SRNL-STI-2011-00074
Revision 0

Keywords *peroxide fusion*

Retention: *permanent*

ANALYSES BY THE DEFENSE WASTE PROCESSING FACILITY LABORATORY OF THORIUM GLASSES FROM THE SLUDGE BATCH 6 VARIABILITY STUDY

M.T. Feller
D.R. Click
T.B. Edwards

February 2011

Applied Computational Engineering and Statistics
Savannah River National Laboratory
Aiken, SC 29808

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy.

SRNL
SAVANNAH RIVER NATIONAL LABORATORY

DISCLAIMER

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy.

REVIEWS AND APPROVALS

AUTHORS:

D. R. Click, Spectroscopy and Separations — Date
Savannah River National Laboratory

M. T. Feller, Waste Laboratory Services — Date
Savannah River Remediation

T. B. Edwards, Applied Computational Engineering and Statistics — Date
Savannah River National Laboratory

TECHNICAL REVIEWERS:

D. R. Best, Process Technology Programs — Date
Savannah River National Laboratory

E. P. Shine, Applied Computational Engineering and Statistics — Date
Savannah River National Laboratory

APPROVERS:

P. L. Lee, Manager, Applied Computational Engineering and Statistics — Date
Savannah River National Laboratory

C. C. Herman, Manager, Process Technology Programs — Date
Savannah River National Laboratory

R. T. McNew, Manager, Waste Laboratory Services — Date
Savannah River Remediation

J. E. Occhipinti, Manager, Waste Solidification Engineering — Date
Savannah River Remediation

EXECUTIVE SUMMARY

The Savannah River Remediation (SRR) Defense Waste Processing Facility (DWPF) is currently processing Sludge Batch 6 (SB6) with Frit 418. At times during the processing of this glass system, thorium is expected to be at concentrations in the final wasteform that make it a reportable element for the first time since startup of radioactive operations at the DWPF. The Savannah River National Laboratory (SRNL) supported the qualification of the processing of this glass system at the DWPF. A recommendation from the SRNL studies was the need for the DWPF Laboratory to establish a method to measure thorium by Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES). This recommendation led to the set of thorium-bearing glasses from the SB6 Variability Study (VS) being submitted to the DWPF Laboratory for chemical composition measurement. The measurements were conducted by the DWPF Laboratory using the sodium peroxide fusion preparation method routinely employed for analysis of samples from the Slurry Mix Evaporator (SME). These measurements are presented and reviewed in this report. The review indicates that the measurements provided by the DWPF Laboratory are comparable to those provided by Analytical Development's laboratory at SRNL for these same glasses. As a result, the authors of this report recommend that the DWPF Laboratory begin using its routine peroxide fusion dissolution method for the measurement of thorium in SME samples of SB6.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS v
1.0 Introduction 1
2.0 Analyses and Comparisons 1
2.1 Measurements by DWPF Laboratory 1
2.2 Tabulated Comparisons of Measured versus Targeted Oxide Concentrations 2
2.3 Supporting Plots Comparing the Results 5
3.0 Conclusions and Recommendations 5
References 5
Appendix 6

LIST OF ABBREVIATIONS

AD	Analytical Development
DWPF	Defense Waste Processing Facility
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
JMP	Statistical software package from SAS Institute, Inc. [3]
SB6	Sludge Batch 6
SB6 VS	Sludge Batch 6 Variability Study
SME	Slurry Mix Evaporator
SRNL	Savannah River National Laboratory
VS	Variability Study
wt%	Weight percent

1.0 INTRODUCTION

The Savannah River Remediation (SRR) Defense Waste Processing Facility (DWPF) is currently processing Sludge Batch 6 (SB6) with Frit 418. At times during the processing of this glass system, thorium is expected to be at concentrations in the final wasteform that make it a reportable element for the first time since the startup of radioactive operations at the DWPF. The Savannah River National Laboratory (SRNL) supported the qualification of the processing of this glass system at the DWPF. A recommendation from one of the supporting studies [1] was the need for the DWPF Laboratory to establish a method to measure thorium by Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES). This recommendation led to the set of thorium-bearing glasses from the SB6 Variability Study (VS) [2] being submitted to the DWPF Laboratory for measurement of their chemical compositions. The measurements were conducted by the DWPF Laboratory using the sodium peroxide fusion preparation method routinely employed for analysis of samples from the Slurry Mix Evaporator (SME). The use of this preparation method for these analyses was guided by information regarding analytical issues, outlined in [2], that are associated with thorium being present in these glasses.

The purpose of this technical report is to present the measurements generated by the DWPF Laboratory for the SB6 VS glasses and to compare the measurements to the targeted compositions for these VS glasses as well as to SRNL's measurements (both sets, targeted and measured, of compositional values were reported by SRNL in [2]). The goal of these comparisons is to provide information that will lead to the qualification of peroxide fusion dissolution as a method for the measurement by the DWPF Laboratory of thorium in SME glass samples.

2.0 ANALYSES AND COMPARISONS

Five glasses of the SB6 VS were batched to contain reportable quantities of thorium (i.e., elemental concentrations of thorium greater than 0.5 weight percent (wt%) of the glass) [2]. The identifying labels of these glasses were SB6VS-18, SB6VS-19, SB6VS-20, SB6VS-21, and SV6VS-22, and these glasses were selected to pursue the implementation of the recommendation cited above regarding the need to establish at DWPF Laboratory a method to measure thorium by ICP-AES.

