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Demonstration of Defense Waste Processing Facility (DWPF) Higher Fissile Content Glass

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EXECUTIVE SUMMARY

The Accelerated Basin De-inventory (ABD) Program has been proposed as an alternative for future spent nuclear fuel (SNF) and nuclear material processing at the Savannah River Site (SRS). This approach would change the baseline H-Canyon (HCAN), Concentrate, Storage, and Transfer Facility (CSTF), and Defense Waste Processing Facility (DWPF) operations. The ABD Program would require that all domestic and foreign research reactor SNF currently at SRS be dissolved, stored, and then transferred to CSTF without the recovery of uranium. Preliminary assessments in the ABD Program plan have shown that ~5000 extra SRS high-level waste (HLW) canisters would be produced if the fissile mass loading remains at the current 897 g/m^3 limit; however, increasing the limit to 2500 g/m^3 would result in ~520 extra canisters. Thus, the ABD Program plan requires an increase of the DWPF fissile mass loading limit to 2500 g/m^3 to minimize canister production.

The Department of Energy (DOE) Office of Environmental Management (EM) authorized a phased approach to increase the fissile mass loading of vitrified HLW at DWPF to 2500 g/m^3. Phase 1 begins with testing actual radioactive waste samples to determine if the DWPF glass will meet relevant requirements. Additionally, Savannah River Remediation (SRR) has performed a Nuclear Criticality Safety Evaluation (NCSE) for the increased fissile mass loading limit. The Savannah River Nuclear Solutions (SRNS) Materials Disposition Engineering group requested that the Savannah River National Laboratory (SRNL) demonstrate that increasing the fissile mass loading in vitrified HLW to 2500 g/m^3 will have no adverse effects on glass quality specifications. The objective of this task was to fabricate and characterize two radioactive glass samples prepared with actual radioactive SRS HLW samples. One glass was prepared with a fissile mass loading below the current 897 g/m^3 limit, and a second glass was prepared with a fissile mass loading bounding the 2500 g/m^3 concentration. Both glasses were evaluated for product consistency to confirm the Waste Acceptance Product Specifications (WAPS) acceptance criterion (section 1.3) can be met with the increased fissile mass loading. Glass product consistency was determined using the Product Consistency Test (PCT) per ASTM C1285-14. Complementary X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used to compare phase homogeneity among both glass samples.

Most of the fissile mass from the ABD Program will be attributed to U-235. DWPF has produced homogeneous HLW glasses with total U_3O_8 concentrations of 1.1-3.5 weight percent (wt.%) that meet the WAPS acceptance criterion for product consistency; however, these glasses have different fissile uranium isotope distributions than those expected for HLW glasses containing ABD material. Therefore, an additional goal of this study was to confirm that DWPF HLW glass durability remains predictable with the DWPF Product Composition Control System (PCCS) durability models when the percentage of U-235 is increased due to the addition of ABD material.

Two glasses were fabricated having fissile mass loadings of 525 and 2670 g/m^3 using actual radioactive SRS waste melter feed from Sludge Batch 9, and dissolver solution from H-Canyon Tank 10.2 as the source of U-235 to raise the fissile mass loading. The glasses were analyzed, and the measured compositions were determined to be acceptable for processing at DWPF. All the predicted properties (viscosity, liquidus temperature, and durability) met the PCCS Measurement Acceptance Region (MAR) criteria. Raising the fissile mass loading to 2670 g/m^3 resulted in an increase in the total U_3O_8 concentration in glass from 1.52 to 2.41 wt.%. These concentrations are below the U_3O_8 upper concentration of 6.24 wt.% for which the PCCS composition-property models have been validated. Releases of B, Li, and Si from both glasses as measured by the PCT were below the corresponding values of the Environmental Assessment (EA) benchmark glass and within the 95% confidence bands of the PCCS models for durability.

Actual radioactive waste testing has demonstrated that a DWPF HLW glass produced with a fissile mass loading of 2670 g/m^3 meets the WAPS acceptance criterion for product consistency, which states that normalized releases of B, Li, and Na be at least two standard deviations below the reported releases for these elements in the EA benchmark glass as measured by the PCT. The normalized concentrations of B, Li, Na and Si released from the HLW glass during the PCT are predictable with the DWPF PCCS durability models

regardless of the ratio of fissile uranium isotopes present in these glasses. As anticipated, based on previously produced DWPF HLW glasses with higher U_3O_8 concentrations, no new crystalline phases were identified in the HLW glass as a result of the increased U-235 content.

The completion of this task provides the glass performance data for the Phase 1 testing outlined in the DOE action memorandum for increasing the fissile mass loading of DWPF glass to 2500 g/m^3. This information is necessary for DOE-EM and the Office of Nuclear Energy to evaluate the impact of the higher fissile mass loading on the federal repository. Contingent upon the acceptability of the Phase 1 glass testing and approval of the NCSE, Phase 2 (production of DWPF canisters that are at or below the 2500 g/m^3 limit) can proceed with concurrence from DOE-EM. Phase 2 relies on the approved sludge batch qualification process required by the DWPF Glass Product Control Program to demonstrate the acceptability of future sludge batch compositions prior to actual processing.

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LIST OF ABBREVIATIONS

ABD	Accelerated Basin De-inventory
AR	aqua regia
ARG-1	Analytical Reference Glass-1
ARM-1	Approved Reference Material-1
BSE	back-scattered electron
CSTF	Concentration, Storage, and Transfer Facility
DOE	Department of Energy
DWPF	Defense Waste Processing Facility
EA	Environmental Assessment
EM	Environmental Management
HCAN	H-Canyon
HFIR	High Flux Test Reactor
HLW	high-level waste
ICP-ES	Inductively Coupled Plasma-Emission Spectroscopy
ICP-MS	Inductively Coupled Plasma-Mass Spectroscopy
MAR	Measurement Acceptance Region
MTR	Material Test Reactor
NCSE	Nuclear Criticality Safety Evaluation
PCCS	Product Composition Control System
PCT	Product Consistency Test
PF	peroxide fusion
%RSD	percent relative standard deviation
REDOX	REDuction/OXidation
SB10	Sludge Batch 10
SB9	Sludge Batch 9
SCF	Shielded Cells Facility
SEM	Scanning Electron Microscopy
SME	Slurry Mix Evaporator
SNF	spent nuclear fuel
SRNL	Savannah River National Laboratory
SRNS	Savannah River Nuclear Solutions
SRR	Savannah River Remediation
SRS	Savannah River Site
TTA	thenoyltrifluoroacetone
TTQAP	Task Technical and Quality Assurance Plan
TTR	Technical Task Request
WAC	Waste Acceptance Criteria
WAPS	Waste Acceptance Product Specifications
wt.%	weight percent
vol%	volume percent
XRD	X-ray Diffraction

1.0 Introduction

The Accelerated Basin De-inventory (ABD) Program has been proposed as an alternative for future spent nuclear fuel (SNF) and nuclear material processing at the Savannah River Site (SRS). This approach would change the baseline H-Canyon (HCAN), Concentrate, Storage, and Transfer Facility (CSTF), and Defense Waste Processing Facility (DWPF) operations.[1] The ABD Program would require that all domestic and foreign research reactor SNF currently at SRS be dissolved, stored, and then transferred to CSTF without the recovery of uranium. Preliminary assessments in the ABD Program plan have shown that ~5000 extra SRS high-level waste (HLW) canisters would be produced if the fissile mass loading remains at the current 897 g/m^3 limit; however, increasing the limit to 2500 g/m^3 would result in ~520 extra canisters.[1,2] Thus, the ABD Program plan requires an increase of the DWPF fissile mass loading limit to 2500 g/m^3 to minimize canister production. DWPF considers the following isotopes in the calculation of fissile mass loading: U-233, U-235, Pu-239 and Pu-241.[1,3]

The current fissile mass loading limit is 897 g/m^3 based on contract direction from the DOE – Savannah River Operations Office and Revision 3 of the Waste Acceptance Product Specifications (WAPS), which relied upon the Preclosure Criticality Safety Analysis for the proposed Yucca Mountain Repository to set the fissile mass loading limit.[2,4,a] In support of the ABD Program, the Department of Energy (DOE) Office of Environmental Management (EM) authorized a phased approach to increase the fissile mass loading of vitrified HLW at DWPF to 2500 g/m^3.[5] Phase 1 begins with testing actual radioactive waste samples to determine if the DWPF glass will meet relevant requirements. Additionally, Savannah River Remediation (SRR) has performed a Nuclear Criticality Safety Evaluation (NCSE) for the increased fissile mass limit.[6] In response to this action memorandum, the Savannah River Nuclear Solutions (SRNS) Materials Disposition Engineering group requested that the Savannah River National Laboratory (SRNL) demonstrate that increasing the fissile mass loading in vitrified HLW to 2500 g/m^3 will have no adverse effects on glass quality specifications.[7,8] The objective of this task was to fabricate and characterize two radioactive glass samples prepared with actual radioactive SRS HLW samples. One glass was prepared with a fissile mass loading below the current 897 g/m^3 limit, and a second glass was prepared with a fissile mass loading bounding the 2500 g/m^3 concentration. Both glasses were evaluated for product consistency to confirm the WAPS acceptance criterion (section 1.3) can be met with the increased fissile mass loading.[8] Glass product consistency was determined using the Product Consistency Test (PCT) per ASTM C1285-14.[9] Complementary X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used to compare phase homogeneity among both glass samples.

Most of the fissile mass from the ABD Program will be attributed to U-235. DWPF has produced homogeneous HLW glasses with total U_3O_8 concentrations of 1.1-3.5 weight percent (wt.%) that meet the WAPS acceptance criterion for product consistency; however, these glasses have different fissile uranium isotope distributions than those expected for HLW glasses containing ABD material.[10] Therefore, an additional goal of this study was to confirm that DWPF HLW glass durability remains predictable with the DWPF Product Composition Control System (PCCS) durability models when the percentage of U-235 is increased due to the addition of ABD material.[11]

This report documents the fabrication and testing of the two glasses prepared with actual radioactive waste along with the characterization results. The completion of this task provides the glass performance data for the Phase 1 testing outlined in the DOE action memorandum for increasing the fissile mass loading of DWPF glass to 2500 g/m^3.[5] This information is necessary for DOE-EM and the Office of Nuclear Energy to evaluate the impact of the higher fissile mass loading on the federal repository. Contingent upon the acceptability of the Phase 1 glass testing and approval of the NCSE, Phase 2 (production of DWPF canisters that are at or below the 2500 g/m^3 limit) can proceed with concurrence from DOE-EM. Phase 2 relies on

[a] Note that Revision 3 of the WAPS is available, but HLW Producers are currently utilizing Revision 2.

the approved sludge batch qualification process required by the DWPF Glass Product Control Program to demonstrate the acceptability of future sludge batch compositions prior to actual processing.

2.0 Quality Assurance

This work was requested via a Technical Task Request (TTR)[7] and directed by a Task Technical and Quality Assurance Plan (TTQAP).[12] The Functional Classification of this task is Production Support. Glass fabrication and analysis is waste form affecting and follows the quality assurance requirements of DOE/RW-0333P.[13] Microsoft Excel and JMP Version 14.3.0[14,15] were used to support this work.[16] Requirements for performing reviews of technical reports and the extent of review are established in Manual E7, Procedure 2.60.[17] This document, including calculations, was reviewed by a Design Check. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.[18] Experimental details for this report are stored in electronic laboratory notebook experiments C7592-00311-37, I7770-00338-11 and L6390-00413-16.

3.0 Assumptions

The following assumptions were agreed upon between HCAN, SRR and SRNL prior to initiating this task.[7,12]

1. Many different batches of material with varying compositions are projected to be processed through DWPF in the future as described in the current revision of the SRR system plan.[19] These current projections are preliminary, thus the selection of the sludge batch for testing was based on availability of material rather than attempting to match a specific set of conditions. The acceptability of each future sludge batch composition and corresponding HLW glass waste form having a fissile mass loading at or below 2500 g/m^3 will be demonstrated with the approved SRS sludge batch qualification process prior to actual processing as described in Phase 2 of the DOE action memorandum.[5,20]
2. The current baseline for the ABD Program beyond Sludge Batch 10 (SB10) will use gadolinium (Gd) as the neutron poison in the SRS flowsheet.[21,22] Gd has a larger neutron capture cross section than manganese (Mn) and Fe (iron) and requires significantly less mass to poison the same amount of fissile material. Therefore, Gd was used as the neutron poison in this testing to simulate the plant process when adding additional U-235 to the sludge batch in order to increase the fissile mass loading in the glass to 2500 g/m^3.

4.0 Experimental Procedures

4.1 Melter Feed Fabrication

Two melter feeds were prepared; one that would produce a glass with a fissile mass loading below 897 g/m^3 and the second producing a glass with a fissile mass loading bounding the 2500 g/m^3 concentration. These melter feeds (and resulting glasses) are referred to as "Nominal" and "High Fissile," respectively, for the remainder of this report.

Due to the high levels of radioactivity, both melter feeds were prepared remotely within the SRNL Shielded Cells Facility (SCF).

