



**Savannah River
National Laboratory®**

A U.S. DEPARTMENT OF ENERGY NATIONAL LAB • SAVANNAH RIVER SITE • AIKEN, SC • USA

Product Consistency Test Results for the HLW HAIG Glasses

M. C. Hsieh

August 2023

SRNL-STI-2022-00659, Revision 0

DISCLAIMER

This work was prepared under an agreement with and funded by the U.S. Government. Neither the U.S. Government or its employees, nor any of its contractors, subcontractors or their employees, makes any express or implied:

1. warranty or assumes any legal liability for the accuracy, completeness, or for the use or results of such use of any information, product, or process disclosed; or
2. representation that such use or results of such use would not infringe privately owned rights; or
3. endorsement or recommendation of any specifically identified commercial product, process, or service.

Any views and opinions of authors expressed in this work do not necessarily state or reflect those of the United States Government, or its contractors, or subcontractors.

Printed in the United States of America

**Prepared for
U.S. Department of Energy**

Keywords: *Hanford, WTP, waste glass, durability*

Retention: *Lifetime*

Product Consistency Test Results for the HLW HAIG Glasses

M. C. Hsieh

August 2023

Savannah River National Laboratory is operated by
Battelle Savannah River Alliance for the U.S. Department
of Energy under Contract No. 89303321CEM000080.



REVIEWS AND APPROVALS

AUTHORS:

M. C. Hsieh, Applied Materials Research

TECHNICAL REVIEW:

A. N. Stanfield, Applied Materials Research, Reviewed per E7 2.60

APPROVAL:

J. Manna, Division Director, Environmental and Legacy Management

ACKNOWLEDGEMENTS

The author would like to thank Matthew Alexander, Daniel Jones, Josh Kitchings, and Whitney Riley at the Savannah River National Laboratory for their skilled assistance with the sample analysis described in this report. The author also thanks Viviana Gervasio at the Pacific Northwest National Laboratory for helpful discussions and review of these data and the report. Funding from the U. S. Department of Energy Contract Work Authorization HAN-M0SRV00101 as managed by Albert A. Kruger is gratefully acknowledged.

EXECUTIVE SUMMARY

This report summarizes the chemical analysis of Product Consistency Test leachates received from Pacific Northwest National Laboratory (PNNL). The leachates are from a series of quenched simulated nuclear waste glasses designated High-Level Waste High Aluminum Glass that were designed and fabricated at PNNL. The reported data is provided to be used in the development, validation, and implementation of enhanced property/composition models for waste glass vitrification at Hanford.

The elemental release for the study glasses is reported as normalized concentration NC_i . NC_i of several elements was computed for both the target and measured glass compositions. Several of the glasses exhibited NC_B , NC_{Li} , and/or NC_{Na} values that were greater than the Environmental Assessment (EA) benchmark values. Several of the leachates from approved reference material (ARM) glasses included with the study glasses had elemental concentrations greater than the expected ranges. Two water blanks contained measurable amounts of Si; measurements confirmed by rerun samples. One water blank also contained a measurable amount of Na.

TABLE OF CONTENTS

LIST OF TABLES	viii
LIST OF ABBREVIATIONS.....	ix
1.0 Introduction.....	1
2.0 Experimental Procedure.....	1
2.1 Quality Assurance	1
2.2 Glasses Selected for Study.....	1
2.3 PCT Leachate Analysis	4
3.0 Results and Discussion	4
3.1 Measured Compositions of the PCT Leachates	4
3.2 Normalization of PCT Data	5
4.0 Summary	9
5.0 References.....	10
Appendix A . Tables and Exhibits Supporting Analysis of the HLW HAIG PCT Leachates	A-1
Appendix B . Normalized PCT Results.....	B-1

LIST OF TABLES

Table 2-1. Identifiers for the Q PCT Leachates	2
Table 2-2. Identifiers for the CCC PCT Leachates	3
Table 3-1. Normalized PCT Results for Selected Elements	7

LIST OF ABBREVIATIONS

ARM	Approved Reference Material
ASTM	American Society for Testing and Materials
BDL	below detection limit
CCC	canister centerline cooled
DF	dilution factor
DOE	U.S. Department of Energy
EA	Environmental Assessment
ICP-OES	inductively coupled plasma – optical emission spectroscopy
ID	identifier
HLW HAIG	High-Level Waste High-Aluminum Glass
NC_i	normalized concentration of element “ <i>i</i> ”
ORP	Office of River Protection
PCT	Product Consistency Test
PNNL	Pacific Northwest National Laboratory
Q	quenched
%RSD	percent relative standard deviation
seq.	sequence
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
std	High Purity Standards ICP multi-element custom solution SM-744-013
TTQAP	Task Technical and Quality Assurance Plan
wt. %	weight percent
WTP	Waste Treatment and Immobilization Plant

1.0 Introduction

The U.S. Department of Energy (DOE) is responsible for building the Waste Treatment and Immobilization Plant (WTP) at the Hanford site in Washington to remediate 56 million gallons of radioactive waste historically stored in 177 underground tanks. The Office of River Protection (ORP) has requested that the Savannah River National Laboratory (SRNL) contribute in areas of recognized capabilities and expertise for glass waste form development to support successful startup of the WTP.

Successful efforts have allowed for demonstration of greatly enhanced treatment efficiencies of those projected from the minimum requirements set forth in the WTP Contract^a. Additional flexibility and expansion of the qualified glass forming region are the current focus.¹ SRNL support of this work is defined in the Task Technical and Quality Assurance Plan (TTQAP).²

This report provides the chemical analysis of the Product Consistency Test (PCT) leachates from the High-Level Waste High-Aluminum Glass (HLW HAIG) study glasses, a series of simulated nuclear waste glasses designed and fabricated at the Pacific Northwest National Laboratory (PNNL). The PCT leachates were from both quenched (Q) and canister centerline cooled (CCC) glasses. The glasses were part of a broader study to evaluate the influence of glass composition on chemical durability, sulfur retention, and other properties.^{3,4} These data will be used in the development, validation, and implementation of enhanced property/composition models for nuclear waste glasses.¹

2.0 Experimental Procedure

2.1 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in Savannah River Site (SRS) Manual E7, Procedure 2.60.⁵ SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.⁶ Laboratory data for this study were recorded in the SRNL Electronic Laboratory Notebook system, experiment L6390-00441-06. The leachates were provided by PNNL following a Task Plan.¹

2.2 Glasses Selected for Study

The glass compositions referred to in this study were selected and fabricated by PNNL. PNNL subsequently performed the ASTM C1285 PCT Method A⁷ on quenched (Q) and canister centerline cooled (CCC) versions of each of the study glasses. The PCT included Approved Reference Material (ARM) and blanks. The resulting PCT leachates were acidified and shipped to SRNL for chemical analysis. Identifiers (ID) for the Q PCT leachates are listed in Table 2-1 and the IDs for the CCC PCT leachates are listed in Table 2-2.

^a Contract DE-AC27-01RV14136, as amended, U.S. Department of Energy, Richland, WA (2000).

Table 2-1. Identifiers for the Q PCT Leachates

PNNL Solution ID	Lab ID	PNNL Solution ID	Lab ID
HAIG-01-Q-PCT-A	S-14545	ARM STD-PCT-A (4/29/22)	S-14593
HAIG-01-Q-PCT-B	S-14546	ARM STD-PCT-B (4/29/22)	S-14594
HAIG-01-Q-PCT-C	S-14547	ARM STD-PCT-C (4/29/22)	S-14595
HAIG-02-Q-PCT-A	S-14548	MQ WATER BLK-PCT-A (4/29/22)	S-14596
HAIG-02-Q-PCT-B	S-14549	MQ WATER BLK-PCT-B (4/29/22)	S-14597
HAIG-02-Q-PCT-C	S-14550	HAIG-15-Q-PCT-A	S-14598
HAIG-03-Q-PCT-A	S-14551	HAIG-15-Q-PCT-B	S-14599
HAIG-03-Q-PCT-B	S-14552	HAIG-15-Q-PCT-C	S-14600
HAIG-03-Q-PCT-C	S-14553	HAIG-16-Q-PCT-A	S-14601
ARM STD-PCT-A (3/9/22)	S-14554	HAIG-16-Q-PCT-B	S-14602
ARM STD-PCT-B (3/9/22)	S-14555	HAIG-16-Q-PCT-C	S-14603
ARM STD-PCT-C (3/9/22)	S-14556	HAIG-17-Q-PCT-A	S-14604
MQ WATER BLK-PCT-A (3/9/22)	S-14557	HAIG-17-Q-PCT-B	S-14605
MQ WATER BLK-PCT-B (3/9/22)	S-14558	HAIG-17-Q-PCT-C	S-14606
HAIG-04-Q-PCT-A	S-14559	HAIG-18-Q-PCT-A	S-14607
HAIG-04-Q-PCT-B	S-14560	HAIG-18-Q-PCT-B	S-14608
HAIG-04-Q-PCT-C	S-14561	HAIG-18-Q-PCT-C	S-14609
HAIG-05-Q-PCT-A	S-14562	HAIG-20-Q-PCT-A	S-14610
HAIG-05-Q-PCT-B	S-14563	HAIG-20-Q-PCT-B	S-14611
HAIG-05-Q-PCT-C	S-14564	HAIG-20-Q-PCT-C	S-14612
HAIG-06-Q-PCT-A	S-14565	ARM STD-PCT-A (5/3/22)	S-14613
HAIG-06-Q-PCT-B	S-14566	ARM STD-PCT-B (5/3/22)	S-14614
HAIG-06-Q-PCT-C	S-14567	ARM STD-PCT-C (5/3/22)	S-14615
HAIG-07-Q-PCT-A	S-14568	MQ WATER BLK-PCT-A (5/3/22)	S-14616
HAIG-07-Q-PCT-B	S-14569	MQ WATER BLK-PCT-B (5/3/22)	S-14617
HAIG-07-Q-PCT-C	S-14570	HAIG-19-Q-PCT-A	S-14618
HAIG-08-Q-PCT-A	S-14571	HAIG-19-Q-PCT-B	S-14619
HAIG-08-Q-PCT-B	S-14572	HAIG-19-Q-PCT-C	S-14620
HAIG-08-Q-PCT-C	S-14573	HAIG-21-Q-PCT-A	S-14621
ARM STD-PCT-A (4/15/22)	S-14574	HAIG-21-Q-PCT-B	S-14622
ARM STD-PCT-B (4/15/22)	S-14575	HAIG-21-Q-PCT-C	S-14623
ARM STD-PCT-C (4/15/22)	S-14576	HAIG-22-Q-PCT-A	S-14624
MQ WATER BLK-PCT-A (4/15/22)	S-14577	HAIG-22-Q-PCT-B	S-14625
MQ WATER BLK-PCT-B (4/15/22)	S-14578	HAIG-22-Q-PCT-C	S-14626
HAIG-09-Q-PCT-A	S-14579	HAIG-23-Q-PCT-A	S-14627
HAIG-09-Q-PCT-B	S-14580	HAIG-23-Q-PCT-B	S-14628
HAIG-09-Q-PCT-C	S-14581	HAIG-23-Q-PCT-C	S-14629
HAIG-11-Q-PCT-A	S-14582	HAIG-24-Q-PCT-A	S-14630
HAIG-11-Q-PCT-B	S-14583	HAIG-24-Q-PCT-B	S-14631
HAIG-11-Q-PCT-C	S-14584	HAIG-24-Q-PCT-C	S-14632
HAIG-12-Q-PCT-A	S-14585	HAIG-25-Q-PCT-A	S-14633
HAIG-12-Q-PCT-B	S-14586	HAIG-25-Q-PCT-B	S-14634
HAIG-12-Q-PCT-C	S-14587	HAIG-25-Q-PCT-C	S-14635
HAIG-13-Q-PCT-A	S-14588	ARM STD-PCT-A (5/6/22)	S-14636
HAIG-13-Q-PCT-B	S-14589	ARM STD-PCT-B (5/6/22)	S-14637
HAIG-13-Q-PCT-C	S-14590	ARM STD-PCT-C (5/6/22)	S-14638
HAIG-14-Q-PCT-A	S-14591	MQ WATER BLK-PCT-A (5/6/22)	S-14639
HAIG-14-Q-PCT-B	S-14592	MQ WATER BLK-PCT-B (5/6/22)	S-14640

Table 2-2. Identifiers for the CCC PCT Leachates

PNNL Solution ID	Lab ID	PNNL Solution ID	Lab ID
HAIG-01-CCC-PCT-A	S-14900	HAIG-14-CCC-PCT-A-1	S-14946
HAIG-01-CCC-PCT-B	S-14901	HAIG-14-CCC-PCT-B-1	S-14947
HAIG-01-CCC-PCT-C	S-14902	HAIG-14-CCC-PCT-C-1	S-14948
HAIG-02-CCC-PCT-A	S-14903	HAIG-15-CCC-PCT-A-1	S-14949
HAIG-02-CCC-PCT-B	S-14904	HAIG-15-CCC-PCT-B-1	S-14950
HAIG-02-CCC-PCT-C	S-14905	HAIG-15-CCC-PCT-C-1	S-14951
HAIG-03-CCC-PCT-A	S-14906	HAIG-16-CCC-PCT-A-1	S-14952
HAIG-03-CCC-PCT-B	S-14907	HAIG-16-CCC-PCT-B-1	S-14953
HAIG-03-CCC-PCT-C	S-14908	HAIG-16-CCC-PCT-C-1	S-14954
HAIG-04-CCC-PCT-A	S-14909	HAIG-17-CCC-PCT-A-1	S-14955
HAIG-04-CCC-PCT-B	S-14910	HAIG-17-CCC-PCT-B-1	S-14956
HAIG-04-CCC-PCT-C	S-14911	HAIG-17-CCC-PCT-C-1	S-14957
HAIG-05-CCC-PCT-A	S-14912	HAIG-18-CCC-PCT-A-1	S-14958
HAIG-05-CCC-PCT-B	S-14913	HAIG-18-CCC-PCT-B-1	S-14959
HAIG-05-CCC-PCT-C	S-14914	HAIG-18-CCC-PCT-C-1	S-14960
ARM-1 STD-PCT-A (5/13/22)	S-14915	ARM-1 STD-PCT-A-1 (6/22/22)	S-14961
ARM-1 STD-PCT-B (5/13/22)	S-14916	ARM-1 STD-PCT-B-1 (6/22/22)	S-14962
ARM-1 STD-PCT-C (5/13/22)	S-14917	ARM-1 STD-PCT-C-1 (6/22/22)	S-14963
MQ Water BLK-PCT-A (5/13/22)	S-14918	MQ Water BLK-PCT-A (6/22/22)	S-14964
MQ Water BLK-PCT-B (5/13/22)	S-14919	MQ Water BLK-PCT-B (6/22/22)	S-14965
HAIG-06-CCC-PCT-A	S-14920	HAIG-19-CCC-PCT-A	S-14966
HAIG-06-CCC-PCT-B	S-14921	HAIG-19-CCC-PCT-B	S-14967
HAIG-06-CCC-PCT-C	S-14922	HAIG-19-CCC-PCT-C	S-14968
HAIG-07-CCC-PCT-A	S-14923	HAIG-20-CCC-PCT-A	S-14969
HAIG-07-CCC-PCT-B	S-14924	HAIG-20-CCC-PCT-B	S-14970
HAIG-07-CCC-PCT-C	S-14925	HAIG-20-CCC-PCT-C	S-14971
HAIG-08-CCC-PCT-A	S-14926	HAIG-21-CCC-PCT-A	S-14972
HAIG-08-CCC-PCT-B	S-14927	HAIG-21-CCC-PCT-B	S-14973
HAIG-08-CCC-PCT-C	S-14928	HAIG-21-CCC-PCT-C	S-14974
HAIG-09-CCC-PCT-A	S-14929	HAIG-22-CCC-PCT-A	S-14975
HAIG-09-CCC-PCT-B	S-14930	HAIG-22-CCC-PCT-B	S-14976
HAIG-09-CCC-PCT-C	S-14931	HAIG-22-CCC-PCT-C	S-14977
HAIG-11-CCC-PCT-A	S-14932	HAIG-23-CCC-PCT-A	S-14978
HAIG-11-CCC-PCT-B	S-14933	HAIG-23-CCC-PCT-B	S-14979
HAIG-11-CCC-PCT-C	S-14934	HAIG-23-CCC-PCT-C	S-14980
ARM-1 STD-PCT-A (5/20/22)	S-14935	HAIG-24-CCC-PCT-A	S-14981
ARM-1 STD-PCT-B (5/20/22)	S-14936	HAIG-24-CCC-PCT-B	S-14982
ARM-1 STD-PCT-C (5/20/22)	S-14937	HAIG-24-CCC-PCT-C	S-14983
MQ Water BLK-PCT-A (5/20/22)	S-14938	HAIG-25-CCC-PCT-A	S-14984
MQ Water BLK-PCT-B (5/20/22)	S-14939	HAIG-25-CCC-PCT-B	S-14985
HAIG-12-1-CCC-PCT-A-1	S-14940	HAIG-25-CCC-PCT-C	S-14986
HAIG-12-1-CCC-PCT-B-1	S-14941	ARM-1 STD-PCT-A (6/10/22)	S-14987
HAIG-12-1-CCC-PCT-C-1	S-14942	ARM-1 STD-PCT-B (6/10/22)	S-14988
HAIG-13-CCC-PCT-A-1	S-14943	ARM-1 STD-PCT-C (6/10/22)	S-14989
HAIG-13-CCC-PCT-B-1	S-14944	MQ Water BLK-PCT-A (6/10/22)	S-14990
HAIG-13-CCC-PCT-C-1	S-14945	MQ Water BLK-PCT-B (6/10/22)	S-14991

2.3 PCT Leachate Analysis

The PCT leachate samples were analyzed by inductively coupled plasma – optical emission spectroscopy (ICP-OES)⁸ according to the analytical study plans designed to statistically randomize the measurements.^{9,10} JMP[®] version 16.0.0 (SAS Institute, Inc.)¹¹ was used to develop the analytical study plans. High purity multi-element custom ICP solution standards^b (std) were prepared at SRNL and included in the analytical study plan as a check of the accuracy of the instrument used for these measurements. The analytical measurements were adjusted for dilution and normalized elemental release values were calculated for each glass based on the target and measured¹² glass compositions.

