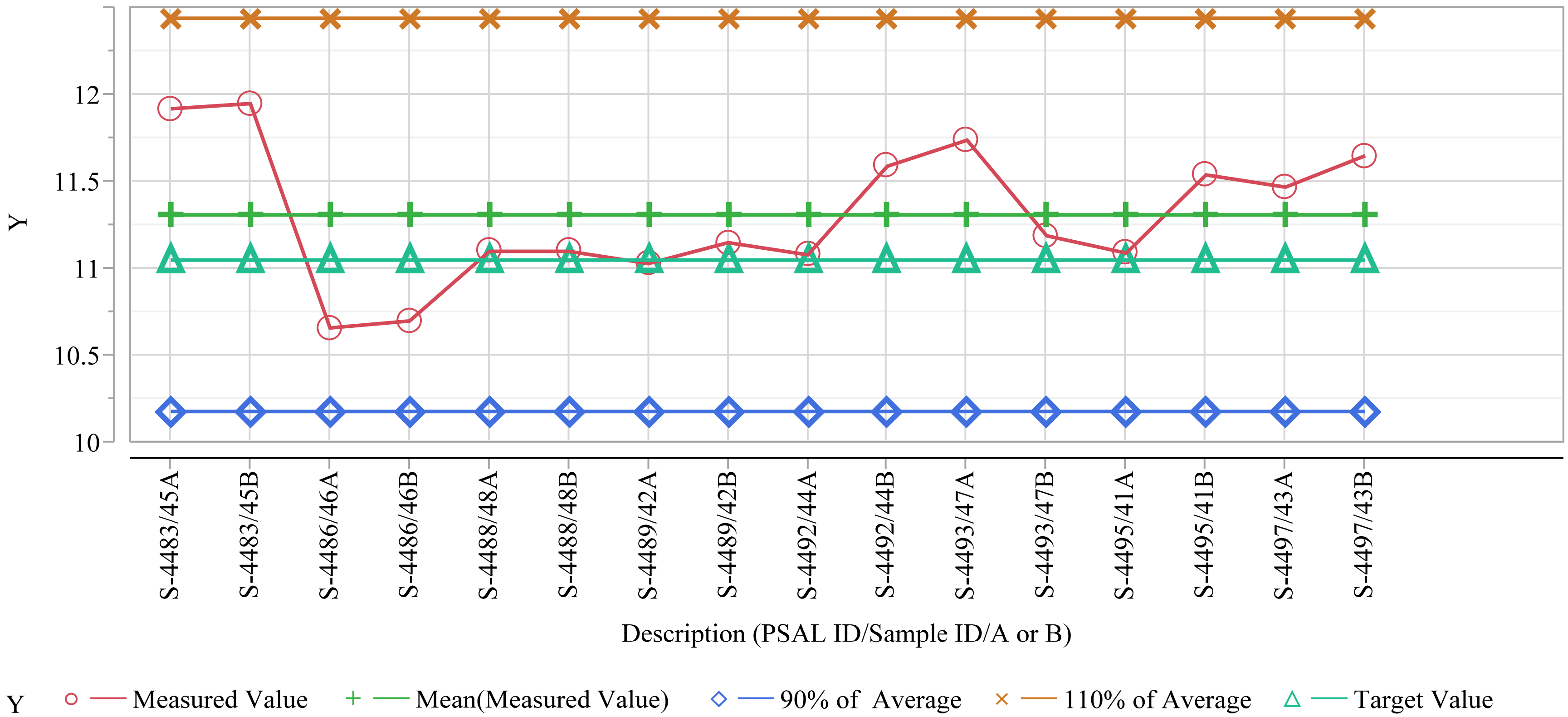
Overlay Plot Test=HLW HB (b), Type=slurry, Analyte=ZrO2, Unit of Measure=wt%



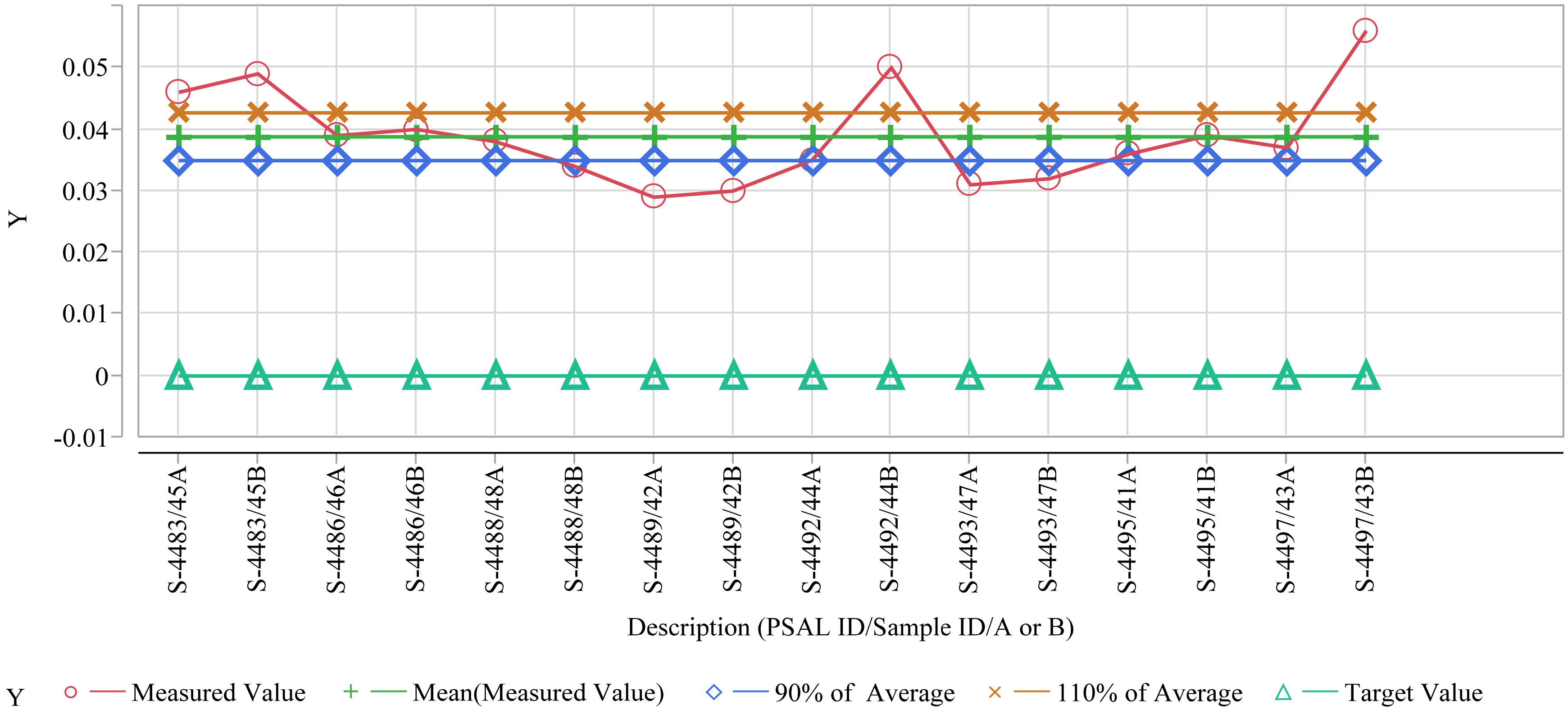
Overlay Plot Test=HLW LB, Type=glass, Analyte=Al2O3, Unit of Measure=wt%



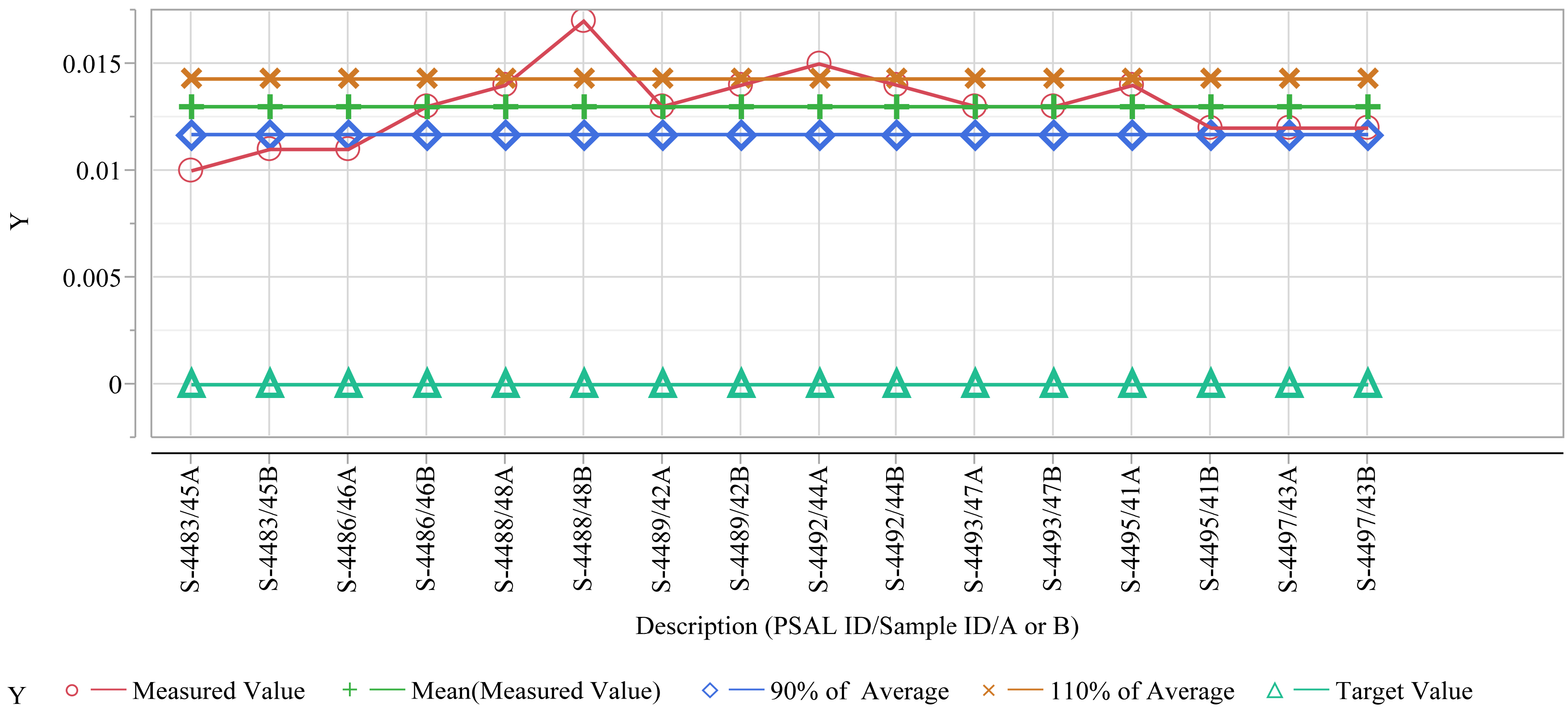
Overlay Plot Test=HLW LB, Type=glass, Analyte=B2O3, Unit of Measure=wt%



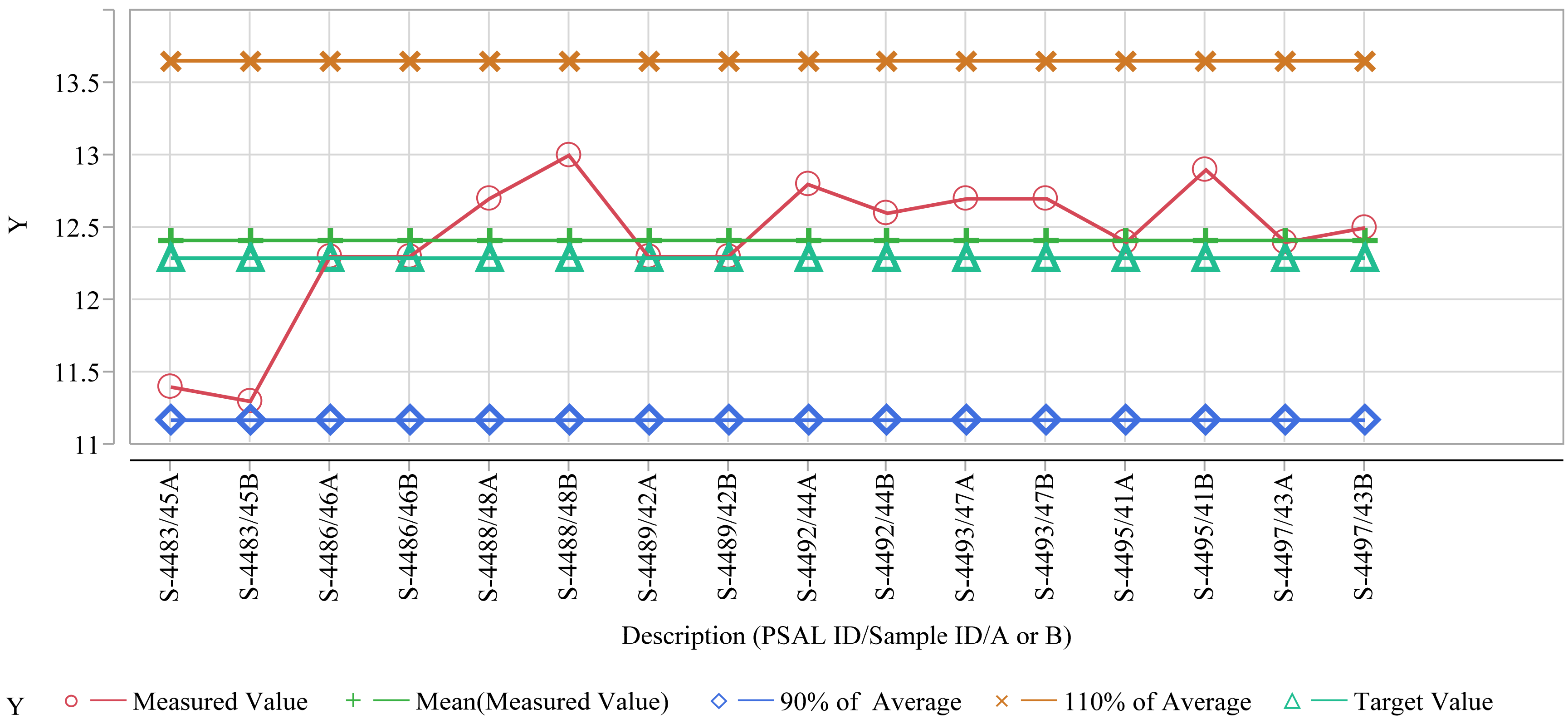
Overlay Plot Test=HLW LB, Type=glass, Analyte=CaO, Unit of Measure=wt%



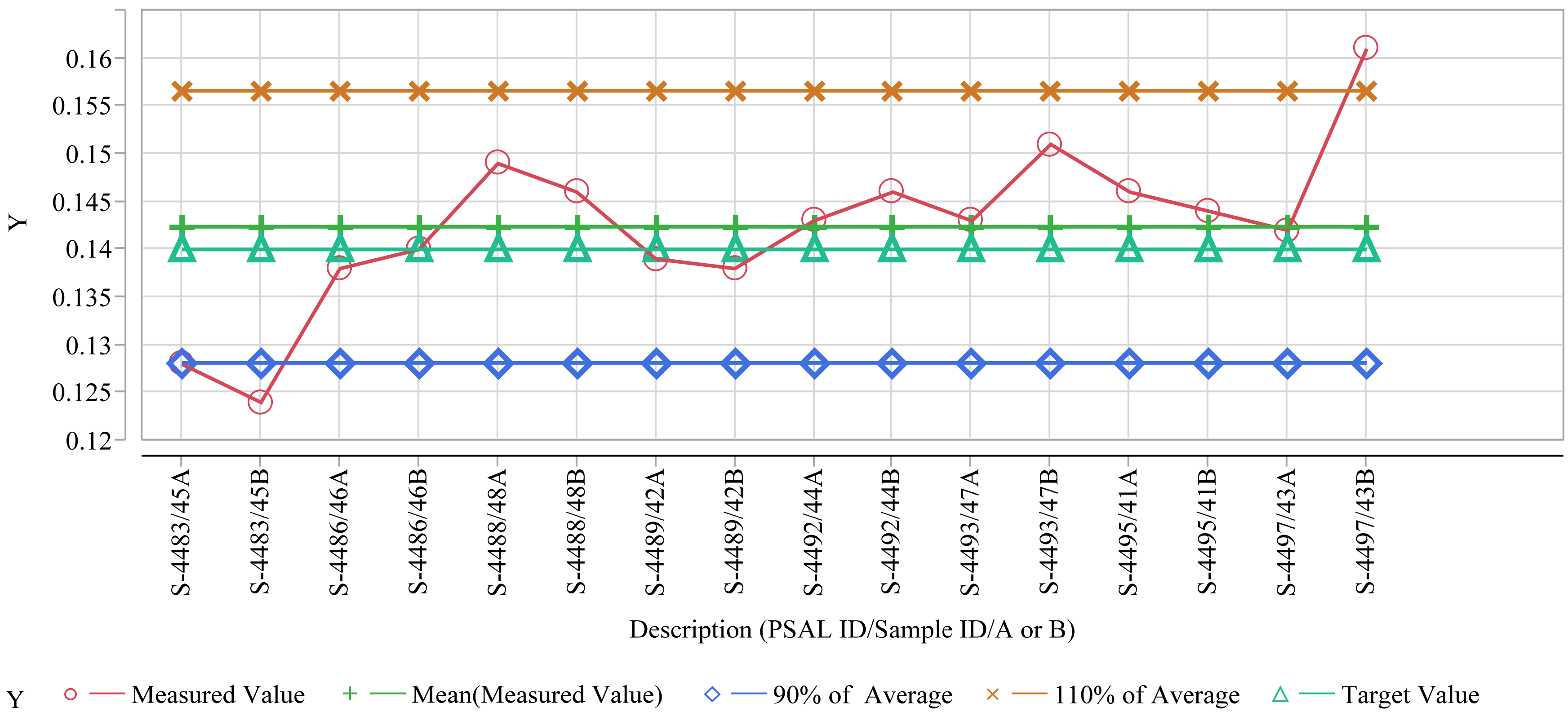
Overlay Plot Test=HLW LB, Type=glass, Analyte=Cu2O, Unit of Measure=wt%



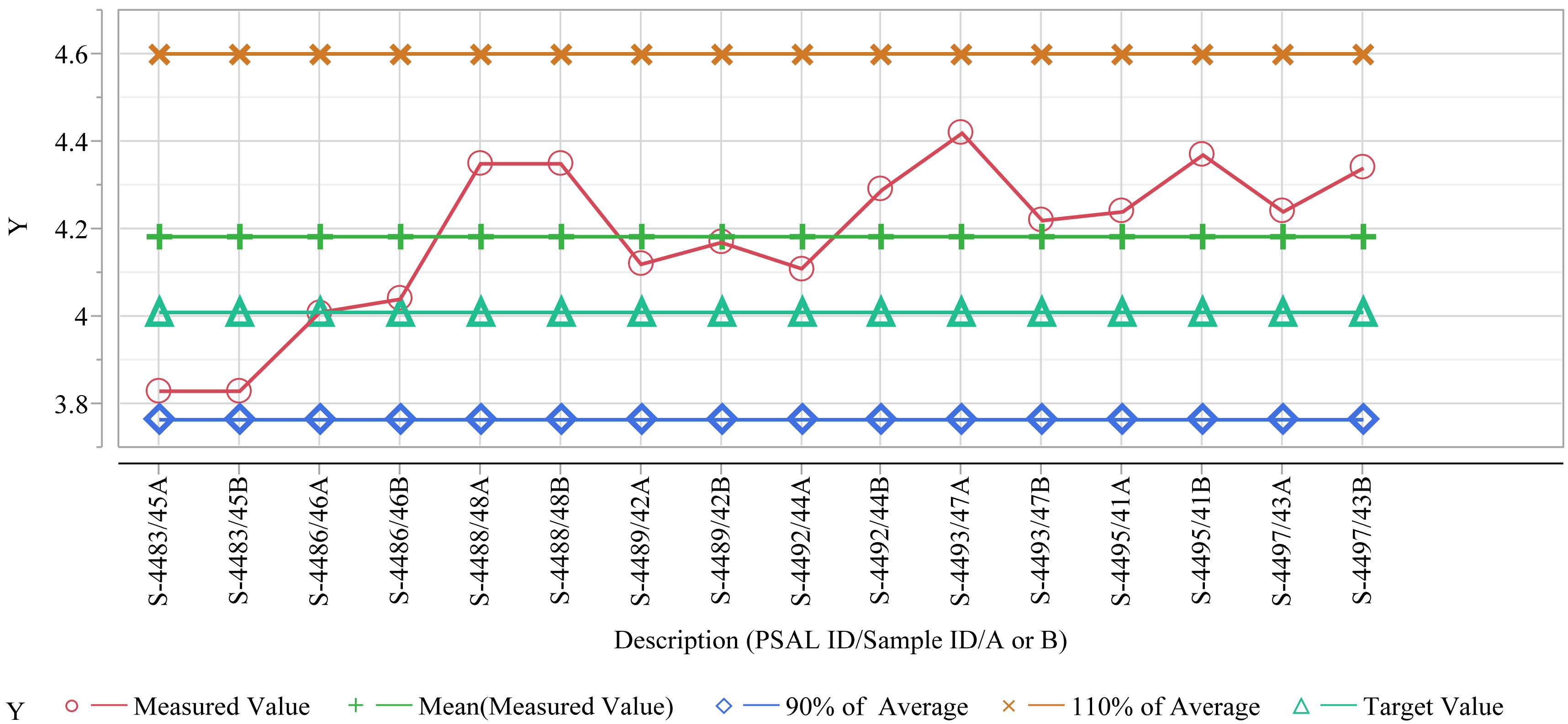
Overlay Plot Test=HLW LB, Type=glass, Analyte=Fe2O3, Unit of Measure=wt%



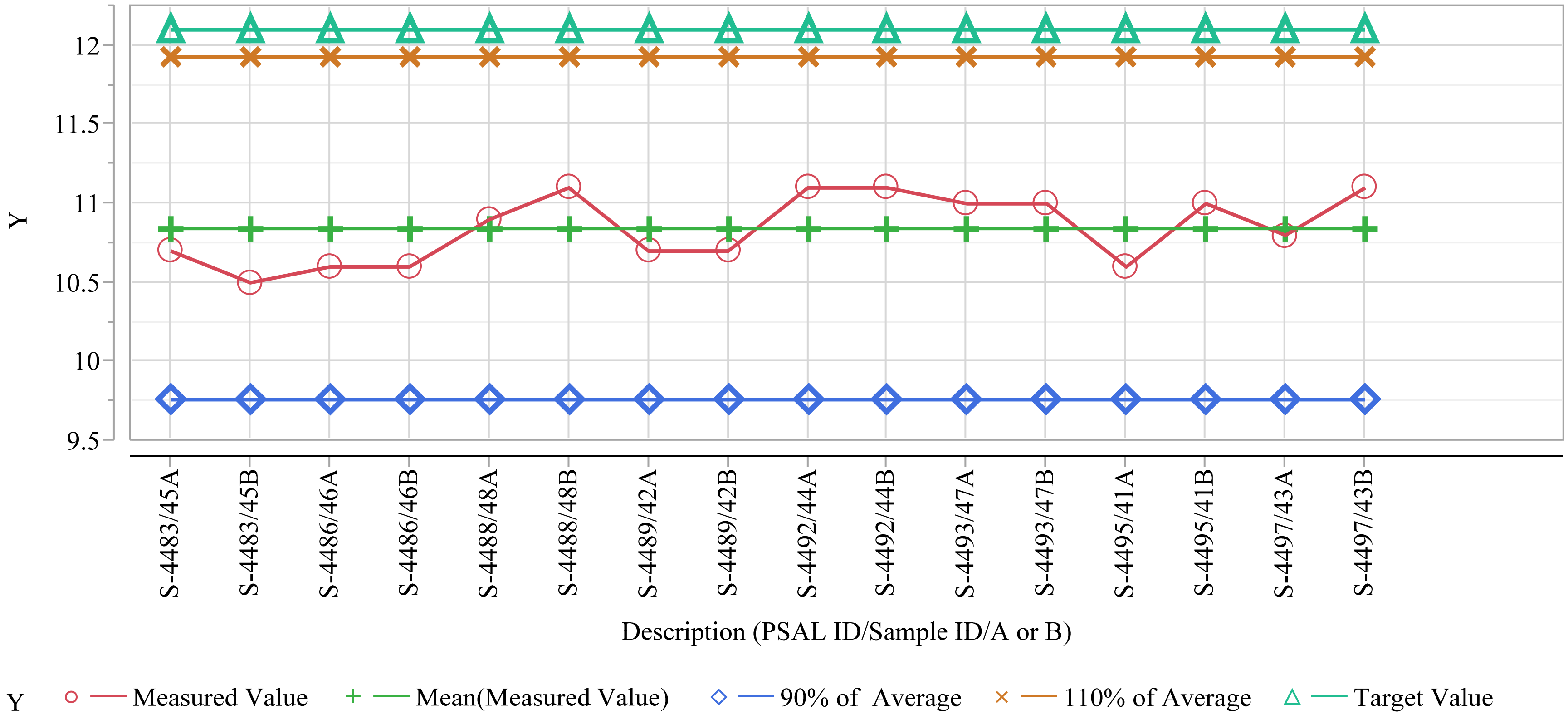
Overlay Plot Test=HLW LB, Type=glass, Analyte=K2O, Unit of Measure=wt%



Overlay Plot Test=HLW LB, Type=glass, Analyte=Li2O, Unit of Measure=wt%



Overlay Plot Test=HLW LB, Type=glass, Analyte=Na2O, Unit of Measure=wt%



Overlay Plot Test=HLW LB, Type=glass, Analyte=P2O5, Unit of Measure=wt%

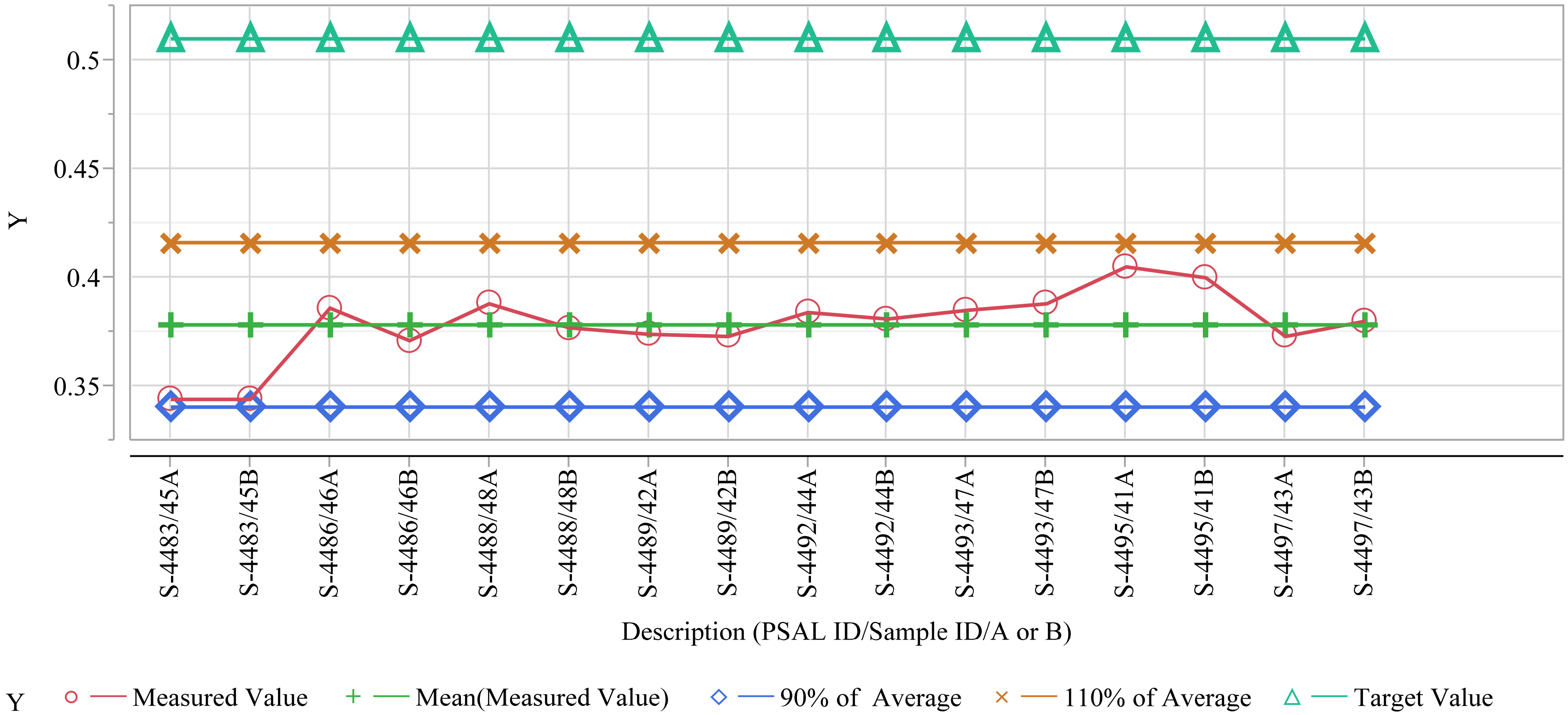
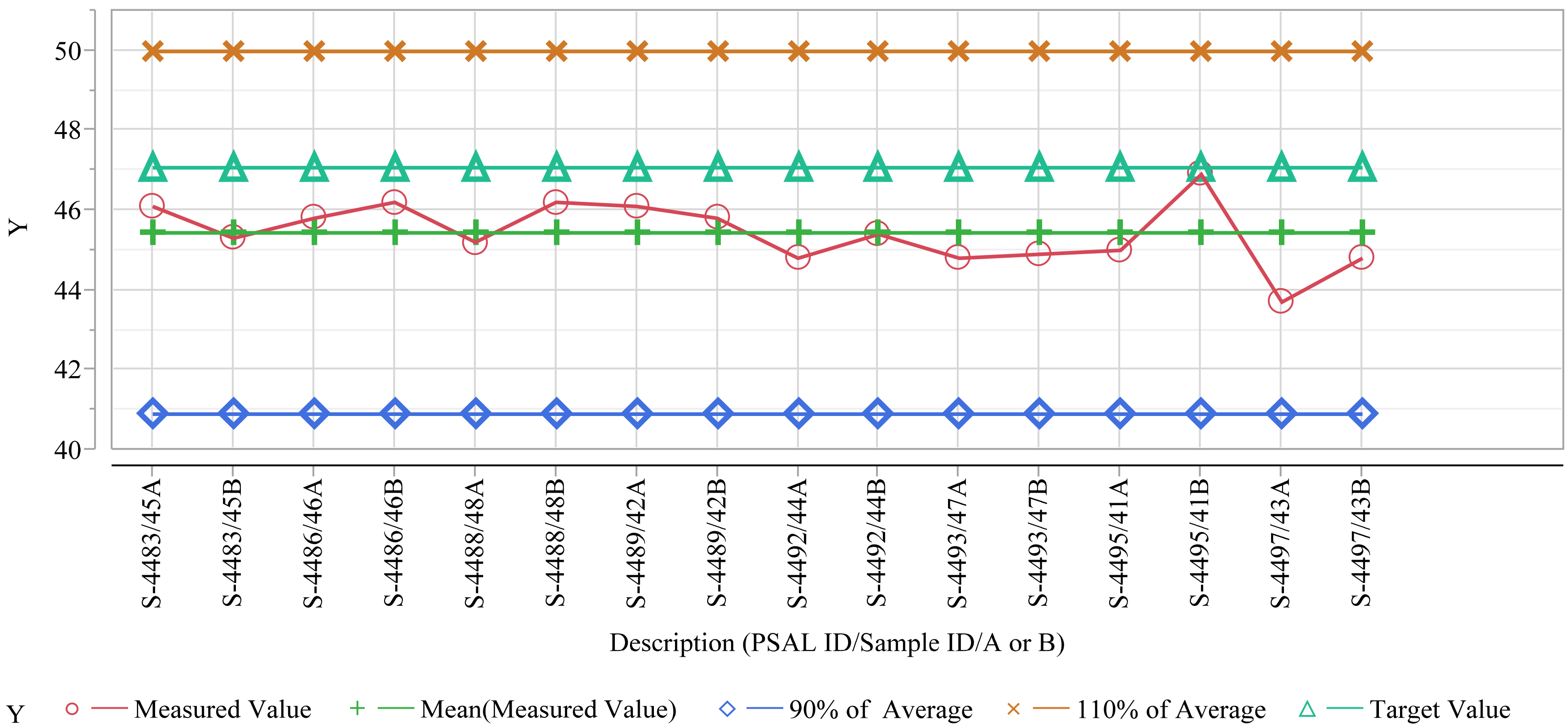
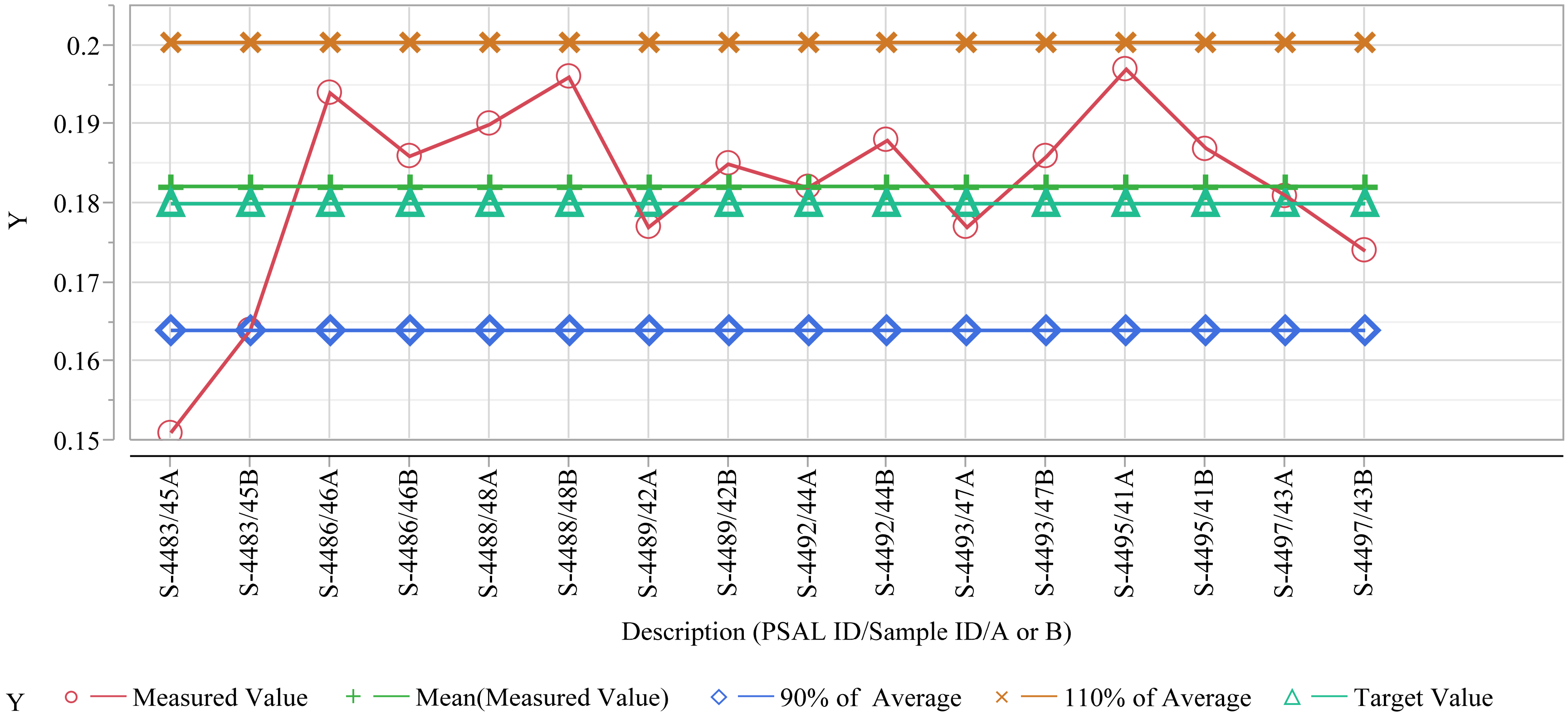