4.1.1 Nominal

Slurry Mix Evaporator (SME) product generated during a prior actual radioactive waste demonstration of the nitric-glycolic flowsheet for Sludge Batch 9 (SB9) was selected as the nominal melter feed for this task. This slurry was already well characterized as part of the SB9 testing and consists of SRS Tank 40 sludge and Frit 803 at a targeted waste loading of 38%.[23] Chemical composition results from this previous study are duplicated in Appendix A for reference. The SB9 glass had an average measured reduction/oxidation ratio (REDOX: $Fe^{2+}/\Sigma Fe$) of 0.046.[24]

SME product was removed from its original storage bottle and transferred to a new container. Water was used to rinse the original storage bottle to recover nearly all the material and the rinsate was added to the new container to facilitate mixing and homogenization.

4.1.2 High Fissile

HCAN dissolver solution from Tank 10.2 was utilized as the source of U-235 to raise the fissile mass loading of the Nominal glass to 2500 g/m^3. Tank 10.2 dissolver solution is a blend of dissolved aluminum SNF from the High Flux Isotope Reactor (HFIR) and Material Test Reactor (MTR) and contains other fission products and actinides associated with these fuels. This solution composition was characterized as part of a separate task and the results are shown in Appendix B for reference.[22]

Note that the goal of the Tank 10.2 dissolver solution preparation methods was to fabricate material that would be of similar composition to the actual material added to the sludge batch rather than replicating the exact HCAN processes. For DWPF criticality control, 0.337 g of gadolinium nitrate solution was combined with 19.2 g of HCAN Tank 10.2 dissolver solution targeting a Gd to equivalent U-235 in the sludge mass ratio (Gd:U-235 (eq_{SLU})[b]) of 0.55:1 (including Gd already present in the feed components).[3,22,25] The Gd:U-235 (eq_{SLU}) ratio in the sludge was based on an assumed target, but the actual ratio will be determined as part of an on-going SRR NCSE for increasing the fissile mass loading to 2500 g/m^3. Sodium hydroxide was added to precipitate the fissile metals and Al as insoluble solids at a target pH value of 8-9. SRNL did not simulate the HCAN process of adding caustic to 1.2 M excess hydroxide (pH>12) since the purpose of this step was simply to precipitate uranium. The poisoned, pH-adjusted Tank 10.2 dissolver solution material was washed with ~500 mL of deionized water to remove excess sodium and nitrate as the additional material would have been washed out during actual processing. Multiple wash-settle-decant cycles occurred over nearly two weeks to remove as much supernate as possible without removing solids.

Approximately 51 g of the prepared Tank 10.2 slurry remained, which was combined with a portion of the Nominal melter feed at a ratio targeting a fissile mass concentration of 2500 g/m^3 in glass. Depleted uranium (U-238) was added in the form of U_3O_8 (0.237 g) to ensure that the U-235 (eq_{SLU}) enrichment did not exceed 5 wt.% per the DWPF Waste Acceptance Criteria (WAC).[3,25,c] This additional U-238 increased the total U concentration; however, it is not considered in the DWPF fissile mass loading calculation.

4.2 Glass Fabrication and Analysis

The methods described in this section apply to both the Nominal and High Fissile glasses. Due to the high level of radioactivity, most of this work was performed remotely in the SRNL SCF except where noted that sub-samples were removed for further analysis.

4.2.1 Fabrication

Approximately 105 g of the High Fissile melter feed and 140 g of Nominal melter feed were divided into four nearly equal portions, placed into high-purity alumina crucibles, and dried overnight at 110 °C. Subsequently, one portion was transferred to an open Pt/Au crucible and heated to 1150 °C at approximately 10 °C/min in an electrically heated furnace.[26] Upon reaching the target furnace temperature of 1150 °C, the sample was held at temperature for approximately 30 minutes. The remaining portions were then added incrementally, allowing the furnace to return to 1150 °C between each addition, resulting in a total of 3.5

[b] U-235(eq_{SLU}) = U-235 + 1.4 × (U-233).
[c] U-235(eq_{SLU}) Enrichment (wt.%) = 100 × U-235(eq_{SLU}) ÷ U, where U is the summation of all uranium isotopes (e.g., U-233, U-234, U-235, U-236, U-238).

hours at the melting temperature of 1150 °C. The crucible was removed from the furnace at temperature and bottom quenched in a shallow pan of water. The surfaces of the glasses were then visually examined to confirm that they were homogeneous (dark and shiny appearance).

4.2.2 Chemical Composition and Radionuclide Analysis

Approximately 4 g of each glass was ground in an agate mechanical pulverizing mixer mill. The glass was sieved and the portion that passed through a 200 mesh (<75 μm) brass sieve was used for the dissolutions. Four replicate samples (nominally 0.25 g each) of the sieved glass were dissolved for analysis by two different methods: sodium peroxide fusion (PF) dissolution and an aqua regia (AR) dissolution.[27,28] Concurrent with each set of dissolutions, three samples of the Analytical Reference Glass-1 (ARG-1) were also dissolved to confirm the performance of the glass dissolution methods.[29]

Aliquots from both dissolution methods were analyzed by Inductively Coupled Plasma Emission Spectroscopy (ICP-ES).[30] A multi-element standard solution containing known concentrations of Al, B, Fe, K, Li, Na, and Si was also analyzed with each set of samples to confirm the accuracy of the ICP-ES measurements.[31] Aliquots of the PF dissolutions were also analyzed by Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) to analyze for certain radioisotopes in the glasses.[32] Blanks processed through the applicable dissolutions for ICP-ES and ICP-MS were also submitted for analysis to check for any gross contamination.

Aliquots of the PF dissolutions were analyzed for plutonium isotopes using traced radiochemical separations followed by α-pulse height analysis for Pu-238 and Pu-239+240, and liquid scintillation counting for Pu-241.[33] Pu-236 was used as the tracer and thenoyltrifluoroacetone (TTA) as the extractant.

4.2.3 PCT

In order to confirm the acceptance criterion stated in section 1.3 of the WAPS, the PCT (Test Method A of ASTM C1285-14) was performed in quadruplicate for the Nominal and High Fissile glasses.[8,9] Duplicate blanks and triplicate samples of the Approved Reference Material-1 (ARM-1) were included in the PCT.[34] Samples were ground, washed, and prepared according to the standard procedure.[9,35] Fifteen milliliters of ASTM-type I water[d] were added to 1.5 grams of glass per stainless steel vessel. The vessels were closed, sealed, and placed in an oven for 7 days at 90 ± 2 °C. After 7 days, the vessels were removed from the oven, allowed to cool to ambient temperature, weighed to determine water loss, and then opened. The leachate from each vessel was then decanted into 30 mL poly bottles. The radioactivity levels of the leachates were low enough that they could be safely removed from the SCF and transported to a radiochemical hood. Subsequently, the pH of each leachate was measured with a pH meter, and then the leachates were filtered through a 0.45 μm nylon syringe filter and acidified to 1 volume percent HNO_3. The leachates were then diluted and analyzed by ICP-ES.[30] Triplicate samples of a multi-element standard solution containing known concentrations of Al, B, Fe, K, Li, Na, and Si were submitted with the leachates and blanks.[31]

4.2.4 XRD and SEM

Approximately 30 mg of each sieved glass (less than 200 mesh as described in section 4.2.2) were removed from the SCF and analyzed by XRD.[36] Samples were analyzed under conditions providing a detection limit of approximately 0.5 volume percent (vol%), i.e., no crystals are detected if the amount in the sample is less than ~0.5 vol%. The XRD patterns were analyzed with JADE Version 7.8 loaded with the International Centre for Diffraction Data database.[37,38]

[d] Minimum resistivity of 18 MΩ-cm at 25 °C.

Double-sided carbon tape was adhered to an SEM mount, which was used to collect a sample of each sieved glass powder (less than 200 mesh). Samples were removed from the SCF and analyzed by SEM to evaluate the phase assemblage of the fabricated glasses.[39]

5.0 Results and Discussion for Glass Fabrication and Analysis

5.1 Visual Examination

Both the Nominal and High Fissile glasses were visually examined from outside of the shielded cell window, both with the naked eye and with a magnifying eyepiece. The glasses appeared dark and shiny without the presence of any visible salt layers or crystals.

5.2 Chemical Composition

Table C-1 and Table C-2 in Appendix C provide the as-measured ICP-ES elemental data from glasses prepared using AR and PF dissolutions, respectively. Data for the ARG-1 glass and blank samples are also provided. Concentration measurements that were reported below the detection limit are denoted with a less than symbol (<). The elemental concentrations in each glass in Table C-1 and Table C-2 were converted to oxide concentrations by multiplying the values for each element by the gravimetric factor for the corresponding oxide.

All Si values shown for the AR dissolution method are for information purposes only as the AR method is not expected to completely dissolve the SiO_2 in the glass. Na values are not listed for the PF dissolution method due to the high bias of sodium from the sodium peroxide used for the dissolution. Zr values are not listed for the PF method due to potential contamination from the zirconium crucibles.

Detectable values of Ca, Cr and Fe were measured for the blank sample submitted with the PF dissolutions. The Ca values from the AR dissolutions were selected for subsequent calculations involving the ARG-1 and glass sample data. The measured Fe concentration in the blank was insignificant (<1% of the measured glass sample values). The measured Cr concentration in the blank was ~30% of the measured glass sample values; however, the Cr_2O_3 concentrations in these glasses are low (~0.07 wt.%) and any introduced bias in the Cr data would not impact the overall conclusions of this study.

5.2.1 Multi-Element Standard Solution

Table 5-1 provides a comparison of measured and reference concentrations for the multi-element standard solutions measured with the glass samples.[31] Each measured concentration is the average of four replicates except for Na, which is the average of two replicates because Na is not measured during the analysis of PF dissolution sets. The measured concentrations of each analyte were within 5% of the reference values and each of the percent relative standard deviations (%RSD) for all elements were less than or equal to 0.6%. These data, along with similar internal standards analyzed by analytical personnel performing the measurements indicate that the ICP-ES analyses are of sufficient accuracy and within the analytical uncertainty. Table C-3 in Appendix C provides the as-measured elemental data for each replicate.

Table 5-1. Multi-Element Standard Solution Results (Included with Glass Dissolutions)

Analyte	Reference[31] (mg/L)	Measured (mg/L)	% Difference	%RSD
Al	4.00	3.98	-0.6	0.3
B	20.0	20.40	2.0	<0.1
Fe	4.00	4.06	1.5	0.3
K	10.0	9.59	-4.1	0.4
Li	10.0	9.89	-1.1	0.6
Na	81.0	79.85	-1.4	0.4
Si	50.0	51.00	2.0	0.6

5.2.2 ARG-1 Glass Standard

Table 5-2 provides a comparison of the published and measured composition of the ARG-1 glass standard.[29] The measured value is the average of three replicates from either the AR or PF dissolution data as noted in the table. The measured concentrations for the major glass components (> 0.5 wt.%) values are consistent with the published values and the %RSD values for these components are less than 10%, indicating good precision in the results. These data indicate proper performance of the glass dissolutions and the ICP-ES analyses are of sufficient accuracy and within the analytical uncertainty. Some of the minor components (< 0.5 wt.%), such as Zr, exhibit higher variation, which is expected based on previous results and does not impact the overall conclusions of this study.

Table 5-2. Comparison of the Published and Measured Compositions of ARG-1

Oxide	Dissolution Method	Published[29] (wt.%)*	Measured (wt.%)	% Difference	%RSD
Al_2O_3	PF	4.73	4.82	1.9	1.0
B_2O_3	PF	8.67	8.55	-1.4	1.4
BaO	PF	0.088	0.09	2.3	1.7
CaO	AR	1.43	1.42	-0.7	0.6
Cr_2O_3	PF	0.093	0.09	-3.2	2.2
Fe_2O_3	PF	14.00	13.43	-4.1	0.4
K_2O	AR	2.71	2.67	-1.5	0.5
Li_2O	PF	3.21	3.12	-2.8	3.1
MgO	PF	0.86	0.88	2.3	1.3
MnO	PF	1.89	1.85	-2.1	1.1
Na_2O	AR	11.50	10.94	-4.9	2.0
NiO	PF	1.05	0.98	-6.7	0.9
P_2O_5	AR	0.22	0.25	13.6	3.2
SiO_2	PF	47.90	47.21	-1.4	1.3
TiO_2	PF	1.15	1.17	1.7	1.0
ZnO	PF	0.02	0.02	0.0	3.6
ZrO_2	AR	0.13	0.08	-38.5	12.2
Total	---	99.65	97.56	---	---

*The published ARG-1 composition represents the mean of the Corning Inc. Glass Composition provided in Reference 23. ARG-1 has a reported concentration of 2.31 wt.% MnO_2 and a total oxide concentration of 100.08 wt.%. For consistency, the MnO_2 value was converted to MnO and the total oxide concentration was adjusted accordingly.

5.2.3 Nominal and High Fissile Glasses

Table 5-3 lists the oxide concentrations calculated from the measured elemental concentrations of the Nominal and High Fissile glasses. The value for each oxide is the average of four replicates from the noted dissolution method. Note that K_2O in the High Fissile glass was reported below the detection limit as indicated by a "<" in Table 5-3; however, this value was set to the detection limit for calculating the %RSD and sum of oxides. The %RSD values for a majority of the major glass components (> 0.5 wt.%) are less than 10%, indicating good precision in the results. CaO and Na_2O measurements for the Nominal glass have %RSDs that are slightly above 10%. The higher variation exhibited by the minor glass components (< 0.5 wt.%) is expected based on previous results and does not impact the overall conclusions of this study.