2.1 Measurements by DWPF Laboratory

Samples of these five glasses were transferred from SRNL to the DWPF Laboratory. The samples were analyzed by peroxide fusion dissolution and the resulting measurements are presented in Table A1 through Table A5 of the Appendix. Note that no sodium or zirconium values are provided in these tables. Measurements of these elements are not available from samples prepared by the peroxide fusion method. Also, note that copper and titanium concentrations were not provided for all of the glasses. Since these two elements are present only in small quantities in all of these glasses, these missing values do not affect the conclusions of this report. The elemental concentrations were converted to oxide concentrations by multiplying by the appropriate gravimetric factors. For those results with duplicate measurements, the average value was determined. The resulting values are presented in Table 1.

Table 1. Measured Oxide Concentrations (wt%'s) by DWPF Laboratory

Oxide	Glass ID				
	SB6VS18	SB6VS19	SB6VS20	SB6VS21	SB6VS22
Al_2O_3	8.267	8.797	9.474	9.755	10.251
B_2O_3	5.173	4.979	4.785	4.588	4.469
CaO	0.378	0.423	0.497	0.569	0.558
Cr_2O_3	0.049	0.062	0.028	0.020	0.034
CuO	Not reported	Not reported	0.038	0.034	0.041
Fe_2O_3	7.537	7.803	8.226	8.494	9.021
K_2O	0.648	1.010	0.025	0.049	0.108
Li_2O	5.406	5.217	5.169	4.904	4.902
MgO	0.254	0.261	0.300	0.292	0.322
MnO	2.137	2.238	2.309	2.403	2.571
NiO	0.906	0.990	0.942	0.962	1.052
SiO_2	52.163	48.641	50.066	47.569	46.213
ThO_2	1.041	1.101	1.084	1.123	1.199
TiO_2	Not reported	Not reported	0.342	0.330	0.369
U_3O_8	1.456	1.688	1.404	1.432	1.579

2.2 Tabulated Comparisons of Measured versus Targeted Oxide Concentrations

Since these thorium glasses that were analyzed by the DWPF Laboratory were part of the SB6 VS conducted by SRNL, their targeted concentrations and the results of their compositional measurements by SRNL's Analytical Development (AD) laboratory are available in the SB6 VS report [2]. Table 2 provides the results from the SB6 VS along with the DWPF Laboratories' measurements.

Table 2. Targeted and Measured Oxide Concentrations for the Thorium Glasses

			SRNL Laboratory			DWPF Laboratory		
		Targeted	Measured	Diff. of	% Diff. of	Measured	Diff. of	% Diff. of
Glass ID	Oxide	(wt%)	(wt%)	Measured	Measured	Oxide wt%	Measured	Measured
SB6VS18	Al_2O_3	8.1160	8.4933	0.3773	4.6%	8.267	0.1511	1.9%
SB6VS18	B_2O_3	5.4400	5.2565	-0.1835	-3.4%	5.173	-0.2669	-4.9%
SB6VS18	CaO	0.4390	0.4334	-0.0056	-1.3%	0.378	-0.0607	-13.8%
SB6VS18	Cr_2O_3	0.0380	0.0333	-0.0047	-12.4%	0.049	0.0111	29.2%
SB6VS18	CuO	0.0330	0.0338	0.0008	2.4%	Not Available		
SB6VS18	Fe_2O_3	7.5090	7.3773	-0.1317	-1.8%	7.537	0.0282	0.4%
SB6VS18	K_2O	0.0270	0.1622	0.1352	500.6%	0.648	0.6206	2298.5%
SB6VS18	Li_2O	5.4400	5.3069	-0.1331	-2.4%	5.406	-0.0343	-0.6%
SB6VS18	MgO	0.2440	0.2442	0.0002	0.1%	0.254	0.0102	4.2%
SB6VS18	MnO	2.1370	2.0885	-0.0485	-2.3%	2.137	-0.0005	0.0%
SB6VS18	NiO	0.9160	0.8440	-0.0720	-7.9%	0.906	-0.0105	-1.1%
SB6VS18	SiO_2	52.3530	54.0708	1.7178	3.3%	52.163	-0.1898	-0.4%
SB6VS18	ThO_2	1.0110	0.8739	-0.1371	-13.6%	1.041	0.0304	3.0%
SB6VS18	TiO_2	0.2940	0.3002	0.0062	2.1%	Not Available		
SB6VS18	U_3O_8	1.4980	1.4298	-0.0682	-4.6%	1.456	-0.0423	-2.8%

Table 2. Targeted and Measured Oxide Concentrations for the Thorium Glasses (continued)

