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Final Report – Enhanced LAW Glass Formulation Testing, VSL-07R1130-1, Rev. 0, dated 10/05/07

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

P.O. Box 450
Richland, Washington 99352

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Final Report

Enhanced LAW Glass Formulation Testing

prepared by

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This report describes the results of testing specified by the above Test Plan. The work was performed in compliance with the quality assurance requirements specified in the Test Plan. Results required by the Test Plan are reported. The test results and this report have been reviewed for correctness, technical adequacy, completeness, and accuracy.

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TABLE OF CONTENTS

List of Tables **4**

List of Figures **7**

List of Abbreviations **8**

SECTION 1.0 INTRODUCTION **9**

1.1 Test Objectives 13
1.2 Quality Assurance 14

SECTION 2.0 WASTE SIMULANT, GLASS FORMULATIONS AND FEED ANALYSIS **15**

2.1 Region A (ORPLA) Waste Simulant and Glass Formulation 16
2.1.1 Region A (ORPLA) Waste Simulant *16*
2.1.2 Region A (ORPLA) Glass Formulation *17*
2.2 Region B (ORPLB) Waste Simulant and Glass Formulation 20
2.2.1 Region B (ORPLB) Waste Simulant *20*
2.2.2 Region B (ORPLB) Glass Formulation *20*
2.3 Region C (ORPLC) Waste Simulant and Glass Formulation 22
2.3.1 Region C (ORPLC) Waste Simulant *22*
2.3.2 Region C (ORPLC) Glass Formulation *23*
2.4 Region D (ORPLD) Waste Simulant and Glass Formulation 24
2.4.1 Region D (ORPLD) Waste Simulant *24*
2.4.2 Region D (ORPLD) Glass Formulation *25*
2.5 Region E (ORPLE) Waste Simulant and Glass Formulation 26
2.5.1 Region E (ORPLE) Waste Simulant *26*
2.5.2 Region E (ORPLE) Glass Formulation *27*
2.6 Sugar Additions 28
2.7 Analysis of Melter Feed Samples 29
2.7.1 General Properties *29*
2.7.2 Chemical Composition *30*

SECTION 3.0 DM10 TESTS **31**

3.1 DM10 System Description 32
3.1.1 Feed System *32*
3.1.2 Melter *32*
3.1.3 Off-Gas System *33*
3.2 DM10 Test Conditions 33
3.3 DM10 Test Results 34
3.3 Gases Monitored by FTIR 35

SECTION 4.0 DM10 GLASS PRODUCTS **36**

4.1 Compositional Analysis 36
4.2 Secondary Phase Observations 37
4.3 Comparison of PCT and VHT of Crucible and Melter Glasses 38

SECTION 5.0 SUMMARY AND CONCLUSIONS **40**

SECTION 6.0 REFERENCES **43**

List of Tables

		Page
Table 1.1.	Waste Compositions and Corresponding Target Concentrations in Glass.	T-1
Table 2.1.	LAW Sub-Envelope A1 (AN-105) Waste Simulant Recipe at 8 Molar Sodium.	T-2
Table 2.2.	Target and Analyzed Compositions (wt%) of Seventeen ORPLA Crucible Glasses.	T-3
Table 2.3.	Descriptions of Seventeen As-Melted and Heat Treated ORPLA Crucible Glasses.	T-6
Table 2.4.	Measured Sulfate Solubility Limits in Seventeen ORPLA Glasses.	T-7
Table 2.5.	Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Seventeen ORPLA Crucible Glasses.	T-8
Table 2.6.	Viscosities and Electrical Conductivities of Seventeen ORPLA Crucible Glasses.	T-10
Table 2.7.	Results of K-3 Corrosion Testing for Seventeen ORPLA Crucible Glasses.	T-12
Table 2.8.	Summary of Test Results for Selected ORPLA Glass Formulation ORPLA15 and Comparison to ILAW Requirements.	T-13
Table 2.9.	Oxide Composition of AN-105 Simulant and ORPLA15 Glass Composition Used in Melter Tests (wt%).	T-14
Table 2.10a.	Glass Former Additives for 1 Liter of AN-105 Simulant (8 M Na) and Corresponding Melter Feed Properties.	T-15
Table 2.10b.	NaOH and Na_2SO_4 Additions Required to Obtain 24 wt% Na_2O and Various SO_3 Concentrations Ranging from 0.1 to 0.6 wt% in the ORPLA15 Glass.	T-15
Table 2.11.	LAW Sub-Envelope C1 (AN-107) Waste Simulant Recipe at 8 Molar Sodium.	T-16
Table 2.12.	Target and Analyzed Compositions (wt%) of Four ORPLB Crucible Glasses.	T-17
Table 2.13.	Descriptions of Four As-Melted and Heat Treated ORPLB Crucible Glasses.	T-18
Table 2.14.	Measured Sulfate Solubility Limits in Four ORPLB Crucible Glasses.	T-18
Table 2.15.	Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Four ORPLB Crucible Glasses.	T-19
Table 2.16.	Viscosities and Electrical Conductivities of Four ORPLB Crucible Glasses.	T-20
Table 2.17.	Results of K-3 Corrosion Testing for Four ORPLB Crucible Glasses.	T-20
Table 2.18.	Summary of Test Results for Selected ORPLB Glass Formulation ORPLB4 and Comparison to ILAW Requirements.	T-21
Table 2.19.	Oxide Composition of AN-107 Simulant and ORPLB4 Glass Composition Used in Melter Tests (wt%).	T-22
Table 2.20a.	Glass Former Additives for 1 Liter of AN-107 Simulant (8 M Na) and Corresponding Melter Feed Properties.	T-23
Table 2.20b.	NaOH and Na_2SO_4 Additions Required to Obtain 24 wt% Na_2O and Various SO_3 Concentrations Ranging from 0.6 to 1.0 wt% in the ORPLB4 Glass.	T-23
Table 2.21.	LAW Sub-Envelope A3 (AN-104) Waste Simulant Recipe at 8 Molar Sodium.	T-24
Table 2.22.	Target and Analyzed Compositions (wt%) of Five ORPLC Crucible Glasses.	T-25

Table 2.23. Descriptions of Five As-Melted and Heat Treated ORPLC Crucible Glasses. T-26
Table 2.24. Measured Sulfate Solubility Limits in Five ORPLC Crucible Glasses. T-26
Table 2.25. Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Five ORPLC Crucible Glasses. T-27
Table 2.26. Viscosities and Electrical Conductivities of Three ORPLC Crucible Glasses. T-28
Table 2.27. Results of K-3 Corrosion Testing for Five ORPLC Crucible Glasses. T-28
Table 2.28. Summary of Test Results for Selected ORPLC Glass Formulation ORPLC5 and Comparison to ILAW Requirements. T-29
Table 2.29. Oxide Composition of AN-104 Simulant and ORPLC5 Glass Composition Used in Melter Tests (wt%). T-30
Table 2.30a. Glass Former Additives for 1 Liter of AN-104 Simulant (8 M Na) and Corresponding Melter Feed Properties. T-31
Table 2.30b. NaOH and Na_2SO_4 Additions Required to Obtain 23.57 wt% Na_2O and Various SO_3 Concentrations Ranging from 0.0 to 0.9 wt% in the ORPLC5 Glass. T-31
Table 2.31. LAW Sub-Envelope C2 (AN-102) Simulant Recipe at 8 Molar Sodium. T-32
Table 2.32. Target and Analyzed Compositions (wt%) of Three ORPLD Crucible Glasses. T-33
Table 2.33. Descriptions of Three As-Melted and Heat Treated ORPLD Crucible Glasses. T-34
Table 2.34. Measured Sulfate Solubility Limits in Three ORPLD Crucible Glasses. T-34
Table 2.35. Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Three ORPLD Crucible Glasses. T-35
Table 2.36. Viscosity and Electrical Conductivity of ORPLD1 Crucible Glass. T-36
Table 2.37. Results of K-3 Corrosion Testing for Three ORPLD Crucible Glasses. T-36
Table 2.38. Summary of Test Results for Selected ORPLD Glass Formulation ORPLD1 and Comparison to ILAW Requirements. T-37
Table 2.39. Oxide Composition of AN-102 Simulant and ORPLD1 Glass Composition Used in Melter Tests (wt%). T-38
Table 2.40a. Glass Former Additives for 1 Liter of AN-102 Simulant (8 M Na) and Corresponding Melter Feed Properties. T-39
Table 2.40b. NaOH and Na_2SO_4 Additions Required to Obtain 21 wt% Na_2O and Various SO_3 Concentrations Ranging from 0.0 to 1.3 wt% in the ORPLD1Glass. T-39
Table 2.41. LAW Sub-Envelope B1 (AZ-101) Waste Simulant Recipe at 7.0 Molar Sodium. T-40
Table 2.42. Target and Analyzed Compositions (wt%) of Twelve ORPLE Crucible Glasses. T-41
Table 2.43. Descriptions of Twelve As-Melted and Heat Treated ORPLE Crucible Glasses. T-43
Table 2.44. Measured Sulfate Solubility Limits in Twelve ORPLE Crucible Glasses. T-44
Table 2.45. Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Twelve ORPLE Crucible Glasses. T-45
Table 2.46. Viscosities and Electrical Conductivities of Twelve ORPLE Crucible Glasses. T-46
Table 2.47. Results of K-3 Corrosion Testing for Ten ORPLE Crucible Glasses. T-47

Table 2.48.	Summary of Test Results for Selected ORPLE Glass Formulation ORPLE12 and Comparison to ILAW Requirements.	T-48
Table 2.49.	Oxide Composition of AZ-101 Simulant and ORPLE12 Glass Composition Used in Melter Tests (wt%).	T-49
Table 2.50a.	Glass Former Additives for 1 Liter of LAW AZ-101 Simulant (7 M Na) and Corresponding Melter Feed Properties.	T-50
Table 2.50b.	NaOH and Na_2SO_4 Additions Required to Obtain 16 wt% Na_2O and Various SO_3 Concentrations Ranging from 1.25 to 1.75 wt% in the ORPLE12 Glass.	T-50
Table 2.51.	Characteristics of Melter Feed Samples During DM10 ORP LAW Tests.	T-51
Table 2.52.	Compositions of Vitrified Melter Feed Samples During DM10 ORP LAW Tests (wt%).	T-52
Table 3.1.	Summary of Region E Test Conditions and Results.	T-53
Table 3.2.	Summary of Region A Test Conditions and Results.	T-54
Table 3.3.	Summary of Region B Test Conditions and Results.	T-56
Table 3.4.	Summary of Region C Test Conditions and Results.	T-57
Table 3.5.	Summary of Region D Test Conditions and Results.	T-58
Table 4.1.	Listing of DM10 Glasses Discharged, Masses, Target Sulfur Contents and Analysis Performed.	T-59
Table 4.2.	XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%).	T-65
Table 4.3.	Compositions of Discharged Glass Samples During DM10 ORP LAW Tests with Maximum Sulfur Concentrations without Secondary Phases (wt%)	T-77
Table 4.4.	DCP Analyzed Compositions of Discharged Glass Samples During DM10 ORP LAW Tests with Maximum Sulfur Concentrations without Secondary Phases (wt%).	T-79
Table 4.5.	Listing of Dip Samples and Presence of Sulfate Layer During DM10 Melter Tests.	T-81
Table 4.6.	Results of PCT Leaching Procedure for Crucible Glass and Corresponding Melter Glass Samples that Contain the Maximum Sulfur Content Without Formation of Secondary Phases During DM10 ORP LAW Tests.	T-85
Table 4.7.	VHT Results (24 Day) for Crucible Glass and Corresponding Melter Glass Samples that Contain the Maximum Sulfur Content Without Formation of Secondary Phases During DM10 ORP LAW Tests.	T-87
Table 5.1.	Maximum Sodium and Sulfur Oxide Concentrations Achieved in Crucible and Melter Tests (wt% in Glass).	T-89

List of Figures

		Page
Figure 2.1.	Sulfate solubility determined by remelting with excess SO_3 for forty one new ORP LAW crucible glasses.	F-1
Figure 2.2.	VHT results for forty one new ORP LAW crucible glasses.	F-2
Figure 2.3.	Normalized PCT releases for forty one new ORP LAW crucible glasses.	F-3
Figure 2.4.	K3 Corrosion results for thirty eight new ORP LAW crucible glasses and three old LAW formulations.	F-4
Figure 2.5.	Results of SO_2/O_2 gas bubbling tests on the new ORP LAW glasses ORPLB4 and ORPLE12 and the previous ORP Envelope A glass LAWA161 at 1150°C showing the partial pressure of SO_3 vs. the SO_3 concentration in the glass melt.	F-5
Figure 3.1.	Representative plot of glass pool temperatures during DM10 tests.	F-6
Figure 3.2.	Representative plot of plenum temperatures during DM10 tests.	F-7
Figure 3.3.	XRF analysis of sulfur in DM10 product glasses.	F-8
Figure 4.1.	Secondary sulfur phases on discharge glass S10-G-109B from the end of Test 4D.	F-9
Figure 4.2.	XRF analysis of sodium in DM10 product glasses.	F-10
Figure 4.3.	XRF analysis of aluminum in DM10 product glasses.	F-11
Figure 4.4.	XRF analysis of silicon in DM10 product glasses.	F-12
Figure 4.5.	XRF analysis of calcium in DM10 product glasses.	F-13
Figure 4.6.	XRF analysis of zirconium in DM10 product glasses.	F-14
Figure 4.7.	XRF analysis of zinc in DM10 product glasses.	F-15
Figure 4.8.	XRF analysis of tin in DM10 product glasses.	F-16
Figure 4.9.	XRF analysis of vanadium in DM10 product glasses.	F-17
Figure 4.10.	XRF analysis of chromium in DM10 product glasses.	F-18
Figure 4.11.	XRF analysis of chlorine in DM10 product glasses.	F-19
Figure 4.12.	XRF analysis of potassium in DM10 product glasses.	F-20
Figure 4.13.	XRF analysis of cesium in DM10 product glasses.	F-21
Figure 4.14.	Secondary sulfur phases on dip sample Q10-D-148C from the end of Test 1D.	F-22
Figure 4.15.	Secondary sulfur phases on dip samples S10-D-110A, B, and C from the end of Test 4D.	F-23
Figure 4.16.	Secondary sulfur phases on dip sample T10-D-24D from the end of Test 5D.	F-24
Figure 4.17.	Comparison of VHT coupons for glass formulation ORPLA15.	F-25
Figure 4.18.	Comparison of VHT coupons for glass formulation ORPLB4.	F-26
Figure 4.19.	Comparison of VHT coupons for glass formulation ORPLC5.	F-27
Figure 5.1.	Overview of Na_2O and SO_3 loadings for WTP and ORP glasses.	F-28

List of Abbreviations

AA	Atomic Absorption Spectroscopy
ANL-LRM	Argonne National Laboratory – Low-Activity Waste Reference Material
CCC	Canister Centerline Cooling
DCP-AES	Direct Current Plasma Atomic Emission Spectroscopy
DM	DuraMelter
DOE	Department of Energy
EDS	Energy Dispersive X-ray Spectroscopy
FTIR	Fourier Transform Infrared Spectroscopy
GFC	Glass Forming Chemical
HEPA	High-Efficiency Particulate Air Filter
HLW	High Level Waste
IC	Ion Chromatography
IHLW	Immobilized High Level Waste
ILAW	Immobilized Low Activity Waste
LAW	Low Activity Waste
M	Molarity
NQA	Nuclear Quality Assurance
ORP	Office of River Protection
PCT	Product Consistency Test
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RPP	River Protection Project
SEM	Scanning Electron Microscope
TFCOUP	Tank Farm Contractor Operation and Utilization Plan
VHT	Vapor Hydration Test
VSL	Vitreous State Laboratory
WTP	Hanford Tank Waste Treatment and Immobilization Plant
XRF	X-Ray Fluorescence Spectroscopy

SECTION 1.0
INTRODUCTION

About 50 million gallons of high-level mixed waste is currently stored in underground tanks at The United States Department of Energy's (DOE's) Hanford site in the State of Washington. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) will provide DOE's Office of River Protection (ORP) with a means of treating this waste by vitrification for subsequent disposal. The tank waste will be separated into low- and high-activity waste fractions, which will then be vitrified respectively into Immobilized Low Activity Waste (ILAW) and Immobilized High Level Waste (IHLW) products. The ILAW product will be disposed in an engineered facility on the Hanford site while the IHLW product will be directed to the national deep geological disposal facility for high-level nuclear waste. The ILAW and IHLW products must meet a variety of requirements with respect to protection of the environment before they can be accepted for disposal.

The Office of River Protection is currently examining options to optimize the Low Activity Waste (LAW) Facility and LAW glass waste form. One option under evaluation is to enhance the waste processing rate of the vitrification plant currently under construction. It is likely that the capacity of the LAW vitrification plant can be increased incrementally by implementation of a variety of low-risk, high-probability changes, either separately or in combination. These changes include:

- Operating at the higher processing rates demonstrated at the LAW pilot melter
- Increasing the glass pool surface area within the existing external melter envelope
- Increasing plant availability
- Increasing the glass waste loading
- Operating the melter at a slightly higher temperature

The Vitreous State Laboratory at The Catholic University of America (VSL) and Energy*Solutions*, Inc. have evaluated several of these potential incremental improvements for ORP in support of its evaluation of WTP LAW facility optimization [1]. Some of these incremental improvements have been tested at VSL including increasing the waste loading, increasing the processing temperature, and increasing the fraction of the sulfur in the feed that is partitioned to the off-gas stream (assuming that the present WTP recycle loop can be broken) [2-4]. These approaches successfully demonstrated increases in glass production rates and significant increases in sulfate incorporation and, therefore, waste loadings. This testing also demonstrated production rate increases and sulfur retention in the glass product at slightly higher than nominal glass processing temperatures. Subsequent tests demonstrated further enhancement of glass formulations for all of the LAW waste envelopes, increasing waste loading in the glass product and thereby reducing the amount of glass to be produced by the WTP for the same amount of waste processed [5, 6]. In particular, test results showed sulfate loadings of up to

1.2 wt% SO_3 in a LAW Envelope A glass containing 20 wt% Na_2O [2]; sulfur target concentrations of 1.6 wt% and 1.2 wt% SO_3, respectively, for glasses produced from LAW Envelope B and C wastes [5, 6]; and a sodium loading of 23 wt% Na_2O in a LAW Envelope A glass [6]. All of these formulations met all of the LAW product quality and processing requirements. Building on these very promising results, the testing described in this final report address a series of tests that expand this formulation approach to a wider range of waste types and assesses the extent to which further increases in waste loadings are possible. These tests entailed the development of glass formulations to maximize waste loading for five different LAW compositions (Regions A, B, C, D and E) followed by confirmatory small-scale melter testing of the selected formulations. The testing was designed to identify the limits of waste loading in glass formulations spanning the range of expected Na_2O and SO_3 concentrations in the LAW glasses in order to provide ORP with an assessment of bounds upon the waste loading improvements that might be possible for the LAW vitrification system. Once process variations and operating envelope requirements are imposed, the waste loadings for practically viable operating target compositions would be expected to have to fall beneath these bounds.

For a large number of Hanford LAW waste streams, sulfur is the main component that limits waste loading in glass. However, for some LAW Envelope A waste streams with low sulfate contents, the alkali concentration becomes the waste loading limiting factor. In general, waste loading is limited by sulfur for wastes with a high sulfur-to-sodium ratio, while those with a low sulfur-to-sodium ratio are limited by sodium (or more specifically, total alkali (sodium plus potassium)). Minimizing overall glass volume across the entire LAW inventory, which is clearly of economic benefit, therefore entails addressing both the sulfur limitation and the alkali limitation, depending on the waste type.

While processing melter feeds with very high sulfate concentrations, a molten sulfate salt phase forms in the cold-cap region during processing. This phase may exist as transient droplets or be sufficiently extensive to produce a separate salt phase that becomes mechanically disengaged from the rest of the cold cap. Once formed, the salt phase is slow to dissolve into the underlying glass melt; consequently, the salt phase typically forms before the underlying glass melt is saturated with sulfate [7-10]. If the feed rate is sufficiently low (which is clearly undesirable), the equilibrium sulfate saturation concentration in the glass can be approached more closely before a separate salt phase forms. However, in general, as the feed rate is increased, for the same sulfate concentration in the feed, the salt phase appears progressively earlier. Thus, in practice, the formation of a sulfate phase is governed by both thermodynamic and kinetic factors and, therefore, the effects of both must be considered in order to avoid the formation of such phases during operations. The presence of the corrosive, low-melting, electrically conductive salt phase is undesirable from the perspectives of melter operation, melter lifetime, safety, and product quality. Accordingly, the WTP plans to control the composition of the LAW melter feed such that formation of a separate salt phase is avoided. Clearly, the control bounds that are imposed will determine the achievable waste loading limits and, therefore, will determine the waste processing rate for a given glass production rate (i.e., melter capacity).

For waste with low sulfur-to-sodium ratio, waste loading is instead limited by the total alkali content in the glass. At high alkali contents, glass leach resistance (PCT and VHT)

decreases and the refractory corrosion rate in the glass melt increases. In addition, the melt viscosity may become too low and the electrical conductivity may become too high. Typically, however, the product leach resistance and the refractory corrosion properties are the first to be compromised as the alkali content in the glass is increased. Accordingly, the present work addresses LAW streams spanning a range of sulfur-to-sodium ratios with the objective of determining the maximum achievable waste loadings across this range, from sodium-limited to sulfur-limited formulations. As noted above, the broader intent is to develop a basis for estimation of the potential maximum waste loadings and corresponding glass volumes for the entire LAW inventory.