The High Fissile glass relative to the Nominal glass contained greater concentrations of Al_2O_3, Gd_2O_3, and U_3O_8 as expected due to the presence of these components in the HCAN Tank 10.2 dissolver solution sample as well as the addition of gadolinium nitrate and depleted uranium (U-238) during melter feed preparation to meet current criticality and waste acceptance requirements. The measured composition of the Tank 10.2 dissolver solution sample is summarized in Table B-1 through Table B-3 in Appendix B for reference. As expected, concentrations of the frit components B_2O_3, Li_2O and SiO_2 were lower in the High Fissile glass relative to the Nominal glass due to their dilution by the added Tank 10.2 sample mass.

Table 5-3. Average Measured Compositions of the Nominal and High Fissile Glasses

Oxide	Dissolution Method	Nominal Glass		High Fissile Glass	
		Measured (wt.%)	%RSD	Measured (wt.%)	%RSD
Al_2O_3	PF	6.51	2.1	10.14	2.1
B_2O_3	PF	4.98	1.8	4.64	1.8
BaO	PF	0.04	0.9	0.04	2.0
CaO	AR	0.67	12.7	0.65	4.2
CdO	AR	0.01	12.2	0.01	3.7
Ce_2O_3	AR	0.12	12.5	0.12	4.7
Cr_2O_3	PF	0.06	2.9	0.07	3.3
CuO	PF	0.04	2.9	0.03	2.5
Fe_2O_3	PF	10.86	1.4	11.40	1.2
Gd_2O_3	PF	0.04	4.4	0.10	3.5
K_2O	AR	0.05	17.3	< 0.07	5.1
La_2O_3	PF	0.02	1.8	0.02	2.8
Li_2O	PF	3.69	0.3	3.50	1.6
MgO	PF	0.18	2.6	0.19	2.1
MnO	PF	3.32	1.8	3.46	0.8
MoO_3	AR	0.02	12.4	0.02	6.02
Na_2O	AR	12.70	11.4	12.82	1.2
NiO	PF	0.71	1.9	0.75	2.4
P_2O_5	AR	0.22	15.5	0.23	9.2
SiO_2	PF	48.78	6.7	48.24	1.4
SO_4^{2-}	PF	0.31	2.1	0.32	1.4
SrO	PF	0.02	3.5	0.02	1.9
ThO_2	PF	0.46	2.2	0.48	2.2
TiO_2	PF	0.03	3.5	0.03	3.0
U_3O_8	PF	1.52	1.9	2.41	1.7
ZnO	PF	0.02	2.5	0.02	3.0
ZrO_2	AR	0.02	64.5	0.06	38.0
Sum of Oxides	---	95.38	---	99.83	---

5.3 DWPF PCCS Evaluation

PCCS is a statistical process control system used in DWPF to assess the acceptability of the melter feed composition against various processing, product quality and solubility constraints.[11] The primary glass properties of interest (viscosity, liquidus temperature and durability) cannot be measured in-situ during DWPF processing and must be predicted using models that relate these properties to the glass composition. Per the DWPF Glass Product Control Program a sample from each batch of melter feed is collected and the composition is analyzed.[40,41] The batch of melter feed is only transferred to the melter for vitrification after acceptability of the composition has been demonstrated with PCCS.

The average measured compositions of the Nominal and High Fissile glasses from Table 5-3 were evaluated against the PCCS constraints and the results are shown in Table 5-4. Note that the durability constraints represent PCT releases that are two standard deviations below the reported mean releases from the Environmental Assessment (EA) benchmark glass, as required per the WAPS product consistency acceptance criterion.[8,42] All the predicted properties met the PCCS Measurement Acceptance Region (MAR) criteria, confirming both the Nominal and High Fissile glasses would be acceptable for processing at DWPF.

Table 5-4. PCCS Evaluation Results

Name	Constraint[11]	Nominal Glass	High Fissile Glass
Sum of Oxides*	95-105 (major oxides in wt.%)	95.02 wt.%	99.39 wt.%
Durability	B release < 14.251 g/L Li release < 8.095 g/L Na release < 11.542 g/L	0.607 g/L 0.656 g/L 0.616 g/L	0.343 g/L 0.414 g/L 0.359 g/L
Homogeneity	$Al_2O_3 \geq 4.0$ wt.%	6.51 wt.%	10.14 wt.%
Liquidus Temperature	< 1050 °C	917 °C	996 °C
TiO_2	< 6.0 wt.%	0.03 wt.%	0.03 wt.%
Viscosity	20-110 Poise	67 P	94 P
Cr_2O_3	< 0.3 wt.%	0.06	0.07
Cu	< 0.5 wt.%	0.03	0.02
Nepheline	$\frac{SiO_2}{SiO_2+Na_2O+Al_2O_3} > 0.62$	0.72	0.68
All PCCS MAR criteria met		YES	YES

*CdO, Gd_2O_3 and SO_4^{2-} are not included in the PCCS sum of oxides.

5.4 Radionuclide Composition

Table 5-5 lists the average radionuclide concentrations from measured quadruplicate analyses. Table C-4 through Table C-7 in Appendix C provide the as-measured ICP-MS and plutonium isotope data for each of the replicates. Mass conversions of the plutonium isotopes Pu-238 and Pu-241were calculated using the corresponding specific activities.[43] Pu-242 was not detected in the Nominal glass, as indicated with a "<" in Table 5-5, and only three replicates exhibited detectable quantities of this isotope in the High Fissile glass. Isotopes included in the DWPF fissile mass loading calculation (shaded in gray in Table 5-5) were used to support the calculations in section 5.5.[3] Detectable values at mass 93 (Zr-93) from ICP-MS data and Pu-238 from the Pu isotope data were measured for the blank samples submitted with the PF dissolutions of the Nominal and the High Fissile glass samples; however, neither is of any practical significance. The measured mass 93 concentration for Zr-93 was only 5% of the lowest measured concentration in the Nominal and High Fissile glasses and the measured Pu-238 concentration was <0.01% of the lowest measured concentration.

Table 5-5. Average Radionuclide Concentrations

Radionuclide	Nominal Glass (wt.%)	High Fissile Glass (wt.%)	Method[32,33]
Zr-93	1.32E-02	1.49E-02	ICP-MS
Tc-99	4.34E-04	3.57E-04	ICP-MS
Th-232	3.88E-01	3.82E-01	ICP-MS
U-233	3.16E-04	2.93E-04	ICP-MS
U-234	3.66E-04	1.54E-03	ICP-MS
U-235	1.47E-02	9.38E-02	ICP-MS
U-236	8.76E-04	7.88E-03	ICP-MS
Np-237	1.36E-03	1.34E-03	ICP-MS
U-238	1.48E+00	2.13E+00	ICP-MS
Pu-238	4.81E-04	4.42E-04	Pu-238/241
Pu-239	4.44E-03	4.54E-03	ICP-MS
Pu-240	4.30E-04	4.86E-04	ICP-MS
Pu-241	1.37E-05	2.98E-05	Pu-238/241
Pu-242	<7.94E-05*	4.70E-05**	ICP-MS

*Since there were no detectable values, the lowest concentration is presented.
**Only the three detectable values were used to calculate the average.

5.5 Fissile Mass Loading

The DWPF fissile mass loading is given by the following equation:

$$Fissile\ Mass\ Loading = \frac{Total\ Fissile\ Isotopes\ (grams)}{Glass\ Volume\ (m^3)}$$

where the *Total Fissile Isotopes* term is defined as the sum of U-233, U-235, Pu-239 and Pu-241.[3] The average mass of the fissile isotopes for each of the glasses was determined based on the average analyzed concentrations shaded in gray in Table 5-5. Glass density was used to convert the results to a volume basis. Using the average measured glass compositions shown in Table 5-3, glass densities were predicted using a composition-based density model developed at SRNL for HLW glasses.[44] The resulting fissile mass loading is 525 g/m^3 for the Nominal glass and 2670 g/m^3 for the High Fissile glass. A summary of this information is provided in Table 5-6.

Table 5-6. Summary of Inputs and Outputs to Fissile Mass Loading Calculation

Value	Nominal Glass	High Fissile Glass
Average Mass of Fissile Isotopes (g/g glass)	1.95E-04	9.87E-04
Predicted Glass Density (g/cm^3)	2.6947	2.7055
Fissile Mass Loading (g/m^3)	525	2670

As shown in Table 5-3, raising the fissile mass loading to 2670 g/m^3 resulted in an increase in the total U_3O_8 concentration in glass from 1.52 to 2.41 wt.%. This increase is mostly due to the U-238 that was added to ensure that the U-235 (eq_{SLU}) enrichment did not exceed 5 wt.% per the DWPF WAC.[3,25] U-238 comprises ~95% of the measured uranium isotopes in the High Fissile glass as shown in Table 5-5. The contribution of U-235 from the added Tank 10.2 dissolver solution is ~4%. The resulting total U_3O_8 concentration in glass is well below the U_3O_8 upper concentration of 6.24 wt.% that the PCCS composition-property models have been validated.[11,42,45,46]

5.6 PCT

Table D-1 in Appendix D provides the as-measured elemental concentration measurements for the solution blanks, multi-element standard solutions and PCT leachates from the ARM-1, Nominal and High Fissile glasses. Measurements below the detection limits are indicated by a "<". To adjust for dilution, the elemental concentrations of B, Li, Na, Si and U were multiplied by a factor of 1.6667 prior to use in subsequent calculations of the normalized releases.[e]

The ratio of leachant volume to mass of ground glass was confirmed to be correct for each vessel by comparing the original mass of glass powder to the added mass of leachant. Per ASTM C1285-14, the allowable leachant volume is 10 ± 0.5 cm^3/gram of sample mass. Based on the measured masses of the PCT vessels before and after the 7-day test, there was negligible water loss, which was within the bounds allowed by the ASTM standard. The measured elemental concentrations in the blanks were reported as less than detectable and thus confirmed to be insignificant per the ASTM guidance (less than 10% of the concentration of the respective element in the sample leachates). The measured concentrations of B, Li, Na, and Si in the leachates from the ARM-1 glasses were compared to the control chart limits to demonstrate proper performance of the PCT.[34] Two of the triplicate Na values fell below the lower limit of the control chart. The expectation is that an error in the performance of a PCT would result in a consistent divergence of the concentrations of the analytes of the ARM-1 glass away from the limits of the control charts. Since there were no consistent deviations in the ARM-1 values, the test was considered to have been performed properly and no bias correction of the data was performed.

The ambient temperature pH values for each of the PCT leachates measured at the conclusion of the test are provided for reference in Table D-3 of Appendix D.

5.6.1 Multi-Element Standard Solution Results

Following the guidance in ASTM C1285-14, the mean, standard deviation and %RSD of the triplicate results for the multi-element standard solution measurements were calculated.[9] The as-measured concentrations for each of the replicates are shown in Table D-2 in Appendix D. As shown in Table 5-7, the mean value 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 element. These analytical results are acceptable per the criteria in ASTM C1285-14, which indicates no significant issues with the analytical outcomes for the measurements of the PCT leachates.

Table 5-7. Multi-Element Standard Solution Results (Included with the PCT Leachates)

Element	Reference[31] (mg/L)	Mean (mg/L)	Standard Deviation	%RSD	% Relative Bias
Al	4.00	3.74	0.06	1.5	-6.6
B	20.0	19.80	0.26	1.3	-1.0
Fe	4.00	3.94	0.05	1.3	-1.6
K	10.0	9.86	0.14	1.4	-1.4
Li	10.0	9.45	0.18	1.9	-5.5
Na	81.0	74.50	2.29	3.1	-8.0
Si	50.0	47.50	0.95	2.0	-5.0

5.6.2 Normalization of the PCT Results

The PCT leachate data were used to determine normalized concentrations for each element of interest using the measured glass compositions following the expression given in ASTM C1285-14:[9]

[e] The leachates were diluted by adding 4 mL of 0.4 M HNO_3 to 6 mL of the filtered leachate (a 6:10 volume to volume, v:v, dilution).

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

where:

NC_i	= normalized concentration, $g_{\text{waste form}}/L_{\text{leachant}}$
c_i(sample)	= concentration of element "i" in the leachate, g_i/L
f_i	= mass fraction of element "i" in the unleached glass, g_i/g_{glass}

An equation was developed to calculate the NC_i values using the units of measurement provided with the analytical results, and to accommodate the triplicate or quadruplicate leachate measurements for each of the glasses. The common logarithm of the normalized concentration for each element "i" (NC_i) for each of the study glasses was determined using the equation:

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

where:

NC_i	= normalized concentration, $g_{\text{waste form}}/L_{\text{leachant}}$
$\log_{10} c_i$	= average of the common logarithms of the measured concentrations of element "i" in the triplicate or quadruplicate leachates, mg/L
$\log_{10} f_i$	= common logarithm of the average measured concentration of element "i" in the glass, wt.% (from Table 5-3)

Note that the symbols in this second equation were kept consistent with those used in ASTM C1285-14, but the units of measurement differ. The calculated NC_i values are discussed further in the following section.