			SRNL Laboratory			DWPF Laboratory		
		Targeted	Measured	Diff. of	% Diff. of	Measured	Diff. of	% Diff. of
Glass ID	Oxide	(wt%)	(wt%)	Measured	Measured	Oxide wt%	Measured	Measured
SB6VS19	Al_2O_3	8.6230	9.0224	0.3994	4.6%	8.797	0.1741	2.0%
SB6VS19	B_2O_3	5.2800	5.0794	-0.2006	-3.8%	4.979	-0.3011	-5.7%
SB6VS19	CaO	0.4670	0.4866	0.0196	4.2%	0.423	-0.0440	-9.4%
SB6VS19	Cr_2O_3	0.0400	0.0377	-0.0023	-5.8%	0.062	0.0217	54.2%
SB6VS19	CuO	0.0360	0.0351	-0.0009	-2.4%	Not Available		
SB6VS19	Fe_2O_3	7.9780	7.8026	-0.1754	-2.2%	7.803	-0.1747	-2.2%
SB6VS19	K_2O	0.0290	0.2417	0.2127	733.4%	1.010	0.9812	3383.4%
SB6VS19	Li_2O	5.2800	5.1562	-0.1238	-2.3%	5.217	-0.0631	-1.2%
SB6VS19	MgO	0.2590	0.2554	-0.0036	-1.4%	0.261	0.0017	0.7%
SB6VS19	MnO	2.2700	2.2209	-0.0491	-2.2%	2.238	-0.0321	-1.4%
SB6VS19	NiO	0.9730	0.8917	-0.0813	-8.4%	0.990	0.0174	1.8%
SB6VS19	SiO_2	50.8750	52.6803	1.8053	3.5%	48.641	-2.2337	-4.4%
SB6VS19	ThO_2	1.0740	0.9123	-0.1617	-15.1%	1.101	0.0266	2.5%
SB6VS19	TiO_2	0.3130	0.3186	0.0056	1.8%	Not Available		
SB6VS19	U_3O_8	1.5910	1.4504	-0.1406	-8.8%	1.688	0.0968	6.1%
SB6VS20	Al_2O_3	9.1300	9.5231	0.3931	4.3%	9.474	0.3440	3.8%
SB6VS20	B_2O_3	5.1200	4.9264	-0.1936	-3.8%	4.785	-0.3352	-6.5%
SB6VS20	CaO	0.4940	0.4656	-0.0284	-5.8%	0.497	0.0027	0.5%
SB6VS20	Cr_2O_3	0.0430	0.0369	-0.0061	-14.3%	0.028	-0.0152	-35.4%
SB6VS20	CuO	0.0380	0.0367	-0.0013	-3.4%	0.038	-0.0004	-1.2%
SB6VS20	Fe_2O_3	8.4470	8.2458	-0.2012	-2.4%	8.226	-0.2205	-2.6%
SB6VS20	K_2O	0.0300	0.3426	0.3126	1041.9%	0.025	-0.0047	-15.7%
SB6VS20	Li_2O	5.1200	5.0163	-0.1037	-2.0%	5.169	0.0491	1.0%
SB6VS20	MgO	0.2750	0.2699	-0.0051	-1.9%	0.300	0.0252	9.1%
SB6VS20	MnO	2.4040	2.3274	-0.0766	-3.2%	2.309	-0.0953	-4.0%
SB6VS20	NiO	1.0300	0.9251	-0.1049	-10.2%	0.942	-0.0884	-8.6%
SB6VS20	SiO_2	49.3970	50.7549	1.3579	2.7%	50.066	0.6690	1.4%
SB6VS20	ThO_2	1.1370	0.9814	-0.1556	-13.7%	1.084	-0.0526	-4.6%
SB6VS20	TiO_2	0.3310	0.3319	0.0009	0.3%	0.342	0.0109	3.3%
SB6VS20	U_3O_8	1.6850	1.6037	-0.0813	-4.8%	1.404	-0.2806	-16.7%

Table 2. Targeted and Measured Oxide Concentrations for the Thorium Glasses (continued)

			SRNL Laboratory			DWPF Laboratory		
		Targeted	Measured	Diff. of	% Diff. of	Measured	Diff. of	% Diff. of
Glass ID	Oxide	(wt%)	(wt%)	Measured	Measured	Oxide wt%	Measured	Measured
SB6VS21	Al_2O_3	9.6370	10.1277	0.4907	5.1%	9.755	0.1185	1.2%
SB6VS21	B_2O_3	4.9600	4.7494	-0.2106	-4.2%	4.588	-0.3716	-7.5%
SB6VS21	CaO	0.5220	0.5523	0.0303	5.8%	0.569	0.0475	9.1%
SB6VS21	Cr_2O_3	0.0450	0.0365	-0.0085	-19.0%	0.020	-0.0245	-54.5%
SB6VS21	CuO	0.0400	0.0398	-0.0002	-0.6%	0.034	-0.0062	-15.5%
SB6VS21	Fe_2O_3	8.9170	8.7462	-0.1708	-1.9%	8.494	-0.4232	-4.7%
SB6VS21	K_2O	0.0320	0.3099	0.2779	868.4%	0.049	0.0174	54.3%
SB6VS21	Li_2O	4.9600	4.8548	-0.1052	-2.1%	4.904	-0.0557	-1.1%
SB6VS21	MgO	0.2900	0.2861	-0.0039	-1.4%	0.292	0.0019	0.6%
SB6VS21	MnO	2.5370	2.4565	-0.0805	-3.2%	2.403	-0.1341	-5.3%
SB6VS21	NiO	1.0880	0.9849	-0.1031	-9.5%	0.962	-0.1260	-11.6%
SB6VS21	SiO_2	47.9190	49.5783	1.6593	3.5%	47.569	-0.3495	-0.7%
SB6VS21	ThO_2	1.2000	1.0662	-0.1338	-11.1%	1.123	-0.0769	-6.4%
SB6VS21	TiO_2	0.3500	0.3494	-0.0006	-0.2%	0.330	-0.0197	-5.6%
SB6VS21	U_3O_8	1.7780	1.7511	-0.0269	-1.5%	1.432	-0.3465	-19.5%
SB6VS22	Al_2O_3	10.1450	10.5245	0.3795	3.7%	10.251	0.1055	1.0%
SB6VS22	B_2O_3	4.8000	4.6206	-0.1794	-3.7%	4.469	-0.3308	-6.9%
SB6VS22	CaO	0.5490	0.5058	-0.0432	-7.9%	0.558	0.0093	1.7%
SB6VS22	Cr_2O_3	0.0470	0.0429	-0.0041	-8.7%	0.034	-0.0134	-28.5%
SB6VS22	CuO	0.0420	0.0406	-0.0014	-3.3%	0.041	-0.0007	-1.6%
SB6VS22	Fe_2O_3	9.3860	9.1965	-0.1895	-2.0%	9.021	-0.3646	-3.9%
SB6VS22	K_2O	0.0340	0.2259	0.1919	564.3%	0.108	0.0744	218.9%
SB6VS22	Li_2O	4.8000	4.7149	-0.0851	-1.8%	4.902	0.1022	2.1%
SB6VS22	MgO	0.3050	0.3031	-0.0019	-0.6%	0.322	0.0167	5.5%
SB6VS22	MnO	2.6710	2.6276	-0.0434	-1.6%	2.571	-0.1002	-3.8%
SB6VS22	NiO	1.1450	1.0390	-0.1060	-9.3%	1.052	-0.0926	-8.1%
SB6VS22	SiO_2	46.4410	47.9203	1.4793	3.2%	46.213	-0.2278	-0.5%
SB6VS22	ThO_2	1.2630	1.1248	-0.1382	-10.9%	1.199	-0.0637	-5.0%
SB6VS22	TiO_2	0.3680	0.3715	0.0035	1.0%	0.369	0.0006	0.2%
SB6VS22	U_3O_8	1.8720	1.8130	-0.0590	-3.2%	1.579	-0.2931	-15.7%