3.0 Results and Discussion

3.1 Measured Compositions of the PCT Leachates

The elemental concentrations, in mg/L, for the HLW HAIG Q and HLW HAIG CCC PCT leachates, along with blanks, ARM glass standards, and multi-element custom standard solutions are provided in Appendix A. The values in Appendix A are dilution corrected, including a dilution factor of 5, provided by PNNL, related to the acidification step in preparing the PCT leachates.

Elemental concentrations were generally less than detectable in the water blanks, with a few exceptions where Na and Si were elevated. Three of the ARM-Q leachates and all of the ARM-CCC leachates exhibited Na and Si concentrations greater than the published ranges.¹³ Six of the ARM-CCC leachates also exhibited B concentrations greater than the published range. The reruns of these samples confirmed the initial measurements, in most cases. Figure 3-1 shows a box plot of the ARM measurement results along with the published ranges. This plot shows both the initial measurements, as well as duplicate measurements taken to support the reproducibility of the result. The measured values in the ARM and blank leachates that were outside the expected ranges are highlighted in Appendix A.

Following the guidance in ASTM C1285,⁷ the mean, standard deviation, and percent relative standard deviation (%RSD) were determined for six elements (Al, B, Li, K, Na, and Si) measured in the multi-element solution standard for each analytical block. As shown in Table A-3 in Appendix A, the mean measured concentration for each analytical block was found to be less than 10% from the reference value (i.e., a percent relative bias less than 10%), and the %RSD was less than 10% for each of the measured elements. The analytical results are acceptable per the criteria in ASTM C1285,⁷ which indicates no significant issues with the analytical outcomes from the measurements of the PCT leachates.

^b ICP-multi-element custom solution, product number SM-744-013, High Purity Standards, North Charleston, SC.

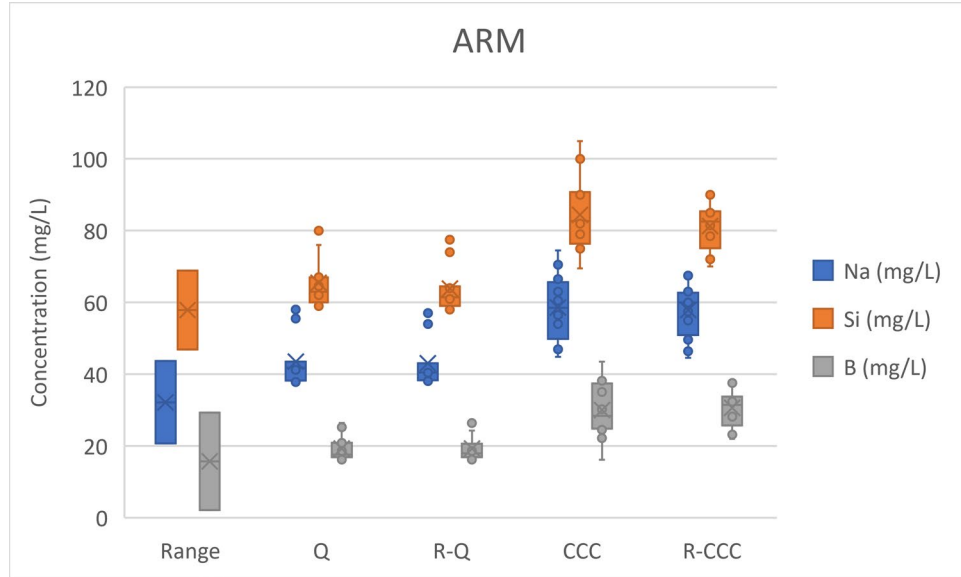


Figure 3-1. Box plot of the Na, Si, and B concentrations for the Q and CCC ARM samples. R designates the sample set was a re-run.

3.2 Normalization of PCT Data

Elemental release was computed as normalized concentration for each element “*i*” (NC_i) for B, Li, Na, and Si for each of the test glasses following the expression given in ASTM C1285,⁷

$$NC_i = \frac{c_i(\text{sample})}{f_i}$$

where NC_i is the normalized concentration in units of $\text{g}_{\text{waste form}}/\text{L}_{\text{leachant}}$, $c_i(\text{sample})$ is the concentration of element “*i*” in the leachate in units of g/L (corrected for the dilutions performed at PNNL), and f_i is the mass fraction of element “*i*” in the unleached glass in units of $\text{g}/\text{g}_{\text{glass}}$.^c NC_i was computed using both the targeted and average measured compositions.¹²

NC_i values were calculated using the units of measurement provided with the analytical results for this study. To accommodate the triplicate leachate measurements for each of the study glasses, the common logarithm of the NC_i for each of the study glasses was determined using the equation:

$$\log_{10}(NC_i) = \overline{\log_{10} c_i} - [1 + \log_{10} f_i]$$

where NC_i remains in units of $\text{g}_{\text{waste form}}/\text{L}_{\text{leachant}}$, $\overline{\log_{10} c_i}$ is the average of the common logarithms of the measured concentrations of element “*i*” in the triplicate leachates in units of mg/L (corrected for the dilutions performed at PNNL as discussed in Section 3.1), and $\log_{10} f_i$ is either the common logarithm of the targeted concentration of element “*i*” in the glass in units of weight percent (wt.%) or the common logarithm of the average measured concentration of element “*i*” in the glass in units of wt.% (reported previously¹²). Note that the symbols in this second equation were kept consistent with those used in ASTM C1285,⁷ but the units of measurement differ.

^c Note that the waste forms in this study were assumed to be of similar density. The PCT-A reference volume of leachant to sample mass ratio was used, and the 100 to 200 mesh reference particle size was used. Thus, no adjustment for the density of the glasses was made in normalizing the PCT results. Data provided in the appendices of this report allow for the calculation of normalized elemental mass loss (NLi) if glass densities are measured at a later date.

Table 3-1 provides the normalized PCT responses for the Q and CCC versions for each of the study glasses as well as the responses for the ARM reference glasses. A less than symbol (<) in Table 3-1 denotes a result that was below the detection limit (BDL) of the instrumental setup.

Table 3-1. Normalized PCT Results for Selected Elements

Glass ID	Comp. View	NC Al (g/L)	NC B (g/L)	NC Li (g/L)	NC Na (g/L)	NC Si (g/L)
ARM STD (3/9/22)	Reference	<0.178	0.500	0.561	0.571	0.295
ARM STD (4/15/22)	Reference	<0.176	0.520	0.568	0.573	0.290
ARM STD (4/29/22)	Reference	<0.172	0.502	0.544	0.567	0.283
ARM STD (5/3/22)	Reference	<0.172	0.469	0.510	0.530	0.272
ARM STD (5/6/22)	Reference	<0.182	0.745	0.854	0.790	0.364
ARM-1 STD (5/13/22)	Reference	<0.169	1.01	0.996	0.933	0.427
ARM-1 STD (5/20/22)	Reference	<0.172	0.892	0.929	0.859	0.398
ARM-1 STD (6/10/22)	Reference	<0.171	0.827	0.935	0.817	0.387
ARM-1 STD-1 (6/22/22)	Reference	<0.179	0.624	0.680	0.651	0.337
ARM STD (3/9/22) Rerun	Reference	<0.169	0.510	0.565	0.562	0.288
ARM STD (4/15/22) Rerun	Reference	<0.169	0.530	0.566	0.566	0.283
ARM STD (4/29/22) Rerun	Reference	<0.169	0.492	0.544	0.560	0.274
ARM STD (5/3/22) Rerun	Reference	<0.169	0.472	0.508	0.531	0.271
ARM STD (5/6/22) Rerun	Reference	<0.172	0.736	0.843	0.783	0.352
ARM-1 STD (5/13/22) Rerun	Reference	<0.169	1.03	1.06	0.910	0.407
ARM-1 STD (5/20/22) Rerun	Reference	<0.172	0.903	0.981	0.835	0.382
ARM-1 STD (6/10/22) Rerun	Reference	<0.171	0.883	0.935	0.825	0.375
ARM-1 STD-1 (6/22/22) Rerun	Reference	0.181	0.664	0.772	0.652	0.331
HAIG-01-CCC	Measured	0.216	47.9	29.7	16.2	0.131
HAIG-01-CCC	Target	0.215	46.3	32.7	15.5	0.133
HAIG-01-Q	Measured	0.328	0.494	<1.98	0.712	0.265
HAIG-01-Q	Target	0.327	0.477	<2.17	0.680	0.269
HAIG-02-CCC	Measured	0.720	81.5	21.2	39.6	0.121
HAIG-02-CCC	Target	0.702	79.5	23.8	39.9	0.121
HAIG-02-Q	Measured	0.566	7.32	4.98	4.75	0.221
HAIG-02-Q	Target	0.552	7.14	5.59	4.77	0.221
HAIG-03-CCC	Measured	0.340	4.71	2.64	2.24	0.177
HAIG-03-CCC	Target	0.332	4.53	2.43	2.14	0.179
HAIG-03-Q	Measured	0.308	1.56	<1.26	1.06	0.281
HAIG-03-Q	Target	0.300	1.50	<1.16	1.01	0.283
HAIG-04-CCC	Measured	<0.0466	95.2	49.1	35.3	0.343
HAIG-04-CCC	Target	<0.0456	93.1	67.4	35.1	0.344
HAIG-04-Q	Measured	0.398	0.623	<2.05	0.795	0.369
HAIG-04-Q	Target	0.390	0.609	<2.82	0.791	0.370
HAIG-05-CCC	Measured	2.15	27.6	12.8	16.8	0.169
HAIG-05-CCC	Target	2.14	26.7	12.8	15.9	0.169
HAIG-05-Q	Measured	0.350	7.10	5.42	5.33	0.184
HAIG-05-Q	Target	0.348	6.86	5.39	5.03	0.184
HAIG-07-CCC	Measured	1.23	82.0	NA	35.3	<0.0428
HAIG-07-CCC	Target	1.23	79.9	<6.15	35.2	<0.0431
HAIG-07-Q	Measured	1.00	2.73	NA	2.22	0.231
HAIG-07-Q	Target	0.996	2.66	<6.15	2.21	0.232
HAIG-08-CCC	Measured	0.607	89.5	8.71	34.7	0.0885
HAIG-08-CCC	Target	0.597	87.2	8.99	35.1	0.0925
HAIG-08-Q	Measured	0.699	3.37	2.28	2.18	0.306
HAIG-08-Q	Target	0.688	3.28	2.35	2.20	0.320
HAIG-09-CCC	Measured	1.11	10.4	7.36	5.51	0.218
HAIG-09-CCC	Target	1.09	10.2	7.35	5.50	0.219
HAIG-09-Q	Measured	0.627	6.58	5.40	4.22	0.247
HAIG-09-Q	Target	0.615	6.39	5.39	4.21	0.248

Table 3-1. Normalized PCT Results for Selected Elements (continued)

Glass ID	Comp. View	NC Al (g/L)	NC B (g/L)	NC Li (g/L)	NC Na (g/L)	NC Si (g/L)
HAIG-11-CCC	Measured	1.54	26.0	18.8	6.59	0.180
HAIG-11-CCC	Target	1.52	24.8	18.2	6.52	0.181
HAIG-11-Q	Measured	3.97	83.4	26.0	38.1	0.318
HAIG-11-Q	Target	3.92	79.4	25.2	37.7	0.319
HAIG-12-1-CCC-1	Measured	0.760	92.7	75.2	36.8	0.109
HAIG-12-1-CCC-1	Target	0.761	89.7	79.6	36.7	0.110
HAIG-12-Q	Measured	0.299	2.86	1.62	1.94	0.227
HAIG-12-Q	Target	0.300	2.77	1.72	1.94	0.230
HAIG-13-CCC-1	Measured	0.549	39.6	41.8	9.22	0.711
HAIG-13-CCC-1	Target	0.549	37.9	42.5	8.75	0.713
HAIG-13-Q	Measured	0.688	1.22	0.930	1.67	0.435
HAIG-13-Q	Target	0.688	1.17	0.944	1.59	0.436
HAIG-14-CCC-1	Measured	0.648	41.5	25.5	18.8	0.0725
HAIG-14-CCC-1	Target	0.635	39.7	26.3	17.7	0.0727
HAIG-14-Q	Measured	1.24	7.77	5.42	6.02	0.697
HAIG-14-Q	Target	1.22	7.43	5.58	5.67	0.699
HAIG-15-CCC-1	Measured	<0.0428	101	43.0	15.2	0.763
HAIG-15-CCC-1	Target	<0.0422	98.7	43.5	14.9	0.767
HAIG-15-Q	Measured	0.381	0.431	0.453	0.700	0.384
HAIG-15-Q	Target	0.375	0.422	0.459	0.687	0.386
HAIG-16-CCC-1	Measured	0.112	97.3	44.7	28.2	0.144
HAIG-16-CCC-1	Target	0.111	91.4	42.6	28.1	0.144
HAIG-16-Q	Measured	0.465	3.30	1.96	1.89	0.308
HAIG-16-Q	Target	0.460	3.10	1.87	1.88	0.309
HAIG-17-CCC-1	Measured	0.193	12.7	8.70	4.55	0.174
HAIG-17-CCC-1	Target	0.190	12.5	9.08	4.55	0.175
HAIG-17-Q	Measured	0.310	0.686	0.430	0.678	0.283
HAIG-17-Q	Target	0.306	0.671	0.448	0.678	0.284
HAIG-18-CCC-1	Measured	2.71	57.0	23.2	33.6	0.159
HAIG-18-CCC-1	Target	2.70	55.4	22.4	32.0	0.160
HAIG-18-Q	Measured	3.14	86.1	17.7	53.3	0.362
HAIG-18-Q	Target	3.12	83.8	17.1	50.7	0.365
HAIG-19-CCC	Measured	2.88	32.2	19.6	10.2	0.263
HAIG-19-CCC	Target	2.86	31.8	20.0	10.2	0.265
HAIG-19-Q	Measured	1.18	2.24	1.23	2.67	0.561
HAIG-19-Q	Target	1.17	2.21	1.25	2.66	0.565
HAIG-20-CCC	Measured	0.291	4.96	3.95	2.63	0.236
HAIG-20-CCC	Target	0.294	4.80	3.82	2.66	0.236
HAIG-20-Q	Measured	0.280	5.67	4.15	2.76	0.234
HAIG-20-Q	Target	0.283	5.49	4.01	2.80	0.234
HAIG-21-CCC	Measured	0.354	85.5	31.0	28.2	<0.0450
HAIG-21-CCC	Target	0.341	82.6	31.4	27.1	<0.0445
HAIG-21-Q	Measured	0.624	76.7	27.0	28.2	0.102
HAIG-21-Q	Target	0.602	74.1	27.5	27.1	0.101
HAIG-22-CCC	Measured	<0.0468	92.4	51.8	16.9	0.242
HAIG-22-CCC	Target	<0.0456	89.1	52.7	17.1	0.243
HAIG-22-Q	Measured	0.288	0.332	0.368	0.491	0.267
HAIG-22-Q	Target	0.280	0.320	0.374	0.495	0.269

Table 3-1. Normalized PCT Results for Selected Elements (continued)

Glass ID	Comp. View	NC Al (g/L)	NC B (g/L)	NC Li (g/L)	NC Na (g/L)	NC Si (g/L)
HAIG-23-CCC	Measured	0.383	1.26	1.89	0.835	0.370
HAIG-23-CCC	Target	0.377	1.21	1.82	0.847	0.370
HAIG-23-Q	Measured	0.337	1.88	1.49	1.03	0.322
HAIG-23-Q	Target	0.333	1.81	1.44	1.04	0.321
HAIG-24-CCC	Measured	0.242	0.367	<0.399	0.394	0.216
HAIG-24-CCC	Target	0.237	0.358	<0.413	0.393	0.216
HAIG-24-Q	Measured	0.264	0.408	0.484	0.464	0.222
HAIG-24-Q	Target	0.258	0.398	0.501	0.463	0.222
HAIG-25-CCC	Measured	0.603	89.3	8.95	34.6	0.104
HAIG-25-CCC	Target	0.599	86.2	9.36	35.1	0.104
HAIG-25-Q	Measured	0.676	3.26	2.21	2.14	0.317
HAIG-25-Q	Target	0.671	3.15	2.31	2.17	0.317

The plots of Exhibit B-1 in Appendix B provide a graphical comparison between the PCT responses for the target and measured compositions.