5.6.3 Review of the PCT Results

Table 5-8 provides the NC_i values of B, Li, Na, Si, and U in the PCT leachates from the ARM-1, Nominal and High Fissile glasses. Published values for the EA benchmark glass are provided with the standard deviations for comparison.[42] Normalized concentrations of each element are comparable for the High Fissile and Nominal glasses, which indicates that durability is not influenced by the increased U-235 content or the increased total U_3O_8 concentration. The NC_i values for both the Nominal and High Fissile glasses are less than the corresponding values for EA, which satisfies the WAPS product consistency acceptance criterion in which normalized releases of B, Li, and Na must be at least two standard deviations below the reported releases for these elements in EA.[8]

Table 5-8. Average Measured Normalized Concentrations in the PCT Leachate

NC_i (g/L)	ARM-1	Nominal Glass	High Fissile Glass	EA Published[42]
NC_B	0.49	0.63	0.57	16.695 ± 1.222
NC_{Li}	0.52	0.68	0.60	9.565 ± 0.735
NC_{Na}	0.41	0.68	0.68	13.346 ± 0.902
NC_{Si}	0.28	0.46	0.35	3.922 ± 0.376
NC_U	---	0.34	0.23	---

Figure 5-1 provides plots of the DWPF PCCS durability models that relate the logarithm of the NCi values (i = B, Li, Na and Si) to a linear function of a free energy of hydration term (ΔGp, kcal/100g glass).[11] The average measured compositions for both glasses were used to generate the ΔGp values used in the plots. Prediction limits at a 95% confidence for an individual PCT result (- - - -) are plotted along with the linear fit (——). The EA and ARM-1 results are also indicated on these plots for reference. All the data points are within the 95% confidence bands of the models. These plots demonstrate that normalized concentrations of B, Li, Na and Si released from the Nominal and High Fissile glasses during the PCT are predictable with the PCCS models for durability regardless of the ratio of fissile uranium isotopes present in these glasses.

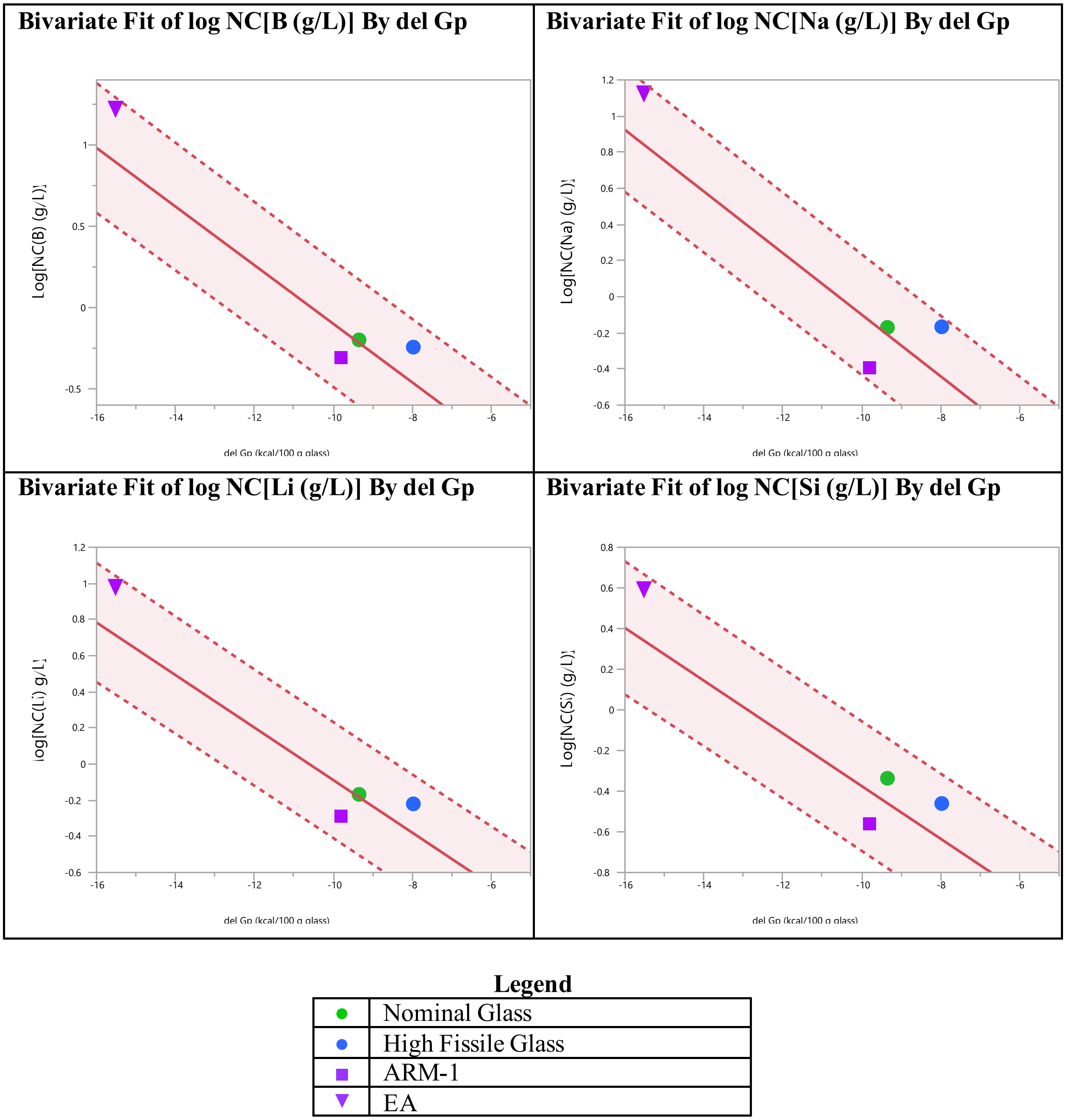

Figure 5-1. Del Gp (ΔGp) predictions versus the common logarithm of the normalized concentrations for B, Li, Na and Si.

5.7 XRD and SEM

Both XRD and SEM analysis of the glasses were peformed to confirm that no new phases form as a result of the increased fissile concentrations in the High Fissile glass relative to the Nominal glass. Figure 5-2 shows the XRD spectra of the glasses. Both spectra exhibit an amorphous hump, characteristic of the expected x-ray amorphous microstructure of the glasses. A few low intensity diffraction peaks can be seen in both the Nominal and High Fissile glass XRD patterns. These peaks were compared to XRD spectra of various crystalline phases expected in DWPF HLW glass, but no conclusive match to any likely phases could be found.[37,38] The crystalline patterns examined included analcime ($Na(Si_2Al)O_6{\cdot}H_2O$), nepheline ($NaAlSiO_4$), trevorite ($NiFe_2O_4$), aluminum iron oxide ($FeAl_2O_4$), manganese iron oxide ($MnFe_2O_4$), quartz (SiO_2) and uranium oxide (U_3O_8). The relatively minor peaks associated with the XRD spectra do not contribute, or constitute, a significant phase fraction to either of the glasses.

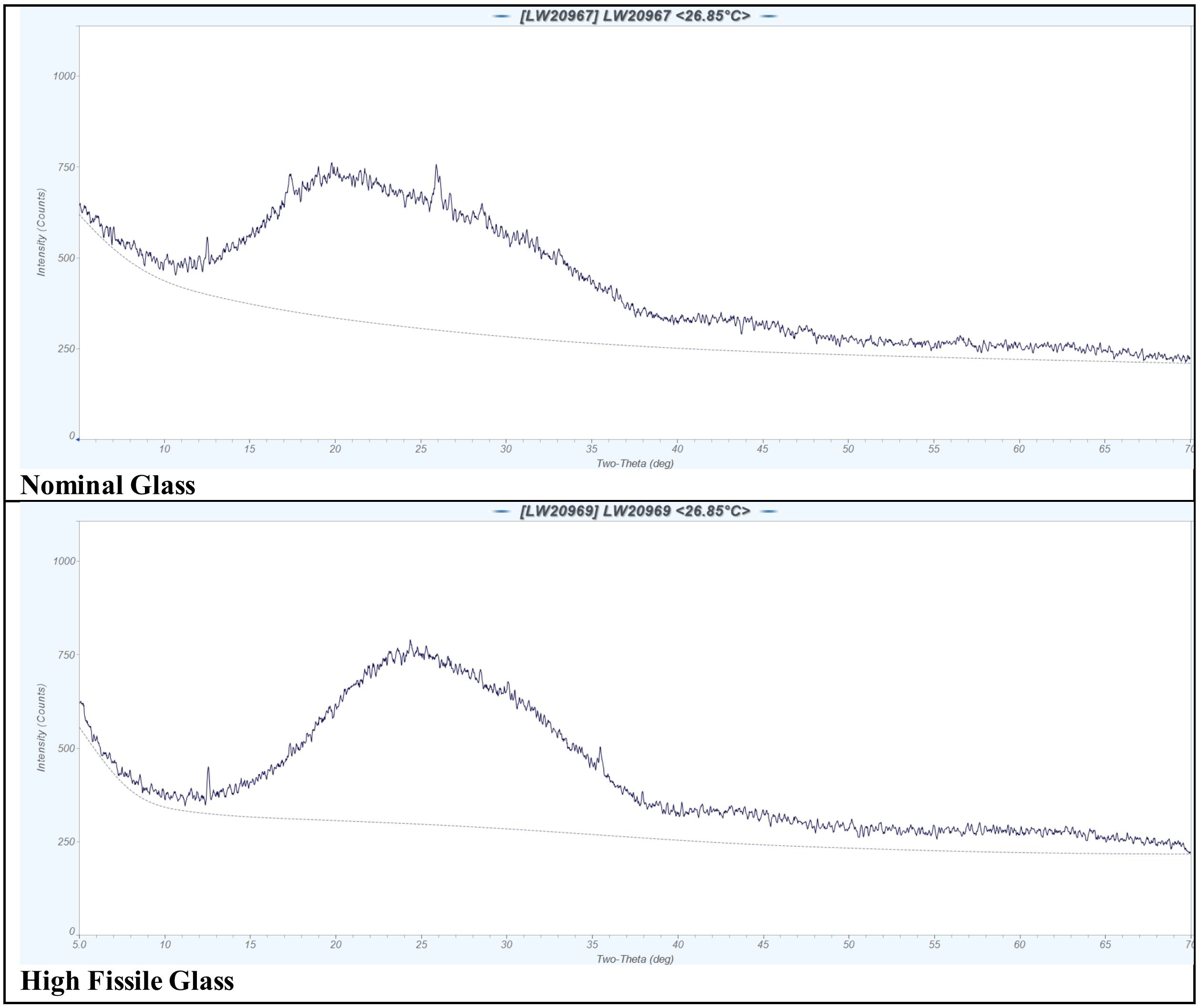

Figure 5-2. XRD spectra of the Nominal and High Fissile glasses.

The glasses were also analyzed using SEM to investigate presence of potential x-ray amorphous, or minor crystalline phases. Glass samples were examined using a back-scattered electron (BSE) detector to reveal any concentrated elemental contrast against the nominal glass composition. Figure 5-3 and Figure 5-4 are the BSE micrographs of particles from the Nominal and High Fissile glasses that passed through the 200 mesh stainless steel sieve after agate pulverization. No discernable phase contrast or crystalline phases could be identified in the Nominal glass (Figure 5-3). Chemical contrast associated with some particles is evident in the High Fissile glass micrograph (Figure 5-4); however, no discernable crystalline phases could be identified.

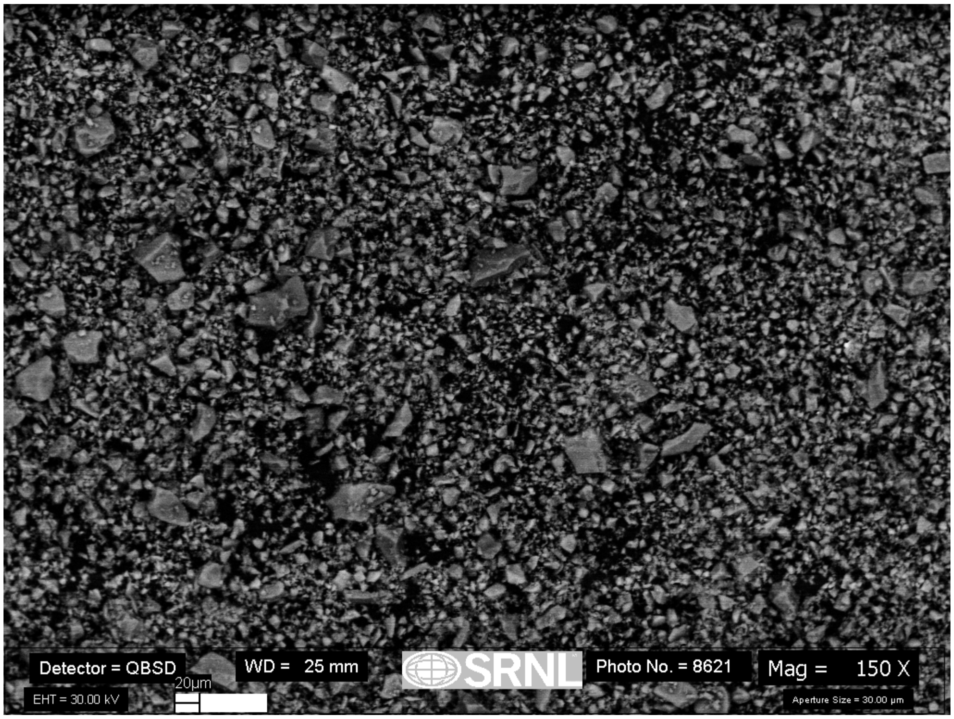

Figure 5-3. SEM BSE image of Nominal glass powder at 150X.