In addition to the targeted and measured concentrations, the differences between the measured and targeted concentrations are provided for both laboratories as well as the percent differences relative to the targeted concentrations for both laboratories. The targeted concentrations are used as the points of comparison since there were no issues seen in the batching of these VS glasses [2]. While there are large percent differences for those oxides at smaller concentrations in these glasses for both laboratories, the entries in this table suggest comparable results for the two laboratories for the measurement of these glasses.

One difference that should be noted between the performance of the fusion methods is that the DWPF Laboratory uses 50 mL of 1:1 HCl to H_2O uptake for the fusion whereas SRNL uses 25 mL of concentrated HNO_3 and sometimes adds H_2O_2 to clarify the solutions. Both laboratories finish volumetric dilution of the samples using deionized water.

2.3 Supporting Plots Comparing the Results

While the information of Table 1 provides an opportunity for a close comparison of the results from the two laboratories for each glass, the plots of Exhibit A1 in the Appendix allow for a comparison of the targeted, SRNL measured, and DWPF measured values for each oxide for all of the glasses. The plots were developed using JMP Version 7.0.2 [3], and they illustrate the performance of the DWPF Laboratory relative to that of the AD laboratory in measuring the oxide concentrations of these thorium glasses. Once again, there is no indication of a problem seen in these plots. Specifically, the DWPF Laboratory measurements for ThO_2 fall closer to the targeted values than do the AD values.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The measurements generated by the DWPF Laboratory for the thorium glasses from SRNL's SB6 VS are presented and reviewed in this report. The DWPF Laboratory used the peroxide fusion dissolution method that it routinely employs in the ICP-AES analysis of SME samples to conduct these measurements. The review of these measurements that is provided in this report indicates that the measurements provided by the DWPF Laboratory are comparable to those provided by AD's laboratory for these same glasses. As a result, the authors of this report recommend that the DWPF Laboratory begin using its routine peroxide fusion dissolution method for the measurement of thorium in SME samples of SB6.

REFERENCES

[1] Click, D.R., T.B. Edwards, M.A. Jones, "Verification of the Defense Waste Processing Facility's (DWPF) Process Digestion Method for the Sludge Batch 6 Qualification Sample," SRNL-STI-2010-00259, Revision 0, June 2010.

[2] Johnson, F.C. and T.B. Edwards, "Sludge Batch 6 Variability Study with Frit 418," SRNL-STI-2010-00242, Revision 0, November 2010.

[3] JMP Version 7.0.2, SAS Institute, Inc., Cary NC, 1989-2007.

APPENDIX

Table A1. DWPF Laboratory Measurements of SB6VS-18

DWPF_RSD_report

Report Date 14-DEC-10 02:14 PM

Sample Id **200004122**
Sample Type **SME-1**

Logged 13-DEC-10

Condition ONLINE

Method ICP FUSIONS
Operation ICP PREP ANALYSIS

Component	Average	LIMITS	RSD	LIMITS
Al_FS corr	4.3753		0.095	<=12
B_FS corr	1.6066		1.338	<=15
Ca_FS corr	.2704		7.622	<=27
Cr_FS corr	.0336		1.659	
Fe_FS corr	5.2719		0.536	<=15
K_FS corr	.5376		1.183	<=15
Li_FS corr	2.5109		2.027	<=15
Mg_FS corr	.1533		0.230	<=15
Mn_FS corr	1.6547		0.508	<=15
Ni_FS corr	.7116		0.278	<=12
Si_FS corr	24.3833		1.413	<=18
Th_FS corr	.9152		2.062	
U_FS corr	1.2345		1.683	<=12

Table A2. DWPF Laboratory Measurements of SB6VS-19

DWPF_RSD_report

Report Date 14-DEC-10 02:19 PM

Sample Id **200004123**
Sample Type **SME-1**

Logged 13-DEC-10
Logged by **L4097**
Condition ONLINE

Method ICP FUSIONS
Operation ICP PREP ANALYSIS

Component	Average	LIMITS	RSD	LIMITS
Al_FS corr	4.6558		0.545	<=12
B_FS corr	1.5463		1.755	<=15
Ca_FS corr	.3023		3.106	<=27
Cr_FS corr	.0422		19.541	
Fe_FS corr	5.4580		1.505	<=15
K_FS corr	.8386		10.904	<=15
Li_FS corr	2.4232		0.478	<=15
Mg_FS corr	.1572		0.269	<=15
Mn_FS corr	1.7332		0.396	<=15
Ni_FS corr	.7783		4.240	<=12
Si_FS corr	22.7370		1.949	<=18
Th_FS corr	.9672		4.633	
U_FS corr	1.4313		11.606	<=12