A review of the PCT data resulted in the following observations:

- The measured glass compositions for the study glasses¹² were generally close to target values; therefore, little difference (average $\leq 1\%$) was seen when evaluating the normalized release using the target or measured glass compositions.
- For most glasses, heat treated samples had significantly higher NC_B , NC_{Li} , and NC_{Na} values and lower NC_{Si} values. NC_{Al} values varied for heat treated samples, but, in general, the values were higher for heat treated samples.
- Of the 24 study glasses:
 - 18 of the CCC glasses and three of the Q glasses have NC_B , NC_{Li} , and/or NC_{Na} values higher than the EA benchmark NC_B value of 16.695 g/L, NC_{Li} value of 9.565 g/L, and NC_{Na} value of 13.346 g/L.¹⁴

4.0 Summary

The elemental release for the study glasses is reported as normalized concentration NC_i . NC_i of several elements was computed for both the target and measured glass compositions. Several of the glasses exhibited NC_B , NC_{Li} , and/or NC_{Na} values that were greater than the EA benchmark NC_B value of 16.695 g/L, NC_{Li} value of 9.565 g/L, and/or NC_{Na} value of 13.346 g/L. Several of the ARM reference glasses included with the study glasses had measurements that fell outside the expected ranges. Two water blanks contained measurable amount of Si; measurements were confirmed by rerun samples. One water blank contained a measurable amount of Na.

5.0 References

1. R.L. Russell, "High-Level Waste (HLW) Glass Testing," EWG-TP-0115, Revision 1.0, 2021.
2. J.W. Amoroso, "Task Technical and Quality Assurance Plan for Hanford Waste Glass Development and Characterization," Savannah River National Laboratory, Aiken, SC, SRNL-RP-2013-00692, Revision 2, 2023.
3. D.K. Peeler, D.S. Kim, J.D. Vienna, M.J. Schweiger, and G.F. Piepel, "Office of River Protection Advanced Low-Activity Waste Glass Research and Development Plan," Pacific Northwest National Laboratory, Richland, WA, PNNL-24883, EWG-RPT-008, Revision 0, 2015.
4. D.K. Peeler, J.D. Vienna, M.J. Schweiger, and K.M. Fox, "Advanced High-Level Waste Glass Research and Development Plan," Pacific Northwest National Laboratory, Richland, WA, PNNL-24450, Revision 0, 2015.
5. "Technical Reviews," Savannah River Site, Aiken, SC, Manual E7, Procedure 2.60, Rev. 22, 2023.
6. "Savannah River National Laboratory Technical Report Design Check Guidelines," Westinghouse Savannah River Company, Aiken, SC, WSRC-IM-2002-00011, Rev. 2, 2004.
7. ASTM, "Standard Test Methods for Determining Chemical Durability of Nuclear, Hazardous, and Mixed Waste Glasses and Multiphase Glass Ceramics: The Product Consistency Test (PCT)," ASTM International, West Conshohocken, PA, C1285 - 21, 2021.
8. "Calibration, Verification, and Operation of the Agilent 5110 ICP-OES Inductively Coupled Plasma-Optical Emission Spectrometer," Savannah River National Laboratory, Aiken, SC, Manual L33, Procedure 0242, Rev. 1, 2021.
9. M.C. Hsieh, "An Analytical Plan for Measuring the Q PCT Solutions of the HLW HAIG Study Glasses," Savannah River National Laboratory, Aiken, SC, SRNL-L3310-2022-00013, Rev. 0, 2022.
10. M.C. Hsieh, "An Analytical Plan for Measuring the CCC PCT Solutions of the HLW HAIG Study Glasses," Savannah River National Laboratory, Aiken, SC, SRNL-L3310-2022-00017, Rev. 0, 2022.
11. JMP(R) Version 16.0.0, SAS Institute Inc., Cary, NC, 2021.
12. M.C. Hsieh, "Composition Measurements of the HLW HAIG Glasses," Savannah River National Laboratory Aiken, SC, SRNL-STI-2022-00297, Rev. 0, 2022.
13. W.L. Ebert, "The Precision of Product Consistency Tests with Reference Glasses ARM-1 and SRM 623," Argonne National Laboratory, Argonne, IL, ANL/CFCT-19/29, Rev. 0, 2019.
14. C.M. Jantzen, N.E. Bibler, D.C. Beam, C.L. Crawford, and M.A. Pickett, "Characterization of the Defense Waste Processing Facility (DWPF) Environmental Assessment (EA) Glass Standard Reference Material," Westinghouse Savannah River Company, Aiken, SC, WSRC-TR-92-346, Revision 1, 1993.

Appendix A. Tables and Exhibits Supporting Analysis of the HLW HAIG PCT Leachates

Table A-1. Dilution-Corrected Q PCT Leachate Measurements (mg/L) Measured by ICP-OES

PNNL Solution ID	Block	Seq.	Lab ID	Al	B	Cd	Cr	K	Li	Na	Si	Zr
HAIG-01-Q-PCT-A	1	20	S-14545	35.9	13.5	<5.00	<5.00	5.75	<5.00	96.5	41.1	<5.00
HAIG-01-Q-PCT-B	2	7	S-14546	36.3	15.1	<5.00	<5.00	<5.00	<5.00	105	39.3	<5.00
HAIG-01-Q-PCT-C	3	32	S-14547	32.9	13.8	<5.00	<5.00	<5.00	<5.00	102	38.5	<5.00
HAIG-02-Q-PCT-A	1	31	S-14548	74.0	463	<5.00	<5.00	9.85	28.0	685	24.4	<5.00
HAIG-02-Q-PCT-B	2	9	S-14549	68.5	419	<5.00	<5.00	6.80	28.1	685	22.4	<5.00
HAIG-02-Q-PCT-C	3	27	S-14550	67.0	430	<5.00	<5.00	6.65	27.4	670	22.6	<5.00
HAIG-03-Q-PCT-A	1	27	S-14551	33.3	76.0	<5.00	<5.00	<5.00	<5.00	124	44.9	<5.00
HAIG-03-Q-PCT-B	2	16	S-14552	31.7	70.0	<5.00	<5.00	<5.00	<5.00	126	42.6	<5.00
HAIG-03-Q-PCT-C	3	34	S-14553	31.0	73.0	<5.00	<5.00	<5.00	<5.00	128	42.6	<5.00
HAIG-04-Q-PCT-A	1	23	S-14559	41.3	17.8	<5.00	<5.00	7.10	<5.00	109	55.0	<5.00
HAIG-04-Q-PCT-B	2	31	S-14560	47.7	22.3	<5.00	<5.00	5.60	<5.00	128	62.5	<5.00
HAIG-04-Q-PCT-C	3	3	S-14561	39.6	18.2	<5.00	<5.00	<5.00	<5.00	109	54.0	<5.00
HAIG-05-Q-PCT-A	1	2	S-14562	38.1	459	<5.00	<5.00	28.1	11.4	575	19.5	<5.00
HAIG-05-Q-PCT-B	2	15	S-14563	37.3	448	<5.00	<5.00	27.2	11.8	615	18.8	<5.00
HAIG-05-Q-PCT-C	3	5	S-14564	35.1	449	<5.00	<5.00	26.4	10.8	570	18.4	<5.00
HAIG-06-Q-PCT-A	1	12	S-14565	61.5	340	<5.00	<5.00	8.15	5.15	520	32.1	<5.00
HAIG-06-Q-PCT-B	2	17	S-14566	57.0	325	<5.00	<5.00	7.45	5.50	540	29.9	<5.00
HAIG-06-Q-PCT-C	3	26	S-14567	55.5	324	<5.00	<5.00	7.05	<5.00	535	30.6	<5.00
HAIG-07-Q-PCT-A	1	13	S-14568	127	95.5	<5.00	<5.00	17.1	<5.00	315	28.3	<5.00
HAIG-07-Q-PCT-B	2	2	S-14569	128	94.5	<5.00	<5.00	15.0	<5.00	336	26.4	<5.00
HAIG-07-Q-PCT-C	3	2	S-14570	121	90.5	<5.00	<5.00	13.7	<5.00	324	26.3	<5.00
HAIG-08-Q-PCT-A	1	34	S-14571	90.5	159	<5.00	<5.00	<5.00	19.1	277	38.0	<5.00
HAIG-08-Q-PCT-B	2	30	S-14572	90.5	146	<5.00	<5.00	<5.00	20.4	291	36.9	<5.00
HAIG-08-Q-PCT-C	3	12	S-14573	84.5	149	<5.00	<5.00	<5.00	19.6	291	36.4	<5.00
HAIG-09-Q-PCT-A	1	29	S-14579	71.0	459	<5.00	<5.00	8.90	142	423	27.5	<5.00
HAIG-09-Q-PCT-B	2	34	S-14580	69.0	415	<5.00	<5.00	5.70	141	426	26.9	<5.00
HAIG-09-Q-PCT-C	3	23	S-14581	66.0	426	<5.00	<5.00	5.50	140	426	26.3	<5.00
HAIG-11-Q-PCT-A	1	15	S-14582	510	2270	<5.00	685	29.1	530	5600	39.0	<5.00
HAIG-11-Q-PCT-B	2	20	S-14583	525	2100	<5.00	635	27.9	540	5600	38.2	<5.00
HAIG-11-Q-PCT-C	3	7	S-14584	492	2170	<5.00	635	25.7	540	5500	38.4	<5.00
HAIG-12-Q-PCT-A	1	17	S-14585	34.9	147	<5.00	<5.00	10.4	5.90	281	31.8	<5.00
HAIG-12-Q-PCT-B	2	13	S-14586	33.6	133	<5.00	<5.00	7.25	6.10	276	30.4	<5.00

Table A-1. Dilution-Corrected Q PCT Leachate Measurements (mg/L) Measured by ICP-OES (continued)

PNNL Solution ID	Block	Seq.	Lab ID	Al	B	Cd	Cr	K	Li	Na	Si	Zr
HAIG-12-Q-PCT-C	3	31	S-14587	32.0	137	<5.00	<5.00	7.40	5.10	280	30.1	<5.00
HAIG-13-Q-PCT-A	1	22	S-14588	76.0	30.0	<5.00	<5.00	9.85	20.7	195	58.5	<5.00
HAIG-13-Q-PCT-B	2	5	S-14589	74.0	29.2	<5.00	<5.00	7.95	21.0	195	57.0	<5.00
HAIG-13-Q-PCT-C	3	16	S-14590	73.0	30.5	<5.00	<5.00	7.60	21.7	204	56.5	<5.00
HAIG-14-Q-PCT-A	1	18	S-14591	149	404	<5.00	<5.00	6.70	137	770	73.0	<5.00
HAIG-14-Q-PCT-B	2	32	S-14592	146	372	<5.00	<5.00	5.35	141	795	72.0	<5.00
HAIG-15-Q-PCT-A	1	21	S-14598	46.6	10.5	<5.00	<5.00	<5.00	12.1	73.0	74.0	<5.00
HAIG-15-Q-PCT-B	2	8	S-14599	44.6	12.2	<5.00	<5.00	<5.00	13.3	78.5	70.5	<5.00
HAIG-15-Q-PCT-C	3	14	S-14600	42.4	11.5	<5.00	<5.00	<5.00	12.7	76.5	72.5	<5.00
HAIG-16-Q-PCT-A	1	26	S-14601	55.0	106	<5.00	<5.00	<5.00	21.9	261	45.8	<5.00
HAIG-16-Q-PCT-B	2	21	S-14602	53.5	98.5	<5.00	<5.00	<5.00	22.7	270	43.1	<5.00
HAIG-16-Q-PCT-C	3	25	S-14603	49.4	96.5	<5.00	<5.00	<5.00	21.7	265	43.5	<5.00
HAIG-17-Q-PCT-A	1	8	S-14604	33.8	26.3	<5.00	<5.00	<5.00	5.55	85.5	48.0	<5.00
HAIG-17-Q-PCT-B	2	22	S-14605	34.1	28.1	<5.00	<5.00	<5.00	5.75	88.5	48.2	<5.00
HAIG-17-Q-PCT-C	3	15	S-14606	32.4	27.6	<5.00	<5.00	<5.00	5.15	90.0	49.3	<5.00
HAIG-18-Q-PCT-A	1	33	S-14607	471	3110	<5.00	180	478	469	7100	39.5	<5.00
HAIG-18-Q-PCT-B	2	26	S-14608	483	2770	<5.00	174	485	466	7050	37.8	<5.00
HAIG-18-Q-PCT-C	3	29	S-14609	465	2880	<5.00	174	472	461	6950	40.0	<5.00
HAIG-19-Q-PCT-A	1	35	S-14618	173	56.5	<5.00	<5.00	<5.00	30.8	382	70.5	<5.00
HAIG-19-Q-PCT-B	2	36	S-14619	173	53.5	<5.00	<5.00	<5.00	32.9	393	68.0	<5.00
HAIG-19-Q-PCT-C	3	33	S-14620	169	55.0	<5.00	<5.00	<5.00	32.2	397	68.5	<5.00
HAIG-20-Q-PCT-A	1	32	S-14610	32.8	359	<5.00	<5.00	5.15	66.0	292	32.9	<5.00
HAIG-20-Q-PCT-B	2	3	S-14611	32.4	332	<5.00	<5.00	<5.00	66.5	295	31.8	<5.00
HAIG-20-Q-PCT-C	3	18	S-14612	29.0	334	<5.00	<5.00	<5.00	65.0	292	31.6	<5.00
HAIG-21-Q-PCT-A	1	24	S-14621	74.5	2870	<5.00	26.6	11.2	595	3190	13.0	<5.00
HAIG-21-Q-PCT-B	2	12	S-14622	74.0	2640	<5.00	25.8	7.95	585	3240	11.5	<5.00
HAIG-21-Q-PCT-C	3	21	S-14623	68.5	2650	<5.00	25.3	7.25	595	3180	11.6	<5.00
HAIG-22-Q-PCT-A	1	7	S-14624	32.2	7.95	<5.00	<5.00	<5.00	7.65	48.8	48.3	<5.00
HAIG-22-Q-PCT-B	2	25	S-14625	31.2	10.4	<5.00	<5.00	<5.00	7.85	49.6	46.5	<5.00
HAIG-22-Q-PCT-C	3	24	S-14626	28.9	9.60	<5.00	<5.00	<5.00	7.05	47.2	45.4	<5.00
HAIG-23-Q-PCT-A	1	30	S-14627	38.1	104	<5.00	<5.00	<5.00	38.3	85.5	51.0	<5.00
HAIG-23-Q-PCT-B	2	4	S-14628	37.8	97.0	<5.00	<5.00	<5.00	39.0	87.0	50.0	<5.00
HAIG-23-Q-PCT-C	3	13	S-14629	34.7	95.0	<5.00	<5.00	<5.00	37.7	85.0	50.0	<5.00

Table A-1. Dilution-Corrected Q PCT Leachate Measurements (mg/L) Measured by ICP-OES (continued)

