

## **Sulfate Solubility Limit Verification for DWPF Sludge Batch 7b**

A. L. Billings  
K. M. Fox

September 2011

Savannah River National Laboratory  
Savannah River Nuclear Solutions, LLC  
Aiken, SC 29808

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contract number DE-AC09-08SR22470.



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## EXECUTIVE SUMMARY

The objective of this study was to determine a sulfate solubility limit in glass for Sludge Batch 7b (SB7b). The SB7b composition projection provided by Savannah River Remediation (SRR) on May 25, 2011 was used as the basis for formulating glass compositions to determine the sulfate limit. Additions of Na<sub>2</sub>O to the projected sludge composition were made by the Savannah River National Laboratory (SRNL) due to uncertainty in the final concentration of Na<sub>2</sub>O for SB7b, which is dependent on washing effectiveness and the potential need to add NaOH to ensure an acceptable projected operating window. Additions of 4, 6, and 8 wt % Na<sub>2</sub>O were made to the nominal May 25, 2011 composition projection. An updated SB7b composition projection was received from SRR on August 4, 2011. Due to compositional similarities, no additional experimental work using the August 4, 2011 compositions was considered to be necessary for this study.

Both Frit 418 and Frit 702 were included in this study. The targeted sulfate (SO<sub>4</sub><sup>2-</sup>) concentrations of the study glasses were selected within the range of 0.6 to 0.9 wt % in glass. A total of 52 glass compositions were selected based on the compositional variables of Na<sub>2</sub>O addition, Actinide Removal Process (ARP) stream addition, waste loading, frit composition, and sulfate concentration.

The glasses were batched, melted, and characterized following SRNL procedures. Visual observations were recorded for each glass after it cooled and used as an indicator of sulfur retention. Representative samples of each of the glasses fabricated were subjected to chemical analysis to determine whether the targeted compositions were met, as well as to determine the quantity of sulfate that was retained after melting. In general, the measured composition data showed that there were only minor issues in meeting the targeted compositions for the study glasses, and the measured sulfate concentrations for each study glass were within 10% of the targeted values.

The results for the SB7b glasses fabricated with Frit 418 showed an apparent trend of increasing sulfate retention with increasing Na<sub>2</sub>O additions to the 5/25/11 sludge projection. This trend appears contradictory to other recent studies of sulfate retention in Defense Waste Processing Facility (DWPF) type glasses. Additional apparent contradictions to this trend were found in the data collected in the present study. Overall, the results for the SB7b sulfate study glasses with Frit 418 and the 5/25/11 projection with Na<sub>2</sub>O additions showed that subtle changes in this complex glass composition impacted the degree of sulfate retention. These results do however provide confidence that a 0.6 wt % sulfate limit in glass is warranted for Frit 418 with the SB7b compositions evaluated in this study. The results for the SB7b glasses fabricated with Frit 702 are consistent with those of the previous SB7a study in that Frit 702 allowed for higher sulfate retention as compared to Frit 418 for the same sludge compositions.

It is recommended that the DWPF implement a sulfate concentration limit of 0.6 wt % in glass for SB7b processing with Frit 418. If a higher than projected sulfate concentration is measured when SB7b processing begins (i.e., if a sulfate concentration higher than 0.6 wt % becomes necessary to achieve targeted waste loadings), DWPF should consider a transition to Frit 702. The sulfate limit could likely be raised to 0.8 wt % by transitioning to this frit. However, if DWPF considers transitioning from Frit 418 to Frit 702, additional glasses should be fabricated to confirm this higher limit due to the issues with incorrect B<sub>2</sub>O<sub>3</sub> concentrations for some of the glasses made with Frit 702 in this study. There are several factors other than sulfate retention that must also be carefully considered prior to changing frit compositions.

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## LIST OF ABBREVIATIONS

ARP	Actinide Removal Process
DWPF	Defense Waste Processing Facility
HLW	High Level Waste
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
LM	Lithium Metaborate
PCCS	Product Composition Control System
SB	Sludge Batch
SMRF	Slurry-fed Melt Rate Furnace
SRAT	Sludge Receipt and Adjustment Tank
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation
SRS	Savannah River Site
WL	Waste Loading

## 1.0 Introduction

Sulfate in high level waste (HLW) from the Savannah River Site (SRS) Tank Farm can partition among at least three paths as it is processed at the Defense Waste Processing Facility (DWPF): (1) incorporation into the glass waste form, (2) volatilization and subsequent capture by the off gas system during melting, and (3) formation of a separate, sulfate-rich salt phase on the surface of the molten glass pool. The main concern for the DWPF when processing a high sulfate concentration feed is the formation of a sulfate-rich molten salt phase on the surface of the glass pool, which can have multiple adverse effects. For example, the presence of this low viscosity melt phase on the surface of the glass pool increases corrosion rates of the materials of construction (e.g., the off-gas system, refractories, and melter top head components). A sulfate concentration limit was implemented in the Product Composition Control System (PCCS) to avoid these issues. For Sludge Batch 1A, 1B, and Sludge Batch 2, the sulfate solubility limit was 0.4 wt % in glass.<sup>1,2</sup> However, because of the increased sulfate concentrations in Sludge Batch 3 (SB3) due to the addition of excess material streams from the canyons and desire for less sludge washing, testing was conducted to determine whether the sulfate solubility limit could be increased to minimize washing of SB3 while achieving the desired waste loading. Based on sealed-crucible studies and Slurry-fed Melt Rate Furnace (SMRF) runs, the limit was raised to 0.6 wt %  $\text{SO}_4^{2-}$  in glass specifically for SB3 with Frit 418.<sup>3</sup> Sludge Batch 4 (SB4),<sup>4</sup> Sludge Batch 5 (SB5),<sup>5</sup> Sludge Batch 6 (SB6),<sup>6</sup> and Sludge Batch 7a (SB7a)<sup>7</sup> were also examined on a batch by batch basis, and a 0.6 wt %  $\text{SO}_4^{2-}$  solubility limit in glass was recommended for each of these sludge batches. However, the sulfate limit in PCCS remains at 0.4 wt % in glass, and therefore any higher limit has to be confirmed for each new sludge batch. The current task was to determine a sulfate solubility limit in glass for the next sludge batch to be processed at DWPF, Sludge Batch 7b (SB7b), coupled with Frit 418 and Frit 702.

This study was performed in response to a Technical Task Request<sup>8</sup> and followed a Task Technical and Quality Assurance Plan.<sup>9</sup>

## 2.0 Experimental Procedure

### 2.1 SB7b Composition Projections

Sludge composition projections for SB7b were provided by Savannah River Remediation (SRR)<sup>a</sup> and were used as the basis for formulating glass compositions to determine the sulfate limit for SB7b. Table 2-1 provides the sludge composition projection from SRR, referred to as 5/25/11. This projection was identified by SRR as a bounding case for the SB7b blend with the Tank 40 SB7a heel remaining after an assumed processing rate of one Sludge Receipt and Adjustment Tank (SRAT) transfer every four days and a targeted SB7a waste loading (WL) of 40%. In other words, the 5/25/11 SB7b composition projection assumed that a smaller heel of SB7a would be present in Tank 40 at the time the SB7b batch from Tank 51 would be transferred into Tank 40 to constitute the SB7b blend. This is conservative from a sulfate concentration perspective since SB7b is projected to be higher in sulfate than is SB7a. The Savannah River National Laboratory (SRNL) calculated the compositional impact of the Actinide Removal Process (ARP) stream<sup>10</sup> to develop the additional projection shown in Table 2-1.

Additions of  $\text{Na}_2\text{O}$  to the projected sludge composition were made due to uncertainty in the final concentration of  $\text{Na}_2\text{O}$  for SB7b, which is dependent on washing effectiveness and the potential need to add NaOH to ensure an acceptable projected operating window. Additions of 4, 6, and 8

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<sup>a</sup> The SB7b composition projection was received via email from H. B. Shah on May 25, 2011. See SRNL-NB-2010-00108, page 134 for further detail.

wt % Na<sub>2</sub>O were made to the nominal 5/25/11 composition projection and the remaining components were normalized to give a total of 100 wt %, as shown in Table 2-1. ARP adjusted compositions were calculated for each of these additional projections.

Also included in Table 2-1 is a SB7b composition projection received from SRR near the end of the sulfate retention study.<sup>a</sup> This projection is labeled 8/4/11 and considered the analyzed composition of SB7a in Tank 40 (i.e., the Waste Acceptance Product Specification sample). The 8/4/11 projections with and without the addition of the ARP stream are very similar to the 5/25/11 projections with 4 wt % Na<sub>2</sub>O added. Note however that the projected sulfate concentration is considerably lower in the 8/4/11 projections. Given the overall compositional similarities and lower projected sulfate concentrations, no additional experimental work was considered to be necessary using the 8/4/11 compositions.

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<sup>a</sup> A revised SB7b composition projection was received via email from D. W. McIlmoyle on August 4, 2011. See SRNL-NB-2010-00108, page 164 for further detail.

**Table 2-1. Sludge Batch 7b Composition Projections used for the Sulfate Retention Study.**

Component (wt %)	5/25/11	5/25/11 w/ARP	5/25/11 +4*	5/25/11 +4 w/ARP	5/25/11 +6	5/25/11 +6 w/ ARP	5/25/11 +8	5/25/11 +8 w/ARP	8/4/11	8/4/11 w/ARP
<b>Al<sub>2</sub>O<sub>3</sub></b>	23.99	22.95	22.80	21.82	22.20	21.26	21.60	20.69	22.14	21.20
<b>BaO</b>	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.11	0.11
<b>CaO</b>	1.25	1.22	1.18	1.17	1.15	1.14	1.12	1.11	1.26	1.24
<b>Ce<sub>2</sub>O<sub>3</sub></b>	0.22	0.22	0.21	0.21	0.21	0.20	0.20	0.20	0.15	0.15
<b>Cr<sub>2</sub>O<sub>3</sub></b>	0.15	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.10	0.10
<b>CuO</b>	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.15	0.14
<b>Fe<sub>2</sub>O<sub>3</sub></b>	28.39	27.39	26.98	26.06	26.27	25.39	25.56	24.72	27.34	26.40
<b>K<sub>2</sub>O</b>	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.07	0.07
<b>MgO</b>	0.61	0.58	0.58	0.56	0.57	0.54	0.55	0.53	0.70	0.66
<b>MnO</b>	5.64	5.55	5.36	5.28	5.22	5.15	5.08	5.02	5.86	5.75
<b>Na<sub>2</sub>O</b>	19.62	20.49	23.62	24.26	25.62	26.15	27.62	28.04	23.16	23.83
<b>NiO</b>	4.80	4.59	4.56	4.37	4.44	4.26	4.32	4.14	4.64	4.45
<b>PbO</b>	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.01
<b>RuO<sub>2</sub></b>	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01
<b>SO<sub>4</sub><sup>2-</sup></b>	1.92	1.95	1.82	1.86	1.77	1.82	1.73	1.77	1.50	1.55
<b>SiO<sub>2</sub></b>	2.95	2.82	2.80	2.68	2.73	2.61	2.66	2.54	3.23	3.08
<b>ThO<sub>2</sub></b>	1.71	1.61	1.62	1.53	1.58	1.49	1.54	1.45	1.82	1.72
<b>TiO<sub>2</sub></b>	0.02	1.31	0.02	1.31	0.02	1.31	0.02	1.31	0.00	1.29
<b>U<sub>3</sub>O<sub>8</sub></b>	8.15	7.85	7.74	7.46	7.54	7.27	7.34	7.08	7.59	7.32
<b>ZnO</b>	0.02	0.03	0.02	0.03	0.02	0.03	0.02	0.02	0.00	0.00
<b>ZrO<sub>2</sub></b>	0.16	0.16	0.15	0.16	0.15	0.15	0.15	0.15	0.18	0.18
<b>Cl</b>	0.00	0.60	0.00	0.60	0.00	0.60	0.00	0.60	0.00	0.60
<b>F</b>	0.00	0.10	0.00	0.10	0.00	0.10	0.00	0.10	0.00	0.10
<b>I</b>	0.00	0.02	0.00	0.02	0.00	0.02	0.00	0.02	0.00	0.02
<b>Total</b>	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

\*Indicates addition of Na<sub>2</sub>O to the composition projection followed by normalization of the other components to 100 wt %. For example, +4 indicates a 4 wt % addition to the projected concentration of Na<sub>2</sub>O. ARP additions were calculated following the respective Na<sub>2</sub>O additions.

## 2.2 Glass Composition Selection

The sludge compositions in Table 2-1 based on the 5/25/11 projection were used to develop targeted glass compositions for the SB7b sulfate retention study. Waste loadings of 36 and 40% were considered to be of interest for DWPF processing of SB7b. Frit 418 was ultimately recommended for SB7b processing.<sup>11</sup> Frit 702 was initially recommended for SB7b because of the concern that a higher sulfate limit would be needed, and was later suggested as an alternative option to Frit 418 should sulfate concentrations in SB7b be found to be higher than anticipated.<sup>11</sup> Therefore, both Frit 418 and Frit 702 were included in this study. The nominal compositions of these frits are provided in Table 2-2.

**Table 2-2. Nominal Frit Compositions (wt %).**

<b>Frit ID</b>	<b>B<sub>2</sub>O<sub>3</sub></b>	<b>Li<sub>2</sub>O</b>	<b>Na<sub>2</sub>O</b>	<b>SiO<sub>2</sub></b>
<b>418</b>	8	8	8	76
<b>702</b>	8	10	6	76

Further review of Table 2-1 shows that the 5/25/11 projection with ARP added and no additional Na<sub>2</sub>O has the highest sulfate concentration at 1.95 wt %. This is equivalent to 0.78 wt % sulfate in glass at an assumed WL of 40% (assuming full retention in glass). The sulfate concentration in the 8/4/11 projection with ARP added is reduced to 1.55 wt %, or 0.62 wt % in glass at 40% WL. The targeted sulfate concentrations of the study glasses were therefore selected within the range of 0.6 to 0.9 wt %.

A total of 52 glass compositions were selected based on these variables (i.e., Na<sub>2</sub>O addition, ARP addition, WL, frit composition, and sulfate concentration), as displayed in Table 2-3. The sludge compositions were renormalized without ThO<sub>2</sub>, U<sub>3</sub>O<sub>8</sub>, and some of the very minor components<sup>a</sup> as the targeted glass compositions were determined. The targeted compositions for all of the study glasses are included as Table A-1 in Appendix A.

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<sup>a</sup> The targeted glass compositions also excluded RuO<sub>2</sub>, Cl, F, and I. The omission of these components is consistent with previous studies that established the 0.6 wt % sulfate limit for sludge processing and is not expected to impact the outcome of the study.

**Table 2-3. Selected Glass Compositions for the SB7b Sulfate Retention Study.**

Glass ID	Frit ID	WL (wt %)	Targeted SO <sub>4</sub> <sup>2-</sup> (wt %)	Na <sub>2</sub> O Addition (wt %)	ARP Addition
SF7b-A-05	702	36	0.80	4	No
SF7b-A-06	702	40	0.80	4	No
SF7b-A-07	702	36	0.80	4	Yes
SF7b-A-08	702	40	0.80	4	Yes
SF7b-A-09	418	36	0.80	6	No
SF7b-A-10	418	40	0.80	6	No
SF7b-A-11	418	36	0.80	6	Yes
SF7b-A-12	418	40	0.80	6	Yes
SF7b-A-13	418	36	0.80	4	No
SF7b-A-14	418	40	0.80	4	No
SF7b-A-15	418	36	0.80	4	Yes
SF7b-A-16	418	40	0.80	4	Yes
SF7b-B-01	702	36	0.90	4	No
SF7b-B-02	702	40	0.90	4	No
SF7b-B-03	702	36	0.90	4	Yes
SF7b-B-04	702	40	0.90	4	Yes
SF7b-B-05	418	36	0.70	4	No
SF7b-B-06	418	40	0.70	4	No
SF7b-B-07	418	36	0.70	4	Yes
SF7b-B-08	418	40	0.70	4	Yes
SF7b-B-09	418	36	0.70	6	No
SF7b-B-10	418	40	0.70	6	No
SF7b-B-11	418	36	0.70	6	Yes
SF7b-B-12	418	40	0.70	6	Yes
SF7b-B-13	702	36	0.90	6	No
SF7b-B-14	702	40	0.90	6	No
SF7b-B-15	702	36	0.90	6	Yes
SF7b-B-16	702	40	0.90	6	Yes
SF7b-C-01	702	36	0.80	6	No
SF7b-C-02	702	40	0.80	6	No
SF7b-C-03	702	36	0.80	6	Yes
SF7b-C-04	702	40	0.80	6	Yes
SF7b-C-05	702	36	0.80	8	No
SF7b-C-06	702	40	0.80	8	No
SF7b-C-07	702	36	0.80	8	Yes
SF7b-C-08	702	40	0.80	8	Yes
SF7b-C-09	702	36	0.90	8	No
SF7b-C-10	702	40	0.90	8	No
SF7b-C-11	702	36	0.90	8	Yes
SF7b-C-12	702	40	0.90	8	Yes
SF7b-C-13	418	36	0.80	8	No
SF7b-C-14	418	40	0.80	8	No
SF7b-C-15	418	36	0.80	8	Yes
SF7b-C-16	418	40	0.80	8	Yes
SF7b-D-01	418	36	0.60	4	No
SF7b-D-02	418	40	0.60	4	No
SF7b-D-03	418	36	0.60	4	Yes
SF7b-D-04	418	40	0.60	4	Yes
SF7b-D-05	418	36	0.90	8	No
SF7b-D-06	418	40	0.90	8	No
SF7b-D-07	418	36	0.90	8	Yes
SF7b-D-08	418	40	0.90	8	Yes

### 2.3 Glass Fabrication

Glasses were batched and melted following the SRNL procedures.<sup>12,13</sup> The glasses were prepared from the proper proportions of reagent grade oxides, carbonates, boric acid, and salts in 100 g batches. The raw materials were thoroughly mixed and placed into 95% platinum-5% gold, 300 ml crucibles and covered with loose fitting lids. The crucibles were placed into an electrically heated furnace at the target melt temperature of 1150 °C. After an isothermal hold at 1150 °C for one hour, the crucibles were removed from the furnace and quenched in shallow pans of water with the glass remaining in the crucible. Visual observations were recorded for each glass after it cooled and used as an indicator of sulfur retention. Specifically, the glasses in the cooled crucibles were examined for evidence of a yellow or white sulfur salt layer on the surface of the cooled glass, or the presence of undissolved batch, spinels, large crystals, etc. When a visible sulfate salt layer was visible on the surface of a cooled glass, it was assumed that the targeted sulfate concentration surpassed the solubility limit for that particular glass composition. If there was no visible evidence of a sulfur salt layer, the targeted sulfate concentration was concluded to have remained below the sulfur solubility limit for that particular glass composition. Visual observations were supported by chemical composition analyses, as described in the following section.

### 2.4 Chemical Analysis

Representative samples of each of the glasses fabricated were subjected to chemical analysis to determine whether the targeted composition was met as well as to determine the quantity of sulfate that was retained after melting. Lithium-metaborate (LM) fusions were used in order to fully digest the glass for measurement of sulfur concentrations. Each glass was prepared in duplicate and all of the digested samples were analyzed by Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES). The instrumentation was re-calibrated between the duplicate analyses.

## 3.0 Results and Discussion

Note that partial results of this study were provided previously in a memorandum to SRR.<sup>14</sup> The complete results of the study are discussed in the following sections.

### 3.1 Measured Compositions

The measured compositions of each of the study glasses are presented along with the targeted values and the associated percent error in Table A-2 of Appendix A. The measured values for each oxide are the averages of the two elemental measurements from ICP-AES multiplied by the appropriate gravimetric factors. Values that were reported as being below the instrument detection limit were taken as one half of that detection limit as the average values were calculated. A review of Table A-2 shows that, in general, there were only minor issues in meeting the targeted compositions for the study glasses. In particular, two discrepancies were noted based on a comparison of the targeted and measured compositions. First, several of the glasses had measured B<sub>2</sub>O<sub>3</sub> concentrations that were approximately 30% below the targeted values. These glasses are the SF7b-A series (see Table 2-3). The batch sheets and ICP-AES results for these glasses were reviewed a second time and no obvious cause for the low measured B<sub>2</sub>O<sub>3</sub> concentrations was found. Therefore, these glasses will be included in the discussions that follow in this section. As will be noted later, the errors in meeting the targeted B<sub>2</sub>O<sub>3</sub> concentrations for these glasses do not impact the outcome of the study for the glasses made with Frit 418, but do impact the results for the glasses made with Frit 702. Second, sulfur appears to have been omitted from one of the glass batches, as described below.

Table 3-1 provides the targeted and measured sulfate concentrations for each of the study glasses, along with the associated percent error. In general, the measured sulfate concentrations for each study glass were within 10% of the targeted values. Most of the measurements show a small loss of sulfate, which was likely due to both measurement error and minor volatility of sulfur. There are three glasses that exhibit further reduced sulfate concentrations. Glass SF7b-C-07 has a very low measured sulfate concentration, indicating that sulfur was unintentionally omitted from the batch for this glass. Glass SF7b-C-07 will therefore be omitted from further discussion. Two other glasses had differences between their targeted and measured sulfate concentrations that were larger relative to those of the rest of the study glasses. Glass SF7b-D-05 and glass SF7b-D-07 had measured sulfate concentrations that were about 25% and 37% below their targeted values, respectively. These two glasses will be included in the discussion below and their reduced sulfate concentrations will be noted.