Table A3. DWPF Laboratory Measurements of SB6VS-20

200003268

DWPF_sample_report

Analytical Report
DWPF 221-S Laboratory

Page 1 of 2

Report Date 26-OCT-10 05:03 AM

Submission ID 100003268

Sample Id **Description SME-1**

200003268

Sample Date 25-OCT-10 08:55 AM Approved 25-OCT-10 10:16 AM

Component	Text Value	Units
Product description	SB6VS-21	NONE
Batch number	SB6VS-21	NONE
Al_FS corr	5.105	wt%
Al_FS corr	4.924	wt%
Al_FS corr average	**5.014**	**wt%**
B_FS corr	1.517	wt%
B_FS corr	1.455	wt%
B_FS corr average	**1.486**	**wt%**
Ca_FS corr	0.369	wt%
Ca_FS corr	0.341	wt%
Ca_FS corr average	**0.355**	**wt%**
Cr_FS corr	0.019	wt%
Cr_FS corr	0.018	wt%
Cr_FS corr average	**0.019**	**wt%**
Cu_FS corr	0.031	wt%
Cu_FS corr	0.028	wt%
Cu_FS corr average	**0.030**	**wt%**
Fe_FS corr	5.848	wt%
Fe_FS corr	5.660	wt%
Fe_FS corr average	**5.754**	**wt%**
K_FS corr	0.026	wt%
K_FS corr	0.015	wt%
K_FS corr average	**0.021**	**wt%**
Li_FS corr	2.437	wt%
Li_FS corr	2.365	wt%
Li_FS corr average	**2.401**	**wt%**
Mg_FS corr	0.192	wt%
Mg_FS corr	0.171	wt%
Mg_FS corr average	**0.181**	**wt%**
Mn_FS corr	1.766	wt%
Mn_FS corr	1.810	wt%
Mn_FS corr average	**1.788**	**wt%**
Ni_FS corr	0.753	wt%

Table A3. DWPF Laboratory Measurements of SB6VS-20 *(continued)*

DWPF_sample_report

Analytical Report
DWPF 221-S Laboratory

200003268
Page 2 of 2
Report Date 26-OCT-10 05:03 AM

Sample Id **Description SME-1**
200003268
Sample Date 25-OCT-10 08:55 AM Approved 25-OCT-10 10:16 AM

Component	Text Value	Units
Ni_FS corr	0.727	wt%
Ni_FS corr average	**0.740**	**wt%**
Si_FS corr	23.606	wt%
Si_FS corr	23.201	wt%
Si_FS corr average	**23.403**	**wt%**
Th_FS corr	0.986	wt%
Th_FS corr	0.921	wt%
Th_FS corr average	**0.953**	**wt%**
Ti_FS corr	0.207	wt%
Ti_FS corr	0.203	wt%
Ti_FS corr average	**0.205**	**wt%**
U_FS corr	1.170	wt%
U_FS corr	1.212	wt%
U_FS corr average	**1.191**	**wt%**

Table A4. DWPF Laboratory Measurements of SB6VS-21

DWPF_sample_report

Analytical Report
DWPF 221-S Laboratory

200003269
Page 1 of 2
Report Date 26-OCT-10 05:04 AM

Submission ID 100003269

Sample Id 200003269 **Description SME-1**

Sample Date 25-OCT-10 08:55 AM Approved 25-OCT-10 10:19 AM

Component	Text Value	Units
Product description	SB6VS-22	NONE
Batch number	SB6VS-22	NONE
Al_FS corr	5.166	wt%
Al_FS corr	5.161	wt%
Al_FS corr average	**5.163**	**wt%**
B_FS corr	1.425	wt%
B_FS corr	1.426	wt%
B_FS corr average	**1.425**	**wt%**
Ca_FS corr	0.387	wt%
Ca_FS corr	0.427	wt%
Ca_FS corr average	**0.407**	**wt%**
Cr_FS corr	0.014	wt%
Cr_FS corr	0.014	wt%
Cr_FS corr average	**0.014**	**wt%**
Cu_FS corr	0.024	wt%
Cu_FS corr	0.031	wt%
Cu_FS corr average	**0.027**	**wt%**
Fe_FS corr	5.951	wt%
Fe_FS corr	5.930	wt%
Fe_FS corr average	**5.941**	**wt%**
K_FS corr	0.024	wt%
K_FS corr	0.058	wt%
K_FS corr average	**0.041**	**wt%**
Li_FS corr	2.284	wt%
Li_FS corr	2.272	wt%
Li_FS corr average	**2.278**	**wt%**
Mg_FS corr	0.175	wt%
Mg_FS corr	0.176	wt%
Mg_FS corr average	**0.176**	**wt%**
Mn_FS corr	1.905	wt%
Mn_FS corr	1.817	wt%
Mn_FS corr average	**1.861**	**wt%**
Ni_FS corr	0.749	wt%