PNNL Solution ID	Block	Seq.	Lab ID	Al	B	Cd	Cr	K	Li	Na	Si	Zr
HAIG-24-Q-PCT-A	1	14	S-14630	31.4	18.5	<5.00	<5.00	<5.00	7.00	39.7	33.1	<5.00
HAIG-24-Q-PCT-B	2	23	S-14631	30.3	20.4	<5.00	<5.00	<5.00	7.35	40.3	32.6	<5.00
HAIG-24-Q-PCT-C	3	11	S-14632	28.7	18.8	<5.00	<5.00	<5.00	6.60	38.6	32.3	<5.00
HAIG-25-Q-PCT-A	1	3	S-14633	84.5	140	<5.00	<5.00	<5.00	17.6	262	36.4	<5.00
HAIG-25-Q-PCT-B	2	11	S-14634	88.5	146	<5.00	<5.00	<5.00	20.6	292	36.7	<5.00
HAIG-25-Q-PCT-C	3	17	S-14635	86.0	149	<5.00	<5.00	<5.00	19.9	293	37.2	<5.00
ARM STD-PCT-A	1	6	S-14554	5.55	17.0	<5.00	<5.00	<5.00	13.7	41.8	67.0	<5.00
ARM STD-PCT-B	2	6	S-14555	5.30	18.2	<5.00	<5.00	<5.00	13.6	41.9	63.5	<5.00
ARM STD-PCT-C	3	22	S-14556	<5.00	17.6	<5.00	<5.00	<5.00	12.5	39.4	62.0	<5.00
ARM STD-PCT-A	1	9	S-14574	5.40	16.9	<5.00	<5.00	<5.00	13.4	41.2	64.5	<5.00
ARM STD-PCT-B	2	35	S-14575	5.20	17.3	<5.00	<5.00	<5.00	13.1	38.7	60.0	<5.00
ARM STD-PCT-C	3	8	S-14576	<5.00	20.9	<5.00	<5.00	<5.00	13.8	43.5	65.0	<5.00
ARM STD-PCT-A	1	25	S-14593	5.25	17.7	<5.00	<5.00	<5.00	13.3	42.0	63.0	<5.00
ARM STD-PCT-B	2	33	S-14594	5.05	18.6	<5.00	<5.00	<5.00	13.8	42.4	62.5	<5.00
ARM STD-PCT-C	3	30	S-14595	<5.00	16.7	<5.00	<5.00	<5.00	11.6	37.8	59.0	<5.00
ARM STD-PCT-A	1	4	S-14613	<5.00	17.0	<5.00	<5.00	<5.00	11.7	38.2	59.0	<5.00
ARM STD-PCT-B	2	24	S-14614	5.30	16.2	<5.00	<5.00	<5.00	12.6	38.2	58.5	<5.00
ARM STD-PCT-C	3	36	S-14615	<5.00	16.2	<5.00	<5.00	<5.00	11.8	37.7	60.0	<5.00
ARM STD-PCT-A	1	16	S-14636	5.65	27.0	<5.00	<5.00	<5.00	20.4	58.0	81.5	<5.00
ARM STD-PCT-B	2	29	S-14637	5.55	25.2	<5.00	<5.00	<5.00	19.8	55.5	76.0	<5.00
ARM STD-PCT-C	3	20	S-14638	<5.00	26.4	<5.00	<5.00	<5.00	20.3	56.5	80.0	<5.00
WATER BLK-PCT-A	1	11	S-14557	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
WATER BLK-PCT-B	3	4	S-14558	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	6.55	<5.00
WATER BLK-PCT-A	3	35	S-14577	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
WATER BLK-PCT-B	2	14	S-14578	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-A	1	5	S-14596	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-B	3	9	S-14597	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-A	3	6	S-14616	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-B	2	18	S-14617	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-A	1	36	S-14639	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-B	2	27	S-14640	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
std-11	1	1	std-11	4.03	20.4	<1.00	<1.00	9.87	9.90	79.3	50.4	<1.00
std-12	1	10	std-12	4.04	20.2	<1.00	<1.00	9.63	9.87	79.1	50.0	<1.00

Table A-1. Dilution-Corrected Q PCT Leachate Measurements (mg/L) Measured by ICP-OES (continued)

PNNL Solution ID	Block	Seq.	Lab ID	Al	B	Cd	Cr	K	Li	Na	Si	Zr
std-13	1	19	std-13	4.08	20.7	<1.00	<1.00	9.96	10.2	81.2	50.7	<1.00
std-14	1	28	std-14	3.97	20.6	<1.00	<1.00	10.0	10.1	80.6	50.4	<1.00
std-15	1	37	std-15	4.03	20.8	<1.00	<1.00	9.97	10.1	80.2	50.8	<1.00
std-21	2	1	std-21	4.36	19.5	<1.00	<1.00	9.88	10.1	79.2	48.5	<1.00
std-22	2	10	std-22	4.26	19.0	<1.00	<1.00	10.0	9.97	78.8	47.5	<1.00
std-23	2	19	std-23	4.31	19.0	<1.00	<1.00	9.82	9.95	78.6	47.8	<1.00
std-24	2	28	std-24	4.36	19.3	<1.00	<1.00	10.1	10.1	79.7	48.2	<1.00
std-25	2	37	std-25	4.32	19.0	<1.00	<1.00	10.2	10.3	81.1	47.9	<1.00
std-31	3	1	std-31	3.67	18.8	<1.00	<1.00	9.01	9.87	80.1	47.8	<1.00
std-32	3	10	std-32	3.75	19.2	<1.00	<1.00	9.31	10.3	83.1	48.5	<1.00
std-33	3	19	std-33	3.81	19.3	<1.00	<1.00	9.47	10.3	82.8	49.1	<1.00
std-34	3	28	std-34	3.72	19.2	<1.00	<1.00	9.30	10.3	82.8	48.5	<1.00
std-35	3	37	std-35	3.77	19.4	<1.00	<1.00	9.50	10.2	82.6	48.7	<1.00
ARM STD-PCT-A	4	28	S-14554-R	<5.00	18.6	<5.00	<5.00	<5.00	14.0	41.1	64.0	<5.00
ARM STD-PCT-B	4	11	S-14555-R	<5.00	18.0	<5.00	<5.00	<5.00	13.3	40.4	62.5	<5.00
ARM STD-PCT-C	4	21	S-14556-R	<5.00	17.3	<5.00	<5.00	<5.00	12.9	39.7	61.5	<5.00
ARM STD-PCT-A	4	3	S-14574-R	<5.00	18.4	<5.00	<5.00	<5.00	13.3	40.5	61.5	<5.00
ARM STD-PCT-B	4	9	S-14575-R	<5.00	17.0	<5.00	<5.00	<5.00	12.4	38.3	58.5	<5.00
ARM STD-PCT-C	4	5	S-14576-R	<5.00	20.6	<5.00	<5.00	<5.00	14.5	43.1	64.5	<5.00
ARM STD-PCT-A	4	27	S-14593-R	<5.00	18.0	<5.00	<5.00	<5.00	13.4	41.2	60.0	<5.00
ARM STD-PCT-B	4	15	S-14594-R	<5.00	18.0	<5.00	<5.00	<5.00	13.2	41.3	61.0	<5.00
ARM STD-PCT-C	4	12	S-14595-R	<5.00	15.9	<5.00	<5.00	<5.00	12.0	38.1	58.0	<5.00
ARM STD-PCT-A	4	29	S-14613-R	<5.00	16.7	<5.00	<5.00	<5.00	12.0	38.3	59.0	<5.00
ARM STD-PCT-B	4	22	S-14614-R	<5.00	16.2	<5.00	<5.00	<5.00	11.8	37.6	58.0	<5.00
ARM STD-PCT-C	4	23	S-14615-R	<5.00	16.9	<5.00	<5.00	<5.00	12.3	38.4	59.5	<5.00
ARM STD-PCT-A	4	2	S-14636-R	5.25	26.4	<5.00	<5.00	<5.00	20.2	57.0	77.5	<5.00
ARM STD-PCT-B	4	17	S-14637-R	<5.00	24.3	<5.00	<5.00	<5.00	18.7	54.0	74.0	<5.00
ARM STD-PCT-C	4	20	S-14638-R	<5.00	26.9	<5.00	<5.00	<5.00	20.8	57.5	78.0	<5.00
MQ WATER BLK-PCT-A	4	10	S-14557-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-B	4	24	S-14558-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	5.40	<5.00
MQ WATER BLK-PCT-A	4	30	S-14577-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-B	4	6	S-14578-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-A	4	16	S-14596-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
MQ WATER BLK-PCT-B	4	26	S-14597-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00

Table A-1. Dilution-Corrected Q PCT Leachate Measurements (mg/L) Measured by ICP-OES (continued)

PNNL Solution ID	Block	Seq.	Lab ID	Al	B	Cd	Cr	K	Li	Na	Si	Zr
<i>MQ WATER BLK-PCT-A</i>	4	8	<i>S-14616-R</i>	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
<i>MQ WATER BLK-PCT-B</i>	4	4	<i>S-14617-R</i>	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
<i>MQ WATER BLK-PCT-A</i>	4	14	<i>S-14639-R</i>	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
<i>MQ WATER BLK-PCT-B</i>	4	18	<i>S-14640-R</i>	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
<i>std-41</i>	4	1	<i>std-41</i>	3.72	18.7	<1.00	<1.00	9.28	9.98	80.8	47.3	<1.00
<i>std-42</i>	4	7	<i>std-42</i>	3.74	18.6	<1.00	<1.00	9.46	9.93	80.4	47.0	<1.00
<i>std-43</i>	4	13	<i>std-43</i>	3.60	18.6	<1.00	<1.00	9.34	9.98	81.0	47.3	<1.00
<i>std-44</i>	4	19	<i>std-44</i>	3.75	18.5	<1.00	<1.00	9.57	10.0	81.3	47.3	<1.00
<i>std-45</i>	4	25	<i>std-45</i>	3.85	18.8	<1.00	<1.00	9.43	10.0	81.4	47.5	<1.00
<i>std-46</i>	4	31	<i>std-46</i>	3.79	18.7	<1.00	<1.00	9.41	9.99	81.0	47.4	<1.00

3 σ Ranges for the ARM-1 mg/L Measurements^dBoron: 2.18 – 29.3 mg/L (15.7 $\pm$ 13.6 mg/L)Sodium: 20.7 – 43.7 mg/L (32.2 $\pm$ 11.5 mg/L)Silicon: 46.9 – 68.9 mg/L (57.9 $\pm$ 11.0 mg/L)

ARM-1 values that fall outside of the reference ranges are shaded grey.

^d W.L. Ebert, "The Precision of Product Consistency Tests with Reference Glasses ARM-1 and SRM 623," Argonne National Laboratory, Argonne, IL, ANL/CFCT-19/29, Rev. 0, 2019

Table A-2. Dilution-Corrected CCC Glass PCT Leachate Measurements (mg/L) Measured by ICP-OES

PNNL Solution ID	Block	Seq.	Lab ID	Al	B	Cd	Cr	K	Li	Na	Si	Zr
HAIG-01-CCC-PCT-A	1	26	S-14900	21.5	1280	<5.00	<5.00	32.3	71.0	2270	17.9	<5.00
HAIG-01-CCC-PCT-B	2	7	S-14901	22.1	1390	<5.00	<5.00	34.3	70.5	2200	19.5	<5.00
HAIG-01-CCC-PCT-C	3	31	S-14902	25.8	1430	<5.00	<5.00	35.6	85.0	2440	21.6	<5.00
HAIG-02-CCC-PCT-A	1	11	S-14903	90.0	4560	<5.00	30.0	21.8	126	5650	12.1	<5.00
HAIG-02-CCC-PCT-B	2	33	S-14904	81.0	4900	<5.00	31.7	22.6	116	5350	12.0	<5.00
HAIG-02-CCC-PCT-C	3	13	S-14905	96.0	5150	<5.00	31.7	23.2	114	6050	14.0	<5.00
HAIG-03-CCC-PCT-A	1	23	S-14906	34.0	205	<5.00	<5.00	<5.00	10.4	259	25.7	<5.00
HAIG-03-CCC-PCT-B	2	27	S-14907	34.6	227	<5.00	<5.00	<5.00	12.0	256	27.3	<5.00
HAIG-03-CCC-PCT-C	3	7	S-14908	37.4	232	<5.00	<5.00	<5.00	9.35	283	29.4	<5.00
HAIG-04-CCC-PCT-A	1	9	S-14909	<5.00	2770	<5.00	62.5	28.5	127	5200	51.5	<5.00
HAIG-04-CCC-PCT-B	2	30	S-14910	<5.00	2990	<5.00	64.5	29.3	117	4760	52.0	<5.00
HAIG-04-CCC-PCT-C	3	17	S-14911	<5.00	3100	<5.00	66.0	31.1	116	5300	56.0	<5.00
HAIG-05-CCC-PCT-A	1	15	S-14912	224	1690	<5.00	<5.00	68.5	26.7	1850	16.1	<5.00
HAIG-05-CCC-PCT-B	2	14	S-14913	219	1760	<5.00	<5.00	71.0	27.1	1760	17.5	<5.00
HAIG-05-CCC-PCT-C	3	25	S-14914	238	1830	<5.00	<5.00	74.5	26.7	1950	18.8	<5.00
HAIG-06-CCC-PCT-A	3	3	S-14920	387	5150	<5.00	22.3	39.2	<5.00	5750	21.4	<5.00
HAIG-06-CCC-PCT-B	1	16	S-14921	368	4750	<5.00	19.6	35.0	<5.00	5700	17.5	<5.00
HAIG-06-CCC-PCT-C	2	6	S-14922	349	4840	<5.00	21.3	36.0	7.35	5100	16.6	<5.00
HAIG-07-CCC-PCT-A	3	4	S-14923	178	2900	<5.00	<5.00	24.0	<5.00	5300	<5.00	<5.00
HAIG-07-CCC-PCT-B	1	31	S-14924	149	2720	<5.00	<5.00	19.2	<5.00	5450	<5.00	<5.00
HAIG-07-CCC-PCT-C	2	9	S-14925	138	2790	<5.00	<5.00	23.5	<5.00	4790	<5.00	<5.00
HAIG-08-CCC-PCT-A	3	32	S-14926	79.5	4180	<5.00	<5.00	16.5	69.5	4750	11.7	<5.00
HAIG-08-CCC-PCT-B	1	14	S-14927	77.5	3800	<5.00	<5.00	15.0	81.0	4700	9.30	<5.00
HAIG-08-CCC-PCT-C	2	31	S-14928	73.5	4060	<5.00	<5.00	17.0	75.5	4240	11.4	<5.00
HAIG-09-CCC-PCT-A	3	21	S-14929	128	700	<5.00	13.6	7.70	187	570	25.1	<5.00
HAIG-09-CCC-PCT-B	1	22	S-14930	118	655	<5.00	12.3	<5.00	195	550	22.2	<5.00
HAIG-09-CCC-PCT-C	2	22	S-14931	119	710	<5.00	14.5	8.60	194	545	24.2	<5.00
HAIG-11-CCC-PCT-A	3	15	S-14932	211	695	<5.00	50.5	<5.00	411	1000	23.1	<5.00
HAIG-11-CCC-PCT-B	1	17	S-14933	197	655	<5.00	48.4	<5.00	391	990	20.3	<5.00
HAIG-11-CCC-PCT-C	2	11	S-14934	186	690	<5.00	52.5	<5.00	365	900	22.2	<5.00
HAIG-12-1-CCC-PCT-A-1	2	32	S-14940	82.5	4520	<5.00	84.0	49.0	256	4960	15.1	<5.00
HAIG-12-1-CCC-PCT-B-1	3	27	S-14941	90.0	4660	<5.00	84.0	51.0	267	5550	16.1	<5.00
HAIG-12-1-CCC-PCT-C-1	1	20	S-14942	82.5	4290	<5.00	79.5	47.7	268	5350	13.2	<5.00
HAIG-13-CCC-PCT-A-1	2	34	S-14943	55.5	945	<5.00	16.0	10.8	830	980	88.5	<5.00
HAIG-13-CCC-PCT-B-1	3	5	S-14944	66.5	1070	<5.00	17.5	12.1	1130	1220	105	<5.00
HAIG-13-CCC-PCT-C-1	1	35	S-14945	56.5	905	<5.00	14.5	7.50	910	1090	89.0	<5.00

Table A-2. Dilution-Corrected CCC Glass PCT Leachate Measurements (mg/L) Measured by ICP-OES (continued)