**Table 3-1. Targeted and Measured Sulfate Concentrations of the Study Glasses.**

Glass ID	Frit ID	WL	Na <sub>2</sub> O Addition (wt %)	ARP Addition	Targeted SO <sub>4</sub> <sup>2-</sup> (wt %)	Measured SO <sub>4</sub> <sup>2-</sup> (wt %)	Percent Error
SF7b-A-05	702	36	4	No	0.80	0.785	-1.9
SF7b-A-06	702	40	4	No	0.80	0.800	0.0
SF7b-A-07	702	36	4	Yes	0.80	0.782	-2.3
SF7b-A-08	702	40	4	Yes	0.80	0.783	-2.1
SF7b-A-09	418	36	6	No	0.80	0.816	2.0
SF7b-A-10	418	40	6	No	0.80	0.809	1.1
SF7b-A-11	418	36	6	Yes	0.80	0.749	-6.4
SF7b-A-12	418	40	6	Yes	0.80	0.753	-5.8
SF7b-A-13	418	36	4	No	0.80	0.718	-10.3
SF7b-A-14	418	40	4	No	0.80	0.724	-9.6
SF7b-A-15	418	36	4	Yes	0.80	0.719	-10.1
SF7b-A-16	418	40	4	Yes	0.80	0.743	-7.1
SF7b-B-01	702	36	4	No	0.90	0.814	-9.6
SF7b-B-02	702	40	4	No	0.90	0.841	-6.5
SF7b-B-03	702	36	4	Yes	0.90	0.864	-4.0
SF7b-B-04	702	40	4	Yes	0.90	0.845	-6.1
SF7b-B-05	418	36	4	No	0.70	0.689	-1.6
SF7b-B-06	418	40	4	No	0.70	0.686	-1.9
SF7b-B-07	418	36	4	Yes	0.70	0.684	-2.3
SF7b-B-08	418	40	4	Yes	0.70	0.684	-2.2
SF7b-B-09	418	36	6	No	0.70	0.694	-0.9
SF7b-B-10	418	40	6	No	0.70	0.728	3.9
SF7b-B-11	418	36	6	Yes	0.70	0.685	-2.2
SF7b-B-12	418	40	6	Yes	0.70	0.705	0.7
SF7b-B-13	702	36	6	No	0.90	0.867	-3.7
SF7b-B-14	702	40	6	No	0.90	0.867	-3.7
SF7b-B-15	702	36	6	Yes	0.90	0.856	-4.9
SF7b-B-16	702	40	6	Yes	0.90	0.870	-3.4
SF7b-C-01	702	36	6	No	0.80	0.772	-3.5
SF7b-C-02	702	40	6	No	0.80	0.862	7.7
SF7b-C-03	702	36	6	Yes	0.80	0.797	-0.4
SF7b-C-04	702	40	6	Yes	0.80	0.779	-2.7
SF7b-C-05	702	36	8	No	0.80	0.797	-0.4
SF7b-C-06	702	40	8	No	0.80	0.745	-6.9
SF7b-C-07	702	36	8	Yes	0.80	0.042	-94.7
SF7b-C-08	702	40	8	Yes	0.80	0.761	-4.8
SF7b-C-09	702	36	8	No	0.90	0.844	-6.2
SF7b-C-10	702	40	8	No	0.90	0.907	0.8
SF7b-C-11	702	36	8	Yes	0.90	0.929	3.2
SF7b-C-12	702	40	8	Yes	0.90	0.918	2.0
SF7b-C-13	418	36	8	No	0.80	0.845	5.6
SF7b-C-14	418	40	8	No	0.80	0.815	1.9
SF7b-C-15	418	36	8	Yes	0.80	0.810	1.3
SF7b-C-16	418	40	8	Yes	0.80	0.819	2.3
SF7b-D-01	418	36	4	No	0.60	0.553	-7.8
SF7b-D-02	418	40	4	No	0.60	0.589	-1.9

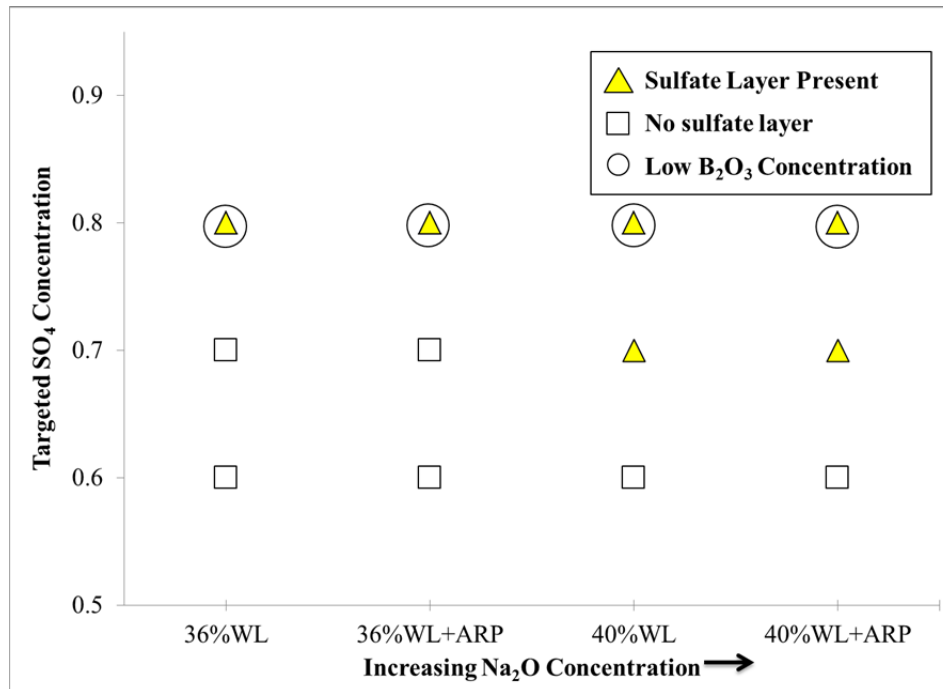
**Table 3-1. Targeted and Measured Sulfate Concentrations of the Study Glasses.  
(continued)**

Glass ID	Frit ID	WL	Na <sub>2</sub> O Addition (wt %)	ARP Addition	Targeted SO <sub>4</sub> <sup>2-</sup> (wt %)	Measured SO <sub>4</sub> <sup>2-</sup> (wt %)	Percent Error
SF7b-D-03	418	36	4	Yes	0.60	0.571	-4.8
SF7b-D-04	418	40	4	Yes	0.60	0.583	-2.8
SF7b-D-05	418	36	8	No	0.90	0.678	-24.7
SF7b-D-06	418	40	8	No	0.90	0.828	-8.0
SF7b-D-07	418	36	8	Yes	0.90	0.572	-36.5
SF7b-D-08	418	40	8	Yes	0.90	0.840	-6.7

### 3.2 Sulfate Retention

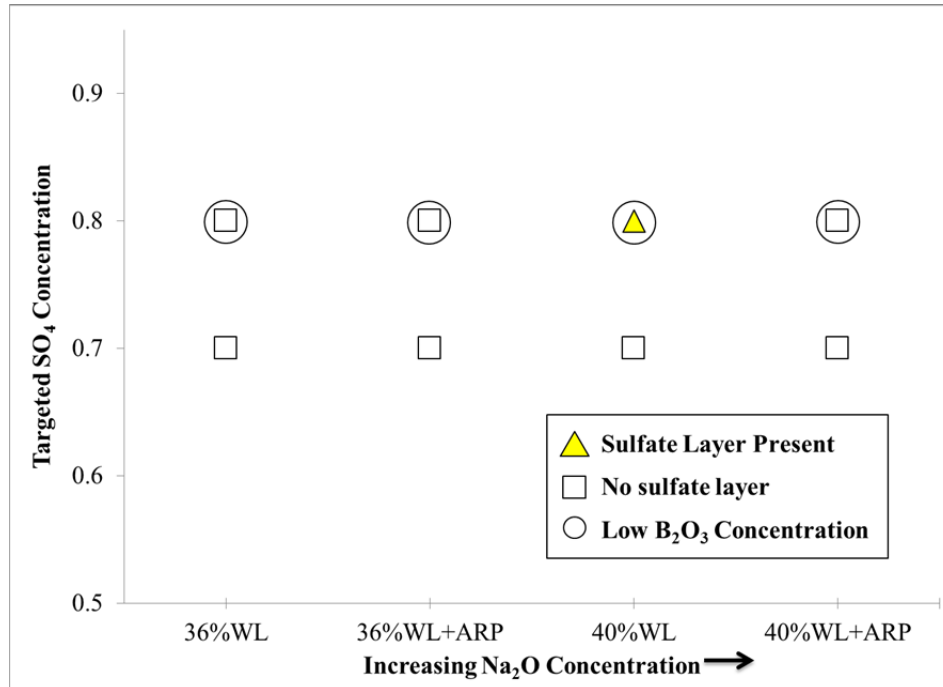
#### 3.2.1 Frit 418 Glasses

Sulfate retention results for the glasses fabricated with Frit 418 will be discussed first since Frit 418 was ultimately recommended for SB7b processing.<sup>11</sup> The results for the SB7b sulfate study glasses with Frit 418 and the 5/25/11 projection with a 4 wt % Na<sub>2</sub>O addition are shown graphically in Figure 3-1. The glass compositions are arranged by targeted sulfate concentration along the vertical axis and by both waste loading and ARP addition along the horizontal axis. By arranging the horizontal axis in this manner, the Na<sub>2</sub>O concentration within the glasses increases from left to right for each targeted concentration of sulfate. A review of Figure 3-1 shows that no sulfate layer was observed on the surfaces of any of the glasses that targeted 0.6 wt % sulfate. Two of the glasses, those fabricated at 40% WL with and without the addition of ARP, had sulfate layers present at targeted sulfate concentrations of 0.7 wt %. All of the glasses fabricated at a targeted sulfate concentration of 0.8 wt % had a sulfate layer present. Note that these four glasses are part of the group mentioned earlier that have B<sub>2</sub>O<sub>3</sub> concentrations that are about 30% lower than the targeted values. Based on the data shown in Figure 3-1 (i.e., the lack of a sulfate layer on any of the glasses that targeted 0.6 wt % sulfate and the presence of a sulfate layer on some of the glasses that targeted 0.7 wt % sulfate), the sulfate retention limit for this particular series of compositions is 0.6 wt %, and therefore the issue with B<sub>2</sub>O<sub>3</sub> concentrations in the glasses targeting 0.8 wt % sulfate do not impact the results.



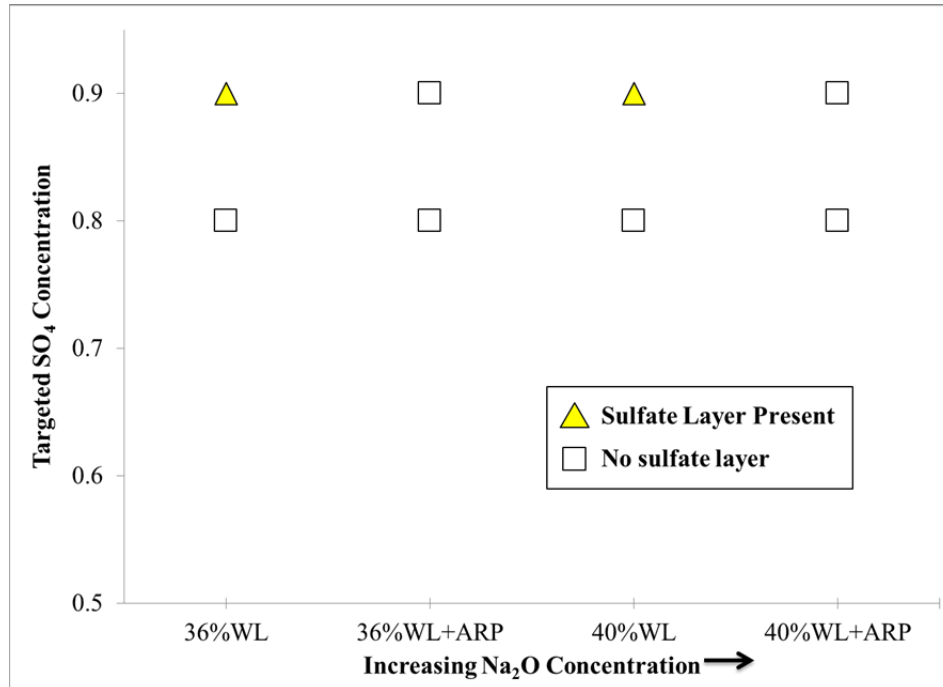
**Figure 3-1. Results of the Sulfate Study Glasses with Frit 418 and the 5/25/11 SB7b Projection with 4 wt % Na<sub>2</sub>O Added.**

The results for the SB7b sulfate study glasses with Frit 418 and the 5/25/11 projection with a 6 wt % Na<sub>2</sub>O addition are shown graphically in Figure 3-2. No sulfate layer was present on the glasses in this system with targeted sulfate concentrations of 0.7 wt %. The glasses that targeted 0.8 wt % sulfate in this system are part of the group with low B<sub>2</sub>O<sub>3</sub> concentrations. One of these glasses, which targeted 40% WL, had a visible sulfate layer. A comparison of the results in Figure 3-2 with those in Figure 3-1 shows that the sulfate retention for Frit 418 increased to 0.7 wt % when the sodium addition to the 5/25/11 SB7b projection was increased from 4 wt % to 6 wt %.



**Figure 3-2. Results of the Sulfate Study Glasses with Frit 418 and the 5/25/11 SB7b Projection with 6 wt %  $\text{Na}_2\text{O}$  Added.**

The results for the SB7b sulfate study glasses with Frit 418 and the 5/25/11 projection with an 8 wt %  $\text{Na}_2\text{O}$  addition are shown graphically in Figure 3-3. In this system, no visible sulfate layer was present on any of the glasses that targeted 0.8 wt % sulfate. At a targeted sulfate concentration of 0.9 wt %, the glasses that targeted 36% and 40% WL without the ARP addition had visible sulfate layers. Note also that, as described earlier, the two glasses that targeted 0.9 wt % sulfate and 36% WL with and without ARP have less sulfate than targeted (see glasses SF7b-D-05 and SF7b-D-07 in Table 3-1). Regardless of this issue, the sulfate retention limit for this system is 0.8 wt % based on the data shown in Figure 3-1.



**Figure 3-3. Results of the Sulfate Study Glasses with Frit 418 and the 5/25/11 SB7b Projection with 8 wt % Na<sub>2</sub>O Added.**

The data for the SB7b glasses fabricated with Frit 418 show an apparent trend of increasing sulfate retention with increasing Na<sub>2</sub>O additions to the 5/25/11 projection. For this system, no sulfate layer was observed on the glasses:

- that targeted 0.6 wt % sulfate with a 4 wt % Na<sub>2</sub>O addition,
- that targeted 0.7 wt % sulfate with a 6 wt % Na<sub>2</sub>O addition, and
- that targeted 0.8 wt % sulfate with an 8 wt % Na<sub>2</sub>O addition.

This trend appears contradictory to other recent studies of sulfate retention in DWPF type glasses.<sup>15</sup> Additional apparent contradictions to this trend can be found in further review of the data presented here. For example, refer to the results in Figure 3-1 for the glasses that targeted 0.7 wt % sulfate. The glasses that targeted 36% WL with and without ARP had no visible sulfate layer. However, the glasses that targeted 40% WL with and without ARP (i.e., those that targeted higher Na<sub>2</sub>O concentrations at the same targeted sulfate concentration<sup>a</sup>) had visible sulfate layers.

Overall, the results for the SB7b sulfate study glasses with Frit 418 and the 5/25/11 projection with Na<sub>2</sub>O additions show that subtle changes in this complex glass composition impacted the degree of sulfate retention. There doesn't appear to be a way to isolate and identify any particular component of the glass that was responsible for driving sulfate retention, at least using the methodology selected for this study. It may be that the nature of the method used in this study (visual analysis of glass compositions that are at or near the sulfur solubility limit) does not provide sufficient sensitivity. SRNL is currently evaluating alternative methodologies that may provide more insight into the mechanisms of sulfate retention in DWPF glasses. These results do

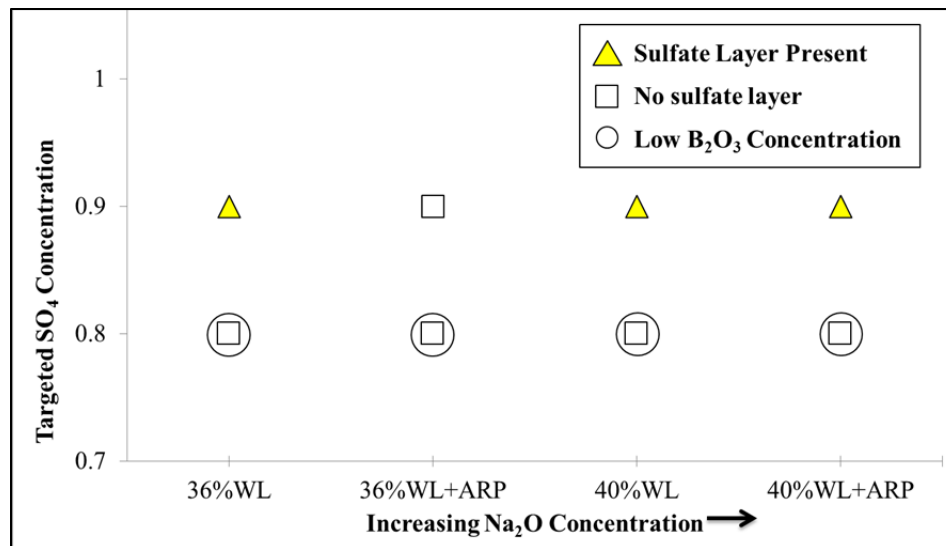
<sup>a</sup> A review of the measured composition data for these glasses shows that the trends in targeted Na<sub>2</sub>O concentrations are the same for the measured values. See Table A-2 in Appendix A.

however provide confidence that a 0.6 wt % sulfate limit in glass is warranted for Frit 418 with the SB7b compositions tested.

### 3.2.2 Frit 702 Glasses

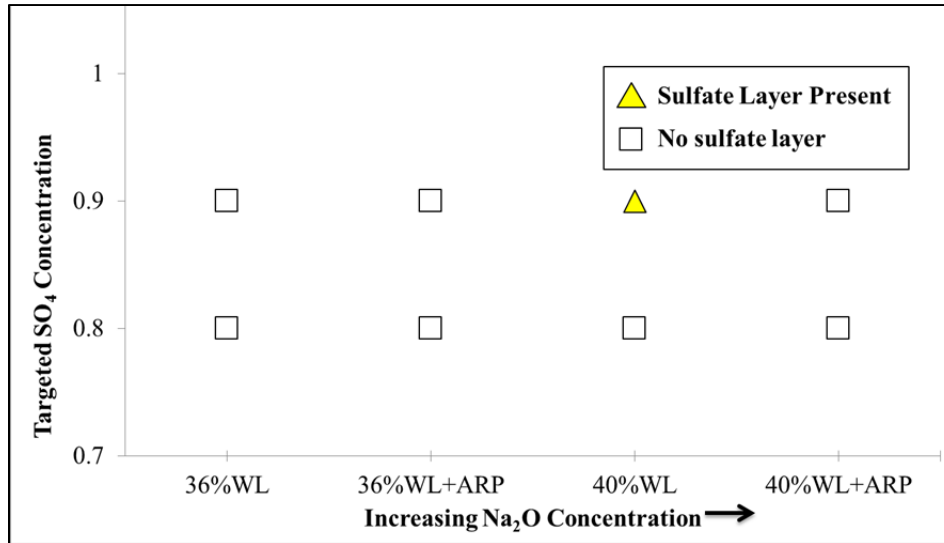
Frit 702 was included in this study since it was suggested as a candidate for SB7b processing should higher than projected sulfate concentrations (i.e., higher than those of the 8/4/11 projection) be realized.<sup>11</sup> The sulfate concentrations of the 5/25/11 SB7b projections (Table 2-1) would have necessitated the use of Frit 702.

The results for the SB7b sulfate study glasses with Frit 702 and the 5/25/11 projection with a 4 wt % Na<sub>2</sub>O addition are shown graphically in Figure 3-4. No visible sulfate layer was present on the glasses that targeted 0.8 wt % sulfate. All but one of the glasses that targeted 0.9 wt % sulfate had visible sulfate layers. Note however that the glasses that targeted 0.8 wt % sulfate are part of the group with low B<sub>2</sub>O<sub>3</sub> concentrations. It is difficult to draw further conclusions from this system of glass compositions because of the issues with B<sub>2</sub>O<sub>3</sub> concentrations.



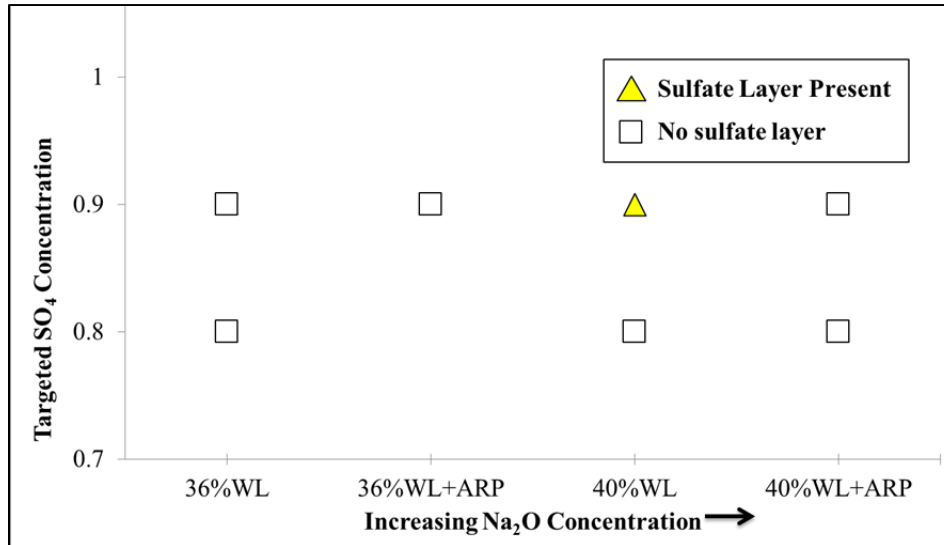
**Figure 3-4. Results of the Sulfate Study Glasses with Frit 702 and the 5/25/11 SB7b Projection with 4 wt % Na<sub>2</sub>O Added.**

The results for the SB7b sulfate study glasses with Frit 702 and the 5/25/11 projection with a 6 wt % Na<sub>2</sub>O addition are shown graphically in Figure 3-5. No visible sulfate layer was present on the glasses that targeted 0.8 wt % sulfate. Of the glasses that targeted 0.9 wt % sulfate, only the glass that targeted 40% WL (without ARP) had a visible sulfate layer. For this system, the sulfate limit would be 0.8 wt %, which is higher than that for the same SB7b composition with Frit 418 (see Figure 3-2, where the sulfate limit is 0.7 wt %). These results are consistent with those of the SB7a study<sup>7</sup> in that Frit 702 allowed for higher sulfate retention as compared to Frit 418 for the same sludge compositions. However, this also contradicts the apparent trend noted earlier in the present study of increasing Na<sub>2</sub>O concentrations being beneficial for sulfate retention, since Frit 702 has a lower Na<sub>2</sub>O concentration than Frit 418. Again, these results show that subtle changes in this complex glass composition impact the degree of sulfate retention.