Under a separate contract to support the WTP Project, the VSL is developing and testing glass formulations for RPP-WTP waste envelopes to provide data to meet the RPP-WTP contract requirements and to support system design activities [11-14]. That work is based upon small-scale batch melts ("crucible melts") using waste simulants. Selected formulations have also been tested in small-scale, continuously-fed, joule-heated melters (DM10 and DM100 systems) [9, 10, 15-24] and, ultimately, in the LAW Pilot Melter [25-36]. Such melter tests provide information on key process factors such as feed processing behavior, dynamic effects during processing, sulfate incorporation, processing rates, off-gas amounts and compositions, foaming control, etc., that cannot be reliably obtained from crucible melts. This sequential scale-up approach in the vitrification testing program ensures that maximum benefit is obtained from the more costly larger-scale melter tests and that the most effective use is made of those resources.

Under the WTP support effort, VSL and Energy*Solutions* have developed and identified glass compositions for processing the Phase I LAW tank waste streams for the WTP. These compositions have been tested for processing and product quality requirements at various scales ranging from crucible melts of about 400 g up to the LAW Pilot Melter at processing rates in excess of 6600 kg/day (2000 kg/m^2/day). The testing included the nominal feed compositions and those with ±15% variations in the waste simulants added to the melter feeds. The melter testing provided high confidence that the selected WTP compositions are unlikely to cause accumulation of a separate sulfate phase in the melter even at high feed processing rates. Feed processing characteristics and off-gas characteristics have been determined at various melter scales and data have been collected to support engineering and permitting requirements. Furthermore, statistically designed composition matrices were generated, and crucible melts of these glass compositions were prepared and characterized to qualify the glass composition region selected for WTP waste processing. The selected WTP compositions have also been tested to ensure their compatibility with melter materials of construction. The glass formulation development and melter testing work for the selected WTP compositions have reached a level of maturity where the compositions can be used for waste processing at the WTP with relatively high confidence.

The glass formulation and melter testing work described in the Test Plan for this work [37] and presented in this final report is aimed at identifying glass compositions that have the potential to accommodate higher waste loadings than does the present WTP baseline. This information will provide ORP with a basis for evaluation of the likely potential for future

enhancements of the WTP over and above the present well-developed baseline. In this regard, this work is complementary to, and necessarily of a more exploratory nature than the work in support of the current WTP baseline. It should be noted, therefore, that to the extent that the present effort is successful, considerable further work would be required to bring the level of confidence in the new glass composition regions to a similar level of maturity to that of the current WTP baseline.

Glass compositions were developed targeting each of the five high sodium-sulfur waste loading regions specified in Table 1.1. Crucible melts were prepared and the samples were tested with respect to properties affecting processing (viscosity, electrical conductivity, crystallization, and refractory corrosion) and product quality (PCT and VHT). Based on the crucible melt results, a formulation was selected for DM10 melter testing for each of the glass regions. It was not known in advance the extent to which the target sulfur and sodium levels could be met, which was one of the principal reasons for performing this work. Thus, since the test outcomes were not known, the testing strategy allowed for appropriate compromises based on the test data that are collected. For each region, the crucible melt work identified suitable formulations for the target sodium content at the target sulfate content. If the target sodium content could not be achieved, the crucible work determined the highest sodium content that can be achieved for the target sulfate content. For example, it was determined that for Region D it was not possible to reach Na_2O = 25 wt% at SO_3 = 1.0 wt% while meeting all of the imposed product quality and processability constraints; instead, the highest Na_2O content was 21 wt% at the target SO_3 = 1.0 wt% level, and therefore the maximum achievable sodium oxide loading used for the subsequent melter tests was 21 wt%. The melter tests would then fix this sodium loading (and the corresponding glass formulation) and scan the SO_3 loading from slightly below the target to the point at which a salt phase is formed. In this way, a point on the Na_2O - SO_3 boundary was determined for each Region. A further constraint on the selection of each composition for melter testing was that the waste loading should not be lower than that indicated by the results from previous testing [2, 5, 6].

Based on the crucible formulation logic described above, DM10 tests were performed on each of the five selected formulations. The melter tests described in this report utilized waste simulants prepared by Optima Chemicals according to VSL specifications that were blended with glass formers at VSL to produce the melter feed. Sufficient feed was prepared to produce over half a metric ton of glass. Reductant in the form of sugar was added to the feed at a stoichiometric ratio of 0.5 (1 mole sucrose per 16 moles NOx or 3 moles carbon per 4 moles NOx). For all but Region E (LAW AZ-101), the waste simulant was procured from Optima without sulfur and a corresponding portion of the sodium such that the sulfur content could be adjusted to desired concentrations by the addition of various combinations of NaOH and Na_2SO_4. The Region E simulant was procured with a target SO_3 concentration of 1.25 wt% in the glass. These tests were performed at 1150^{o}C and with a target glass production rate of 2,250 kg/(m^2-day). Each test segment was nominally 14 hours duration, which corresponds to three melter turnovers for the DM10 melter system that was employed. In each test sequence, composed of about 3 to 6 test segments, the sulfate content was progressively increased to the point at which a sulfate salt phase developed, indicating the limit of sulfate incorporation for that particular formulation. Quantitative measurements of glass production rates, melter operating conditions

(temperatures, pressures, power, flows, etc.), and select gaseous emissions (NOx, SO_2, CO, and acid gases) were made for each test. Glass samples taken from the glass pool and the air-lift discharged glass were inspected throughout testing to determine the limit of feed SO_3 concentration for operation of the melter without a separate sulfate phase.

The glass formulation development for this work followed a methodology developed by VSL/Energy*Solutions* during previous work. The methodology can be summarized as follows:

- Use existing glass formulation data and models to identify initial glass formulations for testing. The data used include ORP and WTP test data, data from other DOE programs, glass literature, geology, etc.
- Characterize the first set of glasses and use the information to refine the glass formulation for the next test set (active glass formulation design approach).
- Characterize glass samples for properties that are likely to be most challenging.
- For promising glasses, complete full characterization.
- Determine sulfur loading and processing characteristics through melter tests.

The glass formulation development work relied heavily on previous ORP work [2, 5, 6] and relevant WTP LAW glass formulation work [11-14]. Some of the earlier ORP glass compositions that were used to select starting glass compositions for the current tests include LAWA187 [6], LAWC100 [5], LAWA161 [2], and LAWB99 [6]. Existing property-composition models were used to guide glass formulation development. However, since the existing models are not expected to be reliable in the new composition regions that were explored in this work, glass science knowledge and experience, and information about the effect of various additives on glass structure and properties were used as additional tools to guide glass formulation development.

1.1 Test Objectives

The principal objective of this work was to extend the glass formulation methodology developed in the earlier work [2, 5, 6] for Envelope A, B and C waste compositions for development of compliant glass compositions targeting five high sodium-sulfur waste loading regions. This was accomplished through a combination of crucible-scale tests, and tests on the DM10 melter system. The DM10 was used for several previous tests on LAW compositions [2-4, 9, 10] to determine the maximum feed sulfur concentrations that can be processed without forming secondary sulfate phases on the surface of the melt pool. This melter is the most efficient melter platform for screening glass compositions over a wide range of sulfate concentrations and therefore was selected for the present tests. The tests were conducted to provide information on melter processing characteristics and off-gas data, including sulfur incorporation and partitioning. As described above, the main objective was to identify the limits of waste loading in compliant glass formulations spanning the range of expected Na_2O and SO_3 concentrations in the LAW glasses.

The five waste types selected and their respective target sodium and sulfur loadings are:

- *Region A*: LAW Sub-Envelope A1 (AN-105) with minimum concentrations of Na_2O and SO_3 of 25 and 0 weight percent, respectively.
- *Region B*: LAW Sub-Envelope C1 (AN-107) with minimum concentrations of Na_2O and SO_3 of 25 and 0.35 weight percent, respectively.
- *Region C*: LAW Sub-Envelope A3 (AN-104) with minimum concentrations of Na_2O and SO_3 of 25 and 0.65 weight percent, respectively.
- *Region D*: LAW Sub-Envelope C2 (AN-105) with minimum concentrations of Na_2O and SO_3 of 25 and 1.0 weight percent, respectively.
- *Region E*: LAW Sub-Envelope B1 (AZ-101) with minimum concentrations of Na_2O and SO_3 of 16 and 1.25 weight percent, respectively.

1.2 Quality Assurance

This work was conducted under a quality assurance program that is in place at the VSL that is based on Nuclear Quality Assurance (NQA)-1 (1989) and NQA-2a (1990) Part 2.7. This program is supplemented by a Quality Assurance Project Plan [38] for WTP work that is conducted at VSL. Test and procedure requirements by which the testing activities were planned and controlled are defined in the Test Plan [37]. The program is supported by VSL standard operating procedures that were used for this work [39]. The requirements of DOE/RW-0333P are not applicable to this work.

SECTION 2.0
WASTE SIMULANT, GLASS FORMULATIONS AND FEED ANALYSIS

Glass formulation development and testing were conducted to identify compliant high waste loading glasses for Hanford LAW streams. The glass formulations covered a large portion of the expected range of Na_2O and SO_3 concentrations in LAW glasses. Based on the target Na_2O and SO_3 concentrations in the glasses, the glass formulation development was divided to focus on five LAW streams. The five waste types selected and their respective target sodium and sulfur loadings, as given in the Test Plan [37], are:

- *Region A: LAW Sub-Envelope A1 (AN-105) with minimum concentrations of Na_2O and SO_3 of 25 and 0 weight percent, respectively.*
- *Region B: LAW Sub-Envelope C1 (AN-107) with minimum concentrations of Na_2O and SO_3 of 25 and 0.35 weight percent, respectively.*
- *Region C: LAW Sub-Envelope A3 (AN-104) with minimum concentrations of Na_2O and SO_3 of 25 and 0.65 weight percent, respectively.*
- *Region D: LAW Sub-Envelope C2 (AN-105) with minimum concentrations of Na_2O and SO_3 of 25 and 1.0 weight percent, respectively.*
- *Region E: LAW Sub-Envelope B1 (AZ-101) with minimum concentrations of Na_2O and SO_3 of 16 and 1.25 weight percent, respectively.*

The waste simulant and glass formulations developed for each of these regions are described in Sections 2.1 through 2.5.

The intent of the testing was, while targeting the above values, to determine the highest achievable Na_2O and SO_3 loadings for each of the waste streams. Thus, as the formulation work progressed and data from testing became available, the target Na_2O and SO_3 concentrations in the glass formulations were revised. The revised target SO_3 values that were used in glass formulation development are given below.

During the planning stages of this work, a total of 30 crucible melts were budgeted to develop glass formulations for all five regions. The plan was to first develop Region E glasses, then Region A, followed by Regions B, C and D with the objective of implementing the lessons learned from glass development for each Region into the next one. Sulfur and sodium loadings achieved for each Region were of value in formulating glasses for the next Region. For example, it was necessary to determine the maximum Na_2O loading possible for Region A before proceeding to Region B glass testing. As testing progressed, it became clear that a much larger number of crucible melts would be required to meet the intent of the glass formulation development work. Ultimately, a total of 41 crucible melts were prepared and characterized. In

addition, for all but the ORPLE glasses, VHT measurements were done in duplicate because of the high variability in the VHT results, particularly at high sodium contents. Following the test strategy stated in the Test Plan [37], more effort was focused on the measurement of glass properties that were judged to be most challenging for each set of glasses. Properties that were judged likely to be compliant with contract and processing requirements were either not measured, or measured only on select samples. The most economical and efficient way to make the best use of a limited number of crucible melts, to meet the test objective of developing high waste loading glasses for five different waste steams, is to prepare and characterize them in very small sets using data from the previous set to guide the design of the next set. In addition, it is most economical to limit initial characterization of the glasses to the properties that are likely to be the most challenging to meet; further characterization need then be done only on those samples that pass the initial tests. However, since VHT was the most challenging criterion to meet and VHT test duration is 24 days, time constraints did not always allow the above approach. In many cases, schedule constraints demanded that a larger number of crucible melts be made together and measurements of different glass properties be done in parallel.

2.1 Region A (ORPLA) Waste Simulant and Glass Formulation

Glass formulation development and testing for Region A (ORPLA) were based on the composition of LAW material from Hanford tank AN-105. Details of the waste simulant, and glass formulation development and testing are given below.

2.1.1 Region A (ORPLA) Waste Simulant

A LAW Envelope A waste simulant based on the composition data for tank AN-105, as given in a WTP Test Specification [40], was used as the basis for ORPLA glass formulations. The base waste composition incorporates TFCOUP [41] data, actual waste analysis data, and WTP flow sheet information. The sodium concentration in the simulant includes a 2.5 % increase to account for sodium additions in pretreatment [12, 42]. The nominal concentration, expressed in terms of the sodium molarity, was determined on the basis of melter feed rheology tests on similar formulations [43, 44]. The results of those tests led to the selection of 8.0 molar sodium as the nominal simulant concentration for the LAW AN-105 waste. This is the same concentration that was used in previous WTP melter tests for LAW AN-105 waste [15, 22].

The nominal simulant formulation is given in Table 2.1. The LAW AN-105 simulant is a solution of predominantly sodium, aluminum, nitrate, and nitrite. Since the simulant was similar to those tested previously at the VSL, it was not necessary to prepare and perform screening tests on new laboratory samples. For the melter tests, Optima Chemicals, who supplied all of the LAW simulants for the previous DM100 and LAW Pilot Melter studies, prepared the waste simulant, which was shipped to VSL in 55-gallon drums. Glass forming chemicals, sugar as a reductant, and the requisite combinations of sodium hydroxide and sodium sulfate to adjust the sodium and sulfur contents of the feed for each test, were added at VSL.

2.1.2 Region A (ORPLA) Glass Formulation

Glass formulation development for Region A (ORPLA) was based on the composition of the LAW AN-105 waste stream. The objective was to develop a glass formulation that can accommodate the highest concentration of Na_2O. High sulfate loading in the glass was not a primary objective for this region. The target Na_2O and SO_3 loadings in the ORPLA glass were 25 wt% and 0 to 0.3 wt%, respectively. A total of seventeen crucible melts were prepared in an effort to identify a glass formulation that meets all processing and product quality requirements [45, 46]. Testing started with ORPLA1-ORPLA4 which showed that K-3 corrosion criteria are unlikely to be met without Cr_2O_3 addition. ORPLA5 showed that ZnO is helpful in reducing K-3 corrosion. ORPLA6 to ORPLA10 showed that the K-3 corrosion criterion can be met with close to 6 wt% ZrO_2, that SnO_2 improves VHT performance but reduces sulfur solubility, and that CaO improves sulfur solubility but increases K-3 corrosion. ORPLA12 to ORPLA14 showed that lower Na_2O is needed to simultaneously meet VHT and K-3 corrosion requirements, but that the viscosity of the glasses needed to be reduced to meet processing limits. ORPLA15 to ORPLA17 were used to adjust the viscosity, so that a glass similar in properties to ORPLA7 or ORPLA12 could be obtained but with lower viscosity (and lower VHT than ORPLA7). Initially, glass formulations were tested at a Na_2O concentration of 25 wt%. Since none of these glasses met both processing and product quality requirements, additional glasses were prepared at lower Na_2O concentrations of 23.5 and 24.0 wt%. Since sulfate loading was not a primary objective, glass former additives such as CaO, Li_2O, and V_2O_5 that facilitate higher sulfate loadings were either reduced in concentration or not added. For the very high Na_2O glasses, the properties of most concern are Vapor Hydration Test (VHT) alteration rates and K-3 refractory corrosion. In order to reduce K-3 refractory corrosion, Al_2O_3, SiO_2, and ZrO_2 concentrations were maintained at high levels in all the glasses, and Cr_2O_3 was added at a concentration of about 0.5 wt% to most of the glasses. ZrO_2 was found to be most beneficial in improving VHT performance, and was therefore maintained at high concentrations (> 4 wt%) in all of the glasses. Based on the results of previous work [47], SnO_2 was also added to improve VHT performance.

Target and analyzed compositions of the ORPLA glasses are given in Table 2.2. Glass compositions were determined by X-ray Fluorescence Spectroscopy (XRF) on powdered glass samples, except for B_2O_3, which was measured by Direct Current Plasma – Atomic Emission Spectroscopy (DCP-AES) after acid dissolution. As expected, measured concentrations of volatile components such as Cl and SO_3 are lower than target. As is evident from the table, the target and analyzed compositions show good agreement. XRF measured Cr_2O_3 concentrations in glasses with target concentration of ~ 0.5 wt% are, in general, about 25% above target. We believe that this is due to a small high bias in the XRF data in this range; no bias correction was applied to the XRF data presented in this report. DCP-AES analysis of the crucible glasses targeting 0.5 wt% Cr_2O_3 gave values ranging from 0.47 to 0.53 wt%, which is in agreement with the target concentration. Testing of all formulations started with glass preparation and optical microscopic evaluation of the as-melted sample. Glass samples were heat treated for 20 hours at 950°C and then evaluated for secondary phases. Observations of the as-melted and heat treated glasses are given in Table 2.3. All of the as-melted glasses appeared clear with some containing small amounts (< 0.1 vol%) of crystals. Some of the heat treated glasses showed spinel crystals.

Na-Zr-silicate crystals were present in some of the glasses that had high ZrO_2 content. Sn-containing crystals also were detected in ORPLA15 glass, which had the highest SnO_2 concentration.

The sulfate solubilities of the ORPLA glass compositions were assessed by batch saturation tests. This is a crucible-scale screening test that is used to obtain an indication of the extent of sulfur incorporation that will be obtained under actual melter operating conditions, which is, of course, the measure that is of practical importance. The results of these screening tests are then used to guide the range over which the melter tests are performed. The batch saturation tests were performed by remelting finely ground samples of the glasses with an excess of sulfate amounting to 4 wt% SO_3 if all of it were retained in the glass. The remelted glass samples are identified with an S4 at the end of the sample name. Results of sulfate batch saturation tests are given in Table 2.4 and Figure 2.1. The results identified as "after acid wash" are analyses of glass samples remelted with 4 wt% SO_3 after grinding and washing to remove any interstitial sulfate phases, to ensure that only the SO_3 that is dissolved in the glass is measured. The sulfate retentions in the glasses ("after acid wash") varied from about 0.27 wt% SO_3 for ORPLA15 to 0.55 wt% SO_3 for ORPLA9. Since high sulfur loading was not an objective of the glass development work for Region A, sulfur solubility in these glasses was not measured by the SO_2 bubbling method. The resources were instead used where most needed, such as for VHT and K-3 corrosion testing.

VHT and PCT results are summarized in Table 2.5 and illustrated in Figures 2.2 and 2.3. Since VHT results typically have fairly large relative standard deviation [48], the measurements were conducted on two samples each for all of the ORPLA glasses; one sample with the nominal SO_3 concentration and the other from the remelt with 4 wt% SO_3. VHT results given in Table 2.5 and Figure 2.2 show that a number of ORPLA glasses exceeded the VHT alteration rate requirement of 50 g/m^2/day. This was not unexpected because VHT requirement becomes more challenging as the alkali content of the glasses are increased and the intent was to examine bounding formulations. All four of the glasses with both VHT alteration rate measurements less than 50 g/m^2/day contain SnO_2 and high concentrations of ZrO_2. PCT releases for the glasses given in Table 2.5 and Figure 2.3 show that all of the glasses met the ILAW product quality requirement of normalized mass loss of less than 2 g/m^2 for B, Na, and Si. The viscosities and electrical conductivities of the glasses at select temperatures are given in Table 2.6. All of the electrical conductivity values are in the acceptable range for processing. However, viscosities of the glasses are generally high and some are outside of the acceptable range for melt processing [45]. Again, this is not unexpected because the glasses were designed to have viscosities towards the high limit for acceptability in order to reduce refractory corrosion. Glasses with viscosities both above and below the acceptance limit had to be prepared and characterized in order to identify glass compositions that are at the limit of acceptable viscosity for processing. Existing viscosity models are not useful for this purpose because the compositions explored in this work are outside of the applicable composition range of the models and, therefore, the model predictions are not reliable. Due to the high alkali content of the ORPLA glass formulations, K-3 refractory corrosion was a significant concern and, therefore, all of the glasses were tested for their K3 corrosion characteristics. K-3 refractory corrosion test results for the glasses are given in Table 2.7 and Figure 2.4, where they are compared to the results for some of the previously

tested ORP LAW glasses [2, 5, 6]. A number of the glasses had unacceptable K-3 corrosion characteristics, which could impact melter life. Acceptability of the corrosion characteristics of a glass composition is somewhat subjective because a glass composition that shows slightly higher K-3 corrosion, but allows higher waste loading, may be a more economic choice than one with lower K-3 corrosion and lower waste loading. However, for WTP LAW glass formulation development, a neck corrosion of 0.035 inches on 6-day K-3 coupon corrosion test at 1208°C has been used as an acceptance limit. A neck loss of about 0.035 inches in the corrosion test corresponds to less than about one inch of K-3 corrosion per year for the WTP melter; however, the precise relationship will depend on other factors, such as the production rate, operating temperature, etc. For the current LAW glass formulation development work for ORP, since higher waste loading compositions are being explored, a slightly higher neck corrosion value of 0.040 inches has been used as a guide for acceptable corrosion characteristics.