Table A4. DWPF Laboratory Measurements of SB6VS-21 *(continued)*

DWPF_sample_report

Analytical Report
DWPF 221-S Laboratory

200003269
Page 2 of 2
Report Date 26-OCT-10 05:04 AM

Sample Id 200003269 **Description** SME-1

Sample Date 25-OCT-10 08:55 AM Approved 25-OCT-10 10:19 AM

Component	Text Value	Units
Ni_FS corr	0.762	wt%
Ni_FS corr average	**0.756**	**wt%**
Si_FS corr	22.370	wt%
Si_FS corr	22.102	wt%
Si_FS corr average	**22.236**	**wt%**
Th_FS corr	1.018	wt%
Th_FS corr	0.956	wt%
Th_FS corr average	**0.987**	**wt%**
Ti_FS corr	0.199	wt%
Ti_FS corr	0.196	wt%
Ti_FS corr average	**0.198**	**wt%**
U_FS corr	1.226	wt%
U_FS corr	1.203	wt%
U_FS corr average	**1.214**	**wt%**

Table A5. DWPF Laboratory Measurements of SB6VS-22

DWPF_sample_report

Analytical Report
DWPF 221-S Laboratory

200003270

Page 1 of 2

Report Date 26-OCT-10 05:02 AM

Submission ID 100003270

Sample Id 200003270 **Description SME-1**

Sample Date 25-OCT-10 08:56 AM Approved 25-OCT-10 10:20 AM

Component	Text Value	Units
Product description	SB6VS-23	NONE
Batch number	SB6VS-23	NONE
Al_FS corr	5.432	wt%
Al_FS corr	5.418	wt%
Al_FS corr average	**5.425**	**wt%**
B_FS corr	1.394	wt%
B_FS corr	1.382	wt%
B_FS corr average	**1.388**	**wt%**
Ca_FS corr	0.407	wt%
Ca_FS corr	0.392	wt%
Ca_FS corr average	**0.399**	**wt%**
Cr_FS corr	0.023	wt%
Cr_FS corr	0.022	wt%
Cr_FS corr average	**0.023**	**wt%**
Cu_FS corr	0.034	wt%
Cu_FS corr	0.032	wt%
Cu_FS corr average	**0.033**	**wt%**
Fe_FS corr	6.304	wt%
Fe_FS corr	6.316	wt%
Fe_FS corr average	**6.310**	**wt%**
K_FS corr	0.087	wt%
K_FS corr	0.093	wt%
K_FS corr average	**0.090**	**wt%**
Li_FS corr	2.282	wt%
Li_FS corr	2.272	wt%
Li_FS corr average	**2.277**	**wt%**
Mg_FS corr	0.183	wt%
Mg_FS corr	0.204	wt%
Mg_FS corr average	**0.194**	**wt%**
Mn_FS corr	1.963	wt%
Mn_FS corr	2.019	wt%
Mn_FS corr average	**1.991**	**wt%**
Ni_FS corr	0.835	wt%

Table A5. DWPF Laboratory Measurements of SB6VS-22 *(continued)*

DWPF_sample_report

Analytical Report
DWPF 221-S Laboratory

200003270
Page 2 of 2
Report Date 26-OCT-10 05:02 AM

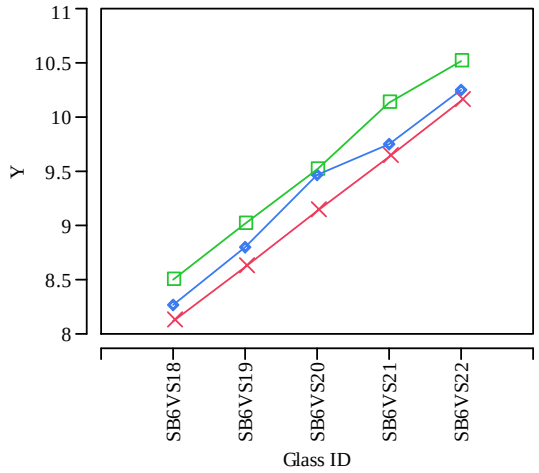
Sample Id **200003270** **Description** **SME-1**

Sample Date 25-OCT-10 08:56 AM Approved 25-OCT-10 10:20 AM

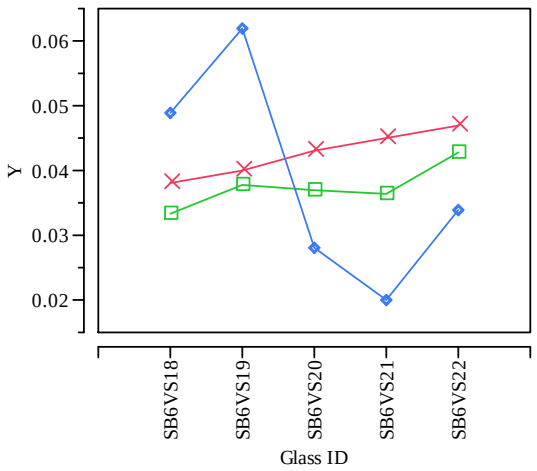
Component	Text Value	Units
Ni_FS corr	0.820	wt%
Ni_FS corr average	**0.827**	**wt%**
Si_FS corr	21.613	wt%
Si_FS corr	21.590	wt%
Si_FS corr average	**21.602**	**wt%**
Th_FS corr	1.046	wt%
Th_FS corr	1.061	wt%
Th_FS corr average	**1.054**	**wt%**
Ti_FS corr	0.221	wt%
Ti_FS corr	0.220	wt%
Ti_FS corr average	**0.221**	**wt%**
U_FS corr	1.337	wt%
U_FS corr	1.341	wt%
U_FS corr average	**1.339**	**wt%**