**Figure 3-5. Results of the Sulfate Study Glasses with Frit 702 and the 5/25/11 SB7b Projection with 6 wt % Na<sub>2</sub>O Added.**

The results for the SB7b sulfate study glasses with Frit 702 and the 5/25/11 projection with an 8 wt % Na<sub>2</sub>O addition are shown graphically in Figure 3-6. No visible sulfate layer was present on the glasses that targeted 0.8 wt % sulfate. Note that a data point is not shown for a targeted sulfate concentration of 0.8 wt % at 36% WL with ARP added. This composition was targeted by glass SF7b-C-07. The measured composition data for this glass showed that sulfur was omitted from the batch; therefore, this glass is not included in Figure 3-6 (refer to Section 3.1 and Table 3-1). Of the glasses that targeted 0.9 wt % sulfate, only the glass that targeted 40% WL (without ARP) had a visible sulfate layer. These results are very similar to those shown in Figure 3-5 for Frit 702, and are also similar to those shown in Figure 3-3 for Frit 418. In all three cases, the sulfate retention for the Frit 702 systems is 0.8 wt %. In general, a sulfate limit of 0.8 wt % appears to be warranted for Frit 702 with the SB7b compositions studied. Additional glasses should be fabricated to confirm this limit, due to the issues with incorrect B<sub>2</sub>O<sub>3</sub> concentrations for some of the study glasses, should it become necessary to employ Frit 702 for DWPF processing of SB7b.



**Figure 3-6. Results of the Sulfate Study Glasses with Frit 702 and the 5/25/11 SB7b Projection with 8 wt % Na<sub>2</sub>O Added.**

#### 4.0 Summary

The objective of this study was to determine a sulfate solubility limit in glass for SB7b. The SB7b composition projection provided by SRR on May 25, 2011 was used as the basis for formulating glass compositions to determine the sulfate limit. Additions of Na<sub>2</sub>O to the projected sludge composition were made by SRNL due to uncertainty in the final concentration of Na<sub>2</sub>O for SB7b, which is dependent on washing effectiveness and the potential need to add NaOH to ensure an acceptable projected operating window. Additions of 4, 6, and 8 wt % Na<sub>2</sub>O were made to the nominal 5/25/11 composition projection. SRNL calculated the impact of the addition of the ARP stream for the 5/25/11 SB7b projection as well as for each composition with Na<sub>2</sub>O added. An updated SB7b composition projection was received from SRR on August 4, 2011. The 8/4/11 projections with and without the addition of the ARP stream are very similar to the 5/25/11 projections with 4 wt % Na<sub>2</sub>O added. Note however that the projected sulfate concentration is considerably lower in the 8/4/11 projections. Therefore, no additional experimental work using the 8/4/11 compositions was considered to be necessary for this study.

Waste loadings of 36 and 40% were considered to be of interest for DWPF processing of SB7b. Both Frit 418 and Frit 702 were included in this study. Frit 418 was ultimately recommended for SB7b processing. Frit 702 was suggested as an option should sulfate concentrations in SB7b be found to be higher than anticipated. The targeted sulfate concentrations of the study glasses were chosen within the range of 0.6 to 0.9 wt %. A total of 52 glass compositions were selected based on these variables (i.e., Na<sub>2</sub>O addition, ARP addition, WL, frit composition, and sulfate concentration).

The glasses were batched, melted, and characterized following SRNL procedures. Visual observations were recorded for each glass after it cooled and used as an indicator of sulfur retention. Representative samples of each of the glasses fabricated were subjected to chemical analysis to determine whether the targeted compositions were met, as well as to determine the quantity of sulfate that was retained after melting. In general, the measured composition data show that there were only minor issues in meeting the targeted compositions for the study glasses.



In particular, some of the glasses had measured  $B_2O_3$  concentrations that were approximately 30% below the targeted values. The errors in meeting the targeted  $B_2O_3$  concentrations for these glasses were found not to impact the outcome of the study for the glasses made with Frit 418, although they necessitate further experiments in order to establish a sulfate limit for Frit 702. In general, the measured sulfate concentrations for each study glass were within 10% of the targeted values. Most of the measurements showed a small loss of sulfate, which was likely due to both measurement error and minor volatility of sulfur. Glass SF7b-C-07 had a very low measured sulfate concentration, indicating that sulfur was unintentionally omitted from the batch for this glass. Glass SF7b-C-07 was therefore omitted from discussion. Two other glasses had differences between their targeted and measured sulfate concentrations that were larger relative to those of the rest of the study glasses. Glass SF7b-D-05 and glass SF7b-D-07 had measured sulfate concentrations that were about 25% and 37% below their targeted values, respectively. This result is not unexpected, since these glasses targeted sulfate concentrations of 0.9 wt % and sulfur volatility is more likely at increasing concentrations.

The results for the SB7b glasses fabricated with Frit 418 showed an apparent trend of increasing sulfate retention with increasing  $Na_2O$  additions to the 5/25/11 projection. This trend appears contradictory to other recent studies of sulfate retention in DWPF type glasses. Additional apparent contradictions to this trend can be found in the data collected in the present study. For example, the glasses made with Frit 418 that targeted 36% WL had no visible sulfate layer, while the glasses that targeted 40% WL for the same sludge compositions (i.e., those that targeted higher  $Na_2O$  concentrations at the same targeted sulfate concentration) did have visible sulfate layers. Overall, the results for the SB7b sulfate study glasses with Frit 418 and the 5/25/11 projection with  $Na_2O$  additions show that subtle changes in this complex glass composition impact the degree of sulfate retention. There doesn't appear to be a way to isolate and identify any particular component of the glass that is responsible for driving sulfate retention, at least using the methodology selected for this study. It may be that the nature of the method used in this study (visual analysis of glass compositions that are at or near the sulfur solubility limit) does not provide sufficient sensitivity. SRNL is currently evaluating alternative methodologies that may provide more insight into the mechanisms of sulfate retention in DWPF glasses. These results do however provide confidence that a 0.6 wt % sulfate limit in glass is warranted for Frit 418 with the SB7b compositions evaluated in this study.

The results for the SB7b glasses fabricated with Frit 702 were consistent with those of the previous SB7a study in that Frit 702 allowed for higher sulfate retention as compared to Frit 418 for the same sludge compositions. However, this also contradicts the apparent trend noted earlier in the present study of increasing  $Na_2O$  concentrations being beneficial for sulfate retention, since Frit 702 has a lower  $Na_2O$  concentration than Frit 418. Again, these results showed that subtle changes in this complex glass composition impact the degree of sulfate retention. In general, a sulfate limit of 0.8 wt % appears to be warranted for Frit 702 with the SB7b compositions evaluated in this study.

## 5.0 Recommendations

It is recommended that the DWPF implement a sulfate concentration limit of 0.6 wt % in glass for SB7b processing with Frit 418. If a higher than projected sulfate concentration is measured when SB7b processing begins (i.e., if a sulfate concentration higher than 0.6 wt % in glass becomes necessary to achieve targeted waste loadings), DWPF should consider a transition to Frit 702. The sulfate limit could likely be raised to 0.8 wt % by transitioning to this frit. Additional glasses should be fabricated to confirm this limit, due to the issues with incorrect  $B_2O_3$  concentrations for

some of the glasses made with Frit 702 in this study. There are several factors other than sulfate retention that must also be carefully considered prior to changing frit compositions.

## 6.0 References

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**Appendix A. Targeted and Measured Composition Data  
for the SB7b Sulfate Retention Study Glasses.**

**Table A-1. Targeted Compositions (wt %) of the SB7b Sulfate Retention Study Glasses.**

Glass ID	Al <sub>2</sub> O <sub>3</sub>	B <sub>2</sub> O <sub>3</sub>	BaO	CaO	Ca <sub>2</sub> O <sub>3</sub>	Cr <sub>2</sub> O <sub>3</sub>	CuO	Fe <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	La <sub>2</sub> O <sub>3</sub>	Li <sub>2</sub> O	MgO	MnO	Na <sub>2</sub> O	NiO	PbO	SO <sub>4</sub>	SiO <sub>2</sub>	TiO <sub>2</sub>	ZnO	ZrO <sub>2</sub>
SF7b-A-05	9.04	5.12	0.04	0.47	0.08	0.06	0.02	10.69	0.06	0.01	6.40	0.23	2.12	13.20	1.81	0.01	0.80	49.75	0.01	0.01	0.06
SF7b-A-06	10.06	4.80	0.05	0.52	0.09	0.06	0.03	11.91	0.07	0.01	6.00	0.26	2.37	14.03	2.01	0.01	0.80	46.84	0.01	0.01	0.07
SF7b-A-07	8.69	5.12	0.04	0.46	0.08	0.05	0.02	10.37	0.06	0.01	6.40	0.22	2.10	13.50	1.74	0.01	0.80	49.71	0.52	0.01	0.06
SF7b-A-08	9.68	4.80	0.05	0.52	0.09	0.06	0.03	11.55	0.06	0.02	6.00	0.25	2.34	14.36	1.94	0.02	0.80	46.79	0.58	0.01	0.07
SF7b-A-09	8.77	5.12	0.04	0.46	0.08	0.05	0.02	10.38	0.06	0.01	5.12	0.22	2.06	15.24	1.75	0.01	0.80	49.72	0.01	0.01	0.06
SF7b-A-10	9.77	4.80	0.05	0.51	0.09	0.06	0.03	11.56	0.06	0.01	4.80	0.25	2.30	16.07	1.95	0.01	0.80	46.80	0.01	0.01	0.07
SF7b-A-11	8.44	5.12	0.04	0.45	0.08	0.05	0.02	10.08	0.06	0.01	5.12	0.21	2.04	15.50	1.69	0.01	0.80	49.68	0.52	0.01	0.06
SF7b-A-12	9.40	4.80	0.04	0.50	0.09	0.06	0.03	11.22	0.06	0.02	4.80	0.24	2.28	16.36	1.88	0.02	0.80	46.75	0.58	0.01	0.07
SF7b-A-13	9.04	5.12	0.04	0.47	0.08	0.06	0.02	10.69	0.06	0.01	5.12	0.23	2.12	14.48	1.81	0.01	0.80	49.75	0.01	0.01	0.06
SF7b-A-14	10.06	4.80	0.05	0.52	0.09	0.06	0.03	11.91	0.07	0.01	4.80	0.26	2.37	15.23	2.01	0.01	0.80	46.84	0.01	0.01	0.07
SF7b-A-15	8.69	5.12	0.04	0.46	0.08	0.05	0.02	10.37	0.06	0.01	5.12	0.22	2.10	14.78	1.74	0.01	0.80	49.71	0.52	0.01	0.06
SF7b-A-16	9.68	4.80	0.05	0.52	0.09	0.06	0.03	11.55	0.06	0.02	4.80	0.25	2.34	15.56	1.94	0.02	0.80	46.79	0.58	0.01	0.07
SF7b-B-01	9.01	5.12	0.04	0.47	0.08	0.05	0.02	10.66	0.06	0.01	6.40	0.23	2.12	13.18	1.80	0.01	0.90	49.75	0.01	0.01	0.06
SF7b-B-02	10.04	4.80	0.05	0.52	0.09	0.06	0.03	11.88	0.07	0.01	6.00	0.26	2.36	14.00	2.01	0.01	0.90	46.83	0.01	0.01	0.07
SF7b-B-03	8.66	5.12	0.04	0.46	0.08	0.05	0.02	10.35	0.06	0.01	6.40	0.22	2.10	13.47	1.73	0.01	0.90	49.70	0.52	0.01	0.06
SF7b-B-04	9.65	4.80	0.05	0.52	0.09	0.06	0.03	11.52	0.06	0.02	6.00	0.25	2.34	14.33	1.93	0.02	0.90	46.79	0.58	0.01	0.07
SF7b-B-05	9.06	5.12	0.04	0.47	0.08	0.06	0.02	10.72	0.06	0.01	5.12	0.23	2.13	14.51	1.81	0.01	0.70	49.75	0.01	0.01	0.06
SF7b-B-06	10.09	4.80	0.05	0.52	0.09	0.06	0.03	11.94	0.07	0.01	4.80	0.26	2.37	15.25	2.02	0.01	0.70	46.84	0.01	0.01	0.07
SF7b-B-07	8.71	5.12	0.04	0.47	0.08	0.05	0.02	10.40	0.06	0.01	5.12	0.22	2.11	14.81	1.74	0.01	0.70	49.71	0.52	0.01	0.06
SF7b-B-08	9.70	4.80	0.05	0.52	0.09	0.06	0.03	11.58	0.06	0.02	4.80	0.25	2.35	15.59	1.94	0.02	0.70	46.79	0.58	0.01	0.07
SF7b-B-09	8.80	5.12	0.04	0.46	0.08	0.05	0.02	10.41	0.06	0.01	5.12	0.22	2.07	15.27	1.76	0.01	0.70	49.72	0.01	0.01	0.06
SF7b-B-10	9.79	4.80	0.05	0.51	0.09	0.06	0.03	11.59	0.06	0.01	4.80	0.25	2.30	16.10	1.96	0.01	0.70	46.80	0.01	0.01	0.07
SF7b-B-11	8.46	5.12	0.04	0.45	0.08	0.05	0.02	10.11	0.06	0.01	5.12	0.22	2.05	15.53	1.69	0.01	0.70	49.68	0.52	0.01	0.06
SF7b-B-12	9.42	4.80	0.05	0.50	0.09	0.06	0.03	11.25	0.06	0.02	4.80	0.24	2.28	16.39	1.89	0.02	0.70	46.76	0.58	0.01	0.07
SF7b-B-13	8.75	5.12	0.04	0.45	0.08	0.05	0.02	10.35	0.06	0.01	6.40	0.22	2.06	13.93	1.75	0.01	0.90	49.72	0.01	0.01	0.06
SF7b-B-14	9.74	4.80	0.05	0.51	0.09	0.06	0.03	11.53	0.06	0.01	6.00	0.25	2.29	14.84	1.95	0.01	0.90	46.80	0.01	0.01	0.07
SF7b-B-15	8.41	5.12	0.04	0.45	0.08	0.05	0.02	10.05	0.06	0.01	6.40	0.21	2.04	14.19	1.68	0.01	0.90	49.67	0.52	0.01	0.06
SF7b-B-16	9.37	4.80	0.04	0.50	0.09	0.06	0.03	11.19	0.06	0.01	6.00	0.24	2.27	15.13	1.88	0.02	0.90	46.75	0.58	0.01	0.07
SF7b-C-01	8.77	5.12	0.04	0.46	0.08	0.05	0.02	10.38	0.06	0.01	6.40	0.22	2.06	13.96	1.75	0.01	0.80	49.72	0.01	0.01	0.06
SF7b-C-02	9.77	4.80	0.05	0.51	0.09	0.06	0.03	11.56	0.06	0.01	6.00	0.25	2.30	14.87	1.95	0.01	0.80	46.80	0.01	0.01	0.07
SF7b-C-03	8.44	5.12	0.04	0.45	0.08	0.05	0.02	10.08	0.06	0.01	6.40	0.21	2.04	14.22	1.69	0.01	0.80	49.68	0.52	0.01	0.06
SF7b-C-04	9.40	4.80	0.04	0.50	0.09	0.06	0.03	11.22	0.06	0.02	6.00	0.24	2.28	15.16	1.88	0.02	0.80	46.75	0.58	0.01	0.07
SF7b-C-05	8.51	5.12	0.04	0.44	0.08	0.05	0.02	10.07	0.06	0.01	6.40	0.22	2.00	14.72	1.70	0.01	0.80	49.69	0.01	0.01	0.06
SF7b-C-06	9.47	4.80	0.04	0.49	0.09	0.06	0.02	11.21	0.06	0.01	6.00	0.24	2.23	15.71	1.89	0.01	0.80	46.77	0.01	0.01	0.06
SF7b-C-07	8.19	5.12	0.04	0.44	0.08	0.05	0.02	9.78	0.05	0.01	6.40	0.21	1.99	14.93	1.64	0.01	0.80	49.65	0.52	0.01	0.06
SF7b-C-08	9.12	4.80	0.04	0.49	0.09	0.06	0.02	10.89	0.06	0.01	6.00	0.23	2.21	15.95	1.83	0.01	0.80	46.72	0.58	0.01	0.07
SF7b-C-09	8.48	5.12	0.04	0.44	0.08	0.05	0.02	10.04	0.06	0.01	6.40	0.22	1.99	14.69	1.70	0.01	0.90	49.68	0.01	0.01	0.06

**Table A-1. Targeted Compositions (wt %) of the SB7b Sulfate Retention Study Glasses. (continued)**

Glass ID	Al <sub>2</sub> O <sub>3</sub>	B <sub>2</sub> O <sub>3</sub>	BaO	CaO	Ce <sub>2</sub> O <sub>3</sub>	Cr <sub>2</sub> O <sub>3</sub>	CuO	Fe <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	La <sub>2</sub> O <sub>3</sub>	Li <sub>2</sub> O	MgO	MnO	Na <sub>2</sub> O	NiO	PbO	SO <sub>4</sub>	SiO <sub>2</sub>	TiO <sub>2</sub>	ZnO	ZrO <sub>2</sub>
SF7b-C-10	9.45	4.80	0.04	0.49	0.09	0.06	0.02	11.18	0.06	0.01	6.00	0.24	2.22	15.68	1.89	0.01	0.90	46.76	0.01	0.01	0.06
SF7b-C-11	8.17	5.12	0.04	0.44	0.08	0.05	0.02	9.76	0.05	0.01	6.40	0.21	1.98	14.90	1.63	0.01	0.90	49.64	0.52	0.01	0.06
SF7b-C-12	9.10	4.80	0.04	0.49	0.09	0.06	0.02	10.87	0.06	0.01	6.00	0.23	2.21	15.92	1.82	0.01	0.90	46.72	0.57	0.01	0.06
SF7b-C-13	8.51	5.12	0.04	0.44	0.08	0.05	0.02	10.07	0.06	0.01	5.12	0.22	2.00	16.00	1.70	0.01	0.80	49.69	0.01	0.01	0.06
SF7b-C-14	9.47	4.80	0.04	0.49	0.09	0.06	0.02	11.21	0.06	0.01	4.80	0.24	2.23	16.91	1.89	0.01	0.80	46.77	0.01	0.01	0.06
SF7b-C-15	8.19	5.12	0.04	0.44	0.08	0.05	0.02	9.78	0.05	0.01	5.12	0.21	1.99	16.21	1.64	0.01	0.80	49.65	0.52	0.01	0.06
SF7b-C-16	9.12	4.80	0.04	0.49	0.09	0.06	0.02	10.89	0.06	0.01	4.80	0.23	2.21	17.15	1.83	0.01	0.80	46.72	0.58	0.01	0.07
SF7b-D-01	9.09	5.12	0.04	0.47	0.08	0.06	0.02	10.75	0.06	0.01	5.12	0.23	2.14	14.54	1.82	0.01	0.60	49.76	0.01	0.01	0.06
SF7b-D-02	10.11	4.80	0.05	0.52	0.09	0.06	0.03	11.97	0.07	0.01	4.80	0.26	2.38	15.28	2.02	0.01	0.60	46.84	0.01	0.01	0.07
SF7b-D-03	8.74	5.12	0.04	0.47	0.08	0.05	0.02	10.43	0.06	0.01	5.12	0.22	2.12	14.84	1.75	0.01	0.60	49.71	0.52	0.01	0.06
SF7b-D-04	9.73	4.80	0.05	0.52	0.09	0.06	0.03	11.61	0.07	0.02	4.80	0.25	2.35	15.61	1.95	0.02	0.60	46.79	0.58	0.01	0.07
SF7b-D-05	8.48	5.12	0.04	0.44	0.08	0.05	0.02	10.04	0.06	0.01	5.12	0.22	1.99	15.97	1.70	0.01	0.90	49.68	0.01	0.01	0.06
SF7b-D-06	9.45	4.80	0.04	0.49	0.09	0.06	0.02	11.18	0.06	0.01	4.80	0.24	2.22	16.88	1.89	0.01	0.90	46.76	0.01	0.01	0.06
SF7b-D-07	8.17	5.12	0.04	0.44	0.08	0.05	0.02	9.76	0.05	0.01	5.12	0.21	1.98	16.18	1.63	0.01	0.90	49.64	0.52	0.01	0.06
SF7b-D-08	9.10	4.80	0.04	0.49	0.09	0.06	0.02	10.87	0.06	0.01	4.80	0.23	2.21	17.12	1.82	0.01	0.90	46.72	0.57	0.01	0.06

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide.**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-A-05	Al <sub>2</sub> O <sub>3</sub>	9.036	4.619	4.635	8.742	-3.247
SF7b-A-05	B <sub>2</sub> O <sub>3</sub>	5.120	1.210	1.208	3.894	-23.954
SF7b-A-05	BaO	0.042	0.036	0.037	0.041	-2.790
SF7b-A-05	CaO	0.469	0.336	0.326	0.463	-1.300
SF7b-A-05	Ce <sub>2</sub> O <sub>3</sub>	0.084	0.070	0.071	0.082	-1.937
SF7b-A-05	Cr <sub>2</sub> O <sub>3</sub>	0.055	0.041	0.040	0.059	7.687
SF7b-A-05	CuO	0.024	0.028	0.042	0.044	85.217
SF7b-A-05	Fe <sub>2</sub> O <sub>3</sub>	10.692	7.273	7.368	10.466	-2.107
SF7b-A-05	K <sub>2</sub> O	0.059	0.052	0.050	0.061	3.617
SF7b-A-05	La <sub>2</sub> O <sub>3</sub>	0.013	0.007	0.007	0.009	-35.131
SF7b-A-05	Li <sub>2</sub> O	6.400	2.765	2.781	5.969	-6.737
SF7b-A-05	MgO	0.231	0.133	0.135	0.222	-3.702
SF7b-A-05	MnO	2.125	1.654	1.675	2.149	1.167
SF7b-A-05	Na <sub>2</sub> O	13.203	9.373	9.379	12.638	-4.276
SF7b-A-05	NiO	1.806	1.378	1.379	1.754	-2.889
SF7b-A-05	PbO	0.012	0.034	0.031	0.035	187.092
SF7b-A-05	SO <sub>4</sub>	0.800	0.261	0.263	0.785	-1.885
SF7b-A-05	SiO <sub>2</sub>	49.752	24.190	24.274	51.840	4.197
SF7b-A-05	TiO <sub>2</sub>	0.008	0.016	0.016	0.026	234.748
SF7b-A-05	ZnO	0.009	0.019	0.019	0.024	151.112
SF7b-A-05	ZrO <sub>2</sub>	0.061	0.046	0.047	0.062	2.272
SF7b-A-05	Sum	100.000	53.540	53.781	99.366	-0.634
SF7b-A-06	Al <sub>2</sub> O <sub>3</sub>	10.063	5.122	5.090	9.648	-4.122
SF7b-A-06	B <sub>2</sub> O <sub>3</sub>	4.800	1.110	1.109	3.572	-25.580
SF7b-A-06	BaO	0.047	0.040	0.041	0.045	-3.517
SF7b-A-06	CaO	0.522	0.359	0.355	0.500	-4.292
SF7b-A-06	Ce <sub>2</sub> O <sub>3</sub>	0.093	0.077	0.077	0.090	-3.143
SF7b-A-06	Cr <sub>2</sub> O <sub>3</sub>	0.061	0.045	0.044	0.065	6.370
SF7b-A-06	CuO	0.026	0.028	0.030	0.036	37.551
SF7b-A-06	Fe <sub>2</sub> O <sub>3</sub>	11.907	8.210	8.299	11.802	-0.881
SF7b-A-06	K <sub>2</sub> O	0.066	0.056	0.054	0.067	1.501
SF7b-A-06	La <sub>2</sub> O <sub>3</sub>	0.015	0.008	0.008	0.010	-32.585
SF7b-A-06	Li <sub>2</sub> O	6.000	2.610	2.609	5.616	-6.399
SF7b-A-06	MgO	0.257	0.148	0.148	0.245	-4.707
SF7b-A-06	MnO	2.366	1.860	1.860	2.401	1.493
SF7b-A-06	Na <sub>2</sub> O	14.027	9.919	9.831	13.311	-5.100
SF7b-A-06	NiO	2.012	1.489	1.478	1.888	-6.157
SF7b-A-06	PbO	0.014	0.034	0.033	0.036	167.078
SF7b-A-06	SO <sub>4</sub>	0.800	0.269	0.265	0.800	-0.013
SF7b-A-06	SiO <sub>2</sub>	46.838	22.815	22.765	48.756	4.095
SF7b-A-06	TiO <sub>2</sub>	0.009	0.015	0.015	0.025	192.520