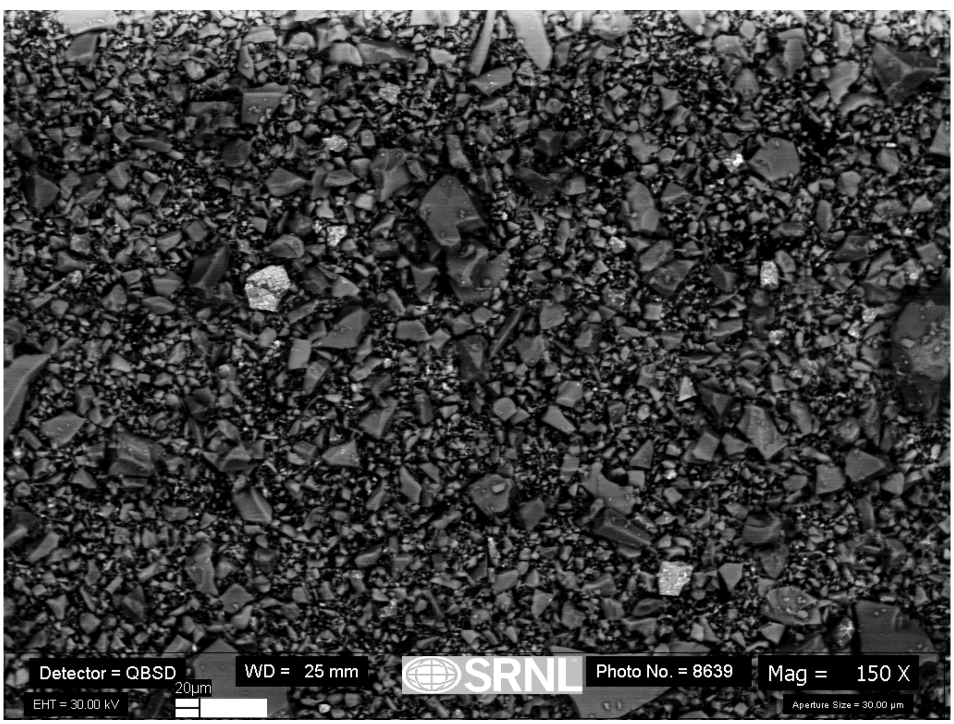

Figure 5-4. SEM BSE image of High Fissile glass powder at 150X.

6.0 Conclusions

Actual radioactive waste testing has demonstrated that a DWPF HLW glass produced with a fissile mass loading of 2670 g/m^3 meets the WAPS acceptance criterion for product consistency, which states that normalized releases of B, Li, and Na must be at least two standard deviations below the reported releases for these elements in the EA benchmark glass. The normalized concentrations of B, Li, Na and Si released from the Nominal and High Fissile glasses during the PCT are predictable with the DWPF PCCS models for durability regardless of the ratio of fissile uranium isotopes present in these glasses. As anticipated, based on previously produced DWPF HLW glasses with higher U_3O_8 concentrations, no new crystalline phases were identified in the HLW glass as a result of the increased U-235 content.

The glass performance data provided in this report should be used by DOE-EM and the Office of Nuclear Energy to (1) assess the performance of SRS HLW glass for disposal in the federal repository, and (2) allow an increase of the fissile mass loading limit in DWPF canisters to enable completion of the ABD mission with minimized impact on the total DWPF canister production.

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46. C.M. Jantzen, T.B. Edwards, and C.L. Trivelpiece, "Defense Waste Processing Facility (DWPF) Liquidus Model: Revisions for Processing Higher TiO_2 Containing Glasses," Savannah River National Laboratory, Aiken, SC, SRNL-STI-2017-00016, Rev. 0, 2017.

Appendix A. Previous Chemical Composition Results of the SB9 SME Product

Concentrations of select radioisotopes in the SB9 SME product slurry are duplicated in Table A-1, both on a mass concentration basis (wt.% total solids (TS)) and a slurry activity basis (Ci/gallon slurry).[23] Percent relative standard deviation (%RSD) for each analyte is also shown. Table A-2 presents the average measured elemental and oxide compositions of vitrified SB9 SME product along with the %RSD for each analyte. Full details of the testing and analysis are available in the source report and will not be repeated here.[a]

Table A-1. Select Radioisotopes in the SB9 SME Product Slurry

Isotope	Average Mass Concentration, wt.% TS	Average Activity Concentration, Ci/gal slurry	%RSD
Tc-99	6.15E-04	2.76E-04	4.0
Th-232	3.20E-01	9.32E-07	4.2
U-233	2.90E-04	7.44E-05	2.6
U-234	2.83E-04	4.70E-05	3.0
U-235	1.22E-02	6.97E-07	3.6
U-236	7.57E-04	1.30E-06	3.7
U-238	1.26E+00	1.12E-05	2.5
Np-237	1.20E-03	2.24E-05	2.9
Pu-238	3.97E-04	1.80E-01	16
Pu-239	3.92E-03	6.46E-03	2.4
Pu-240	3.76E-04	2.28E-03	3.4
Pu-239/240	NA	9.99E-03	15
Pu-241*	1.37E-05	3.73E-02	----
Am-241	2.01E-04	1.83E-02	2.5
Am-242m**	7.11E-08	1.83E-05	33
Am-243	3.02E-05	1.60E-04	4.4
Cm-242**	1.73E-10	1.52E-05	33
Cm-244	3.25E-06	6.98E-03	3.6
Cm-245	<6.8E-05	<3.1E-04	----

* Pu-241 is calculated from Pu-238 activity using the ratio from the Sludge Receipt and Adjustment Tank (SRAT) receipt.
** Am-242m and Cm-242 are calculated form a combination of below and above detection limit values

[a] Tables duplicated from Reference 23 (Table 3-33 and Table 3-69).

Table A-2. Chemical Composition of Vitrified SB9 SME Product

Element	Average Measured (wt.%)	Oxide	Average Measured (wt.%)	%RSD
Al	3.28	Al_2O_3	6.20	1.1
B	1.44	B_2O_3	4.64	1.0
Ba	0.04	BaO	0.04	1.5
Ca	0.46	CaO	0.65	1.8
Ce	0.02	Ce_2O_3	0.02	3.0
Cr	0.04	Cr_2O_3	0.06	5.4
Cs	0.001	Cs_2O	0.001	5.5
Cu	0.10	CuO	0.12	1.0
Fe	7.91	Fe_2O_3	11.31	1.2
K	<0.20	K_2O	<0.24	----
La	0.02	La_2O_3	0.03	1.8
Li	1.78	Li_2O	3.82	1.0
Mg	<0.08	MgO	<0.14	----
Mn	2.61	MnO	3.37	1.1
Mo	<0.01	MoO_3	<0.01	----
Na	10.00	Na_2O	13.48	5.5
Nd	0.05	Nd_2O_3	0.06	----
Ni	0.55	NiO	0.71	1.7
P	0.10	P_2O_5	0.22	5.7
Pb	<0.03	PbO	<0.03	----
S	0.09	SO_4^{2-}	0.26	4.3
Si	23.90	SiO_2	51.13	2.0
Th	0.40	ThO_2	0.46	1.6
Ti	<0.06	TiO_2	<0.10	----
U	1.52	U_3O_8	1.79	1.1
Y	0.01	Y_2O_3	0.01	3.9
Zn	0.02	ZnO	0.03	5.9
Zr	0.09	ZrO_2	0.12	1.5
----	----	Total	99.05	----

Appendix B. Chemical Composition Results of the HCAN Tank 10.2 Dissolver Solution

Table B-1 provides a summary of select analytes in the HCAN Tank 10.2 dissolver solution. Table B-2 and Table B-3 contain the full analytical results from ICP-ES and ICP-MS for reference.

Table B-1. Summary of Select Analytical Results for HCAN Tank 10.2 Dissolver Solution

Analyte	Concentration	
	mg/L	wt.%
Al	4.49E+04	3.51E+00
Gd	2.28E+02	1.78E-02
Mn	4.60E+01	3.57E-03
U	3.32E+03	2.59E-01
U-233	<1.00E-01	<1.00E-05
U-235	2.05E+03	1.60E-01
U-238	1.27E+03	9.93E-02
Pu-239	1.19E+01	9.30E-04
Pu-241	1.51E+00	1.20E-04

Table B-2. ICP-ES Results for As-Received HCAN Tank 10.2 Dissolver Solution

Analyte	Average Concentration (mg/L)	%RSD	Analyte	Average Concentration (mg/L)	%RSD
Ag	<5.41E+00	----	Mn	4.57E+01	10.5
Al	4.49E+04	10.0	Mo	<3.10E+01	----
B	<7.73E+00	----	Na	<1.57E+01	----
Ba	6.07E+01	10.0	Ni	1.35E+02	10.5
Be	<1.57E-01	----	P	<9.58E+01	----
Ca	8.13E+02	10.3	Pb	<3.79E+01	----
Cd	<4.51E+00	----	Sb	<1.17E+02	----
Ce	7.87E+01	10.0	Si	<1.72E+01	----
Co	<5.60E+00	----	Sn	<3.32E+01	----
Cr	2.91E+02	10.2	Sr	<2.89E+01	----
Cu	6.12E+01	11.1	Th	<1.52E+02	----
Fe	1.06E+03	10.2	Ti	7.92E+00	11.4
Gd	2.28E+02	10.9	U	3.32E+03	10.1
K	<1.12E+02	----	V	<3.00E+00	--
La	3.52E+01	10.8	Zn	4.73E+01	11.4
Li	<5.82E+00	----	Zr	8.02E+01	10.1
Mg	3.49E+02	10.8			

Table B-3. ICP-MS Results for HCAN Tank 10.2 Dissolver Solution

Analyte (m/z)	Average Concentration (mg/L)	%RSD	Analyte (m/z)	Average Concentration (mg/L)	%RSD	Analyte (m/z)	Average Concentration (mg/L)	%RSD
59	1.22E+00	8.5	126	1.17E+01	9.4	173	5.38E-01	9.0
82	3.98E-01	11.4	128	3.12E+00	11.0	174	5.37E-01	11.0
84	<3.13E-02	----	130	8.55E+00	9.1	175	6.70E-01	10.8
85	4.47E+00	10.4	133	3.44E+01	8.9	176	2.26E-01	9.6
86	<6.26E-02	----	134	1.79E+00	8.8	177	4.63E-01	9.5
87	9.01E+00	10.0	135	2.96E+00	10.2	178	<3.13E-02	----
88	1.31E+01	9.8	136	1.22E-01	14.0	179	<3.13E-02	----
89	1.71E+01	9.4	137	3.19E+01	11.4	180	<3.13E-02	----
90	1.20E+01	10.3	138	4.05E+01	8.7	181	<3.13E-02	----
91	1.46E+01	9.6	139	3.91E+01	9.2	182	<3.13E-02	----
92	1.36E+01	10.5	140	3.83E+01	9.7	183	<3.13E-02	----
93	1.58E+01	9.8	141	3.56E+01	7.7	184	<3.13E-02	----
94	1.49E+01	10.2	142	3.88E+01	9.2	185	<3.13E-02	----
95	7.47E+00	9.1	143	2.99E+01	11.0	186	<3.13E-02	----
96	1.34E+01	10.1	144	3.99E+01	9.8	187	<6.26E-02	----
97	6.60E+00	9.4	145	2.22E+01	10.3	191	<3.13E-02	----
98	6.71E+00	9.8	146	2.04E+01	8.2	193	<3.13E-02	----
99	1.90E+01	9.6	147	1.08E+01	8.8	194	<3.13E-02	----
100	7.91E+00	8.7	148	1.25E+01	9.1	195	<3.13E-02	----
101	2.15E+01	10.0	149	4.75E-01	8.7	196	7.66E-01	9.1
102	1.82E+01	9.7	150	1.03E+01	9.1	198	4.39E+01	9.9
103	1.09E+01	8.8	151	4.37E-01	7.4	203	<3.13E-02	----
104	9.29E+00	9.5	152	3.52E+00	9.6	204	2.75E+01	9.8
105	1.81E+00	11.8	153	1.65E+00	7.2	205	<3.13E-02	----
106	1.96E+00	9.6	154	6.16E+00	8.6	206	3.79E-01	13.8
107	6.43E-01	7.3	155	3.15E+01	9.8	207	3.48E-01	14.0
108	2.48E-01	11.6	156	4.27E+01	9.9	208	8.19E-01	13.3
109	3.08E-01	5.3	157	3.25E+01	10.1	230	<3.13E-02	----
110	2.09E-01	12.3	158	5.32E+01	9.8	232	<3.13E-02	----
111	1.60E-01	9.6	159	5.57E-01	9.9	233	<3.13E-02	----
112	1.62E-01	15.9	160	4.83E+01	10.1	234	2.90E+01	7.9
113	<9.39E-02	----	161	4.74E-01	9.1	235	2.05E+03	9.3
114	1.35E-01	19.6	162	3.00E-01	8.5	236	2.12E+02	9.4
116	1.10E-01	10.4	163	1.80E-01	8.5	237	5.96E+00	9.6
117	6.25E-01	9.3	164	1.24E-01	14.5	238	1.27E+03	8.8
118	2.25E+01	8.4	165	1.07E-01	12.5	239	1.19E+01	9.6
119	2.63E+01	9.8	166	<6.26E-02	----	240	2.83E+00	10.1
120	1.79E-01	10.1	167	7.43E-02	7.3	241	1.51E+00	9.8
121	5.23E-02	18.6	168	<3.13E-02	----	242	5.24E-01	9.3
122	7.54E-02	7.1	169	<3.13E-02	----	243	5.93E-02	6.2
123	<6.26E-02	----	170	<3.13E-02	----	244	<3.13E-02	----
124	1.42E-01	6.2	171	1.81E-01	10.7			
125	1.84E-01	11.8	172	4.65E-01	7.7			