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

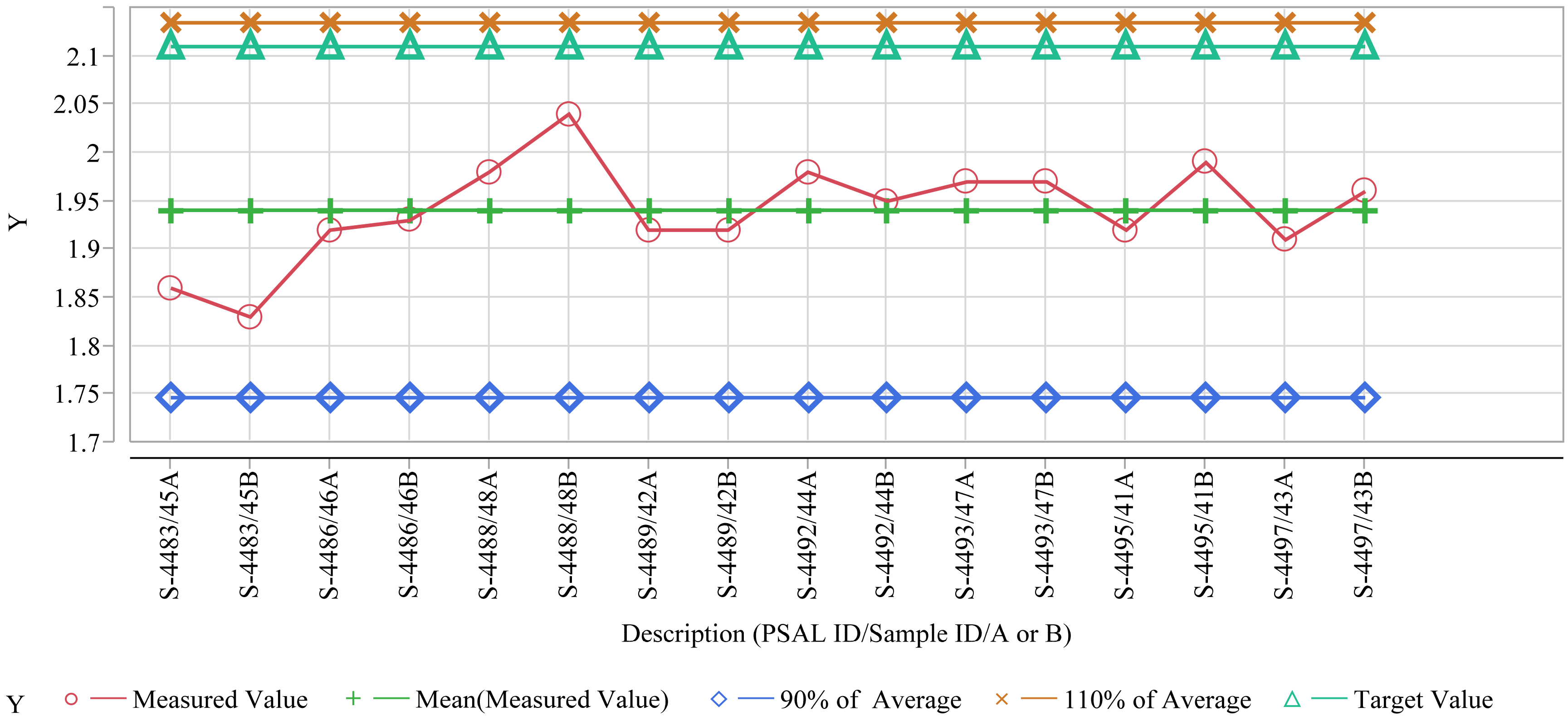
Overlay Plot Test=HLW LB, Type=glass, Analyte=SiO2, Unit of Measure=wt%



Overlay Plot Test=HLW LB, Type=glass, Analyte=SO4, Unit of Measure=wt%



Overlay Plot Test=HLW LB, Type=glass, Analyte=ZnO, Unit of Measure=wt%



Overlay Plot Test=HLW LB, Type=glass, Analyte=ZrO2, Unit of Measure=wt%

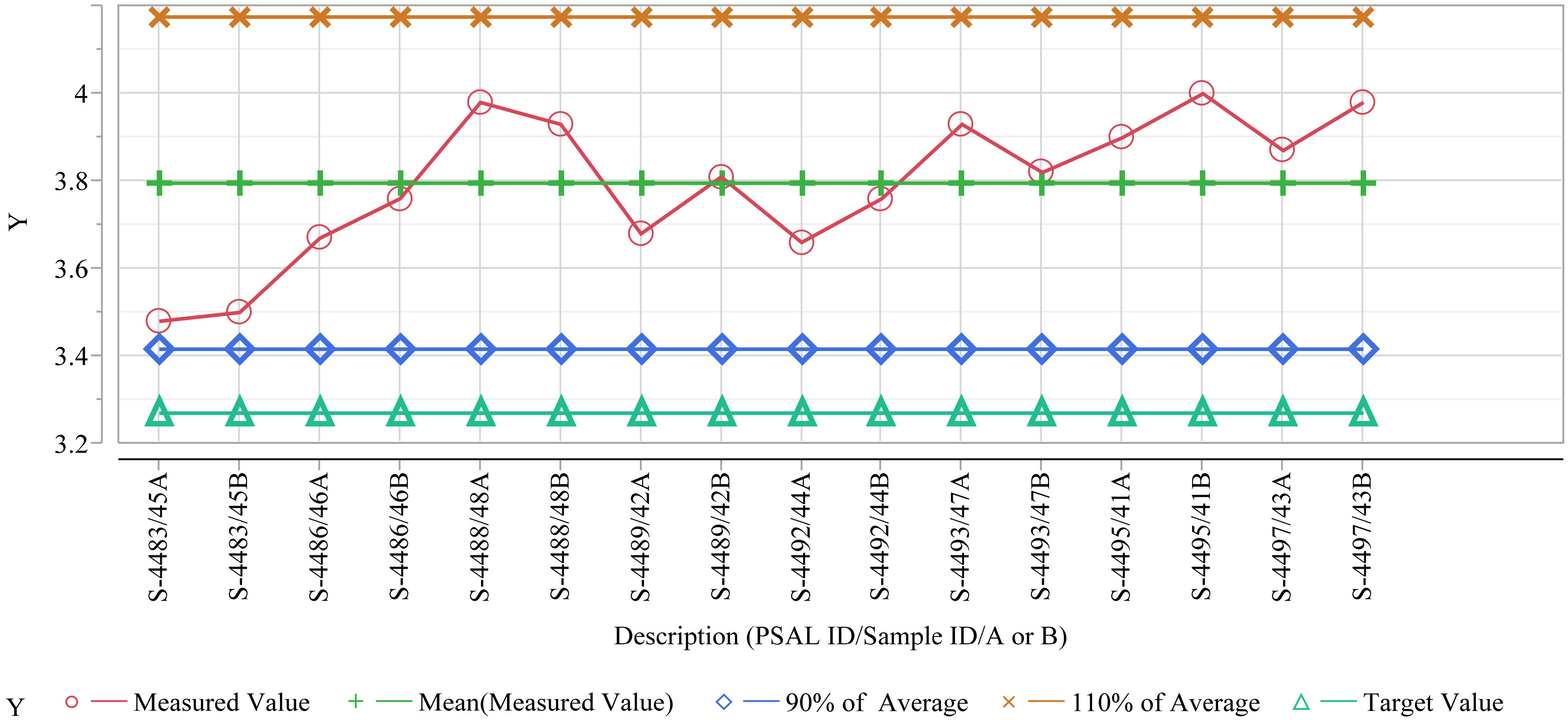
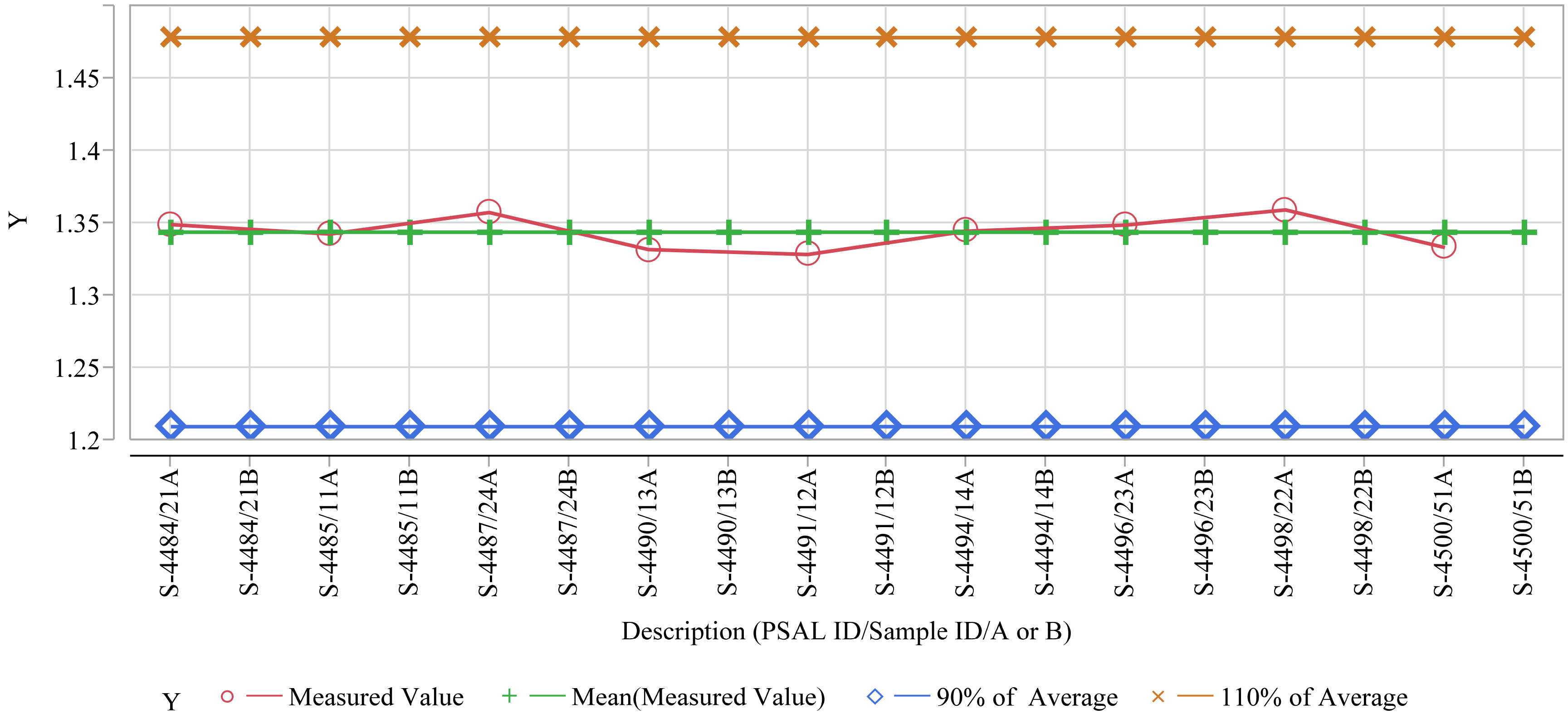
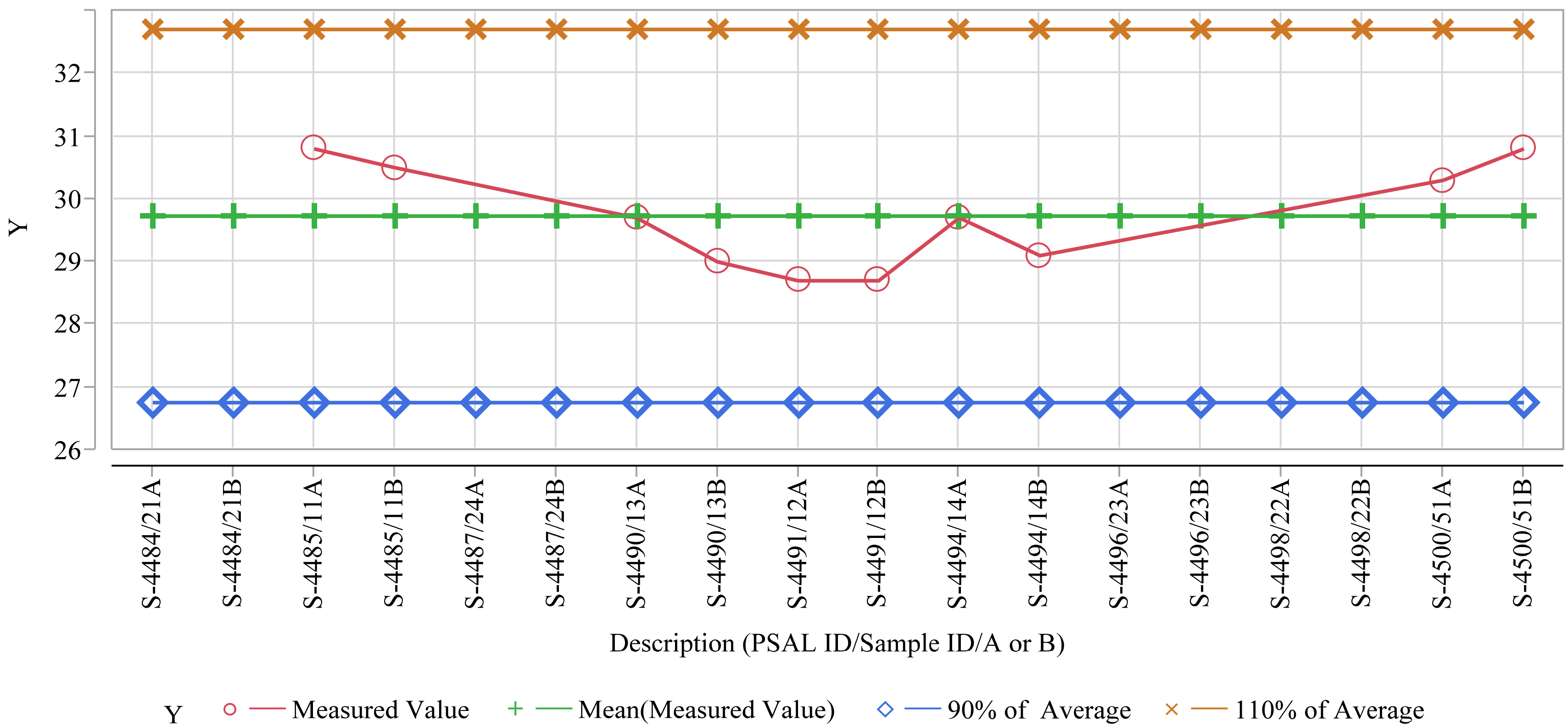


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

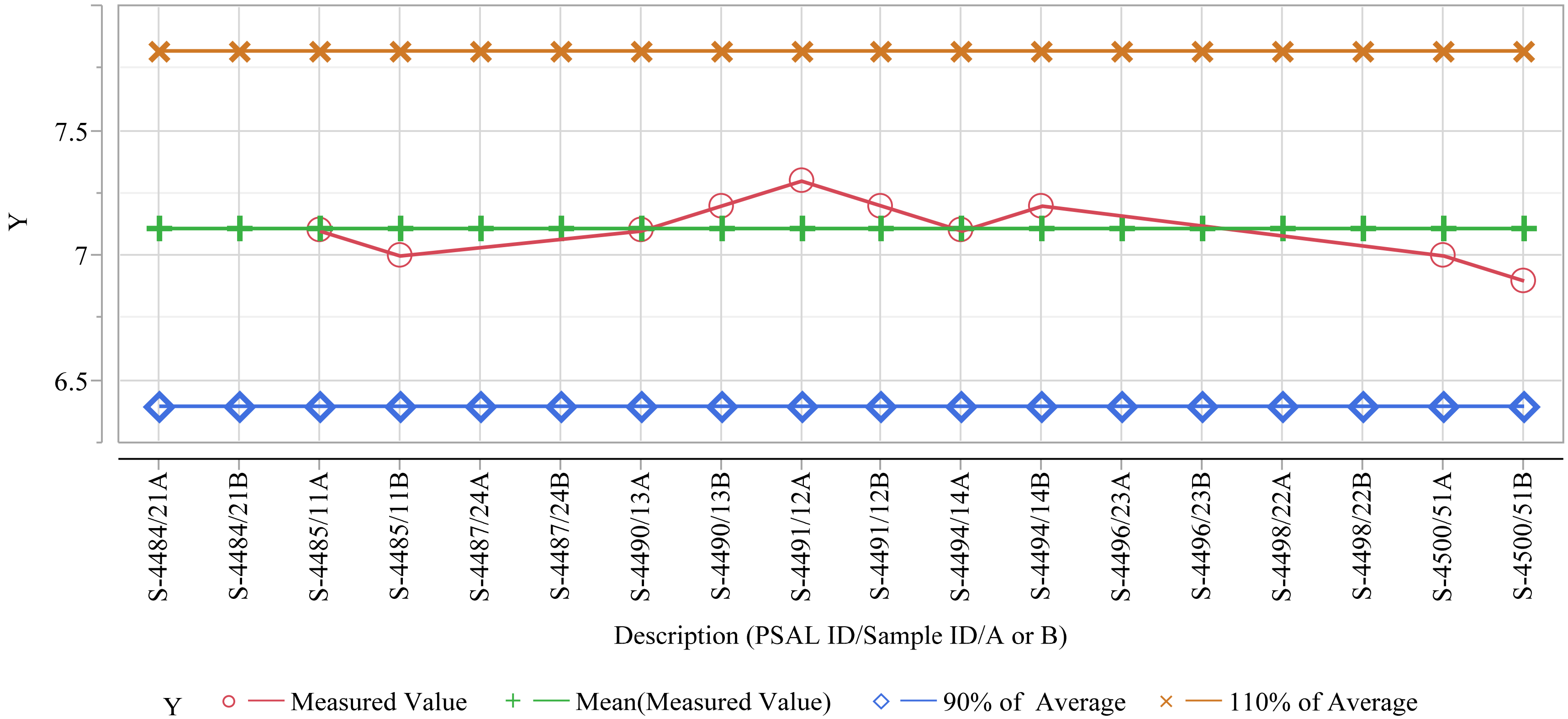
Overlay Plot Test=HLW LB, Type=physical property, Analyte=Density, Unit of Measure=g/mL



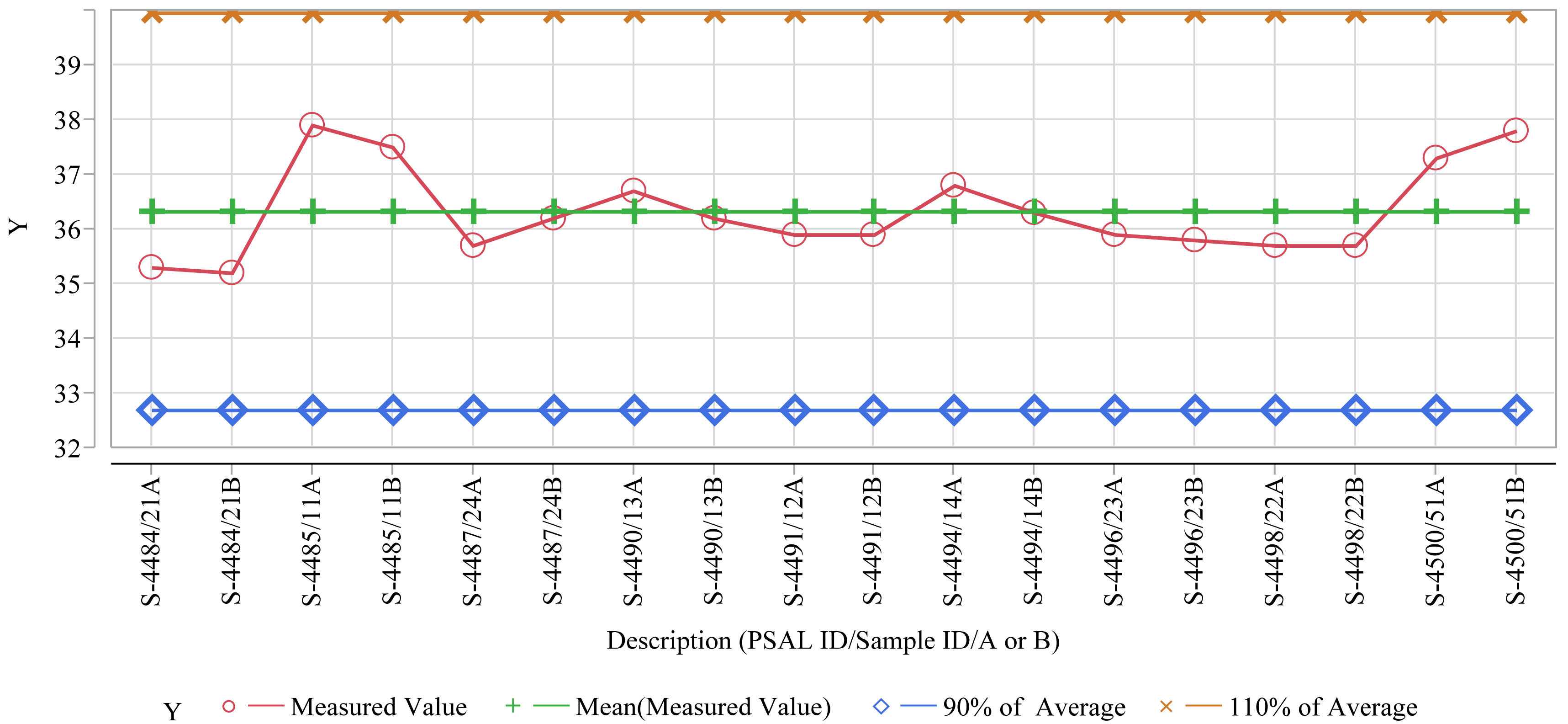
Overlay Plot Test=HLW LB, Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%



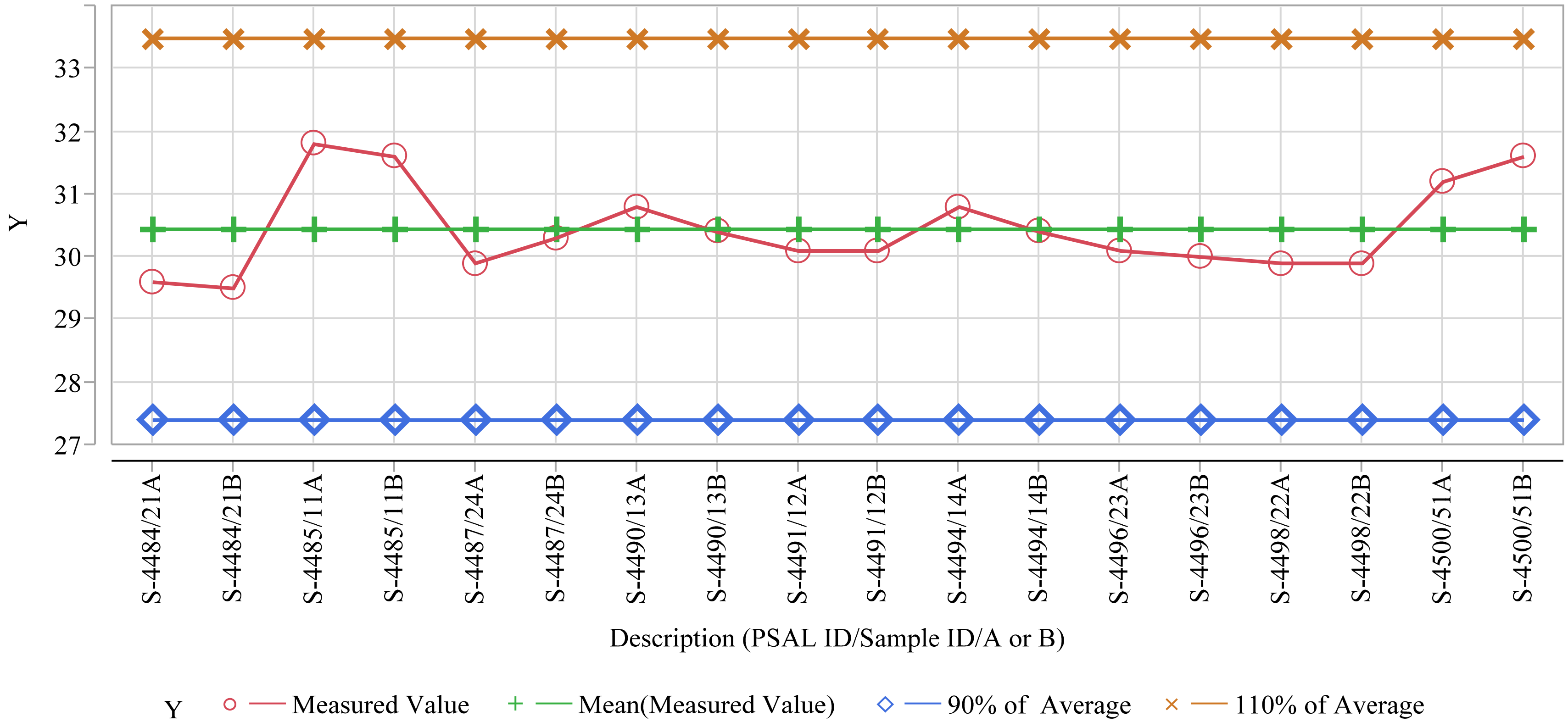
Overlay Plot Test=HLW LB, Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%



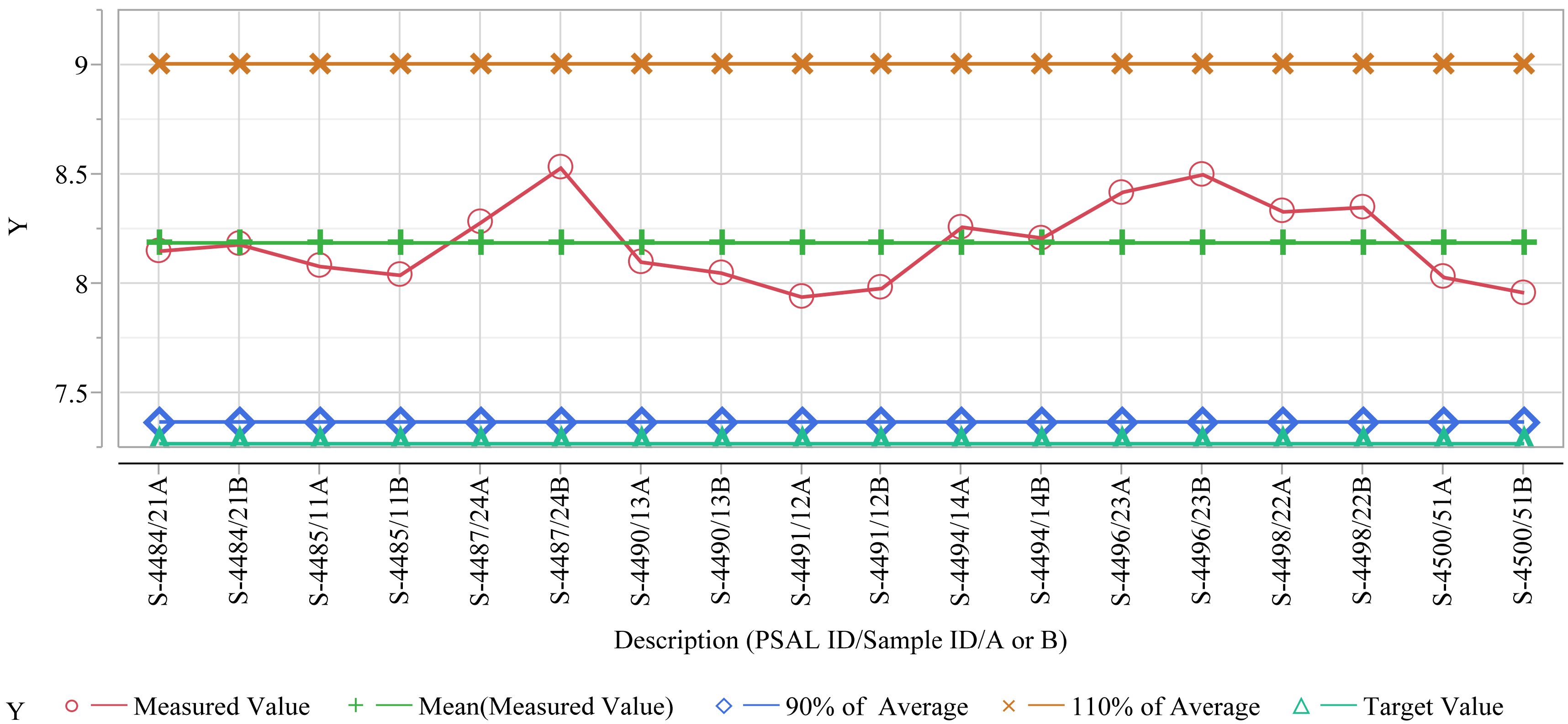
Overlay Plot Test=HLW LB, Type=physical property, Analyte=Total Solids, Unit of Measure=wt%