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-A-06	ZnO	0.010	0.021	0.020	0.025	143.538
SF7b-A-06	ZrO <sub>2</sub>	0.068	0.053	0.053	0.071	4.933
SF7b-A-06	Sum	100.000	54.287	54.186	99.011	-0.989
SF7b-A-07	Al <sub>2</sub> O <sub>3</sub>	8.689	4.407	4.393	8.314	-4.315
SF7b-A-07	B <sub>2</sub> O <sub>3</sub>	5.120	1.179	1.154	3.756	-26.636
SF7b-A-07	BaO	0.042	0.037	0.037	0.041	-1.205
SF7b-A-07	CaO	0.464	0.320	0.320	0.448	-3.434
SF7b-A-07	Ce <sub>2</sub> O <sub>3</sub>	0.083	0.068	0.068	0.080	-3.340
SF7b-A-07	Cr <sub>2</sub> O <sub>3</sub>	0.054	0.033	0.035	0.050	-7.318
SF7b-A-07	CuO	0.023	0.029	0.029	0.036	56.969
SF7b-A-07	Fe <sub>2</sub> O <sub>3</sub>	10.375	7.187	7.174	10.266	-1.047
SF7b-A-07	K <sub>2</sub> O	0.058	0.049	0.047	0.058	-1.017
SF7b-A-07	La <sub>2</sub> O <sub>3</sub>	0.014	0.008	0.009	0.010	-27.730
SF7b-A-07	Li <sub>2</sub> O	6.400	2.782	2.746	5.950	-7.030
SF7b-A-07	MgO	0.221	0.128	0.130	0.214	-3.326
SF7b-A-07	MnO	2.104	1.648	1.639	2.122	0.881
SF7b-A-07	Na <sub>2</sub> O	13.500	9.437	9.328	12.647	-6.319
SF7b-A-07	NiO	1.739	1.301	1.297	1.653	-4.944
SF7b-A-07	PbO	0.014	0.039	0.037	0.041	197.276
SF7b-A-07	SO <sub>4</sub>	0.800	0.260	0.262	0.782	-2.260
SF7b-A-07	SiO <sub>2</sub>	49.707	24.107	23.889	51.340	3.285
SF7b-A-07	TiO <sub>2</sub>	0.521	0.301	0.297	0.498	-4.302
SF7b-A-07	ZnO	0.010	0.020	0.020	0.025	139.289
SF7b-A-07	ZrO <sub>2</sub>	0.062	0.047	0.047	0.064	3.021
SF7b-A-07	Sum	100.000	53.387	52.961	98.397	-1.603
SF7b-A-08	Al <sub>2</sub> O <sub>3</sub>	9.676	4.766	4.775	9.014	-6.847
SF7b-A-08	B <sub>2</sub> O <sub>3</sub>	4.800	1.038	0.976	3.243	-32.445
SF7b-A-08	BaO	0.046	0.043	0.043	0.048	3.652
SF7b-A-08	CaO	0.517	0.351	0.354	0.493	-4.564
SF7b-A-08	Ce <sub>2</sub> O <sub>3</sub>	0.092	0.075	0.075	0.088	-4.281
SF7b-A-08	Cr <sub>2</sub> O <sub>3</sub>	0.060	0.037	0.038	0.055	-9.116
SF7b-A-08	CuO	0.026	0.026	0.031	0.036	38.008
SF7b-A-08	Fe <sub>2</sub> O <sub>3</sub>	11.554	8.274	8.100	11.705	1.307
SF7b-A-08	K <sub>2</sub> O	0.065	0.052	0.051	0.062	-3.939
SF7b-A-08	La <sub>2</sub> O <sub>3</sub>	0.015	0.010	0.010	0.012	-23.297
SF7b-A-08	Li <sub>2</sub> O	6.000	2.543	2.430	5.352	-10.794
SF7b-A-08	MgO	0.246	0.138	0.140	0.230	-6.393
SF7b-A-08	MnO	2.343	1.780	1.756	2.283	-2.541
SF7b-A-08	Na <sub>2</sub> O	14.358	9.932	9.950	13.400	-6.673
SF7b-A-08	NiO	1.937	1.430	1.439	1.825	-5.771
SF7b-A-08	PbO	0.015	0.036	0.037	0.039	151.496



**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-A-08	SO <sub>4</sub>	0.800	0.260	0.263	0.783	-2.072
SF7b-A-08	SiO <sub>2</sub>	46.789	22.215	22.262	47.575	1.681
SF7b-A-08	TiO <sub>2</sub>	0.580	0.315	0.319	0.529	-8.823
SF7b-A-08	ZnO	0.012	0.021	0.021	0.026	124.548
SF7b-A-08	ZrO <sub>2</sub>	0.069	0.047	0.049	0.065	-5.848
SF7b-A-08	Sum	100.000	53.390	53.117	96.863	-3.137
SF7b-A-09	Al <sub>2</sub> O <sub>3</sub>	8.770	4.467	4.420	8.396	-4.271
SF7b-A-09	B <sub>2</sub> O <sub>3</sub>	5.120	1.171	1.129	3.703	-27.685
SF7b-A-09	BaO	0.041	0.036	0.037	0.041	-0.020
SF7b-A-09	CaO	0.455	0.312	0.316	0.440	-3.391
SF7b-A-09	Ce <sub>2</sub> O <sub>3</sub>	0.081	0.070	0.070	0.082	0.894
SF7b-A-09	Cr <sub>2</sub> O <sub>3</sub>	0.053	0.035	0.035	0.051	-4.400
SF7b-A-09	CuO	0.023	0.026	0.030	0.035	52.755
SF7b-A-09	Fe <sub>2</sub> O <sub>3</sub>	10.377	7.247	7.167	10.304	-0.711
SF7b-A-09	K <sub>2</sub> O	0.057	0.045	0.045	0.054	-5.685
SF7b-A-09	La <sub>2</sub> O <sub>3</sub>	0.013	0.008	0.008	0.010	-25.356
SF7b-A-09	Li <sub>2</sub> O	5.120	2.241	2.185	4.763	-6.974
SF7b-A-09	MgO	0.224	0.129	0.130	0.215	-4.050
SF7b-A-09	MnO	2.062	1.625	1.611	2.089	1.308
SF7b-A-09	Na <sub>2</sub> O	15.242	10.722	10.604	14.373	-5.700
SF7b-A-09	NiO	1.753	1.338	1.330	1.698	-3.181
SF7b-A-09	PbO	0.012	0.031	0.033	0.034	191.087
SF7b-A-09	SO <sub>4</sub>	0.800	0.275	0.270	0.816	2.047
SF7b-A-09	SiO <sub>2</sub>	49.719	24.204	23.960	51.520	3.622
SF7b-A-09	TiO <sub>2</sub>	0.008	0.011	0.011	0.018	137.541
SF7b-A-09	ZnO	0.009	0.025	0.026	0.032	246.435
SF7b-A-09	ZrO <sub>2</sub>	0.059	0.051	0.049	0.068	14.006
SF7b-A-09	Sum	100.000	54.069	53.465	98.740	-1.260
SF7b-A-10	Al <sub>2</sub> O <sub>3</sub>	9.767	4.869	4.880	9.210	-5.704
SF7b-A-10	B <sub>2</sub> O <sub>3</sub>	4.800	1.031	1.007	3.281	-31.655
SF7b-A-10	BaO	0.045	0.040	0.040	0.045	-1.526
SF7b-A-10	CaO	0.507	0.347	0.345	0.484	-4.480
SF7b-A-10	Ce <sub>2</sub> O <sub>3</sub>	0.091	0.073	0.073	0.086	-5.093
SF7b-A-10	Cr <sub>2</sub> O <sub>3</sub>	0.059	0.034	0.036	0.051	-14.107
SF7b-A-10	CuO	0.025	0.028	0.028	0.035	36.625
SF7b-A-10	Fe <sub>2</sub> O <sub>3</sub>	11.557	7.946	7.903	11.330	-1.961
SF7b-A-10	K <sub>2</sub> O	0.064	0.054	0.053	0.064	1.067
SF7b-A-10	La <sub>2</sub> O <sub>3</sub>	0.014	0.011	0.011	0.013	-9.276
SF7b-A-10	Li <sub>2</sub> O	4.800	2.065	2.040	4.418	-7.954
SF7b-A-10	MgO	0.250	0.140	0.140	0.232	-7.110
SF7b-A-10	MnO	2.297	1.774	1.764	2.285	-0.525

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-A-10	Na <sub>2</sub> O	16.072	11.363	11.269	15.253	-5.095
SF7b-A-10	NiO	1.953	1.441	1.440	1.833	-6.109
SF7b-A-10	PbO	0.013	0.033	0.031	0.034	160.426
SF7b-A-10	SO <sub>4</sub>	0.800	0.267	0.273	0.809	1.111
SF7b-A-10	SiO <sub>2</sub>	46.802	22.471	22.543	48.150	2.880
SF7b-A-10	TiO <sub>2</sub>	0.008	0.012	0.012	0.020	135.296
SF7b-A-10	ZnO	0.010	0.020	0.020	0.024	140.790
SF7b-A-10	ZrO <sub>2</sub>	0.066	0.047	0.048	0.064	-3.440
SF7b-A-10	Sum	100.000	54.065	53.956	97.721	-2.279
SF7b-A-11	Al <sub>2</sub> O <sub>3</sub>	8.438	4.222	4.282	8.034	-4.789
SF7b-A-11	B <sub>2</sub> O <sub>3</sub>	5.120	1.165	1.105	3.654	-28.629
SF7b-A-11	BaO	0.040	0.035	0.035	0.039	-4.069
SF7b-A-11	CaO	0.451	0.315	0.314	0.440	-2.315
SF7b-A-11	Ce <sub>2</sub> O <sub>3</sub>	0.080	0.065	0.066	0.077	-4.474
SF7b-A-11	Cr <sub>2</sub> O <sub>3</sub>	0.053	0.035	0.036	0.052	-1.664
SF7b-A-11	CuO	0.023	0.030	0.026	0.035	56.748
SF7b-A-11	Fe <sub>2</sub> O <sub>3</sub>	10.078	6.933	6.885	9.878	-1.984
SF7b-A-11	K <sub>2</sub> O	0.057	0.044	0.046	0.054	-4.137
SF7b-A-11	La <sub>2</sub> O <sub>3</sub>	0.013	0.016	0.016	0.019	42.086
SF7b-A-11	Li <sub>2</sub> O	5.120	2.201	2.198	4.735	-7.529
SF7b-A-11	MgO	0.215	0.125	0.125	0.207	-3.520
SF7b-A-11	MnO	2.044	1.589	1.574	2.042	-0.119
SF7b-A-11	Na <sub>2</sub> O	15.500	10.906	10.988	14.756	-4.795
SF7b-A-11	NiO	1.689	1.246	1.258	1.593	-5.683
SF7b-A-11	PbO	0.014	0.034	0.031	0.035	158.411
SF7b-A-11	SO <sub>4</sub>	0.800	0.251	0.249	0.749	-6.379
SF7b-A-11	SiO <sub>2</sub>	49.676	23.820	24.079	51.236	3.139
SF7b-A-11	TiO <sub>2</sub>	0.519	0.289	0.290	0.483	-6.863
SF7b-A-11	ZnO	0.010	0.019	0.018	0.023	127.986
SF7b-A-11	ZrO <sub>2</sub>	0.060	0.046	0.060	0.072	19.635
SF7b-A-11	Sum	100.000	53.387	53.681	98.214	-1.786
SF7b-A-12	Al <sub>2</sub> O <sub>3</sub>	9.397	4.770	4.720	8.965	-4.597
SF7b-A-12	B <sub>2</sub> O <sub>3</sub>	4.800	0.992	0.988	3.188	-33.588
SF7b-A-12	BaO	0.045	0.039	0.039	0.044	-2.174
SF7b-A-12	CaO	0.502	0.348	0.343	0.484	-3.710
SF7b-A-12	Ce <sub>2</sub> O <sub>3</sub>	0.089	0.074	0.073	0.086	-3.633
SF7b-A-12	Cr <sub>2</sub> O <sub>3</sub>	0.059	0.036	0.037	0.053	-9.190
SF7b-A-12	CuO	0.025	0.026	0.029	0.035	38.430
SF7b-A-12	Fe <sub>2</sub> O <sub>3</sub>	11.223	7.745	7.737	11.067	-1.391
SF7b-A-12	K <sub>2</sub> O	0.063	0.049	0.049	0.059	-5.660
SF7b-A-12	La <sub>2</sub> O <sub>3</sub>	0.015	0.012	0.012	0.014	-7.105

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-A-12	Li <sub>2</sub> O	4.800	2.025	2.036	4.371	-8.932
SF7b-A-12	MgO	0.239	0.138	0.137	0.228	-4.484
SF7b-A-12	MnO	2.277	1.749	1.751	2.260	-0.736
SF7b-A-12	Na <sub>2</sub> O	16.359	11.414	11.375	15.359	-6.113
SF7b-A-12	NiO	1.881	1.420	1.404	1.797	-4.482
SF7b-A-12	PbO	0.015	0.038	0.030	0.037	143.330
SF7b-A-12	SO <sub>4</sub>	0.800	0.251	0.252	0.753	-5.817
SF7b-A-12	SiO <sub>2</sub>	46.754	22.862	22.616	48.646	4.046
SF7b-A-12	TiO <sub>2</sub>	0.578	0.328	0.325	0.544	-5.869
SF7b-A-12	ZnO	0.011	0.021	0.021	0.026	130.081
SF7b-A-12	ZrO <sub>2</sub>	0.067	0.048	0.049	0.066	-2.038
SF7b-A-12	Sum	100.000	54.386	54.022	98.082	-1.918
SF7b-A-13	Al <sub>2</sub> O <sub>3</sub>	9.036	4.586	4.619	8.696	-3.766
SF7b-A-13	B <sub>2</sub> O <sub>3</sub>	5.120	1.079	1.084	3.482	-31.983
SF7b-A-13	BaO	0.042	0.038	0.038	0.042	0.403
SF7b-A-13	CaO	0.469	0.323	0.326	0.454	-3.136
SF7b-A-13	Ce <sub>2</sub> O <sub>3</sub>	0.084	0.072	0.072	0.085	0.899
SF7b-A-13	Cr <sub>2</sub> O <sub>3</sub>	0.055	0.033	0.033	0.049	-11.512
SF7b-A-13	CuO	0.024	0.027	0.025	0.033	39.624
SF7b-A-13	Fe <sub>2</sub> O <sub>3</sub>	10.692	7.189	7.331	10.380	-2.916
SF7b-A-13	K <sub>2</sub> O	0.059	0.047	0.047	0.057	-3.988
SF7b-A-13	La <sub>2</sub> O <sub>3</sub>	0.013	0.008	0.008	0.010	-27.620
SF7b-A-13	Li <sub>2</sub> O	5.120	2.195	2.191	4.720	-7.808
SF7b-A-13	MgO	0.231	0.133	0.134	0.221	-4.141
SF7b-A-13	MnO	2.125	1.630	1.657	2.122	-0.128
SF7b-A-13	Na <sub>2</sub> O	14.483	10.208	10.161	13.728	-5.210
SF7b-A-13	NiO	1.806	1.353	1.354	1.722	-4.652
SF7b-A-13	PbO	0.012	0.031	0.040	0.038	216.332
SF7b-A-13	SO <sub>4</sub>	0.800	0.235	0.244	0.718	-10.311
SF7b-A-13	SiO <sub>2</sub>	49.752	24.265	24.359	52.012	4.544
SF7b-A-13	TiO <sub>2</sub>	0.008	0.010	0.011	0.018	131.573
SF7b-A-13	ZnO	0.009	0.020	0.020	0.025	165.776
SF7b-A-13	ZrO <sub>2</sub>	0.061	0.046	0.047	0.063	3.273
SF7b-A-13	Sum	100.000	53.529	53.803	98.675	-1.325
SF7b-A-14	Al <sub>2</sub> O <sub>3</sub>	10.063	5.124	5.147	9.704	-3.567
SF7b-A-14	B <sub>2</sub> O <sub>3</sub>	4.800	0.974	0.982	3.150	-34.382
SF7b-A-14	BaO	0.047	0.043	0.043	0.048	1.659
SF7b-A-14	CaO	0.522	0.363	0.360	0.506	-3.073
SF7b-A-14	Ce <sub>2</sub> O <sub>3</sub>	0.093	0.079	0.078	0.092	-1.778
SF7b-A-14	Cr <sub>2</sub> O <sub>3</sub>	0.061	0.040	0.040	0.059	-4.065
SF7b-A-14	CuO	0.026	0.029	0.027	0.035	34.844

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-A-14	Fe <sub>2</sub> O <sub>3</sub>	11.907	8.101	8.268	11.702	-1.719
SF7b-A-14	K <sub>2</sub> O	0.066	0.054	0.055	0.066	-0.139
SF7b-A-14	La <sub>2</sub> O <sub>3</sub>	0.015	0.010	0.010	0.012	-17.689
SF7b-A-14	Li <sub>2</sub> O	4.800	2.075	2.080	4.472	-6.830
SF7b-A-14	MgO	0.257	0.148	0.147	0.245	-4.888
SF7b-A-14	MnO	2.366	1.844	1.879	2.404	1.604
SF7b-A-14	Na <sub>2</sub> O	15.227	10.661	10.678	14.382	-5.549
SF7b-A-14	NiO	2.012	1.505	1.515	1.921	-4.495
SF7b-A-14	PbO	0.014	0.033	0.030	0.034	151.827
SF7b-A-14	SO <sub>4</sub>	0.800	0.244	0.239	0.724	-9.562
SF7b-A-14	SiO <sub>2</sub>	46.838	23.078	23.102	49.397	5.464
SF7b-A-14	TiO <sub>2</sub>	0.009	0.010	0.010	0.017	95.087
SF7b-A-14	ZnO	0.010	0.019	0.019	0.024	130.060
SF7b-A-14	ZrO <sub>2</sub>	0.068	0.052	0.053	0.071	4.308
SF7b-A-14	Sum	100.000	54.489	54.762	99.063	-0.937
SF7b-A-15	Al <sub>2</sub> O <sub>3</sub>	8.689	4.506	4.464	8.475	-2.464
SF7b-A-15	B <sub>2</sub> O <sub>3</sub>	5.120	1.041	1.039	3.349	-34.592
SF7b-A-15	BaO	0.042	0.036	0.036	0.040	-3.423
SF7b-A-15	CaO	0.464	0.327	0.322	0.454	-2.100
SF7b-A-15	Ce <sub>2</sub> O <sub>3</sub>	0.083	0.071	0.070	0.083	-0.040
SF7b-A-15	Cr <sub>2</sub> O <sub>3</sub>	0.054	0.036	0.035	0.052	-3.987
SF7b-A-15	CuO	0.023	0.022	0.024	0.029	24.005
SF7b-A-15	Fe <sub>2</sub> O <sub>3</sub>	10.375	7.126	7.039	10.126	-2.396
SF7b-A-15	K <sub>2</sub> O	0.058	0.064	0.048	0.067	15.058
SF7b-A-15	La <sub>2</sub> O <sub>3</sub>	0.014	0.009	0.009	0.011	-21.806
SF7b-A-15	Li <sub>2</sub> O	5.120	2.190	2.193	4.718	-7.860
SF7b-A-15	MgO	0.221	0.128	0.127	0.212	-4.161
SF7b-A-15	MnO	2.104	1.628	1.612	2.092	-0.570
SF7b-A-15	Na <sub>2</sub> O	14.780	10.503	10.386	14.078	-4.750
SF7b-A-15	NiO	1.739	1.345	1.331	1.703	-2.109
SF7b-A-15	PbO	0.014	0.036	0.034	0.038	171.907
SF7b-A-15	SO <sub>4</sub>	0.800	0.242	0.238	0.719	-10.124
SF7b-A-15	SiO <sub>2</sub>	49.707	24.645	24.498	52.566	5.751
SF7b-A-15	TiO <sub>2</sub>	0.521	0.298	0.291	0.492	-5.565
SF7b-A-15	ZnO	0.010	0.019	0.019	0.023	125.731
SF7b-A-15	ZrO <sub>2</sub>	0.062	0.048	0.044	0.062	0.217
SF7b-A-15	Sum	100.000	54.320	53.859	99.388	-0.612
SF7b-A-16	Al <sub>2</sub> O <sub>3</sub>	9.676	4.987	4.973	9.409	-2.759
SF7b-A-16	B <sub>2</sub> O <sub>3</sub>	4.800	0.967	0.961	3.104	-35.331
SF7b-A-16	BaO	0.046	0.041	0.041	0.046	-0.699
SF7b-A-16	CaO	0.517	0.357	0.359	0.501	-3.062