PNNL Solution ID	Block	Seq.	Lab ID	Al	B	Cd	Cr	K	Li	Na	Si	Zr
HAIG-14-CCC-PCT-A-1	2	20	S-14946	76.0	2090	<5.00	82.0	<5.00	605	2300	7.90	<5.00
HAIG-14-CCC-PCT-B-1	3	14	S-14947	82.0	2160	<5.00	81.0	<5.00	715	2580	8.35	<5.00
HAIG-14-CCC-PCT-C-1	1	2	S-14948	73.0	1970	<5.00	79.5	<5.00	640	2460	6.50	<5.00
HAIG-15-CCC-PCT-A-1	2	18	S-14949	<5.00	2660	<5.00	132	7.95	1080	1570	140	<5.00
HAIG-15-CCC-PCT-B-1	3	26	S-14950	<5.00	2800	<5.00	135	8.50	1490	1770	156	<5.00
HAIG-15-CCC-PCT-C-1	1	13	S-14951	<5.00	2510	<5.00	125	<5.00	1080	1620	137	<5.00
HAIG-16-CCC-PCT-A-1	2	13	S-14952	13.0	2960	<5.00	264	6.50	500	3650	21.5	<5.00
HAIG-16-CCC-PCT-B-1	3	11	S-14953	13.4	3070	<5.00	255	5.65	515	4110	21.4	<5.00
HAIG-16-CCC-PCT-C-1	1	29	S-14954	11.8	2850	<5.00	247	<5.00	494	4150	18.9	<5.00
HAIG-17-CCC-PCT-A-1	2	15	S-14955	20.4	510	<5.00	<5.00	5.45	107	550	29.4	<5.00
HAIG-17-CCC-PCT-B-1	3	24	S-14956	22.5	525	<5.00	<5.00	5.70	110	630	32.6	<5.00
HAIG-17-CCC-PCT-C-1	1	8	S-14957	19.5	486	<5.00	<5.00	<5.00	116	595	28.1	<5.00
HAIG-18-CCC-PCT-A-1	2	4	S-14958	391	1970	<5.00	16.1	23.8	560	4080	16.4	<5.00
HAIG-18-CCC-PCT-B-1	3	30	S-14959	434	2000	<5.00	15.3	23.0	670	4570	19.3	<5.00
HAIG-18-CCC-PCT-C-1	1	32	S-14960	401	1830	<5.00	13.5	19.0	605	4690	15.8	<5.00
HAIG-19-CCC-PCT-A	1	4	S-14966	409	810	<5.00	104	<5.00	535	1610	30.7	<5.00
HAIG-19-CCC-PCT-B	2	29	S-14967	409	785	<5.00	97.0	<5.00	483	1380	32.7	<5.00
HAIG-19-CCC-PCT-C	3	9	S-14968	438	780	<5.00	96.0	<5.00	515	1510	33.7	<5.00
HAIG-20-CCC-PCT-A	1	12	S-14969	31.6	290	<5.00	<5.00	<5.00	62.0	288	30.8	<5.00
HAIG-20-CCC-PCT-B	2	25	S-14970	30.7	293	<5.00	<5.00	5.70	56.5	254	31.1	<5.00
HAIG-20-CCC-PCT-C	3	18	S-14971	35.6	313	<5.00	<5.00	6.15	70.0	296	35.2	<5.00
HAIG-21-CCC-PCT-A	1	27	S-14972	37.1	2870	<5.00	26.5	14.4	665	3270	<5.00	<5.00
HAIG-21-CCC-PCT-B	2	8	S-14973	41.1	3030	<5.00	30.3	18.7	635	2970	5.25	<5.00
HAIG-21-CCC-PCT-C	3	12	S-14974	45.1	3200	<5.00	29.3	17.4	735	3370	5.70	<5.00
HAIG-22-CCC-PCT-A	1	3	S-14975	<5.00	2460	<5.00	32.2	77.0	1020	1670	40.5	<5.00
HAIG-22-CCC-PCT-B	2	23	S-14976	<5.00	2610	<5.00	34.4	78.5	1010	1590	41.8	<5.00
HAIG-22-CCC-PCT-C	3	29	S-14977	<5.00	2660	<5.00	34.4	82.5	1150	1760	44.5	<5.00
HAIG-23-CCC-PCT-A	1	25	S-14978	39.7	56.5	<5.00	<5.00	<5.00	46.6	66.0	55.0	<5.00
HAIG-23-CCC-PCT-B	2	24	S-14979	39.3	70.0	<5.00	<5.00	<5.00	46.1	68.0	55.5	<5.00
HAIG-23-CCC-PCT-C	3	16	S-14980	46.6	72.5	<5.00	<5.00	<5.00	53.0	75.5	63.5	<5.00
HAIG-24-CCC-PCT-A	1	5	S-14981	25.7	12.0	<5.00	<5.00	<5.00	<5.00	31.8	29.0	<5.00
HAIG-24-CCC-PCT-B	2	2	S-14982	26.6	19.5	<5.00	<5.00	<5.00	7.65	32.8	31.8	<5.00
HAIG-24-CCC-PCT-C	3	22	S-14983	30.8	21.9	<5.00	<5.00	<5.00	<5.00	36.2	35.0	<5.00
HAIG-25-CCC-PCT-A	1	6	S-14984	75.0	3720	<5.00	<5.00	13.8	81.5	4570	10.4	<5.00
HAIG-25-CCC-PCT-B	2	16	S-14985	74.5	4010	<5.00	<5.00	16.6	79.5	4260	12.6	<5.00
HAIG-25-CCC-PCT-C	3	34	S-14986	82.0	4180	<5.00	<5.00	16.4	74.0	4840	13.5	<5.00
ARM-1 STD-PCT-A	1	30	S-14915	<5.00	26.0	<5.00	<5.00	<5.00	21.4	60.5	83.5	<5.00

Table A-2. Dilution-Corrected CCC Glass PCT Leachate Measurements (mg/L) Measured by ICP-OES (continued)

PNNL Solution ID	Block	Seq.	Lab ID	Al	B	Cd	Cr	K	Li	Na	Si	Zr
ARM-1 STD-PCT-B	2	26	S-14916	<5.00	39.5	<5.00	<5.00	<5.00	23.6	66.5	91.0	<5.00
ARM-1 STD-PCT-C	3	6	S-14917	<5.00	43.5	<5.00	<5.00	<5.00	25.8	74.5	105	<5.00
ARM-1 STD-PCT-A	3	2	S-14935	5.15	38.2	<5.00	<5.00	<5.00	25.6	70.5	100	<5.00
ARM-1 STD-PCT-B	1	21	S-14936	<5.00	26.6	<5.00	<5.00	<5.00	21.6	61.5	82.0	<5.00
ARM-1 STD-PCT-C	2	21	S-14937	5.10	30.2	<5.00	<5.00	<5.00	19.1	54.0	79.0	<5.00
ARM-1 STD-PCT-A-1	2	12	S-14961	5.45	26.5	<5.00	<5.00	<5.00	17.7	48.5	75.0	<5.00
ARM-1 STD-PCT-B-1	3	8	S-14962	5.45	24.5	<5.00	<5.00	<5.00	14.7	46.9	75.5	<5.00
ARM-1 STD-PCT-C-1	1	7	S-14963	<5.00	16.2	<5.00	<5.00	<5.00	16.0	44.8	69.5	<5.00
ARM-1 STD-PCT-A	1	33	S-14987	<5.00	22.2	<5.00	<5.00	<5.00	19.5	56.5	79.0	<5.00
ARM-1 STD-PCT-B	2	3	S-14988	<5.00	31.4	<5.00	<5.00	<5.00	21.9	56.5	83.5	<5.00
ARM-1 STD-PCT-C	3	20	S-14989	5.20	35.1	<5.00	<5.00	<5.00	25.3	63.0	90.0	<5.00
Water BLK-PCT-A	1	34	S-14918	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-B	2	17	S-14919	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-A	3	23	S-14938	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-B	1	18	S-14939	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-A	2	5	S-14964	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	6.20	9.95	<5.00
Water BLK-PCT-B	3	33	S-14965	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-A	1	24	S-14990	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-B	2	35	S-14991	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
std-11	1	1	std-11	3.67	18.2	<1.00	<1.00	9.60	10.1	82.1	49.2	<1.00
std-12	1	10	std-12	3.89	19.3	<1.00	<1.00	10.3	10.6	86.2	50.6	<1.00
std-13	1	19	std-13	3.88	19.2	<1.00	<1.00	9.68	10.3	83.3	50.3	<1.00
std-14	1	28	std-14	3.74	18.6	<1.00	<1.00	10.0	10.3	84.4	49.1	<1.00
std-15	1	36	std-15	3.87	19.1	<1.00	<1.00	9.74	10.2	82.8	50.3	<1.00
std-21	2	1	std-21	3.69	19.4	<1.00	<1.00	9.72	9.74	76.1	48.1	<1.00
std-22	2	10	std-22	3.88	21.2	<1.00	<1.00	10.1	9.82	79.2	50.0	<1.00
std-23	2	19	std-23	3.86	21.3	<1.00	<1.00	9.86	9.60	77.8	49.4	<1.00
std-24	2	28	std-24	3.81	21.0	<1.00	<1.00	9.24	9.16	74.3	48.9	<1.00
std-25	2	36	std-25	3.85	20.8	<1.00	<1.00	9.67	9.38	76.9	49.1	<1.00
std-31	3	1	std-31	4.10	21.0	<1.00	<1.00	10.2	10.8	85.0	53.2	<1.00
std-32	3	10	std-32	4.16	21.1	<1.00	<1.00	10.0	9.90	84.1	52.3	<1.00
std-33	3	19	std-33	4.05	20.6	<1.00	<1.00	9.73	10.5	81.1	50.6	<1.00
std-34	3	28	std-34	4.01	20.6	<1.00	<1.00	9.47	11.0	80.0	50.2	<1.00
std-35	3	35	std-35	4.04	20.7	<1.00	<1.00	9.57	10.1	80.8	50.5	<1.00
ARM-1 STD-PCT-A	4	10	S-14915-R	<5.00	33.2	<5.00	<5.00	<5.00	23.6	61.0	85.0	<5.00
ARM-1 STD-PCT-B	4	8	S-14916-R	<5.00	37.7	<5.00	<5.00	<5.00	25.9	67.5	90.0	<5.00
ARM-1 STD-PCT-C	4	24	S-14917-R	<5.00	37.6	<5.00	<5.00	<5.00	25.9	67.5	90.5	<5.00

Table A-2. Dilution-Corrected CCC Glass PCT Leachate Measurements (mg/L) Measured by ICP-OES (continued)

PNNL Solution ID	Block	Seq.	Lab ID	Al	B	Cd	Cr	K	Li	Na	Si	Zr
ARM-1 STD-PCT-A	4	25	S-14935-R	<5.00	33.9	<5.00	<5.00	<5.00	24.7	63.0	85.5	<5.00
ARM-1 STD-PCT-B	4	19	S-14936-R	<5.00	33.4	<5.00	<5.00	<5.00	24.2	62.0	85.0	<5.00
ARM-1 STD-PCT-C	4	13	S-14937-R	5.25	28.2	<5.00	<5.00	<5.00	20.8	55.0	78.5	<5.00
ARM-1 STD-PCT-A-1	4	23	S-14961-R	5.35	24.9	<5.00	<5.00	<5.00	19.0	49.6	74.0	<5.00
ARM-1 STD-PCT-B-1	4	4	S-14962-R	5.30	23.2	<5.00	<5.00	<5.00	18.2	46.4	72.0	<5.00
ARM-1 STD-PCT-C-1	4	14	S-14963-R	5.45	22.0	<5.00	<5.00	<5.00	17.5	44.6	70.0	<5.00
ARM-1 STD-PCT-A	4	15	S-14987-R	5.15	30.3	<5.00	<5.00	<5.00	21.3	60.0	79.5	<5.00
ARM-1 STD-PCT-B	4	9	S-14988-R	5.05	30.4	<5.00	<5.00	<5.00	22.0	57.5	81.5	<5.00
ARM-1 STD-PCT-C	4	12	S-14989-R	<5.00	32.4	<5.00	<5.00	<5.00	23.0	60.0	83.5	<5.00
Water BLK-PCT-A	4	5	S-14918-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-B	4	26	S-14919-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-A	4	17	S-14938-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-B	4	2	S-14939-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-A	4	18	S-14964-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	9.65	<5.00
Water BLK-PCT-B	4	20	S-14965-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-A	4	3	S-14990-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Water BLK-PCT-B	4	7	S-14991-R	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
std-41	4	1	std-41	3.94	20.1	<1.00	<1.00	9.70	10.0	79.9	48.8	<1.00
std-42	4	6	std-42	3.96	20.2	<1.00	<1.00	9.80	10.2	81.2	49.2	<1.00
std-43	4	11	std-43	4.01	20.3	<1.00	<1.00	9.86	10.3	81.8	49.3	<1.00
std-44	4	16	std-44	3.99	20.2	<1.00	<1.00	9.93	10.3	82.0	49.3	<1.00
std-45	4	21	std-45	4.01	20.2	<1.00	<1.00	9.88	10.2	81.8	49.3	<1.00
std-46	4	27	std-46	4.04	20.2	<1.00	<1.00	9.71	10.2	81.6	49.2	<1.00

3σ Ranges for the ARM-1 mg/L Measurements^e

Boron: 2.18 – 29.3 mg/L (15.7 ± 13.6 mg/L)

Sodium: 20.7 – 43.7 mg/L (32.2 ± 11.5 mg/L)

Silicon: 46.9 – 68.9 mg/L (57.9 ± 11.0 mg/L)

ARM-1 values that fall outside of the reference ranges are shaded grey.

^e W.L. Ebert, “The Precision of Product Consistency Tests with Reference Glasses ARM-1 and SRM 623,” Argonne National Laboratory, Argonne, IL, ANL/CFCT-19/29, Rev. 0, 2019

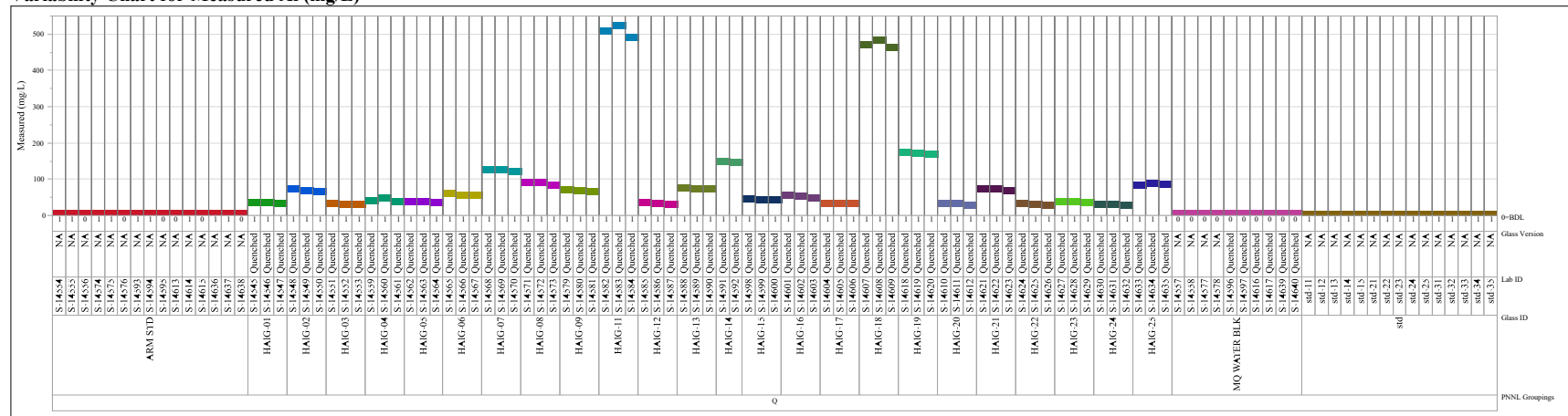
Table A-3. Results from Samples of the Multi-Element Solution Standard Included with the PCT Leachate Analysis

Analytical Block	Q-1	Q-2	Q-3	Q-4 (Rerun)	CCC-1	CCC-2	CCC-3	CCC-4 (Rerun)	Reference Values (mg/L)
Mean (Al (mg/L))	4.03	4.32	3.74	3.74	3.81	3.82	4.07	3.99	4.00
Mean (B (mg/L))	20.5	19.2	19.2	18.7	18.9	20.7	20.8	20.2	20.0
Mean (K (mg/L))	9.89	10.0	9.32	9.42	9.86	9.72	9.79	9.81	10.0
Mean (Li (mg/L))	10.0	10.1	10.2	9.98	10.3	9.54	10.5	10.2	10.0
Mean (Na (mg/L))	80.1	79.5	82.3	81.0	83.8	76.9	82.2	81.4	81.0
Mean (Si (mg/L))	50.5	48.0	48.5	47.3	49.9	49.1	51.4	49.2	50.0
% relative bias, Al	0.75	8.05	-6.40	-6.46	-4.75	-4.55	1.80	-0.21	<10% per ASTM C1285
% relative bias, B	2.70	-4.20	-4.10	-6.75	-5.60	3.70	4.00	1.00	
% relative bias, K	-1.14	0.00	-6.82	-5.85	-1.36	-2.82	-2.06	-1.87	
% relative bias, Li	0.34	0.84	1.94	-0.20	3.00	-4.60	4.60	2.00	
% relative bias, Na	-1.14	-1.88	1.58	-0.02	3.41	-5.11	1.48	0.47	
% relative bias, Si	0.92	-4.04	-2.96	-5.40	-0.20	-1.80	2.72	-1.63	
Standard Deviation (Al (mg/L))	0.04	0.04	0.05	0.08	0.10	0.08	0.06	0.04	
Standard Deviation (B (mg/L))	0.24	0.23	0.23	0.10	0.47	0.77	0.23	0.06	
Standard Deviation (K (mg/L))	0.15	0.16	0.19	0.10	0.29	0.31	0.30	0.09	
Standard Deviation (Li (mg/L))	0.14	0.14	0.19	0.03	0.19	0.27	0.46	0.11	
Standard Deviation (Na (mg/L))	0.88	1.00	1.23	0.36	1.60	1.84	2.21	0.78	
Standard Deviation (Si (mg/L))	0.31	0.38	0.47	0.17	0.70	0.70	1.32	0.19	
%RSD (Al)	0.98	0.96	1.41	2.23	2.60	1.99	1.45	0.92	<10% per ASTM C1285
%RSD (B)	1.17	1.20	1.19	0.56	2.47	3.73	1.13	0.31	
%RSD (K)	1.53	1.56	2.09	1.06	2.90	3.24	3.09	0.96	
%RSD (Li)	1.42	1.39	1.83	0.26	1.82	2.83	4.41	1.07	
%RSD (Na)	1.10	1.26	1.50	0.44	1.91	2.39	2.68	0.95	
%RSD (Si)	0.62	0.80	0.97	0.35	1.40	1.42	2.56	0.39	