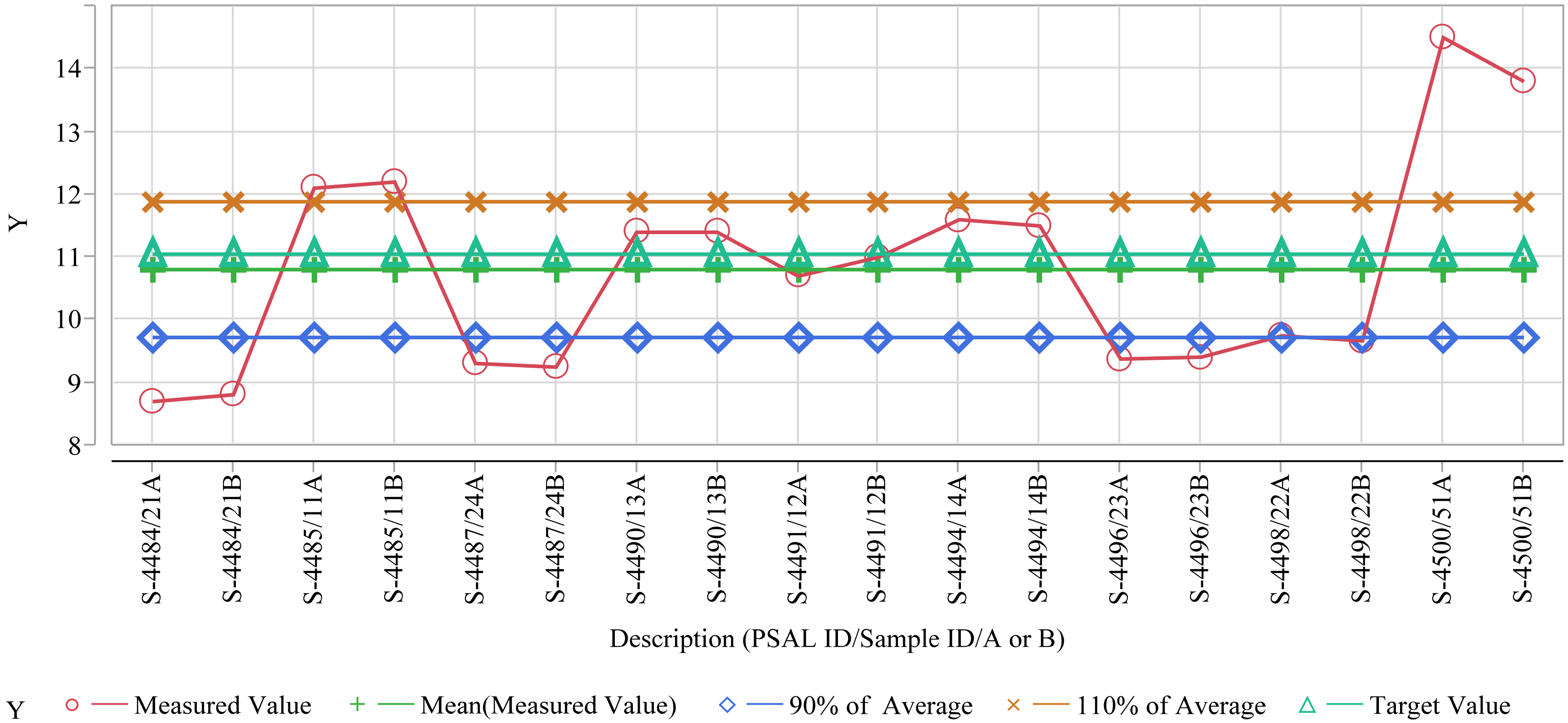
Overlay Plot Test=HLW LB, Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%



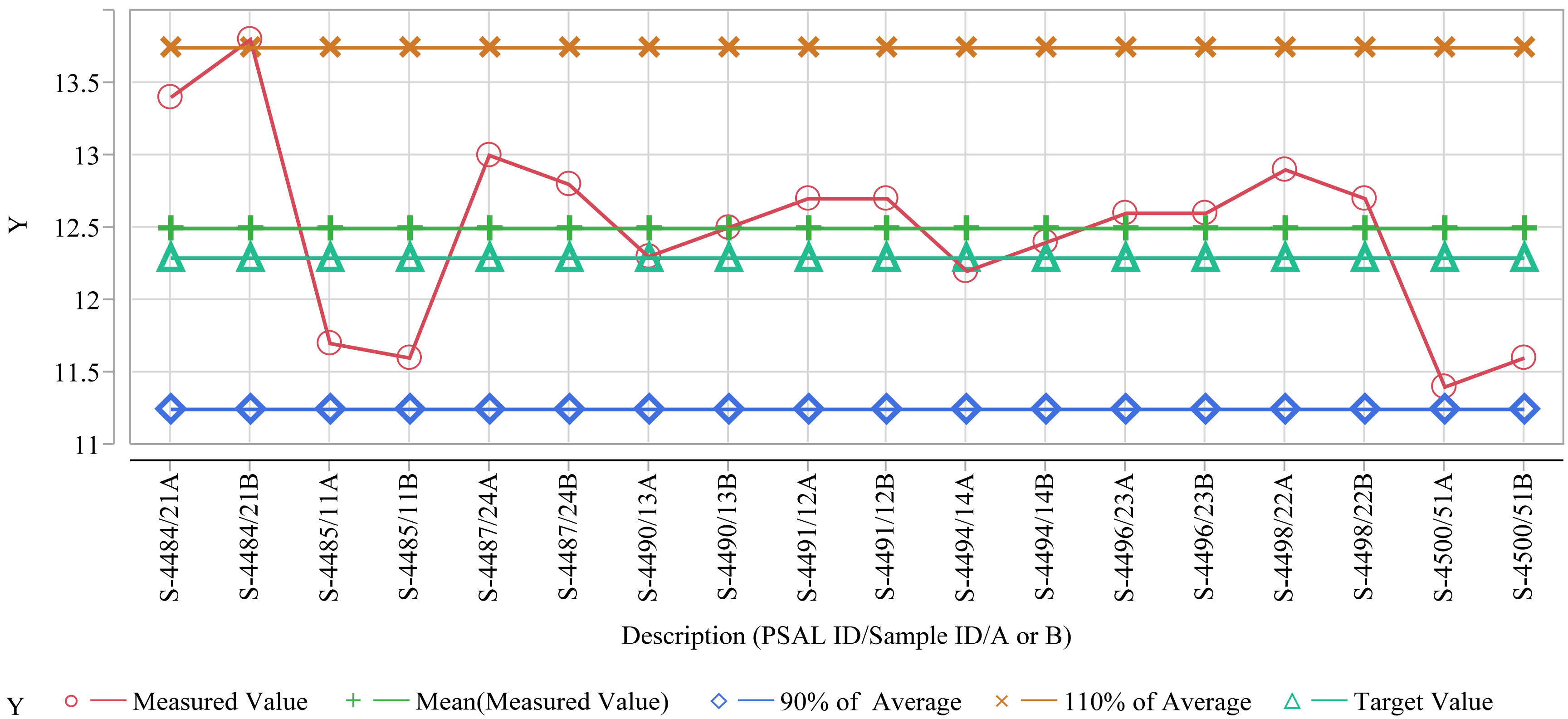
Overlay Plot Test=HLW LB, Type=slurry, Analyte=Al2O3, Unit of Measure=wt%



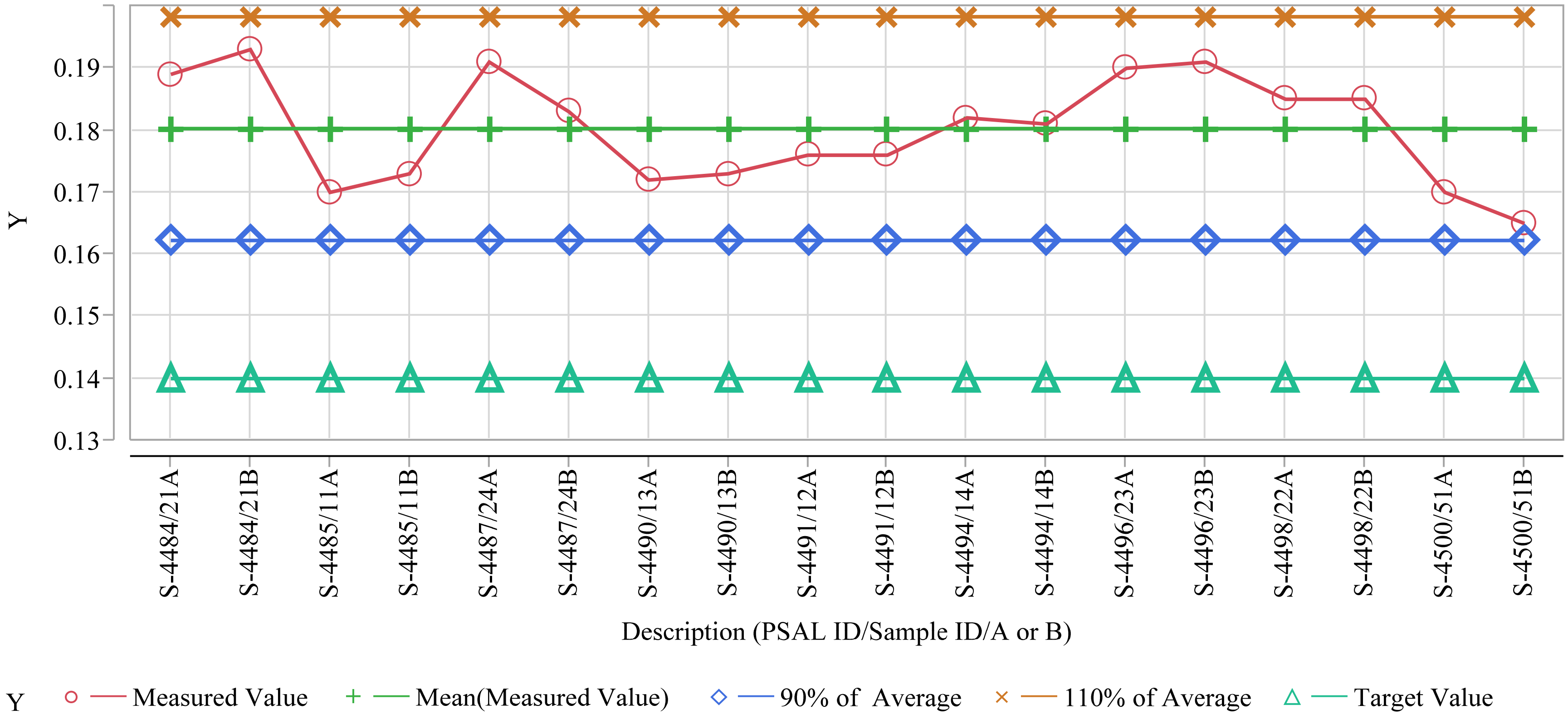
Overlay Plot Test=HLW LB, Type=slurry, Analyte=B2O3, Unit of Measure=wt%



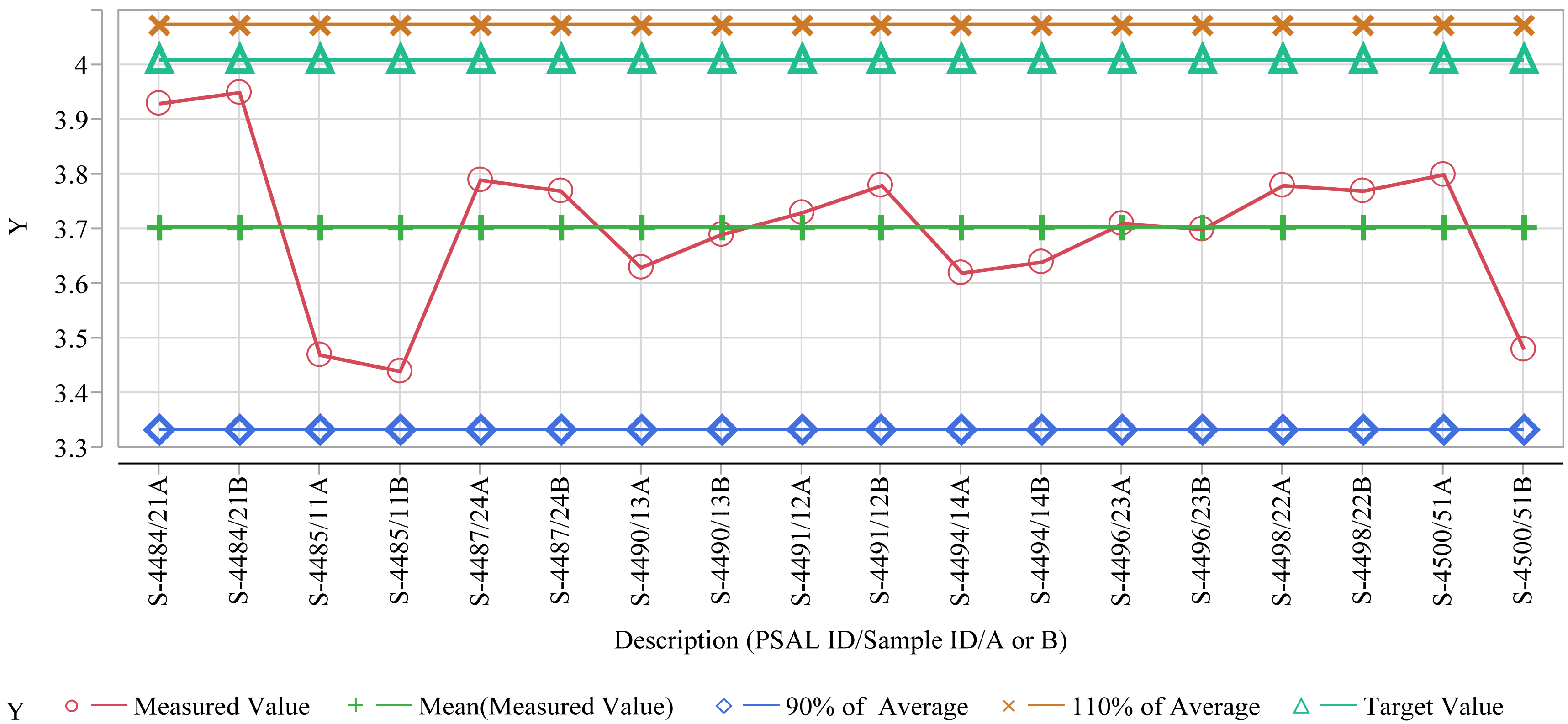
Overlay Plot Test=HLW LB, Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%



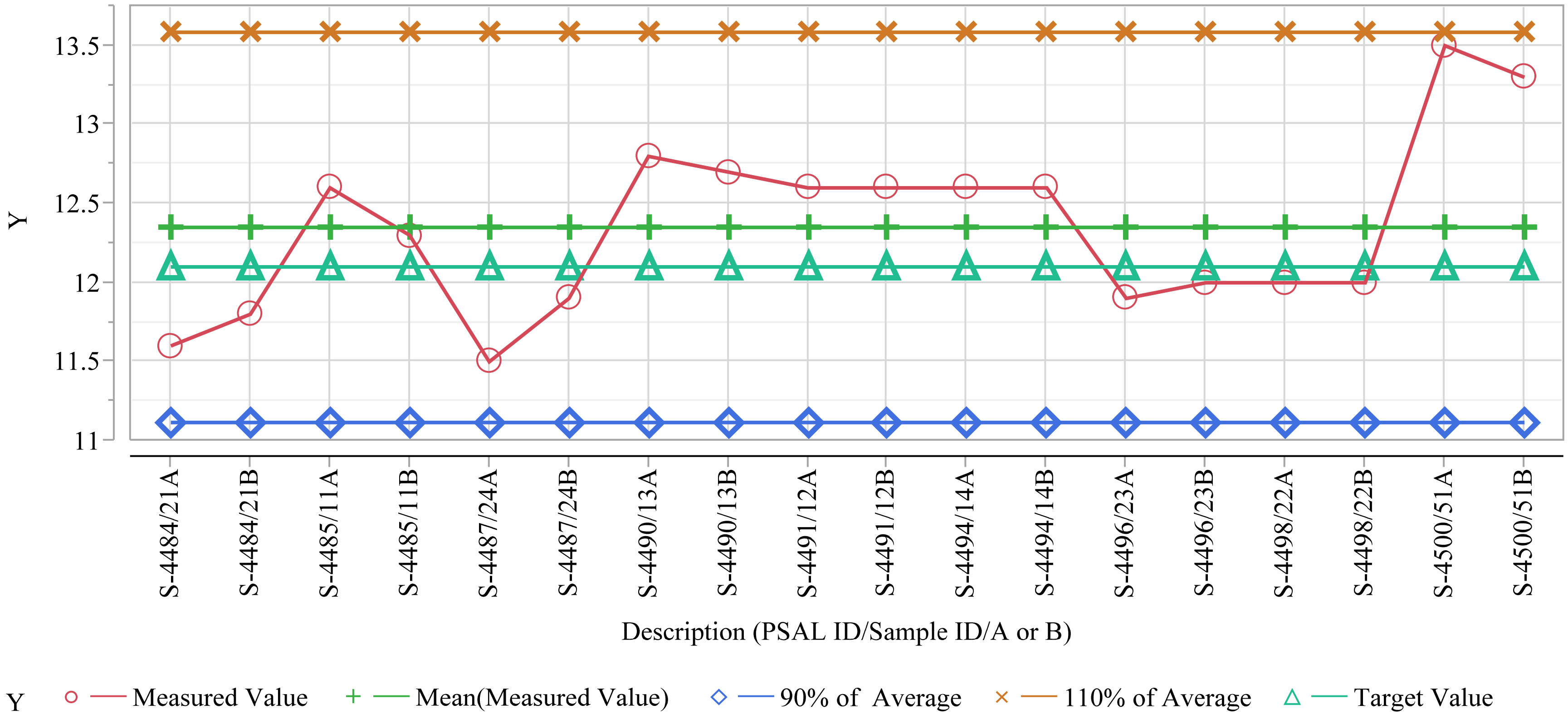
Overlay Plot Test=HLW LB, Type=slurry, Analyte=K2O, Unit of Measure=wt%



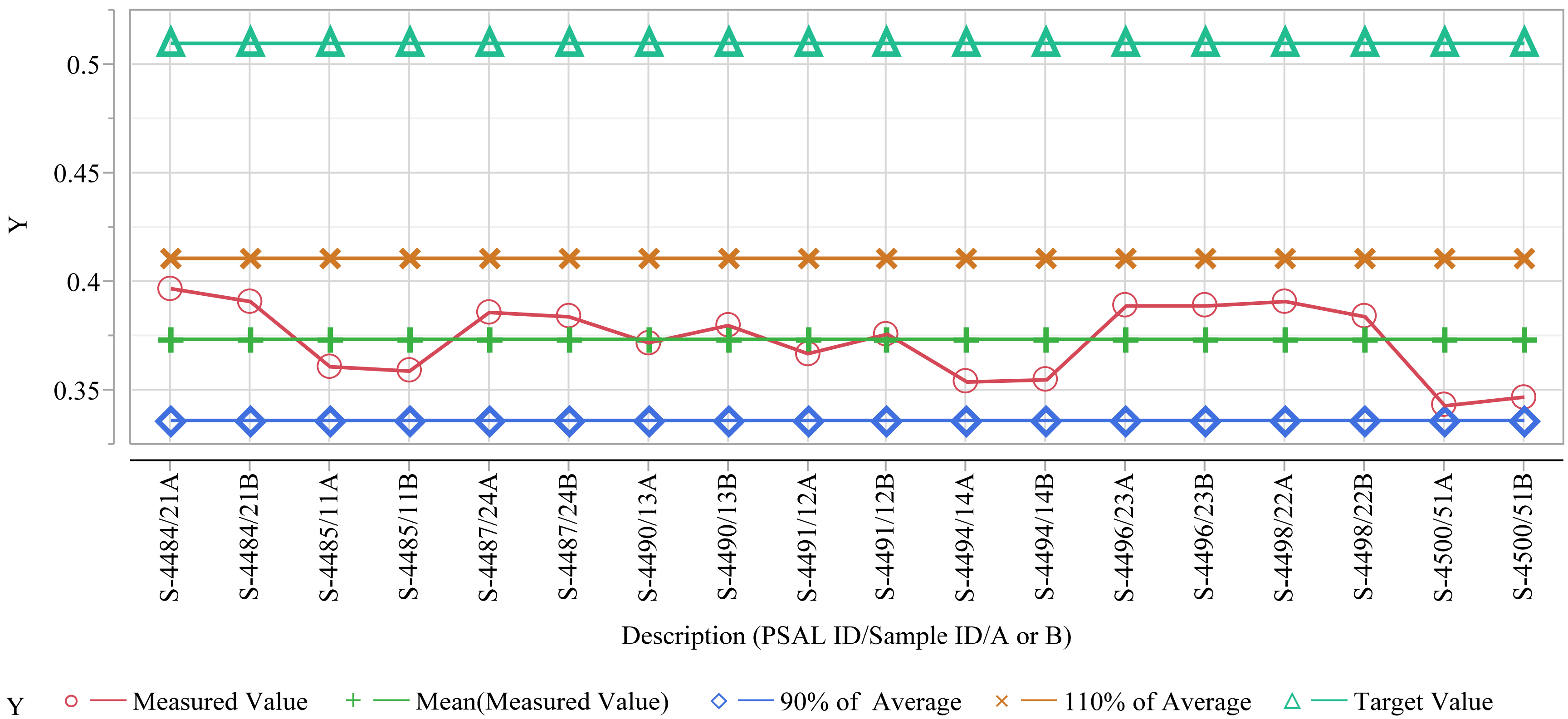
Overlay Plot Test=HLW LB, Type=slurry, Analyte=Li2O, Unit of Measure=wt%



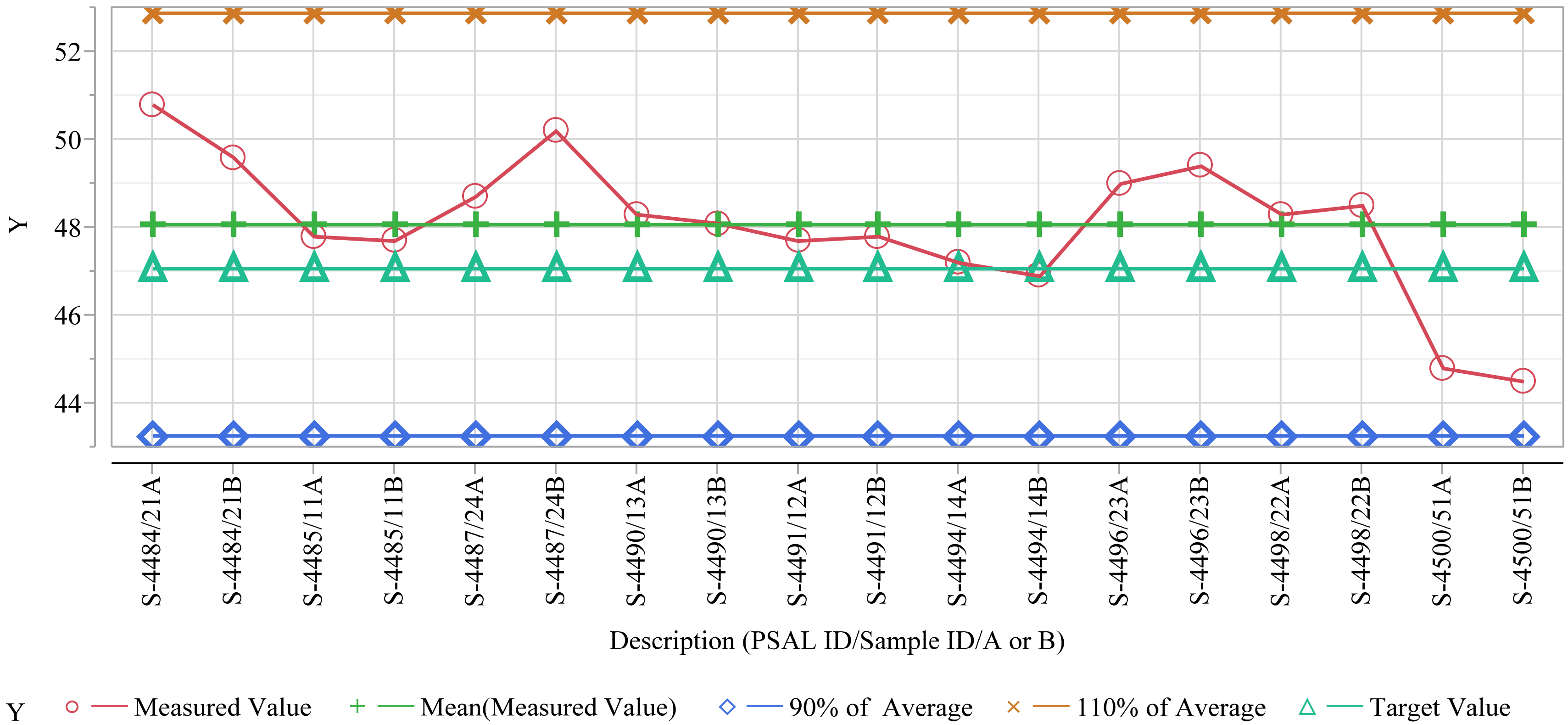
Overlay Plot Test=HLW LB, Type=slurry, Analyte=Na2O, Unit of Measure=wt%



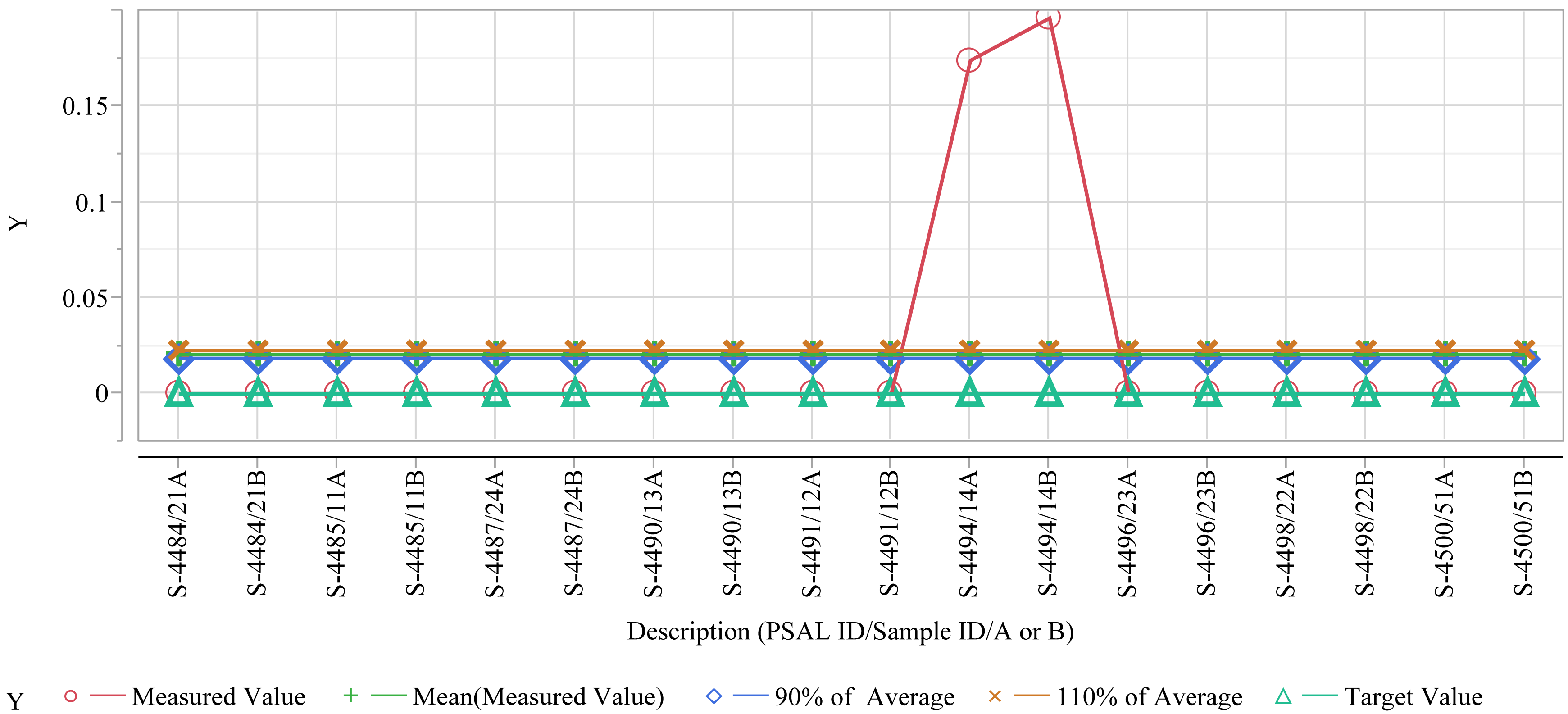
Overlay Plot Test=HLW LB, Type=slurry, Analyte=P2O5, Unit of Measure=wt%



Overlay Plot Test=HLW LB, Type=slurry, Analyte=SiO2, Unit of Measure=wt%



Overlay Plot Test=HLW LB, Type=slurry, Analyte=TiO2, Unit of Measure=wt%



Overlay Plot Test=HLW LB, Type=slurry, Analyte=ZnO, Unit of Measure=wt%

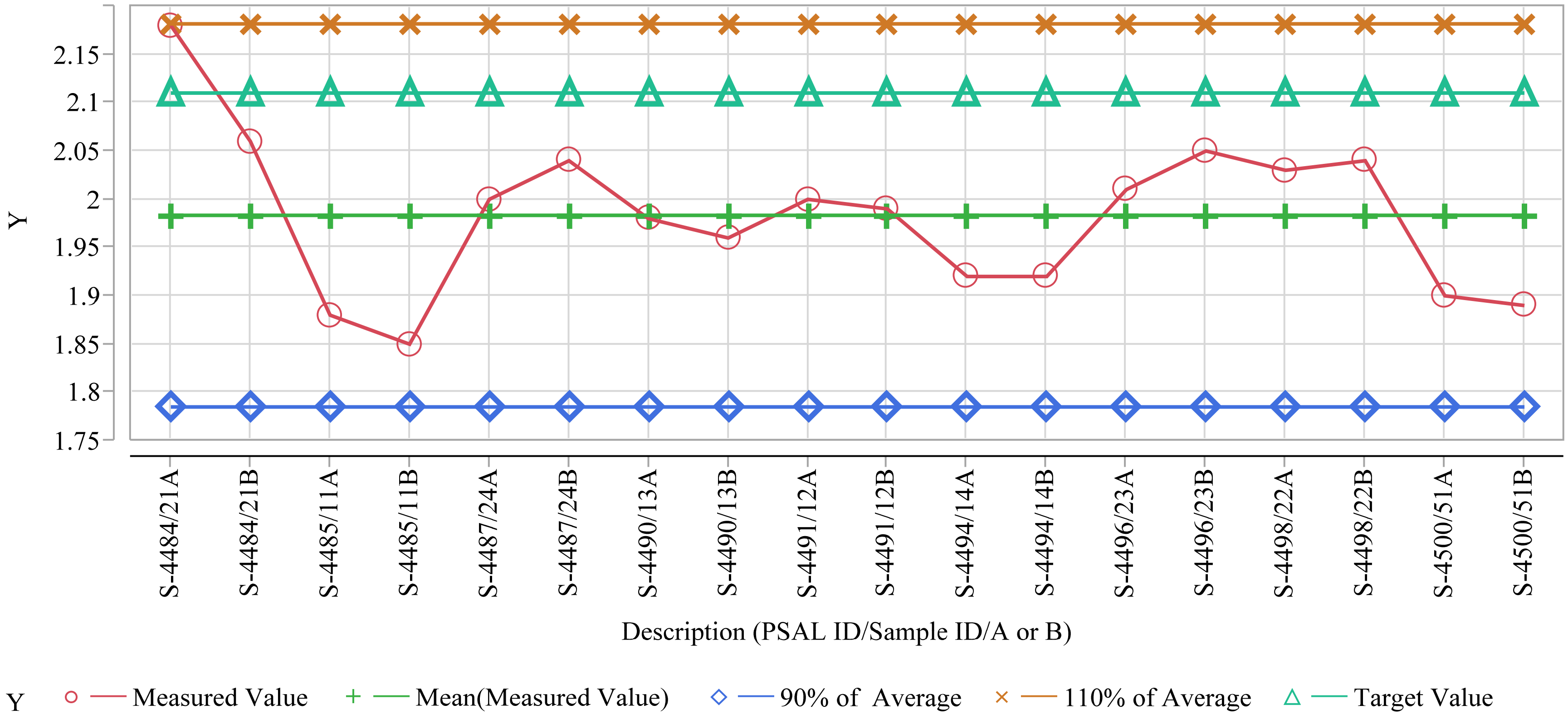
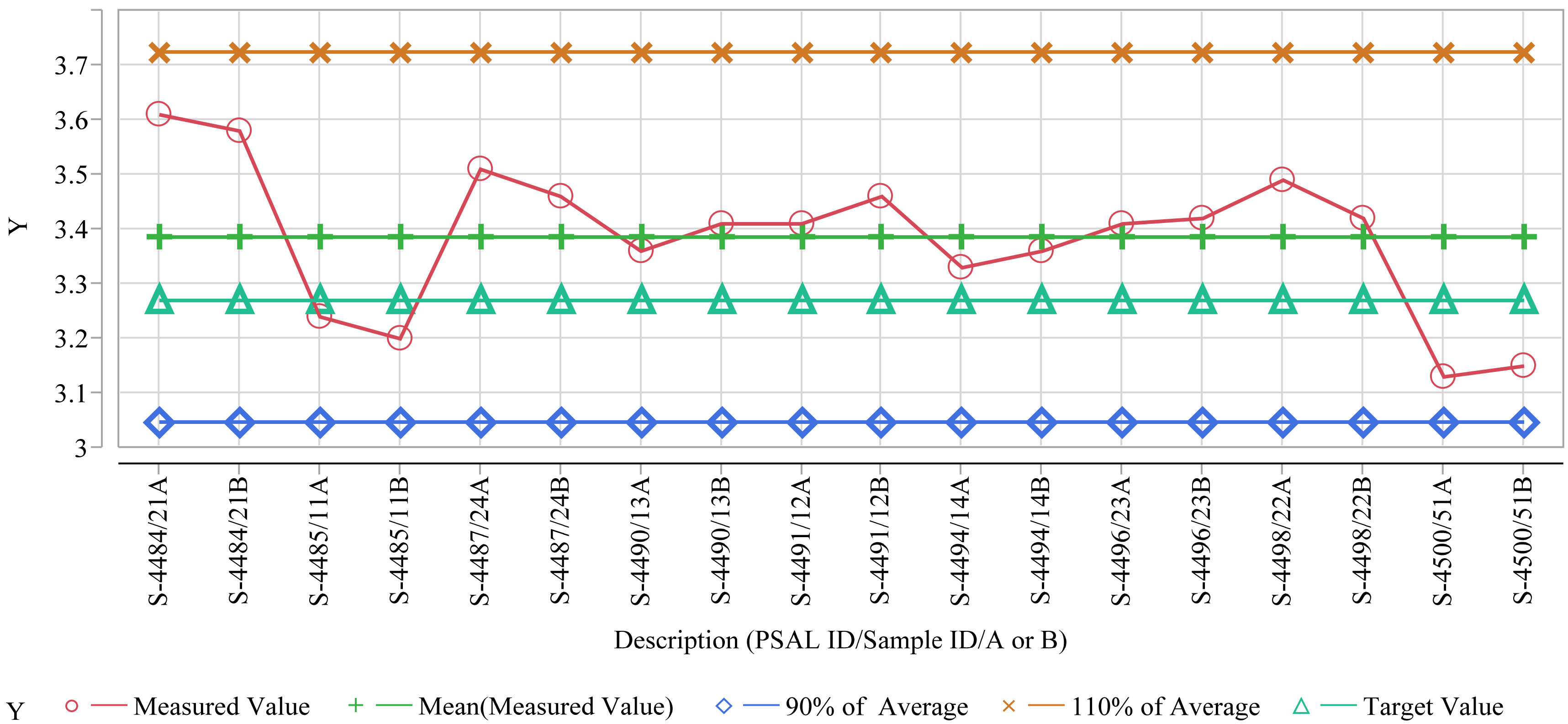