Appendix C. As-Measured Chemical Composition Results of the Nominal and High Fissile Glasses

Table C-1. As-Measured Elemental Concentrations (µg/g) in Glasses via ICP-ES (AR)

Glass ID	Nominal Glass				ARG-1		
Lab ID	20848	20850	20852	20854	20856	20858	20860
Replicate	1	2	3	4	1	2	3
Ag	< 62.6	< 54.0	< 54.0	< 53.7	< 55.1	< 63.2	< 51.4
Al	38400	32900	33700	28200	23500	23300	23600
B	18000	15400	15600	13200	26300	26500	26100
Ba	391	333	339	285	758	752	756
Be	< 1.30	< 1.12	< 1.12	< 1.11	21.1	21.0	21.2
Ca	5520	4680	4800	4050	10200	10100	10200
Cd	74.5	63.6	64.6	55.3	< 5.64	< 6.47	< 5.26
Ce	1170	1010	1020	859	< 25.4	< 29.1	< 23.7
Co	< 40.7	< 35.1	< 35.1	< 34.9	55.4	54.8	53.4
Cr	493	415	432	372	631	626	638
Cu	295	267	310	224	23.3	22.4	23.6
Fe	90100	80000	78900	67700	95100	97100	97000
Gd	441	377	383	321	< 14.6	< 16.7	< 13.6
K	546	368	449	407	22300	22100	22100
La	228	194	197	165	< 4.37	< 5.01	< 4.07
Li	21600	18400	18800	15700	15500	15200	15500
Mg	1220	1040	1060	895	5060	5050	5040
Mn	29000	24700	25200	21500	14000	14100	14000
Mo	163	141	144	120	< 5.31	< 6.09	< 4.96
Na	107000	95100	94100	80700	83000	80300	80100
Ni	6720	5710	5810	4940	7980	8000	8000
P	1180	888	900	864	1110	1110	1050
Pb	< 212.0	< 183.0	< 183.0	< 182.0	< 186.0	< 214	< 174.0
S	1130	978	986	834	343	345	354
Sb	< 98.2	< 84.6	< 84.6	< 84.2	< 86.4	< 99.0	< 80.6
Sn	< 82.2	< 70.8	< 70.8	< 70.5	< 72.3	< 82.9	< 67.4
Sr	143	124	127	104	< 30.1	< 34.5	< 28.1
Th	4560	3910	4000	3410	96.1	91.5	90.0
Ti	134	118	122	105	5790	5810	5720
U	16800	14300	14500	12300	< 68.6	< 78.7	< 64.0
V	< 90.9	< 78.4	< 78.4	< 78.0	< 79.9	< 91.7	< 74.6
Zn	153	133	134	113	146	147	146
Zr	276	65.5	80.9	215	603	612	488

Table C-1. As-Measured Elemental Concentrations (µg/g) in Glasses via ICP-ES (AR)
(continued)

Glass ID	**Blank**	**High Fissile Glass**			
Lab ID	20862	20926	20927	20928	20929
Replicate	1	1	2	3	4
Ag	< 54.8	< 67.5	< 66.5	< 60.6	< 62.6
Al	< 6.68	49600	50200	51500	46400
B	< 201	13700	13900	14100	12900
Ba	< 1.69	331	335	341	307
Be	< 1.14	< 1.40	< 1.38	< 1.25	< 1.30
Ca	< 43.3	4690	4760	4810	4370
Cd	< 5.61	60.6	61.1	62.3	57.1
Ce	< 13.2	1020	1030	1040	937
Co	< 35.6	< 38.7	< 38.1	< 34.8	< 35.9
Cr	< 26.4	506	512	519	471
Cu	< 17.3	245	248	253	227
Fe	< 23.8	78700	80300	80100	79400
Gd	< 5.34	891	907	918	834
K	< 184	< 590	< 582	< 530	< 547
La	< 4.35	197	198	204	184
Li	< 15.3	16600	16900	17200	15600
Mg	< 3.19	1090	1100	1110	1010
Mn	< 5.59	25500	25700	26000	23700
Mo	< 5.29	107	117	113	102
Na	< 3290	93600	95700	96300	94700
Ni	< 7.33	5890	6040	6050	5500
P	< 61.7	1100	989	883	1040
Pb	< 185.0	< 192	< 189	< 173	< 178
S	< 174	985	998	996	918
Sb	< 85.9	< 106	< 104	< 95.0	< 98.2
Si	< 98.3	16900	20000	13900	15500
Sn	< 71.9	< 88.6	< 87.2	< 79.5	< 82.2
Sr	< 6.88	117	118	126	110
Th	< 15.4	4200	4270	4330	3920
Ti	< 3.29	131	134	133	124
U	< 68.3	21400	21500	21900	19900
V	< 79.6	< 22.1	< 21.7	< 19.8	< 20.5
Zn	< 10.3	148	148	151	136
Zr	< 16.3	569	353	227	532

Table C-2. As-Measured Elemental Concentrations (µg/g) in Glasses via ICP-ES (PF)

Glass ID	Nominal Glass				ARG-1		
Lab ID	20867	20871	20875	20879	20882	20884	20886
Replicate	1	2	3	4	1	2	3
Ag	< 143	< 109	< 124	< 113	< 118	< 119	< 102
Al	35300	33700	34800	34000	25800	25400	25300
B	15800	15200	15600	15300	27000	26300	26400
Ba	334	330	336	330	774	751	772
Be	< 2.96	< 2.25	< 2.57	< 2.34	21.1	20.0	21.2
Ca	9230	7630	8320	7300	13100	13000	12600
Cd	< 89.6	< 68.3	< 77.8	< 70.9	< 74.2	< 74.8	< 64.0
Ce	917	875	890	830	< 131	< 133	< 113
Co	< 86.9	< 66.2	< 75.4	< 68.7	< 71.9	< 72.5	< 62.0
Cr	409	386	400	386	637	656	628
Cu	289	285	273	292	< 37.4	< 37.7	< 32.3
Fe	77200	74700	76400	75500	94300	94000	93600
Gd	392	370	381	353	< 10.8	< 10.9	< 9.35
K	< 2600	< 1980	< 2250	< 2050	21100	21200	21300
La	183	180	183	176	< 9.37	< 9.45	< 8.08
Li	17200	17100	17200	17100	14500	14000	14900
Mg	1100	1050	1080	1040	5360	5280	5220
Mn	26200	25200	26000	25500	14500	14300	14200
Mo	< 205	< 156	< 178	< 162	< 170	< 171	< 146.0
Ni	5650	5460	5670	5500	7820	7720	7680
P	672	838	542	976	1050	961	982
Pb	< 221	< 168	< 191	< 174	< 183	< 184	< 158
S	1070	1020	1040	1030	< 506	< 511	< 437
Sb	< 224	< 171	< 194	< 177	< 185	< 187	< 160
Si	244000	220000	211000	237000	224000	219000	219000
Sn	< 270	< 206	< 234	< 213	< 223	< 225	< 193
Sr	143	133	138	133	34.9	33.5	33.9
Th	4090	3960	4050	3900	< 159	< 161	< 138
Ti	171	158	164	160	6910	7040	7000
U	13100	12600	13000	12700	< 147	< 148	< 127
V	< 102	< 77.5	< 88.2	< 80.4	< 84.1	< 84.9	< 72.6
Zn	135	130	134	128	166	167	177

Table C-2. As-Measured Elemental Concentrations (µg/g) in Glasses via ICP-ES (PF) ***(continued)***

Glass ID	High Fissile Glass				Blank
Lab ID	20939	20943	20947	20951	20958
Replicate	1	2	3	4	1
Ag	< 120	< 113	< 124	< 120	< 110
Al	55000	53000	52500	54100	< 52.0
B	14700	14300	14100	14500	< 403
Ba	349	339	333	342	< 3.37
Be	< 2.49	< 2.34	< 2.57	< 2.49	< 2.27
Ca	8170	7890	8050	8520	3110
Cd	< 75.5	< 71.1	< 77.8	< 75.5	< 68.8
Ce	895	886	854	910	< 122
Co	< 73.2	< 68.9	< 75.4	< 73.2	< 66.7
Cr	518	479	490	494	110
Cu	278	268	262	273	< 34.7
Fe	81100	79600	79400	78900	690
Gd	902	911	866	942	< 10.1
K	< 2190	< 2060	< 2250	< 2190	< 1990
La	198	193	186	197	< 8.69
Li	16500	16300	15900	16400	< 30.5
Mg	1170	1150	1120	1170	< 6.38
Mn	27100	26900	26700	26600	< 1.93
Mo	< 173	< 162	< 178	< 173	< 157
Ni	6080	5840	5760	5950	< 70.8
P	1010	987	1060	979	< 123
Pb	< 186	< 175	< 191	< 186	< 169
S	1080	1050	1050	1050	< 470
Sb	< 189	< 177	< 194	< 189	< 172
Si	229000	224000	222000	227000	< 256
Sn	< 227	< 214	< 234	< 227	< 207
Sr	143	139	138	143	< 3.96
Th	4300	4210	4100	4290	< 56.4
Ti	169	160	159	167	< 6.59
U	20300	20800	20000	20500	< 137
V	< 85.7	< 80.6	< 88.2	< 85.7	< 78.1
Zn	156	157	147	152	< 20.7

Table C-3. As-Measured Elemental Concentrations (mg/L) in Multi-Element Standard Solution Samples Measured with Glass Dissolutions via ICP-ES

Lab ID	20934	20935	20961	20962
Replicate	1	2	3	4
Al	3.98	3.96	3.99	3.97
B	20.4	20.4	20.4	20.4
Fe	4.07	4.05	4.05	4.07
K	9.62	9.60	9.61	9.53
Li	9.84	9.86	9.97	9.89
Na	79.6	80.1	not measured*	not measured*
Si	50.8	50.8	51.0	51.4

*Na is not measured with PF dissolution sets.

Table C-4. As-Measured Concentrations of m/z (µg/g) via ICP-MS (PF) for the Nominal Glass

Sample ID	Nominal Glass				Blank
Lab ID	20868	20872	20876	20880	20890
Replicate	1	2	3	4	1
59	3.57E+01	3.28E+01	3.48E+01	3.39E+01	< 8.00E-01
84	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
85	< 5.21E+00	< 3.97E+00	< 4.52E+00	< 4.12E+00	< 4.00E+00
86	6.35E+00	5.47E+00	5.83E+00	5.72E+00	1.79E+00
87	6.86E+00	6.13E+00	6.75E+00	6.24E+00	1.57E+00
88	1.11E+02	1.03E+02	1.09E+02	1.03E+02	1.47E+01
89	8.42E+01	7.91E+01	8.22E+01	7.82E+01	3.49E+00
90	5.01E+04	3.34E+04	3.80E+04	2.20E+04	7.39E+04
91	1.18E+04	7.89E+03	8.92E+03	5.21E+03	1.71E+04
92	1.58E+04	1.06E+04	1.20E+04	7.05E+03	2.31E+04
93	1.41E+02	1.28E+02	1.34E+02	1.25E+02	7.88E+00
94	1.62E+04	1.08E+04	1.22E+04	7.24E+03	2.37E+04
95	2.58E+01	2.43E+01	2.53E+01	2.48E+01	< 8.00E-01
96	2.61E+03	1.75E+03	2.00E+03	1.21E+03	3.68E+03
97	1.82E+01	1.72E+01	1.78E+01	1.72E+01	< 8.00E-01
98	3.40E+01	3.22E+01	3.39E+01	3.27E+01	< 8.00E-01
99	4.27E+00	4.28E+00	4.28E+00	4.53E+00	< 8.00E-01
100	1.85E+01	1.77E+01	1.89E+01	1.82E+01	< 8.00E-01
101	4.25E+01	4.80E+01	5.02E+01	5.79E+01	< 8.00E-01
102	3.74E+01	4.28E+01	4.41E+01	5.08E+01	< 8.00E-01
103	4.78E+01	4.48E+01	4.66E+01	4.53E+01	< 8.00E-01
104	2.03E+01	2.39E+01	2.49E+01	2.89E+01	< 8.00E-01
105	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
106	5.49E+01	3.69E+01	4.30E+01	2.42E+01	8.14E+01
107	3.99E+01	3.35E+01	3.69E+01	2.97E+01	3.20E+01
108	1.84E+01	1.20E+01	1.36E+01	7.08E+00	2.77E+01
109	1.94E+01	2.01E+01	2.14E+01	2.08E+01	2.35E+00
110	3.20E+01	2.30E+01	2.57E+01	1.67E+01	3.99E+01
111	1.14E+01	9.78E+00	1.08E+01	9.35E+00	3.59E+00
112	2.29E+01	1.89E+01	2.11E+01	1.79E+01	1.17E+01
113	5.05E+00	5.68E+00	7.24E+00	5.68E+00	< 8.00E-01
114	1.82E+01	1.71E+01	1.83E+01	1.76E+01	8.66E-01
116	1.21E+02	1.10E+02	1.15E+02	1.08E+02	1.39E+01
117	8.48E+00	5.66E+00	6.09E+00	5.04E+00	9.69E+00
118	2.47E+01	1.68E+01	1.96E+01	1.55E+01	2.86E+01
119	2.38E+02	2.18E+02	2.29E+02	2.21E+02	8.90E+00
120	3.33E+01	2.15E+01	2.52E+01	2.11E+01	3.90E+01