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-A-16	Ce <sub>2</sub> O <sub>3</sub>	0.092	0.077	0.077	0.091	-1.585
SF7b-A-16	Cr <sub>2</sub> O <sub>3</sub>	0.060	0.038	0.039	0.056	-7.153
SF7b-A-16	CuO	0.026	0.027	0.028	0.035	33.487
SF7b-A-16	Fe <sub>2</sub> O <sub>3</sub>	11.554	7.786	7.954	11.252	-2.609
SF7b-A-16	K <sub>2</sub> O	0.065	0.055	0.055	0.066	1.812
SF7b-A-16	La <sub>2</sub> O <sub>3</sub>	0.015	0.011	0.011	0.013	-15.464
SF7b-A-16	Li <sub>2</sub> O	4.800	2.049	2.082	4.446	-7.373
SF7b-A-16	MgO	0.246	0.142	0.142	0.235	-4.470
SF7b-A-16	MnO	2.343	1.797	1.842	2.349	0.273
SF7b-A-16	Na <sub>2</sub> O	15.558	11.035	11.066	14.896	-4.256
SF7b-A-16	NiO	1.937	1.437	1.458	1.842	-4.910
SF7b-A-16	PbO	0.015	0.040	0.039	0.042	173.027
SF7b-A-16	SO <sub>4</sub>	0.800	0.246	0.250	0.743	-7.128
SF7b-A-16	SiO <sub>2</sub>	46.789	23.222	23.226	49.683	6.187
SF7b-A-16	TiO <sub>2</sub>	0.580	0.325	0.323	0.540	-6.855
SF7b-A-16	ZnO	0.012	0.020	0.021	0.026	121.434
SF7b-A-16	ZrO <sub>2</sub>	0.069	0.051	0.052	0.069	0.224
SF7b-A-16	Sum	100.000	54.710	54.997	99.444	-0.556
SF7b-B-01	Al <sub>2</sub> O <sub>3</sub>	9.010	4.593	4.579	8.665	-3.831
SF7b-B-01	B <sub>2</sub> O <sub>3</sub>	5.120	1.688	1.625	5.333	4.169
SF7b-B-01	BaO	0.042	0.039	0.039	0.044	4.296
SF7b-B-01	CaO	0.468	0.314	0.311	0.437	-6.511
SF7b-B-01	Ce <sub>2</sub> O <sub>3</sub>	0.084	0.071	0.071	0.083	-0.407
SF7b-B-01	Cr <sub>2</sub> O <sub>3</sub>	0.055	0.043	0.043	0.063	14.158
SF7b-B-01	CuO	0.024	0.024	0.025	0.031	30.176
SF7b-B-01	Fe <sub>2</sub> O <sub>3</sub>	10.661	7.303	7.215	10.379	-2.649
SF7b-B-01	K <sub>2</sub> O	0.059	0.048	0.048	0.058	-1.350
SF7b-B-01	La <sub>2</sub> O <sub>3</sub>	0.013	0.012	0.012	0.014	5.064
SF7b-B-01	Li <sub>2</sub> O	6.400	2.888	2.844	6.169	-3.616
SF7b-B-01	MgO	0.230	0.136	0.137	0.227	-1.636
SF7b-B-01	MnO	2.119	1.673	1.654	2.148	1.389
SF7b-B-01	Na <sub>2</sub> O	13.176	9.190	9.215	12.404	-5.857
SF7b-B-01	NiO	1.801	1.379	1.366	1.747	-3.031
SF7b-B-01	PbO	0.012	0.013	0.013	0.014	16.849
SF7b-B-01	SO <sub>4</sub>	0.900	0.272	0.271	0.814	-9.565
SF7b-B-01	SiO <sub>2</sub>	49.748	24.357	24.137	51.873	4.271
SF7b-B-01	TiO <sub>2</sub>	0.008	0.012	0.012	0.020	161.848
SF7b-B-01	ZnO	0.009	0.018	0.018	0.022	136.975
SF7b-B-01	ZrO <sub>2</sub>	0.061	0.066	0.048	0.077	26.296
SF7b-B-01	Sum	100.000	54.140	53.683	100.622	0.622
SF7b-B-02	Al <sub>2</sub> O <sub>3</sub>	10.037	5.055	5.082	9.577	-4.586

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-B-02	B <sub>2</sub> O <sub>3</sub>	4.800	1.511	1.486	4.826	0.542
SF7b-B-02	BaO	0.047	0.044	0.044	0.049	4.190
SF7b-B-02	CaO	0.521	0.357	0.371	0.510	-2.179
SF7b-B-02	Ce <sub>2</sub> O <sub>3</sub>	0.093	0.079	0.080	0.093	-0.156
SF7b-B-02	Cr <sub>2</sub> O <sub>3</sub>	0.061	0.048	0.049	0.071	16.663
SF7b-B-02	CuO	0.026	0.024	0.024	0.030	14.901
SF7b-B-02	Fe <sub>2</sub> O <sub>3</sub>	11.876	8.623	8.481	12.227	2.950
SF7b-B-02	K <sub>2</sub> O	0.065	0.052	0.052	0.063	-3.791
SF7b-B-02	La <sub>2</sub> O <sub>3</sub>	0.015	0.013	0.013	0.015	4.791
SF7b-B-02	Li <sub>2</sub> O	6.000	2.663	2.646	5.714	-4.763
SF7b-B-02	MgO	0.257	0.150	0.151	0.250	-2.600
SF7b-B-02	MnO	2.360	1.858	1.853	2.396	1.511
SF7b-B-02	Na <sub>2</sub> O	14.000	9.853	9.945	13.343	-4.691
SF7b-B-02	NiO	2.007	1.615	1.606	2.050	2.147
SF7b-B-02	PbO	0.014	0.015	0.016	0.017	24.066
SF7b-B-02	SO <sub>4</sub>	0.900	0.279	0.283	0.841	-6.515
SF7b-B-02	SiO <sub>2</sub>	46.835	22.571	22.492	48.203	2.920
SF7b-B-02	TiO <sub>2</sub>	0.009	0.013	0.013	0.022	147.969
SF7b-B-02	ZnO	0.010	0.019	0.019	0.024	126.429
SF7b-B-02	ZrO <sub>2</sub>	0.068	0.054	0.055	0.074	8.694
SF7b-B-02	Sum	100.000	54.898	54.759	100.393	0.393
SF7b-B-03	Al <sub>2</sub> O <sub>3</sub>	8.664	4.436	4.443	8.389	-3.179
SF7b-B-03	B <sub>2</sub> O <sub>3</sub>	5.120	1.595	1.595	5.136	0.304
SF7b-B-03	BaO	0.041	0.038	0.038	0.042	2.040
SF7b-B-03	CaO	0.463	0.307	0.310	0.432	-6.684
SF7b-B-03	Ce <sub>2</sub> O <sub>3</sub>	0.082	0.069	0.069	0.081	-2.323
SF7b-B-03	Cr <sub>2</sub> O <sub>3</sub>	0.054	0.041	0.040	0.059	9.837
SF7b-B-03	CuO	0.023	0.022	0.022	0.027	18.539
SF7b-B-03	Fe <sub>2</sub> O <sub>3</sub>	10.345	7.011	7.099	10.086	-2.503
SF7b-B-03	K <sub>2</sub> O	0.058	0.045	0.045	0.055	-5.989
SF7b-B-03	La <sub>2</sub> O <sub>3</sub>	0.014	0.011	0.011	0.013	-6.179
SF7b-B-03	Li <sub>2</sub> O	6.400	2.861	2.877	6.176	-3.500
SF7b-B-03	MgO	0.220	0.122	0.122	0.202	-8.425
SF7b-B-03	MnO	2.098	1.654	1.675	2.149	2.456
SF7b-B-03	Na <sub>2</sub> O	13.473	9.571	9.532	12.875	-4.436
SF7b-B-03	NiO	1.734	1.305	1.333	1.679	-3.200
SF7b-B-03	PbO	0.014	0.017	0.017	0.018	32.076
SF7b-B-03	SO <sub>4</sub>	0.900	0.290	0.287	0.864	-3.966
SF7b-B-03	SiO <sub>2</sub>	49.704	24.082	24.292	51.745	4.105
SF7b-B-03	TiO <sub>2</sub>	0.519	0.309	0.312	0.518	-0.249
SF7b-B-03	ZnO	0.010	0.016	0.016	0.020	92.947

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-B-03	ZrO <sub>2</sub>	0.062	0.048	0.049	0.065	5.736
SF7b-B-03	Sum	100.000	53.851	54.184	100.631	0.631
SF7b-B-04	Al <sub>2</sub> O <sub>3</sub>	9.651	4.817	4.890	9.171	-4.978
SF7b-B-04	B <sub>2</sub> O <sub>3</sub>	4.800	1.483	1.465	4.747	-1.114
SF7b-B-04	BaO	0.046	0.040	0.041	0.046	-1.246
SF7b-B-04	CaO	0.515	0.338	0.343	0.477	-7.515
SF7b-B-04	Ce <sub>2</sub> O <sub>3</sub>	0.092	0.075	0.076	0.089	-3.319
SF7b-B-04	Cr <sub>2</sub> O <sub>3</sub>	0.060	0.044	0.045	0.066	8.855
SF7b-B-04	CuO	0.026	0.025	0.027	0.032	25.291
SF7b-B-04	Fe <sub>2</sub> O <sub>3</sub>	11.524	8.080	8.067	11.543	0.160
SF7b-B-04	K <sub>2</sub> O	0.065	0.051	0.052	0.062	-3.715
SF7b-B-04	La <sub>2</sub> O <sub>3</sub>	0.015	0.015	0.015	0.017	13.361
SF7b-B-04	Li <sub>2</sub> O	6.000	2.651	2.643	5.698	-5.039
SF7b-B-04	MgO	0.246	0.139	0.142	0.233	-5.222
SF7b-B-04	MnO	2.337	1.839	1.833	2.371	1.466
SF7b-B-04	Na <sub>2</sub> O	14.331	9.939	10.070	13.486	-5.897
SF7b-B-04	NiO	1.932	1.462	1.458	1.858	-3.831
SF7b-B-04	PbO	0.015	0.018	0.017	0.019	21.210
SF7b-B-04	SO <sub>4</sub>	0.900	0.280	0.285	0.845	-6.088
SF7b-B-04	SiO <sub>2</sub>	46.786	22.536	22.579	48.257	3.145
SF7b-B-04	TiO <sub>2</sub>	0.579	0.339	0.345	0.570	-1.474
SF7b-B-04	ZnO	0.012	0.018	0.019	0.023	102.474
SF7b-B-04	ZrO <sub>2</sub>	0.069	0.053	0.054	0.072	5.372
SF7b-B-04	Sum	100.000	54.242	54.466	99.681	-0.319
SF7b-B-05	Al <sub>2</sub> O <sub>3</sub>	9.062	4.630	4.606	8.726	-3.708
SF7b-B-05	B <sub>2</sub> O <sub>3</sub>	5.120	1.575	1.550	5.031	-1.740
SF7b-B-05	BaO	0.042	0.038	0.038	0.042	0.542
SF7b-B-05	CaO	0.470	0.312	0.318	0.441	-6.324
SF7b-B-05	Ce <sub>2</sub> O <sub>3</sub>	0.084	0.072	0.073	0.085	1.035
SF7b-B-05	Cr <sub>2</sub> O <sub>3</sub>	0.055	0.040	0.046	0.063	13.795
SF7b-B-05	CuO	0.024	0.023	0.024	0.030	25.416
SF7b-B-05	Fe <sub>2</sub> O <sub>3</sub>	10.722	7.521	7.479	10.723	0.014
SF7b-B-05	K <sub>2</sub> O	0.059	0.047	0.047	0.056	-4.608
SF7b-B-05	La <sub>2</sub> O <sub>3</sub>	0.013	0.013	0.013	0.015	12.422
SF7b-B-05	Li <sub>2</sub> O	5.120	2.294	2.270	4.912	-4.068
SF7b-B-05	MgO	0.232	0.136	0.138	0.226	-2.249
SF7b-B-05	MnO	2.131	1.672	1.662	2.152	1.008
SF7b-B-05	Na <sub>2</sub> O	14.509	10.121	10.181	13.683	-5.696
SF7b-B-05	NiO	1.812	1.407	1.394	1.783	-1.598
SF7b-B-05	PbO	0.012	0.014	0.014	0.015	26.489
SF7b-B-05	SO <sub>4</sub>	0.700	0.233	0.227	0.689	-1.643

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-B-05	SiO <sub>2</sub>	49.755	24.154	23.937	51.441	3.390
SF7b-B-05	TiO <sub>2</sub>	0.008	0.012	0.013	0.021	164.776
SF7b-B-05	ZnO	0.009	0.014	0.015	0.018	91.858
SF7b-B-05	ZrO <sub>2</sub>	0.061	0.037	0.048	0.057	-6.231
SF7b-B-05	Sum	100.000	54.363	54.093	100.209	0.209
SF7b-B-06	Al <sub>2</sub> O <sub>3</sub>	10.088	5.077	5.121	9.635	-4.498
SF7b-B-06	B <sub>2</sub> O <sub>3</sub>	4.800	1.454	1.437	4.655	-3.017
SF7b-B-06	BaO	0.047	0.043	0.043	0.048	1.949
SF7b-B-06	CaO	0.524	0.352	0.354	0.494	-5.694
SF7b-B-06	Ce <sub>2</sub> O <sub>3</sub>	0.094	0.079	0.079	0.092	-1.456
SF7b-B-06	Cr <sub>2</sub> O <sub>3</sub>	0.061	0.051	0.050	0.074	19.952
SF7b-B-06	CuO	0.026	0.026	0.025	0.032	22.163
SF7b-B-06	Fe <sub>2</sub> O <sub>3</sub>	11.937	8.427	8.433	12.053	0.970
SF7b-B-06	K <sub>2</sub> O	0.066	0.054	0.053	0.065	-1.566
SF7b-B-06	La <sub>2</sub> O <sub>3</sub>	0.015	0.013	0.013	0.015	3.909
SF7b-B-06	Li <sub>2</sub> O	4.800	2.123	2.131	4.578	-4.626
SF7b-B-06	MgO	0.258	0.154	0.153	0.255	-1.121
SF7b-B-06	MnO	2.372	1.866	1.870	2.412	1.666
SF7b-B-06	Na <sub>2</sub> O	15.253	10.643	10.795	14.449	-5.272
SF7b-B-06	NiO	2.017	1.569	1.582	2.005	-0.603
SF7b-B-06	PbO	0.014	0.014	0.015	0.016	17.920
SF7b-B-06	SO <sub>4</sub>	0.700	0.228	0.230	0.686	-1.942
SF7b-B-06	SiO <sub>2</sub>	46.841	22.658	22.763	48.584	3.722
SF7b-B-06	TiO <sub>2</sub>	0.009	0.012	0.012	0.020	134.150
SF7b-B-06	ZnO	0.010	0.018	0.018	0.022	109.093
SF7b-B-06	ZrO <sub>2</sub>	0.068	0.052	0.052	0.070	2.388
SF7b-B-06	Sum	100.000	54.911	55.230	100.260	0.260
SF7b-B-07	Al <sub>2</sub> O <sub>3</sub>	8.713	4.934	4.455	8.870	1.794
SF7b-B-07	B <sub>2</sub> O <sub>3</sub>	5.120	1.521	1.500	4.864	-5.002
SF7b-B-07	BaO	0.042	0.042	0.039	0.045	8.599
SF7b-B-07	CaO	0.465	0.347	0.310	0.460	-1.074
SF7b-B-07	Ce <sub>2</sub> O <sub>3</sub>	0.083	0.077	0.072	0.087	4.986
SF7b-B-07	Cr <sub>2</sub> O <sub>3</sub>	0.054	0.051	0.049	0.073	34.000
SF7b-B-07	CuO	0.023	0.031	0.027	0.037	58.376
SF7b-B-07	Fe <sub>2</sub> O <sub>3</sub>	10.404	7.172	7.172	10.254	-1.447
SF7b-B-07	K <sub>2</sub> O	0.058	0.052	0.048	0.060	2.568
SF7b-B-07	La <sub>2</sub> O <sub>3</sub>	0.014	0.014	0.013	0.015	11.389
SF7b-B-07	Li <sub>2</sub> O	5.120	2.240	2.229	4.810	-6.061
SF7b-B-07	MgO	0.222	0.148	0.134	0.234	5.371
SF7b-B-07	MnO	2.110	1.639	1.635	2.113	0.170
SF7b-B-07	Na <sub>2</sub> O	14.808	10.997	10.457	14.459	-2.356



**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-B-07	NiO	1.744	1.328	1.327	1.689	-3.144
SF7b-B-07	PbO	0.014	0.020	0.015	0.019	36.751
SF7b-B-07	SO <sub>4</sub>	0.700	0.227	0.230	0.684	-2.281
SF7b-B-07	SiO <sub>2</sub>	49.710	23.713	23.483	50.484	1.556
SF7b-B-07	TiO <sub>2</sub>	0.522	0.350	0.315	0.555	6.214
SF7b-B-07	ZnO	0.010	0.024	0.018	0.026	147.781
SF7b-B-07	ZrO <sub>2</sub>	0.062	0.055	0.049	0.070	13.692
SF7b-B-07	Sum	100.000	54.981	53.575	99.908	-0.092
SF7b-B-08	Al <sub>2</sub> O <sub>3</sub>	9.701	4.874	4.850	9.187	-5.300
SF7b-B-08	B <sub>2</sub> O <sub>3</sub>	4.800	1.420	1.416	4.565	-4.898
SF7b-B-08	BaO	0.046	0.041	0.042	0.046	-0.393
SF7b-B-08	CaO	0.518	0.347	0.341	0.481	-7.169
SF7b-B-08	Ce <sub>2</sub> O <sub>3</sub>	0.092	0.075	0.076	0.089	-3.701
SF7b-B-08	Cr <sub>2</sub> O <sub>3</sub>	0.061	0.050	0.051	0.074	21.616
SF7b-B-08	CuO	0.026	0.030	0.030	0.037	44.485
SF7b-B-08	Fe <sub>2</sub> O <sub>3</sub>	11.583	7.695	7.791	11.071	-4.426
SF7b-B-08	K <sub>2</sub> O	0.065	0.054	0.051	0.063	-2.682
SF7b-B-08	La <sub>2</sub> O <sub>3</sub>	0.015	0.013	0.013	0.016	1.552
SF7b-B-08	Li <sub>2</sub> O	4.800	2.088	2.090	4.497	-6.310
SF7b-B-08	MgO	0.247	0.144	0.146	0.240	-2.622
SF7b-B-08	MnO	2.349	1.813	1.829	2.351	0.095
SF7b-B-08	Na <sub>2</sub> O	15.586	10.828	10.775	14.560	-6.581
SF7b-B-08	NiO	1.942	1.440	1.459	1.845	-4.997
SF7b-B-08	PbO	0.016	0.019	0.020	0.021	35.121
SF7b-B-08	SO <sub>4</sub>	0.700	0.226	0.231	0.684	-2.248
SF7b-B-08	SiO <sub>2</sub>	46.792	22.413	22.597	48.146	2.895
SF7b-B-08	TiO <sub>2</sub>	0.581	0.340	0.343	0.570	-2.015
SF7b-B-08	ZnO	0.012	0.023	0.023	0.029	148.890
SF7b-B-08	ZrO <sub>2</sub>	0.069	0.060	0.054	0.077	11.227
SF7b-B-08	Sum	100.000	53.994	54.227	98.648	-1.352
SF7b-B-09	Al <sub>2</sub> O <sub>3</sub>	8.795	4.500	4.456	8.461	-3.805
SF7b-B-09	B <sub>2</sub> O <sub>3</sub>	5.120	1.512	1.500	4.849	-5.285
SF7b-B-09	BaO	0.041	0.037	0.037	0.041	0.486
SF7b-B-09	CaO	0.456	0.303	0.307	0.427	-6.362
SF7b-B-09	Ce <sub>2</sub> O <sub>3</sub>	0.082	0.069	0.070	0.081	-0.290
SF7b-B-09	Cr <sub>2</sub> O <sub>3</sub>	0.054	0.046	0.046	0.067	25.102
SF7b-B-09	CuO	0.023	0.024	0.021	0.028	22.935
SF7b-B-09	Fe <sub>2</sub> O <sub>3</sub>	10.407	7.234	7.159	10.289	-1.132
SF7b-B-09	K <sub>2</sub> O	0.057	0.047	0.048	0.057	-0.928
SF7b-B-09	La <sub>2</sub> O <sub>3</sub>	0.013	0.013	0.013	0.015	17.754
SF7b-B-09	Li <sub>2</sub> O	5.120	2.262	2.262	4.869	-4.904

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-B-09	MgO	0.225	0.130	0.131	0.216	-3.759
SF7b-B-09	MnO	2.068	1.610	1.601	2.073	0.231
SF7b-B-09	Na <sub>2</sub> O	15.271	10.829	10.746	14.542	-4.775
SF7b-B-09	NiO	1.758	1.344	1.327	1.700	-3.339
SF7b-B-09	PbO	0.012	0.015	0.015	0.016	38.758
SF7b-B-09	SO <sub>4</sub>	0.700	0.229	0.234	0.694	-0.896
SF7b-B-09	SiO <sub>2</sub>	49.722	23.955	23.884	51.172	2.915
SF7b-B-09	TiO <sub>2</sub>	0.008	0.010	0.010	0.017	126.266
SF7b-B-09	ZnO	0.009	0.016	0.016	0.019	113.053
SF7b-B-09	ZrO <sub>2</sub>	0.059	0.048	0.047	0.064	7.663
SF7b-B-09	Sum	100.000	54.232	53.930	99.698	-0.302
SF7b-B-10	Al <sub>2</sub> O <sub>3</sub>	9.792	4.957	4.973	9.381	-4.196
SF7b-B-10	B <sub>2</sub> O <sub>3</sub>	4.800	1.400	1.410	4.524	-5.742
SF7b-B-10	BaO	0.046	0.041	0.041	0.046	0.037
SF7b-B-10	CaO	0.508	0.337	0.333	0.469	-7.740
SF7b-B-10	Ce <sub>2</sub> O <sub>3</sub>	0.091	0.075	0.075	0.087	-3.704
SF7b-B-10	Cr <sub>2</sub> O <sub>3</sub>	0.060	0.052	0.048	0.073	23.156
SF7b-B-10	CuO	0.026	0.023	0.026	0.031	19.716
SF7b-B-10	Fe <sub>2</sub> O <sub>3</sub>	11.586	8.191	8.195	11.714	1.107
SF7b-B-10	K <sub>2</sub> O	0.064	0.053	0.058	0.067	4.882
SF7b-B-10	La <sub>2</sub> O <sub>3</sub>	0.014	0.012	0.012	0.014	-0.529
SF7b-B-10	Li <sub>2</sub> O	4.800	2.090	2.101	4.511	-6.019
SF7b-B-10	MgO	0.250	0.147	0.147	0.244	-2.541
SF7b-B-10	MnO	2.302	1.792	1.783	2.308	0.241
SF7b-B-10	Na <sub>2</sub> O	16.101	11.354	11.394	15.332	-4.777
SF7b-B-10	NiO	1.958	1.555	1.553	1.978	1.028
SF7b-B-10	PbO	0.013	0.016	0.015	0.017	25.746
SF7b-B-10	SO <sub>4</sub>	0.700	0.245	0.240	0.728	3.931
SF7b-B-10	SiO <sub>2</sub>	46.805	22.431	22.471	48.031	2.619
SF7b-B-10	TiO <sub>2</sub>	0.008	0.014	0.014	0.023	170.222
SF7b-B-10	ZnO	0.010	0.017	0.016	0.020	101.604
SF7b-B-10	ZrO <sub>2</sub>	0.066	0.051	0.051	0.069	4.312
SF7b-B-10	Sum	100.000	54.852	54.959	99.667	-0.333
SF7b-B-11	Al <sub>2</sub> O <sub>3</sub>	8.462	4.339	4.233	8.098	-4.297
SF7b-B-11	B <sub>2</sub> O <sub>3</sub>	5.120	1.556	1.539	4.982	-2.699
SF7b-B-11	BaO	0.040	0.037	0.037	0.041	2.103
SF7b-B-11	CaO	0.452	0.303	0.296	0.419	-7.272
SF7b-B-11	Ce <sub>2</sub> O <sub>3</sub>	0.081	0.067	0.066	0.078	-3.397
SF7b-B-11	Cr <sub>2</sub> O <sub>3</sub>	0.053	0.047	0.046	0.068	27.798
SF7b-B-11	CuO	0.023	0.027	0.024	0.032	41.360
SF7b-B-11	Fe <sub>2</sub> O <sub>3</sub>	10.107	7.257	7.069	10.241	1.327