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

Overlay Plot Test=HLW LB, Type=slurry, Analyte=ZrO2, Unit of Measure=wt%



Overlay Plot Test=LAW HB, Type=physical property, Analyte=Density, Unit of Measure=g/mL

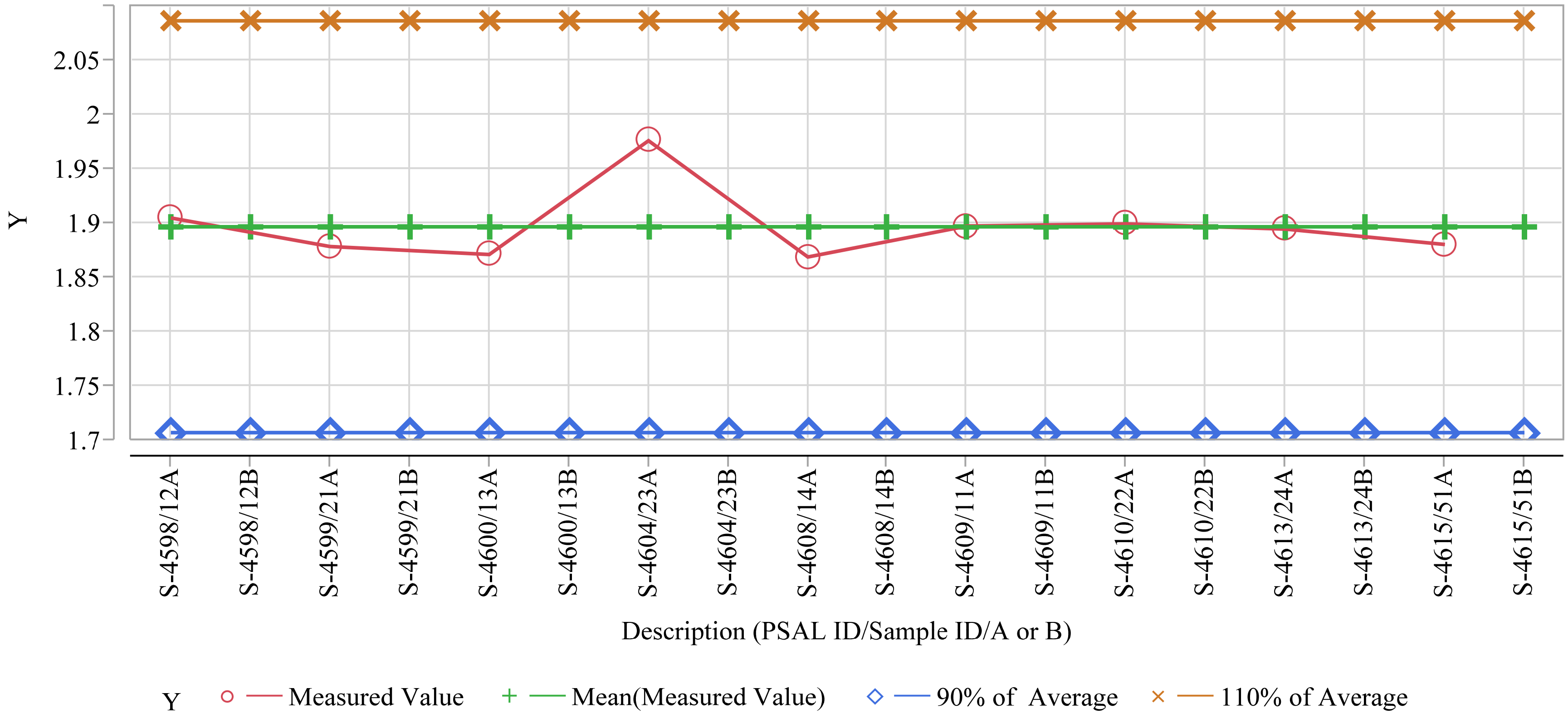
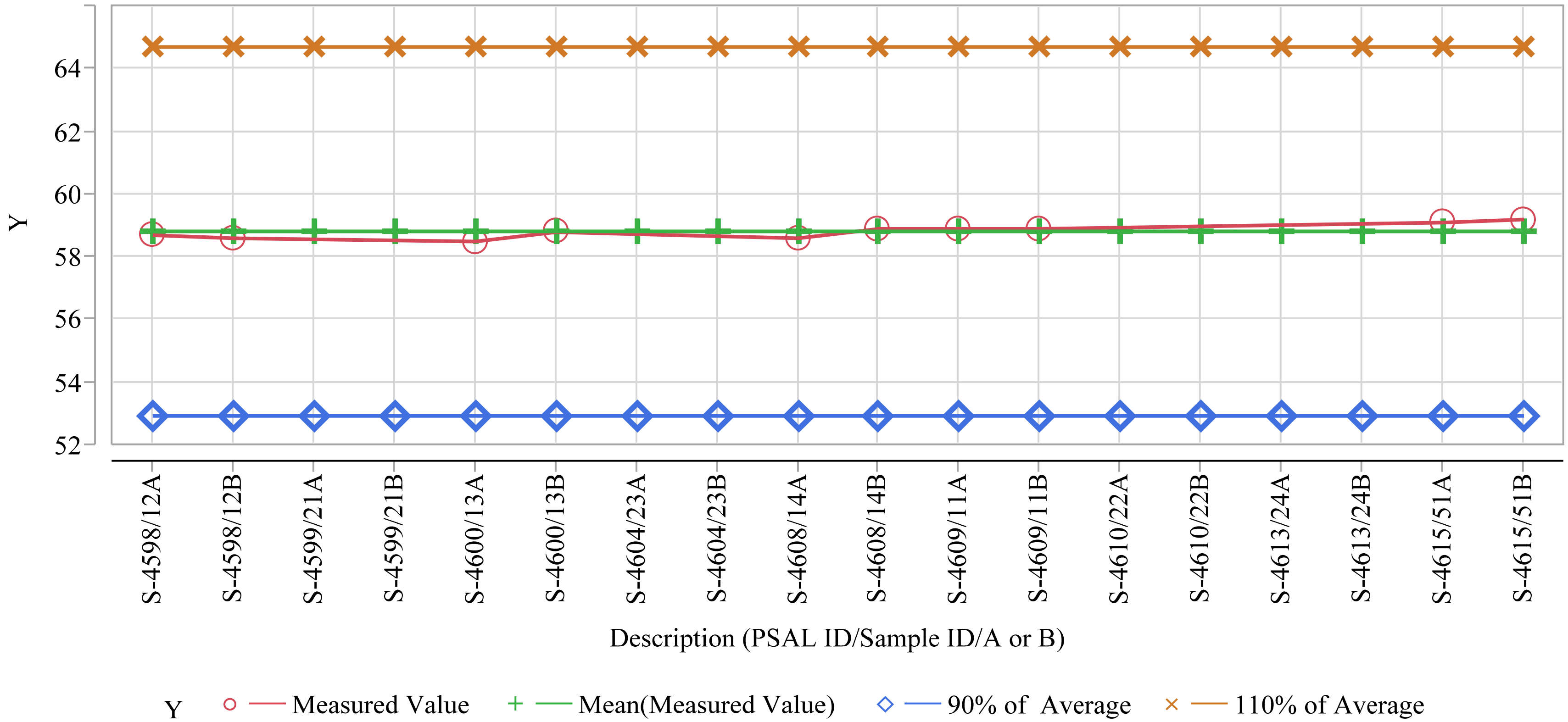
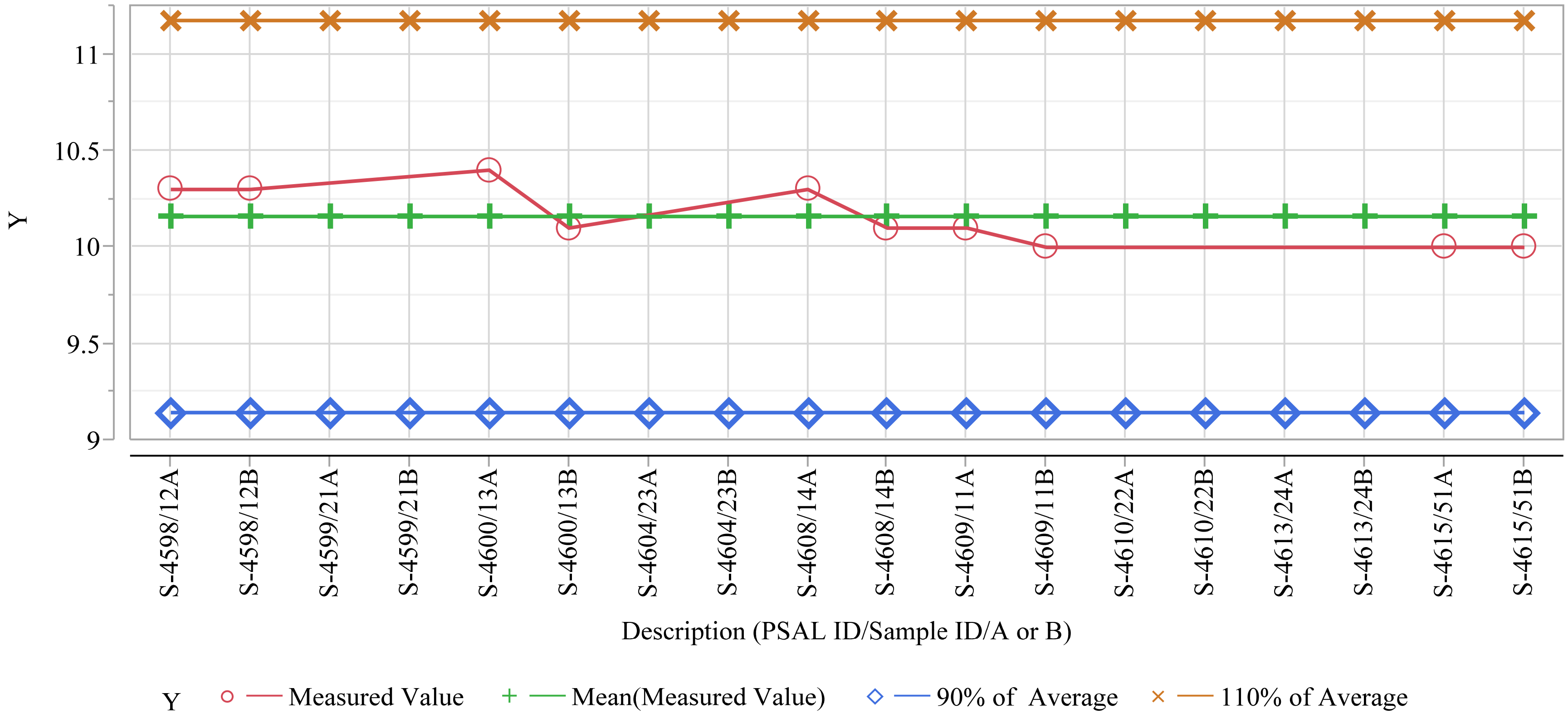


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

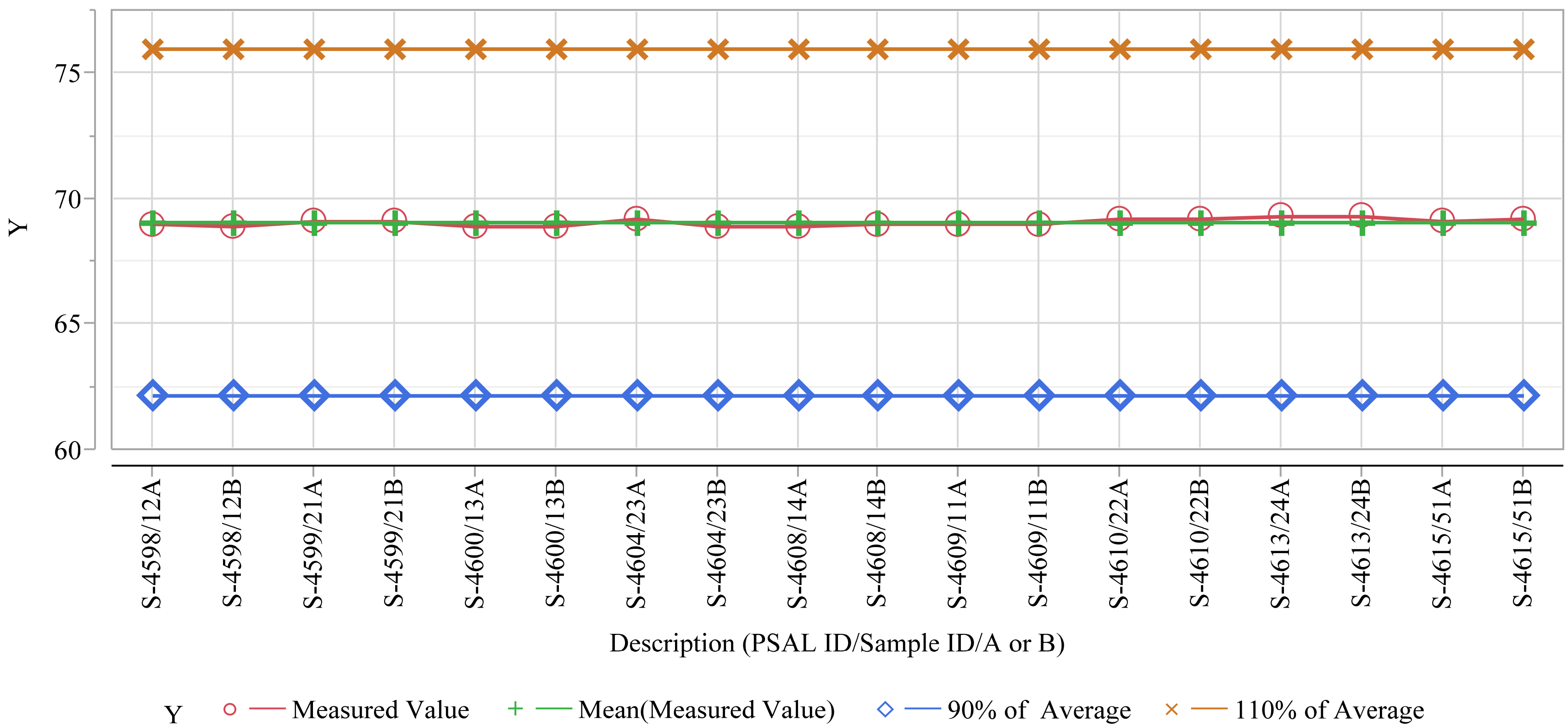
Overlay Plot Test=LAW HB, Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%



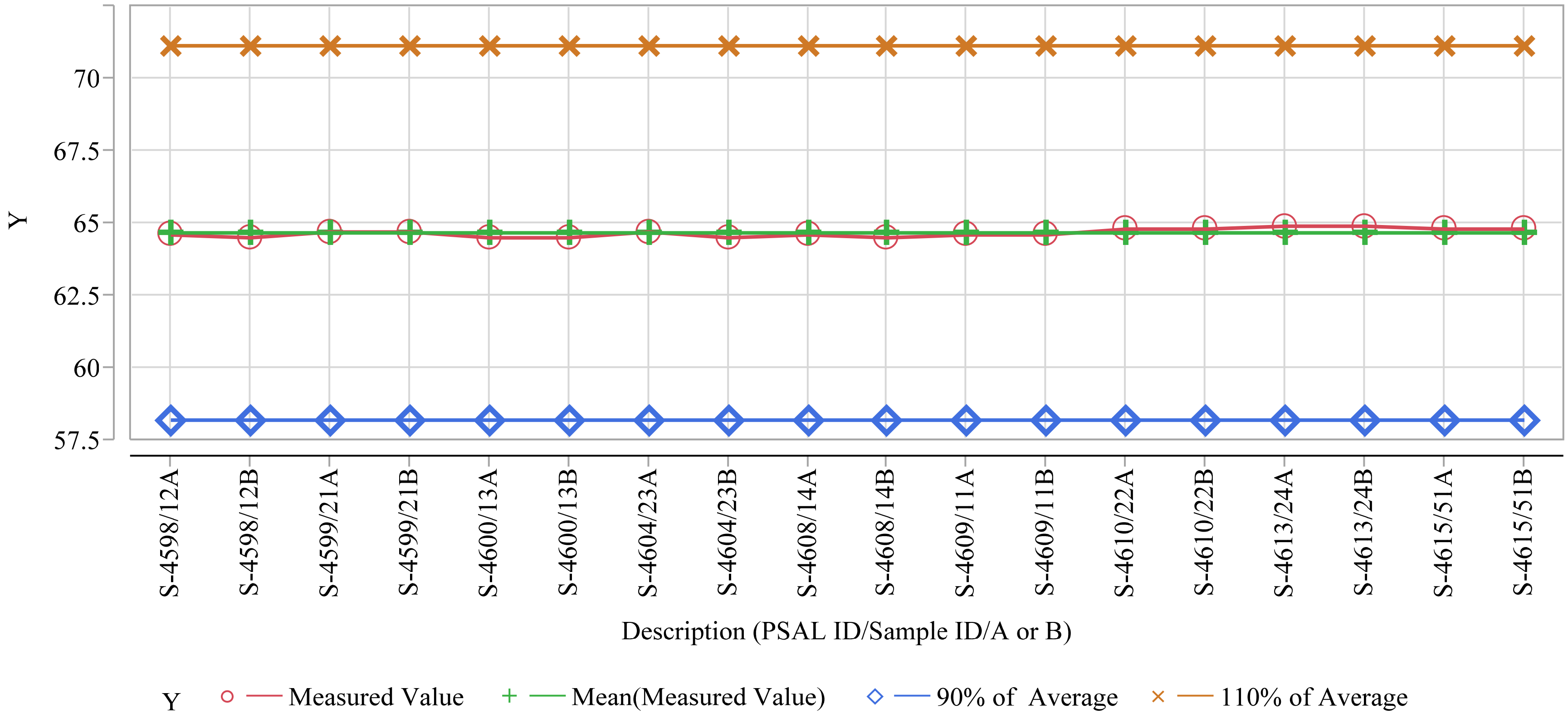
Overlay Plot Test=LAW HB, Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%



Overlay Plot Test=LAW HB, Type=physical property, Analyte=Total Solids, Unit of Measure=wt%



Overlay Plot Test=LAW HB, Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%



Overlay Plot Test=LAW HB, Type=slurry, Analyte=Al2O3, Unit of Measure=wt%

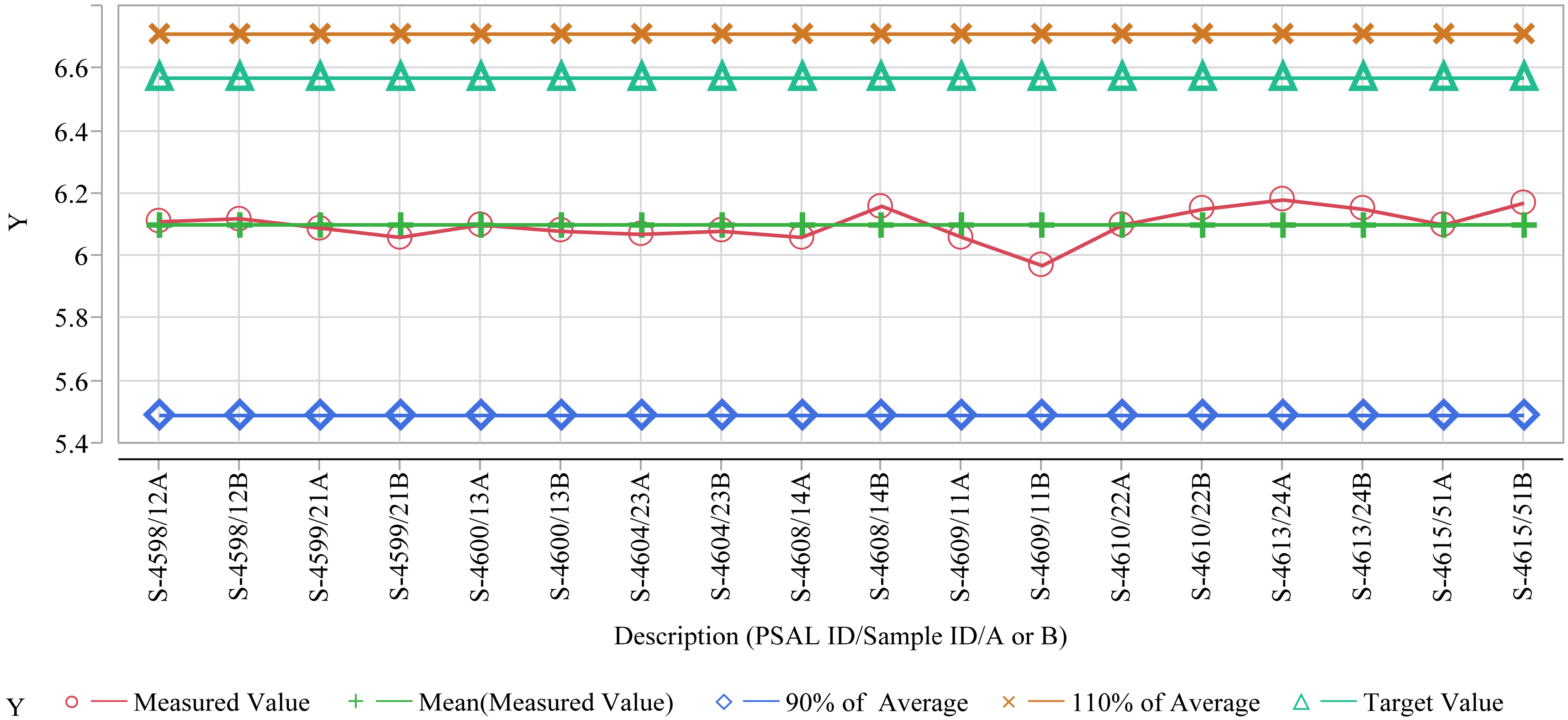
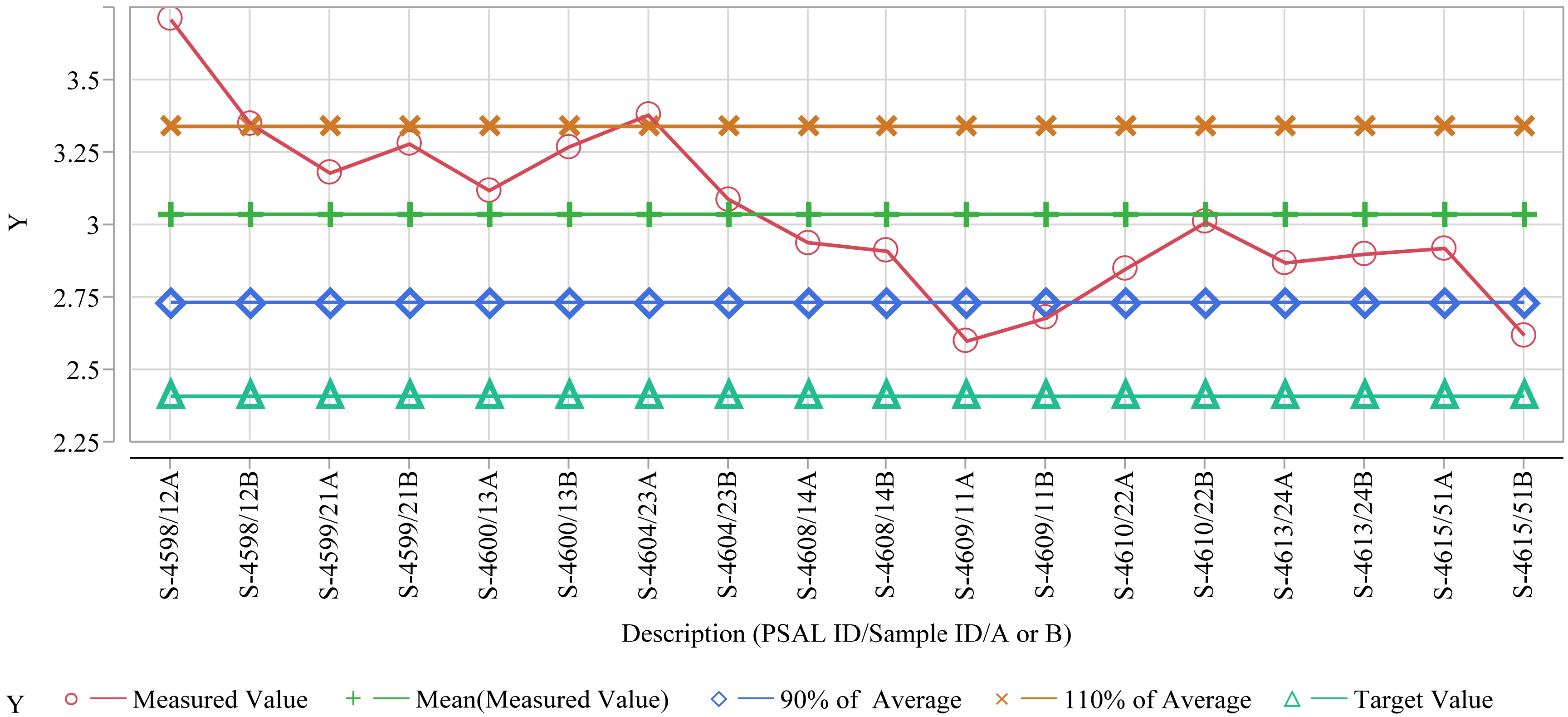


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

Overlay Plot Test=LAW HB, Type=slurry, Analyte=B2O3, Unit of Measure=wt%



Overlay Plot Test=LAW HB, Type=slurry, Analyte=CaO, Unit of Measure=wt%

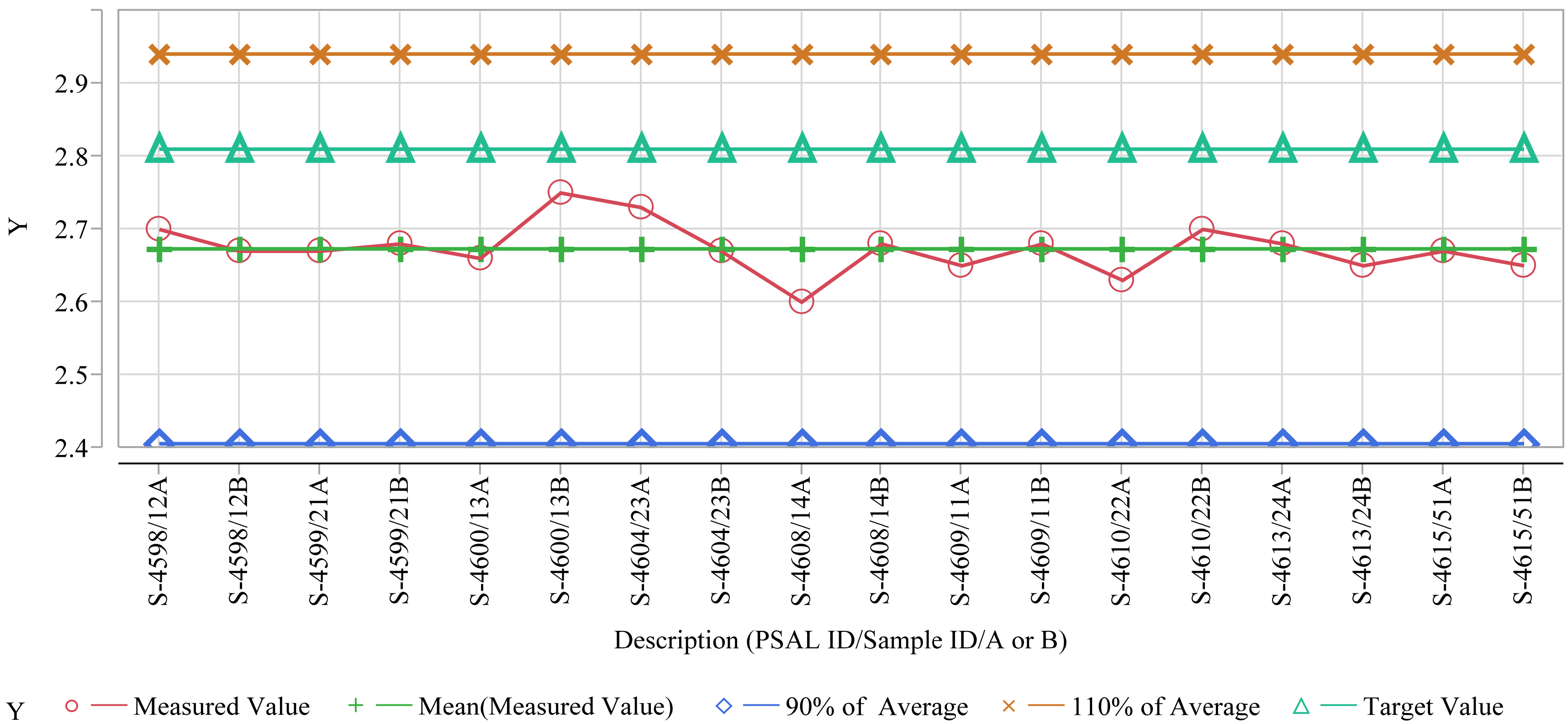
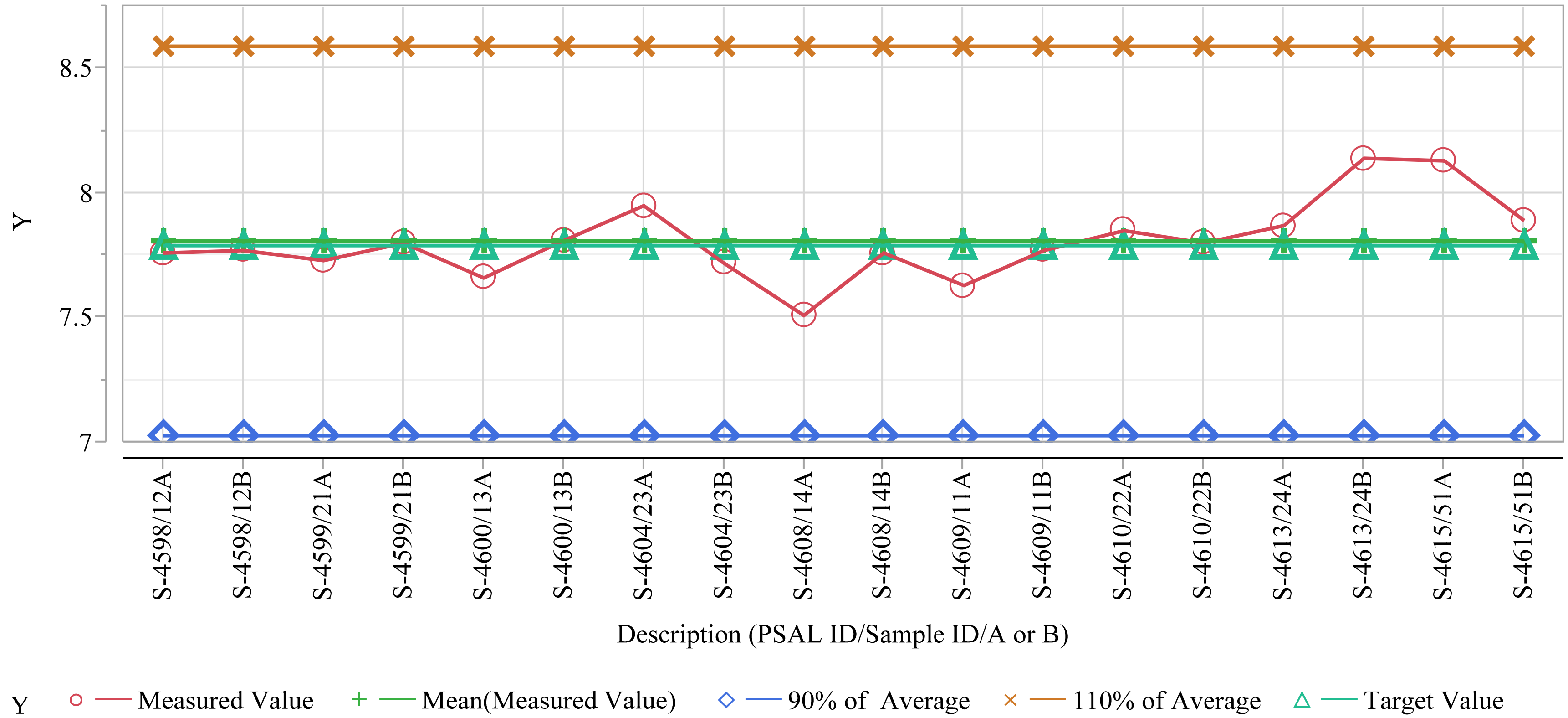
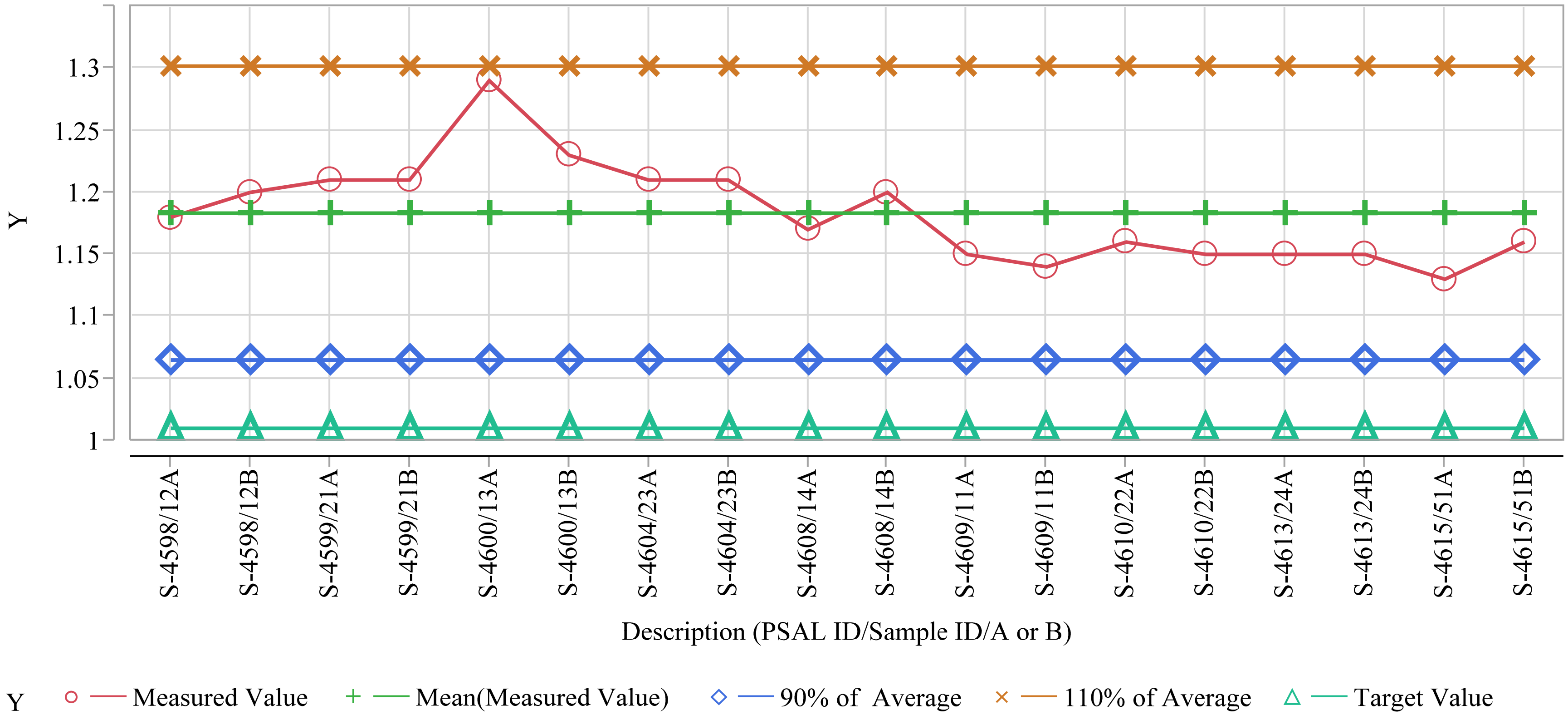