Of all seventeen ORPLA glass formulations tested, only one, ORPLA15, met all processing and product quality requirements and was, therefore, selected for melter testing. The measured properties of the glass ORPLA15 are compared to the ILAW performance requirements [45, 46] in Table 2.8. Density and glass transition temperature (T_g) measurements, and canister centerline cooling (CCC) heat treatment were not conducted on ORPLA15 glass because the glass is expected to be acceptable with respect to these properties. Of all the LAW glasses tested to date for Hanford, none had density values over or near the contract limit of 3.7 g/cc and therefore with high confidence ORPLA15 is expected to have a density of less than 3.7 g/cc. The only requirement for T_g is that it be measured and reported. Since the sample heat treated at 950°C for 20 hours showed only 0.3 vol% of crystals, CCC treatment is not expected to cause extensive crystallization. Though cooling of the glass discharged from the DM10 melter occurs faster than in a WTP LAW canister, examination of cooled ORPLA15 glass samples from the DM10 melter corroborated this expectation in that very few crystals were present in the discharge glass samples.

The composition of the ORPLA15 glass used in melter tests is given in Table 2.9 along with the oxide contributions from the LAW AN-105 waste simulant and from the glass former additives. The simulant was procured with no SO_3 and the sulfur concentration was increased in steps during the melter tests by adding the appropriate amounts of Na_2SO_4 and NaOH to the feed. The melter feed was procured at a Na_2O concentration of 23.41 wt% in order to accommodate Na_2SO_4 and NaOH additions, without increasing the Na_2O concentration above 24.0 wt%. The types and amounts of glass former additives used to prepare the melter feed along with the target feed properties are given in Table 2.10a. The glass former additives are the same as those planned for use at the WTP, with the exception of chromium and tin, which would be new additives. The amounts of Na_2SO_4 and NaOH added to the feed to obtain 24 wt% Na_2O and 0.10 to 0.60 wt% SO_3 are given in Table 2.10b.

2.2 Region B (ORPLB) Waste Simulant and Glass Formulation

Glass formulation development and testing for Region B (ORPLB) were based on the composition of LAW material from Hanford tank AN-107. Details of the waste simulant and glass formulation development and testing are given below.

2.2.1 Region B (ORPLB) Waste Simulant

A LAW Envelope C waste simulant based on the composition data for tank AN-107, as given in a WTP Test Specification [40], was used as the basis for ORPLB glass formulations. The base waste composition incorporates TFCOUP [41] data, actual waste analysis data, and WTP flow sheet information. The sodium concentration in the simulant includes a 17.65 % increase to account for sodium additions in pretreatment [12, 42]. The nominal concentration, expressed in terms of the sodium molarity, was estimated on the basis of melter feed rheology tests on similar formulations [43, 44]. The concentration of the simulant used in melter tests was 8.0 molar sodium. This is higher than that used in previous melter tests [20, 22] because of the higher waste loading in the ORPLB glasses. As the waste loading increases, waste simulants at higher concentrations can be used to prepare melter feed because lesser amounts of glass forming chemicals need to be added.

The nominal simulant formulation is given in Table 2.11. The LAW AN-107 simulant is a solution of predominantly sodium, nitrate, nitrite, and sulfate. Preparation of the waste simulant and melter feed were done in a manner similar to that for ORPLA simulant, which is described in Section 2.1.1.

2.2.2 Region B (ORPLB) Glass Formulation

Glass formulation development for Region B (ORPLB) was based on the composition of the LAW AN-107 waste stream. For glass formulation purposes, the target SO_3 loading in the ORPLB glass was 0.2 to 0.5 wt%. Four crucible melts were prepared in an effort to identify a glass formulation that meets all processing and product quality requirements. Similar to the ORPLA glasses, the properties of most concern were VHT alteration rate and K-3 refractory corrosion. In order to reduce K-3 refractory corrosion, Al_2O_3, SiO_2, and ZrO_2 concentrations were maintained at high levels in all the glasses, and Cr_2O_3 was added at a concentration of about 0.5 wt% to all of the glasses. In order to improve VHT performance, ZrO_2 was maintained at high concentrations (> 5 wt%) and SnO_2 was added to all of the glasses [47]. Since the target SO_3 loadings were higher in ORPLB glasses than for the ORPLA glasses, V_2O_5 was added to all of the ORPLB glass formulations. In addition, based on the results of Region A glass testing, the Na_2O concentration was reduced to 24 wt% in ORPLB3 and ORPLB4. Lessons learned from Region A glass development, which are listed above, were valuable in guiding the Region B glass development work.

Target and analyzed compositions of the ORPLB glasses are given in Table 2.12. Testing and analysis of the glasses followed the same methods used for ORPLA glasses, which are described in Section 2.1.2. As is evident from the table, the target and analyzed compositions show good agreement. Glass samples were heat treated for 20 hours at 950°C and then evaluated for secondary phases. Observations of the as-melted, and heat treated glasses are given in Table 2.13. All of the as-melted glasses appeared clear with one containing small amounts (< 0.1 vol%) of crystals. All of the heat treated glasses showed small amounts of spinel crystals at concentrations not greater than 0.2 vol%.

The sulfate solubilities of the ORPLB glass compositions were assessed by both batch saturation and bubbling tests. The batch saturation tests are described in Section 2.1.2. The results of batch saturation tests are given in Figure 2.1 and Table 2.14. In the bubbling test, a sample of the test glass that does not contain any sulfate is melted in a platinum crucible and held at a constant temperature of 1150°C. Mixtures of SO_2 and O_2 are then bubbled through the glass melt at controlled flow rates through a platinum tube. From the flow rates and the temperature, together with known thermodynamic data, the partial pressure of SO_3 can be calculated. Samples of the glass melt are removed at selected time intervals and subjected to analysis by XRF to determine their sulfur content. Prior to analysis, the glass samples are ground and washed to remove any sulfate phase that might adhere to the sample in order to determine only the sulfate that is dissolved in the glass. Figure 2.5 shows the results of these tests for one of the ORPLB glasses, ORPLB4; also shown are the results for a previously tested high sulfate ORP LAW Envelope A glass LAWA161 [2], and an ORPLE glass formulation (see Section 2.5.2). The results show that the ORPLB4 glass has lower sulfate solubility than the other two glasses. This is expected, because as indicated in Figure 2.5, ORPLB4 has higher Na_2O concentration than the other two glasses. The results of sulfate solubility determinations by batch saturation tests and gas bubbling tests for ORPLB glasses are given in Table 2.14. The sulfate solubilities varied from 0.52 to 0.58 wt% by batch saturation tests and 0.62 to 0.70 wt% by bubbling tests.

VHT and PCT results are summarized in Table 2.15 and illustrated in Figures 2.2 and 2.3. Similar to ORPLA glasses, VHT alteration rates were measured using one sample with nominal SO_3 concentration and another from the remelt with 4 wt% SO_3. VHT results show that only ORPLB4 met the contract requirement that alteration rate be less than 50 g/m^2/day. Again, this was not unexpected because glasses were formulated with the objective of attaining the highest possible Na_2O loading and VHT performance becomes the limiting factor in these formulations. PCT releases for the glasses given in Table 2.15 and Figure 2.3 show that all of the glasses met the ILAW product quality requirement of normalized mass loss of less than 2 g/m^2 for B, Na, and Si. The viscosities and electrical conductivities of the glasses at select temperatures are given in Table 2.16. All of the viscosity and electrical conductivity values are in the acceptable range for processing. However, as intended, the viscosities of the glasses are generally on the high end of acceptability in order to reduce refractory corrosion. Due to the high alkali content of the new ORPLB glass formulations, K-3 refractory corrosion was a significant concern and, therefore, all of the glasses were tested for their K3 corrosion characteristics. K-3 refractory corrosion test results for the glasses are given in Table 2.17 and Figure 2.4. All four of the ORPLB glasses met the guidance of no more than 0.040 inches of neck loss in the K-3 corrosion test.

Of the four ORPLB glass formulations tested, only one, ORPLB4, met all processing and product quality requirements and was, therefore, selected for melter testing. The measured properties of the glass ORPLB4 are compared to the ILAW performance requirements [45, 46] in Table 2.18. Density and glass transition temperature measurements, and canister centerline cooling (CCC) heat treatment were not conducted on ORPLB4 glass. Examination of cooled ORPLB4 glass samples from the DM10 melter tests showed little crystallization, indicating that the glass is unlikely to show substantial crystallization on CCC heat treatment.

The composition of the ORPLB4 glass used in melter tests is given in Table 2.19 along with the oxide contributions from the LAW AN-107 waste simulant and from the glass former additives. The simulant was procured with no SO_3 and the sulfur concentration was increased in steps during the melter tests by adding the appropriate amounts of Na_2SO_4 and NaOH to the feed. The melter feed was procured at a Na_2O concentration of 22.89 wt% in order to accommodate Na_2SO_4 and NaOH additions, without increasing the Na_2O concentration above 24.0 wt%. The types and amounts of glass former additives used to prepare the melter feed along with the target feed properties are given in Table 2.20a. The glass former additives are the same as those planned for use at the WTP, with the exception of chromium, tin, and vanadium, which are new additives. The amounts of Na_2SO_4 and NaOH added to the feed to obtain 24 wt% Na_2O and 0.60 to 1.0 wt% SO_3 are given in Table 2.20b.

2.3 Region C (ORPLC) Waste Simulant and Glass Formulation

Glass formulation development and testing for Region C (ORPLC) were based on the composition of LAW material from Hanford tank AN-104. Details of the waste simulant, and glass formulation development and testing are given below.

2.3.1 Region C (ORPLC) Waste Simulant

A LAW Envelope A waste simulant based on the composition data for tank AN-104, as given in a WTP Test Specification [40], was used as the basis for ORPLC glass formulations. The base waste composition incorporates TFCOUP [41] data, actual waste analysis data, and WTP flow sheet information. The sodium concentration in the simulant includes a 2.5 % increase to account for sodium additions in pretreatment [12, 42]. The nominal concentration, expressed in terms of the sodium molarity, was estimated on the basis of melter feed rheology tests on similar formulations [43, 44]. The concentration of the simulant used in melter tests was 8.0 molar sodium. This is higher than that used in previous melter tests [17, 24] because of the higher waste loading in the ORPLC glasses.

The nominal simulant formulation is given in Table 2.21. The LAW AN-104 simulant is a solution of predominantly sodium, nitrate, nitrite, chlorine and sulfate. Preparation of the waste simulant and melter feed were done in a manner similar to that for ORPLA simulant, which is described in Section 2.1.1.

2.3.2 Region C (ORPLC) Glass Formulation

Glass formulation development for Region C (ORPLC) was based on the composition of the LAW AN-104 waste stream. The target SO_3 loading in the ORPLC glass was 0.45 to 0.75 wt%. Five crucible melts were prepared in an effort to identify a glass formulation that meets all processing and product quality requirements. Similar to the ORPLA and ORPLB glasses, due to their high Na_2O concentrations, the properties of most concern were VHT alteration rate and K-3 refractory corrosion. In order to reduce K-3 refractory corrosion, Al_2O_3, SiO_2, and ZrO_2 concentrations were maintained at high levels in all the glasses, and Cr_2O_3 was added at a concentration of about 0.5 wt% to all of the glasses. In order to improve VHT performance, ZrO_2 was maintained at high concentrations (> 3.4 wt%) and SnO_2 was added to all of the glasses [47]. Since the target SO_3 loadings were higher in ORPLC glasses than for the ORPLA glasses, V_2O_5 was added to all of the ORPLC glass formulations.

Target and analyzed compositions of the ORPLC glasses are given in Table 2.22. Testing and analysis of the glasses followed the same methods used for ORPLA glasses, which are described in Section 2.1.2. As is evident from the table, the target and analyzed compositions show good agreement. Glass samples were heat treated for 20 hours at 950°C and then evaluated for secondary phases. Observations of the as-melted and heat treated glasses are given in Table 2.23. All of the as-melted glasses appeared clear with very small amounts (< 0.1 vol%) of crystals. The heat treated glasses also showed little crystallization (< 0.3 vol%).

The sulfate solubilities of the ORPLC glass compositions were assessed by both batch saturation and bubbling tests. The batch saturation tests are described in Section 2.1.2 and the bubbling tests are described in Section 2.2.2. The results of the tests are given in Figure 2.1 and Table 2.24. The sulfate solubilities of the ORPLC glasses varied from 0.56 to 0.70 wt% by batch saturation tests and 0.58 to 1.09 wt% by bubbling tests.

VHT and PCT results are summarized in Table 2.25 and illustrated in Figures 2.2 and 2.3. Similar to ORPLA and ORPLB glasses, VHT was measured on two samples each for all the glasses. Although all of the glasses met the PCT release limits, only ORPLC5 passed the VHT contract requirement that alteration rate be less than 50 g/m^2/day. Again, this was not unexpected because glasses were formulated with the objective of attaining the highest possible Na_2O loading and VHT performance becomes the limiting factor in these formulations. The viscosities and electrical conductivities of three of the ORPLC glasses at select temperatures are given in Table 2.26. All of the viscosity and electrical conductivity values are in the acceptable range for processing. All of the ORPLC glasses were tested for their K3 corrosion characteristics. K-3 refractory corrosion test results for the glasses are given in Table 2.27 and Figure 2.4. Only two of the glasses met the guidance of no more than 0.040 inches of neck loss in the K-3 corrosion test.

Of the five ORPLC glass formulations tested, only one, ORPLC5, met all processing and product quality requirements and was, therefore, selected for melter testing. The measured

properties of the glass ORPLC5 are compared to the ILAW performance requirements [45, 46] in Table 2.28. Density and glass transition temperature measurements, and canister centerline cooling (CCC) heat treatment were not conducted on ORPLC5 glass. Examination of cooled ORPLC5 glass samples from the melter tests showed little crystallization, indicating that the glass is unlikely to show substantial crystallization on CCC heat treatment. Again, an acceptable Region C glass for melter testing was more easily identified because it was possible to build on the results from the Region A and B testing, as was the intended strategy. ORPLC5 was modeled after ORPLB4 with adjustment for K_2O content of the Region C waste stream.

The composition of the ORPLC5 glass used in melter tests is given in Table 2.29 along with the oxide contributions from the LAW AN-104 waste simulant and from the glass former additives. The simulant was procured with no SO_3 and the sulfur concentration was increased in steps during the melter tests by adding the appropriate amounts of Na_2SO_4 and NaOH to the feed. The melter feed was procured at a Na_2O concentration of 22.11 wt% in order to accommodate Na_2SO_4 and NaOH additions without increasing the Na_2O concentration above 23.57 wt%. The types and amounts of glass former additives used to prepare the melter feed along with the target feed properties are given in Table 2.30a. The glass former additives are the same as those planned for use at the WTP, with the exception of chromium, tin, and vanadium, which are new additives. The amounts of Na_2SO_4 and NaOH added to the feed to obtain 23.57 wt% Na_2O and 0.0 to 0.9 wt% SO_3 are given in Table 2.30b.

2.4 Region D (ORPLD) Waste Simulant and Glass Formulation

Glass formulation development and testing for Region D (ORPLD) were based on the composition of LAW material from Hanford tank AN-102. Details of the waste simulant, and glass formulation development and testing are given below.

2.4.1 Region D (ORPLD) Waste Simulant

A LAW Envelope C waste simulant based on the composition data for tank AN-102, as given in a WTP Test Specification [40], was used as the basis for ORPLD glass formulations. The base waste composition incorporates TFCOUP [41] data, actual waste analysis data, and WTP flow sheet information. The sodium concentration in the simulant includes a 17.65 % increase to account for sodium additions in pretreatment [12, 42]. The nominal concentration, expressed in terms of the sodium molarity, was estimated on the basis of melter feed rheology tests on similar formulations [43, 44]. The concentration of the simulant used in melter tests was 8.0 molar sodium. This is higher than that used in previous melter tests [21, 24] because of the higher waste loading in the ORPLD glasses.

The nominal simulant formulation is given in Table 2.31. The LAW AN-102 simulant is a solution of predominantly sodium, nitrate, nitrite, and sulfate. Preparation of the waste simulant and melter feed were done in a manner similar to that for ORPLA simulant, which is described in Section 2.1.1.

2.4.2 Region D (ORPLD) Glass Formulation

Glass formulation development for Region D (ORPLD) was based on the composition of the LAW AN-102 waste stream. The target SO_3 loading in the ORPLD glass was 0.6 to 1.2 wt%. Three crucible melts were prepared in an effort to identify a glass formulation that meets all processing and product quality requirements. Since target SO_3 loadings were higher in ORPLD glasses than for ORPLA, ORPLB, and ORPLC glasses, V_2O_5 was added to all of the ORPLD glass formulations. The concentration of CaO, which facilitates higher SO_3 loadings, was increased in all three glasses and Li_2O, which is another additive that is very beneficial in increasing SO_3 loadings, was added in small amounts to two of the glasses. Higher Li_2O concentrations could not be employed because the glass already contains a high concentration (21 wt%) of Na_2O and higher combined alkali loadings will have adverse effects on PCT, VHT, and K-3 refractory corrosion. In order to reduce K-3 refractory corrosion, Cr_2O_3 was added at a concentration of about 0.5 wt% to all of the glasses. Region D glass development work benefited greatly from Regions A, B, C and E testing, as was the intended strategy. In addition, the Na_2O concentration was reduced, making Region D glasses comparable to previously tested ORP glasses such as LAWA161 [2] and LAWC100 [5].

Target and analyzed compositions of the ORPLD glasses are given in Table 2.32. Testing and analysis of the glasses followed the same methods used for ORPLA glasses, which are described in Section 2.1.2. As is evident from the table, the target and analyzed compositions show good agreement. Glass samples were heat treated for 20 hours at 950°C and evaluated for secondary phases. Observations of the as-melted, and heat treated glasses are given in Table 2.33. All of the as-melted glasses appeared clear with small amounts (0.2 vol% or less) of crystals. The heat treated glasses also showed little crystallization (0.2 vol% or less).

The sulfate solubilities of the ORPLD glass compositions were assessed by batch saturation tests. The batch saturation tests are described in Section 2.1.2 and the results of the tests are given in Figure 2.1 and Table 2.34. The sulfate solubilities of the ORPLD glasses varied from 0.70 to 0.89 wt% by batch saturation tests. Region D glasses were the last ones tested. At this time, the equipment used to do sulfate saturation by bubbling failed and had to be repaired. It was, therefore, decided to use the sulfate saturation by batch testing to make the glass selection rather than delay the melter testing and reporting schedule. In addition, comparisons were made to other ORP glasses (ORPLE12, ORPLE4, ORPLE5, LAWA161, LAWC100) to make the judgment that the glass will likely meet or exceed sulfate loading in the feed of about 1.0 wt%. VHT and PCT results are summarized in Table 2.35 and illustrated in Figures 2.2 and 2.3. All three of the glasses met the PCT release and VHT alteration rate limits. The viscosities and electrical conductivities of ORPLD1 glass at select temperatures are given in Table 2.36. The viscosities and electrical conductivities of the other two glasses were not measured because they did not meet the K-3 refractory corrosion criterion. K-3 refractory corrosion test results for the glasses are given in Table 2.37 and Figure 2.4. Only ORPLD1 met the guidance of no more than 0.040 inches of neck loss in the K-3 corrosion test.

Of the three ORPLD glass formulations tested, only one, ORPLD1, met all processing and product quality requirements and was, therefore, selected for melter testing. The measured properties of the glass ORPLD1 are compared to the ILAW performance requirements [45, 46] in Table 2.38. Density and glass transition temperature measurements, and canister centerline cooling (CCC) heat treatments were not conducted on ORPLD1 glass. Examination of cooled ORPLD1 glass samples from the melter showed little crystallization, indicating that the glass is unlikely to show substantial crystallization on CCC heat treatment.

The composition of the ORPLD1 glass used in melter tests is given in Table 2.39 along with the oxide contributions from the LAW AN-102 waste simulant and from the glass former additives. The simulant was procured with no SO_3 and the sulfur concentration was increased in steps during the melter tests by adding the appropriate amounts of Na_2SO_4 and NaOH to the feed. The melter feed was procured at a Na_2O concentration of 19.37 wt% in order to accommodate Na_2SO_4 and NaOH additions, without increasing the Na_2O concentration above 21.0 wt%. The types and amounts of glass former additives used to prepare the melter feed along with the target feed properties are given in Table 2.40a. The glass former additives are the same as those planned for use at the WTP, with the exception of chromium and vanadium, which are new additives. The amounts of Na_2SO_4 and NaOH added to the feed to obtain 21.0 wt% Na_2O and 0.0 to 1.3 wt% SO_3 are given in Table 2.40b.

2.5 Region E (ORPLE) Waste Simulant and Glass Formulation

Glass formulation development and testing for Region E (ORPLE) were based on the composition of LAW material from Hanford tank AZ-101. Details of the waste simulant, and glass formulation development and testing are given below.

2.5.1 Region E (ORPLE) Waste Simulant

A LAW Envelope B waste simulant based on the composition data for tank AZ-101, as given in a WTP Test Specification [40], was used as the basis for ORPLA glass formulations. The base waste composition incorporates TFCOUP [41] data, actual waste analysis data, and WTP flow sheet information. The sodium concentration in the simulant includes a 5.33 % increase to account for sodium additions in pretreatment [12, 42]. The nominal concentration, expressed in terms of the sodium molarity, was estimated on the basis of melter feed rheology tests on similar formulations [43, 44]. The concentration of the simulant used in melter tests was 7.0 molar sodium. This is higher than that used in previous melter tests [18, 23] because of the higher waste loading in the ORPLE glasses.