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-B-11	K <sub>2</sub> O	0.057	0.046	0.045	0.054	-4.342
SF7b-B-11	La <sub>2</sub> O <sub>3</sub>	0.014	0.012	0.012	0.015	7.179
SF7b-B-11	Li <sub>2</sub> O	5.120	2.253	2.226	4.821	-5.847
SF7b-B-11	MgO	0.215	0.130	0.128	0.213	-0.916
SF7b-B-11	MnO	2.050	1.605	1.584	2.059	0.420
SF7b-B-11	Na <sub>2</sub> O	15.529	11.052	10.748	14.693	-5.382
SF7b-B-11	NiO	1.694	1.317	1.295	1.662	-1.885
SF7b-B-11	PbO	0.014	0.017	0.017	0.018	32.807
SF7b-B-11	SO <sub>4</sub>	0.700	0.230	0.227	0.685	-2.190
SF7b-B-11	SiO <sub>2</sub>	49.679	24.067	23.879	51.286	3.234
SF7b-B-11	TiO <sub>2</sub>	0.520	0.313	0.312	0.521	0.178
SF7b-B-11	ZnO	0.010	0.015	0.015	0.019	87.605
SF7b-B-11	ZrO <sub>2</sub>	0.060	0.046	0.046	0.062	2.959
SF7b-B-11	Sum	100.000	54.736	53.843	100.067	0.067
SF7b-B-12	Al <sub>2</sub> O <sub>3</sub>	9.421	4.033	4.875	8.415	-10.677
SF7b-B-12	B <sub>2</sub> O <sub>3</sub>	4.800	1.427	1.415	4.575	-4.696
SF7b-B-12	BaO	0.045	0.032	0.043	0.042	-6.800
SF7b-B-12	CaO	0.503	0.288	0.361	0.454	-9.837
SF7b-B-12	Ce <sub>2</sub> O <sub>3</sub>	0.090	0.064	0.078	0.083	-6.958
SF7b-B-12	Cr <sub>2</sub> O <sub>3</sub>	0.059	0.043	0.050	0.068	14.813
SF7b-B-12	CuO	0.025	0.021	0.027	0.030	19.427
SF7b-B-12	Fe <sub>2</sub> O <sub>3</sub>	11.252	7.772	7.800	11.132	-1.066
SF7b-B-12	K <sub>2</sub> O	0.063	0.044	0.055	0.059	-5.943
SF7b-B-12	La <sub>2</sub> O <sub>3</sub>	0.015	0.011	0.013	0.014	-4.395
SF7b-B-12	Li <sub>2</sub> O	4.800	2.066	2.067	4.447	-7.349
SF7b-B-12	MgO	0.240	0.118	0.143	0.216	-9.723
SF7b-B-12	MnO	2.283	1.763	1.767	2.279	-0.159
SF7b-B-12	Na <sub>2</sub> O	16.389	10.919	11.795	15.309	-6.590
SF7b-B-12	NiO	1.886	1.468	1.474	1.872	-0.747
SF7b-B-12	PbO	0.015	0.018	0.019	0.020	29.869
SF7b-B-12	SO <sub>4</sub>	0.700	0.242	0.229	0.705	0.684
SF7b-B-12	SiO <sub>2</sub>	46.757	22.015	22.137	47.228	1.008
SF7b-B-12	TiO <sub>2</sub>	0.579	0.297	0.356	0.545	-6.021
SF7b-B-12	ZnO	0.011	0.017	0.017	0.021	88.668
SF7b-B-12	ZrO <sub>2</sub>	0.067	0.044	0.053	0.066	-2.026
SF7b-B-12	Sum	100.000	52.701	54.772	97.580	-2.420
SF7b-B-13	Al <sub>2</sub> O <sub>3</sub>	8.745	4.439	4.452	8.399	-3.957
SF7b-B-13	B <sub>2</sub> O <sub>3</sub>	5.120	1.488	1.547	4.886	-4.576
SF7b-B-13	BaO	0.041	0.036	0.036	0.040	-1.408
SF7b-B-13	CaO	0.454	0.306	0.303	0.426	-6.132
SF7b-B-13	Ce <sub>2</sub> O <sub>3</sub>	0.081	0.070	0.070	0.082	0.999

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-B-13	Cr <sub>2</sub> O <sub>3</sub>	0.053	0.047	0.047	0.069	28.968
SF7b-B-13	CuO	0.023	0.024	0.022	0.029	28.268
SF7b-B-13	Fe <sub>2</sub> O <sub>3</sub>	10.348	7.256	7.526	10.567	2.121
SF7b-B-13	K <sub>2</sub> O	0.057	0.048	0.047	0.057	0.520
SF7b-B-13	La <sub>2</sub> O <sub>3</sub>	0.013	0.010	0.010	0.012	-5.986
SF7b-B-13	Li <sub>2</sub> O	6.400	2.753	2.849	6.030	-5.785
SF7b-B-13	MgO	0.224	0.134	0.133	0.222	-0.810
SF7b-B-13	MnO	2.056	1.572	1.628	2.065	0.443
SF7b-B-13	Na <sub>2</sub> O	13.933	9.746	9.790	13.167	-5.499
SF7b-B-13	NiO	1.748	1.348	1.378	1.735	-0.790
SF7b-B-13	PbO	0.012	0.014	0.014	0.015	29.757
SF7b-B-13	SO <sub>4</sub>	0.900	0.292	0.286	0.867	-3.698
SF7b-B-13	SiO <sub>2</sub>	49.716	23.386	24.536	51.261	3.108
SF7b-B-13	TiO <sub>2</sub>	0.008	0.012	0.011	0.019	151.535
SF7b-B-13	ZnO	0.009	0.017	0.017	0.021	129.040
SF7b-B-13	ZrO <sub>2</sub>	0.059	0.049	0.049	0.066	11.920
SF7b-B-13	Sum	100.000	53.049	54.751	100.036	0.036
SF7b-B-14	Al <sub>2</sub> O <sub>3</sub>	9.742	4.937	5.005	9.393	-3.582
SF7b-B-14	B <sub>2</sub> O <sub>3</sub>	4.800	1.408	1.401	4.522	-5.789
SF7b-B-14	BaO	0.045	0.042	0.043	0.047	4.531
SF7b-B-14	CaO	0.506	0.337	0.337	0.472	-6.676
SF7b-B-14	Ce <sub>2</sub> O <sub>3</sub>	0.090	0.076	0.076	0.089	-1.613
SF7b-B-14	Cr <sub>2</sub> O <sub>3</sub>	0.059	0.047	0.049	0.070	17.892
SF7b-B-14	CuO	0.025	0.031	0.031	0.038	50.901
SF7b-B-14	Fe <sub>2</sub> O <sub>3</sub>	11.527	7.972	7.959	11.388	-1.204
SF7b-B-14	K <sub>2</sub> O	0.064	0.051	0.053	0.062	-2.288
SF7b-B-14	La <sub>2</sub> O <sub>3</sub>	0.014	0.012	0.013	0.015	2.578
SF7b-B-14	Li <sub>2</sub> O	6.000	2.602	2.602	5.601	-6.648
SF7b-B-14	MgO	0.249	0.145	0.147	0.242	-2.807
SF7b-B-14	MnO	2.291	1.768	1.759	2.277	-0.600
SF7b-B-14	Na <sub>2</sub> O	14.844	10.451	10.458	14.092	-5.063
SF7b-B-14	NiO	1.948	1.491	1.481	1.891	-2.895
SF7b-B-14	PbO	0.013	0.018	0.019	0.020	53.140
SF7b-B-14	SO <sub>4</sub>	0.900	0.289	0.290	0.867	-3.658
SF7b-B-14	SiO <sub>2</sub>	46.799	22.415	22.374	47.909	2.373
SF7b-B-14	TiO <sub>2</sub>	0.008	0.010	0.010	0.017	99.906
SF7b-B-14	ZnO	0.010	0.017	0.017	0.022	114.414
SF7b-B-14	ZrO <sub>2</sub>	0.066	0.053	0.067	0.081	23.824
SF7b-B-14	Sum	100.000	54.173	54.189	99.116	-0.884
SF7b-B-15	Al <sub>2</sub> O <sub>3</sub>	8.414	4.235	4.274	8.038	-4.468
SF7b-B-15	B <sub>2</sub> O <sub>3</sub>	5.120	1.492	1.485	4.793	-6.389

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-B-15	BaO	0.040	0.037	0.037	0.041	2.264
SF7b-B-15	CaO	0.450	0.301	0.300	0.421	-6.452
SF7b-B-15	Ce <sub>2</sub> O <sub>3</sub>	0.080	0.069	0.070	0.081	1.246
SF7b-B-15	Cr <sub>2</sub> O <sub>3</sub>	0.053	0.048	0.048	0.070	32.441
SF7b-B-15	CuO	0.022	0.024	0.024	0.030	33.664
SF7b-B-15	Fe <sub>2</sub> O <sub>3</sub>	10.049	7.029	6.989	10.021	-0.284
SF7b-B-15	K <sub>2</sub> O	0.056	0.045	0.046	0.055	-2.356
SF7b-B-15	La <sub>2</sub> O <sub>3</sub>	0.013	0.011	0.011	0.013	-6.457
SF7b-B-15	Li <sub>2</sub> O	6.400	2.782	2.778	5.984	-6.502
SF7b-B-15	MgO	0.214	0.128	0.129	0.213	-0.452
SF7b-B-15	MnO	2.039	1.571	1.555	2.018	-1.027
SF7b-B-15	Na <sub>2</sub> O	14.190	9.824	9.959	13.334	-6.035
SF7b-B-15	NiO	1.684	1.298	1.282	1.641	-2.570
SF7b-B-15	PbO	0.014	0.017	0.018	0.019	40.828
SF7b-B-15	SO <sub>4</sub>	0.900	0.287	0.284	0.856	-4.890
SF7b-B-15	SiO <sub>2</sub>	49.674	23.834	23.607	50.746	2.160
SF7b-B-15	TiO <sub>2</sub>	0.518	0.314	0.316	0.526	1.546
SF7b-B-15	ZnO	0.010	0.015	0.015	0.019	85.990
SF7b-B-15	ZrO <sub>2</sub>	0.060	0.047	0.047	0.064	6.023
SF7b-B-15	Sum	100.000	53.407	53.273	98.981	-1.019
SF7b-B-16	Al <sub>2</sub> O <sub>3</sub>	9.373	4.695	4.730	8.903	-5.008
SF7b-B-16	B <sub>2</sub> O <sub>3</sub>	4.800	1.426	1.373	4.506	-6.127
SF7b-B-16	BaO	0.045	0.040	0.041	0.045	0.493
SF7b-B-16	CaO	0.501	0.343	0.337	0.476	-4.978
SF7b-B-16	Ce <sub>2</sub> O <sub>3</sub>	0.089	0.073	0.076	0.087	-2.483
SF7b-B-16	Cr <sub>2</sub> O <sub>3</sub>	0.059	0.046	0.048	0.069	17.150
SF7b-B-16	CuO	0.025	0.026	0.027	0.033	31.697
SF7b-B-16	Fe <sub>2</sub> O <sub>3</sub>	11.195	7.949	7.751	11.223	0.255
SF7b-B-16	K <sub>2</sub> O	0.063	0.054	0.052	0.064	1.647
SF7b-B-16	La <sub>2</sub> O <sub>3</sub>	0.015	0.012	0.013	0.015	-3.195
SF7b-B-16	Li <sub>2</sub> O	6.000	2.668	2.599	5.668	-5.529
SF7b-B-16	MgO	0.238	0.137	0.143	0.232	-2.565
SF7b-B-16	MnO	2.271	1.799	1.737	2.282	0.505
SF7b-B-16	Na <sub>2</sub> O	15.130	10.488	10.568	14.191	-6.201
SF7b-B-16	NiO	1.876	1.473	1.430	1.847	-1.551
SF7b-B-16	PbO	0.015	0.020	0.021	0.022	44.640
SF7b-B-16	SO <sub>4</sub>	0.900	0.285	0.295	0.870	-3.365
SF7b-B-16	SiO <sub>2</sub>	46.751	22.996	22.197	48.342	3.402
SF7b-B-16	TiO <sub>2</sub>	0.577	0.334	0.348	0.569	-1.326
SF7b-B-16	ZnO	0.011	0.018	0.019	0.023	102.842
SF7b-B-16	ZrO <sub>2</sub>	0.067	0.048	0.053	0.068	1.387

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-B-16	Sum	100.000	54.928	53.856	99.535	-0.465
SF7b-C-01	Al <sub>2</sub> O <sub>3</sub>	8.770	4.472	4.602	8.573	-2.254
SF7b-C-01	B <sub>2</sub> O <sub>3</sub>	5.120	1.476	1.477	4.754	-7.155
SF7b-C-01	BaO	0.041	0.039	0.039	0.043	5.873
SF7b-C-01	CaO	0.455	0.314	0.322	0.445	-2.165
SF7b-C-01	Ce <sub>2</sub> O <sub>3</sub>	0.081	0.069	0.070	0.081	-0.180
SF7b-C-01	Cr <sub>2</sub> O <sub>3</sub>	0.053	0.046	0.046	0.067	25.037
SF7b-C-01	CuO	0.023	0.027	0.025	0.033	42.355
SF7b-C-01	Fe <sub>2</sub> O <sub>3</sub>	10.377	7.190	7.250	10.323	-0.528
SF7b-C-01	K <sub>2</sub> O	0.057	0.056	0.057	0.068	19.166
SF7b-C-01	La <sub>2</sub> O <sub>3</sub>	0.013	0.005	0.005	0.006	-54.399
SF7b-C-01	Li <sub>2</sub> O	6.400	2.777	2.769	5.969	-6.731
SF7b-C-01	MgO	0.224	0.131	0.132	0.219	-2.496
SF7b-C-01	MnO	2.062	1.576	1.585	2.040	-1.066
SF7b-C-01	Na <sub>2</sub> O	13.962	9.833	10.153	13.471	-3.520
SF7b-C-01	NiO	1.753	1.321	1.337	1.691	-3.542
SF7b-C-01	PbO	0.012	0.020	0.015	0.019	58.009
SF7b-C-01	SO <sub>4</sub>	0.800	0.257	0.258	0.772	-3.526
SF7b-C-01	SiO <sub>2</sub>	49.719	23.772	23.767	50.851	2.276
SF7b-C-01	TiO <sub>2</sub>	0.008	0.017	0.011	0.024	210.263
SF7b-C-01	ZnO	0.009	0.016	0.014	0.019	108.535
SF7b-C-01	ZrO <sub>2</sub>	0.059	0.045	0.046	0.062	4.276
SF7b-C-01	Sum	100.000	53.459	53.980	99.527	-0.473
SF7b-C-02	Al <sub>2</sub> O <sub>3</sub>	9.767	5.448	5.089	9.955	1.922
SF7b-C-02	B <sub>2</sub> O <sub>3</sub>	4.800	1.429	1.448	4.632	-3.500
SF7b-C-02	BaO	0.045	0.044	0.042	0.048	6.163
SF7b-C-02	CaO	0.507	0.387	0.358	0.521	2.876
SF7b-C-02	Ce <sub>2</sub> O <sub>3</sub>	0.091	0.080	0.076	0.091	0.896
SF7b-C-02	Cr <sub>2</sub> O <sub>3</sub>	0.059	0.050	0.050	0.073	22.212
SF7b-C-02	CuO	0.025	0.024	0.023	0.029	15.233
SF7b-C-02	Fe <sub>2</sub> O <sub>3</sub>	11.557	8.228	8.360	11.859	2.615
SF7b-C-02	K <sub>2</sub> O	0.064	0.069	0.059	0.077	20.329
SF7b-C-02	La <sub>2</sub> O <sub>3</sub>	0.014	0.010	0.010	0.011	-20.168
SF7b-C-02	Li <sub>2</sub> O	6.000	2.677	2.734	5.823	-2.951
SF7b-C-02	MgO	0.250	0.159	0.152	0.258	3.419
SF7b-C-02	MnO	2.297	1.809	1.837	2.354	2.497
SF7b-C-02	Na <sub>2</sub> O	14.872	11.604	10.793	15.095	1.498
SF7b-C-02	NiO	1.953	1.480	1.512	1.904	-2.495
SF7b-C-02	PbO	0.013	0.014	0.014	0.015	13.119
SF7b-C-02	SO <sub>4</sub>	0.800	0.298	0.277	0.862	7.740
SF7b-C-02	SiO <sub>2</sub>	46.802	21.176	21.633	45.792	-2.158

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-C-02	TiO <sub>2</sub>	0.008	0.011	0.011	0.018	113.618
SF7b-C-02	ZnO	0.010	0.017	0.017	0.021	108.143
SF7b-C-02	ZrO <sub>2</sub>	0.066	0.059	0.056	0.077	17.146
SF7b-C-02	Sum	100.000	55.073	54.550	99.516	-0.484
SF7b-C-03	Al <sub>2</sub> O <sub>3</sub>	8.438	4.372	4.247	8.142	-3.506
SF7b-C-03	B <sub>2</sub> O <sub>3</sub>	5.120	1.526	1.499	4.869	-4.894
SF7b-C-03	BaO	0.040	0.035	0.034	0.039	-4.257
SF7b-C-03	CaO	0.451	0.312	0.302	0.430	-4.644
SF7b-C-03	Ce <sub>2</sub> O <sub>3</sub>	0.080	0.070	0.069	0.081	1.432
SF7b-C-03	Cr <sub>2</sub> O <sub>3</sub>	0.053	0.048	0.047	0.070	32.396
SF7b-C-03	CuO	0.023	0.023	0.023	0.029	29.071
SF7b-C-03	Fe <sub>2</sub> O <sub>3</sub>	10.078	6.797	6.804	9.723	-3.523
SF7b-C-03	K <sub>2</sub> O	0.057	0.049	0.046	0.057	1.628
SF7b-C-03	La <sub>2</sub> O <sub>3</sub>	0.013	0.012	0.011	0.013	-0.941
SF7b-C-03	Li <sub>2</sub> O	6.400	2.768	2.781	5.972	-6.685
SF7b-C-03	MgO	0.215	0.131	0.129	0.216	0.627
SF7b-C-03	MnO	2.044	1.550	1.554	2.004	-2.002
SF7b-C-03	Na <sub>2</sub> O	14.220	10.186	9.869	13.517	-4.943
SF7b-C-03	NiO	1.689	1.258	1.260	1.602	-5.148
SF7b-C-03	PbO	0.014	0.016	0.015	0.017	23.151
SF7b-C-03	SO <sub>4</sub>	0.800	0.266	0.266	0.797	-0.429
SF7b-C-03	SiO <sub>2</sub>	49.676	23.446	23.481	50.196	1.046
SF7b-C-03	TiO <sub>2</sub>	0.519	0.318	0.311	0.525	1.162
SF7b-C-03	ZnO	0.010	0.017	0.016	0.021	104.772
SF7b-C-03	ZrO <sub>2</sub>	0.060	0.050	0.048	0.066	10.077
SF7b-C-03	Sum	100.000	53.249	52.814	98.386	-1.614
SF7b-C-04	Al <sub>2</sub> O <sub>3</sub>	9.397	4.777	4.736	8.988	-4.353
SF7b-C-04	B <sub>2</sub> O <sub>3</sub>	4.800	1.398	1.387	4.484	-6.589
SF7b-C-04	BaO	0.045	0.040	0.041	0.046	1.289
SF7b-C-04	CaO	0.502	0.338	0.339	0.474	-5.633
SF7b-C-04	Ce <sub>2</sub> O <sub>3</sub>	0.089	0.074	0.076	0.088	-1.231
SF7b-C-04	Cr <sub>2</sub> O <sub>3</sub>	0.059	0.047	0.049	0.070	19.825
SF7b-C-04	CuO	0.025	0.024	0.024	0.030	19.021
SF7b-C-04	Fe <sub>2</sub> O <sub>3</sub>	11.223	7.781	7.724	11.084	-1.240
SF7b-C-04	K <sub>2</sub> O	0.063	0.054	0.049	0.062	-1.135
SF7b-C-04	La <sub>2</sub> O <sub>3</sub>	0.015	0.014	0.014	0.016	8.121
SF7b-C-04	Li <sub>2</sub> O	6.000	2.581	2.561	5.533	-7.776
SF7b-C-04	MgO	0.239	0.139	0.144	0.235	-1.791
SF7b-C-04	MnO	2.277	1.731	1.731	2.235	-1.846
SF7b-C-04	Na <sub>2</sub> O	15.159	10.749	10.613	14.397	-5.025
SF7b-C-04	NiO	1.881	1.438	1.442	1.832	-2.603