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

Overlay Plot Test=LAW HB, Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%



Overlay Plot Test=LAW HB, Type=slurry, Analyte=K2O, Unit of Measure=wt%



Overlay Plot Test=LAW HB, Type=slurry, Analyte=MgO, Unit of Measure=wt%

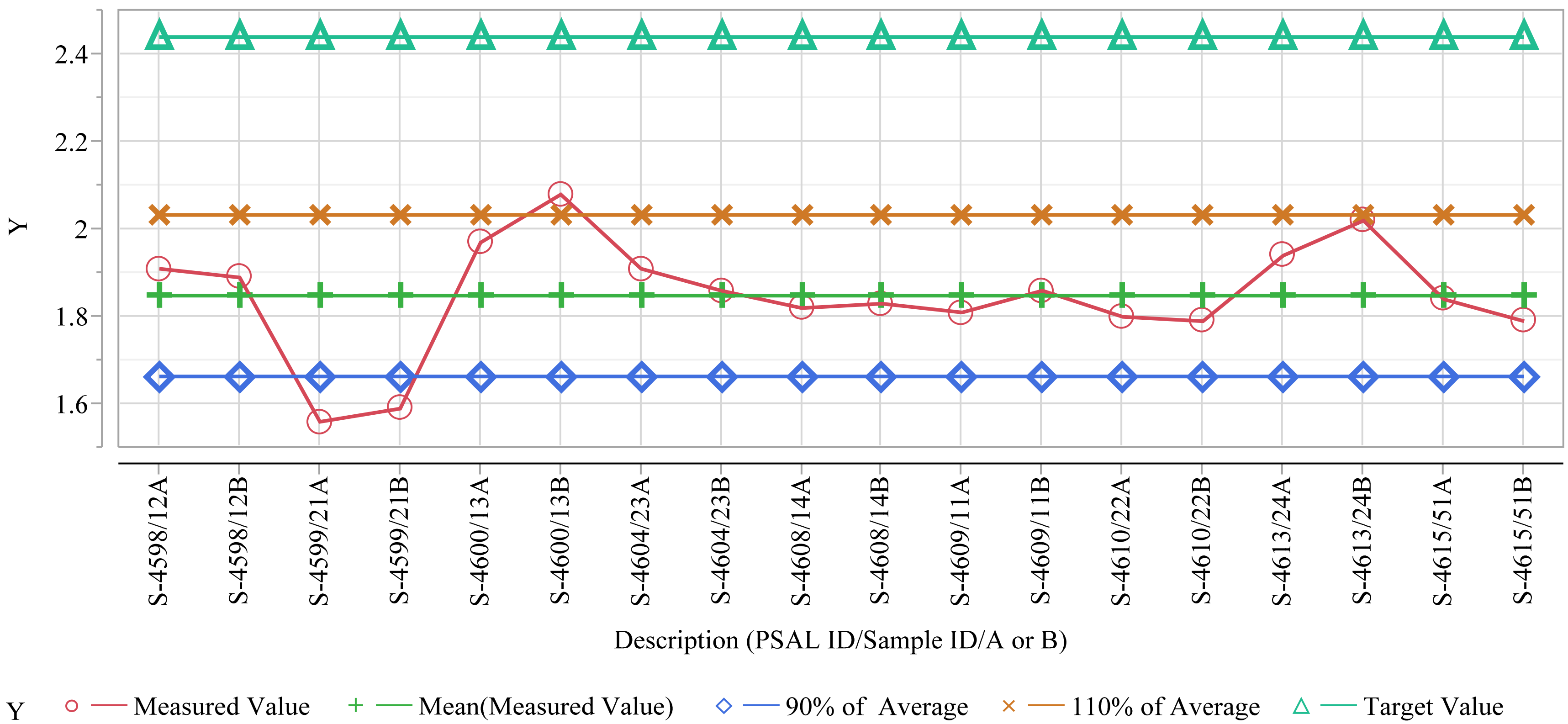
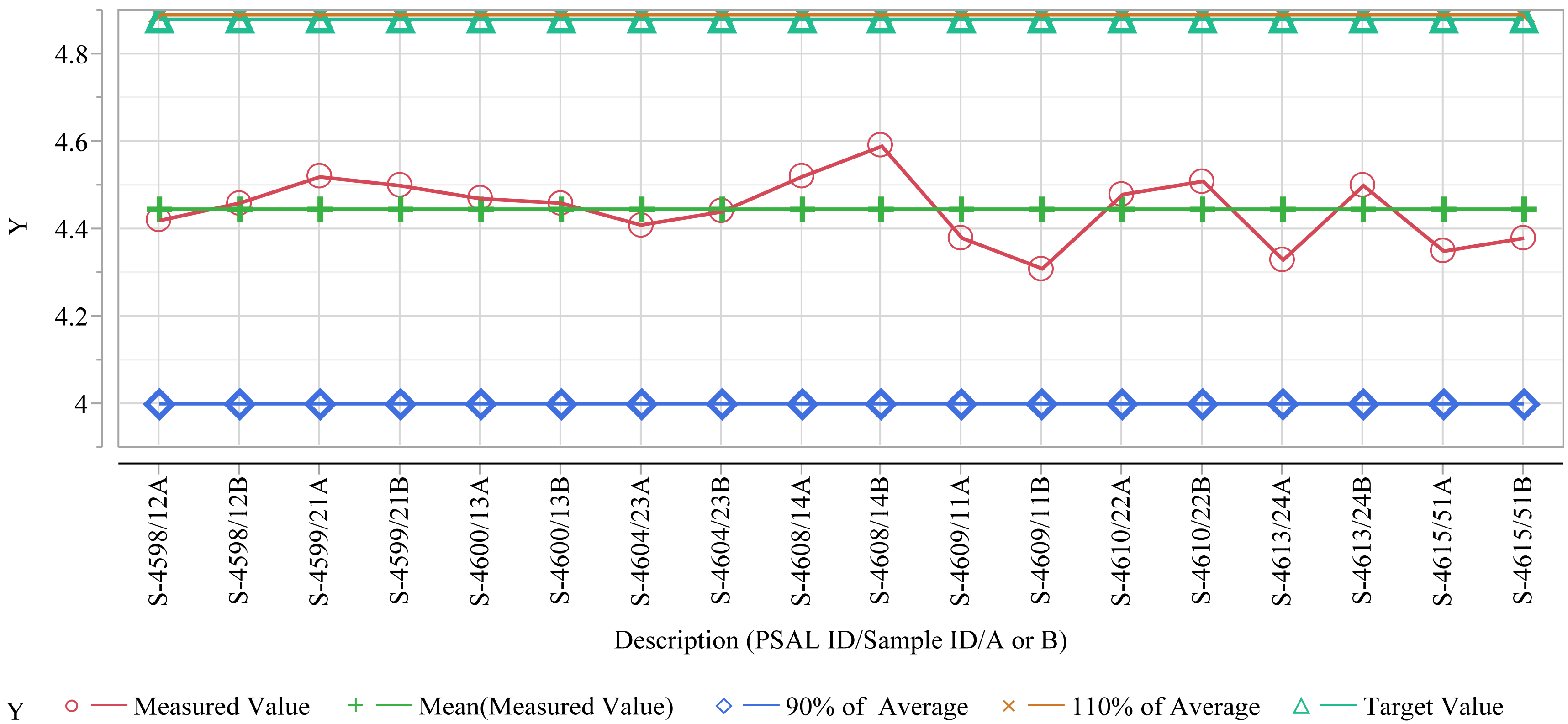
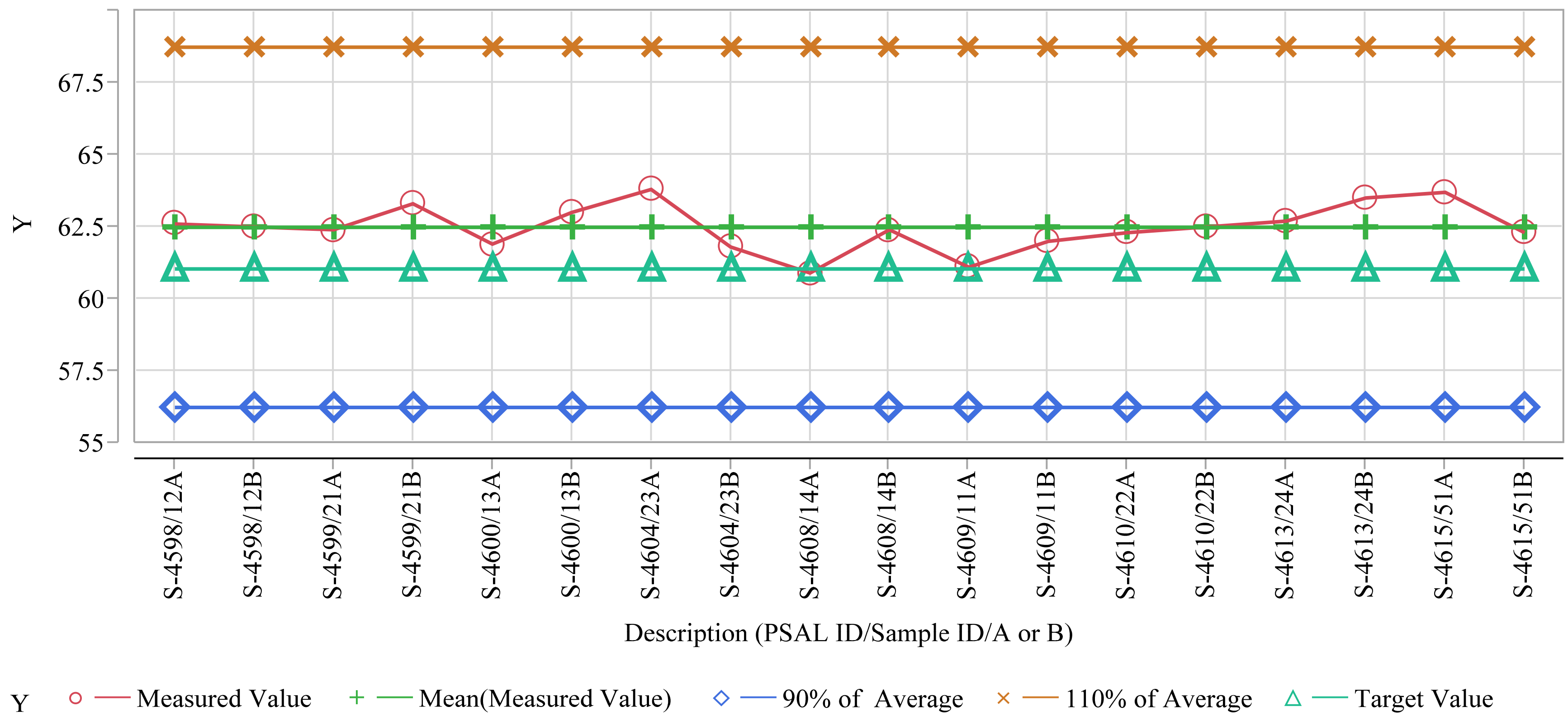


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

Overlay Plot Test=LAW HB, Type=slurry, Analyte=Na2O, Unit of Measure=wt%



Overlay Plot Test=LAW HB, Type=slurry, Analyte=SiO2, Unit of Measure=wt%



Overlay Plot Test=LAW HB, Type=slurry, Analyte=TiO2, Unit of Measure=wt%

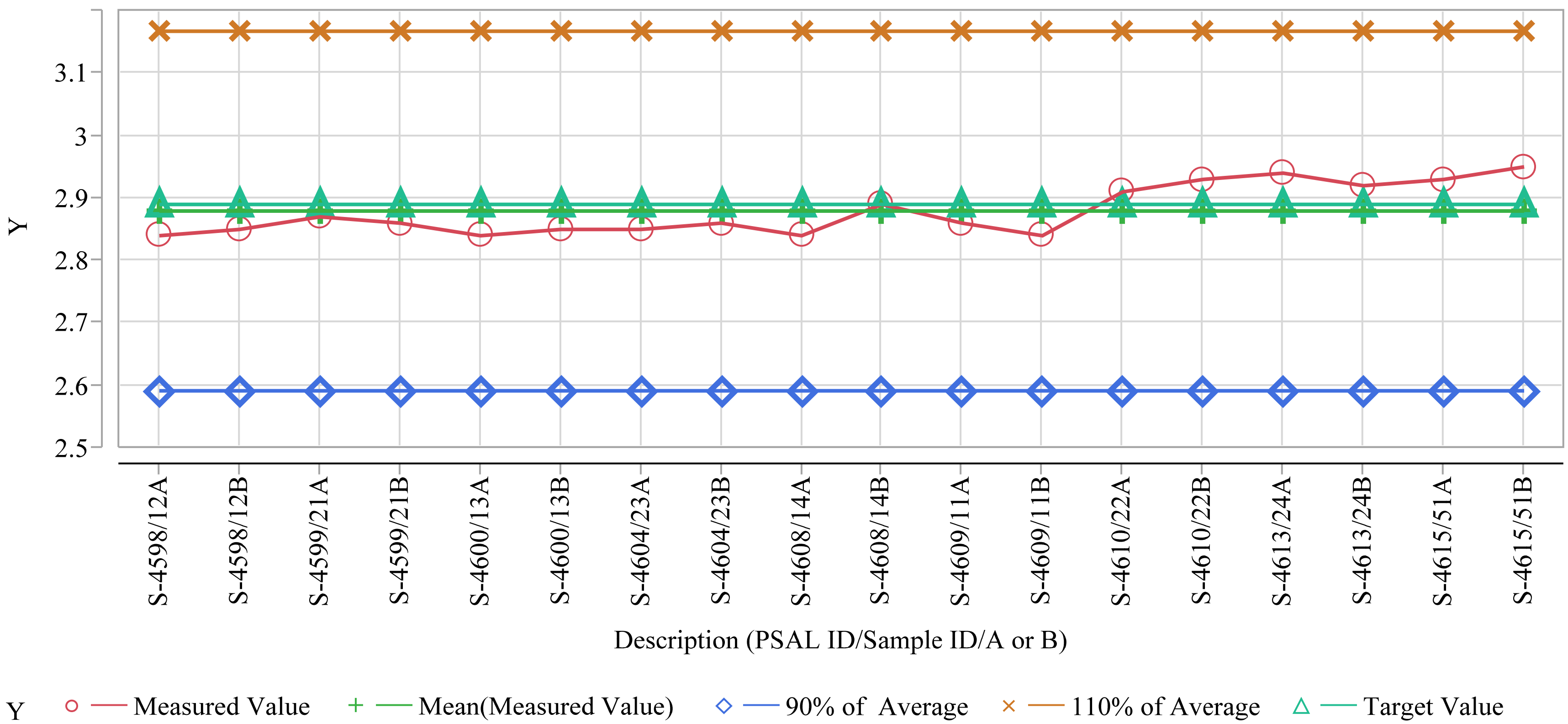
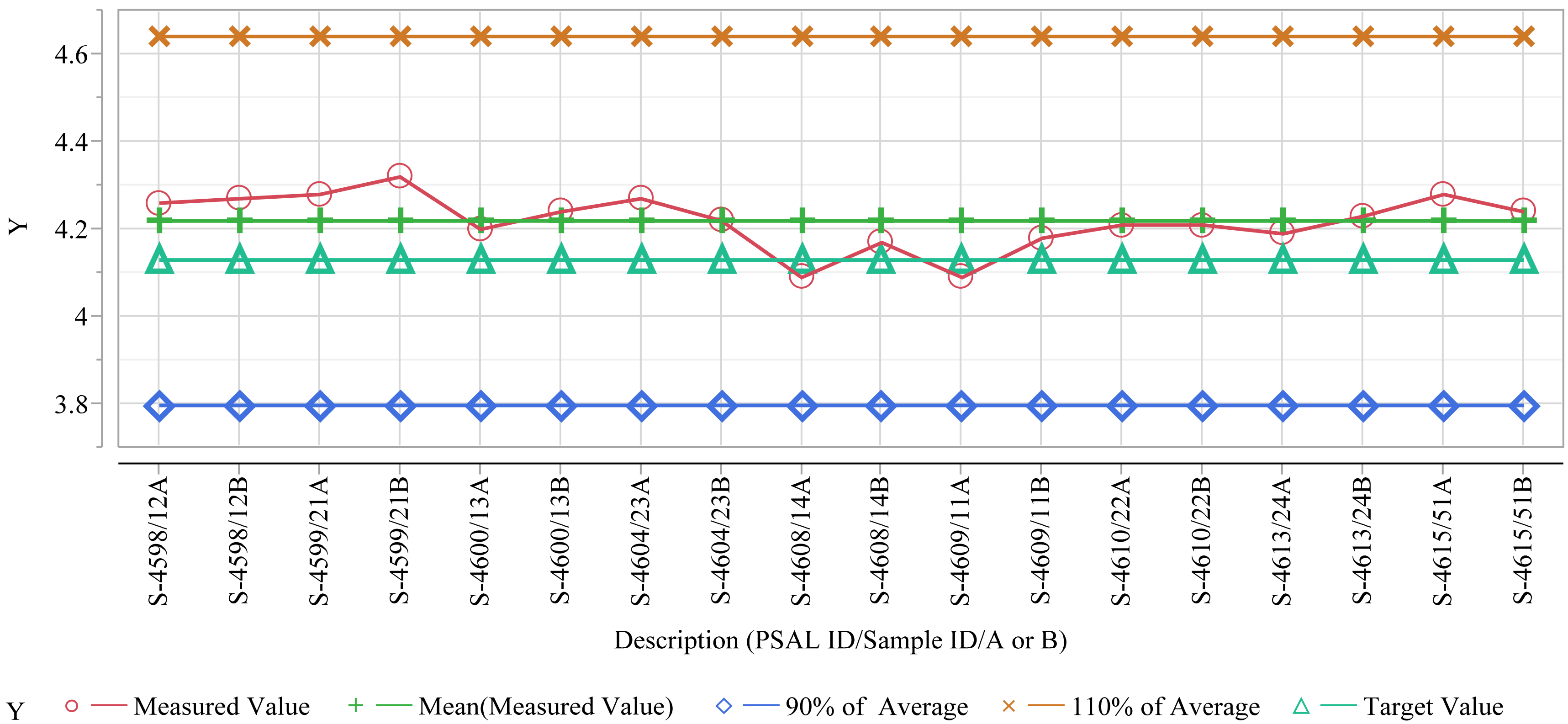
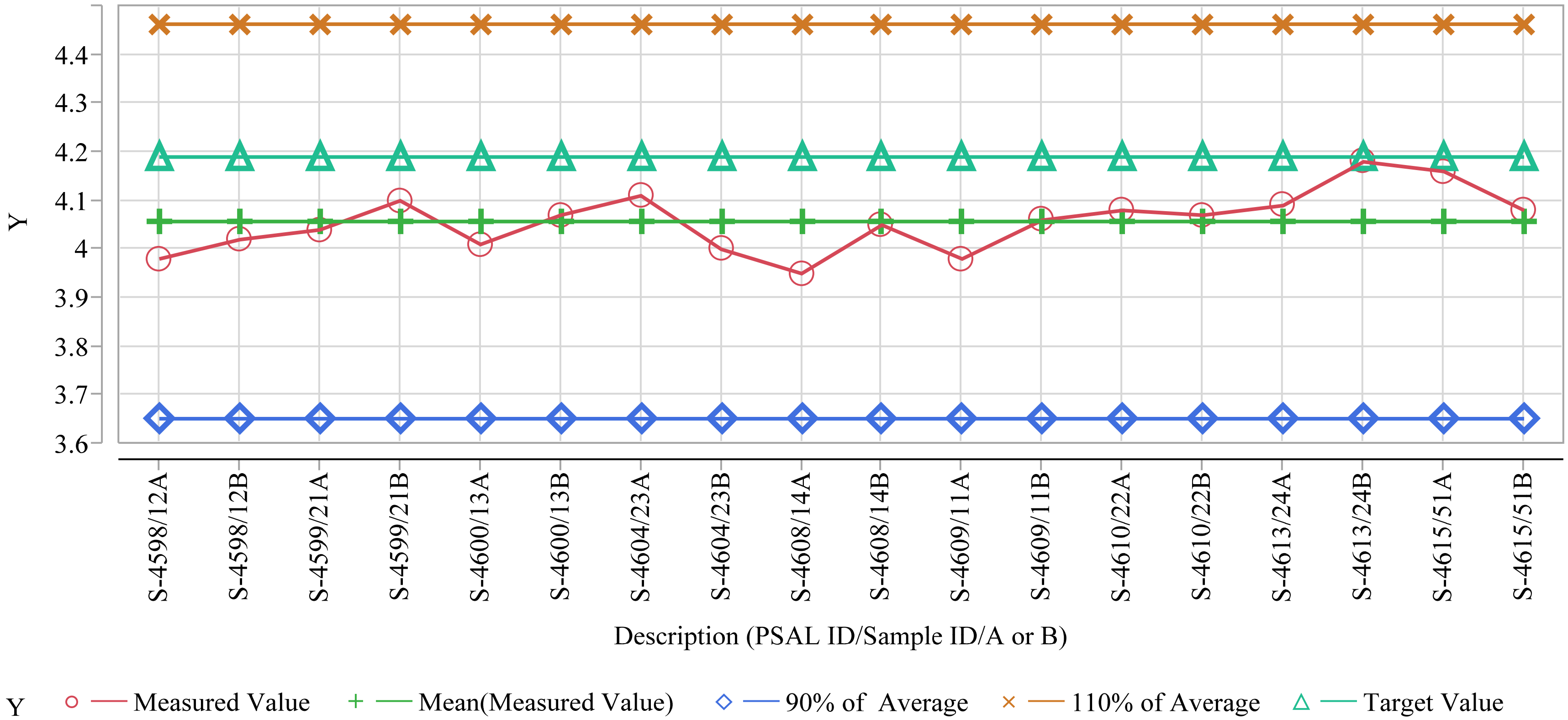


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

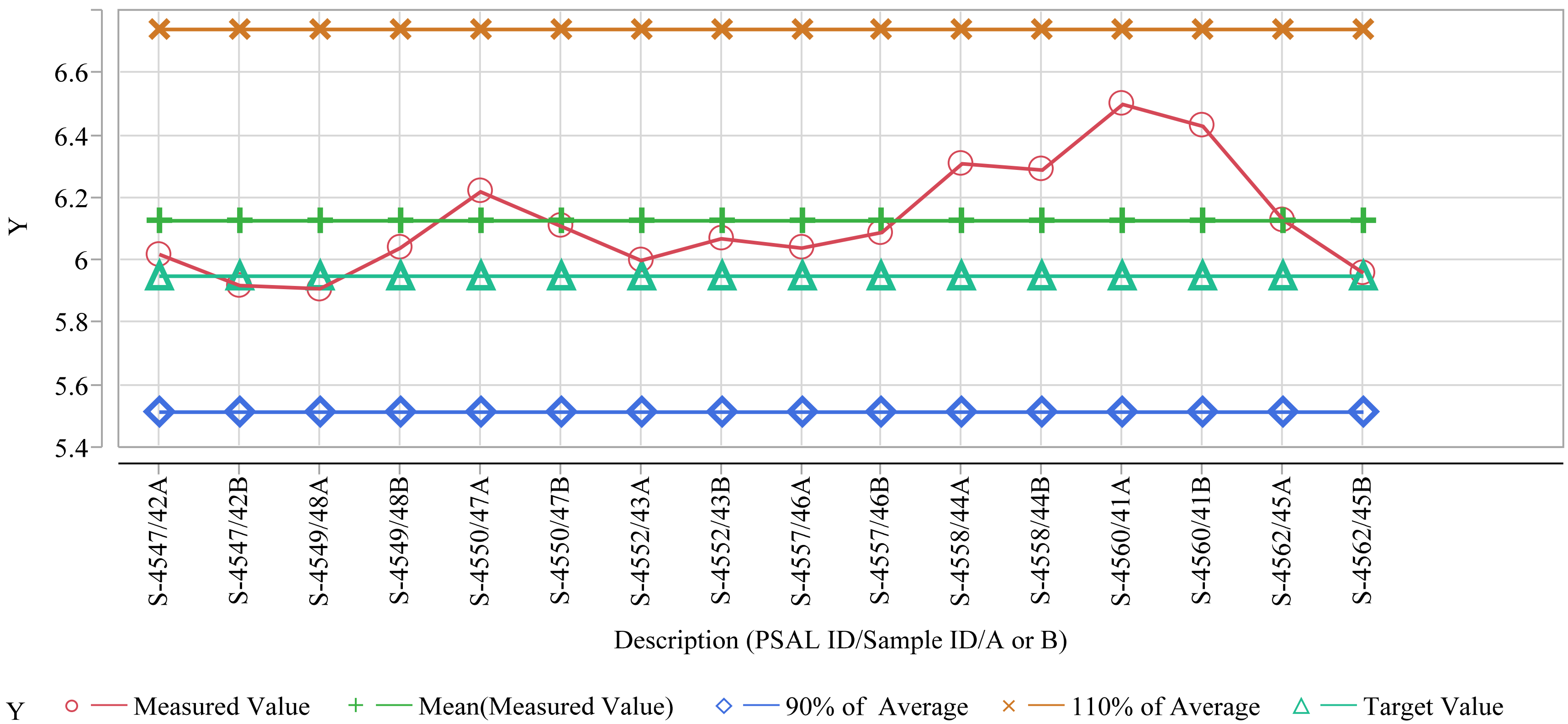
Overlay Plot Test=LAW HB, Type=slurry, Analyte=ZnO, Unit of Measure=wt%



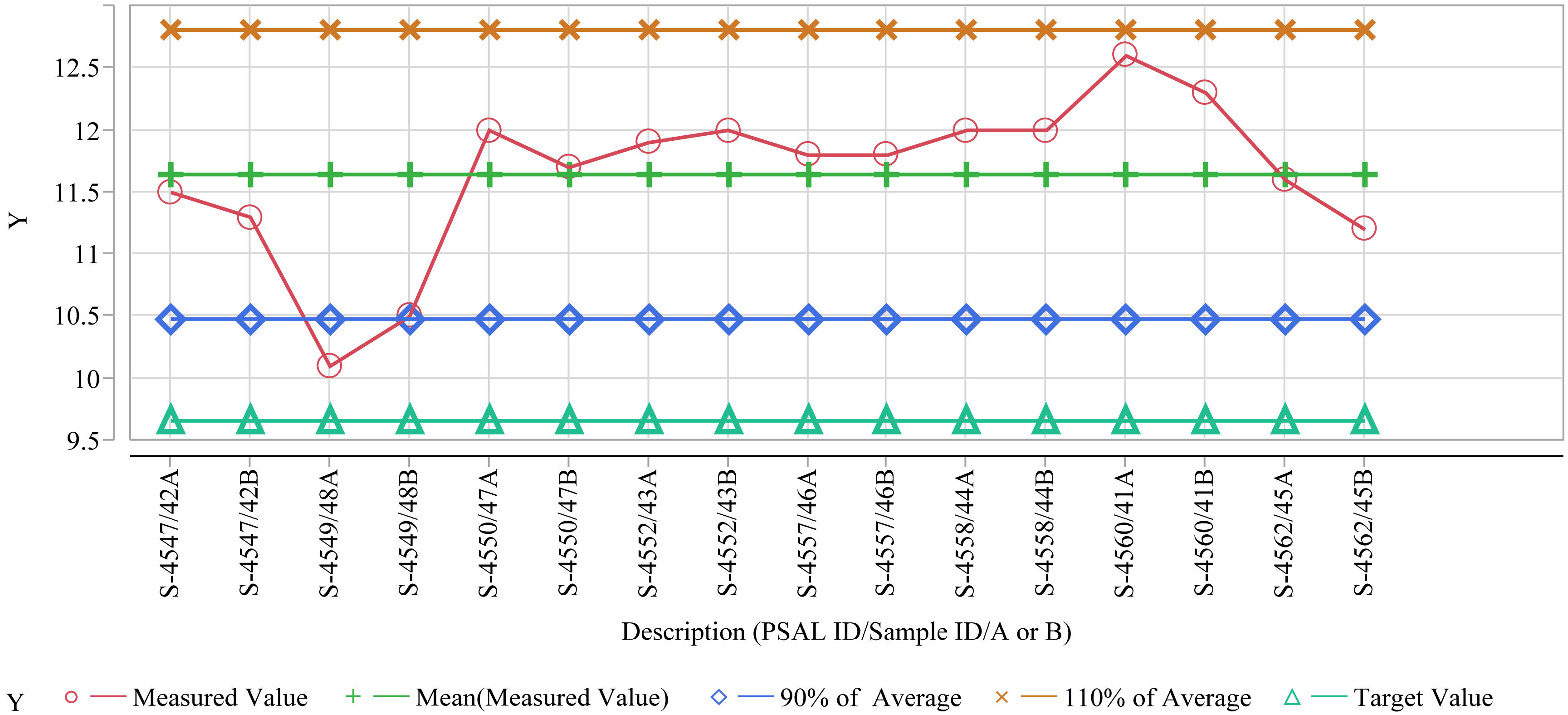
Overlay Plot Test=LAW HB, Type=slurry, Analyte=ZrO2, Unit of Measure=wt%