The nominal simulant formulation is given in Table 2.41. The LAW AZ-101 simulant is a solution of predominantly sodium, nitrate, nitrite, and sulfate. Preparation of the waste simulant and melter feed were done in a manner similar to that for ORPLA simulant, which is described in Section 2.1.1.

2.5.2 Region E (ORPLE) Glass Formulation

Glass formulation development for Region E (ORPLE) was based on the composition of the LAW AZ-101 waste stream. The target SO_3 loading in the ORPLE glass was 0.8 to 1.4 wt%. Twelve crucible melts were prepared and characterized to identify a glass formulation that meets all processing and product quality requirements. Since target SO_3 loadings were the highest in ORPLE glasses, the CaO concentration was maintained at a high level (> 9 wt%) and Li_2O and V_2O_5 were added to all of the ORPLE glass formulations. In order to reduce K-3 refractory corrosion, Cr_2O_3 was added at a concentration of about 0.5 wt% to some of the glasses, especially those with Li_2O as an additive. Five glasses, OPRLE1-ORPLE5, were tested initially, followed by ORPLE6 to ORPLE12 in the next set. ORPLE1 to ORPLE5 testing showed that addition of Li_2O is beneficial in increasing sulfate solubility but at the expense of K-3 corrosion, that VHT becomes an issue at higher Na_2O concentrations, and that the target SO_3 loading of 1.25 wt% can be achieved. Since higher sulfate loading was the primary focus of Region E glass formulation, and since ORPLE1 showed the highest sulfate solubility, glasses ORPLE6 to ORPLE12 looked at variations in the composition of ORPLE1. All of the additives were varied (0.1 to 1.2 wt%) in one glass or another, with two to four oxide components changed in any one glass.

Target and analyzed compositions of the ORPLE glasses are given in Table 2.42. Testing and analysis of the glasses followed the same methods used for ORPLA glasses, which are described in Section 2.1.2. As is evident from the table, the target and analyzed compositions show good agreement. Glass samples were heat treated for 20 hours at 950°C and then evaluated for secondary phases. Observations of the as-melted, and heat treated glasses are given in Table 2.43. All of the as-melted glasses appeared clear with no crystals. The heat treated glasses also showed little crystallization (0.2 vol% or less).

The sulfate solubilities of the ORPLE glass compositions were assessed by batch saturation and bubbling tests. The batch saturation tests are described in Section 2.1.2 and the bubbling tests are described in Section 2.2.2. The results of the tests are given in Figures 2.1 and 2.5 and Table 2.44. The sulfate solubilities of the ORPLE glasses varied from 1.18 to 1.66 wt% by batch saturation tests and 1.38 to 1.66 wt% by bubbling tests. VHT and PCT results are summarized in Table 2.45 and illustrated in Figures 2.2 and 2.3. All twelve glasses met the PCT release limits and all but one met the VHT alteration rate limit. Since ORPLE glasses have comparatively lower alkali concentrations and VHT performance was not a major concern, the VHT measurements were done only on samples with the nominal SO_3 concentration. The viscosities and electrical conductivities of ORPLE glasses at select temperatures, all of which are within acceptable limits, are given in Table 2.46. K-3 refractory corrosion test results for the glasses are given in Table 2.47 and Figure 2.4. Only two glasses, ORPLE7 and ORPLE12, met the guidance of no more than 0.040 inches of neck loss in the K-3 corrosion test.

Of the ten ORPLE glass formulations tested, only two, ORPLE7 and ORPLE12, met all processing and product quality requirements. Compared to other ORPLE glasses, the major difference is that ORPLE7 and ORPLE12 contained Cr_2O_3 and lower concentrations of Li_2O,

CaO, or B_2O_3. Of the two, ORPLE12 showed higher sulfate solubility and better performance on VHT, and therefore was selected for melter testing. The measured properties of the glass ORPLE12 are compared to the ILAW performance requirements [45, 46] in Table 2.48. Density and glass transition temperature measurements, and canister centerline cooling (CCC) heat treatments were not conducted on ORPLE12 glass. Examination of cooled ORPLE12 glass samples from the melter tests showed little crystallization, indicating that the glass is unlikely to show substantial crystallization on CCC heat treatment.

The composition of the ORPLE12 glass used in melter tests is given in Table 2.49 along with the oxide contributions from the LAW AZ-101 waste simulant and from the glass former additives. The simulant was procured with 1.25 wt% SO_3 and the sulfur concentration was increased in steps during the melter tests by adding the appropriate amounts of Na_2SO_4 and NaOH to the feed. The melter feed was procured at a Na_2O concentration of 15.81 wt% in order to accommodate Na_2SO_4 and NaOH additions, without increasing the Na_2O concentration above 16.0 wt%. The types and amounts of glass former additives used to prepare the melter feed along with the target feed properties are given in Table 2.50a. The glass former additives are the same as those planned for use at the WTP, with the exception of chromium and vanadium, which are new additives. The amounts of Na_2SO_4 and NaOH added to the feed to obtain 16.0 wt% Na_2O and 1.25 to 1.75 wt% SO_3 are given in Table 2.50b.

2.6 Sugar Additions

With high nitrate feeds, the addition of reductants is necessary in order to control melt foaming. Sugar, which was used for this purpose at West Valley, has also been selected as the baseline reductant for the WTP. The amount of sugar required increases with the amount of nitrates present in the feed and decreases with the amount of waste organics present in the feed, which themselves act as reductants. Excessive additions of reductants can be deleterious, leading to over-reduction of the melt and formation of sulfides and molten metals. Consequently, the oxidants and reductants in the feed must be suitably balanced. The basis for achieving this balance was developed by VSL and Energy*Solutions* for the vitrification of high-sodium-nitrate feeds at Savannah River's M-Area and has been successfully applied to the processing of a wide variety of simulated WTP feeds over the past six years. In developing this approach, we elected to conservatively adopt the most reducing potential reaction as the basis for the *definition* of a "sugar" or stoichiometric ratio of 1.0 as a result of concerns for over-reducing the melt. Such a reaction, using sodium salts as an example, is:

$$C_{12}H_{22}O_{11} + 8NaNO_3 = 8CO_2 + 4CO + 4N_2 + 11H_2O + 4Na_2O$$

Fundamentally, the basis that is selected is simply a convention, since the precise stoichiometry of the reactions involved is neither known nor constant under the conditions prevailing in the melter. However, with this convention, a sugar ratio of 1.0 corresponds to one mole of sucrose per eight moles of nitrate or, more generally, 1.5 moles of organic carbon per mole of nitrate. It is then expected that significantly less sugar than this will be required in

practice. The empirically determined amount required to successfully control melt foaming without significantly reducing the glass melt was found to correspond to a ratio of 0.5 when any nitrites present were counted as nitrates (i.e., 0.75 moles of organic carbon per mole of nitrate + nitrite). This approach has been employed for all WTP melter testing. It is, however, expected that slight variations around the nominal value of 0.5 may be necessary to account for differences in the reducing power of waste organics in comparison to sugar, particularly for LAW streams that are high in organics.

As an example, the calculation of the amount of sugar needed for the present LAW AN-105 (Envelope A) feed to achieve a sugar ratio of 0.5 proceeds as follows:

- One liter of 8 Molar sodium simulant contains 1.857 moles of nitrite and 2.048 moles of nitrate, giving a total of 3.905 moles of NOx (see Table 2.1)
- Required total amount of organic carbon for a sugar ratio of 0.5 is $3.905 \times 0.75 = 2.929$ moles
- One liter of simulant contains 0.174 moles of organic carbon (see Table 2.1)
- Therefore, $2.929 - 0.174 = 2.755$ moles of organic carbon must be added.

Since the molecular weight of sucrose is 342 g, $2.755 \times 342/12 = 78.5$ g sugar must be added per liter of simulant, as shown in Table 2.10.a.

2.7 Analysis of Melter Feed Samples

2.7.1 General Properties

Feed samples were analyzed from melter tests to confirm physical properties and chemical composition. Samples were taken from residual melter feed from most of the test segments. Sample names, sampling dates, measured properties and comparisons with feed analysis for similar waste streams [2, 3, 5, 6, 17, 18, 21-24, 49, 50] are provided in Table 2.51. The average measured glass yield for the melter samples was less than 6% below the target values (on a mass per unit mass basis) provided in Tables 2.10.a, 2.20.a, 2.30.a, 2.40.a, and 2.50.a, validating the use of the target value for calculating glass production rates. This small low bias for glass yield and density is observed in most LAW feeds due perhaps to high estimates in the purity of the additives as well as water added during the transfer of feed [51]. In all but the AN-102 (Sub-Envelope C2) waste, the measured densities and glass yields are lower in samples from the current tests due to the greater proportion of sodium in the feed, which is contained in the soluble fraction of the feed. Similarly, the measured pH is higher in the samples from the current tests since much of the additional sodium is introduced to the feed as sodium hydroxide. The trend is less evident for the AN-102 (Sub-Envelope C2) feed, presumably due to the effect of the somewhat lower water content.

2.7.2 Chemical Composition

The chemical compositions of the feed samples were determined by first making a glass from the feed sample via crucible melt. The glass was subsequently crushed and analyzed directly by XRF. The boron and lithium oxide target values were used for normalizing the XRF data since their concentration was not determined by XRF. The XRF-analyzed compositions of the feed samples are provided in Table 2.52. The results generally show good agreement with the target composition for the major components. Of the oxides with a target concentration of one percent or greater, the XRF values for magnesium and zirconium in Test 1 samples, and for vanadium, tin, and sulfur oxides, as well as sodium and silicon in Test 5 samples, had deviations of greater than 10% from target. The deviations in tin and vanadium were also observed in the product glasses and may be attributable to a potential analytical bias for these elements using the XRF [2, 6, 51] (see Section 4.1). Deficits of measured magnesium oxide in the feed samples were not measured in the product glass; this trend has been observed in several previous studies [3, 4, 9, 10, 49-52] but the origin of the effect remains unclear.

The soda deficit and silica surplus measured in the feed sample from Test 5 (Region D) was also observed in product glasses (see Section 4.1). This trend and the comparison of measured physical properties suggest that either the waste simulant was deficient in sodium or the proportion of simulant to glass forming additives was low. However, direct analysis of the waste simulant and review of feed batching records indicate these were not the causes of the disparity. Excessive foaming occurred during the preparation of these feeds resulting in the loss of several kilograms of material. If the lost portion of the feed were enriched in sodium, this may account for the sodium deficit. The feed foaming is most likely a result of carbon dioxide release as the pH of the basic feed is reduced during the addition of boric acid to the feed.

Volatile minor elements such as sulfur and chlorine are, as expected, below target due to loss during crucible melting. The target sulfur concentration in the feed, which is important for determining sulfur retention in the glass, is verified from the simulant vendor's batching sheets. The additional amounts of sulfur added at VSL are calculated, checked, and weighed out using calibrated balances. Measured chromium concentrations are about half the target concentrations, as intended, since the remaining chromium is incorporated into the glass pool as a result of corrosion of melter bricks and Inconel components (see Section 4.1). Even though addition of Cr_2O_3 reduces the corrosion rate, some level of corrosion of the K-3 brick will always occur. Titanium oxide was measured in the feed samples from about a tenth to a quarter of a weight percent, even though it was not included in the target composition. Similar observations were made in previous tests with LAW melter feeds [9, 10, 13, 16-18, 51] and is due to its presence as a contaminant in the glass forming additives, most notably kyanite [2]. Common elements such as iron, phosphorus, and potassium, which are typical impurities in bulk chemicals, are over-represented when the constituent is a minor component.

SECTION 3.0
DM10 TESTS

Melter tests were conducted on the DM10 with the LAW simulants from 1/23/07 to 1/26/07 and 6/6/07 to 7/18/07 to determine the maximum sulfur concentration that can be processed without forming secondary phases for each of the five compositional regions. These tests produced over half a metric ton of glass from more than a metric ton of feed. Tables 3.1 - 3.5 provide summaries of the DM10 tests, including run times, the amount of sulfur in the feed, the amount of feed processed, the amount of feed sulfur retained in the glass product, observations of secondary phases, key processing parameters, and measured concentrations of gaseous species. The tests, listed in the order in which they were performed, were as follows:

- Test 1 (Region E): Five nominally 14-hour feeding segments with LAW AZ-101/Sub-Envelope B1 wastes targeting a Na_2O concentration of 16 wt% in the glass product. Segments tested SO_3 concentrations of 1.25, 1.5, 1.625, and 1.75 wt% in the glass product (assuming total retention). Based on the result of analysis of product glasses, the chromium feed concentrations were reduced after two segments, as well as for all future tests, in order to compensate for chromium leached from melter components.

- Test 2 (Region A): Six nominally 14-hour feeding segments with LAW AN-105/Sub-Envelope A1 wastes targeting a Na_2O concentration of 24 wt% in the glass product. Segments tested SO_3 concentrations of 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6 wt% in the glass product (assuming total retention). No secondary phases were observed at sulfur concentrations of twice the maximum of the range stipulated for testing. Significant foaming occurred during this test, yielding a foamy glass product.

- Test 3 (Region B): Four nominally 14-hour feeding segments with LAW AN-107/Sub-Envelope C1 wastes targeting a Na_2O concentration of 24 wt% in the glass product. Segments tested SO_3 concentrations of 0.6, 0.7, 0.85, and 1.0 wt% in the glass product (assuming total retention). Significant foaming occurred during this test, yielding a foamy glass product.

- Test 4 (Region C): Three nominally 14-hour feeding segments with LAW AN-104/Sub-Envelope A3 wastes targeting a Na_2O concentration of 23.6 wt% in the glass product. Segments tested SO_3 concentrations of 0.7, 0.8, and 0.9 wt% in the glass product (assuming total retention). Additional short test segments with sulfur free feed to reduce sulfur concentration in the glass pool were conducted in between test segments 4A and 4C as well as after test segment 4D. Significant foaming occurred during this test, yielding a foamy glass product.

- Test 5 (Region D): Four nominally 14-hour feeding segments with LAW AN-102/Sub-Envelope C2 wastes targeting a Na_2O concentration of 21 wt% in the glass product. Segments tested SO_3 concentrations of 0.7, 0.9, 1.1, and 1.3 wt% in the glass product (assuming total retention).

The principal objective of these tests was to determine, for each feed, the maximum amount of sulfur that can be fed into the melter without forming secondary sulfate phases. The bubbling rate was adjusted to maintain the target production rate of 2250 kg/m^2/day and a complete cold cap. Test segment durations of 12 to 18 hours were selected since, at the target glass production rate, this provided three melt pool turnovers (24 kg) for each sulfur concentration. Sugar was added to the feed at a stoichiometric carbon ratio of 0.5 for all of the melter tests. At the end of each test segment, dip samples were taken to detect the presence of separated sulfur phases on the glass pool surface. The melt surface was considered free of a sulfate layer if no visible secondary sulfate phases were observed on any of the three dip samples. If a sulfate layer was detected on the melt surface, the glass pool was bubbled until the dip samples indicated that the sulfate layer had dissipated prior to commencing the subsequent test segment.

3.1 DM10 System Description

3.1.1 Feed System

The feed container is mounted on a load cell for weight monitoring and is stirred continuously except for periodic, momentary interruptions during which the weight is recorded. The material in the feed container is constantly recirculated, which provides additional mixing. The recirculation loop extends to the top of the melter where feed is diverted from the recirculation loop through a peristaltic pump into the melter through a Teflon-lined feed line and vertical water-cooled feed tube. A diverter valve permits direction of the feed stream either to the melter or to a sampling vessel.

3.1.2 Melter

The DM10 system used for this work is a ceramic refractory lined melter, which includes two Inconel 690 plate electrodes that are used for joule-heating of the glass pool and a bubbler for agitating the melt. Glass is discharged from the melter using an air-lift system. The melt pool has a surface area of 0.021 m^2 and typically contains about 8 kg of glass. The plenum volume is 19.5 liters at the nominal glass level. Inconel 690 thermowells were custom fabricated and installed in the DM10 for the current tests since in previous tests, thermowells made from Inconel 601 experienced rapid corrosion [5].

3.1.3 Off-Gas System

For operational simplicity, the DM10 is equipped with a dry off-gas treatment system involving gas filtration operations only. Exhaust gases leave the melter plenum through a film cooler device that minimizes the formation of solid deposits. The film cooler air has constant flow rate and its temperature is thermostatically controlled. The geometry of the transition line (between the melter and the first filtration device) conforms to the requirements of the 40-CFR-60 air sampling techniques. Immediately downstream of the transition line are cyclonic filters followed by conventional pre-filters and HEPA filters. The temperature of the cyclonic filters is maintained above 150^{o}C while the HEPAs are held above 100^{o}C to prevent moisture condensation. The entire train of gas filtration operations is duplicated and each train is used alternately. An induced draft fan completes the system. The sampling location for gaseous species monitored by FTIR is immediately downstream of the draft fan.

3.2 DM10 Test Conditions

Target processing conditions, including bubbling rate adjusted to maintain the target production rate of 2250 kg/m^2/day, a melt pool temperature of 1150°C, and a complete cold cap were achieved throughout the majority of the melter tests. The main challenge to achieving these conditions was foaming of the glass during Tests 2, 3, and 4. The foaming coincided with the use of tin and vanadium as additives at oxide concentrations greater than one and half weight percent. It is also worth noting that foaming occurred while processing glass compositions with relatively high viscosities. Since foaming is a result of gas evolution in the glass combined with the inability of the gas bubbles to rise and dissipate, there is probably a combination of contributing factors such as the concentrations of redox species in the glass, glass melt temperature, glass melt viscosity, glass redox state, etc. Average test segment production rates were within 10% of the target rate except for test segments with extensive foaming, which required feed interruptions to allow foam to dissipate or reduced feed rates. Test segment average bubbling rates ranged from 1.8 to 6.5 liters per minute and were significantly lower while processing the AZ-101/Sub-Envelope B1 (Region E) simulant in Test 1. The measured test segment average glass temperatures two inches from the melt pool floor were between 1148 - 1153°C for all but two of the test segments, thus indicating that the target glass temperature of 1150°C was achieved. During these two segments, test segment average temperatures were 20°C lower due to the high conductivity of the glass (in combination with the high glass production rate and foam), which limited the amount of power that could be used with this particular melter system. Measured glass temperatures two inches higher in the glass pool were 5 to 40°C lower throughout testing due to the proximity to the glass surface. Each test segment started with the melt pool at the nominal operating temperature of 1150°C. A typical plot of DM10 melter temperatures is given in Figure 3.1. The plot is from the first conducted test segment (Region E, Test 1A) and a portion of the idling time prior to Test 1B. As mentioned above, the data at 2” from the melter bottom are most representative of the bulk glass temperature; these data average very close to the target of 1150 C and vary little over the course of the test. The measurement 4” from the bottom is closer to the melt surface and varies by about 80^{o}C as the level of the class changes. In keeping with previous DM10 tests, the electrode

temperatures were 50 to 100°C lower than the highest glass pool temperatures. The measured test segment average plenum temperatures were well below 600°C, indicating that a complete cold cap covered the melt pool surface throughout the tests. A typical plot of DM10 plenum temperatures is given in Figure 3.2. Unlike plenum temperature measurements on larger melters, the exposed thermocouple often gave a lower temperature reading than the thermocouple in the thermowell due to variable amounts of feed coating the exposed thermocouple.

3.3 DM10 Test Results

Evaluation of glass pool samples provided a clear indication of the tolerance of the glass formulations to sulfur at nominal melter conditions. The only exception is the AN-105 Region A formulation ORPLA15, where feeds with twice the maximum target SO_3 concentration of 0.3 wt% were processed without the formation of secondary sulfate phases; cost and schedule constraints did not permit the addition of yet more test segments to determine the upper limit for this formulation. Depictions of the target and measured sulfur contents are provided in Figure 3.3 for all five test series. During the initial test series with Region E (AZ-101) feeds, it was discerned from preliminary XRF measurements of product glass that the chromium concentration far exceeded the target concentration due to leaching of chromium from melter bricks and Inconel components. Recent melter test with LAW simulants have shown that high chromium concentration facilitate the formation of secondary sulfate phases that would not form otherwise [52]. In response to this, the chromium concentration in the feed was reduced after the second test segment (1B) to compensate for the expected chromium input from corrosion. As expected, the secondary phases that were observed while processing feed targeting Region E (AZ-101) wastes with 1.5 wt% SO_3 at elevated chromium concentrations were not observed at target chromium concentrations. Subsequent tests with sulfur at higher concentrations resulted in secondary sulfur phases despite the adjustment of the feed chromium content. Five test segments with the Region A (AN-105) waste and increasing sulfur content demonstrated a doubling of sulfur content from the target maximum, a doubling of sulfur content from the crucible batch saturation tests (see Section 2.1.2), and the need to perform additional tests at yet higher feed sulfur concentrations. Sulfur feed and glass concentrations continued to increase during tests with Region B (AN-107) waste; secondary sulfur phases were observed at 1 wt% SO_3 and therefore saturation occurred between 0.85 and 1 wt% SO_3 targeted in the feed. Subsequent tests with the Region C (AN-104) waste resulted in a decrease in feed sulfur contents to 0.7 wt% SO_3 in order to prevent the formation of a secondary sulfur phase. The most extensive secondary phases were observed during tests with this waste stream, which required short intervals of feeding sulfur-free feed to insure unbiased results in subsequent test segments. The sulfur concentration was increased in the test series with Region D (AN-102) waste, reaching a feed concentration of 1.1 wt% SO_3 without the formation of secondary sulfur phases, while tests at 1.3 wt% SO_3 did show secondary sulfur phases.