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-C-04	PbO	0.015	0.018	0.018	0.019	28.547
SF7b-C-04	SO <sub>4</sub>	0.800	0.260	0.259	0.779	-2.683
SF7b-C-04	SiO <sub>2</sub>	46.754	22.015	22.218	47.314	1.198
SF7b-C-04	TiO <sub>2</sub>	0.578	0.340	0.350	0.576	-0.347
SF7b-C-04	ZnO	0.011	0.016	0.016	0.020	79.075
SF7b-C-04	ZrO <sub>2</sub>	0.067	0.051	0.052	0.069	3.385
SF7b-C-04	Sum	100.000	53.886	53.843	98.352	-1.648
SF7b-C-05	Al <sub>2</sub> O <sub>3</sub>	8.507	4.498	4.506	8.507	0.001
SF7b-C-05	B <sub>2</sub> O <sub>3</sub>	5.120	1.612	1.602	5.175	1.079
SF7b-C-05	BaO	0.040	0.034	0.034	0.038	-3.775
SF7b-C-05	CaO	0.441	0.331	0.310	0.448	1.497
SF7b-C-05	Ce <sub>2</sub> O <sub>3</sub>	0.079	0.068	0.069	0.080	1.788
SF7b-C-05	Cr <sub>2</sub> O <sub>3</sub>	0.052	0.048	0.048	0.070	35.685
SF7b-C-05	CuO	0.022	0.024	0.024	0.030	33.449
SF7b-C-05	Fe <sub>2</sub> O <sub>3</sub>	10.065	7.844	7.873	11.236	11.629
SF7b-C-05	K <sub>2</sub> O	0.056	0.039	0.039	0.047	-15.547
SF7b-C-05	La <sub>2</sub> O <sub>3</sub>	0.012	0.005	0.005	0.006	-52.985
SF7b-C-05	Li <sub>2</sub> O	6.400	2.711	2.710	5.835	-8.832
SF7b-C-05	MgO	0.218	0.126	0.130	0.213	-2.188
SF7b-C-05	MnO	2.000	1.527	1.483	1.943	-2.866
SF7b-C-05	Na <sub>2</sub> O	14.716	11.204	11.279	15.153	2.969
SF7b-C-05	NiO	1.701	1.488	1.447	1.867	9.806
SF7b-C-05	PbO	0.011	0.014	0.014	0.015	32.508
SF7b-C-05	SO <sub>4</sub>	0.800	0.265	0.267	0.797	-0.362
SF7b-C-05	SiO <sub>2</sub>	49.687	22.448	22.533	48.114	-3.164
SF7b-C-05	TiO <sub>2</sub>	0.007	0.005	0.005	0.008	13.242
SF7b-C-05	ZnO	0.009	0.018	0.017	0.022	151.859
SF7b-C-05	ZrO <sub>2</sub>	0.057	0.042	0.043	0.058	0.623
SF7b-C-05	Sum	100.000	54.349	54.441	99.663	-0.337
SF7b-C-06	Al <sub>2</sub> O <sub>3</sub>	9.473	4.776	4.758	9.007	-4.922
SF7b-C-06	B <sub>2</sub> O <sub>3</sub>	4.800	1.413	1.402	4.531	-5.599
SF7b-C-06	BaO	0.044	0.036	0.036	0.040	-8.840
SF7b-C-06	CaO	0.492	0.329	0.324	0.457	-7.054
SF7b-C-06	Ce <sub>2</sub> O <sub>3</sub>	0.088	0.073	0.072	0.085	-3.732
SF7b-C-06	Cr <sub>2</sub> O <sub>3</sub>	0.058	0.045	0.045	0.065	13.189
SF7b-C-06	CuO	0.025	0.026	0.028	0.034	37.290
SF7b-C-06	Fe <sub>2</sub> O <sub>3</sub>	11.209	7.484	7.482	10.699	-4.550
SF7b-C-06	K <sub>2</sub> O	0.062	0.047	0.043	0.055	-11.642
SF7b-C-06	La <sub>2</sub> O <sub>3</sub>	0.014	0.005	0.005	0.006	-57.782
SF7b-C-06	Li <sub>2</sub> O	6.000	2.769	2.780	5.973	-0.455
SF7b-C-06	MgO	0.242	0.135	0.134	0.223	-7.847



**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-C-06	MnO	2.228	1.608	1.585	2.062	-7.435
SF7b-C-06	Na <sub>2</sub> O	15.712	11.281	11.346	15.250	-2.940
SF7b-C-06	NiO	1.894	1.287	1.266	1.625	-14.217
SF7b-C-06	PbO	0.013	0.011	0.012	0.013	0.022
SF7b-C-06	SO <sub>4</sub>	0.800	0.252	0.246	0.745	-6.928
SF7b-C-06	SiO <sub>2</sub>	46.765	22.782	22.652	48.599	3.921
SF7b-C-06	TiO <sub>2</sub>	0.008	0.011	0.011	0.018	116.023
SF7b-C-06	ZnO	0.010	0.016	0.016	0.020	98.565
SF7b-C-06	ZrO <sub>2</sub>	0.064	0.051	0.048	0.067	4.394
SF7b-C-06	Sum	100.000	54.436	54.291	99.572	-0.428
SF7b-C-07	Al <sub>2</sub> O <sub>3</sub>	8.189	4.356	4.247	8.128	-0.749
SF7b-C-07	B <sub>2</sub> O <sub>3</sub>	5.120	1.517	1.532	4.909	-4.131
SF7b-C-07	BaO	0.039	0.034	0.033	0.037	-4.520
SF7b-C-07	CaO	0.438	0.310	0.304	0.430	-1.835
SF7b-C-07	Ce <sub>2</sub> O <sub>3</sub>	0.078	0.068	0.066	0.079	0.633
SF7b-C-07	Cr <sub>2</sub> O <sub>3</sub>	0.051	0.039	0.038	0.057	10.553
SF7b-C-07	CuO	0.022	0.028	0.023	0.032	44.023
SF7b-C-07	Fe <sub>2</sub> O <sub>3</sub>	9.783	6.957	6.762	9.808	0.253
SF7b-C-07	K <sub>2</sub> O	0.055	0.041	0.038	0.047	-13.653
SF7b-C-07	La <sub>2</sub> O <sub>3</sub>	0.013	0.005	0.005	0.006	-55.336
SF7b-C-07	Li <sub>2</sub> O	6.400	2.788	2.836	6.054	-5.410
SF7b-C-07	MgO	0.208	0.124	0.122	0.204	-2.015
SF7b-C-07	MnO	1.986	1.468	1.508	1.921	-3.242
SF7b-C-07	Na <sub>2</sub> O	14.934	11.092	10.780	14.741	-1.291
SF7b-C-07	NiO	1.639	1.253	1.278	1.611	-1.731
SF7b-C-07	PbO	0.013	0.013	0.013	0.014	4.740
SF7b-C-07	SO <sub>4</sub>	0.800	0.015	0.013	0.042	-94.744
SF7b-C-07	SiO <sub>2</sub>	49.646	23.974	23.345	50.615	1.952
SF7b-C-07	TiO <sub>2</sub>	0.517	0.309	0.301	0.509	-1.657
SF7b-C-07	ZnO	0.010	0.017	0.017	0.021	115.792
SF7b-C-07	ZrO <sub>2</sub>	0.058	0.042	0.042	0.057	-3.175
SF7b-C-07	Sum	100.000	54.448	53.306	99.319	-0.681
SF7b-C-08	Al <sub>2</sub> O <sub>3</sub>	9.119	4.713	4.685	8.879	-2.638
SF7b-C-08	B <sub>2</sub> O <sub>3</sub>	4.800	1.420	1.431	4.590	-4.384
SF7b-C-08	BaO	0.044	0.037	0.037	0.041	-6.406
SF7b-C-08	CaO	0.488	0.336	0.333	0.468	-4.076
SF7b-C-08	Ce <sub>2</sub> O <sub>3</sub>	0.087	0.072	0.072	0.084	-3.375
SF7b-C-08	Cr <sub>2</sub> O <sub>3</sub>	0.057	0.044	0.045	0.065	14.010
SF7b-C-08	CuO	0.024	0.037	0.033	0.044	78.891
SF7b-C-08	Fe <sub>2</sub> O <sub>3</sub>	10.894	7.328	7.397	10.526	-3.379
SF7b-C-08	K <sub>2</sub> O	0.061	0.046	0.043	0.054	-11.561

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-C-08	La <sub>2</sub> O <sub>3</sub>	0.015	0.010	0.010	0.012	-17.477
SF7b-C-08	Li <sub>2</sub> O	6.000	2.648	2.150	5.164	-13.931
SF7b-C-08	MgO	0.232	0.133	0.135	0.222	-4.252
SF7b-C-08	MnO	2.211	1.601	1.636	2.090	-5.492
SF7b-C-08	Na <sub>2</sub> O	15.955	11.926	11.877	16.043	0.553
SF7b-C-08	NiO	1.826	1.251	1.311	1.630	-10.733
SF7b-C-08	PbO	0.015	0.015	0.013	0.015	5.054
SF7b-C-08	SO <sub>4</sub>	0.800	0.256	0.253	0.761	-4.825
SF7b-C-08	SiO <sub>2</sub>	46.720	22.094	22.032	47.201	1.028
SF7b-C-08	TiO <sub>2</sub>	0.576	0.328	0.332	0.551	-4.324
SF7b-C-08	ZnO	0.011	0.022	0.022	0.027	146.711
SF7b-C-08	ZrO <sub>2</sub>	0.065	0.047	0.047	0.063	-2.576
SF7b-C-08	Sum	100.000	54.365	53.892	98.530	-1.470
SF7b-C-09	Al <sub>2</sub> O <sub>3</sub>	8.482	4.114	4.090	7.751	-8.627
SF7b-C-09	B <sub>2</sub> O <sub>3</sub>	5.120	1.386	1.369	4.437	-13.348
SF7b-C-09	BaO	0.039	0.037	0.037	0.041	4.965
SF7b-C-09	CaO	0.440	0.277	0.278	0.388	-11.744
SF7b-C-09	Ce <sub>2</sub> O <sub>3</sub>	0.079	0.063	0.062	0.073	-7.110
SF7b-C-09	Cr <sub>2</sub> O <sub>3</sub>	0.052	0.044	0.044	0.064	23.750
SF7b-C-09	CuO	0.022	0.022	0.022	0.028	25.297
SF7b-C-09	Fe <sub>2</sub> O <sub>3</sub>	10.037	7.688	7.606	10.933	8.934
SF7b-C-09	K <sub>2</sub> O	0.055	0.051	0.048	0.060	7.659
SF7b-C-09	La <sub>2</sub> O <sub>3</sub>	0.012	0.012	0.012	0.014	9.226
SF7b-C-09	Li <sub>2</sub> O	6.400	2.581	2.586	5.561	-13.104
SF7b-C-09	MgO	0.217	0.125	0.123	0.206	-5.241
SF7b-C-09	MnO	1.995	1.706	1.687	2.190	9.805
SF7b-C-09	Na <sub>2</sub> O	14.685	9.880	9.735	13.220	-9.980
SF7b-C-09	NiO	1.696	1.407	1.388	1.779	4.890
SF7b-C-09	PbO	0.011	0.015	0.015	0.016	43.202
SF7b-C-09	SO <sub>4</sub>	0.900	0.282	0.281	0.844	-6.236
SF7b-C-09	SiO <sub>2</sub>	49.684	22.225	22.170	47.488	-4.420
SF7b-C-09	TiO <sub>2</sub>	0.007	0.012	0.012	0.019	163.821
SF7b-C-09	ZnO	0.009	0.014	0.014	0.017	98.106
SF7b-C-09	ZrO <sub>2</sub>	0.057	0.045	0.045	0.061	6.392
SF7b-C-09	Sum	100.000	51.985	51.624	95.190	-4.810
SF7b-C-10	Al <sub>2</sub> O <sub>3</sub>	9.449	4.819	4.841	9.126	-3.418
SF7b-C-10	B <sub>2</sub> O <sub>3</sub>	4.800	1.375	1.360	4.403	-8.272
SF7b-C-10	BaO	0.044	0.038	0.038	0.043	-3.304
SF7b-C-10	CaO	0.490	0.338	0.338	0.473	-3.562
SF7b-C-10	Ce <sub>2</sub> O <sub>3</sub>	0.088	0.074	0.073	0.086	-1.791
SF7b-C-10	Cr <sub>2</sub> O <sub>3</sub>	0.058	0.051	0.057	0.079	37.237

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-C-10	CuO	0.025	0.027	0.026	0.033	34.355
SF7b-C-10	Fe <sub>2</sub> O <sub>3</sub>	11.180	7.575	7.582	10.835	-3.089
SF7b-C-10	K <sub>2</sub> O	0.062	0.071	0.059	0.078	26.470
SF7b-C-10	La <sub>2</sub> O <sub>3</sub>	0.014	0.014	0.013	0.016	14.000
SF7b-C-10	Li <sub>2</sub> O	6.000	2.585	2.602	5.583	-6.946
SF7b-C-10	MgO	0.242	0.145	0.141	0.237	-1.727
SF7b-C-10	MnO	2.222	1.689	1.681	2.176	-2.068
SF7b-C-10	Na <sub>2</sub> O	15.681	11.018	11.157	14.945	-4.695
SF7b-C-10	NiO	1.889	1.389	1.384	1.765	-6.580
SF7b-C-10	PbO	0.013	0.015	0.012	0.015	14.737
SF7b-C-10	SO <sub>4</sub>	0.900	0.309	0.297	0.907	0.762
SF7b-C-10	SiO <sub>2</sub>	46.762	22.224	22.181	47.498	1.574
SF7b-C-10	TiO <sub>2</sub>	0.008	0.013	0.011	0.020	140.461
SF7b-C-10	ZnO	0.010	0.026	0.023	0.030	210.360
SF7b-C-10	ZrO <sub>2</sub>	0.064	0.074	0.051	0.085	32.637
SF7b-C-10	Sum	100.000	53.868	53.927	98.432	-1.568
SF7b-C-11	Al <sub>2</sub> O <sub>3</sub>	8.166	4.187	4.315	8.032	-1.637
SF7b-C-11	B <sub>2</sub> O <sub>3</sub>	5.120	1.465	1.457	4.703	-8.137
SF7b-C-11	BaO	0.039	0.034	0.035	0.039	-0.558
SF7b-C-11	CaO	0.437	0.308	0.314	0.435	-0.469
SF7b-C-11	Ce <sub>2</sub> O <sub>3</sub>	0.078	0.069	0.070	0.081	4.326
SF7b-C-11	Cr <sub>2</sub> O <sub>3</sub>	0.051	0.047	0.049	0.070	37.053
SF7b-C-11	CuO	0.022	0.025	0.025	0.031	41.076
SF7b-C-11	Fe <sub>2</sub> O <sub>3</sub>	9.755	6.586	6.577	9.410	-3.537
SF7b-C-11	K <sub>2</sub> O	0.055	0.047	0.050	0.058	6.824
SF7b-C-11	La <sub>2</sub> O <sub>3</sub>	0.013	0.014	0.014	0.017	26.933
SF7b-C-11	Li <sub>2</sub> O	6.400	2.788	2.769	5.981	-6.548
SF7b-C-11	MgO	0.208	0.126	0.129	0.212	1.999
SF7b-C-11	MnO	1.980	1.490	1.490	1.924	-2.832
SF7b-C-11	Na <sub>2</sub> O	14.903	10.478	10.917	14.420	-3.240
SF7b-C-11	NiO	1.635	1.191	1.191	1.516	-7.292
SF7b-C-11	PbO	0.013	0.015	0.016	0.017	26.818
SF7b-C-11	SO <sub>4</sub>	0.900	0.308	0.313	0.929	3.224
SF7b-C-11	SiO <sub>2</sub>	49.643	23.816	23.578	50.695	2.120
SF7b-C-11	TiO <sub>2</sub>	0.516	0.316	0.324	0.534	3.450
SF7b-C-11	ZnO	0.010	0.023	0.022	0.028	189.404
SF7b-C-11	ZrO <sub>2</sub>	0.058	0.048	0.049	0.066	13.020
SF7b-C-11	Sum	100.000	53.379	53.704	99.197	-0.803
SF7b-C-12	Al <sub>2</sub> O <sub>3</sub>	9.096	4.614	4.562	8.669	-4.693
SF7b-C-12	B <sub>2</sub> O <sub>3</sub>	4.800	1.357	1.353	4.364	-9.087
SF7b-C-12	BaO	0.044	0.040	0.039	0.044	1.282

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-C-12	CaO	0.486	0.332	0.350	0.477	-1.948
SF7b-C-12	Ce <sub>2</sub> O <sub>3</sub>	0.087	0.074	0.073	0.086	-0.609
SF7b-C-12	Cr <sub>2</sub> O <sub>3</sub>	0.057	0.051	0.049	0.073	28.012
SF7b-C-12	CuO	0.024	0.024	0.025	0.030	25.150
SF7b-C-12	Fe <sub>2</sub> O <sub>3</sub>	10.867	7.432	7.428	10.623	-2.245
SF7b-C-12	K <sub>2</sub> O	0.061	0.054	0.054	0.065	6.307
SF7b-C-12	La <sub>2</sub> O <sub>3</sub>	0.015	0.015	0.015	0.017	17.583
SF7b-C-12	Li <sub>2</sub> O	6.000	2.583	2.554	5.529	-7.850
SF7b-C-12	MgO	0.231	0.137	0.135	0.226	-2.325
SF7b-C-12	MnO	2.206	1.665	1.666	2.150	-2.511
SF7b-C-12	Na <sub>2</sub> O	15.923	11.154	10.996	14.929	-6.246
SF7b-C-12	NiO	1.821	1.352	1.347	1.717	-5.687
SF7b-C-12	PbO	0.015	0.016	0.016	0.017	18.276
SF7b-C-12	SO <sub>4</sub>	0.900	0.306	0.307	0.918	2.003
SF7b-C-12	SiO <sub>2</sub>	46.717	22.113	22.188	47.387	1.434
SF7b-C-12	TiO <sub>2</sub>	0.575	0.347	0.340	0.573	-0.232
SF7b-C-12	ZnO	0.011	0.018	0.018	0.022	100.191
SF7b-C-12	ZrO <sub>2</sub>	0.065	0.054	0.045	0.067	3.185
SF7b-C-12	Sum	100.000	53.737	53.560	97.985	-2.015
SF7b-C-13	Al <sub>2</sub> O <sub>3</sub>	8.507	4.774	4.819	9.064	6.548
SF7b-C-13	B <sub>2</sub> O <sub>3</sub>	5.120	1.361	1.358	4.378	-14.499
SF7b-C-13	BaO	0.040	0.042	0.042	0.047	18.449
SF7b-C-13	CaO	0.441	0.340	0.343	0.478	8.187
SF7b-C-13	Ce <sub>2</sub> O <sub>3</sub>	0.079	0.074	0.075	0.088	11.176
SF7b-C-13	Cr <sub>2</sub> O <sub>3</sub>	0.052	0.046	0.047	0.067	29.929
SF7b-C-13	CuO	0.022	0.028	0.026	0.034	53.325
SF7b-C-13	Fe <sub>2</sub> O <sub>3</sub>	10.065	7.597	7.568	10.841	7.709
SF7b-C-13	K <sub>2</sub> O	0.056	0.052	0.056	0.065	17.139
SF7b-C-13	La <sub>2</sub> O <sub>3</sub>	0.012	0.015	0.015	0.018	41.064
SF7b-C-13	Li <sub>2</sub> O	5.120	2.027	2.039	4.376	-14.541
SF7b-C-13	MgO	0.218	0.145	0.147	0.242	11.296
SF7b-C-13	MnO	2.000	1.696	1.686	2.183	9.157
SF7b-C-13	Na <sub>2</sub> O	15.996	11.946	12.011	16.147	0.943
SF7b-C-13	NiO	1.701	1.417	1.395	1.789	5.203
SF7b-C-13	PbO	0.011	0.016	0.016	0.017	51.808
SF7b-C-13	SO <sub>4</sub>	0.800	0.279	0.286	0.845	5.625
SF7b-C-13	SiO <sub>2</sub>	49.687	22.319	22.254	47.679	-4.041
SF7b-C-13	TiO <sub>2</sub>	0.007	0.011	0.011	0.018	146.051
SF7b-C-13	ZnO	0.009	0.019	0.019	0.024	167.746
SF7b-C-13	ZrO <sub>2</sub>	0.057	0.049	0.053	0.069	19.710
SF7b-C-13	Sum	100.000	54.253	54.265	98.467	-1.533

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-C-14	Al <sub>2</sub> O <sub>3</sub>	9.473	4.278	4.479	8.273	-12.670
SF7b-C-14	B <sub>2</sub> O <sub>3</sub>	4.800	1.430	1.445	4.630	-3.550
SF7b-C-14	BaO	0.044	0.037	0.038	0.042	-5.295
SF7b-C-14	CaO	0.492	0.300	0.313	0.429	-12.821
SF7b-C-14	Ce <sub>2</sub> O <sub>3</sub>	0.088	0.069	0.071	0.082	-6.472
SF7b-C-14	Cr <sub>2</sub> O <sub>3</sub>	0.058	0.044	0.046	0.066	13.868
SF7b-C-14	CuO	0.025	0.023	0.026	0.030	22.401
SF7b-C-14	Fe <sub>2</sub> O <sub>3</sub>	11.209	6.916	6.884	9.865	-11.987
SF7b-C-14	K <sub>2</sub> O	0.062	0.046	0.048	0.057	-8.400
SF7b-C-14	La <sub>2</sub> O <sub>3</sub>	0.014	0.010	0.011	0.012	-10.938
SF7b-C-14	Li <sub>2</sub> O	4.800	2.157	2.199	4.689	-2.310
SF7b-C-14	MgO	0.242	0.136	0.141	0.229	-5.421
SF7b-C-14	MnO	2.228	1.531	1.520	1.970	-11.574
SF7b-C-14	Na <sub>2</sub> O	16.912	11.161	11.641	15.368	-9.129
SF7b-C-14	NiO	1.894	1.257	1.261	1.602	-15.403
SF7b-C-14	PbO	0.013	0.012	0.013	0.013	4.113
SF7b-C-14	SO <sub>4</sub>	0.800	0.271	0.273	0.815	1.928
SF7b-C-14	SiO <sub>2</sub>	46.765	23.323	23.707	50.306	7.571
SF7b-C-14	TiO <sub>2</sub>	0.008	0.009	0.010	0.016	93.774
SF7b-C-14	ZnO	0.010	0.020	0.021	0.025	158.686
SF7b-C-14	ZrO <sub>2</sub>	0.064	0.046	0.046	0.062	-2.366
SF7b-C-14	Sum	100.000	53.077	54.192	98.582	-1.418
SF7b-C-15	Al <sub>2</sub> O <sub>3</sub>	8.189	4.192	4.199	7.926	-3.205
SF7b-C-15	B <sub>2</sub> O <sub>3</sub>	5.120	1.445	1.439	4.644	-9.306
SF7b-C-15	BaO	0.039	0.035	0.035	0.039	-1.102
SF7b-C-15	CaO	0.438	0.297	0.297	0.415	-5.149
SF7b-C-15	Ce <sub>2</sub> O <sub>3</sub>	0.078	0.069	0.069	0.080	3.190
SF7b-C-15	Cr <sub>2</sub> O <sub>3</sub>	0.051	0.046	0.046	0.067	30.816
SF7b-C-15	CuO	0.022	0.020	0.020	0.025	12.758
SF7b-C-15	Fe <sub>2</sub> O <sub>3</sub>	9.783	6.703	6.744	9.613	-1.733
SF7b-C-15	K <sub>2</sub> O	0.055	0.046	0.046	0.056	1.302
SF7b-C-15	La <sub>2</sub> O <sub>3</sub>	0.013	0.012	0.012	0.014	4.862
SF7b-C-15	Li <sub>2</sub> O	5.120	2.191	2.165	4.688	-8.428
SF7b-C-15	MgO	0.208	0.127	0.127	0.211	1.157
SF7b-C-15	MnO	1.986	1.503	1.512	1.946	-1.980
SF7b-C-15	Na <sub>2</sub> O	16.214	11.336	11.307	15.261	-5.879
SF7b-C-15	NiO	1.639	1.223	1.243	1.569	-4.275
SF7b-C-15	PbO	0.013	0.020	0.019	0.021	61.026
SF7b-C-15	SO <sub>4</sub>	0.800	0.270	0.271	0.810	1.260
SF7b-C-15	SiO <sub>2</sub>	49.646	23.614	23.679	50.588	1.898
SF7b-C-15	TiO <sub>2</sub>	0.517	0.318	0.321	0.533	3.111