Exhibit A1. Comparison Plots by Oxide

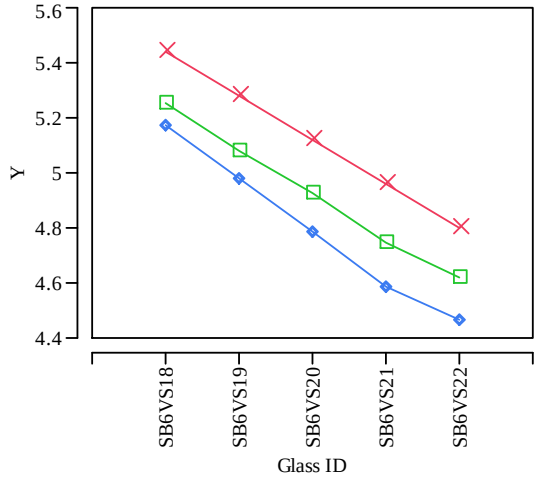
Overlay Plot Oxide=Al2O3 (wt%)



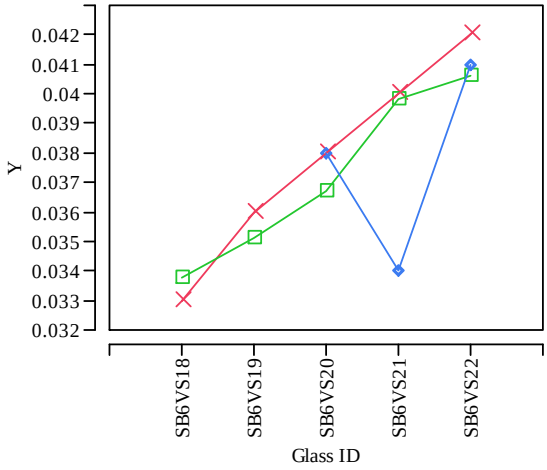
Overlay Plot Oxide=Cr2O3 (wt%)



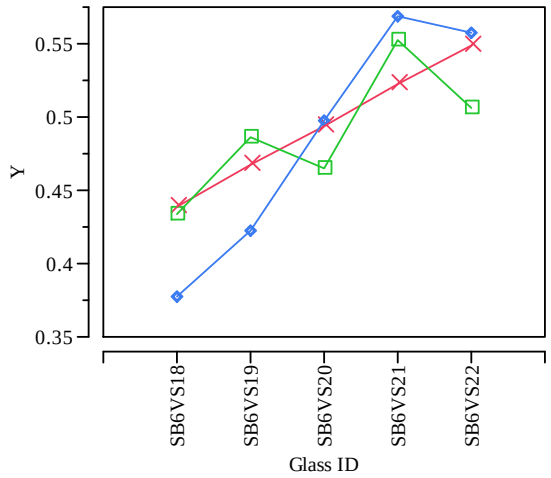
Overlay Plot Oxide=B2O3 (wt%)



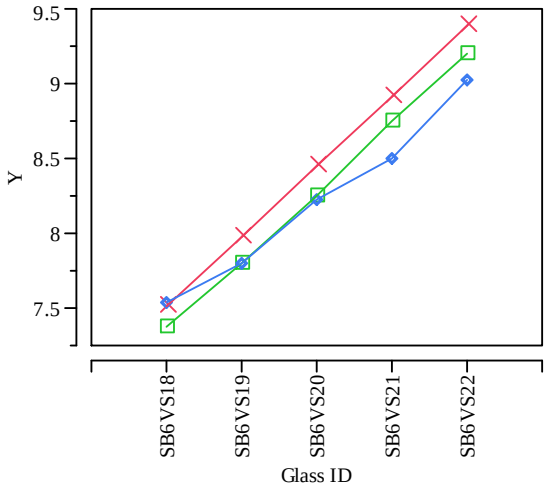
Overlay Plot Oxide=CuO (wt%)

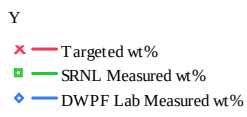


Overlay Plot Oxide=CaO (wt%)



Overlay Plot Oxide=Fe2O3 (wt%)