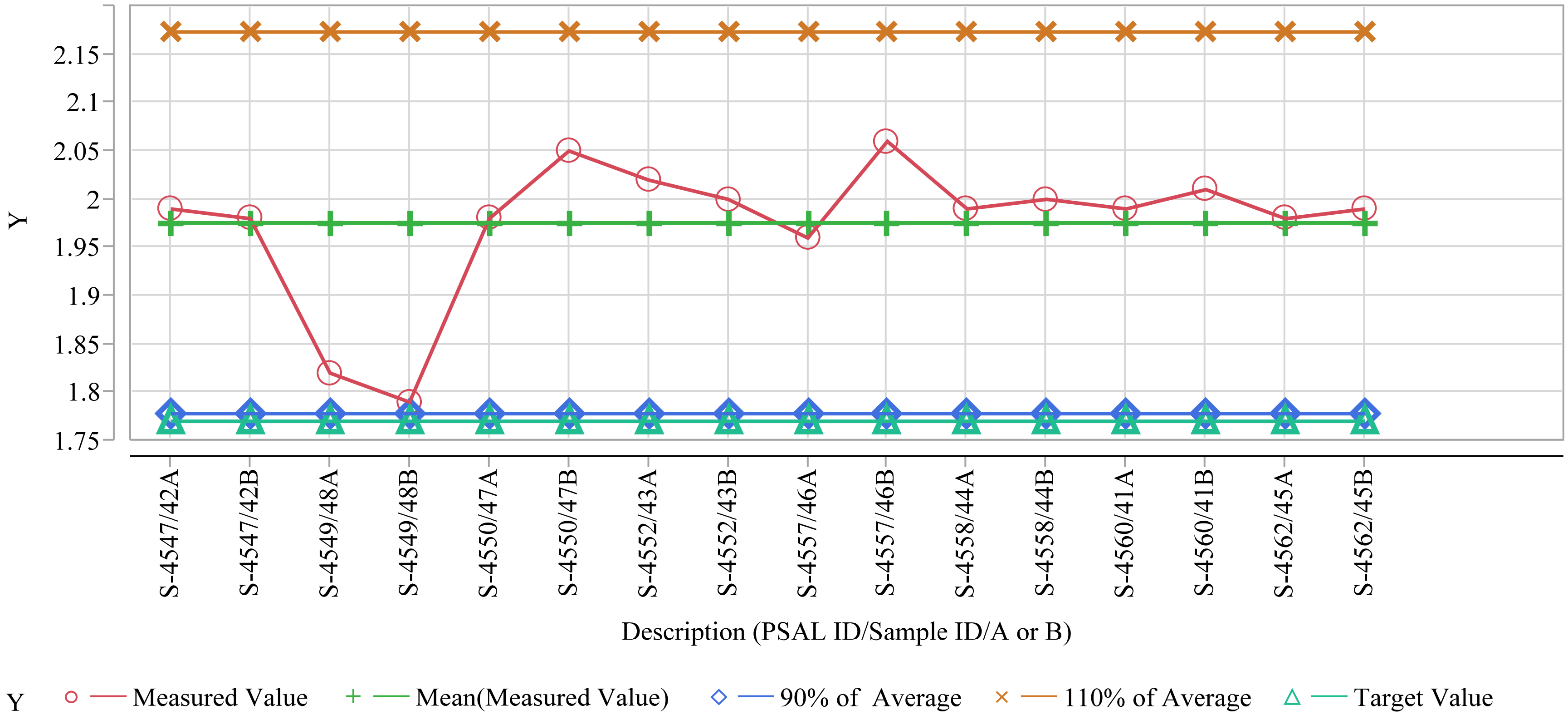
Overlay Plot Test=LAW LB, Type=glass, Analyte=Al2O3, Unit of Measure=wt%



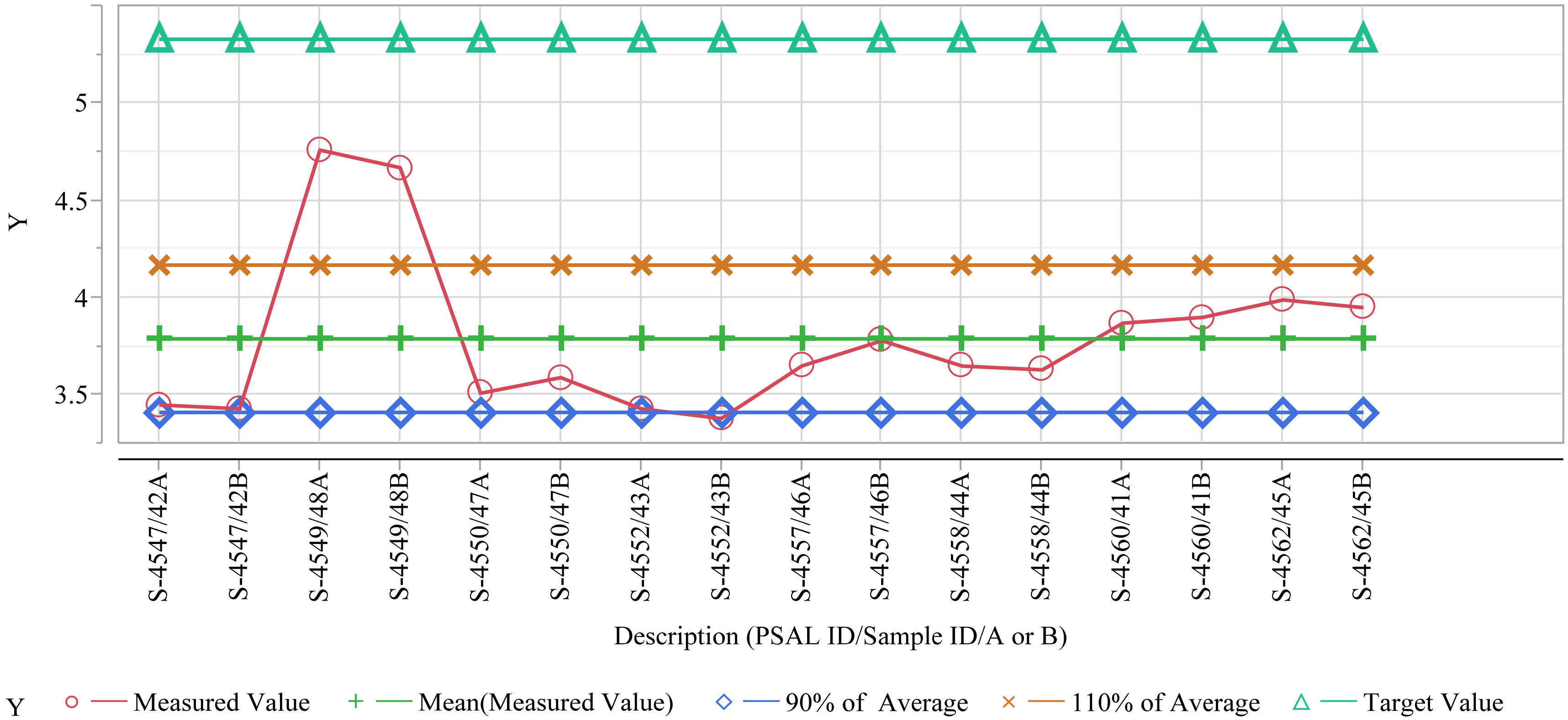
Overlay Plot Test=LAW LB, Type=glass, Analyte=B2O3, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=glass, Analyte=CaO, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=glass, Analyte=Fe2O3, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=glass, Analyte=K2O, Unit of Measure=wt%

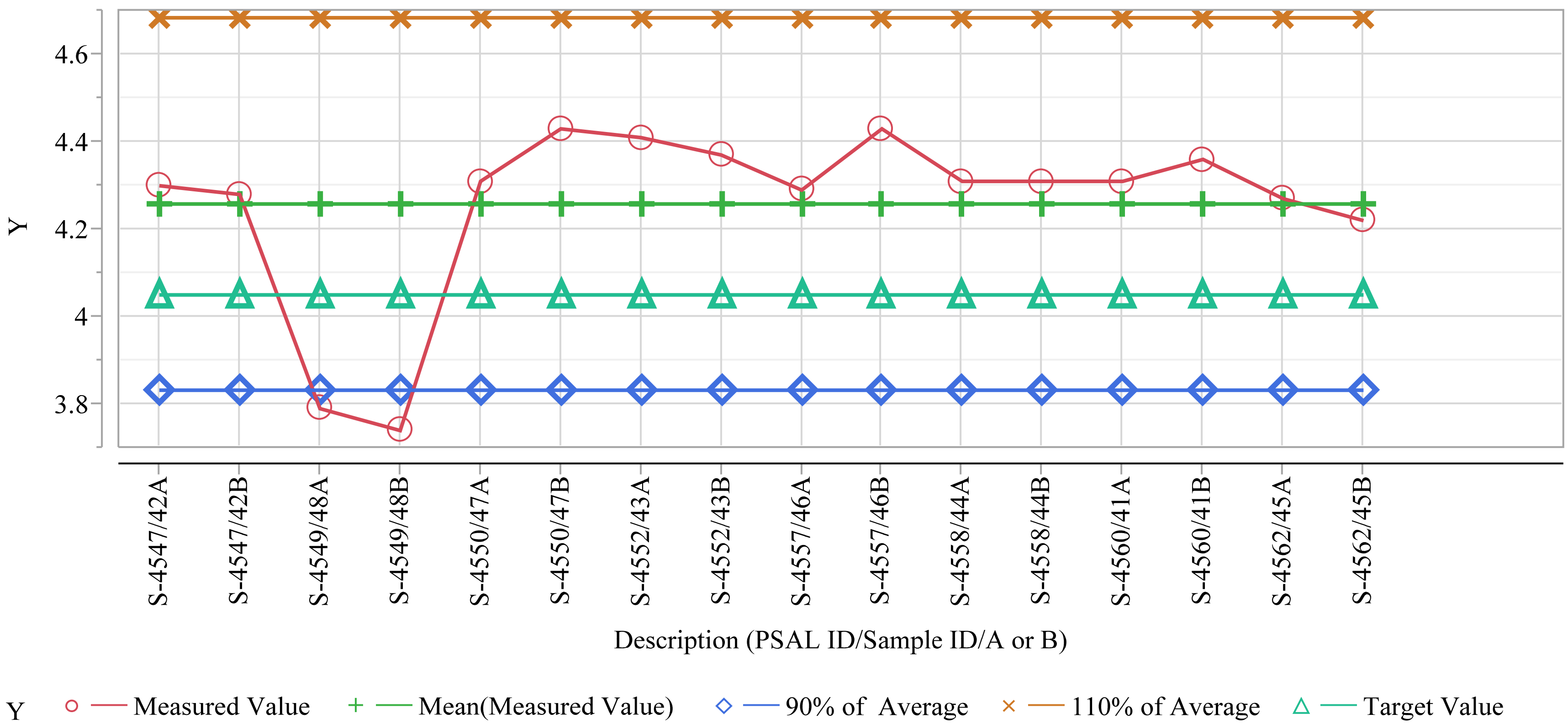


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

Overlay Plot Test=LAW LB, Type=glass, Analyte=MgO, Unit of Measure=wt%

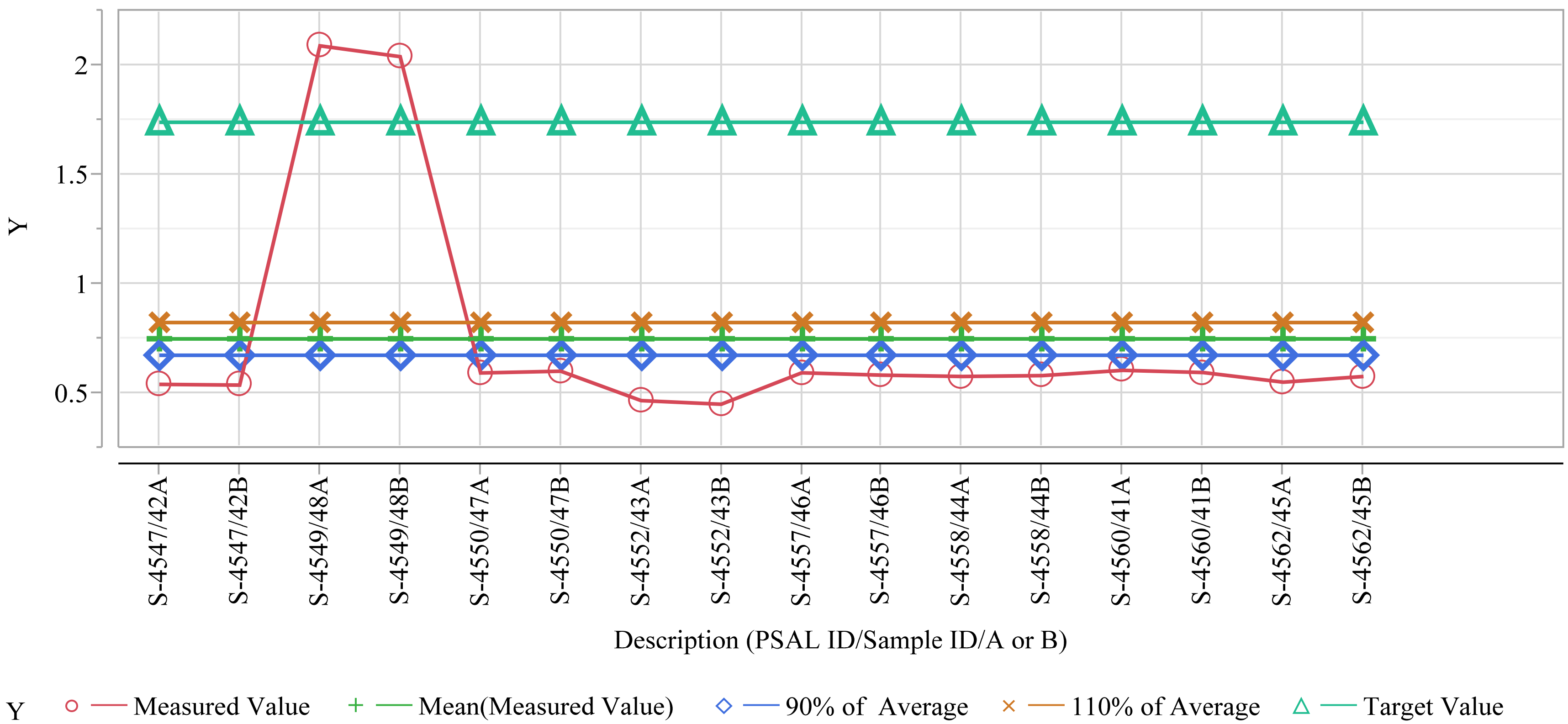
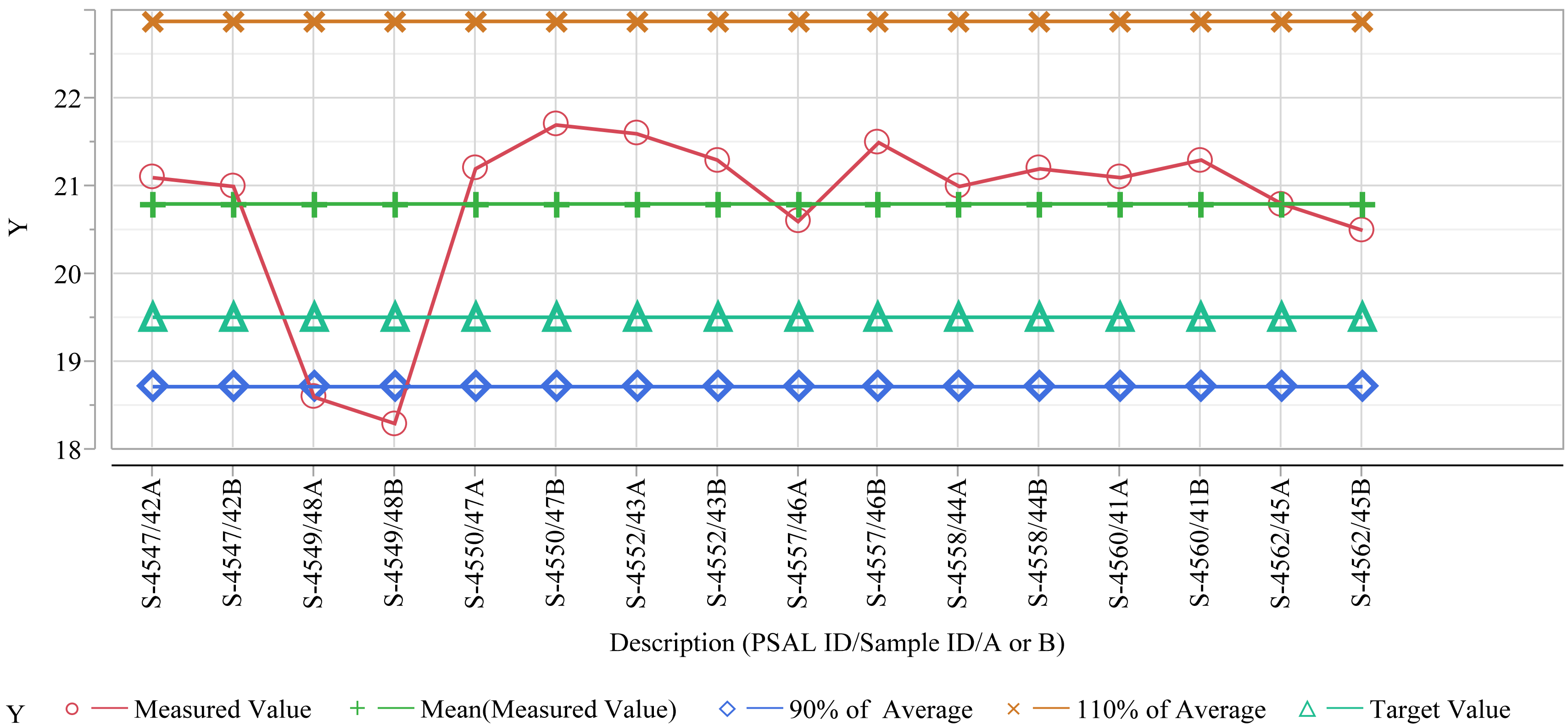
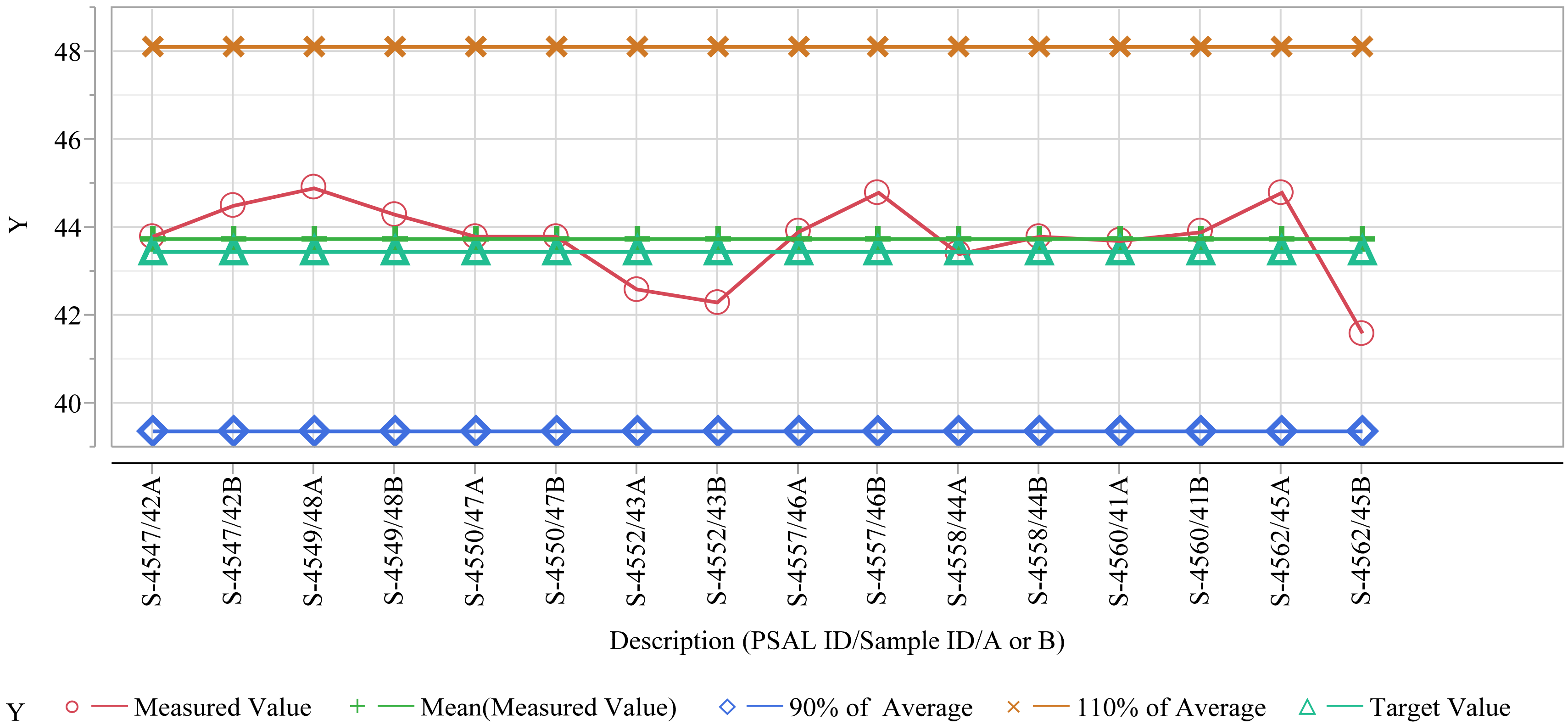


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

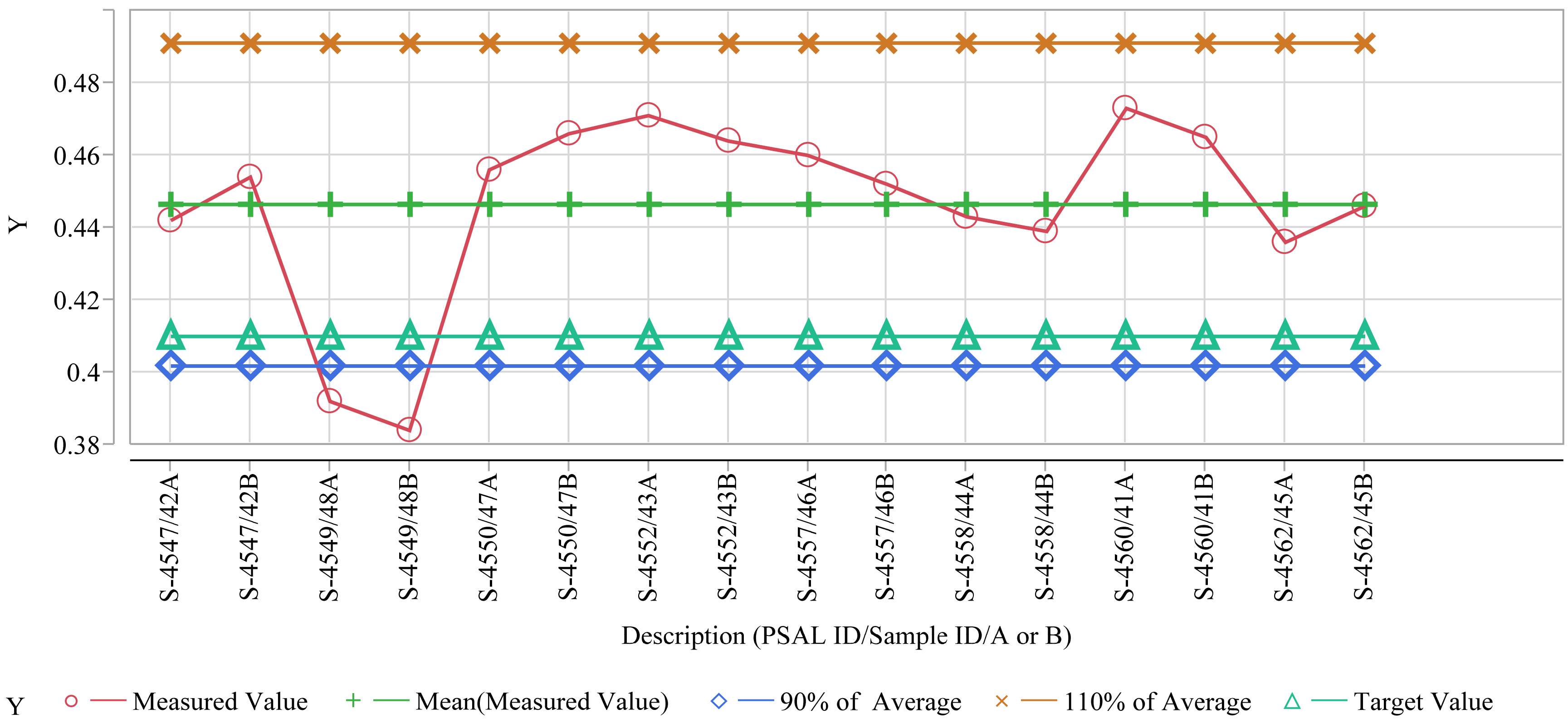
Overlay Plot Test=LAW LB, Type=glass, Analyte=Na2O, Unit of Measure=wt%



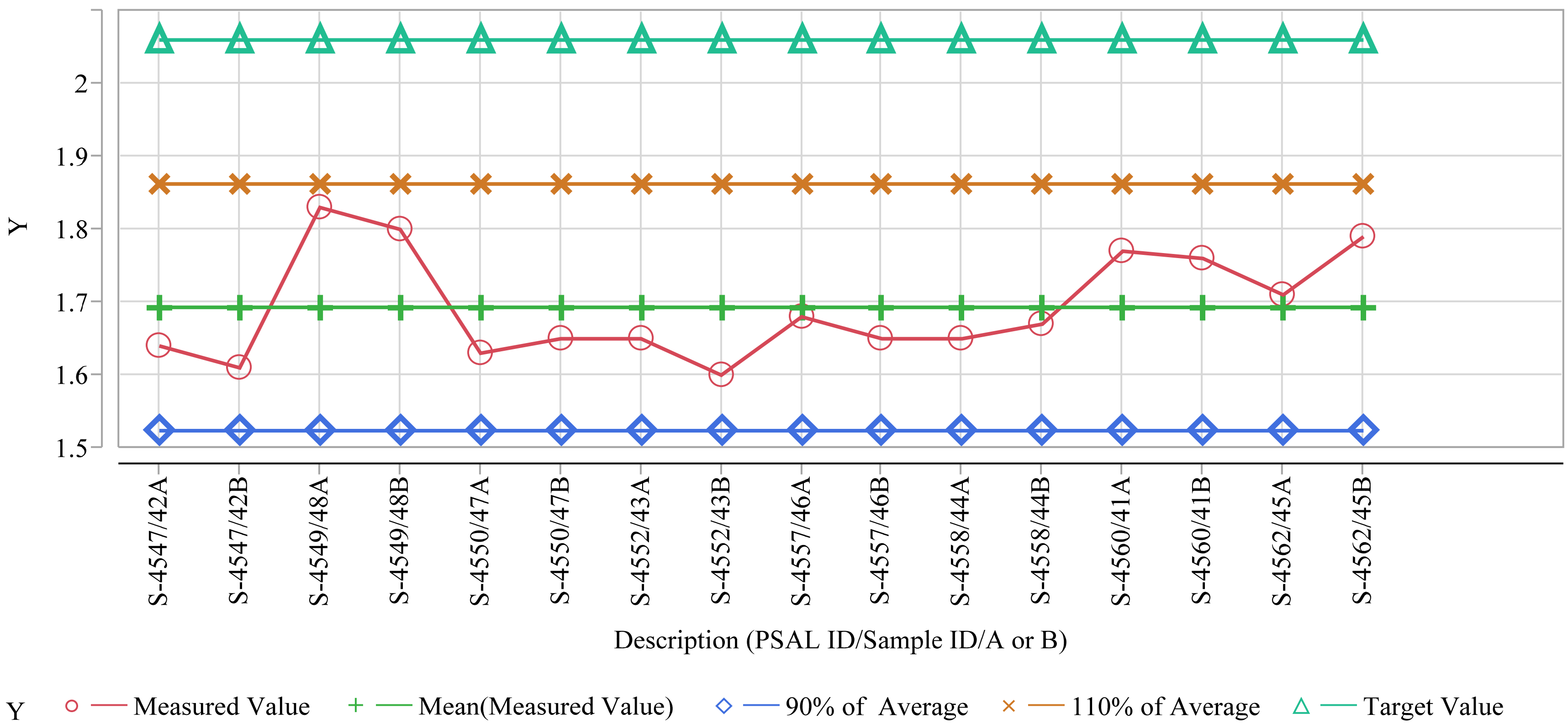
Overlay Plot Test=LAW LB, Type=glass, Analyte=SiO2, Unit of Measure=wt%



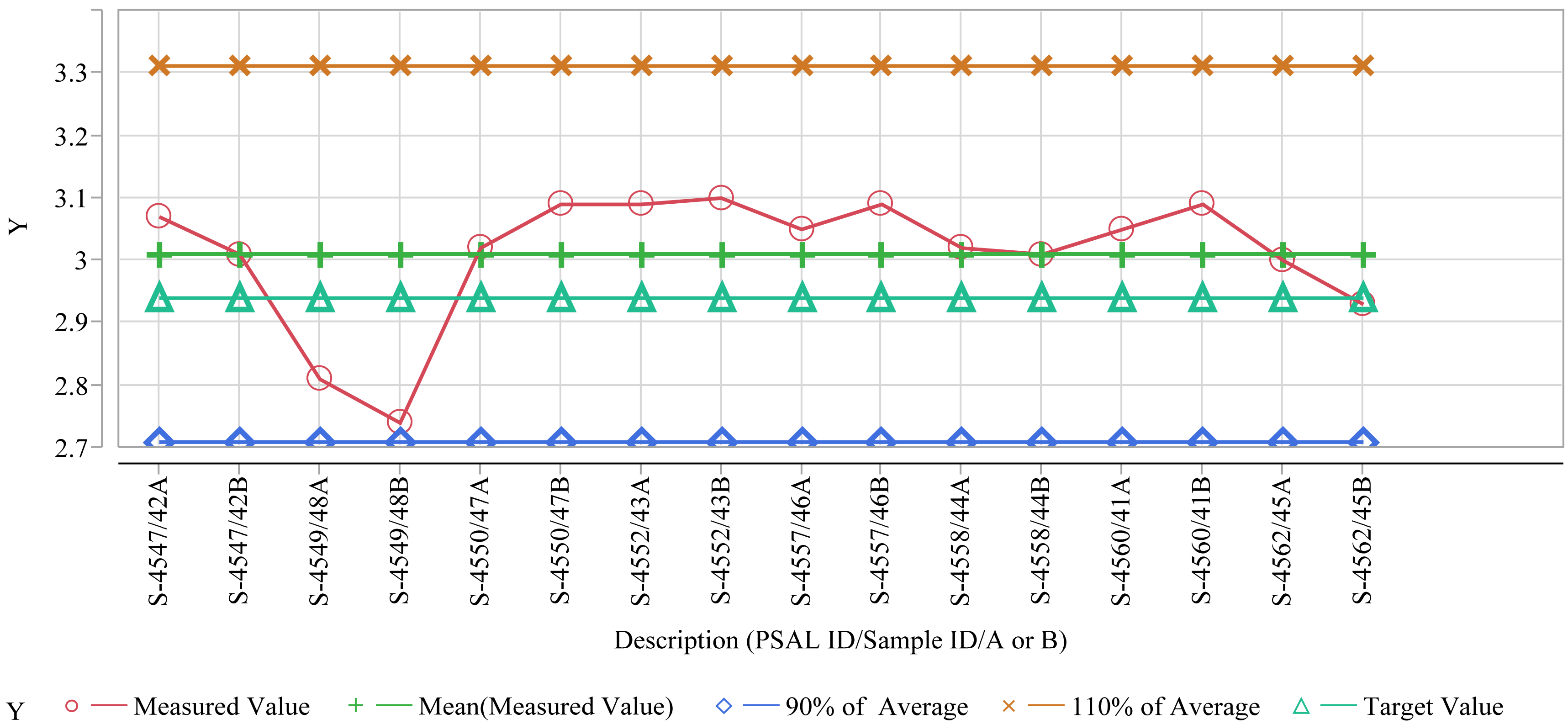
Overlay Plot Test=LAW LB, Type=glass, Analyte=SO4, Unit of Measure=wt%