Exhibit A-1. Quenched Glass PCT Measurements by Glass ID

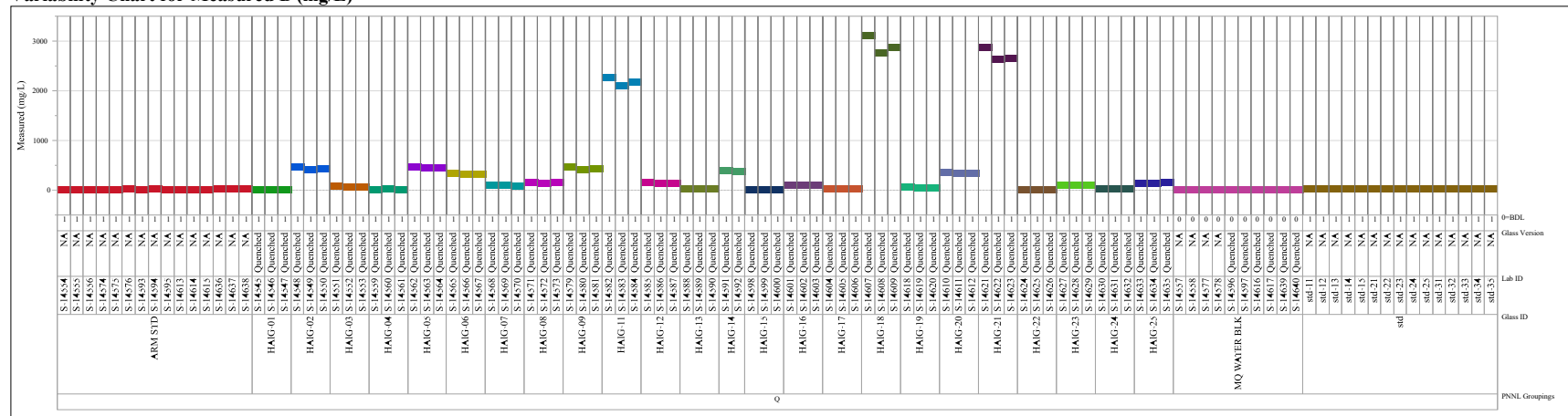
Analyte=Al

Variability Chart for Measured Al (mg/L)



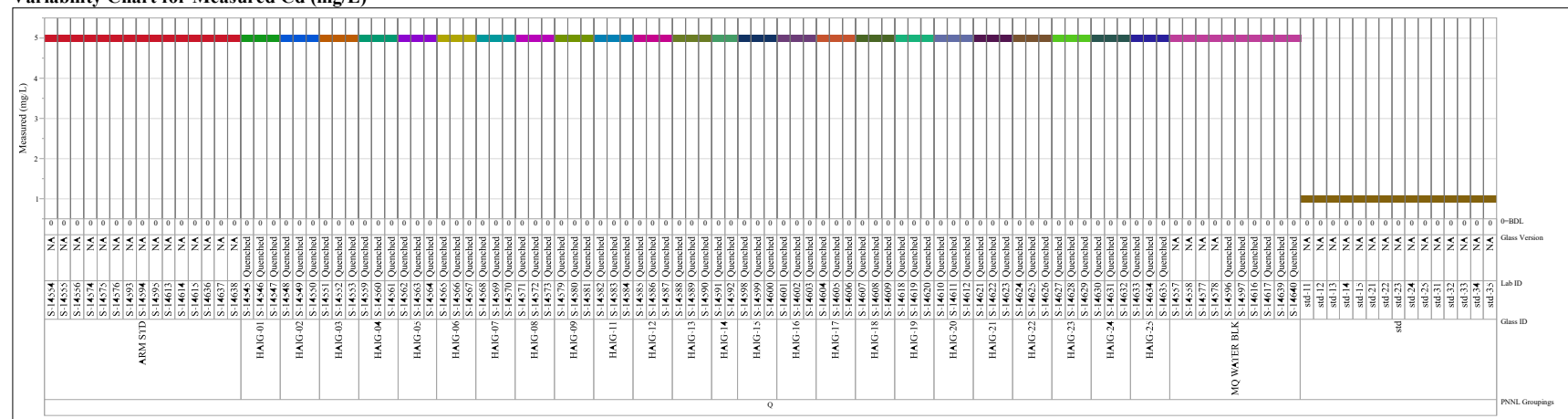
Analyte=B

Variability Chart for Measured B (mg/L)



Analyte=Cd

Variability Chart for Measured Cd (mg/L)



Analyte=Cr

Variability Chart for Measured Cr (mg/L)

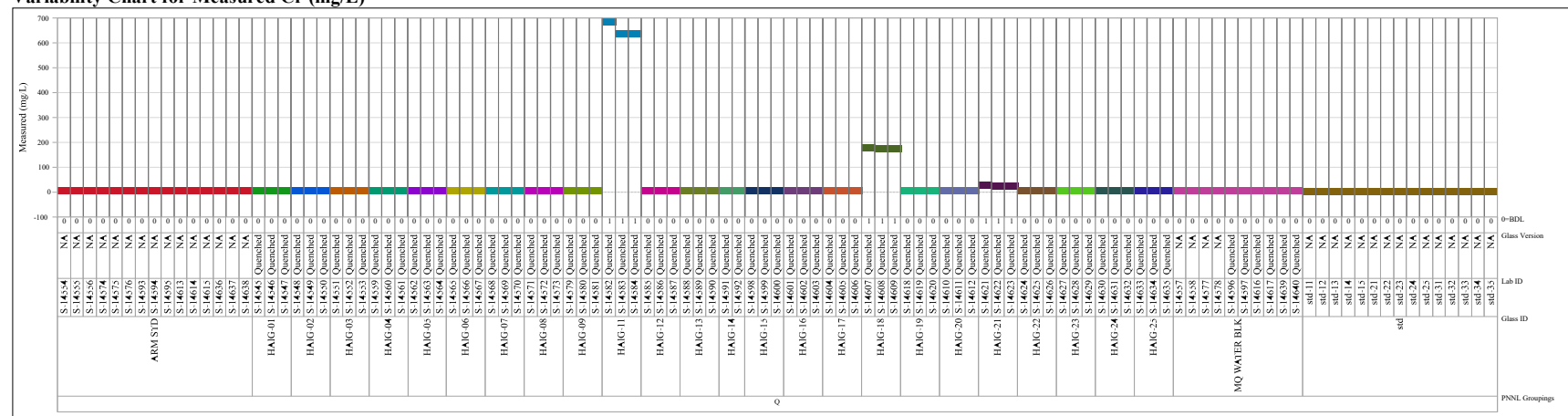
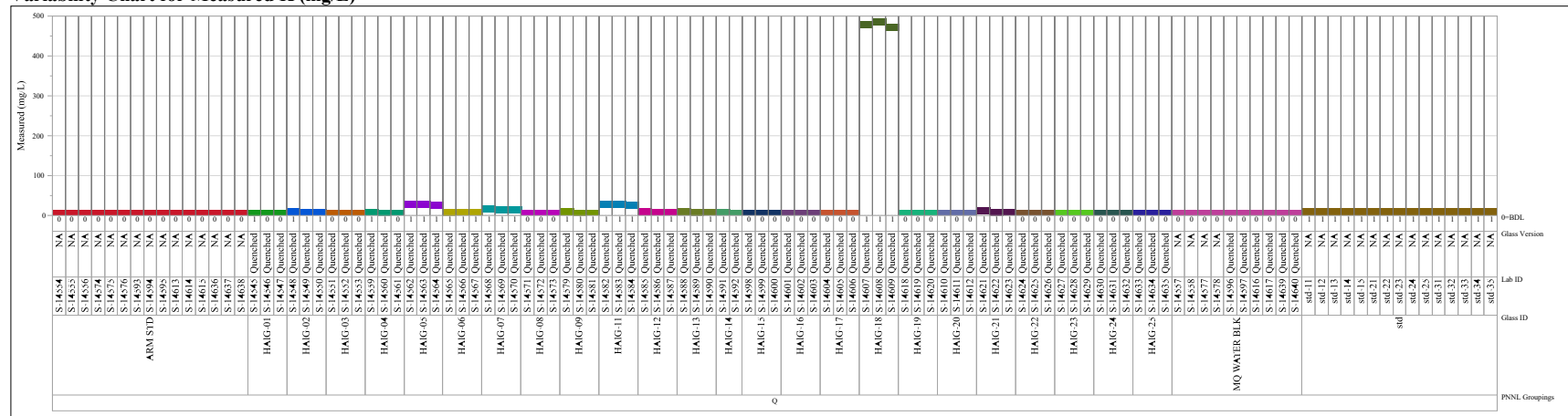


Exhibit A-1. Quenched Glass PCT Measurements by Glass ID (continued)

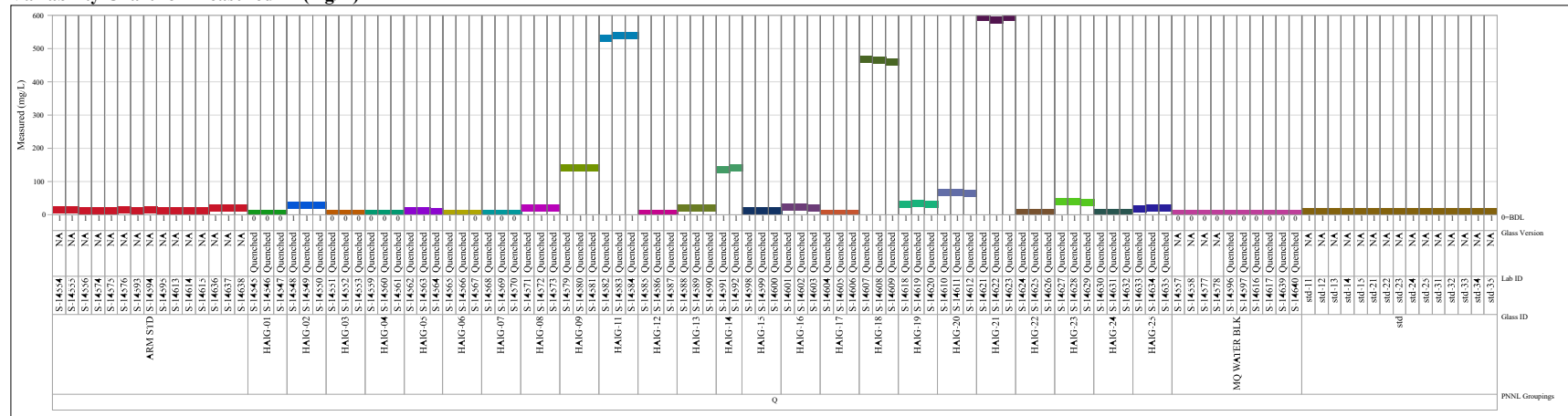
Analyte=K

Variability Chart for Measured K (mg/L)



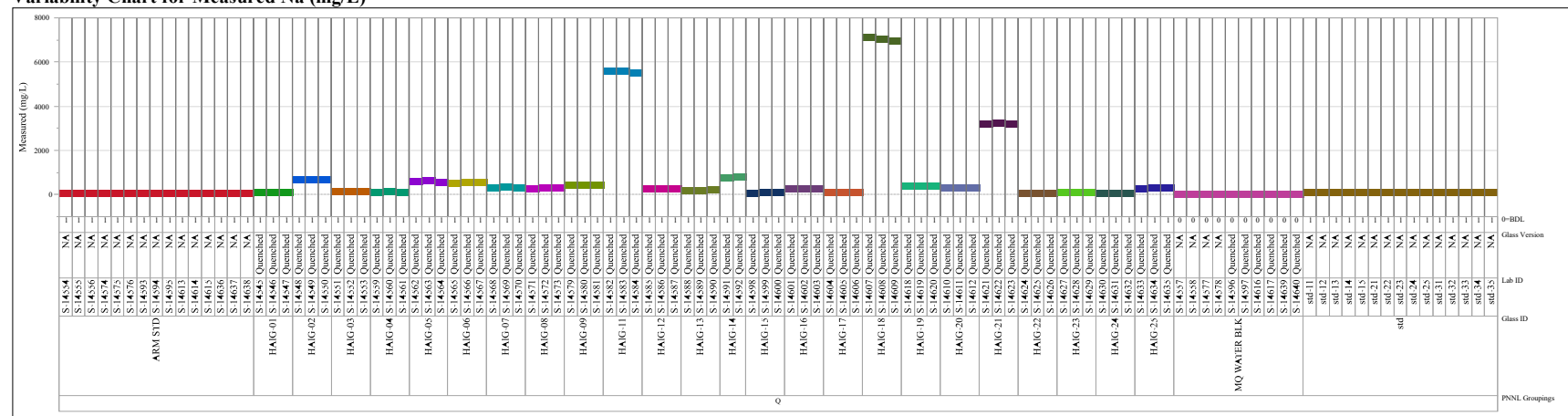
Analyte=Li

Variability Chart for Measured Li (mg/L)



Analyte=Na

Variability Chart for Measured Na (mg/L)



Analyte=Si

Variability Chart for Measured Si (mg/L)

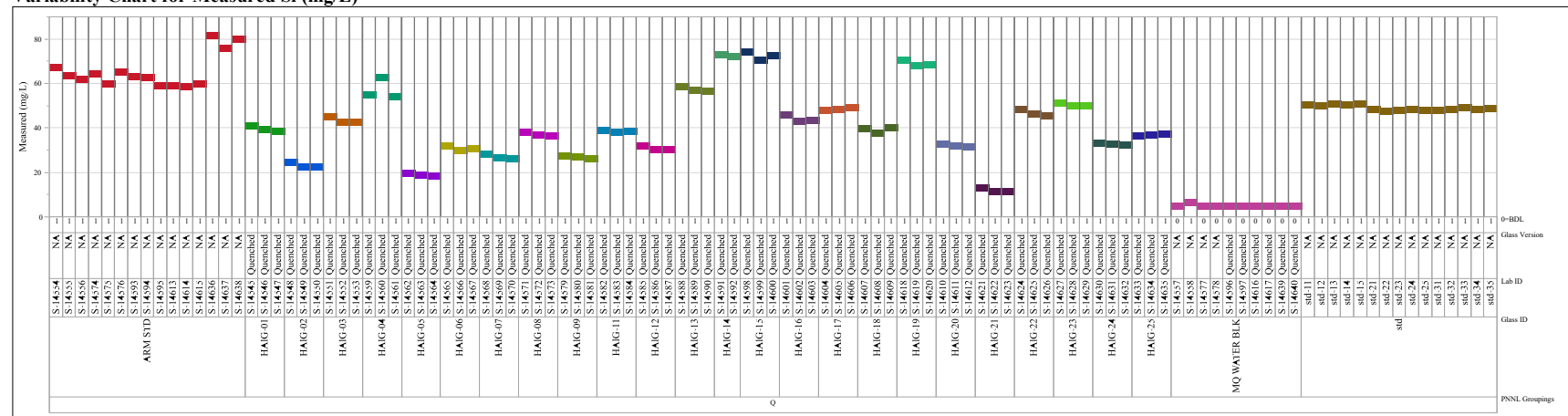


Exhibit A-1. Quenched Glass PCT Measurements by Glass ID (continued)

Analyte=Zr

Variability Chart for Measured Zr (mg/L)

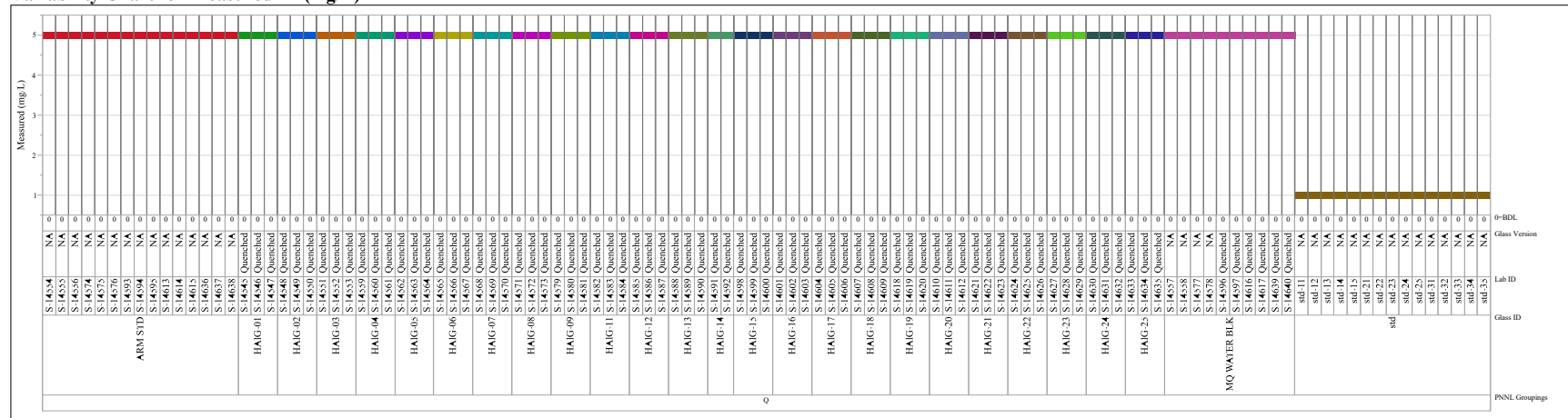
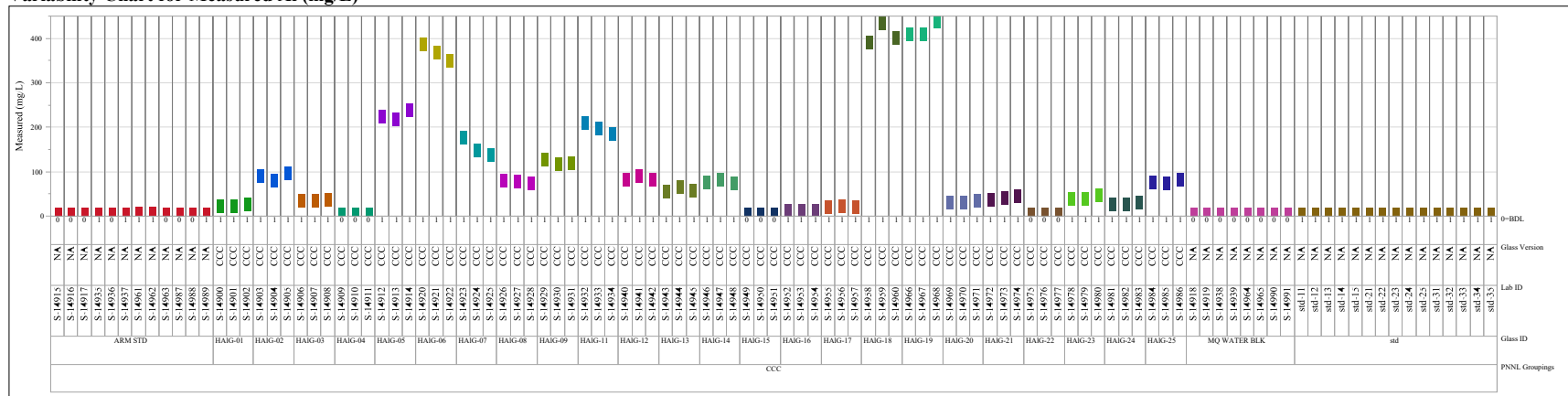