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-C-15	ZnO	0.010	0.018	0.018	0.022	125.215
SF7b-C-15	ZrO <sub>2</sub>	0.058	0.048	0.048	0.065	11.736
SF7b-C-15	Sum	100.000	53.532	53.617	98.595	-1.405
SF7b-C-16	Al <sub>2</sub> O <sub>3</sub>	9.119	5.095	4.583	9.144	0.267
SF7b-C-16	B <sub>2</sub> O <sub>3</sub>	4.800	1.336	1.326	4.285	-10.734
SF7b-C-16	BaO	0.044	0.041	0.041	0.046	4.445
SF7b-C-16	CaO	0.488	0.349	0.333	0.477	-2.147
SF7b-C-16	Ce <sub>2</sub> O <sub>3</sub>	0.087	0.077	0.077	0.090	3.950
SF7b-C-16	Cr <sub>2</sub> O <sub>3</sub>	0.057	0.067	0.050	0.086	50.326
SF7b-C-16	CuO	0.024	0.026	0.026	0.032	32.341
SF7b-C-16	Fe <sub>2</sub> O <sub>3</sub>	10.894	7.479	7.496	10.705	-1.736
SF7b-C-16	K <sub>2</sub> O	0.061	0.052	0.051	0.062	1.387
SF7b-C-16	La <sub>2</sub> O <sub>3</sub>	0.015	0.013	0.013	0.015	4.701
SF7b-C-16	Li <sub>2</sub> O	4.800	2.036	2.022	4.368	-9.005
SF7b-C-16	MgO	0.232	0.141	0.141	0.234	0.878
SF7b-C-16	MnO	2.211	1.661	1.667	2.149	-2.815
SF7b-C-16	Na <sub>2</sub> O	17.155	12.000	11.945	16.139	-5.923
SF7b-C-16	NiO	1.826	1.368	1.370	1.742	-4.574
SF7b-C-16	PbO	0.015	0.016	0.016	0.017	18.897
SF7b-C-16	SO <sub>4</sub>	0.800	0.270	0.277	0.819	2.346
SF7b-C-16	SiO <sub>2</sub>	46.720	21.907	22.109	47.083	0.776
SF7b-C-16	TiO <sub>2</sub>	0.576	0.355	0.355	0.593	2.905
SF7b-C-16	ZnO	0.011	0.017	0.017	0.021	95.604
SF7b-C-16	ZrO <sub>2</sub>	0.065	0.054	0.047	0.068	4.383
SF7b-C-16	Sum	100.000	54.360	53.964	98.175	-1.825
SF7b-D-01	Al <sub>2</sub> O <sub>3</sub>	9.087	4.639	4.702	8.825	-2.887
SF7b-D-01	B <sub>2</sub> O <sub>3</sub>	5.120	1.474	1.501	4.789	-6.459
SF7b-D-01	BaO	0.042	0.036	0.036	0.040	-4.774
SF7b-D-01	CaO	0.472	0.333	0.343	0.473	0.336
SF7b-D-01	Ce <sub>2</sub> O <sub>3</sub>	0.084	0.071	0.071	0.083	-1.214
SF7b-D-01	Cr <sub>2</sub> O <sub>3</sub>	0.055	0.039	0.039	0.057	3.786
SF7b-D-01	CuO	0.024	0.032	0.031	0.040	67.983
SF7b-D-01	Fe <sub>2</sub> O <sub>3</sub>	10.752	7.299	7.301	10.437	-2.933
SF7b-D-01	K <sub>2</sub> O	0.059	0.042	0.041	0.050	-15.327
SF7b-D-01	La <sub>2</sub> O <sub>3</sub>	0.013	0.005	0.005	0.006	-55.989
SF7b-D-01	Li <sub>2</sub> O	5.120	2.240	2.267	4.851	-5.260
SF7b-D-01	MgO	0.232	0.135	0.133	0.222	-4.365
SF7b-D-01	MnO	2.137	1.732	1.735	2.238	4.756
SF7b-D-01	Na <sub>2</sub> O	14.536	11.860	12.031	16.102	10.774
SF7b-D-01	NiO	1.817	1.423	1.431	1.816	-0.048
SF7b-D-01	PbO	0.012	0.011	0.011	0.012	-2.389

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-D-01	SO <sub>4</sub>	0.600	0.187	0.182	0.553	-7.806
SF7b-D-01	SiO <sub>2</sub>	49.758	23.200	23.427	49.875	0.236
SF7b-D-01	TiO <sub>2</sub>	0.008	0.011	0.011	0.019	138.491
SF7b-D-01	ZnO	0.009	0.018	0.019	0.023	141.422
SF7b-D-01	ZrO <sub>2</sub>	0.061	0.049	0.049	0.066	7.058
SF7b-D-01	Sum	100.000	54.837	55.367	100.578	0.578
SF7b-D-02	Al <sub>2</sub> O <sub>3</sub>	10.114	5.202	5.080	9.714	-3.950
SF7b-D-02	B <sub>2</sub> O <sub>3</sub>	4.800	1.414	1.364	4.473	-6.814
SF7b-D-02	BaO	0.047	0.040	0.041	0.045	-4.753
SF7b-D-02	CaO	0.525	0.363	0.388	0.525	0.039
SF7b-D-02	Ce <sub>2</sub> O <sub>3</sub>	0.094	0.075	0.077	0.089	-5.227
SF7b-D-02	Cr <sub>2</sub> O <sub>3</sub>	0.062	0.049	0.050	0.072	16.856
SF7b-D-02	CuO	0.026	0.028	0.033	0.038	43.773
SF7b-D-02	Fe <sub>2</sub> O <sub>3</sub>	11.967	8.329	7.967	11.650	-2.655
SF7b-D-02	K <sub>2</sub> O	0.066	0.071	0.069	0.084	27.459
SF7b-D-02	La <sub>2</sub> O <sub>3</sub>	0.015	0.014	0.014	0.017	11.329
SF7b-D-02	Li <sub>2</sub> O	4.800	2.134	2.096	4.552	-5.168
SF7b-D-02	MgO	0.259	0.149	0.150	0.248	-4.062
SF7b-D-02	MnO	2.378	1.981	1.903	2.508	5.456
SF7b-D-02	Na <sub>2</sub> O	15.280	12.726	12.643	17.099	11.903
SF7b-D-02	NiO	2.022	1.705	1.628	2.121	4.888
SF7b-D-02	PbO	0.014	0.013	0.013	0.014	3.903
SF7b-D-02	SO <sub>4</sub>	0.600	0.194	0.199	0.589	-1.898
SF7b-D-02	SiO <sub>2</sub>	46.844	22.364	21.055	46.444	-0.855
SF7b-D-02	TiO <sub>2</sub>	0.009	0.009	0.010	0.016	81.553
SF7b-D-02	ZnO	0.010	0.018	0.020	0.024	125.233
SF7b-D-02	ZrO <sub>2</sub>	0.068	0.052	0.052	0.070	2.546
SF7b-D-02	Sum	100.000	56.930	54.851	100.390	0.390
SF7b-D-03	Al <sub>2</sub> O <sub>3</sub>	8.738	4.518	4.504	8.524	-2.448
SF7b-D-03	B <sub>2</sub> O <sub>3</sub>	5.120	1.514	1.494	4.844	-5.398
SF7b-D-03	BaO	0.042	0.034	0.034	0.038	-9.839
SF7b-D-03	CaO	0.467	0.367	0.384	0.525	12.560
SF7b-D-03	Ce <sub>2</sub> O <sub>3</sub>	0.083	0.067	0.067	0.079	-5.092
SF7b-D-03	Cr <sub>2</sub> O <sub>3</sub>	0.055	0.049	0.049	0.072	31.458
SF7b-D-03	CuO	0.023	0.034	0.037	0.045	91.920
SF7b-D-03	Fe <sub>2</sub> O <sub>3</sub>	10.434	7.173	7.025	10.150	-2.724
SF7b-D-03	K <sub>2</sub> O	0.059	0.062	0.065	0.077	30.918
SF7b-D-03	La <sub>2</sub> O <sub>3</sub>	0.014	0.010	0.005	0.009	-38.997
SF7b-D-03	Li <sub>2</sub> O	5.120	2.240	2.217	4.797	-6.305
SF7b-D-03	MgO	0.222	0.127	0.126	0.209	-5.813
SF7b-D-03	MnO	2.116	1.723	1.711	2.217	4.791

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-D-03	Na <sub>2</sub> O	14.835	12.360	12.302	16.622	12.042
SF7b-D-03	NiO	1.749	1.416	1.402	1.793	2.485
SF7b-D-03	PbO	0.014	0.013	0.012	0.014	-2.677
SF7b-D-03	SO <sub>4</sub>	0.600	0.192	0.189	0.571	-4.775
SF7b-D-03	SiO <sub>2</sub>	49.713	23.322	23.076	49.630	-0.167
SF7b-D-03	TiO <sub>2</sub>	0.524	0.300	0.297	0.498	-4.999
SF7b-D-03	ZnO	0.010	0.019	0.020	0.024	131.836
SF7b-D-03	ZrO <sub>2</sub>	0.062	0.046	0.046	0.062	-0.893
SF7b-D-03	Sum	100.000	55.586	55.061	100.797	0.797
SF7b-D-04	Al <sub>2</sub> O <sub>3</sub>	9.725	5.040	4.992	9.478	-2.549
SF7b-D-04	B <sub>2</sub> O <sub>3</sub>	4.800	1.411	1.400	4.525	-5.728
SF7b-D-04	BaO	0.046	0.037	0.036	0.041	-12.412
SF7b-D-04	CaO	0.519	0.390	0.384	0.542	4.285
SF7b-D-04	Ce <sub>2</sub> O <sub>3</sub>	0.093	0.076	0.076	0.089	-3.791
SF7b-D-04	Cr <sub>2</sub> O <sub>3</sub>	0.061	0.045	0.045	0.066	8.574
SF7b-D-04	CuO	0.026	0.026	0.026	0.033	25.864
SF7b-D-04	Fe <sub>2</sub> O <sub>3</sub>	11.613	8.119	8.167	11.643	0.256
SF7b-D-04	K <sub>2</sub> O	0.065	0.064	0.065	0.078	19.038
SF7b-D-04	La <sub>2</sub> O <sub>3</sub>	0.016	0.005	0.005	0.006	-62.226
SF7b-D-04	Li <sub>2</sub> O	4.800	2.116	2.110	4.548	-5.243
SF7b-D-04	MgO	0.247	0.142	0.139	0.233	-5.912
SF7b-D-04	MnO	2.355	1.915	1.907	2.468	4.804
SF7b-D-04	Na <sub>2</sub> O	15.613	13.178	13.114	17.720	13.497
SF7b-D-04	NiO	1.947	1.558	1.534	1.967	1.049
SF7b-D-04	PbO	0.016	0.015	0.015	0.016	3.870
SF7b-D-04	SO <sub>4</sub>	0.600	0.197	0.193	0.583	-2.783
SF7b-D-04	SiO <sub>2</sub>	46.795	21.060	21.977	46.035	-1.624
SF7b-D-04	TiO <sub>2</sub>	0.583	0.334	0.335	0.558	-4.207
SF7b-D-04	ZnO	0.012	0.020	0.020	0.024	111.118
SF7b-D-04	ZrO <sub>2</sub>	0.069	0.050	0.051	0.068	-1.993
SF7b-D-04	Sum	100.000	55.797	56.590	100.720	0.720
SF7b-D-05	Al <sub>2</sub> O <sub>3</sub>	8.482	3.936	3.991	7.489	-11.711
SF7b-D-05	B <sub>2</sub> O <sub>3</sub>	5.120	1.328	1.362	4.330	-15.420
SF7b-D-05	BaO	0.039	0.031	0.030	0.034	-13.115
SF7b-D-05	CaO	0.440	0.322	0.296	0.433	-1.721
SF7b-D-05	Ce <sub>2</sub> O <sub>3</sub>	0.079	0.062	0.060	0.071	-9.302
SF7b-D-05	Cr <sub>2</sub> O <sub>3</sub>	0.052	0.035	0.035	0.051	-1.002
SF7b-D-05	CuO	0.022	0.026	0.026	0.033	48.099
SF7b-D-05	Fe <sub>2</sub> O <sub>3</sub>	10.037	12.885	13.159	18.618	85.501
SF7b-D-05	K <sub>2</sub> O	0.055	0.054	0.051	0.063	13.377
SF7b-D-05	La <sub>2</sub> O <sub>3</sub>	0.012	0.005	0.005	0.006	-52.851



**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-D-05	Li <sub>2</sub> O	5.120	2.023	2.044	4.377	-14.511
SF7b-D-05	MgO	0.217	0.116	0.111	0.188	-13.262
SF7b-D-05	MnO	1.995	1.444	1.470	1.881	-5.677
SF7b-D-05	Na <sub>2</sub> O	15.965	12.099	11.976	16.226	1.632
SF7b-D-05	NiO	1.696	1.113	1.148	1.439	-15.156
SF7b-D-05	PbO	0.011	0.012	0.012	0.012	9.154
SF7b-D-05	SO <sub>4</sub>	0.900	0.232	0.220	0.678	-24.675
SF7b-D-05	SiO <sub>2</sub>	49.684	20.752	21.206	44.882	-9.665
SF7b-D-05	TiO <sub>2</sub>	0.007	0.011	0.011	0.018	146.310
SF7b-D-05	ZnO	0.009	0.014	0.014	0.017	98.799
SF7b-D-05	ZrO <sub>2</sub>	0.057	0.038	0.037	0.051	-11.061
SF7b-D-05	Sum	100.000	56.537	57.265	100.898	0.898
SF7b-D-06	Al <sub>2</sub> O <sub>3</sub>	9.449	4.769	4.827	9.066	-4.054
SF7b-D-06	B <sub>2</sub> O <sub>3</sub>	4.800	1.369	1.399	4.458	-7.130
SF7b-D-06	BaO	0.044	0.036	0.036	0.040	-8.079
SF7b-D-06	CaO	0.490	0.364	0.340	0.492	0.353
SF7b-D-06	Ce <sub>2</sub> O <sub>3</sub>	0.088	0.067	0.067	0.079	-9.991
SF7b-D-06	Cr <sub>2</sub> O <sub>3</sub>	0.058	0.043	0.042	0.062	8.361
SF7b-D-06	CuO	0.025	0.032	0.034	0.041	67.656
SF7b-D-06	Fe <sub>2</sub> O <sub>3</sub>	11.180	7.706	7.919	11.170	-0.091
SF7b-D-06	K <sub>2</sub> O	0.062	0.059	0.058	0.070	14.024
SF7b-D-06	La <sub>2</sub> O <sub>3</sub>	0.014	0.010	0.005	0.009	-38.289
SF7b-D-06	Li <sub>2</sub> O	4.800	2.096	2.110	4.526	-5.708
SF7b-D-06	MgO	0.242	0.139	0.140	0.232	-4.050
SF7b-D-06	MnO	2.222	1.786	1.809	2.321	4.463
SF7b-D-06	Na <sub>2</sub> O	16.881	14.125	14.232	19.112	13.215
SF7b-D-06	NiO	1.889	1.475	1.499	1.892	0.181
SF7b-D-06	PbO	0.013	0.014	0.015	0.015	20.328
SF7b-D-06	SO <sub>4</sub>	0.900	0.276	0.277	0.828	-7.960
SF7b-D-06	SiO <sub>2</sub>	46.762	21.559	21.917	46.505	-0.551
SF7b-D-06	TiO <sub>2</sub>	0.008	0.011	0.011	0.018	117.360
SF7b-D-06	ZnO	0.010	0.022	0.021	0.026	167.498
SF7b-D-06	ZrO <sub>2</sub>	0.064	0.045	0.048	0.063	-1.607
SF7b-D-06	Sum	100.000	56.003	56.806	101.027	1.027
SF7b-D-07	Al <sub>2</sub> O <sub>3</sub>	8.166	4.338	4.396	8.251	1.046
SF7b-D-07	B <sub>2</sub> O <sub>3</sub>	5.120	1.455	1.485	4.734	-7.546
SF7b-D-07	BaO	0.039	0.019	0.020	0.022	-44.863
SF7b-D-07	CaO	0.437	0.198	0.216	0.289	-33.767
SF7b-D-07	Ce <sub>2</sub> O <sub>3</sub>	0.078	0.005	0.005	0.006	-92.471
SF7b-D-07	Cr <sub>2</sub> O <sub>3</sub>	0.051	0.026	0.027	0.039	-23.954
SF7b-D-07	CuO	0.022	0.013	0.015	0.018	-17.806

**Table A-2. Targeted and Measured Compositions by Glass ID by Oxide. (continued)**

Glass ID	Oxide	Targeted Oxide (wt %)	First Measurement (Elemental wt %)	Second Measurement (Elemental wt %)	Average Measured Oxide (wt %)	Percent Error
SF7b-D-07	Fe <sub>2</sub> O <sub>3</sub>	9.755	6.790	6.889	9.779	0.244
SF7b-D-07	K <sub>2</sub> O	0.055	0.035	0.037	0.043	-21.315
SF7b-D-07	La <sub>2</sub> O <sub>3</sub>	0.013	0.005	0.005	0.006	-55.209
SF7b-D-07	Li <sub>2</sub> O	5.120	2.242	2.262	4.847	-5.331
SF7b-D-07	MgO	0.208	0.074	0.077	0.125	-39.918
SF7b-D-07	MnO	1.980	1.597	1.634	2.086	5.355
SF7b-D-07	Na <sub>2</sub> O	16.183	8.931	9.023	12.101	-25.221
SF7b-D-07	NiO	1.635	1.291	1.337	1.672	2.293
SF7b-D-07	PbO	0.013	0.009	0.009	0.010	-26.761
SF7b-D-07	SO <sub>4</sub>	0.900	0.186	0.196	0.572	-36.454
SF7b-D-07	SiO <sub>2</sub>	49.643	22.950	23.474	49.659	0.032
SF7b-D-07	TiO <sub>2</sub>	0.516	0.194	0.201	0.329	-36.158
SF7b-D-07	ZnO	0.010	0.009	0.010	0.012	19.266
SF7b-D-07	ZrO <sub>2</sub>	0.058	0.029	0.030	0.040	-31.992
SF7b-D-07	Sum	100.000	50.396	51.348	94.638	-5.362
SF7b-D-08	Al <sub>2</sub> O <sub>3</sub>	9.096	4.715	4.610	8.809	-3.153
SF7b-D-08	B <sub>2</sub> O <sub>3</sub>	4.800	1.402	2.042	5.545	15.517
SF7b-D-08	BaO	0.044	0.040	0.040	0.044	1.959
SF7b-D-08	CaO	0.486	0.364	0.337	0.491	0.839
SF7b-D-08	Ce <sub>2</sub> O <sub>3</sub>	0.087	0.066	0.067	0.078	-9.553
SF7b-D-08	Cr <sub>2</sub> O <sub>3</sub>	0.057	0.039	0.041	0.058	2.391
SF7b-D-08	CuO	0.024	0.024	0.025	0.031	26.202
SF7b-D-08	Fe <sub>2</sub> O <sub>3</sub>	10.867	7.631	7.470	10.795	-0.661
SF7b-D-08	K <sub>2</sub> O	0.061	0.044	0.045	0.053	-12.859
SF7b-D-08	La <sub>2</sub> O <sub>3</sub>	0.015	0.005	0.005	0.006	-59.791
SF7b-D-08	Li <sub>2</sub> O	4.800	2.130	2.296	4.764	-0.756
SF7b-D-08	MgO	0.231	0.130	0.132	0.218	-5.968
SF7b-D-08	MnO	2.206	1.796	1.747	2.287	3.683
SF7b-D-08	Na <sub>2</sub> O	17.123	12.379	12.379	16.686	-2.552
SF7b-D-08	NiO	1.821	1.455	1.417	1.827	0.338
SF7b-D-08	PbO	0.015	0.016	0.017	0.018	21.734
SF7b-D-08	SO <sub>4</sub>	0.900	0.278	0.283	0.840	-6.690
SF7b-D-08	SiO <sub>2</sub>	46.717	21.895	21.418	46.330	-0.829
SF7b-D-08	TiO <sub>2</sub>	0.575	0.331	0.333	0.554	-3.538
SF7b-D-08	ZnO	0.011	0.016	0.016	0.020	82.964
SF7b-D-08	ZrO <sub>2</sub>	0.065	0.048	0.048	0.065	-0.134
SF7b-D-08	Sum	100.000	54.803	54.767	99.519	-0.481

**Distribution:**

J. W. Amoroso, 999-W  
A. B. Barnes, 999-W  
D. R. Best, 999-W  
H. M. Boyd, 704-27S  
J. M. Bricker, 704-27S  
C. L. Crawford, 773-42A  
T. B. Edwards, 999-W  
H. H. Elder, 704-24S  
T. L. Fellingner, 704-26S  
S. D. Fink, 773-A  
K. M. Fox, 999-W  
J. M. Gillam, 766-H  
C. C. Herman, 999-W  
E. W. Holtzscheiter, 704-15S  
J. F. Iaukea, 704-30S  
P. R. Jackson, 703-46A  
C. M. Jantzen, 773-A

F. C. Johnson, 999-W  
M. T. Keefer, 241-156H  
P. A. Lee, 703-41A  
D. W. Mcilmoyle, 766-H  
S. L. Marra, 773-A  
J. E. Occhipinti, 704-S  
D. K. Peeler, 999-W  
F. M. Pennebaker, 773-42A  
J. W. Ray, 704-S  
A. R. Shafer, 704-27S  
H. B. Shah, 766-H  
D. C. Sherburne, 704-S  
M. E. Smith, 704-30S  
K. H. Subramanian, 766-H  
A. V. Staub, 704-27S  
M. E. Stone, 999-W