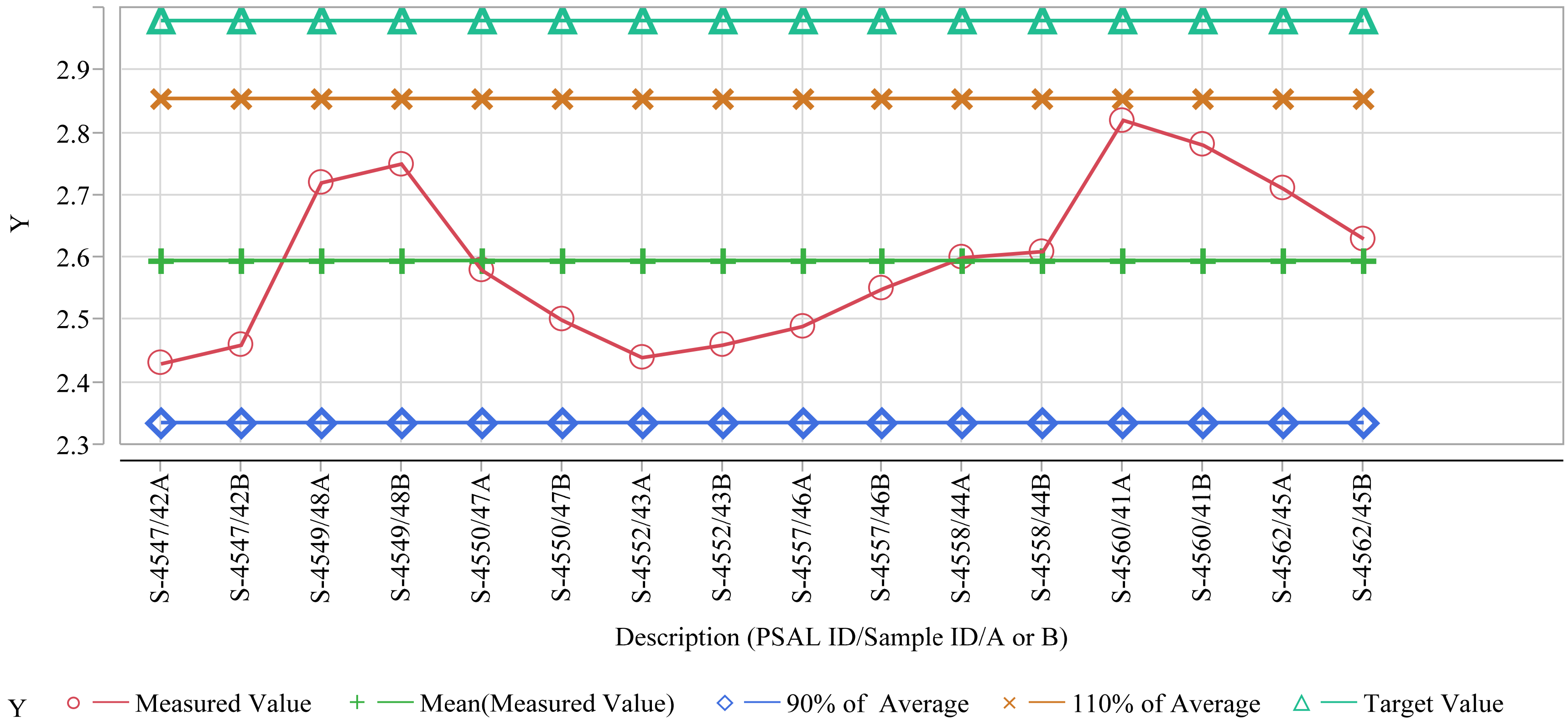
Overlay Plot Test=LAW LB, Type=glass, Analyte=TiO2, Unit of Measure=wt%



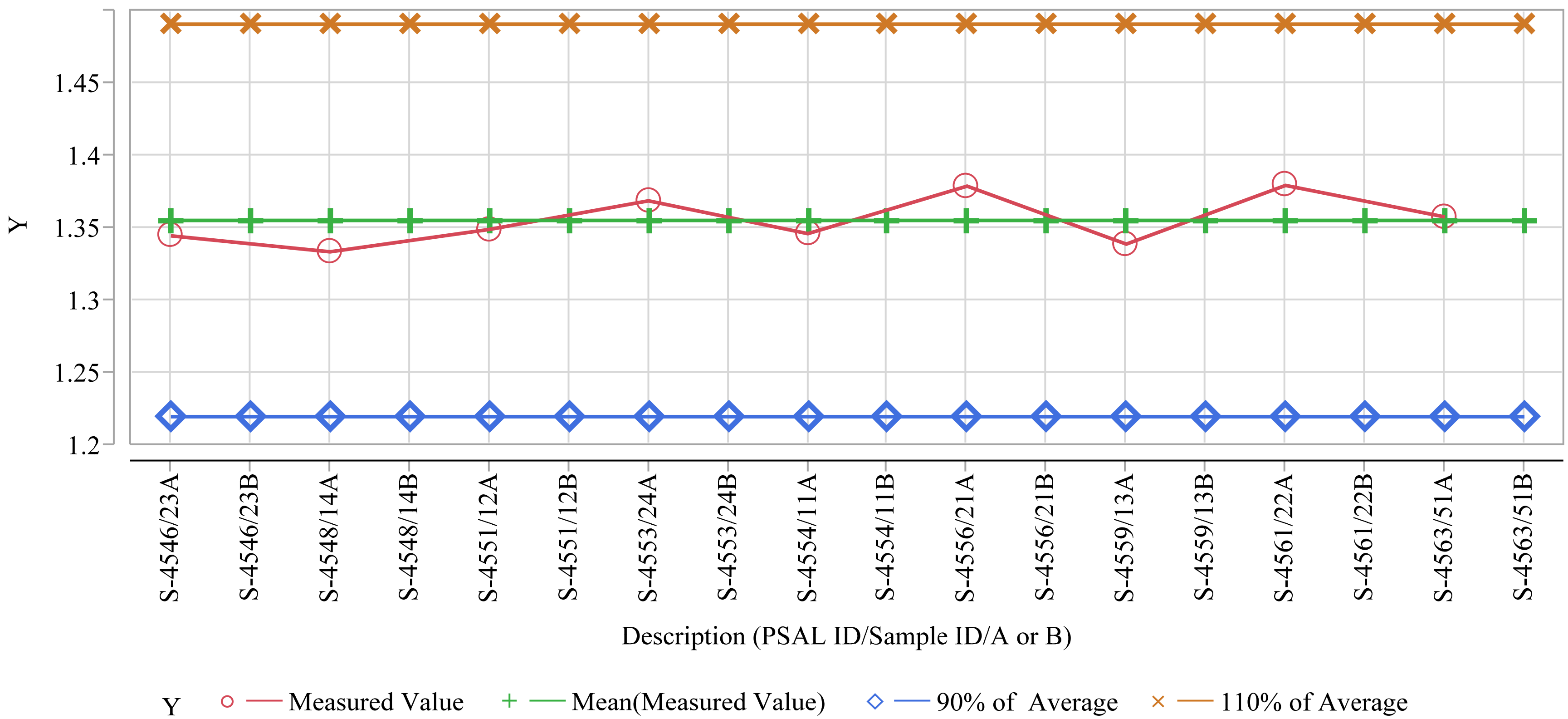
Overlay Plot Test=LAW LB, Type=glass, Analyte=ZnO, Unit of Measure=wt%



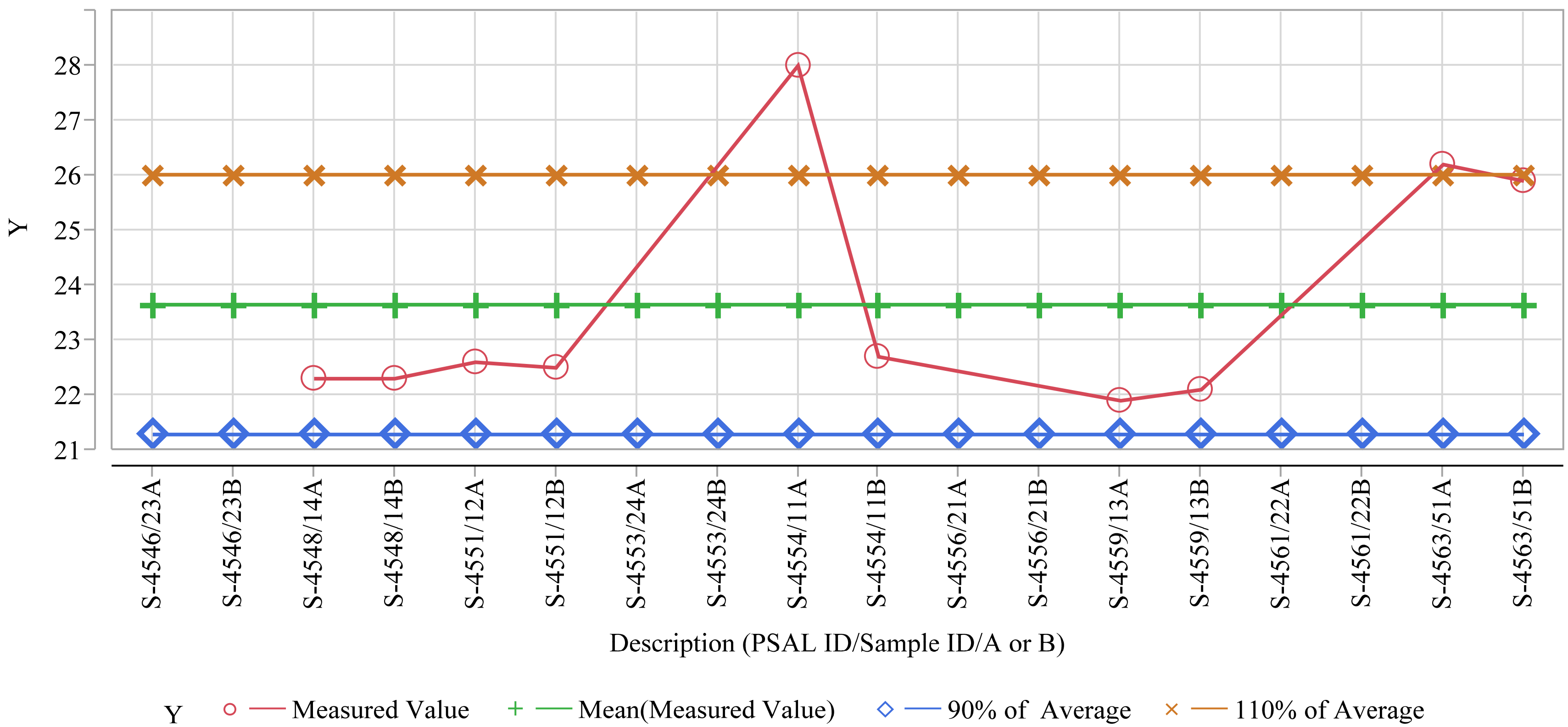
Overlay Plot Test=LAW LB, Type=glass, Analyte=ZrO2, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=physical property, Analyte=Density, Unit of Measure=g/mL



Overlay Plot Test=LAW LB, Type=physical property, Analyte=Insoluble Solids, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=physical property, Analyte=Soluble Solids, Unit of Measure=wt%

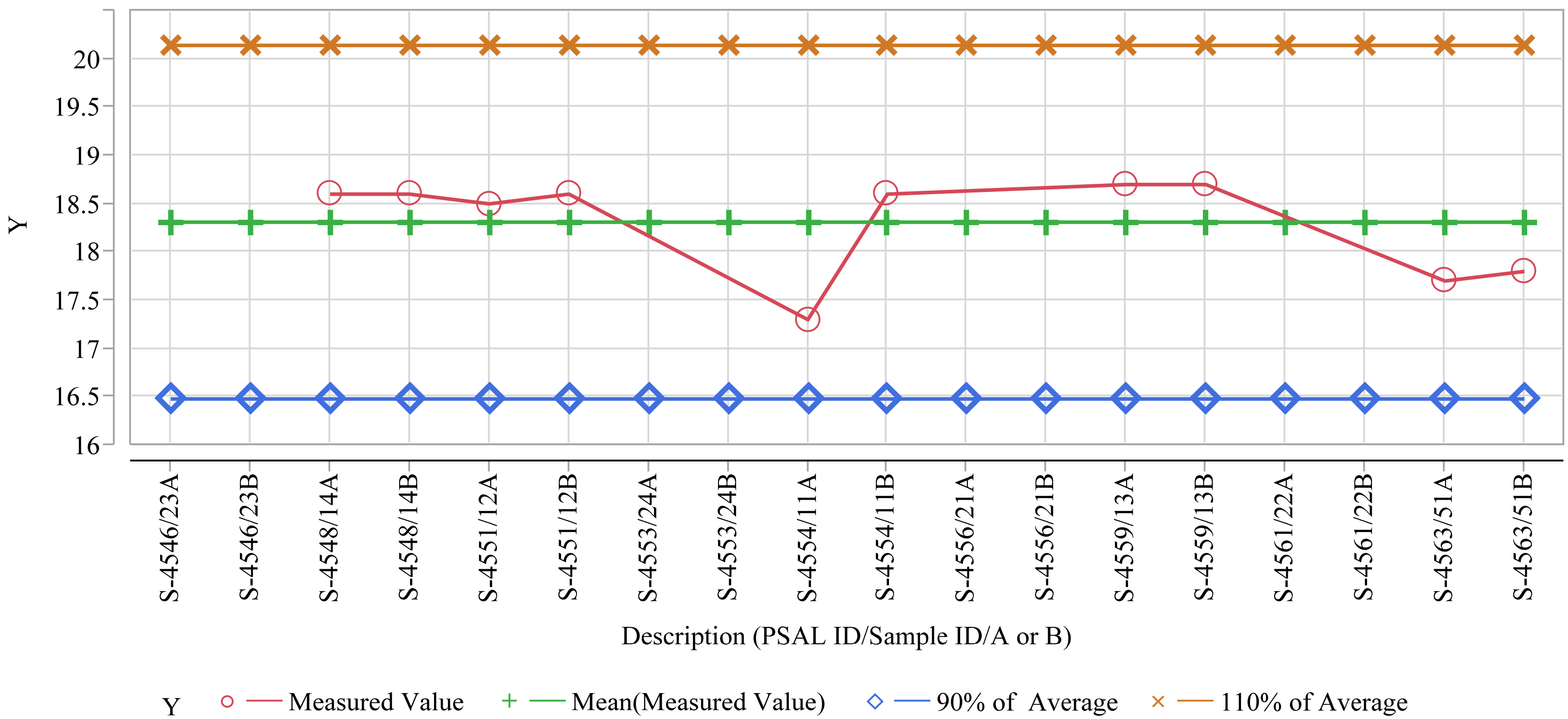


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

Overlay Plot Test=LAW LB, Type=physical property, Analyte=Total Solids, Unit of Measure=wt%

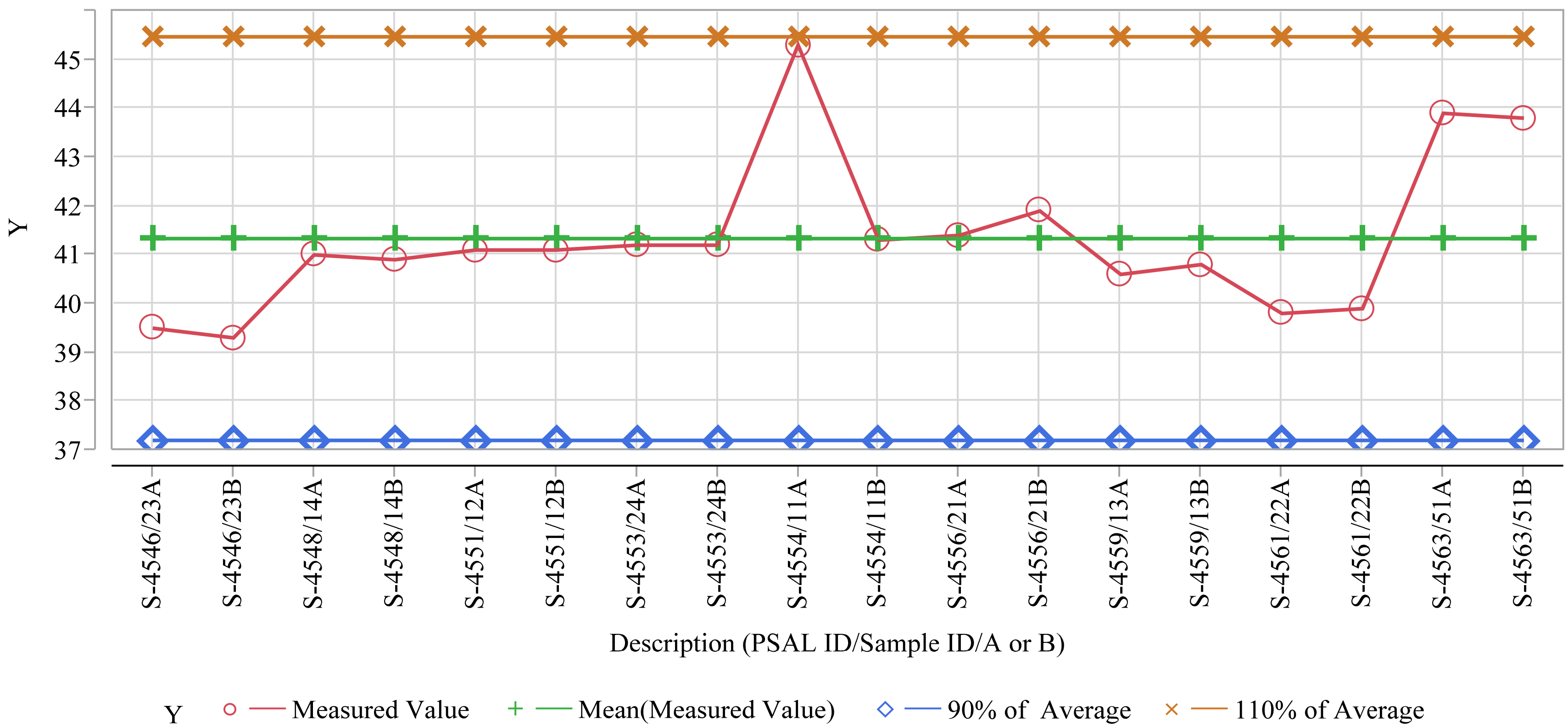
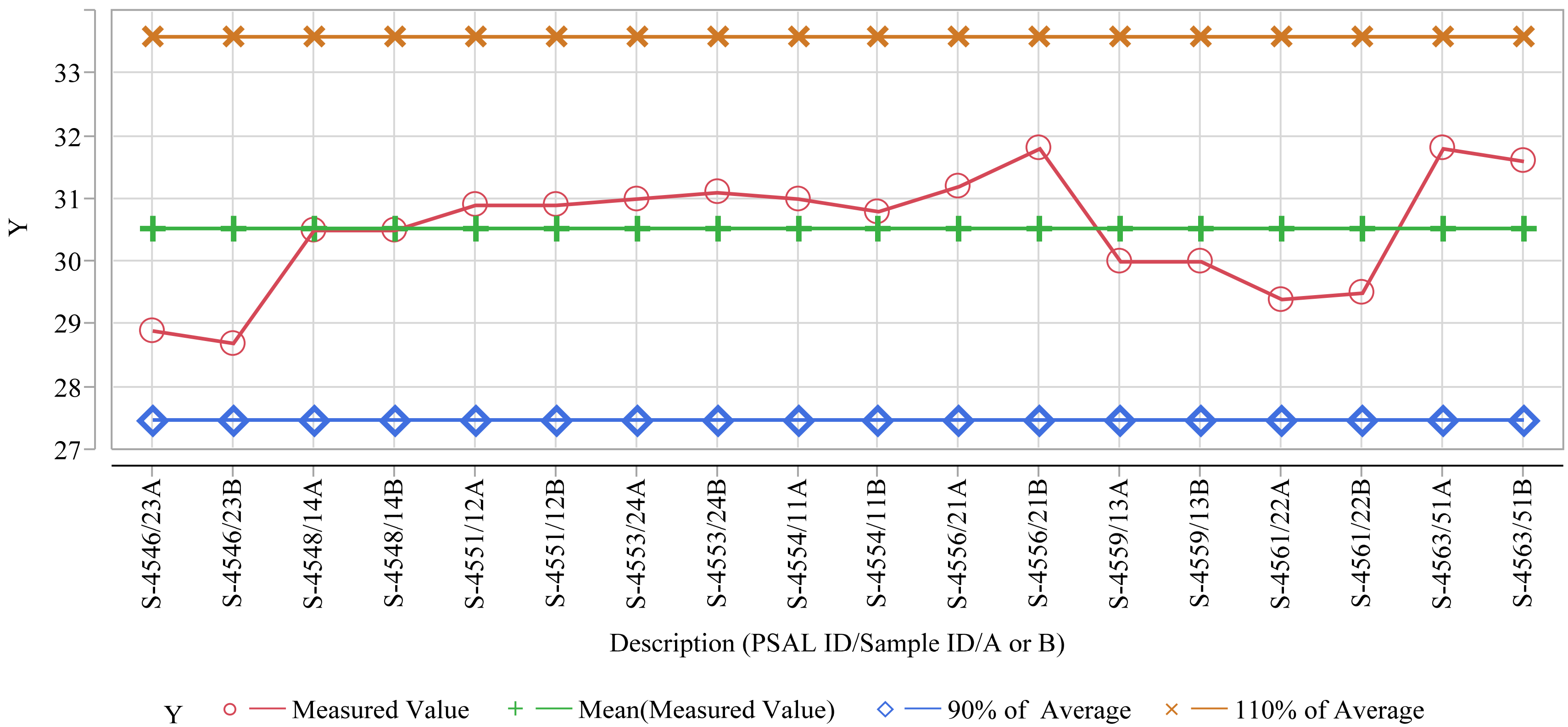
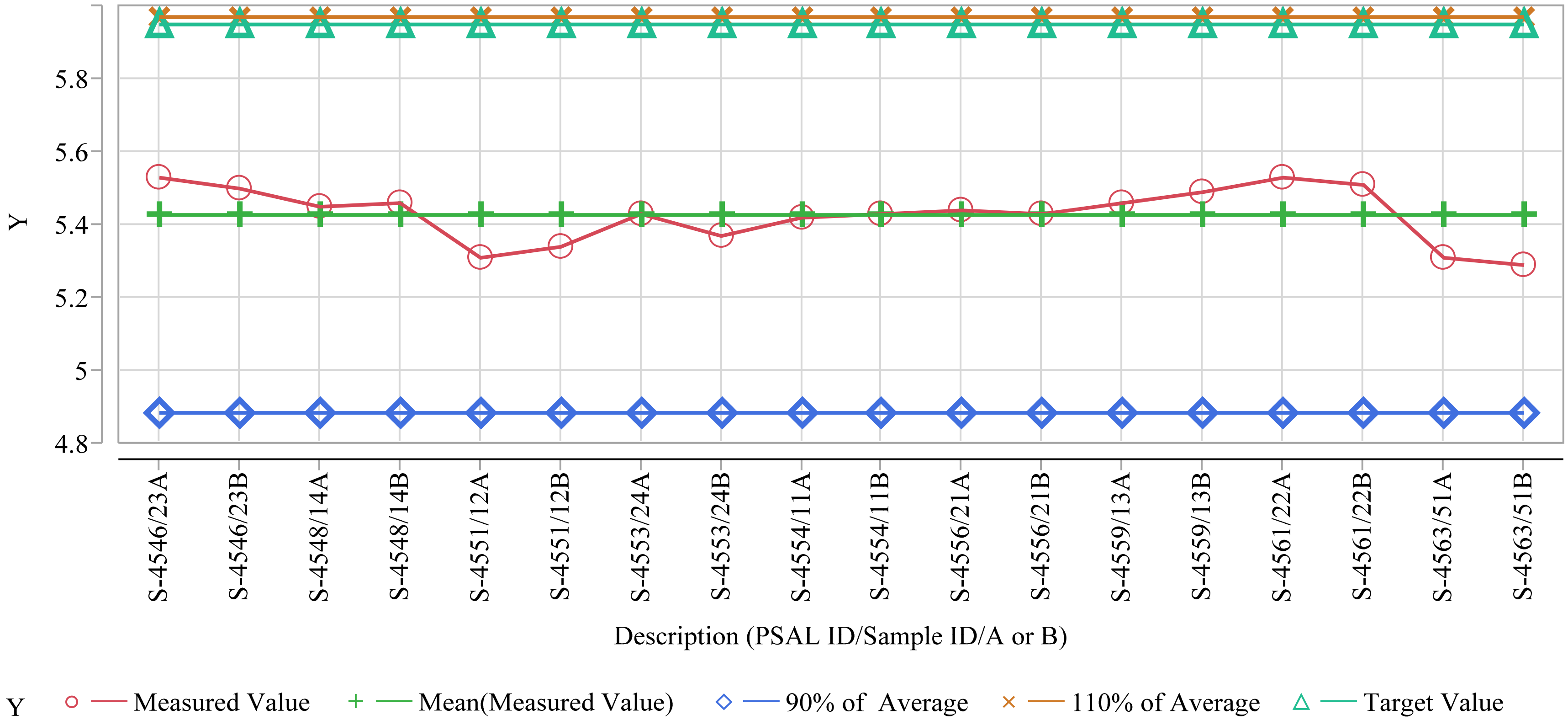


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

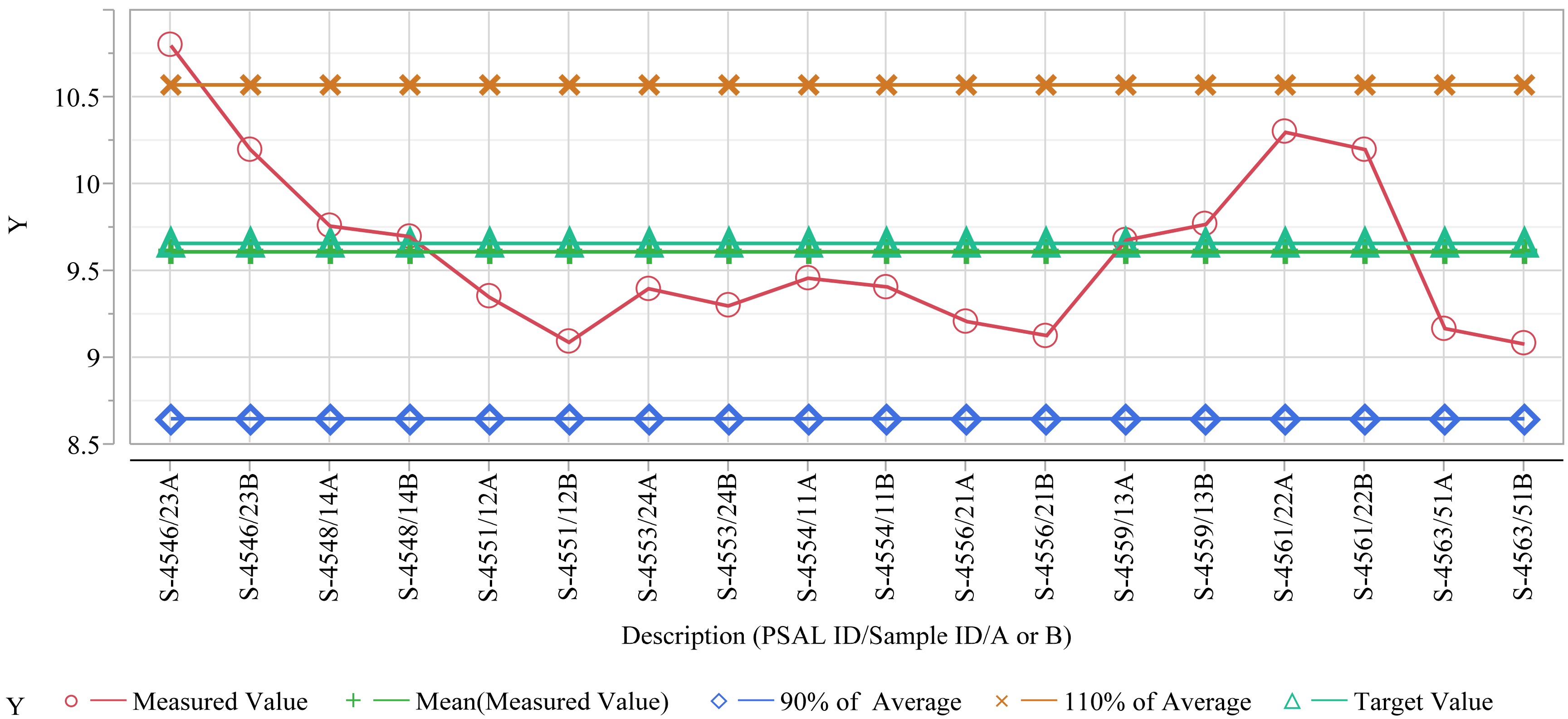
Overlay Plot Test=LAW LB, Type=physical property, Analyte=Wt% Calcine, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=slurry, Analyte=Al_2O_3, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=slurry, Analyte=B2O3, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=slurry, Analyte=CaO, Unit of Measure=wt%