3.3 Gases Monitored by FTIR

Melter emissions were monitored in each test for a variety of gaseous components, most notably carbon monoxide, ammonia, sulfur dioxide and nitrogen species, by Fourier Transform Infra Red Spectroscopy (FTIR). The off-gas system temperature is maintained well above 100°C beyond the sampling port downstream of the HEPA filter in order to prevent analyte loss due to condensation prior to monitoring. Test segment average concentrations of NO, NO_2, CO, and NH_3 are provided in Tables 3.1-3.5; these analytes are those that were expected to be observed during the test, based on previous work. No SO_2 was detected in any of the tests and therefore none is reported in the tabular data. The FTIR detection limit for sulfur dioxide is relatively high (5 ppmv) and, therefore, measurable quantities are only observed with high sulfur containing feeds and in systems with minimal dilution of the melter exhaust by film cooler or process air. The most abundant nitrogen species monitored was NO, which is consistent with previous tests [2-4, 5, 6, 9, 10, 15-24, 49, 50, 52] in which nitrates and nitrites were abundant in the feed. The measured concentrations of most monitored components increase with increasing feed nitrogen oxide content and feed rates. Nitrogen oxide, carbon monoxide, and ammonia concentrations are higher in tests with the feed containing the Region A (AN-105), C (AN-104), and D (AN-102) simulants as a result of the higher nitrate and, therefore, organic content in the feed.

SECTION 4.0
DM10 GLASS PRODUCTS

Over half a metric ton of glass was produced in these tests. The glass was discharged from the melter periodically into square steel cans using an airlift system. The discharged product glass was sampled at the end of each test by removing sufficient glass from the top of the cans for total inorganic analysis. Care was exercised during sampling of each can to identify and segregate any secondary phases that were observed. Secondary phases in the discharged glass were only observed in test segments from Test 4, which also had secondary sulfur phases on the glass pool dip samples. These secondary phases are shown in Figure 4.1. Much of the discharged glass from Tests 2 – 4 was foamy and, therefore, appeared somewhat translucent in appearance. Additional samples were taken from the end of each test and sealed in containers for shipment to ORP, as required by the Test Plan [37]. Product glass masses, discharge date, and analysis performed are listed in Table 4.1. Glass samples were also obtained by dipping a rod into the glass pool at the beginning and end of each test. These "dip samples" underwent visual examination to detect the presence of a separate sulfate phase on the glass pool surface.

4.1 Compositional Analysis

Glass discharge samples were crushed and analyzed directly by XRF. No visible secondary phases were included in the samples used for compositional analysis. The target values for boron and lithium oxides, which are not determined by XRF, were used for normalizing the XRF data to 100 wt%. The XRF-analyzed compositions of all discharged glass samples are provided in Tables 4.2. XRF analysis of samples from the end of tests with the highest sulfur concentrations without forming secondary phases on the melt pool surface are compared with the target composition and results of DCP analysis of solutions generated by microwave aided acid dissolution in Tables 4.3 and 4.4, respectively. The majority of the XRF analysis results compare favorably to their corresponding target values and feed sample analysis (see Section 2.7.2). The concentrations of vanadium and tin oxides derived from additives were 11 to 22 relative percent above target concentrations. In all but one tin analysis, the concentrations measured by the DCP method were closer to target values, suggesting that the XRF may have a high bias for these elements. Above target concentrations of vanadium were also measured in previous tests [2, 6, 51]. Similar to the feed samples, zirconium oxide concentrations were up to fifteen relative percent below target concentrations, due presumably to chemical purity. Iron oxide concentrations were above the low target concentrations due to the ubiquity of the element in bulk chemicals. Elements not included in the target glass compositions, including iodine, manganese, neodymium, nickel, lead, titanium, and tin were observed in the product analysis as a result of corrosion of melter components, carry-over from previous tests, and trace contamination of additives. The lower than target concentration of sodium observed in the feed samples for Test 5 (see Section 2.7.2) is also observed in the glass product. Measured boron concentrations were within four percent of the target, validating the use of the target value for normalizing the XRF data. Agreement between the two analytical methods was excellent, except for low sodium values obtained from the DCP analysis, which is due in

part to a low-bias for sodium [6, 51]; previous experience indicates that the XRF results are more reliable in this regard.

Compositional trends of the major and select oxides during the tests are shown in Figures 4.2 - 4.13. They illustrate the differences between the tested compositions and closeness to target over the course of the tests. These depictions also show the sampling and analytical variations attributable to the methods used; for example, calcium shows minimal variability whereas zirconia can vary by about 1 weight percent in sequential glass discharges. Scatter in the data for some elements were also observed at the beginning of the second test. Unlike the last four tests, which were conducted within a short amount of time, the first test was conducted five months earlier with other glass compositions not associated with the current study being processed during the intervening interval. This discontinuity is readily observed in the changes in silicon, calcium, zirconium, and potassium between 125 and 150 kg glass production. The glass compositions tested derive all the alkali metals, halides, sulfur, and almost none to half of the aluminum from the waste. The changes in additive concentrations shown in Figures 4.4 – 4.9 reflect the manipulation of glass forming additives to achieve the desired glass properties. The deviations described above for vanadium, tin, zirconium, and silicon (last test sequence only) are evident in the plotted data. As intended, sodium spanned a range of about ten percent oxide, which was greater than for any other element. The plotted sodium data show considerable scatter but a close approximation to target for four of the compositions. The measured cesium concentrations show an even greater amount of relative scatter, whereas measured potassium concentrations showed little deviation during steady state processing. The potassium plot also shows a frequently observed trend of measured concentrations being above target for very low target values of very common elements due to trace contamination of feed [51]. The cesium data suggest, despite the noise in the data, that cesium is more volatile at the higher alkali concentrations in Tests 2 and 3, in agreement with previous observations [53]. Also supporting previous observations of volatility is the near 50% loss of chlorine from the glass at target concentrations greater than 0.3 weight percent [24, 52]. Another previously documented volatility trend [5, 6, 9, 10, 24, 52] implied by the data is the higher degree of sulfur retention in compositions with higher glass sodium concentrations (see Figure 3.3). Complete sampling and analysis of melter exhaust commonly conducted on larger melters [2-6, 9, 10, 15-24, 49, 50, 52, 53] is required for a more accurate assessment of elemental volatility and mass balance calculations. Measured chromium oxide concentrations were about 0.25 weight percent above target concentrations until adjustments were made to the feed to account for melter brick and Inconel component corrosion. Subsequent to this modification at about 50 kg glass production, chromium values more closely approximated the target, although chromium concentrations varied in response to idling periods, the formation of secondary sulfur phases, and the differences in corrosion rate for each composition.

4.2 Secondary Phase Observations

All discharged glass and glass “dip” samples taken directly from the melt pool were closely examined to document the presence or absence of secondary phases. Glass dip samples were obtained from three separate locations in the melt pool at the end of each test to ascertain

whether a secondary sulfate layer had formed on the surface of the glass melt in response to each feed sulfur concentration during each test segment. Samples were also taken to ensure the melt surface was free of secondary phases prior to starting each test segment, as well as after bubbling intended to volatilize sulfur from a previously formed sulfur layer. Table 4.5 provides a listing of all of the dip samples and whether or not a separate salt phase was evident. Examples of secondary phases observed while processing three of the formulations are shown in Figures 4.14 – 4.16. Notice the powdery yellow material adhering to the rod and interspersed throughout some of the glass, both of which are indicative of a sample taken from a melt pool with a sulfate layer on the surface. Some of the sulfur layers that formed on the glass pool surface were extensive. Several hours of melt pool bubbling, and in some instances water feeding, were required to rid the melt pool of secondary phases.

4.3 Comparison of PCT and VHT of Crucible and Melter Glasses

Samples of DM10 discharge glasses from each of Regions A, B, C, D and E melter tests were subjected to the PCT. Samples were collected from test segments during which the highest sulfate concentrations that did not result in secondary sulfate phases were processed. The PCT releases of the melter glasses, along with those of crucible glasses with the same target compositions, are given in Table 4.6. PCT releases of all of the melter and crucible glasses are well below the WTP contract limit mass loss of 2.0 g/m^2 for B, Na and Si. The PCT release of Regions A, B, C and E melter and crucible glasses are similar, with the differences within expected variations based on round robin PCT testing of an Argonne National Laboratory-Low Activity Reference Material (ANL-LRM) glass sample [54]. The PCT releases of the Region D crucible glass ORPLD1 and the melter glass of the same target composition T10-G-16A are different, with the melter glass showing PCT releases of about half that of the crucible glass. This is due to the lower than target Na_2O concentration measured in the melter glass (see Sections 2.7.2 and 4.1). Previous PCT testing [11-14, 48] has shown that PCT releases of glasses with similar compositions increase as the alkali content of the glass is increased.

VHT results for the melter and corresponding crucible glasses with the same target composition are given in Table 4.7. VHT alteration rates calculated by two different methods are given in Table 4.7. One method involves direct measurement of the alteration layer thickness, while the other involves measurement of the remaining glass. The VSL Standard Operating Procedure (SOP) for VHT measurement specifies that when the alteration layer thickness is greater than 100 μm, it should be determined based on the remaining glass. This is because when the alteration layer thickness is sufficiently large, measuring the dimensions of the remaining glass and subtracting it from the original sample dimensions gives a better estimate of the thickness of the altered glass. A direct measurement of the layer thickness can provide erroneous values because the altered layer may have expanded, thus giving a larger value than the actual thickness of the altered part of the glass sample, particularly for thick layers. The VHT alteration rates given in Section 2 are mostly based on the measurement of the remaining glass.

The VHT alteration rates for the Region E crucible and melter glasses given in Table 4.7 show good agreement with each other. The VHT alteration rate measurements based on layer

thickness and remaining glass also are in agreement for these glasses. The VHT results for the Region D melter and crucible glasses given in Table 4.7 show very good agreement with each other. The alteration rates based on layer thickness and remaining glass also show reasonable agreement with the alteration rates based on remaining glass showing somewhat lower values than those based on layer thickness.

The alteration rates for the Region A crucible glass ORPLA15 based on layer thickness and remaining glass show good agreement. For two of the three melter glasses, the alteration rates based on layer thickness agree with the results from the crucible glass; however, the alteration rates based on the remaining glass are substantially higher and above the contract limit of 50 g/m^2/day. Since the measured compositions of the crucible and melter glasses show good agreement with the target and with each other, the origin of these differences is of interest. Figure 4.17 shows SEM images of cross sections of coupons of the Region A glass after VHT; Figure 4.17a shows the VHT coupon of the crucible glass and 4.17b shows the coupon of the melter glass. Unlike the crucible glass, the melter glass contains a number of fractures and extensive alteration of the glass is evident around these fractures. The higher measured VHT alteration rates for the melter glass are mainly due to the presence of these fractures (as well as some bubbles that are not shown). The fractures are more common in high alkali glasses, and especially in high alkali melter glasses. These could be micro cracks that exist in the glass sample or cracks that form from imperfections such as bubbles or small secondary phases. In any case, the occurrence of these cracks substantially increases the VHT alteration rates of high alkali glasses. Since the extent of cracking was much more in the melter glasses, in some cases their VHT alteration rates are above the contract limit even though the VHT for the corresponding crucible glass falls below that limit. From earlier work [5, 6, 48] it was already clear that increasingly large variations in VHT alteration rates can be expected for high Na_2O (> 23 wt%) glasses and, therefore, for these glasses the measurements were done in duplicate. This large inherent variability in the VHT response coupled with the VHT alteration rate enhancement due to cracking suggests that relaxation of the VHT criterion may be necessary if Na_2O loadings higher than about 23-24 wt% are desired.

VHT alteration rates for the Region B crucible and melter glasses also show behavior similar to that of Region A glasses. The alteration rates for the crucible glass based on layer thickness and remaining glass and for the melter glass based on layer thickness are in agreement with each other. The alteration rates for the Region B melter glass based on remaining glass are higher, and above the contract limit of 50 g/m^2/day. SEM micrographs of cross sections of the VHT coupons given in Figure 4.18 show that the crucible glass has no bubbles and less fractures compared to the melter glass. Again, measured VHT alteration rates increase substantially when the VHT coupon has more fractures.

VHT alteration rates for the Region C glasses show good agreement between the crucible and melter glasses, as well as between measurements based on layer thickness and remaining glass. SEM micrographs of cross sections of the VHT coupons given in Figure 4.19 show that the crucible and melter glasses are similar in that the melter glass sample does not have too many fractures and that the there is little alteration near the bubbles in the melter glass.

SECTION 5.0
SUMMARY AND CONCLUSIONS

Several tests were conducted on the DM10 vitrification system to evaluate newly developed LAW glass formulations intended to maximize sodium content while incorporating high levels of sulfur without the formation of secondary salt phases. Glass formulations selected for the melter tests were developed on the basis of a series of crucible melts that were prepared and characterized. Glasses were formulated for five different waste streams, maximizing sodium content at progressively higher target sulfur contents while meeting requirements for product quality (PCT and VHT), refractory corrosion characteristics, and processing properties. Glass former additives that were beneficial in reducing VHT alteration rate include ZrO_2 and SnO_2. Cr_2O_3 was beneficial in reducing K-3 corrosion, whereas CaO, Li_2O, and V_2O_5 additions improved sulfur solubility in the glass. However, the effect of the addition of each of these components cannot be taken in isolation. They have to be considered in combination with the other glass former additives, the overall composition of the glass, and relevant glass melt properties such as viscosity and glass redox state. Each glass formulation was processed on the DM10 with progressively more sulfur until a secondary sulfur phase formed, in order to determine the maximum feed sulfur concentration that could be processed. Glasses from each formulation with the highest sulfur content that did not form secondary sulfur phases were fully analyzed for comparison to the results obtained on the corresponding crucible glasses.

The GFC additives that are used in the LAW glasses are Al_2O_3, B_2O_3, CaO, Cr_2O_3, Fe_2O_3, Li_2O, MgO, SiO_2, SnO_2, V_2O_5, ZnO and ZrO_2. ZnO is added at concentrations in the range of 2 to 3 wt% mainly to reduce corrosion of K-3 refractory by the glass. It is also beneficial in reducing corrosion of Inconel components. MgO and Fe_2O_3 are added at concentrations of about 1 wt% to reduce K-3 corrosion and as an allowance for their presence as impurities in other GFCs. In general, components such as Al_2O_3, SiO_2, SnO_2, and ZrO_2 improve the chemical durability of the glass including performance on PCT and VHT. Of these ZrO_2 and SnO_2 are the most effective in reducing VHT alteration rates. These components usually are also effective in reducing corrosion of both K-3 and Inconel by the glass. Increases in B_2O_3 concentration can have variable effects on chemical durability and typically tend to reduce melt viscosity. Cr_2O_3 is added solely to reduce corrosion of K-3 refractory by the glass. Li_2O, CaO and V_2O_5 all are beneficial in increasing sulfate loading in the feed with Li_2O being most effective. In general, as very high sodium glasses are formulated the concentration of components that reduce corrosion and improve chemical durability need to be increased. In addition, these components usually increase the viscosity of the glass melt. As relatively lower sodium and higher sulfate glasses are formulated, the concentrations of additives that increase sulfate solubility are increased.

VSL and Energy*Solutions* have previously developed and tested a number of LAW glass formulations for ORP [4-6] and WTP [11-14]. The WTP formulations were tested at the crucible scale and at various melter scales including the one-third scale LAW Pilot Melter at

Energy*Solutions*. As a result of the considerable testing completed with the WTP formulations, there is high confidence that they can be used to process LAW at Hanford with little additional testing. The recommended glass compositions for waste processing were selected such that they can tolerate process variations without adverse effects on processing or product quality. Based on these well-tested formulations, VSL developed a LAW glass formulation correlation that is currently being used by the WTP [55]. Compositions produced by this correlation fall along the dotted lines in Figure 5.1. The WTP formulations were developed to comply with the requirements of the Bechtel contract with ORP [46]. Although these formulations are fully compliant, extensive further optimization with respect to waste loading could not be performed due to the schedule constraints imposed by the LAW Pilot Melter testing program defined by the WTP Project. As a result, while this extensive basis set of formulations provides a solid underpinning of the WTP baseline, there is also potential for improvement of waste loadings. Exploiting this potential has been the subject of the present and previous work for ORP.

LAW testing for ORP at VSL and Energy*Solutions* was aimed at optimizing the glass formulations and processing parameters in order to minimize the volume of glass produced and to shorten the plant operating schedule. Since the major waste loading limiting constituents in Hanford LAW are sodium and sulfur, glass formulation development and testing were focused on maximizing the incorporation of these components in the glass. Earlier testing for ORP targeted glass formulations at about 20-23 wt% Na_2O and highest achievable SO_3 [2, 5, 6], and 10 wt% Na_2O and highest achievable SO_3 [6]. The LAW glass formulations developed from those tests, LAWA187, LAWA161, LAWC100, and LAWB99, are shown in Figure 5.1; target and measured Na_2O and SO_3 concentrations in current and previous ORP LAW glasses are given in Table 5.1. As is evident from Figure 5.1, these glasses represent considerable increases in waste loadings over the WTP baseline and therefore considerable potential for reductions in cost and schedule. The principle objective of the present work was to assess the likely limits to the extent of this improvement over the relevant range of sodium and sulfur content by formulating and testing bounding glasses. Five high waste loading glass formulations spanning the range of expected Na_2O and SO_3 concentrations in the LAW glasses were developed and subjected to melter testing. Glass formulation development and testing were designed such that the maximum achievable waste loadings could be determined. This required that the testing focus on those properties of the high waste loading glasses that are most challenging with respect to processing or product quality. For the high Na_2O glasses, the most challenging property was VHT alteration rate. Therefore, glasses were designed to have VHT alteration rates near the contract limit of 50 g/m^2/day and, in fact, by design, many of the candidate glasses exceeded this limit. Glasses for melter testing also were selected with the intent of determining the limits of achievable waste loadings. The LAW glasses selected for the current set of melter tests for the five regions (ORPLA15, ORPLB4, ORPLC5, ORPLD1 and ORPLE12) are also shown in Figure 5.1. As is evident from the figure, the current ORP glasses have much higher waste loadings than the WTP glasses, and higher combined Na_2O and SO_3 loadings than previous ORP glasses, with the exception of LAWA187, which falls on the trend line defined by the results for the current glasses[1].

[1] It is recognized that the melter test for the Region D glass was somewhat lower in sodium than targeted. While it would therefore be useful to repeat this test, this is unlikely to significantly affect the trend line shown in Figure 5.1.

At the very high Na_2O loadings (23 wt% or higher), VHT becomes especially challenging due to the rapid increase of VHT alteration rate with increasing alkali content, the increased variability in VHT response at high alkali content, and increased VHT alteration rates due to cracking in melter glasses. Relaxation of the VHT alteration rate limit may be necessary if higher Na_2O glasses are desired. At the low sodium end, a glass formulation, ORPLE12, with 16 wt% Na_2O that can accommodate 1.5 wt% SO_3 was identified. This was the same SO_3 loading limit that was observed in LAWB99 with 10 wt% Na_2O at a nominal melter operating temperature of 1150°C. Achieving significantly higher SO_3 loadings in borosilicate glasses would appear to be unlikely without changing the processing conditions or the processing and/or product quality constraints (it is a simple matter to achieve higher SO_3 loadings by increasing the contents of Li, Ca, V, etc., but such glasses do not meet VHT and refractory corrosion requirements). Thus, the glasses identified during the current work serve to define the likely limits of possible Na_2O and SO_3 loadings in Hanford LAW glasses that are compliant with the current product quality and processing requirements. It should be noted, however, that these glasses were tested only at the crucible and DM10 melter scales. Additional testing at larger scales is required to confirm the results from smaller scale testing and the results of such testing may result in refinement of these limits. It should also be noted that because of the bounding nature of the formulations (they are deliberately close to the limits of the requirements), practically viable operating points would fall at somewhat lower waste loadings since nominal glass compositions selected for waste processing need to accommodate process variations without adverse effects on processing or product quality. In addition, the corrosion rate of Inconel in these new glass compositions has not been tested. While experience suggests that the adjustments made to the glass compositions to reduce VHT alteration rate and K-3 corrosion, along with the higher viscosity, will also maintain acceptable Inconel corrosion rates, this needs to be confirmed through testing..

The LAW correlation was developed for the WTP by VSL/Energy*Solutions* to determine the types and amounts of glass forming chemicals (GFCs) to be used at the WTP for LAW processing under the current WTP baseline. This was possible only after the completion of much more extensive testing than has been done for the new ORP glasses and after a set of nominal Sub-Envelope formulations were refined. The data collected so far for the ORP higher waste loading glasses is not sufficient to attempt a revised LAW correlation algorithm, but does serve to define what types of waste loadings might be possible. Once the glass compositions are refined, GFC additives are defined, and suitable scale-up testing is completed, a new LAW formulation correlation, similar to the one currently being used by the WTP, would be developed to support the implementation of these higher waste loading glass compositions at the WTP in order to realize the cost and schedule reductions.

SECTION 6.0
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Table 1.1. Waste Compositions and Corresponding Target Concentrations in Glass.