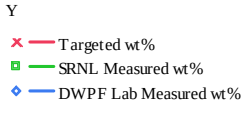


Exhibit A1. Comparison Plots by Oxide

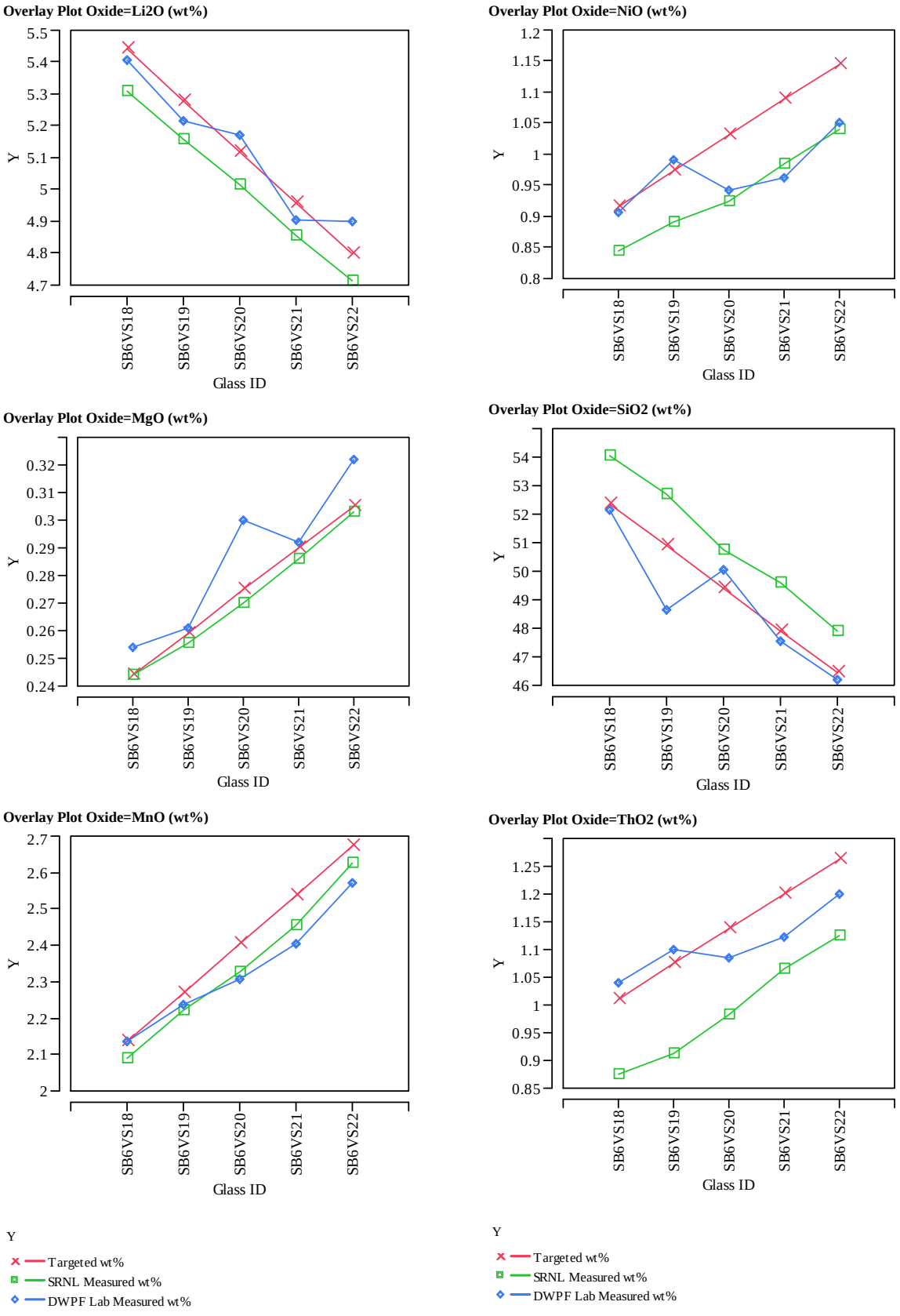
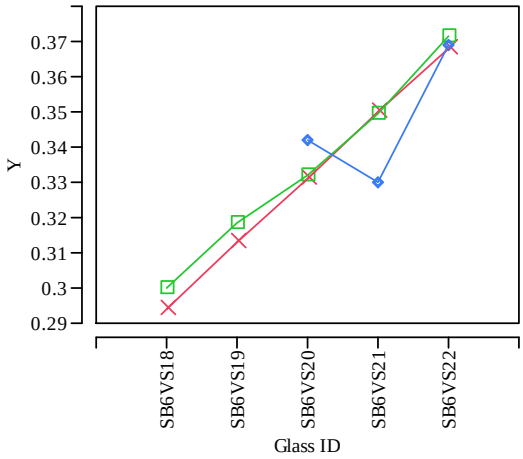
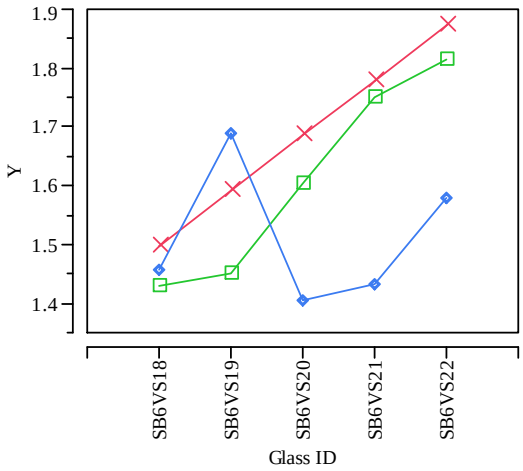


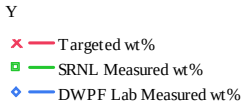
Exhibit A1. Comparison Plots by Oxide

Overlay Plot Oxide=TiO2 (wt%)



Overlay Plot Oxide=U3O8 (wt%)





Distribution:

Name:	Location:
Sharon Marra	773-A
Connie Herman	999-W
Charles J. Coleman	773-A
Clint Gregory	773-A
Mark Barnes	773-A
Patricia Lee	703-41A
Gene Shine	703-41A
Damon R. Click	773-A
L. Curtis Johnson	773-A
Michael Stone	999-W
John Pareizs	773-A
David Peeler	999-W
Tommy Edwards	999-W
Kevin Fox	999-W
Fabienne Johnson	999-W
Charles Crawford	773-42A
David Best	999-W
John Occhipinti	704-S
Jonathan Bricker	704-27S
John Iaukea	704-30S
Aaron Staub	704-27S
Jeff Ray	704-S
Robert Hinds	704-S
Terri Fellinger	704-26S
Ryan McNew	704-S
Michael T. Hart	210-S
Roger N. Mahannah	704-28S
Michael T. Feller	704-28S
Omar Cardona-Quiles	704-24S
Amanda Shafer	704-27S
Mason Clark	704-27S
Helen Pittman	704-27S
Hank Elder	704-24S
Bill Holtzscheiter	704-15S
Pat Vaughan	773-41A