Table C-4. As-Measured Concentrations of m/z (µg/g) via ICP-MS (PF) for the Nominal Glass (*continued*)

Sample ID	Nominal Glass				Blank
Lab ID	20868	20872	20876	20880	20890
Replicate	1	2	3	4	1
121	1.15E+00	1.04E+00	9.07E-01	9.98E-01	< 8.00E-01
122	7.04E+00	5.00E+00	5.52E+00	4.75E+00	8.22E+00
123	1.05E+00	9.05E-01	< 9.05E-01	1.04E+00	< 8.00E-01
124	1.11E+01	8.08E+00	9.04E+00	7.59E+00	1.15E+01
125	< 5.21E+00	< 3.97E+00	< 4.52E+00	< 4.12E+00	< 8.00E-01
126	< 5.21E+00	< 3.97E+00	< 4.52E+00	< 4.12E+00	< 8.00E-01
128	8.93E+00	8.01E+00	8.60E+00	7.99E+00	< 8.00E-01
130	4.27E+01	4.09E+01	4.26E+01	4.17E+01	< 8.00E-01
133	1.43E+01	1.34E+01	1.67E+01	1.37E+01	< 1.00E+00
134	6.43E+00	6.25E+00	6.62E+00	6.32E+00	< 8.00E-01
135	4.67E+00	4.66E+00	4.81E+00	4.76E+00	< 8.00E-01
136	7.24E+00	6.58E+00	6.71E+00	6.34E+00	< 8.00E-01
137	1.16E+02	1.10E+02	1.14E+02	1.14E+02	< 8.00E-01
138	2.24E+02	2.16E+02	2.24E+02	2.21E+02	1.68E+00
139	2.02E+02	1.91E+02	1.98E+02	1.90E+02	< 8.00E-01
140	7.97E+02	7.42E+02	7.78E+02	7.24E+02	< 8.00E-01
141	1.69E+02	1.57E+02	1.65E+02	1.52E+02	< 8.00E-01
142	2.61E+02	2.43E+02	2.53E+02	2.35E+02	< 8.00E-01
143	1.64E+02	1.53E+02	1.60E+02	1.48E+02	< 8.00E-01
144	1.70E+02	1.58E+02	1.65E+02	1.52E+02	< 8.00E-01
145	1.15E+02	1.07E+02	1.11E+02	1.04E+02	< 8.00E-01
146	9.35E+01	8.70E+01	9.00E+01	8.30E+01	< 8.00E-01
147	6.16E+01	5.69E+01	5.91E+01	5.46E+01	< 8.00E-01
148	5.69E+01	5.26E+01	5.43E+01	5.11E+01	< 8.00E-01
149	3.68E+00	3.34E+00	3.52E+00	3.15E+00	< 8.00E-01
150	5.22E+01	4.83E+01	5.04E+01	4.59E+01	< 8.00E-01
151	4.85E+00	4.25E+00	4.72E+00	4.31E+00	< 8.00E-01
152	1.81E+01	1.66E+01	1.73E+01	1.58E+01	< 8.00E-01
153	7.60E+00	6.80E+00	7.22E+00	6.80E+00	< 8.00E-01
154	1.28E+01	1.19E+01	1.26E+01	1.16E+01	< 8.00E-01
155	5.45E+01	5.01E+01	5.20E+01	4.82E+01	< 8.00E-01
156	7.75E+01	7.05E+01	7.38E+01	6.86E+01	< 8.00E-01
157	5.59E+01	5.15E+01	5.38E+01	4.97E+01	< 8.00E-01
158	9.12E+01	8.42E+01	8.73E+01	8.10E+01	< 8.00E-01
159	< 1.04E+00	8.92E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
160	8.03E+01	7.33E+01	7.73E+01	7.03E+01	< 8.00E-01
161	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
162	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
163	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
164	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01

Table C-4. As-Measured Concentrations of m/z (µg/g) via ICP-MS (PF) for the Nominal Glass (*continued*)

Sample ID	Nominal Glass				Blank
Lab ID	20868	20872	20876	20880	20890
Replicate	1	2	3	4	1
165	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
166	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
167	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
168	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
169	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
170	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
171	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
172	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
173	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
174	1.81E+00	1.41E+00	1.51E+00	1.01E+00	2.33E+00
175	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
176	5.13E+01	3.45E+01	3.81E+01	2.30E+01	7.86E+01
177	1.85E+02	1.24E+02	1.38E+02	8.33E+01	2.84E+02
178	2.68E+02	1.81E+02	2.02E+02	1.20E+02	4.37E+02
179	1.36E+02	8.95E+01	1.01E+02	6.05E+01	2.08E+02
180	3.42E+02	2.30E+02	2.57E+02	1.53E+02	5.60E+02
181	5.53E+00	3.33E+00	3.26E+00	3.49E+00	< 8.00E-01
182	3.72E+00	3.16E+00	3.17E+00	3.14E+00	< 8.00E-01
183	1.94E+00	1.63E+00	1.66E+00	1.71E+00	< 8.00E-01
184	4.43E+00	3.53E+00	3.72E+00	3.69E+00	< 8.00E-01
185	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
186	4.13E+00	3.47E+00	3.63E+00	3.51E+00	< 8.00E-01
187	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
191	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
193	1.60E+00	1.10E+00	1.12E+00	< 8.23E-01	2.31E+00
194	3.95E+00	2.96E+00	3.31E+00	2.24E+00	4.90E+00
195	2.94E+00	2.09E+00	2.41E+00	1.83E+00	2.99E+00
196	4.54E+00	3.33E+00	3.63E+00	2.38E+00	6.13E+00
198	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
203	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
204	2.08E+00	2.07E+00	2.17E+00	2.00E+00	< 8.00E-01
205	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
206	3.80E+01	3.60E+01	3.76E+01	3.68E+01	< 8.00E-01
207	3.24E+01	3.10E+01	3.21E+01	3.21E+01	< 8.00E-01
208	7.84E+01	7.50E+01	7.72E+01	7.59E+01	< 8.00E-01
229	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
230	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
232	4.02E+03	3.78E+03	3.92E+03	3.80E+03	< 8.00E-01
233	3.25E+00	3.08E+00	3.16E+00	3.13E+00	< 8.00E-01
234	3.76E+00	3.57E+00	3.67E+00	3.66E+00	< 8.00E-01

Table C-4. As-Measured Concentrations of m/z (µg/g) via ICP-MS (PF) for the Nominal Glass (*continued*)

Sample ID	**Nominal Glass**				**Blank**
Lab ID	20868	20872	20876	20880	20890
Replicate	1	2	3	4	1
235	1.52E+02	1.44E+02	1.48E+02	1.45E+02	< 8.00E-01
236	8.92E+00	8.69E+00	8.85E+00	8.56E+00	< 8.00E-01
237	1.42E+01	1.31E+01	1.38E+01	1.34E+01	< 8.00E-01
238	1.54E+04	1.44E+04	1.49E+04	1.45E+04	< 8.00E-01
239	4.64E+01	4.32E+01	4.50E+01	4.30E+01	< 8.00E-01
240	4.45E+00	4.21E+00	4.33E+00	4.20E+00	< 8.00E-01
241	2.76E+00	2.57E+00	2.54E+00	2.54E+00	< 8.00E-01
242	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
243	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01
244	< 1.04E+00	< 7.94E-01	< 9.05E-01	< 8.23E-01	< 8.00E-01

Table C-5. As-Measured Concentrations of m/z (µg/g) via ICP-MS (PF) for the High Fissile Glass

Sample ID	High Fissile Glass				Blank
Lab ID	20940	20944	20948	20952	20959
Replicate	1	2	3	4	1
59	3.70E+01	3.75E+01	3.59E+01	3.59E+01	1.75E+00
84	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
85	1.39E+00	1.30E+00	1.28E+00	1.32E+00	< 6.00E-01
86	6.23E+00	6.05E+00	6.52E+00	6.35E+00	1.66E+00
87	6.19E+00	6.30E+00	6.79E+00	6.63E+00	1.59E+00
88	1.16E+02	1.17E+02	1.18E+02	1.16E+02	1.51E+01
89	9.26E+01	9.43E+01	9.07E+01	9.45E+01	< 4.00E-01
90	3.12E+04	2.29E+04	3.70E+04	3.40E+04	4.52E+04
91	7.26E+03	5.34E+03	8.58E+03	7.86E+03	9.72E+03
92	1.00E+04	7.25E+03	1.18E+04	1.08E+04	1.35E+04
93	1.49E+02	1.51E+02	1.45E+02	1.50E+02	5.69E+00
94	1.04E+04	7.63E+03	1.22E+04	1.12E+04	1.40E+04
95	2.37E+01	2.29E+01	2.25E+01	2.25E+01	6.71E-01
96	1.68E+03	1.23E+03	1.93E+03	1.79E+03	2.14E+03
97	1.70E+01	1.70E+01	1.62E+01	1.63E+01	< 4.00E-01
98	2.70E+01	2.65E+01	2.62E+01	2.62E+01	5.21E-01
99	3.65E+00	3.49E+00	3.54E+00	3.60E+00	< 4.00E-01
100	1.89E+01	1.87E+01	1.84E+01	1.86E+01	< 6.00E-01
101	7.08E+01	6.63E+01	6.65E+01	6.97E+01	< 4.00E-01
102	6.33E+01	5.92E+01	5.92E+01	6.32E+01	< 6.00E-01
103	5.20E+01	5.04E+01	4.92E+01	4.96E+01	< 4.00E-01
104	3.62E+01	3.42E+01	3.44E+01	3.58E+01	< 4.00E-01
105	2.09E+00	1.76E+00	1.49E+00	1.69E+00	< 4.00E-01
106	4.55E+01	3.45E+01	5.37E+01	4.90E+01	5.73E+01
107	3.27E+01	2.95E+01	3.54E+01	3.39E+01	1.98E+01
108	1.39E+01	1.03E+01	1.70E+01	1.60E+01	1.96E+01
109	1.97E+01	1.95E+01	1.93E+01	1.94E+01	1.97E+00
110	2.54E+01	1.99E+01	2.89E+01	2.78E+01	2.80E+01
111	1.04E+01	9.70E+00	1.06E+01	1.03E+01	2.80E+00
112	2.09E+01	1.90E+01	2.15E+01	2.09E+01	8.19E+00
113	7.47E+00	7.25E+00	7.35E+00	7.30E+00	< 4.00E-01
114	1.78E+01	1.76E+01	1.71E+01	1.71E+01	6.07E-01
116	1.26E+02	1.21E+02	1.19E+02	1.22E+02	1.23E+01
117	5.70E+00	4.81E+00	6.57E+00	6.13E+00	7.75E+00
118	1.90E+01	1.55E+01	2.07E+01	1.97E+01	2.39E+01
119	4.48E+02	4.42E+02	4.13E+02	4.40E+02	6.90E+00
120	2.28E+01	1.83E+01	2.57E+01	2.40E+01	3.26E+01

Table C-5. As-Measured Concentrations of m/z (µg/g) via ICP-MS (PF) for the High Fissile Glass (*continued*)