Exhibit A-2. CCC Glass PCT Measurements by Glass ID

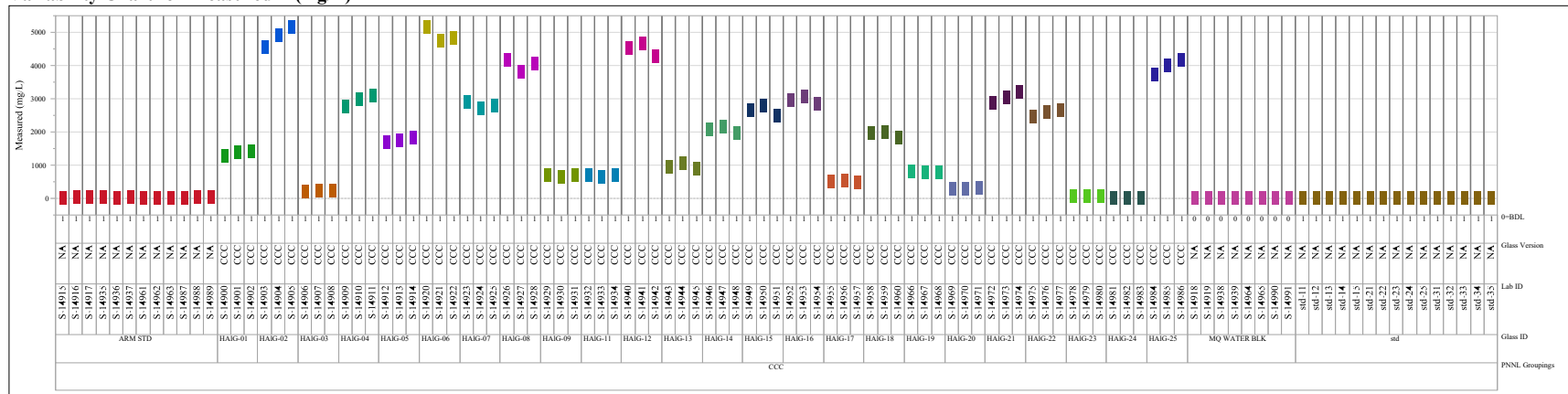
Analyte=Al

Variability Chart for Measured Al (mg/L)



Analyte=B

Variability Chart for Measured B (mg/L)



Analyte=Cd

Lab ID	Glass ID	Glass Version	0-BDL	Measured (mg/L)
PSNEL Groupings	CCC	ARM STD	S-14915	NA
			S-14916	NA
			S-14917	NA
			S-14935	NA
			S-14936	NA
			S-14937	NA
			S-14962	NA
			S-14963	NA
			S-14987	NA
			S-14988	NA
			S-14988	NA
			S-14989	NA
			S-14990	CCC
			S-14991	CCC
			S-14992	CCC
			S-14993	CCC
			S-14994	CCC
			S-14995	CCC
			S-14996	CCC
			S-14997	CCC
			S-14998	CCC
			S-14999	CCC
			S-14910	CCC
			S-14911	CCC
			S-14912	CCC
			S-14913	CCC
			S-14914	CCC
			S-14920	CCC
			S-14921	CCC
			S-14922	CCC
			S-14923	CCC
			S-14924	CCC
			S-14925	CCC
			S-14926	CCC
			S-14927	CCC
			S-14928	CCC
			S-14929	CCC
			S-14930	CCC
			S-14931	CCC
			S-14932	CCC
			S-14933	CCC
			S-14934	CCC
			S-14941	CCC
			S-14942	CCC
			S-14943	CCC
			S-14944	CCC
			S-14945	CCC
			S-14946	CCC
S-14947	CCC			
S-14948	CCC			
S-14949	CCC			
S-14950	CCC			
S-14951	CCC			
S-14952	CCC			
S-14953	CCC			
S-14954	CCC			
S-14955	CCC			
S-14956	CCC			
S-14957	CCC			
S-14958	CCC			
S-14959	CCC			
S-14960	CCC			
S-14961	CCC			
S-14968	CCC			
S-14970	CCC			
S-14971	CCC			
S-14972	CCC			
S-14973	CCC			
S-14974	CCC			
S-14975	CCC			
S-14976	CCC			
S-14977	CCC			
S-14978	CCC			
S-14979	CCC			
S-14980	CCC			
S-14982	CCC			
S-14983	CCC			
S-14984	CCC			
S-14985	CCC			
S-14986	CCC			
S-14918	NA			
S-14938	NA			
S-14939	NA			
S-14994	NA			
S-14965	NA			
S-14966	NA			
S-14991	NA			
sd-11	NA			
sd-12	NA			
sd-13	NA			
sd-14	NA			
sd-15	NA			
sd-21	NA			
sd-22	NA			
sd-23	NA			
sd-24	NA			
sd-25	NA			
sd-31	NA			
sd-32	NA			
sd-33	NA			
sd-34	NA			
sd-35	NA			
MQ WATER BLK				
sd				

Variability Chart for Measured Cr (mg/L)

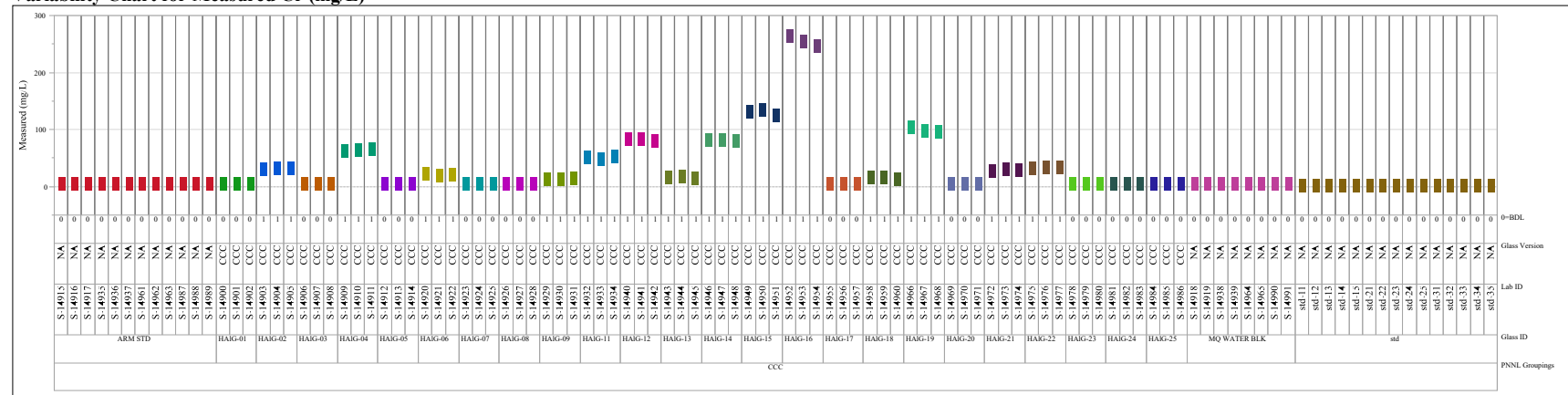
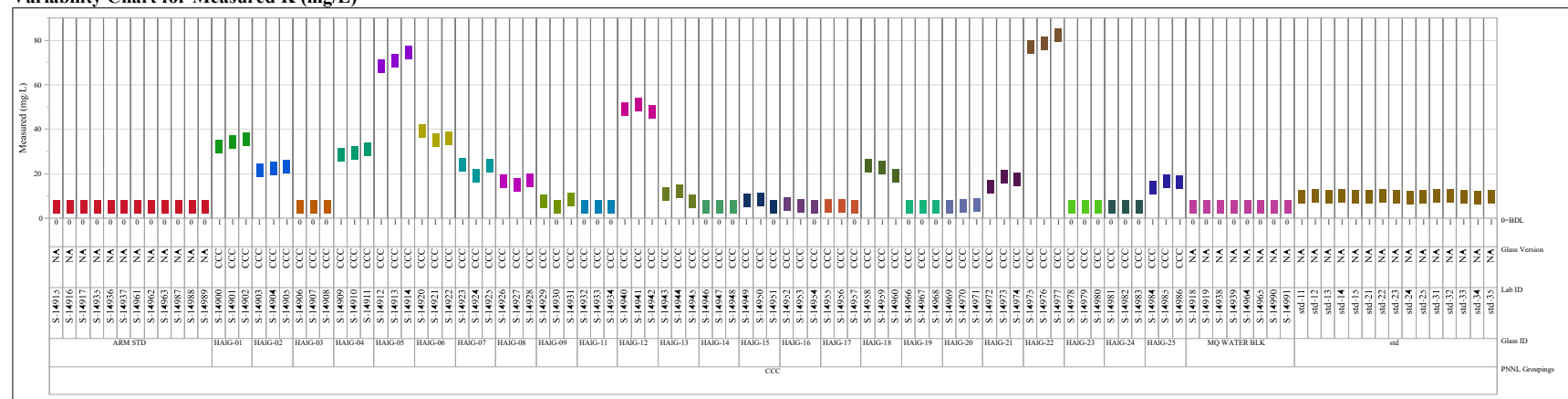


Exhibit A-2. CCC Glass PCT Measurements by Glass ID (continued)

Analyte=K

Variability Chart for Measured K (mg/L)



Analyte=Li

Variability Chart for Measured Li (mg/L)

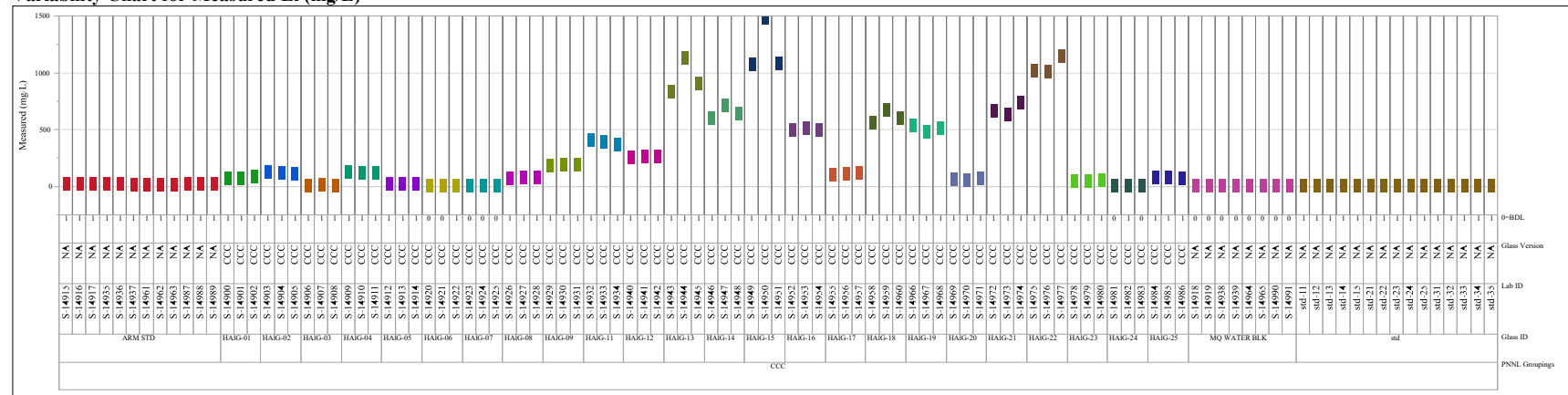
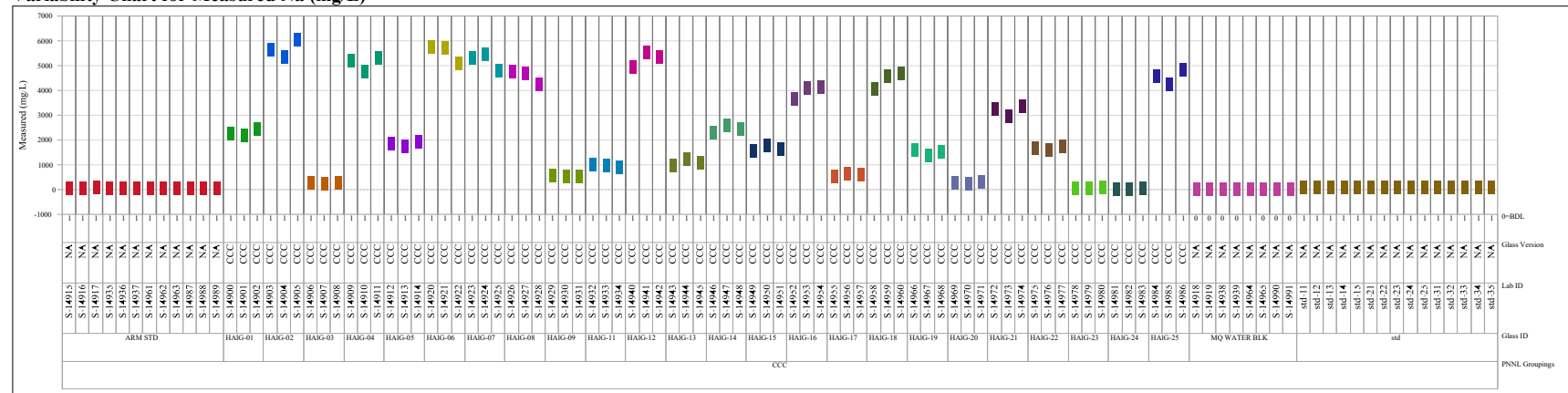


Exhibit A-2. CCC Glass PCT Measurements by Glass ID (continued)

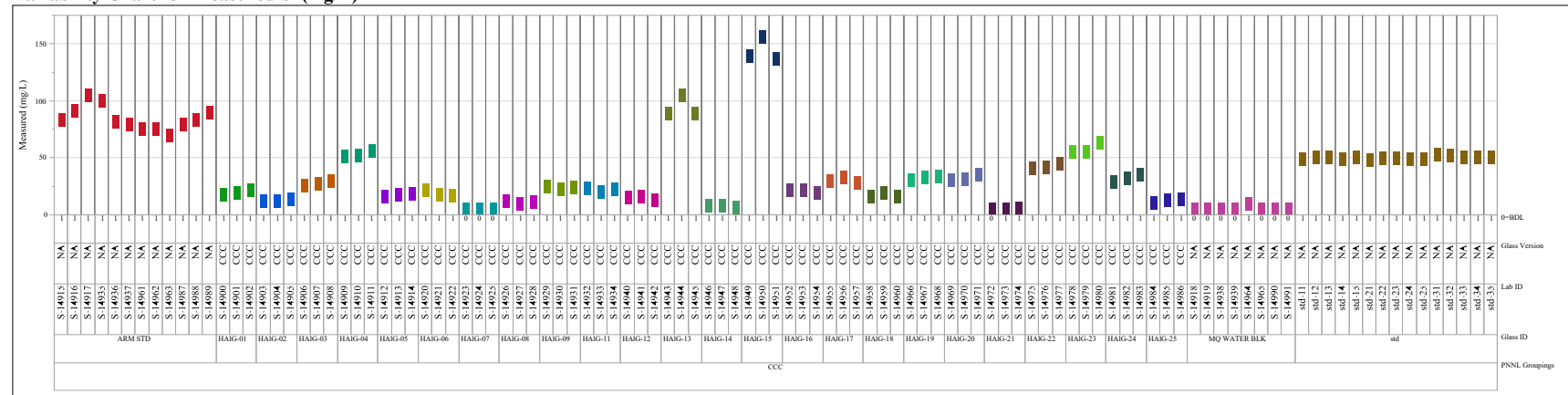
Analyte=Na

Variability Chart for Measured Na (mg/L)