Region Designation	Tank Waste/ Sub-Envelope Identification	Target Minimum Na_2O Concentration in Glass, wt%	Target Minimum SO_3 Concentration in Glass, wt%
A	AN-105/ Sub-Envelope A1	25	0
B	AN-107/ Sub-Envelope C1	25	0.35
C	AN-104/ Sub-Envelope A3	25	0.65
D	AN-102/ Sub-Envelope C2	25	1.00
E	AZ-101/ Sub-Envelope B1	16	1.25

Table 2.1. LAW Sub-Envelope A1 (AN-105) Waste Simulant Recipe at 8 Molar Sodium.

Envelope Constituents	Simulant AN-105 including pretreatment		Glass Oxides	AN-105 Wt%	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
-	mg/L	M	-	-	In 274.40 ml water add following compounds in the order listed below				
Al	30554	1.132	Al_2O_3	17.906	$Al(NO_3)_3.9H_2O$, 60% sol. $Al(OH)_3$	1 8	375.14 78.00	0.61 1.00	419.84 35.50
B	79	0.007	B_2O_3	0.078	H_3BO_3	3	61.83	0.99	0.45
Cr	149	0.003	Cr_2O_3	0.067	$Na_2CrO_4*4H_2O$	7	234.04	0.99	0.68
Cs (spike)	1403	0.011	Cs_2O	0.461	$CsNO_3$	2	194.91	1.00	2.06
K	4608	0.118	K_2O	1.722	KOH	6	56.10	0.91	7.28
Na	183920	8.000	Na_2O	76.892	NaOH, 50% sol. d=1.53	5	40.00	0.50	463.20
Si	157	0.006	SiO_2	0.104	SiO_2	4	60.09	0.99	0.34
Cl	6996	0.197	Cl	2.170	NaCl	9	58.45	0.99	11.65
F	35	0.002	F	0.011	NaF	10	42.00	0.99	0.08
SO_4 (Nominal)	2274	0.024	SO_3	0.588	Na_2SO_4 (varied content per run)	11	142.06	0.99	See Table 2.10b
NO_2	85428	1.857	-	-	$NaNO_2$	15	69.00	0.97	128.79
NO_3	126988	2.048	-	-	$NaNO_3$	-	84.99	0.99	0.00
TOC	2093	0.174	-	-	-	-	-	-	-
Acetate	2251	0.038	-	-	Sodium Acetate (C2)	12	136.08	0.99	5.24
Formate	2135	0.047	-	-	Sodium Formate (C1)	13	68.01	0.99	3.26
Glycolate	1936	0.025	-	-	Glycolic Acid (C2)	14	76.05	0.71	2.73
-	-	-	SUM	100	Total simulant wt.				1358.89

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

** Ratio provides the factor to convert the glass former additive into the corresponding oxide in the glass.

Table 2.2. Target and Analyzed Compositions (wt%) of Seventeen ORPLA Crucible Glasses.

GLASS	ORPLA1		ORPLA2		ORPLA3		ORPLA4		ORPLA5		ORPLA6	
Oxides	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*
Al_2O_3	10.00	10.31	10.00	10.14	10.00	10.32	8.00	8.29	10.00	10.30	10.88	10.95
B_2O_3	9.00	9.26	9.00	9.57	9.00	9.31	9.00	9.36	7.00	6.81	7.78	NA
CaO	3.50	3.66	2.50	2.62	3.04	3.13	3.50	3.57	1.00	1.08	1.00	1.10
Cr_2O_3	0.02	0.03	0.02	0.04	0.49	0.60	0.02	0.03	0.49	0.61	0.49	0.63
Cs_2O (spike)	0.19	0.16	0.19	0.19	0.19	0.21	0.19	0.20	0.19	0.21	0.19	0.17
Fe_2O_3	1.01	1.05	1.01	1.05	1.01	1.03	3.02	2.99	1.01	1.06	0.94	1.04
K_2O	0.56	0.63	0.56	0.63	0.56	0.60	0.56	0.61	0.56	0.59	0.56	0.60
MgO	1.35	1.29	1.35	1.27	1.35	1.30	1.35	1.36	1.35	1.20	0.91	0.93
Na_2O	25.00	24.66	25.00	24.55	25.00	24.91	25.00	25.46	25.00	24.20	25.00	24.45
SiO_2	41.31	41.48	41.31	41.36	41.31	40.98	41.31	40.41	43.31	43.16	41.92	41.61
SnO_2	0.00	0.01	1.00	1.07	0.00	0.00	0.00	0.02	1.00	1.13	1.00	1.10
TiO_2	0.00	0.04	0.00	0.03	0.00	0.04	0.00	0.03	0.00	0.03	0.00	0.04
V_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZnO	2.36	2.41	2.36	2.42	2.36	2.36	2.36	2.42	3.36	3.48	2.36	2.53
ZrO_2	4.80	4.18	4.80	4.52	4.80	4.39	4.80	4.54	4.80	4.73	6.07	5.89
Cl	0.71	0.68	0.71	0.69	0.71	0.71	0.71	0.62	0.71	0.76	0.71	0.69
F	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA
P_2O_5	0.00	0.04	0.00	0.05	0.00	0.05	0.00	0.05	0.00	0.05	0.00	0.05
SO_3	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.21	0.19	0.20	0.19	0.19
SUM	100.0	100.1	100.0	100.4	100.0	100.1	100.0	100.2	100.0	99.6	100.0	99.8

* – Analyzed by X-ray fluorescence except for boron which was measured by DCP
NA – Not analyzed

Table 2.2. Target and Analyzed Compositions (wt%) of Seventeen ORPLA Crucible Glasses (continued).

GLASS	ORPLA7		ORPLA8		ORPLA9		ORPLA10		ORPLA11		ORPLA12	
Oxides	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*
Al_2O_3	10.88	11.03	5.82	6.09	10.90	10.86	10.90	10.88	10.90	10.97	10.77	10.48
B_2O_3	7.78	NA	8.48	NA	7.80	NA	7.80	NA	7.00	NA	7.13	7.18
CaO	1.47	1.52	0.00	0.07	6.52	6.46	6.52	6.54	2.00	2.16	2.03	2.17
Cr_2O_3	0.49	0.61	0.49	0.66	0.49	0.60	0.49	0.61	0.49	0.65	0.50	0.65
Cs_2O (spike)	0.19	0.19	0.19	0.20	0.19	0.18	0.19	0.16	0.19	0.19	0.18	0.19
Fe_2O_3	0.94	0.98	2.70	2.95	0.91	0.90	0.91	0.93	0.91	1.01	0.93	1.02
K_2O	0.56	0.68	0.56	0.64	0.56	0.57	0.56	0.57	0.56	0.66	0.54	0.57
MgO	0.91	0.98	3.37	3.22	0.91	1.03	0.91	1.03	0.91	0.83	0.93	0.86
Na_2O	25.00	25.18	25.00	23.49	25.00	25.31	25.00	25.44	25.00	23.64	24.00	23.07
SiO_2	40.50	40.17	42.10	41.68	35.51	34.94	35.78	34.97	40.15	39.99	41.00	40.93
SnO_2	1.00	1.08	1.94	2.29	2.00	2.28	2.68	2.92	2.70	3.08	2.75	3.14
TiO_2	0.00	0.01	1.55	1.77	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.02
V_2O_5	0.94	1.00	0.00	0.00	0.94	1.01	0.00	0.00	0.00	0.00	0.00	0.00
ZnO	2.36	2.33	1.00	1.13	2.36	2.31	2.36	2.36	2.36	2.59	2.45	2.66
ZrO_2	6.07	5.29	5.90	6.05	5.00	4.61	5.00	4.64	5.94	5.97	5.95	5.93
Cl	0.71	0.67	0.71	0.69	0.71	0.63	0.71	0.60	0.71	0.71	0.68	0.70
F	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA
P_2O_5	0.00	0.04	0.00	0.05	0.00	0.03	0.00	0.04	0.00	0.04	0.00	0.01
SO_3	0.19	0.20	0.19	0.23	0.19	0.18	0.19	0.19	0.19	0.19	0.18	0.17
SUM	100.0	99.7	100.0	99.7	100.0	99.7	100.0	99.7	100.0	99.7	100.0	99.8

* – Analyzed by X-ray fluorescence except for boron which was measured by DCP
NA – Not analyzed

Table 2.2. Target and Analyzed Compositions (wt%) of Seventeen ORPLA Crucible Glasses (continued).

GLASS	ORPLA13		ORPLA14		ORPLA15		ORPLA16		ORPLA17	
Oxides	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*
Al_2O_3	10.83	10.64	10.70	10.37	9.46	9.20	9.87	9.80	9.89	9.70
B_2O_3	7.07	7.15	7.20	7.42	8.65	8.90	7.78	7.85	8.78	8.88
CaO	2.01	2.11	2.05	2.00	3.34	3.53	1.47	1.53	2.99	3.04
Cr_2O_3	0.49	0.65	0.50	0.65	0.50	0.65	0.49	0.64	0.50	0.65
Cs_2O (spike)	0.18	0.19	0.17	0.19	0.15	0.16	0.19	0.18	0.15	0.17
Fe_2O_3	0.92	0.99	0.94	0.97	0.93	1.04	0.94	1.02	0.94	0.99
K_2O	0.55	0.57	0.53	0.54	0.54	0.55	0.56	0.55	0.54	0.54
MgO	0.92	0.89	0.94	0.90	0.93	0.87	0.91	0.97	0.91	0.86
Na_2O	24.50	23.53	23.50	23.19	24.00	22.57	25.00	24.26	24.00	23.44
SiO_2	40.61	40.80	41.38	41.13	39.50	39.52	41.58	41.45	40.03	40.21
SnO_2	2.72	3.03	2.78	3.29	2.75	3.27	1.00	1.22	1.00	1.18
TiO_2	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.02	0.00	0.02
V_2O_5	0.00	0.00	0.00	0.00	0.00	0.00	0.94	1.11	0.98	1.10
ZnO	2.42	2.60	2.47	2.58	2.45	2.68	2.36	2.49	2.36	2.40
ZrO_2	5.89	5.71	6.00	5.80	5.95	6.03	6.00	6.00	6.07	5.78
Cl	0.69	0.71	0.66	0.66	0.68	0.71	0.71	0.58	0.68	0.67
F	0.00	NA	0.00	NA	0.00	NA	0.00	NA	0.00	NA
P_2O_5	0.00	0.01	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.02
SO_3	0.19	0.19	0.18	0.17	0.18	0.18	0.19	0.17	0.18	0.18
SUM	100.0	99.8	100.0	99.9	100.0	99.9	100.0	99.8	100.0	99.8

* – Analyzed by X-ray fluorescence except for boron which was measured by DCP
NA – Not analyzed

Table 2.3. Descriptions of Seventeen As-Melted and Heat Treated ORPLA Crucible Glasses.

Glass ID	As-melted glass	Glass remelted at 1200°C for 1 hour, heat treated for 20 hours at 950°C, and quenched.
ORPLA1	Clear glass	Not tested
ORPLA2	Clear glass	Not tested
ORPLA3	Clear glass	Mostly clear glass. <<0.1 vol% of small Cr-Fe spinel crystals
ORPLA4	Clear glass	Not tested
ORPLA5	Clear glass	Clear glass. <<0.1 vol% of small Cr-Fe spinel crystals
ORPLA6	Clear glass. <<0.1 vol% of small Cr oxide crystals	Clear glass. <<0.1 vol% of small Cr-Fe spinel crystals
ORPLA7	Clear glass. <<0.1 vol% of small Cr oxide crystals	Clear glass. <<0.1 vol% of small Cr-Fe spinel crystals
ORPLA8	Clear glass	Not tested
ORPLA9	Clear glass	Clear glass. <<0.1 vol% of Na-Zr-silicate crystals
ORPLA10	Clear glass	Mostly clear glass. ~0.1 vol% of Na-Zr-silicate crystals
ORPLA11	Clear glass	Clear glass
ORPLA12	Clear glass. <<0.1 vol% of small Cr-Fe spinel crystals	Clear glass. <<0.1 vol% of small Cr-Fe spinel crystals
ORPLA13	Clear glass. <<0.1 vol% of small Cr oxide crystals	Clear glass. <0.1 vol% of Na-Zr-silicate crystals
ORPLA14	Clear glass. <<0.1 vol% of small Cr oxide crystals	Clear glass. <0.1 vol% of Na-Zr-silicate crystals + Cr crystal
ORPLA15	Clear glass. <<0.1 vol% of small Cr+Zn crystals	0.2 – 0.3 vol% of Na-Zr-silicate crystals + Sn crystal
ORPLA16	Clear glass. <<0.1 vol% of small Cr+Zn crystals	Clear glass
ORPLA17	Clear glass. <0.1 vol% of small Cr+Zn crystals	Clear glass. ~0.1 vol% of Na-Zr-silicate crystals + Cr oxide crystals

Table 2.4. Measured Sulfate Solubility Limits in Seventeen ORPLA Glasses.

Sample ID	**SO_3 Content (wt%)** (Target Minimum = 0 to 0.3 wt%)		
	Batch Saturation		**Bubbling**
	As-Melted	**After Acid Wash**	
ORPLA1S4	0.68	0.48	-
ORPLA2 S4	0.46	0.42	-
ORPLA3 S4	0.42	0.41	-
ORPLA4S4	0.85	0.44	-
ORPLA5S4	0.34	0.34	-
ORPLA6S4	0.32	0.33	-
ORPLA7S4	0.32	0.28	-
ORPLA8S4	0.40	0.39	-
ORPLA9S4	0.61	0.55	-
ORPLA10S4	0.53	0.49	-
ORPLA11S4	0.30	0.29	-
ORPLA12S4	0.27	0.27	-
ORPLA13S4	0.31	0.30	-
ORPLA14S4	0.28	0.28	-
ORPLA15S4	0.29	0.27	-
ORPLA16S4	0.30	0.30	-
ORPLA17S4	0.32	0.32	-

- Empty data field

Table 2.5. Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Seventeen ORPLA Crucible Glasses.

Glass ID	ORPLA1	ORPLA2	ORPLA3	ORPLA4	ORPLA5	ORPLA6	ORPLA7	ORPLA8	ORPLA9
7-Day PCT, Stainless Steel Vessel; S/V=2000m^{-1} (ppm)									
B	51.36	55.35	50.28	66.42	27.53	27.78	31.69	75.46	43.27
Na	287.20	291.10	278.40	396.10	276.30	233.90	243.10	381.10	348.60
Si	78.22	75.22	74.00	104.90	90.10	72.40	71.97	109.10	77.16
Normalized Concentrations (g/L)									
B	1.84	1.98	1.80	2.38	1.31	1.15	1.31	2.86	1.79
Na	1.55	1.57	1.50	2.14	1.49	1.26	1.31	2.05	1.88
Si	0.41	0.39	0.38	0.54	0.44	0.37	0.38	0.55	0.46
pH	11.74	11.75	11.7	11.85	11.76	11.66	11.68	11.85	11.97
7-Day PCT Normalized Mass Loss (g/m^2)									
B	0.92	0.99	0.90	1.19	0.65	0.57	0.66	1.43	0.89
Na	0.77	0.78	0.75	1.07	0.74	0.63	0.66	1.03	0.94
Si	0.20	0.19	0.19	0.27	0.22	0.18	0.19	0.28	0.23
7-Day PCT Normalized Loss Rate (g/m^2/d)									
B	0.13	0.14	0.13	0.17	0.09	0.08	0.09	0.20	0.13
Na	0.11	0.11	0.11	0.15	0.11	0.09	0.09	0.15	0.13
Si	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.03
VHT Alteration (24 days at 200°C) – Measurements on ORPLA and ORPLAS4 Samples									
Alteration Depth (μm)	>1362	1179	1039	1031	934	821	613	894	514
Alteration Rate (g/m^2/day)*	>150	130	115	114	103	91	68	99	57
Alteration Depth (μm)	>1264	858	1212	918	>1225	561	680	>1238	340
Alteration Rate (g/m^2/day)*	>140	95	134	101	>135	62	75	>137	38

* Alteration rates calculated using estimated density of 2.65 g/cc

Table 2.5. Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Seventeen ORPLA Crucible Glasses (continued).

Glass ID	ORPLA10	ORPLA11	ORPLA12	ORPLA13	ORPLA14	ORPLA15	ORPLA16	ORPLA17
7-Day PCT, Stainless Steel Vessel; S/V=2000m^{-1} (ppm)								
B	42.11	21.12	16.64	19.29	14.33	35.39	36.25	42.33
Na	358.70	224.00	180.30	198.60	159.90	242.40	258.70	238.70
Si	77.32	74.37	75.36	75.54	70.40	69.91	76.51	66.98
Normalized Concentrations (g/L)								
B	1.74	0.97	0.75	0.88	0.64	1.32	1.50	1.55
Na	1.93	1.21	1.01	1.09	0.92	1.36	1.39	1.34
Si	0.46	0.40	0.39	0.40	0.36	0.38	0.39	0.36
pH	11.99	11.67	11.5	11.58	11.45	11.58	11.61	11.55
7-Day PCT Normalized Mass Loss (g/m^2)								
B	0.87	0.49	0.38	0.44	0.32	0.66	0.75	0.78
Na	0.97	0.60	0.51	0.55	0.46	0.68	0.70	0.67
Si	0.23	0.20	0.20	0.20	0.18	0.19	0.20	0.18
7-Day PCT Normalized Loss Rate (g/m^2/d)								
B	0.12	0.07	0.05	0.06	0.05	0.09	0.11	0.11
Na	0.14	0.09	0.07	0.08	0.07	0.10	0.10	0.10
Si	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
VHT Alteration (24 days at 200°C) – Measurements on ORPLA and ORPLAS4 Samples								
Alteration Depth (μm)	136	>1252	145	183	77	230	975	674
Alteration Rate (g/m^2/day)*	15	>138	16	20	9	25	108	74
Alteration Depth (μm)	114	>1301	168	695	5	279	1016	600 to 1115
Alteration Rate (g/m^2/day)*	13	>144	19	77	1	31	112	66 to 123

* Alteration rates calculated using estimated density of 2.65 g/cc

Table 2.6. Viscosities and Electrical Conductivities of Seventeen ORPLA Crucible Glasses.

Glass ID	ORPLA1	ORPLA2	ORPLA3	ORPLA4	ORPLA5	ORPLA6	ORPLA7	ORPLA8	ORPLA9
Viscosity (poise)									
900°C	1747	1919	2118	833	5221	4170	5833	2045	1752
950°C	701	814	799	383	2040	1749	1989	796	624
1000°C	323	386	356	194	896	808	798	354	268
1050°C	167	200	181	107	434	405	364	175	132
1100°C	94	112	101	63	228	217	184	94	73
1150°C	57	67	61	39	128	124	101	55	44
1200°C	36	42	40	25	76	74	60	34	28
1250°C	25	28	27	17	48	47	37	22	19
Electrical Conductivity (S/cm)									
900°C	0.305	0.288	0.209	0.280	0.221	0.099	0.261	0.294	0.262
950°C	0.372	0.351	0.286	0.347	0.316	0.198	0.319	0.366	0.320
1000°C	0.447	0.422	0.373	0.421	0.419	0.325	0.385	0.448	0.384
1050°C	0.530	0.500	0.469	0.505	0.525	0.470	0.458	0.540	0.455
1100°C	0.621	0.585	0.572	0.597	0.631	0.627	0.537	0.641	0.532
1150°C	0.719	0.677	0.681	0.697	0.735	0.789	0.624	0.753	0.615
1200°C	0.824	0.776	0.794	0.806	0.837	0.953	0.717	0.874	0.705
1250°C	0.936	0.881	0.911	0.923	0.935	1.115	0.816	1.005	0.800

Table 2.6. Viscosities and Electrical Conductivities of Seventeen ORPLA Crucible Glasses (continued).

Glass ID	ORPLA10	ORPLA11	ORPLA12	ORPLA13	ORPLA14	ORPLA15	ORPLA16	ORPLA17
Viscosity (poise)								
900°C	1620	4242	5978	5089	6741	2253	3863	2879
950°C	653	1696	2218	1958	2494	909	1461	1095
1000°C	296	757	941	851	1057	413	636	478
1050°C	148	371	445	409	500	207	310	233
1100°C	80	196	230	214	259	112	165	124
1150°C	47	110	128	120	145	65	95	71
1200°C	29	66	76	71	86	40	58	44
1250°C	18	41	47	44	54	26	38	28
Electrical Conductivity (S/cm)								
900°C	0.227	0.253	0.208	0.148	0.148	0.275	0.211	0.171
950°C	0.308	0.315	0.264	0.239	0.239	0.342	0.289	0.260
1000°C	0.398	0.385	0.329	0.336	0.336	0.418	0.378	0.350
1050°C	0.496	0.463	0.403	0.435	0.435	0.504	0.475	0.438
1100°C	0.600	0.550	0.486	0.531	0.531	0.598	0.580	0.521
1150°C	0.709	0.645	0.579	0.623	0.623	0.702	0.691	0.599
1200°C	0.822	0.749	0.682	0.710	0.710	0.814	0.807	0.672
1250°C	0.937	0.860	0.794	0.792	0.792	0.936	0.927	0.738

Table 2.7. Results of K-3 Corrosion Testing for Seventeen ORPLA Crucible Glasses.