Sample ID	High Fissile Glass				Blank
Lab ID	20940	20944	20948	20952	20959
Replicate	1	2	3	4	1
121	1.16E+00	1.06E+00	1.09E+00	1.16E+00	< 4.00E-01
122	4.84E+00	3.82E+00	5.57E+00	5.20E+00	6.90E+00
123	1.25E+00	1.10E+00	1.22E+00	1.07E+00	< 4.00E-01
124	8.25E+00	6.90E+00	9.36E+00	8.63E+00	9.60E+00
125	1.19E+00	1.06E+00	1.44E+00	1.05E+00	< 4.00E-01
126	3.43E+00	3.12E+00	3.24E+00	3.19E+00	< 4.00E-01
128	9.78E+00	9.91E+00	9.78E+00	9.18E+00	< 4.00E-01
130	4.70E+01	4.65E+01	4.58E+01	4.68E+01	< 4.00E-01
133	1.36E+01	1.35E+01	1.33E+01	1.30E+01	< 4.00E-01
134	7.12E+00	6.99E+00	6.84E+00	6.84E+00	< 4.00E-01
135	4.70E+00	4.62E+00	4.69E+00	4.54E+00	< 4.00E-01
136	7.14E+00	6.79E+00	6.89E+00	6.72E+00	< 4.00E-01
137	1.23E+02	1.20E+02	1.18E+02	1.19E+02	< 4.00E-01
138	2.42E+02	2.37E+02	2.33E+02	2.32E+02	9.66E-01
139	2.18E+02	2.13E+02	2.08E+02	2.10E+02	< 4.00E-01
140	8.17E+02	8.12E+02	7.75E+02	8.10E+02	< 4.00E-01
141	1.79E+02	1.78E+02	1.69E+02	1.78E+02	< 4.00E-01
142	2.76E+02	2.88E+02	2.61E+02	2.80E+02	< 4.00E-01
143	1.68E+02	1.68E+02	1.60E+02	1.67E+02	< 4.00E-01
144	1.82E+02	1.81E+02	1.74E+02	1.81E+02	< 4.00E-01
145	1.21E+02	1.20E+02	1.14E+02	1.20E+02	< 4.00E-01
146	9.98E+01	9.85E+01	9.32E+01	9.84E+01	< 4.00E-01
147	6.41E+01	6.41E+01	6.01E+01	6.43E+01	< 4.00E-01
148	6.09E+01	6.06E+01	5.72E+01	6.03E+01	< 4.00E-01
149	3.66E+00	3.71E+00	3.47E+00	3.59E+00	< 4.00E-01
150	5.61E+01	5.60E+01	5.25E+01	5.60E+01	< 4.00E-01
151	4.84E+00	4.86E+00	4.54E+00	4.87E+00	< 4.00E-01
152	2.02E+01	2.00E+01	1.88E+01	1.99E+01	< 4.00E-01
153	7.98E+00	7.94E+00	7.31E+00	7.93E+00	< 4.00E-01
154	2.63E+01	2.60E+01	2.45E+01	2.60E+01	< 4.00E-01
155	1.30E+02	1.29E+02	1.22E+02	1.28E+02	< 4.00E-01
156	1.84E+02	1.85E+02	1.74E+02	1.81E+02	< 4.00E-01
157	1.36E+02	1.34E+02	1.28E+02	1.34E+02	< 4.00E-01
158	2.27E+02	2.25E+02	2.15E+02	2.26E+02	< 4.00E-01
159	9.53E-01	1.08E+00	9.90E-01	1.03E+00	< 4.00E-01
160	1.96E+02	2.03E+02	1.86E+02	1.96E+02	< 4.00E-01
161	5.42E-01	5.56E-01	5.26E-01	5.65E-01	< 4.00E-01
162	4.86E-01	4.94E-01	5.00E-01	4.50E-01	< 4.00E-01
163	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
164	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01

Table C-5. As-Measured Concentrations of m/z (µg/g) via ICP-MS (PF) for the High Fissile Glass (*continued*)

Sample ID	**High Fissile Glass**				**Blank**
Lab ID	20940	20944	20948	20952	20959
Replicate	1	2	3	4	1
165	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
166	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
167	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
168	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
169	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
170	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
171	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
172	4.81E-01	4.93E-01	4.90E-01	5.62E-01	< 4.00E-01
173	< 4.39E-01	< 4.13E-01	< 4.52E-01	4.58E-01	< 4.00E-01
174	1.47E+00	1.24E+00	1.62E+00	1.60E+00	1.31E+00
175	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
176	3.01E+01	2.14E+01	3.47E+01	3.21E+01	4.80E+01
177	1.05E+02	7.49E+01	1.22E+02	1.13E+02	1.74E+02
178	1.55E+02	1.10E+02	1.80E+02	1.66E+02	2.64E+02
179	7.70E+01	5.46E+01	8.94E+01	8.29E+01	1.26E+02
180	2.07E+02	1.42E+02	2.42E+02	2.21E+02	3.41E+02
181	3.11E+00	3.08E+00	3.13E+00	3.12E+00	< 6.00E-01
182	2.89E+00	2.66E+00	2.84E+00	2.78E+00	7.74E-01
183	1.58E+00	1.49E+00	1.50E+00	1.50E+00	< 4.00E-01
184	3.28E+00	3.19E+00	3.16E+00	3.16E+00	8.50E-01
185	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
186	3.16E+00	3.01E+00	3.00E+00	3.02E+00	8.77E-01
187	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
191	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
193	9.27E-01	5.99E-01	9.58E-01	8.81E-01	1.69E+00
194	3.16E+00	2.54E+00	3.47E+00	3.33E+00	3.14E+00
195	2.59E+00	2.11E+00	2.52E+00	2.44E+00	1.92E+00
196	3.26E+00	2.61E+00	3.76E+00	3.59E+00	3.99E+00
198	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
203	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
204	1.71E+00	1.60E+00	1.62E+00	1.67E+00	< 4.00E-01
205	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
206	3.10E+01	3.03E+01	3.03E+01	3.04E+01	< 4.00E-01
207	2.71E+01	2.62E+01	2.63E+01	2.64E+01	< 4.00E-01
208	6.47E+01	6.37E+01	6.35E+01	6.39E+01	< 4.00E-01
229	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
230	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
232	3.91E+03	3.89E+03	3.82E+03	3.65E+03	< 4.00E-01
233	2.99E+00	2.91E+00	2.85E+00	2.99E+00	< 4.00E-01
234	1.55E+01	1.58E+01	1.51E+01	1.53E+01	< 4.00E-01

Table C-5. As-Measured Concentrations of m/z (µg/g) via ICP-MS (PF) for the High Fissile Glass (*continued*)

Sample ID	High Fissile Glass				Blank
Lab ID	20940	20944	20948	20952	20959
Replicate	1	2	3	4	1
235	9.45E+02	9.38E+02	9.23E+02	9.44E+02	< 4.00E-01
236	8.04E+01	7.79E+01	7.75E+01	7.95E+01	< 4.00E-01
237	1.36E+01	1.32E+01	1.30E+01	1.38E+01	< 4.00E-01
238	2.15E+04	2.14E+04	2.08E+04	2.16E+04	< 4.00E-01
239	4.59E+01	4.51E+01	4.42E+01	4.62E+01	< 4.00E-01
240	4.97E+00	4.78E+00	4.68E+00	4.99E+00	< 4.00E-01
241	2.87E+00	2.77E+00	2.78E+00	2.82E+00	< 4.00E-01
242	4.88E-01	4.61E-01	< 4.52E-01	4.60E-01	< 4.00E-01
243	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01
244	< 4.39E-01	< 4.13E-01	< 4.52E-01	< 4.39E-01	< 4.00E-01

Table C-6. As-Measured Radionuclide Concentrations (dpm/g) for Nominal Glass via Plutonium Separation and Alpha Pulse Height Analysis (Pu-238, Pu-239/Pu-240) and Liquid Scintillation Counting (Pu-241)

Sample ID	**Nominal Glass**				**Blank**
Lab ID	20869	20873	20877	20881	20891
Replicate	1	2	3	4	1
Pu-238	2.03E+08	1.47E+08	2.43E+08	1.38E+08	1.61E+03
Pu-239/Pu-240	1.10E+07	7.35E+06	1.15E+07	7.98E+06	<1.28E+03
Pu-241	3.53E+07	2.65E+07	4.06E+07	2.29E+07	<1.17E+04

Table C-7. As-Measured Radionuclide Concentrations (dpm/g) for High Fissile Glass via Plutonium Separation and Alpha Pulse Height Analysis (Pu-238, Pu-239/Pu-240) and Liquid Scintillation Counting (Pu-241)

Sample ID	**High Fissile Glass**				**Blank**
Lab ID	20941	20945	20949	20953	20960
Replicate	1	2	3	4	1
Pu-238	1.49E+08	1.65E+08	2.17E+08	1.41E+08	1.95E+03
Pu-239/Pu-240	9.19E+06	1.03E+07	1.07E+07	6.88E+06	<9.62E+02
Pu-241	6.17E+07	6.56E+07	8.75E+07	5.76E+07	<3.02E+03

Appendix D. As-Measured PCT Leachate Results for the Nominal and High Fissile Glasses

Table D-1. As-Measured Elemental Concentrations (mg/L) via ICP-ES for PCT Leachates

Glass ID	Nominal Glass				ARM-1		
Lab ID	21088	21089	21090	21091	21085	21086	21087
Replicate	1	2	3	4	1	2	3
Ag	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
Al	7.39	7.69	7.59	7.74	2.81	2.75	2.70
B	5.66	6.06	5.91	5.86	11.2	10.2	9.76
Ba	< 0.009	< 0.009	< 0.009	< 0.009	< 0.009	< 0.009	< 0.009
Be	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Ca	< 0.262	< 0.262	< 0.262	< 0.262	< 0.262	< 0.262	< 0.262
Cd	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
Ce	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080
Co	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018
Cr	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078
Cu	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073
Fe	3.33	2.94	3.43	3.44	< 0.028	< 0.028	< 0.028
Gd	< 0.048	< 0.048	< 0.048	< 0.048	< 0.048	< 0.048	< 0.048
K	< 5.27	< 5.27	< 5.27	< 5.27	< 5.27	< 5.27	< 5.27
La	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
Li	6.69	7.19	7.04	7.04	7.74	7.19	6.99
Mg	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073
Mn	0.884	0.739	0.937	0.926	< 0.032	< 0.032	< 0.032
Mo	< 0.056	< 0.056	< 0.056	< 0.056	3.60	3.31	3.16
Na	36.5	39.6	38.8	38.1	18.6	17.0	16.8
Ni	< 0.167	< 0.167	< 0.167	< 0.167	< 0.167	< 0.167	< 0.167
P	0.405	0.420	0.409	0.461	0.575	0.565	0.497
Pb	< 0.281	< 0.281	< 0.281	< 0.281	< 0.281	< 0.281	< 0.281
S	< 0.586	< 0.586	< 0.586	< 0.586	< 0.586	< 0.586	< 0.586
Sb	< 0.215	< 0.215	< 0.215	< 0.215	< 0.215	< 0.215	< 0.215
Si	61.4	64.4	63.4	62.9	37.6	35.6	34.6
Sn	< 1.43	< 1.43	< 1.43	< 1.43	< 1.43	< 1.43	< 1.43
Sr	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017
Th	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316
Ti	< 0.034	< 0.034	< 0.034	< 0.034	< 0.034	< 0.034	< 0.034
U	2.46	2.67	2.61	2.63	< 0.171	< 0.171	< 0.171
V	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036
Zn	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175
Zr	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042

Table D-1. As-Measured Elemental Concentrations (mg/L) via ICP-ES for PCT Leachates (*continued*)

Glass ID	High Fissile Glass				Blank	
Lab ID	21093	21094	21095	21096	21097	21098
Replicate	1	2	3	4	1	2
Ag	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
Al	15.4	15.4	14.9	15.6	< 0.065	< 0.065
B	5.00	5.00	4.77	4.98	< 0.503	< 0.503
Ba	< 0.009	< 0.009	< 0.009	< 0.009	< 0.009	< 0.009
Be	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Ca	< 0.262	< 0.262	< 0.262	< 0.262	< 0.262	< 0.262
Cd	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
Ce	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080
Co	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018	< 0.018
Cr	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078	< 0.078
Cu	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073
Fe	2.22	1.90	1.91	1.95	< 0.028	< 0.028
Gd	< 0.048	< 0.048	< 0.048	< 0.048	< 0.048	< 0.048
K	< 5.27	< 5.27	< 5.27	< 5.27	< 5.27	< 5.27
La	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012	< 0.012
Li	5.90	5.95	5.70	5.95	< 0.050	< 0.050
Mg	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073	< 0.073
Mn	0.595	0.500	0.522	0.504	< 0.032	< 0.032
Mo	< 0.056	< 0.056	< 0.056	< 0.056	< 0.056	< 0.056
Na	38.7	39.2	37.6	40.1	< 0.333	< 0.333
Ni	< 0.167	< 0.167	< 0.167	< 0.167	< 0.167	< 0.167
P	0.628	0.633	0.603	0.628	< 0.154	< 0.154
Pb	< 0.281	< 0.281	< 0.281	< 0.281	< 0.281	< 0.281
S	< 0.586	< 0.586	< 0.586	< 0.586	< 0.586	< 0.586
Sb	< 0.215	< 0.215	< 0.215	< 0.215	< 0.215	< 0.215
Si	47.8	47.1	45.2	47.3	< 0.320	< 0.320
Sn	< 1.43	< 1.43	< 1.43	< 1.43	< 1.43	< 1.43
Sr	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017	< 0.017
Th	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316	< 0.316
Ti	< 0.034	< 0.034	< 0.034	< 0.034	< 0.034	< 0.034
U	2.92	2.81	2.74	2.90	< 0.171	< 0.171
V	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036
Zn	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175	< 0.175
Zr	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042

Table D-2. As-Measured Elemental Concentrations (mg/L) in Multi-Element Standard Solution Samples Measured with PCT Leachates via ICP-ES

Lab ID	21084	21092	21099
Replicate	1	2	3
Al	3.71	3.70	3.80
B	19.9	19.5	20.0
Fe	3.97	3.88	3.96
K	9.93	9.70	9.95
Li	9.49	9.25	9.60
Na	72.5	74.0	77.0
Si	48.5	46.6	47.4

Table D-3. Ambient Temperature PCT Leachate pH Data

Sample	**Replicate**	**pH**
ARM-1	1	9.74
	2	9.73
	3	9.84
Nominal Glass	1	10.24
	2	10.33
	3	10.30
	4	10.31
High Fissile Glass	1	10.48
	2	10.51
	3	10.35
	4	10.35

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