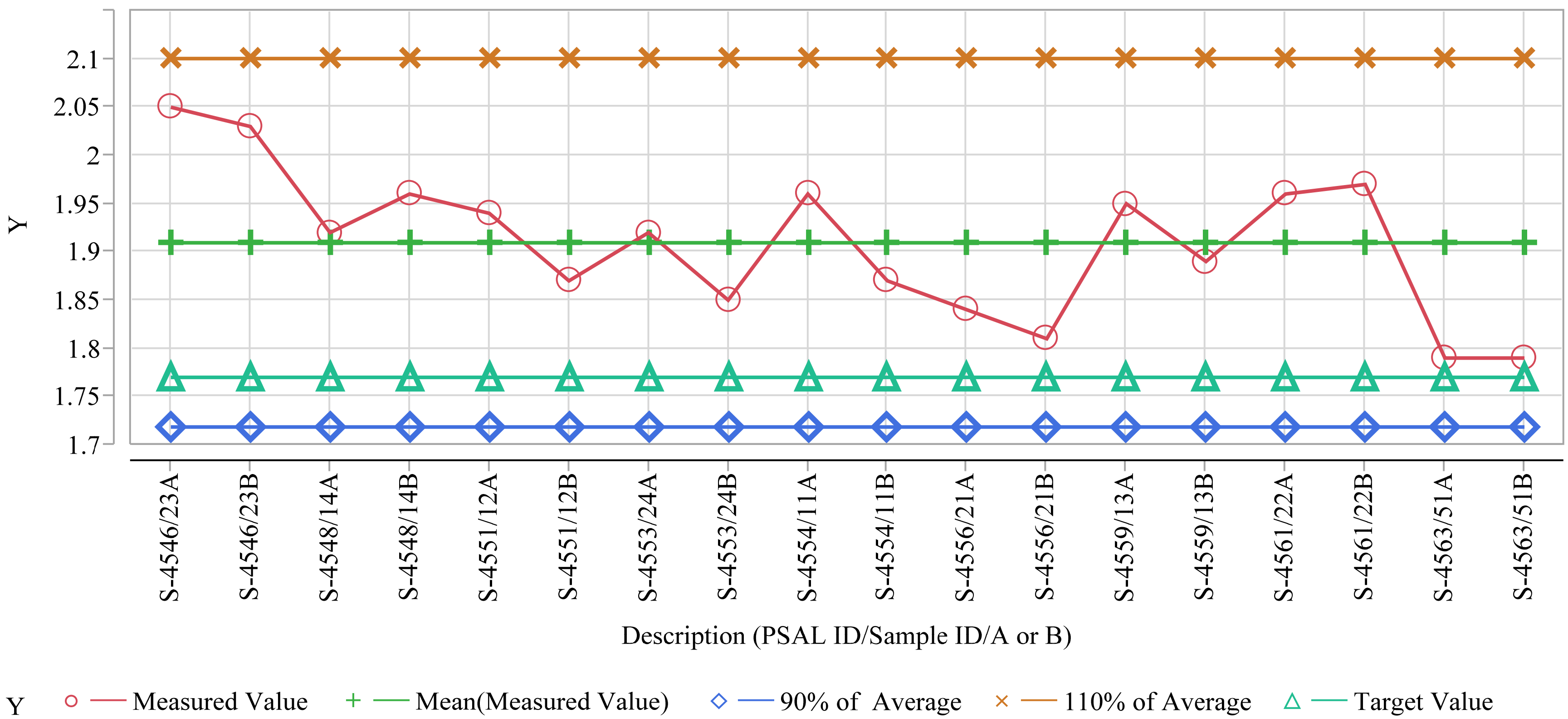
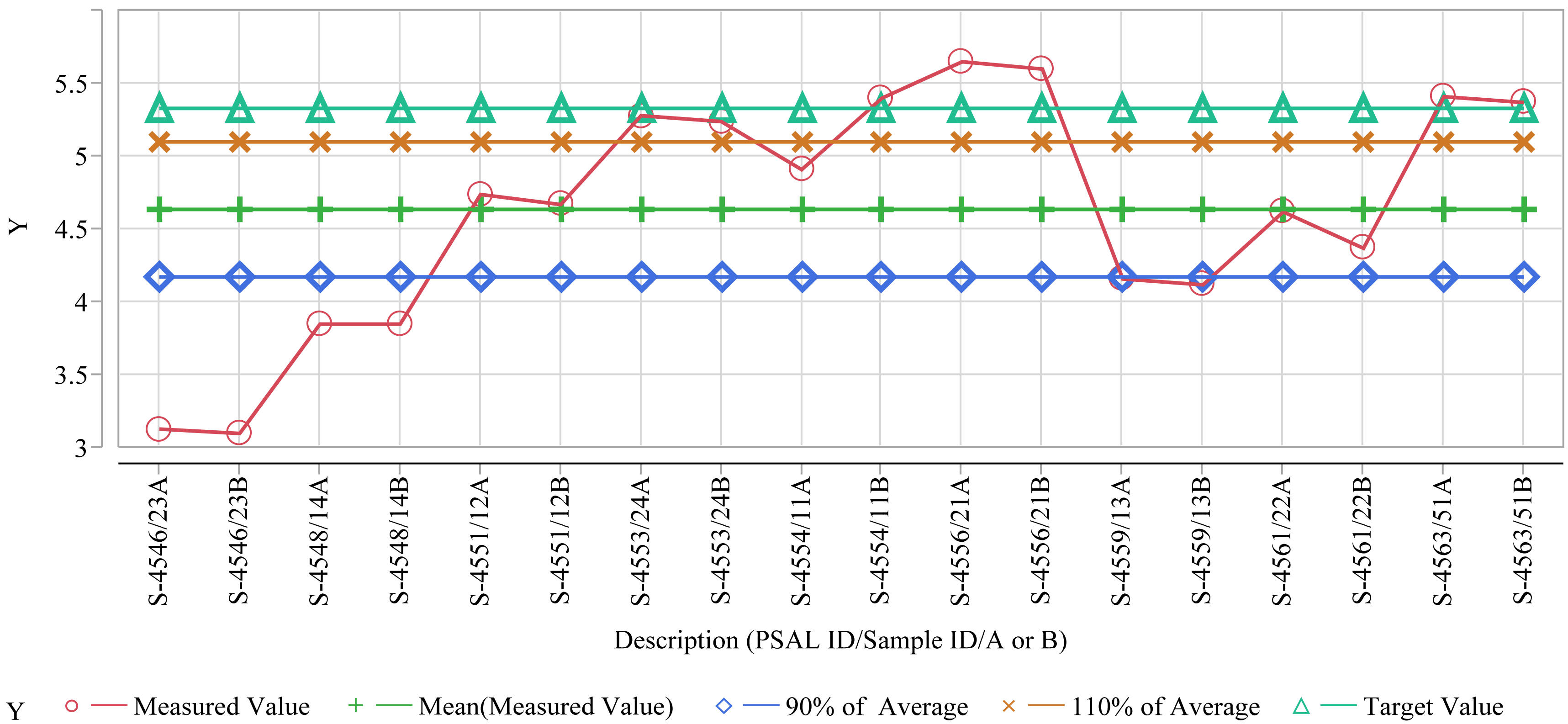
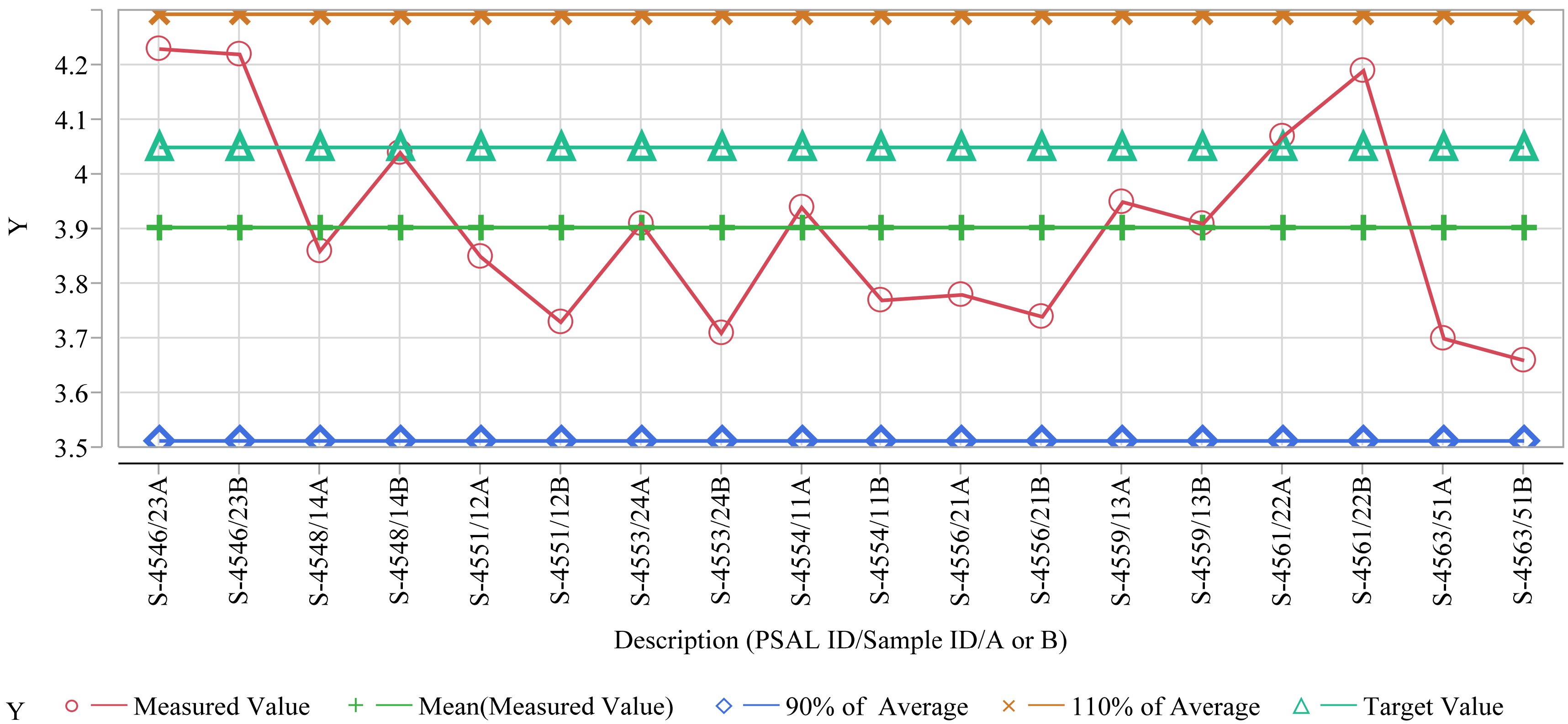


Exhibit G4. Plots of the Measurements with a ±10% Reference Lines Around the Average Value

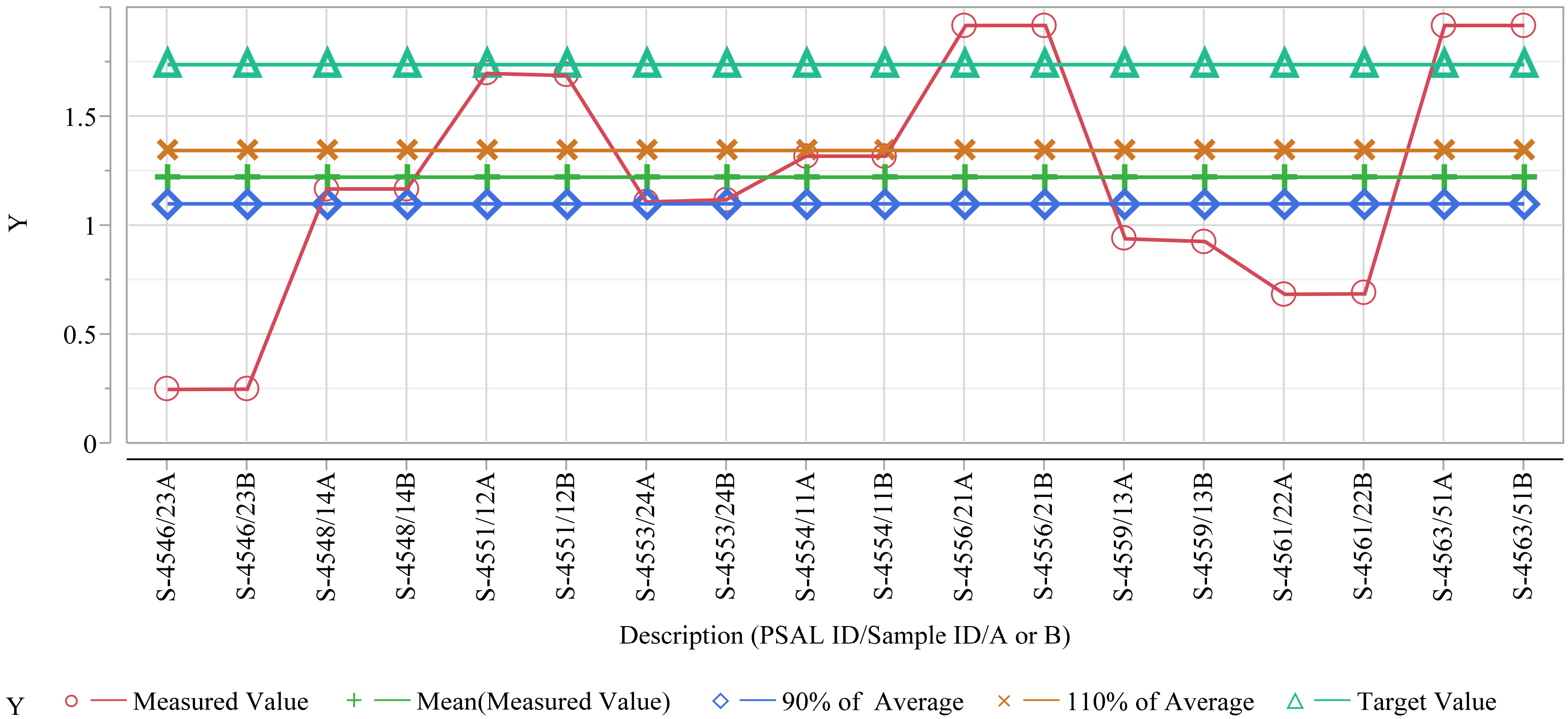
Overlay Plot Test=LAW LB, Type=slurry, Analyte=Fe2O3, Unit of Measure=wt%



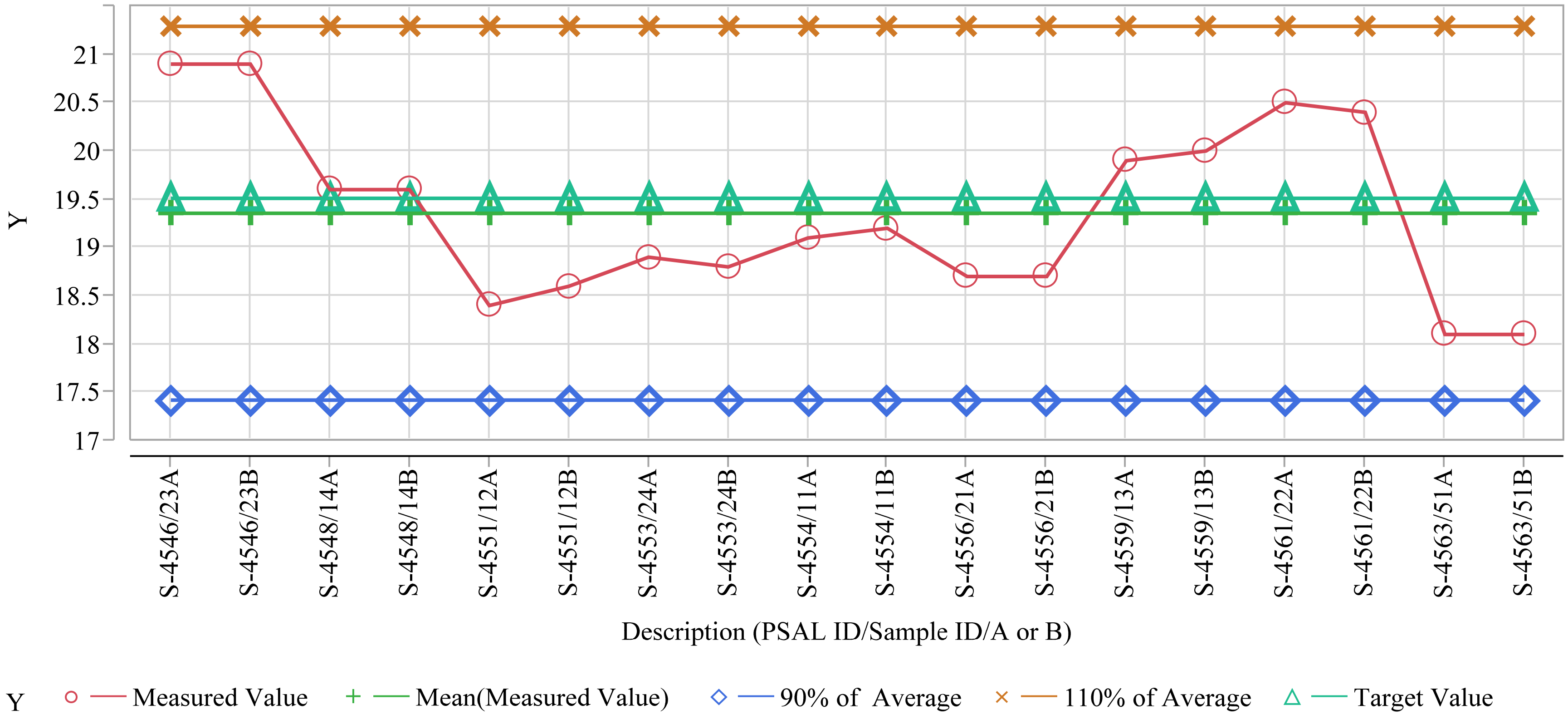
Overlay Plot Test=LAW LB, Type=slurry, Analyte=K2O, Unit of Measure=wt%



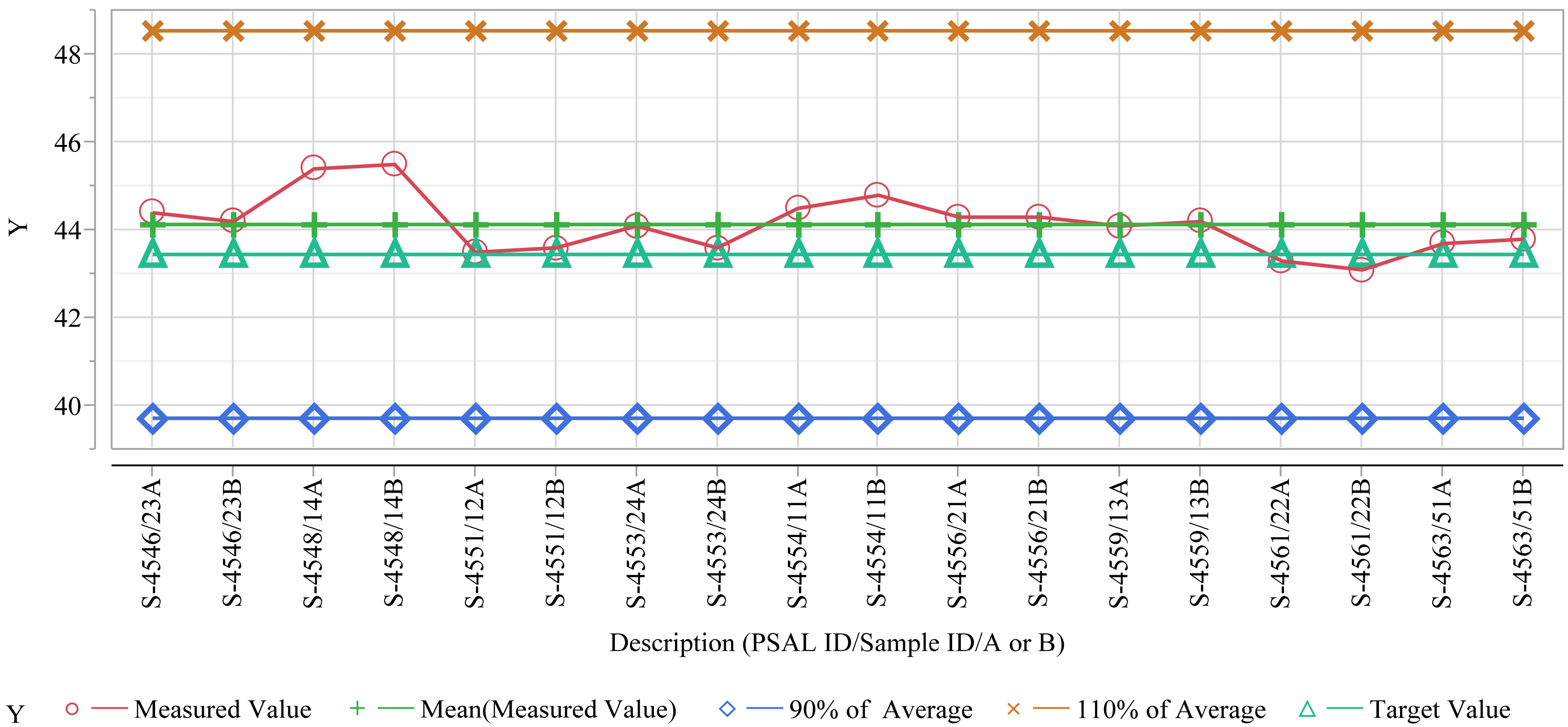
Overlay Plot Test=LAW LB, Type=slurry, Analyte=MgO, Unit of Measure=wt%



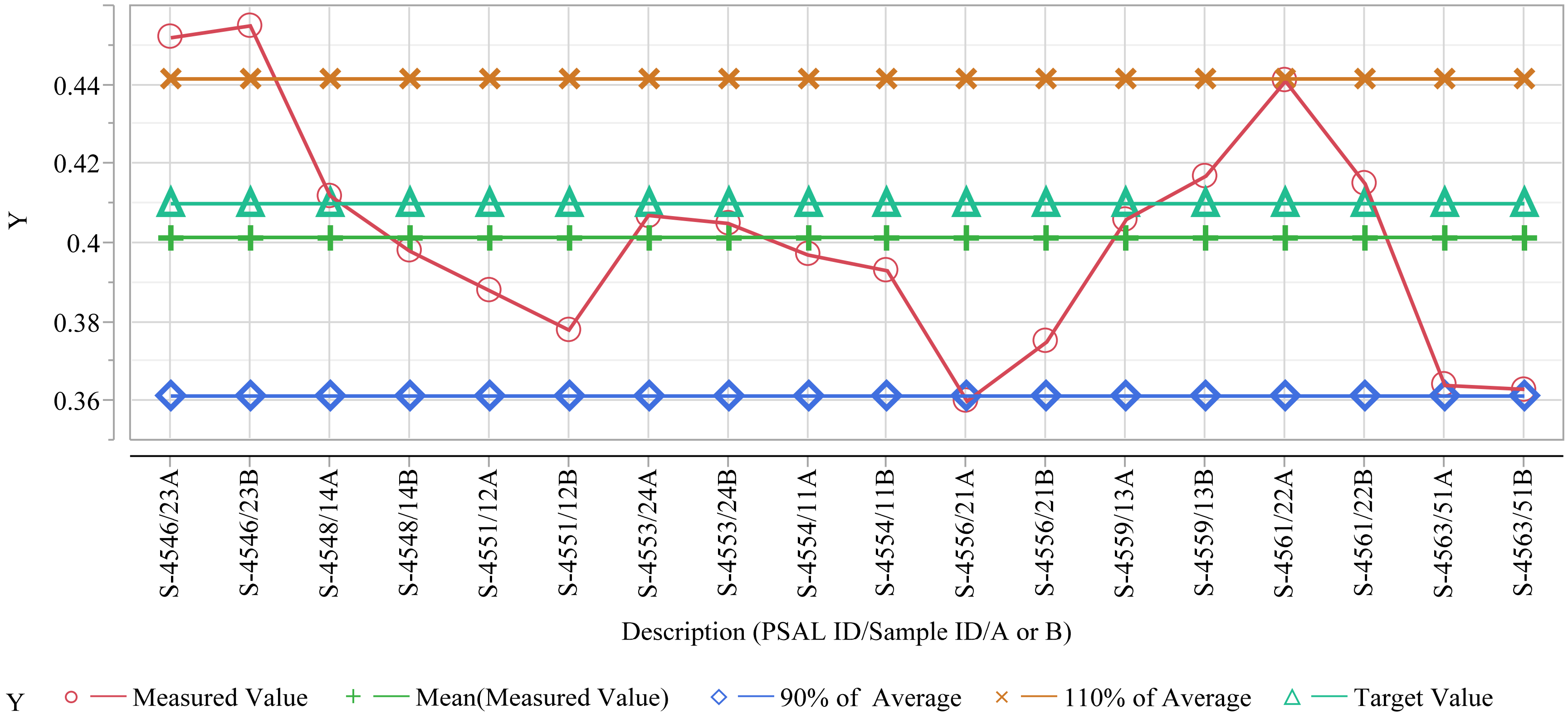
Overlay Plot Test=LAW LB, Type=slurry, Analyte=Na2O, Unit of Measure=wt%



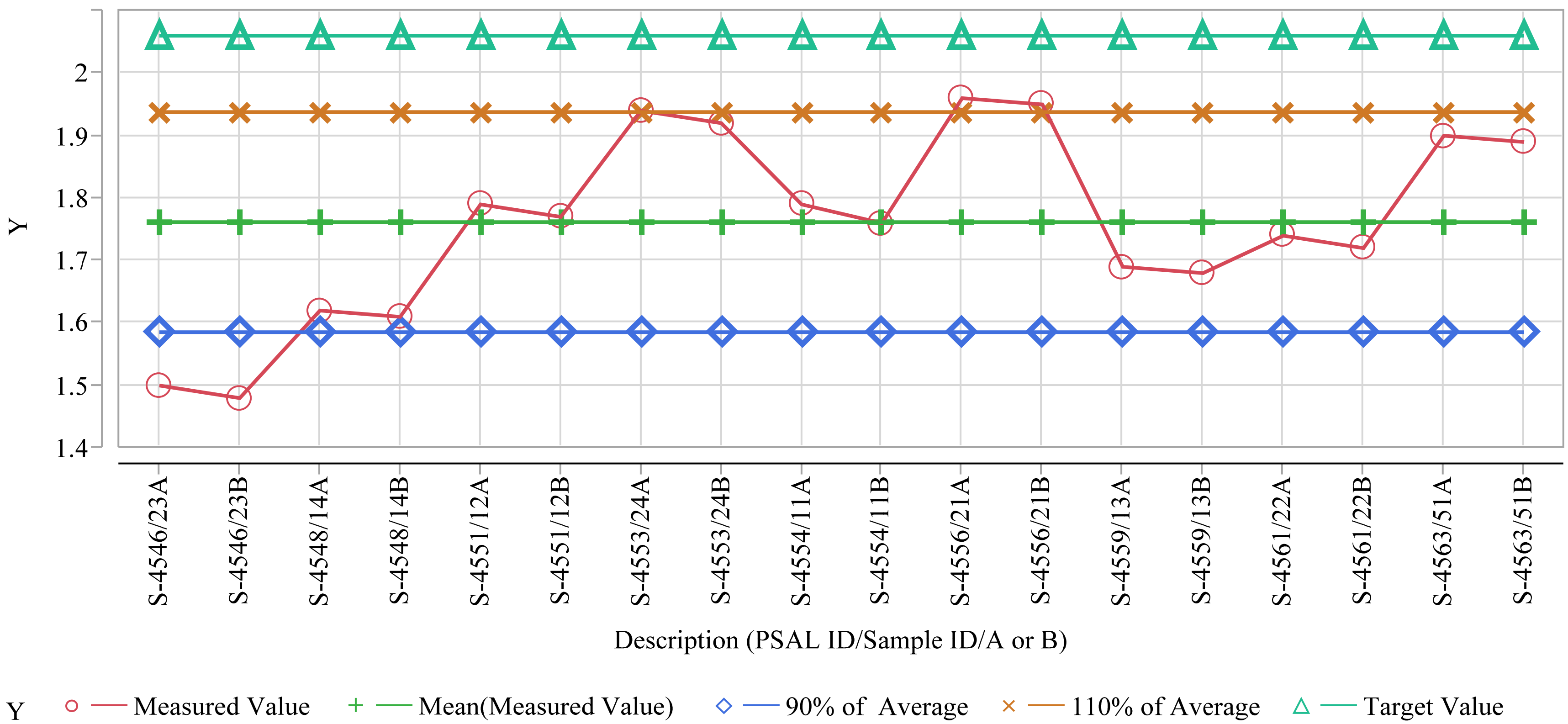
Overlay Plot Test=LAW LB, Type=slurry, Analyte=SiO2, Unit of Measure=wt%



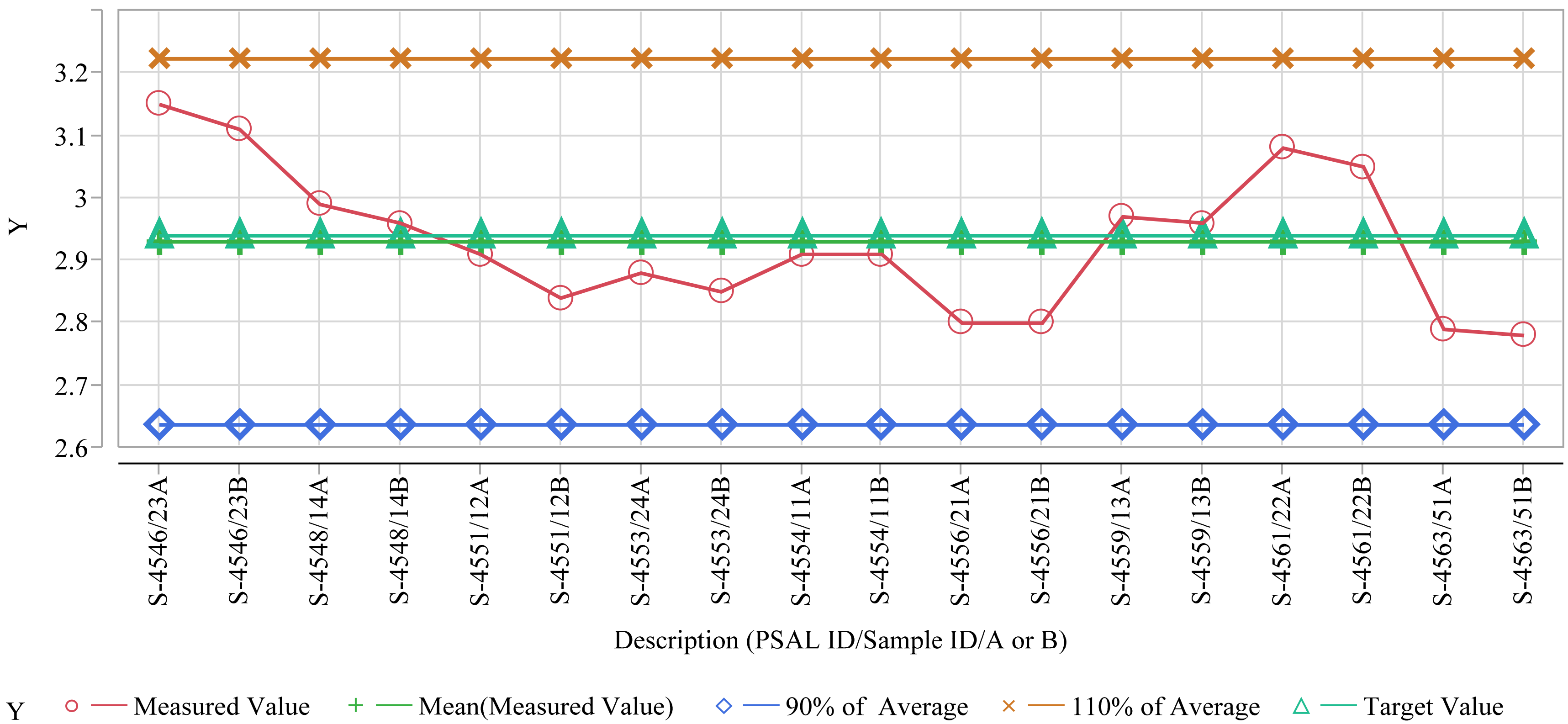
Overlay Plot Test=LAW LB, Type=slurry, Analyte=SO4, Unit of Measure=wt%



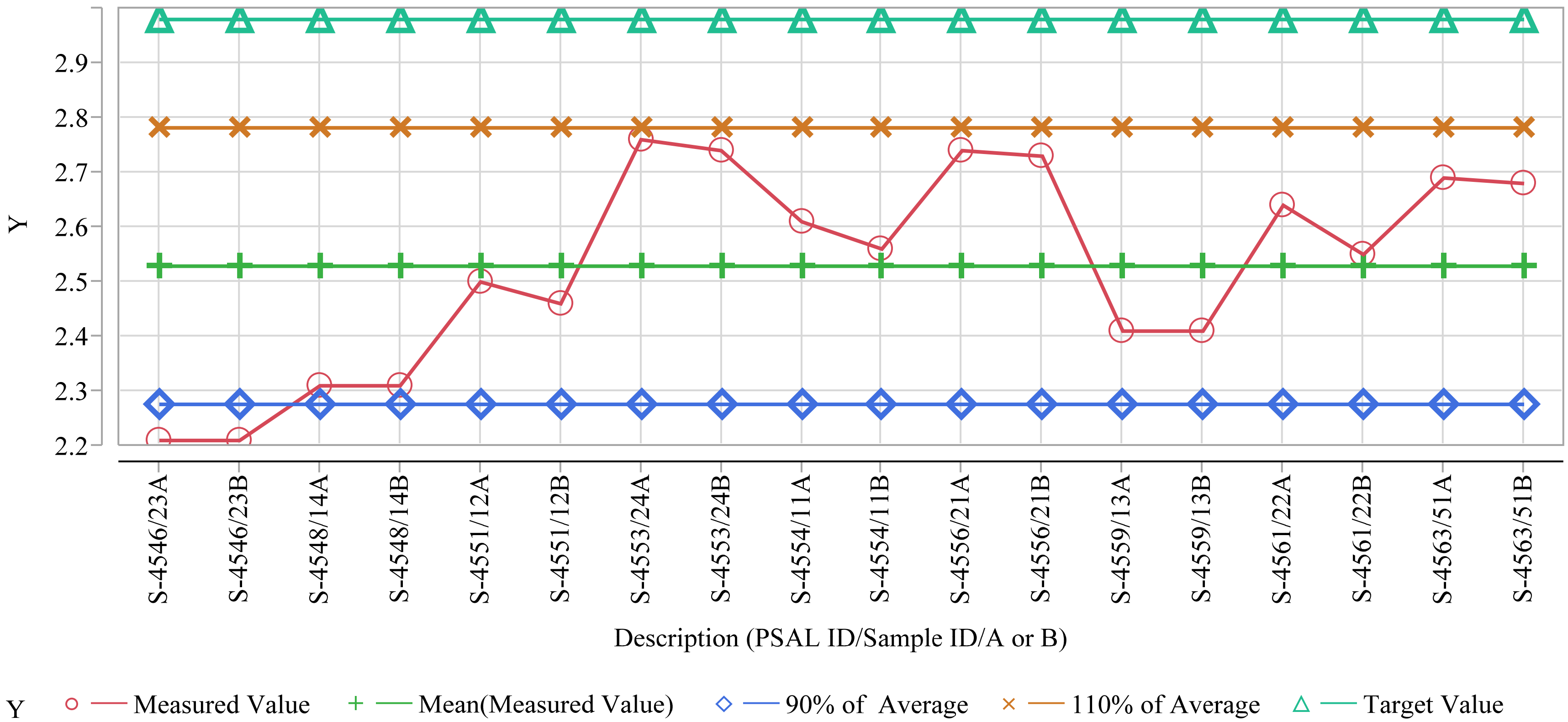
Overlay Plot Test=LAW LB, Type=slurry, Analyte=TiO2, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=slurry, Analyte=ZnO, Unit of Measure=wt%



Overlay Plot Test=LAW LB, Type=slurry, Analyte=ZrO2, Unit of Measure=wt%



Distribution:

T. B. Brown, 773-A
M. E. Cercy, 773-42A
D. A. Crowley, 773-43A
D. E. Dooley, 773-A
A. P. Fellinger. 773-42A
S. D. Fink, 773-A
C. C. Herman, 773-A
D. T. Hobbs, 773-A
E. N. Hoffman, 999-W
J. E. Hyatt, 773-A
K. M. Kostelnik, 773-42A
B. B. Looney, 773-42A
D. A. McGuire, 773-42A
T. O. Oliver, 773-42A
F. M. Pennebaker, 773-42A
G. N. Smoland, 773-42A
B. J. Wiedenman, 773-42A
W. R. Wilmarth, 773-A
Records Administration
(EDWS)

V. Jain, 766-H
R. E. Edwards, 766-H
E. J. Freed, 704-S
J. M. Bricker, 704-S
J. S. Contardi, 704-56H
T. L. Fellinger, 766-H
R. T. McNew, 766-H
H. H. Burns, 773-41A
A. D. Cozzi, 999-W
S. D. Fink, 773-A
K. M. Fox, 999-W
E. K. Hansen, 999-W
J. E. Hyatt, 733-A
D. J. McCabe, 773-42A
M. R. Poirier, 773-42A
M. E. Stone, 999-W
F.C. Johnson, 999-W
T. B. Edwards, 999-W
J. D. Newell, 999-W
M. R. Williams, 786-1A
D.L. McClane, 999-W
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