Glass ID	Neck loss (inches)	Depth of altered zone (inches)	Half-down loss (inches)
ORPLA1	0.108	0.027	0.002
ORPLA2	0.071	0.021	0.002
ORPLA3	0.041	0.021	0.001
ORPLA4	0.123	0.023	0.003
ORPLA5	0.015	0.017	0.001
ORPLA6	0.024	0.021	0.001
ORPLA7	0.030	0.018	0.001
ORPLA8	0.054	0.022	0.001
ORPLA9	0.083	0.030	Coupon expanded – no measurable loss
ORPLA10	0.073	0.029	Coupon expanded – no measurable loss
ORPLA11	0.028	0.028	Coupon expanded – no measurable loss
ORPLA12	0.015	0.020	Coupon expanded – no measurable loss
ORPLA13	0.025	0.017	Coupon expanded – no measurable loss
ORPLA14	0.012	0.017	Coupon expanded – no measurable loss
ORPLA15	0.036	0.023	Coupon expanded – no measurable loss
ORPLA16	0.039	0.018	Coupon expanded – no measurable loss
ORPLA17	0.042	0.024	Coupon expanded – no measurable loss

Table 2.8. Summary of Test Results for Selected ORPLA Glass Formulation ORPLA15 and Comparison to ILAW Requirements.

Test	**Requirement [45, 46]**	**Test Result for ORPLA15**
Density of glass	< 3.7 g/cc	Not measured
Crystalline Phase	Phase identification	Clear homogeneous glass with no more than 0.3 vol% crystals after heat treatment at 950°C for 20 hours
Liquidus	< 950°C	< 950°C
Centerline Canister Cooling	Phase identification	Not measured
PCT B (g/m^2)	< 2.0 g/m^2	0.66 g/m^2
PCT Na (g/m^2)	< 2.0 g/m^2	0.68 g/m^2
PCT Si (g/m^2)	< 2.0 g/m^2	0.19 g/m^2
VHT at 200°C (g/m^2/day)	< 50 g/m^2/day	25 and 31 g/m^2/day (measurements on ORPLA and ORPLAS4 samples)
Viscosity (poise) at 1100°C	10 to 150 P	112 P
Conductivity (S/cm) at 1100°C	0.2 to 0.7 S/cm	0.598 S/cm
T_G (°C)	Report for modeling	Not measured

Table 2.9. Oxide Composition of AN-105 Simulant and ORPLA15 Glass Composition Used in Melter Tests (wt%).

Component	AN-105 waste contribution	Glass former additives	ORPLA15 (for AN-105)
Loading	31.6%	68.4%	-
Al_2O_3	5.589	3.86	9.45
B_2O_3	0.024	8.58	8.60
CaO	-	3.32	3.32
Cr_2O_3	0.021	0.47	0.49
Cs_2O	0.144	-	0.14
Fe_2O_3	-	0.92	0.92
K_2O	0.537	-	0.537
MgO	-	0.92	0.92
Na_2O[(a)]	23.405 + 0.465[(1)] + 0.13[(2)]	-	24.00
SiO_2	0.033	39.22	39.25
SnO_2	-	2.73	2.73
ZnO	-	2.43	2.43
ZrO_2	-	5.91	5.91
Cl	0.680	-	0.68
F	0.003	-	0.00
P_2O_5	0.000	-	0.00
SO_3[(b)]	0.60[(1)]	-	0.60
SUM	31.6	68.4	100.0

(a) Simulant was ordered at a concentration of 23.41 wt% Na_2O and modified before each melter test with (1) Na_2SO_4 and (2) NaOH additions to obtain 24 wt% Na_2O in the glass.
(b) Concentration of SO_3 was increased in steps during the melter tests from 0.1 wt% SO_3 in the glass up to 0.6 wt%.
– Empty data field

Table 2.10a. Glass Former Additives for 1 Liter of AN-105 Simulant (8 M Na) and Corresponding Melter Feed Properties.

Additives Source	Feed ORPLA15
Additives in Glass (wt%)	68.37
Kyanite (Al_2SiO_5) 325 Mesh (Kyanite Mining) (g)	69.6
H_3BO_3 (US Borax – Technical Granular) (g)	158.43
Wollanstonite NYAD 325 Mesh (NYCO Minerals) (g)	76.02
Cr_2O_3 oxide	5.00[(1)]
Fe_2O_3 (Prince Manufacturing) (g)	7.42
Olivine (Mg_2SiO_4) 325 Mesh (#180 Unimin) (g)	20.18
SiO_2 (Sil-co-Sil 75 US Silica) (g)	300.84
SnO_2 - Stannous Oxide - Mason color	28.64
ZnO (KADOX – 920 Zinc Corp. of America) (g)	25.32
Zircon $ZrSiO_4$ (Flour) Mesh 325 (AM. Mineral) (g)	92.32
Supplemental Na_2SO_4	Variable – Table 2.10b
Addition of Sucrose as Reductant (g)	78.5
Simulant Weight for 1 liter (g)	1359
Sum of Additives (g)	962
Sum of Complete Batch (g)	2221
Target Final Volume (l)	1.31
Estimated Density (g/ml)	1.70
Target Glass Produced (g)	1033
Target Weight % Additives in Slurry	39
Target Glass Yield (g/kg of Feed)	465
Target Glass Yield (g/l of Feed)	791
Target Total Solids (g/l of Feed)	969
Target Additives (g/l of Feed)	660

[(1)] Note that a Cr_2O_3 addition was cut down by 50% to account for K3-brick contribution.

Table 2.10b. NaOH and Na_2SO_4 Additions Required to Obtain 24 wt% Na_2O and Various SO_3 Concentrations Ranging from 0.1 to 0.6 wt% in the ORPLA15 Glass.

Final SO_3 wt%	NaOH needed per kg of feed (grams)	Na_2SO_4 needed per kg of feed (grams)
0.1	6.26	0.84
0.2	5.32	1.68
0.3	4.37	2.53
0.4	3.45	3.37
0.5	2.51	4.21
0.6	1.57	5.05

Table 2.11. LAW Sub-Envelope C1 (AN-107) Waste Simulant Recipe at 8 Molar Sodium.

Envelope Constituents	Simulant AN-107 including pretreatment		Glass Oxides	AN-107 (Wt%)	AN-107 (Wt% in glass)	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
-	mg/L	M	Loading	-	25.90%	In 560 ml water add following compounds in the order listed below				
Al	160	0.006	Al_2O_3	0.113	0.030	$Al(NO_3)_3.9H_2O$ - 60% sol.	8	375.14	0.61	3.67
Ca	353	0.009	CaO	0.184	0.048	$Ca(NO_3)_2*4H_2O$	2	236.16	0.99	2.10
Cr	103	0.002	Cr_2O_3	0.056	0.015	$Na_2CrO_4.4H_2O$	3	234.04	0.99	0.47
Cs (spike)	1402	0.011	Cs_2O	0.556	0.144	$CsNO_3$	4	194.91	1.00	2.06
Fe	1070	0.019	Fe_2O_3	0.572	0.148	$Fe(NO_3)_3*9H_2O$	5	404.01	1.00	7.75
K	980	0.025	K_2O	0.441	0.114	KOH	7	56.10	0.91	1.55
Mn	374	0.007	MnO_2	0.221	0.057	MnO_2	15	86.97	0.99	0.59
Na	183920	8.000	Na_2O	92. 671	24.00	NaOH - 50% sol. d=1.53	6	40.00	0.50	327.96
Ni	339	0.006	NiO	0.161	0.042	NiO	14	74.69	1.00	0.43
Cl	1112	0.031	Cl	0.416	0.108	NaCl	11	58.45	0.99	1.85
F	4870	0.256	F	1.821	0.471	NaF	12	42.00	0.99	10.87
PO_4	3042	0.032	P_2O_5	0.850	0.220	$Na_3PO_4.12H_2O$	10	380.12	0.99	12.30
SO_4	6222	0.065	SO_3	1.938	0.502	Na_2SO_4 (varied content per run)	13	142.06	0.99	See Table 2.20b
NO_2	41158	0.895	-	-	-	$NaNO_2$	25	69.00	1.00	62.05
NO_3	132583	2.138	-	-	-	$NaNO_3$	26	84.99	0.99	175.61
Org. Carbon	24683	2.057	-	-	-	-	-	-	-	-
EDTA	5855	-	-	-	-	$Na_2EDTA.2H_2O$ (C10)	16	372.24	0.99	7.59
HEDTA	5855	-	-	-	-	Na_3HEDTA (C10) - 41%sol.	17	344.20	0.42	17.65
Acetate	5855	-	-	-	-	Sodium Acetate (C2)	18	136.08	0.99	13.62
Formate	5855	-	-	-	-	Sodium Formate (C1)	19	68.01	0.99	8.94
Oxalate	3253	-	-	-	-	Sodium Oxalate (C2)	20	134.00	0.99	5.00
Gluconate	4879	-	-	-	-	Sodium Gluconate (C6)	1	218.14	0.99	5.51
Glycolic	13012	-	-	-	-	Glycolic Acid (C2)	21	76.05	0.71	18.35
NTA	5205	-	-	-	-	Nitrilotriacetic Acid (C6)	22	191.14	0.98	5.31
Citric	14313	-	-	-	-	Citric Acid (C6)	23	192.12	0.99	14.46
Iminodiacetic	4587	-	-	-	-	Iminodiacetic Acid (C4)	24	133.10	0.98	4.68
-	-	-	-	-	-	Target Glass				1033.00
-	-		SUM	100	25.90	Total simulant weight				1279.66

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

Table 2.12. Target and Analyzed Compositions (wt%) of Four ORPLB Crucible Glasses.

GLASS	ORPLB1		ORPLB2		ORPLB3		ORPLB4	
Oxides	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*
Al_2O_3	12.00	11.82	10.00	9.91	9.88	9.89	10.03	9.85
B_2O_3	7.30	7.54	7.30	8.07	8.57	8.70	8.52	8.29
CaO	1.10	1.20	1.10	1.30	3.00	3.11	1.90	1.92
Cr_2O_3	0.52	0.66	0.52	0.67	0.53	0.67	0.53	0.70
Cs_2O (spike)	0.15	0.16	0.15	0.17	0.14	0.17	0.14	0.17
Fe_2O_3	1.10	1.15	1.10	1.19	0.96	1.00	0.96	1.03
K_2O	0.12	0.14	0.12	0.18	0.11	0.14	0.11	0.15
MgO	1.10	1.17	1.10	1.18	0.93	0.85	0.93	0.85
MnO	0.06	0.06	0.06	0.00	0.06	0.06	0.06	0.06
Na_2O	25.00	24.93	25.00	24.64	24.00	23.05	24.00	23.34
NiO	0.04	0.04	0.04	0.12	0.04	0.05	0.04	0.04
SiO_2	37.98	38.16	39.98	39.68	40.06	40.86	40.06	40.28
SnO_2	1.08	1.17	1.08	1.23	1.00	1.14	1.00	1.21
TiO_2	0.00	0.02	0.00	0.02	0.00	0.01	0.00	0.02
V_2O_5	2.00	2.20	2.00	2.24	1.00	1.11	2.00	2.24
ZnO	3.65	3.72	3.65	3.86	2.37	2.44	2.37	2.52
ZrO_2	5.44	5.05	5.44	5.34	6.04	5.78	6.04	6.06
Cl	0.11	0.10	0.11	0.10	0.11	0.10	0.11	0.10
F	0.49	NA	0.49	NA	0.47	NA	0.47	NA
P_2O_5	0.23	0.27	0.23	0.28	0.22	0.25	0.22	0.25
SO_3	0.52	0.48	0.52	0.48	0.50	0.47	0.50	0.45
SUM	100.0	100.5	100.0	101.2	100.0	100.3	100.0	100.0

* – Analyzed by X-ray fluorescence except for boron which was measured by DCP
NA – Not analyzed

Table 2.13. Descriptions of Four As-Melted and Heat Treated ORPLB Crucible Glasses.

Glass ID	As-melted glass	Glass remelted at 1200°C for 1 hour, heat treated for 20 hours at 950°C, and quenched.
ORPLB1	Clear glass	0.1 to 0.2 vol% of Cr-rich spinel with Zn, Al, and Sn.
ORPLB2	Clear glass	0.1 to 0.2 vol% of Cr-rich spinel with Zn, Al, and Sn.
ORPLB3	Clear glass	< 0.1 vol% of Cr-rich spinel with Zn, Al, and Sn.
ORPLB4	Clear glass. < 0.1 vol% of small Cr+Zn crystals	< 0.1 vol% of Cr-rich spinel with Zn, Al, and Sn.

Table 2.14. Measured Sulfate Solubility Limits in Four ORPLB Crucible Glasses.

Sample ID	**SO_3 Content (wt%)** (Target Minimum = 0.2 to 0.5 wt%)		
	Batch Saturation		Bubbling*
	As-Melted	After Acid Wash	
ORPLB1S4	0.59	0.56	0.62
ORPLB2S4	0.60	0.58	0.68
ORPLB3S4	0.55	0.54	-
ORPLB4S4	0.53	0.52	0.70

"-" Empty data field
* Starting glass for bubbling tests contained no SO_3.

Table 2.15. Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Four ORPLB Crucible Glasses.

Glass ID	ORPLB1	ORPLB2	ORPLB3	ORPLB4
7-Day PCT, Stainless Steel Vessel; S/V=2000m^{-1} (ppm)				
B	27.45	38.24	29.41	37.18
Na	242.30	285.10	205.20	236.30
Si	73.97	82.30	65.43	69.70
Normalized Concentrations (g/L)				
B	1.21	1.69	1.10	1.41
Na	1.31	1.54	1.15	1.33
Si	0.42	0.44	0.35	0.37
pH	11.65	11.74	11.46	11.53
7-Day PCT Normalized Mass Loss (g/m^2)				
B	0.61	0.84	0.55	0.70
Na	0.65	0.77	0.58	0.66
Si	0.21	0.22	0.17	0.19
7-Day PCT Normalized Loss Rate (g/m^2/d)				
B	0.09	0.12	0.08	0.10
Na	0.09	0.11	0.08	0.09
Si	0.03	0.03	0.02	0.03
VHT Alteration (24 days at 200°C) – Measurements on ORPLB and ORPLBS4 Samples				
Alteration Depth (µm)	>> 1200	995	344	369
Alteration Rate (g/m^2/day)*	>> 130	110	38	41
Alteration Depth (µm)	>1175	526	797	320
Alteration Rate (g/m^2/day)*	>130	58	88	35

* Alteration rates calculated using estimated density of 2.65 g/cc

Table 2.16. Viscosities and Electrical Conductivities of Four ORPLB Crucible Glasses.

Glass ID	ORPLB1	ORPLB2	ORPLB3	ORPLB4
Viscosity (poise)				
900°C	2873	2668	1928	2592
950°C	1157	1058	821	1034
1000°C	525	478	388	468
1050°C	263	240	200	235
1100°C	142	131	111	128
1150°C	83	77	65	75
1200°C	51	48	40	46
1250°C	33	31	26	30
Electrical Conductivity (S/cm)				
900°C	0.265	0.305	0.288	0.258
950°C	0.365	0.376	0.365	0.319
1000°C	0.469	0.456	0.447	0.388
1050°C	0.573	0.546	0.533	0.466
1100°C	0.676	0.644	0.620	0.551
1150°C	0.776	0.751	0.709	0.644
1200°C	0.873	0.867	0.799	0.744
1250°C	0.965	0.991	0.889	0.853

Table 2.17. Results of K-3 Corrosion Testing for Four ORPLB Crucible Glasses.

Glass ID	Neck loss (inches)	Depth of altered zone (inches)	Half-down loss (inches)
ORPLB1	0.036	0.019	Coupon expanded – no measurable loss
ORPLB2	0.039	0.023	0.001
ORPLB3	0.036	0.027	Coupon expanded – no measurable loss
ORPLB4	0.033	0.023	Coupon expanded – no measurable loss

Table 2.18. Summary of Test Results for Selected ORPLB Glass Formulation ORPLB4 and Comparison to ILAW Requirements.

Test	**Requirement [45, 46]**	**Test Result for ORPLB4**
Density of glass	< 3.7 g/cc	Not measured
Crystalline Phase	Phase identification	Clear homogeneous glass with less than 0.1 vol% crystals after heat treatment at 950°C for 20 hours
Liquidus	< 950°C	< 950°C
Centerline Canister Cooling	Phase identification	Not measured
PCT B (g/m^2)	< 2.0 g/m^2	0.70 g/m^2
PCT Na (g/m^2)	< 2.0 g/m^2	0.66 g/m^2
PCT Si (g/m^2)	< 2.0 g/m^2	0.19 g/m^2
VHT at 200°C (g/m^2/day)	< 50 g/m^2/day	35 and 41 g/m^2/day (measurements on ORPLB and ORPLBS4 samples)
Viscosity (poise) at 1100°C	10 to 150 P	128 P
Conductivity (S/cm) at 1100°C	0.2 to 0.7 S/cm	0.551 S/cm
T_G (°C)	Report for modeling	Not measured

Table 2.19. Oxide Composition of AN-107 Simulant and ORPLB4 Glass Composition Used in Melter Tests (wt%).

Component	AN-107 waste contribution	Glass former additives	ORPLB4 (for AN-107)
Loading	26.2%	73.8%	-
Al_2O_3	0.028	9.95	9.98
B_2O_3	-	8.48	8.48
CaO	0.046	1.84	1.89
Cr_2O_3	0.014	0.51	0.52
Cs_2O	0.137	-	0.14
Fe_2O_3	0.141	0.82	0.96
K_2O	0.109	-	0.11
MgO	-	0.93	0.93
MnO_2	0.055	-	0.05
Na_2O[a]	22.885 + 0.658[1] + 0.457[2]	-	24.00
NiO	0.040	-	0.04
SiO_2	-	39.88	39.88
SnO_2	-	1.00	1.00
V_2O_5	-	1.99	1.99
ZnO	-	2.36	2.36
ZrO_2	-	6.02	6.02
Cl	0.108	-	0.11
F	0.471	-	0.47
P_2O_5	0.220	-	0.22
SO_3[b]	0.85[1]	-	0.85
SUM	26.2	73.8	100.0

(a) Simulant was ordered at a concentration of 22.89 wt% Na_2O and modified before each melter test with (1) Na_2SO_4 and (2) NaOH additions to obtain 24 wt% Na_2O in the glass.
(b) Concentration of SO_3 was increased in steps during the melter tests from 0.6 wt% SO_3 in the glass up to 1.0 wt%.
– Empty data field

Table 2.20a. Glass Former Additives for 1 Liter of AN-107 Simulant (8 M Na) and Corresponding Melter Feed Properties.

Additives Source	Feed ORPLB4
Additives in Glass (wt%)	73.78
Kyanite (Al_2SiO_5) 325 Mesh (Kyanite Mining) (g)	181.47
H_3BO_3 (US Borax – Technical Granular) (g)	156.33
Wollanstonite NYAD 325 Mesh (NYCO Minerals) (g)	42.10
Cr_2O_3 oxide	5.33[(1)]
Fe_2O_3 (Prince Manufacturing) (g)	5.94
Olivine (Mg_2SiO_4) 325 Mesh (#180 Unimin) (g)	19.49
SiO_2 (Sil-co-Sil 75 US Silica) (g)	275.73
SnO2 - Stannous Oxide - Mason color	10.34
V_2O_5 – Pulva Ground - Stratcor	20.67
ZnO (KADOX – 920 Zinc Corp. of America) (g)	24.48
Zircon $ZrSiO_4$ (Flour) Mesh 325 (AM. Mineral) (g)	94.11
Supplemental Na_2SO_4	Variable – Table 2.20b
Addition of Sucrose as Reductant (g)	6.21
Simulant Weight for 1 liter (g)	1279.66
Sum of Additives (g)	936
Sum of Complete Batch (g)	2116
Target Final Volume (l)	1.24
Estimated Density (g/ml)	1.70
Target Glass Produced (g)	1033
Target Weight % Additives in Slurry	40
Target Glass Yield (g/kg of Feed)	488
Target Glass Yield (g/l of Feed)	830
Target Total Solids (g/l of Feed)	1117
Target Additives (g/l of Feed)	672

[(1)] Note that a Cr_2O_3 addition was cut down by 50% to account for K3-brick contribution.

Table 2.20b. NaOH and Na_2SO_4 Additions Required to Obtain 24 wt% Na_2O and Various SO_3 Concentrations Ranging from 0.6 to 1.0 wt% in the ORPLB4 Glass.

Final SO_3 wt%	NaOH needed per kg of feed (grams)	Na_2SO_4 needed per kg of feed (grams)
0.6	8.31	5.31
0.7	7.32	6.22
0.8	6.33	7.11
0.85	5.84	7.56
0.9	5.34	8.00
1.0	4.35	8.89

Table 2.21. LAW Sub-Envelope A3 (AN-104) Waste Simulant Recipe at 8 Molar Sodium.