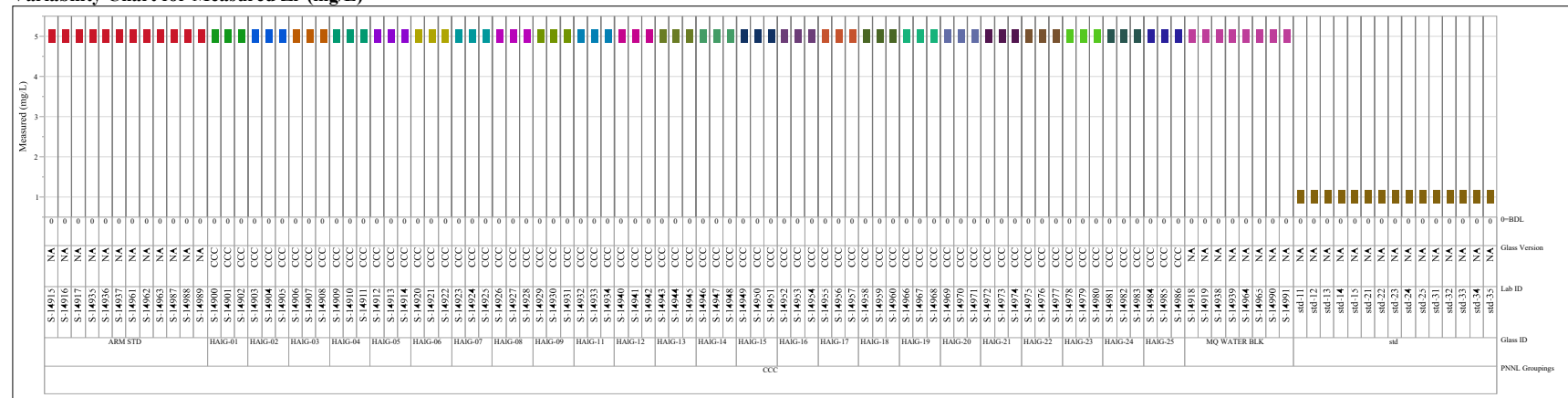
Analyte=Si

Variability Chart for Measured Si (mg/L)



Analyte=Zr

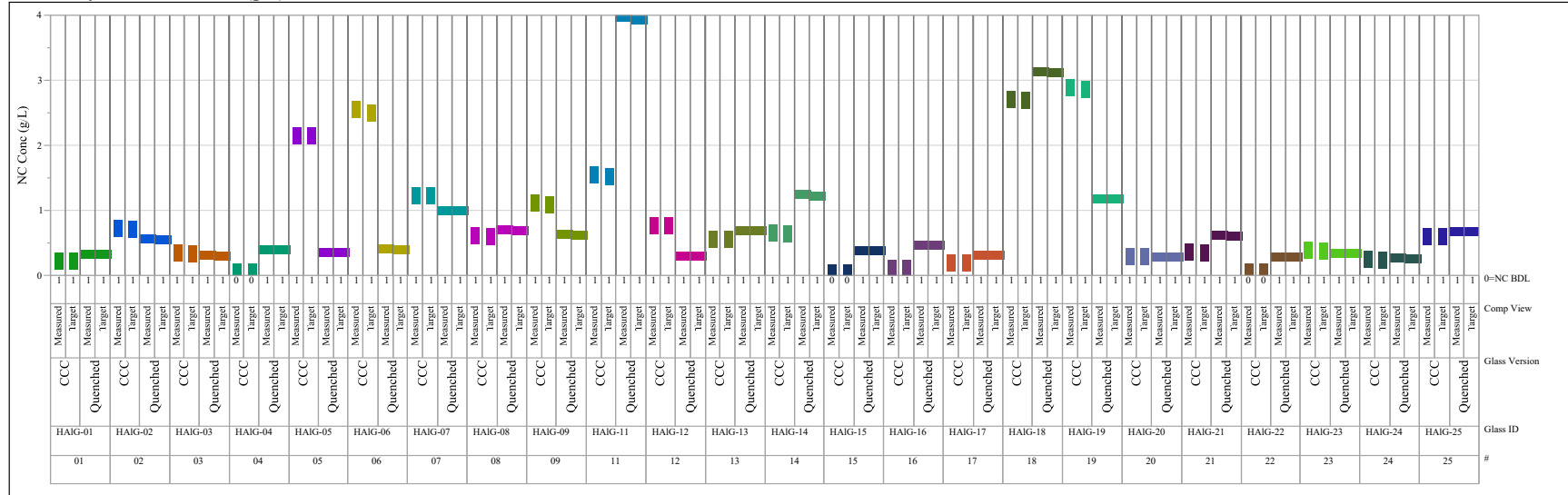
Variability Chart for Measured Zr (mg/L)



Appendix B. Normalized PCT Results

Exhibit B-1. Normalized PCT Results by Glass Version by Compositional View for Each Glass

Variability Chart for NC Al (g/L)



Variability Chart for NC B (g/L)

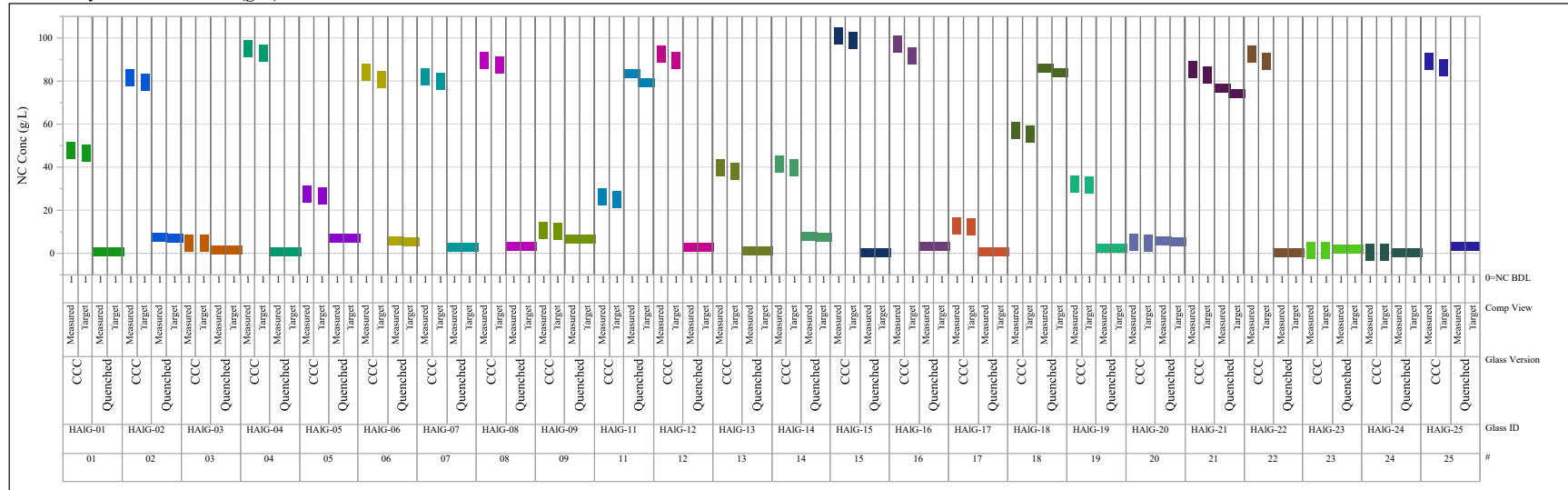
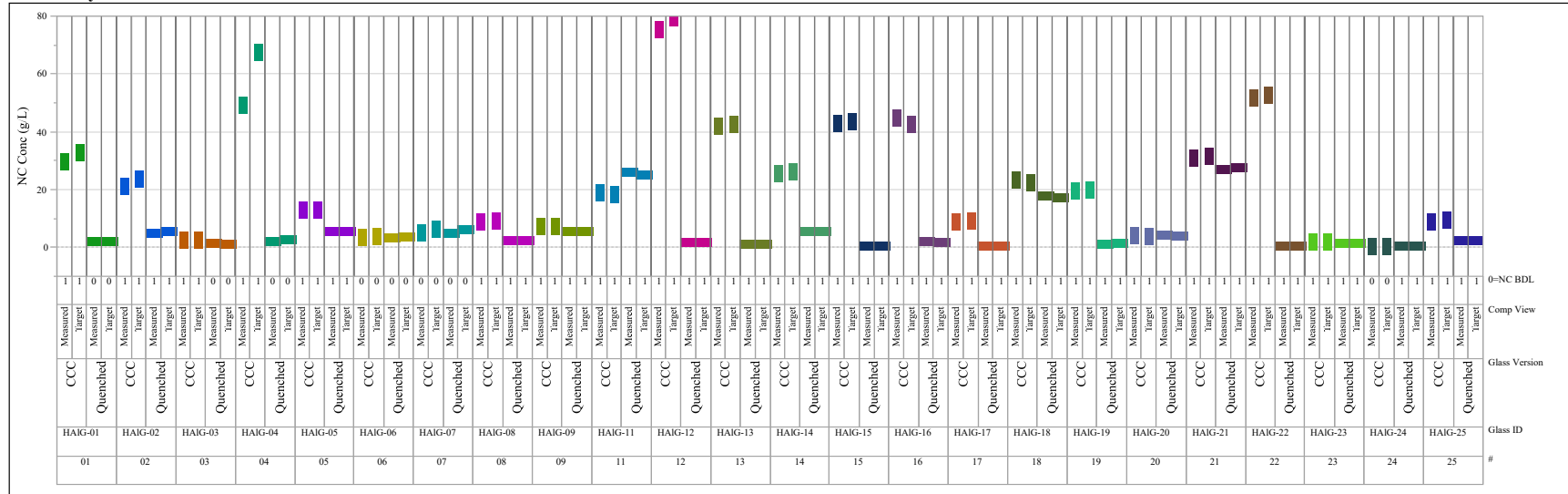


Exhibit B-1. Normalized PCT Results by Glass Version by Compositional View for Each Glass (continued)

Variability Chart for NC Li



Variability Chart for NC Na

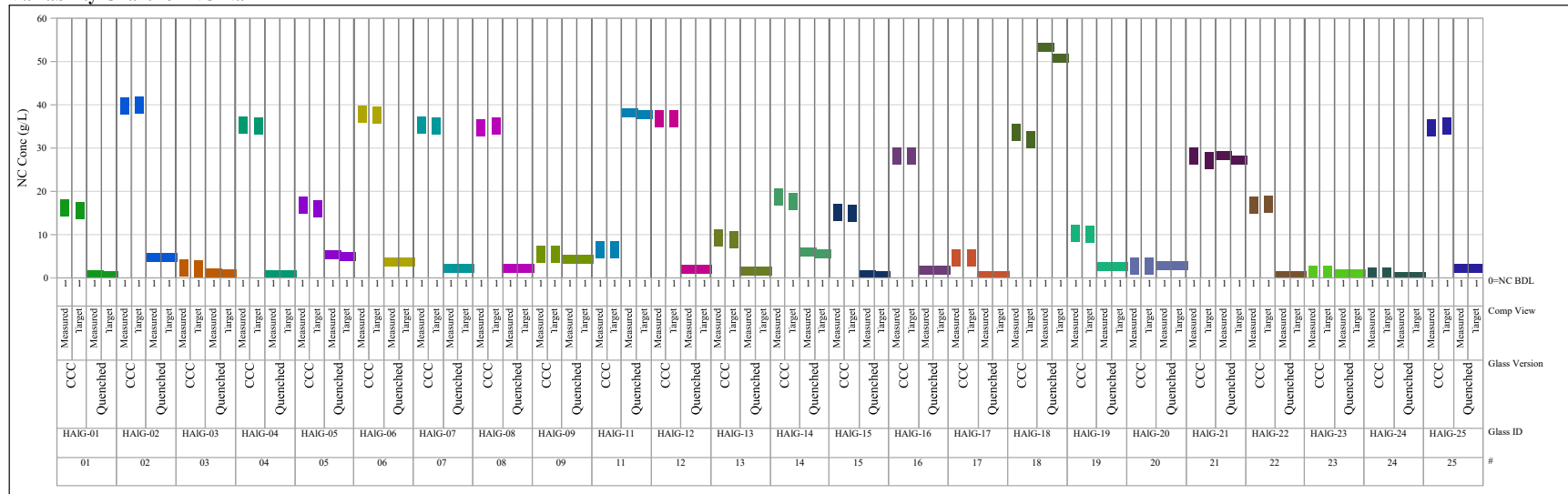
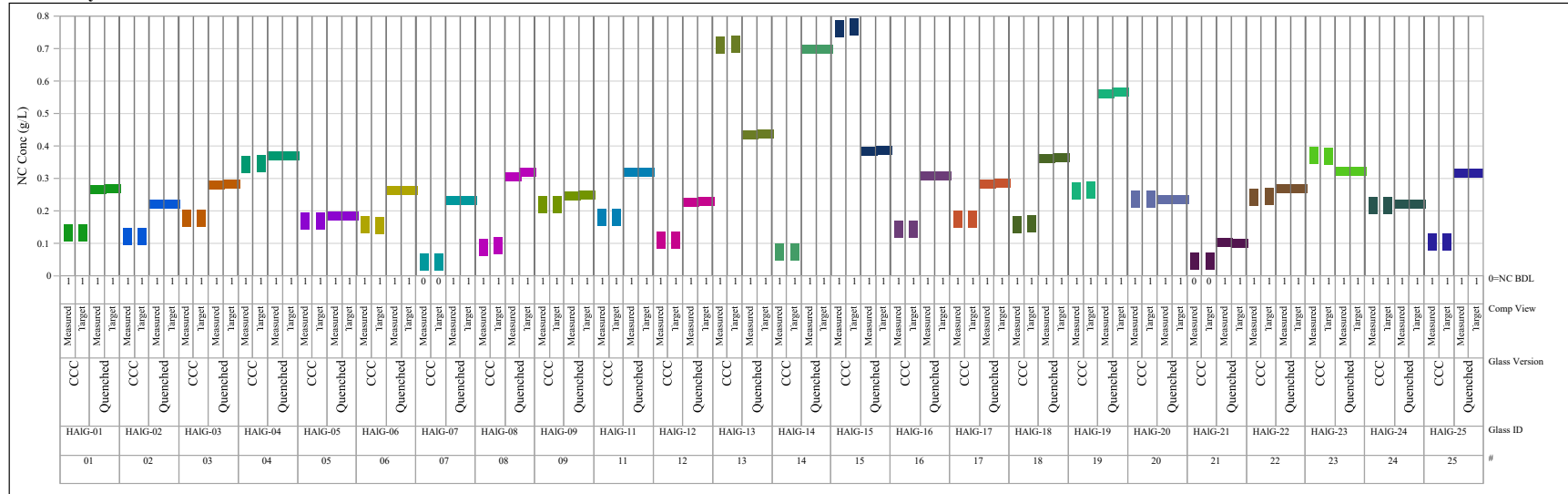


Exhibit B-1. Normalized PCT Results by Glass Version by Compositional View for Each Glass (continued)

Variability Chart for NC Si



Distribution:

Jake.Amoroso@srnl.doe.gov
CJ.Bannochie@srnl.doe.gov
William.Bates@srnl.doe.gov
Marion.Cofer@srnl.doe.gov
Alex.Cozzi@srnl.doe.gov
Charles.Crawford@srnl.doe.gov
Elaine_N_Diaz@orp.doe.gov
William.C.Eaton@pnnl.gov
Vivianaluxa.Gervasio@pnnl.gov
Holly.Hall@srnl.doe.gov
Erich.Hansen@srnl.doe.gov
Connie.Herman@srnl.doe.gov
Anthony.Howe@srnl.doe.gov
Madison.Hsieh@srnl.doe.gov
Fabienne.Johnson@srnl.doe.gov
Albert_A_Kruger@orp.doe.gov
Christine.Langton@srnl.doe.gov
Brady.Lee@srnl.doe.gov
Joseph.Manna@srnl.doe.gov
Daniel.McCabe@srnl.doe.gov
Gregg.Morgan@srnl.doe.gov
Eric_Nelson@orp.doe.gov
Ivan_G_Papp@orp.doe.gov
Frank.Pennebaker@srnl.doe.gov
Elaine_N_Porcaro@orp.doe.gov
William.Ramsey@srnl.doe.gov
Whitney.Riley@srnl.doe.gov
Renee.Russell@pnnl.gov
Eric.Skidmore@srnl.doe.gov
Anna.Stanfield@srnl.doe.gov
Michael.Stone@srnl.doe.gov
William.Swift@srnl.doe.gov
John.Vienna@pnnl.gov
Boyd.Wiedenman@srnl.doe.gov
Richard.Wyrwas@srnl.doe.gov
Records Administration (EDWS)