Envelope Constituents	Simulant AN-104 Including Pretreatment		Glass Oxides	LAW A3 Simulant as Oxides (wt%)	Waste Contribution to Glass	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
—	mg/L	Molarity	Loading	—	18.84%	In 300 ml water add following compounds in the order listed below				
Al	28650	1.062	Al_2O_3	16.700	5.147	$Al(NO_3)_3.9H_2O$, 60% sol.	1	375.14	0.61	469.55
—	—	—	—	—	—	$Al(OH)_3$	4	78.00	1.00	23.67
Cr	248	0.005	Cr_2O_3	0.112	0.034	$Na_2CrO_4*4H_2O$	7	234.04	0.99	1.13
Cs spike	1402	0.011	Cs_2O	0.458	0.141	$CsNO_3$	2	194.91	1.00	2.06
K	4737	0.121	K_2O	1.760	0.543	KOH	6	56.10	0.91	7.49
Na	183920	8.000	Na_2O	76.479	23.57	NaOH, 50% sol. d=1.53	5	40.00	0.50	341.04
Si	260	0.009	SiO_2	0.172	0.053	SiO_2	3	60.09	0.99	0.56
Cl	6499	0.183	Cl	2.005	0.618	NaCl	9	58.45	0.99	10.82
F	84	0.004	F	0.026	0.008	NaF	10	42.00	0.99	0.19
PO_4	2607	0.027	P_2O_5	0.601	0.185	$Na_3PO_4.12H_2O$	8	380.12	0.99	10.54
SO_4 (Nominal)	6561	0.068	SO_3	1.687	0.520	Na_2SO_4 (varied content per run)	11	142.06	0.99	See Table 2.30b
NO_2	89867	1.954	NO_2	—	—	$NaNO_2$	14	69.00	1.00	135.48
NO_3	141946	2.289	NO_3	—	—	$NaNO_3$		84.99	0.99	0.00
CO_3	36182	0.603	CO_3	—	—	Na_2CO_3	15	105.99	1.00	63.91
Org.Carbon	2339	0.195	—	—	—	—	—	—	—	—
Acetate	2611	0.044	—	—	—	Sodium Acetate (C2)	12	136.08	0.99	6.08
Formate	4772	0.106	—	—	—	Sodium Formate (C1)	13	68.01	0.99	7.28
—	—	—	—	—	—	Target Glass Weight				1051.85
—	—	—	SUM	100.00	18.839	Total Simulant Weight				1389.59

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

Table 2.22. Target and Analyzed Compositions (wt%) of Five ORPLC Crucible Glasses.

GLASS	ORPLC1		ORPLC2		ORPLC3		ORPLC4		ORPLC5	
Oxides	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*
Al_2O_3	9.50	9.52	10.67	10.53	10.67	10.30	10.65	10.28	10.04	9.17
B_2O_3	6.06	6.16	11.67	NA	11.67	NA	11.19	NA	8.52	8.07
CaO	3.00	3.16	6.42	6.52	4.11	4.45	6.47	6.76	1.91	1.92
Cr_2O_3	0.50	0.66	0.51	0.65	0.51	0.69	0.51	0.68	0.53	0.66
Cs_2O (spike)	0.15	0.15	0.14	0.13	0.14	0.13	0.14	0.16	0.14	0.17
Fe_2O_3	1.00	1.11	0.90	0.93	0.90	0.99	0.91	1.00	0.97	0.96
K_2O	0.58	0.63	0.54	0.52	0.54	0.56	0.54	0.55	0.54	0.52
MgO	1.00	0.96	0.90	0.81	0.90	0.82	0.91	0.86	0.93	0.98
Na_2O	25.00	23.88	23.50	23.01	23.50	22.02	23.50	22.45	23.57	23.92
SiO_2	38.32	37.61	34.52	35.08	34.52	34.88	34.86	34.92	40.10	40.46
SnO_2	2.00	2.36	0.99	1.02	0.99	1.05	1.00	1.20	1.00	1.14
TiO_2	1.00	1.11	0.00	0.02	0.00	0.01	0.00	0.01	0.00	0.01
V_2O_5	3.00	3.46	1.47	1.61	1.47	1.71	1.48	1.70	2.00	2.12
ZnO	3.00	3.24	2.97	3.02	2.97	3.29	3.00	3.22	2.37	2.36
ZrO_2	4.50	4.51	3.46	3.15	3.46	3.43	3.50	3.53	6.04	5.53
Cl	0.66	0.59	0.62	0.54	0.62	0.59	0.62	0.60	0.62	0.64
F	0.01	NA	0.01	NA	0.01	NA	0.01	NA	0.01	NA
P_2O_5	0.20	0.25	0.18	0.20	2.50	2.69	0.18	0.22	0.19	0.22
SO_3	0.55	0.50	0.52	0.49	0.52	0.52	0.52	0.51	0.52	0.48
SUM	100.0	99.9	100.0	99.9	100.0	99.8	100.0	99.8	100.0	99.4

* – Analyzed by X-ray fluorescence except for boron which was measured by DCP
NA – Not analyzed

Table 2.23. Descriptions of Five As-Melted and Heat Treated ORPLC Crucible Glasses.

Glass ID	As-melted glass	Glass remelted at 1200°C for 1 hour, heat treated for 20 hours at 950°C, and quenched.
ORPLC1	Clear glass. << 0.1 vol% of small Cr crystals	~ 0.1 to 0.3 vol% sodalite (Na,Al-silicate sulfate) and Cr crystals
ORPLC2	Clear glass. << 0.1 vol% of small Cr+Zn crystals	Clear glass
ORPLC3	Clear glass. << 0.1 vol% of small Cr+Zn crystals	Clear glass
ORPLC4	Clear glass. << 0.1 vol% of small Cr+Zn crystals	Clear glass
ORPLC5	Clear glass. << 0.1 vol% of small Cr crystals	Clear glass. << 0.1 vol% of small Cr crystals

Table 2.24. Measured Sulfate Solubility Limits in Five ORPLC Crucible Glasses.

Sample ID	**SO3 Content (wt%)** (Target Minimum = 0.45 to 0.75 wt%)		
	Batch Saturation		Bubbling*
	As-Melted	After Acid Wash	
ORPLC1S4	0.62	0.59	0.58
ORPLC2S4	0.74	0.68	-
ORPLC3S4	0.70	0.63	-
ORPLC4S4	0.77	0.70	1.09
ORPLC5S4	0.57	0.56	-

- Empty data field
* Starting glass for bubbling tests contained no SO_3.

Table 2.25. Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Five ORPLC Crucible Glasses.

Glass ID	ORPLC1	ORPLC2	ORPLC3	ORPLC4	ORPLC5
7-Day PCT, Stainless Steel Vessel; S/V=2000m^{-1} (ppm)					
B	-	81.20	126.30	72.72	44.97
Na	-	392.20	446.30	359.60	260.5
Si	-	73.28	68.20	71.01	67.71
Normalized Concentrations (g/L)					
B	-	2.24	3.48	2.09	1.70
Na	-	2.25	2.56	2.06	1.49
Si	-	0.45	0.42	0.44	0.36
pH	-	11.77	11.61	11.75	11.38
7-Day PCT Normalized Mass Loss (g/m^2)					
B	-	1.12	1.74	1.05	0.85
Na	-	1.12	1.28	1.03	0.74
Si	-	0.23	0.21	0.22	0.18
7-Day PCT Normalized Loss Rate (g/m^2/d)					
B	-	0.16	0.25	0.15	0.12
Na	-	0.16	0.18	0.15	0.11
Si	-	0.03	0.03	0.03	0.03
VHT Alteration (24 days at 200°C) – Measurements on ORPLC and ORPLCS4 Samples					
Alteration Depth (μm)	1116	>> 1200	>> 1200	>> 1200	362
Alteration Rate (g/m^2/day)*	123	>> 130	>> 130	>> 130	40
Alteration Depth (μm)	1066	753	>> 1200	>> 1200	224
Alteration Rate (g/m^2/day)*	118	83	>> 130	>> 130	25

* Alteration rates calculated using estimated density of 2.65 g/cc

Table 2.26. Viscosities and Electrical Conductivities of Three ORPLC Crucible Glasses.

Glass ID	ORPLC1	ORPLC2	ORPLC5
Viscosity (poise)			
900°C	2489	546	3159
950°C	883	245	1152
1000°C	376	124	493
1050°C	184	69	239
1100°C	100	42	128
1150°C	59	27	74
1200°C	37	18	46
1250°C	25	13	30
Electrical Conductivity (S/cm)			
900°C	0.238	0.183	0.162
950°C	0.336	0.238	0.221
1000°C	0.443	0.302	0.288
1050°C	0.554	0.376	0.363
1100°C	0.668	0.462	0.445
1150°C	0.782	0.559	0.532
1200°C	0.895	0.667	0.625
1250°C	1.005	0.787	0.721

Table 2.27. Results of K-3 Corrosion Testing for Five ORPLC Crucible Glasses.

Glass ID	Neck loss (inches)	Depth of altered zone (inches)	Half-down loss (inches)
ORPLC1	0.071	0.018	0.001
ORPLC2	0.083	0.032	Coupon expanded – no measurable loss
ORPLC3	0.030	0.028	Coupon expanded – no measurable loss
ORPLC4	0.073	0.029	0.003
ORPLC5	0.021	0.021	Coupon expanded – no measurable loss

Table 2.28. Summary of Test Results for Selected ORPLC Glass Formulation ORPLC5 and Comparison to ILAW Requirements.

Test	**Requirement [45, 46]**	**Test Result for ORPLC5**
Density of glass	< 3.7 g/cc	Not measured
Crystalline Phase	Phase identification	Clear glass. << 0.1 vol% of small Cr crystals
Liquidus	< 950°C	< 950°C
Centerline Canister Cooling	Phase identification	Not measured
PCT B (g/m^2)	< 2.0 g/m^2	0.85 g/m^2
PCT Na (g/m^2)	< 2.0 g/m^2	0.74 g/m^2
PCT Si (g/m^2)	< 2.0 g/m^2	0.18 g/m^2
VHT at 200°C (g/m^2/day)	< 50 g/m^2/day	25 and 40 g/m^2/day (measurements on ORPLC and ORPLCS4 samples)
Viscosity (poise) at 1100°C	10 to 150 P	128 P
Conductivity (S/cm) at 1100°C	0.2 to 0.7 S/cm	0.445 S/cm
T_G (°C)	Report for modeling	Not measured

Table 2.29. Oxide Composition of AN-104 Simulant and ORPLC5 Glass Composition Used in Melter Tests (wt%).

Component	AN-104 waste contribution	Glass former additives	ORPLC5 (for AN-104)
Loading	31.0%	69.0%	-
Al_2O_3	5.147	4.87	10.02
B_2O_3	-	8.50	8.50
CaO	-	1.91	1.91
Cr_2O_3	0.034	0.50	0.53
Cs_2O	0.141	-	0.14
Fe_2O_3	-	0.97	0.97
K_2O	0.543	-	0.54
MgO	-	0.93	0.93
Na_2O[(a)]	22.110 + 0.542[(1)] + 0.918[(2)]	-	23.57
SiO_2	0.053	39.96	40.01
SnO_2	-	1.00	1.00
V_2O_5	-	2.00	2.00
ZnO	-	2.36	2.36
ZrO_2	-	6.02	6.02
Cl	0.618	-	0.62
F	0.008	-	0.01
P_2O_5	0.184	-	0.18
SO_3[(b)]	0.700[(1)]	-	0.70
SUM	31.0	69.0	100.0

(a) Simulant was ordered at a concentration of 22.11 wt% Na_2O and modified before each melter test with (1) Na_2SO_4 and (2) NaOH additions to obtain 23.57 wt% Na_2O in the glass.
(b) Concentration of SO_3 was increased in steps during the melter tests from 0.7 wt% SO_3 in the glass up to 0.9 wt%.
– Empty data field

Table 2.30a. Glass Former Additives for 1 Liter of AN-104 Simulant (8 M Na) and Corresponding Melter Feed Properties.

Additives Source	Feed ORPLC5
Additives in Glass (wt%)	69.01
Kyanite (Al_2SiO_5) 325 Mesh (Kyanite Mining) (g)	94.96
H_3BO_3 (US Borax – Technical Granular) (g)	161.44
Wollanstonite NYAD 325 Mesh (NYCO Minerals) (g)	42.59
Cr_2O_3 oxide	5.32[(1)]
Fe_2O_3 (Prince Manufacturing) (g)	8.16
Olivine (Mg_2SiO_4) 325 Mesh (#180 Unimin) (g)	19.85
SiO_2 (Sil-co-Sil 75 US Silica) (g)	320.66
SnO2 - Stannous Oxide - Mason color	10.66
V_2O_5 – Pulva Ground - Stratcor	21.04
ZnO (KADOX – 920 Zinc Corp. of America) (g)	25.00
Zircon $ZrSiO_4$ (Flour) Mesh 325 (AM. Mineral) (g)	95.42
Supplemental Na_2SO_4	Variable – Table 2.30b
Addition of Sucrose as Reductant (g)	6.21
Simulant Weight for 1 liter (g)	1389.59
Sum of Additives (g)	890
Sum of Complete Batch (g)	2280
Target Final Volume (l)	1.34
Estimated Density (g/ml)	1.70
Target Glass Produced (g)	1052
Target Weight % Additives in Slurry	39
Target Glass Yield (g/kg of Feed)	461
Target Glass Yield (g/l of Feed)	784
Target Total Solids (g/l of Feed)	1007
Target Additives (g/l of Feed)	664

[(1)] Note that a Cr_2O_3 addition was cut down by 50% to account for K3-brick contribution.

Table 2.30b. NaOH and Na_2SO_4 Additions Required to Obtain 23.57 wt% Na_2O and Various SO_3 Concentrations Ranging from 0.0 to 0.9 wt% in the ORPLC5 Glass.

Final SO_3 wt%	NaOH needed per kg of feed (grams)	Na_2SO_4 needed per kg of feed (grams)
0.0	17.61	-
0.7	11.07	5.88
0.8	10.14	6.72
0.9	9.21	7.56

Table 2.31. LAW Sub-Envelope C2 (AN-102) Simulant Recipe at 8 Molar Sodium.

Envelope Constituents	Simulant AN-102 Including Pretreatment		Glass Oxides	AN-102 Simulant as Oxides (wt%)	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
-	mg/L	Molarity	Loading	-	In 430 ml water add following compounds in the order listed below				
Al	9922	0.368	Al_2O_3	6.412	$Al(NO_3)_3.9H_2O$, 60% sol.	1	375.14	0.61	227.31
B	30	0.003	B_2O_3	0.033	H3BO3	5	61.83	0.99	0.17
Ca	396	0.010	CaO	0.190	$Ca(NO_3)_2*4H_2O$	2	236.16	0.99	2.36
Cr	174	0.003	Cr_2O_3	0.087	$Na_2CrO_4*4H_2O$	8	234.04	0.99	0.79
Cs spike	1402	0.011	Cs_2O	0.508	$CsNO_3$	3	194.91	1.00	2.06
K	1604	0.041	K_2O	0.661	KOH	7	56.10	0.91	2.53
Na	183920	8.000	Na_2O	84.786	NaOH, 50% sol. D=1.53	6	40.00	0.50	161.17
Ni	337	0.006	NiO	0.147	$Ni(NO_3)_2*6H_2O$	4	290.81	1.00	1.67
Pb	150	0.001	PbO	0.055	PbO	9	223.20	1.00	0.16
Si	73	0.003	SiO_2	0.053	SiO_2	10	60.09	0.99	0.16
Cl	3904	0.110	Cl	1.335	NaCl	11	58.45	0.99	6.50
F	2025	0.107	F	0.692	NaF	12	42.00	0.99	4.52
PO_4	4508	0.047	P_2O_5	1.152	$Na_3PO_4.12H_2O$	13	380.12	0.99	18.23
SO_4(Nominal)	13648	0.142	SO_3	3.890	Na_2SO_4 (varied content per run)	14	142.06	0.99	See Table 2.40b
NO_2	169129	1.503	NO_2	-	$NaNO_2$	20	69.00	1.00	104.21
NO_3	178997	2.887	NO_3	-	$NaNO_3$	21	84.99	0.99	148.93
CO_3	44356	0.739	CO_3	-	Na_2CO_3	22	105.99	1.00	78.34
NH_3	123	0.007	NH_3	-	NH_4NO_3	19	80.04	1.00	0.58
Org.Carbon	23569	1.964	-	-	-	-	-	-	-
Formate	26113	0.580	-	-	Sodium Formate (C1)	15	68.01	0.99	38.85
Oxalate	1501	0.017	-	-	Sodium Oxalate (C2)	16	134.00	0.99	2.31
Glycolate	34273	0.451	-	-	Glycolic Acid (C2)	17	76.05	0.71	48.34
Citric Acid	14362	0.075	-	-	Citric Acid (C6)	18	192.12	0.99	14.51
-	-	-	-	-	Target Glass Weight				1180.57
-	-	-	SUM	100.000	Total Simulant Weight				1315.10

- Empty data field.
* Assay refers to the purity of the raw material as specified by the vendor.

Table 2.32. Target and Analyzed Compositions (wt%) of Three ORPLD Crucible Glasses.

GLASS	ORPLD1		ORPLD2		ORPLD3	
Oxides	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*
Al_2O_3	10.16	10.36	9.11	8.94	8.11	8.07
B_2O_3	12.05	NA	7.61	NA	8.61	NA
CaO	8.02	8.12	8.02	8.18	10.02	10.05
Cr_2O_3	0.50	0.65	0.50	0.63	0.50	0.61
Cs_2O (spike)	0.13	0.14	0.13	0.12	0.13	0.12
Fe_2O_3	1.00	1.05	0.75	0.77	0.75	0.76
K_2O	0.16	0.22	0.16	0.18	0.16	0.18
Li_2O	0.00	NA	0.75	NA	0.75	NA
MgO	1.00	0.97	1.00	0.95	1.00	0.93
Na_2O	21.00	20.39	21.00	20.71	21.00	20.69
NiO	0.04	0.02	0.04	0.04	0.04	0.00
PbO	0.01	0.02	0.01	0.02	0.01	0.02
SiO_2	37.17	37.20	39.40	39.82	39.40	40.14
SnO_2	0.00	0.01	1.00	1.06	0.00	0.01
TiO_2	0.00	0.03	0.00	0.02	0.00	0.01
V_2O_5	1.00	1.10	1.00	1.10	1.00	1.06
ZnO	3.00	3.06	2.51	2.57	2.51	2.45
ZrO_2	3.00	2.81	5.26	4.92	4.26	3.97
Cl	0.33	0.30	0.33	0.28	0.33	0.24
F	0.17	NA	0.17	NA	0.17	NA
P_2O_5	0.29	0.32	0.29	0.32	0.29	0.33
SO_3	0.96	1.06	0.96	0.77	0.96	0.84
SUM	100.0	99.9	100.0	99.8	100.0	99.8

* – Analyzed by X-ray fluorescence
NA – Not analyzed

Table 2.33. Descriptions of Three As-Melted and Heat Treated ORPLD Crucible Glasses.

Glass ID	As-melted glass	Glass remelted at 1200°C for 1 hour, heat treated for 20 hours at 950°C, and quenched.
ORPLD1	Mostly clear glass. ~ 0.1 to 0.2 vol% of small Cr+Zn crystals	Mostly clear glass. ~ 0.1 to 0.2 vol% of small Cr+Zn crystals
ORPLD2	Clear glass	Clear glass
ORPLD3	Clear glass	Clear glass

Table 2.34. Measured Sulfate Solubility Limits in Three ORPLD Crucible Glasses.

Sample ID	**SO3 Content (wt%)** (Target Minimum = 0.6 to 1.2 wt%)		
	Batch Saturation		Bubbling
	As-Melted	After Acid Wash	
ORPLD1S4	0.79	0.70	-
ORPLD2S4	0.90	0.82	-
ORPLD3S4	0.92	0.89	-

- Empty data field

Table 2.35. Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Three ORPLD Crucible Glasses.

Glass ID	ORPLD1	ORPLD2	ORPLD3
7-Day PCT, Stainless Steel Vessel; S/V=2000m^{-1} (ppm)			
B	49.32	26.95	22.44
Na	223.60	234.00	203.90
Si	53.61	70.99	66.27
Normalized Concentrations (g/L)			
B	1.32	1.14	0.84
Na	1.44	1.50	1.31
Si	0.31	0.39	0.36
pH	11.45	11.71	11.72
7-Day PCT Normalized Mass Loss (g/m^2)			
B	0.66	0.57	0.42
Na	0.72	0.75	0.65
Si	0.15	0.19	0.18
7-Day PCT Normalized Loss Rate (g/m^2/d)			
B	0.09	0.08	0.06
Na	0.10	0.11	0.09
Si	0.02	0.03	0.03
VHT Alteration (24 days at 200°C) – Measurements on ORPLD and ORPLDS4 Samples			
Alteration Depth (µm)	99± 30	99 ± 126	99± 15
Alteration Rate (g/m^2/day)*	11 ± 3	11± 14	11± 2
Alteration Depth (µm)	141	34	209
Alteration Rate (g/m^2/day)*	16	4	23

* Alteration rates calculated using estimated density of 2.65 g/cc

Table 2.36. Viscosity and Electrical Conductivity of ORPLD1 Crucible Glass.

Temperature (°C)	Viscosity (poise)	Electrical Conductivity (S/cm)
900°C	744	0.107
950°C	325	0.146
1000°C	162	0.189
1050°C	89	0.238
1100°C	53	0.291
1150°C	33	0.347
1200°C	22	0.406
1250°C	16	0.467

Table 2.37. Results of K-3 Corrosion Testing for Three ORPLD Crucible Glasses.

Glass ID	Neck loss (inches)	Depth of altered zone (inches)	Half-down loss (inches)
ORPLD1	0.030	0.028	Coupon expanded – no measurable loss
ORPLD2	0.050	0.021	0.002
ORPLD3	0.091	0.026	0.003

Table 2.38. Summary of Test Results for Selected ORPLD Glass Formulation ORPLD1 and Comparison to ILAW Requirements.

Test	**Requirement [45, 46]**	**Test Result for ORPLD1**
Density of glass	< 3.7 g/cc	Not measured
Crystalline Phase	Phase identification	Clear homogeneous glass with not more than 0.2 vol% crystals after heat treatment at 950°C for 20 hours
Liquidus	< 950°C	< 950°C
Centerline Canister Cooling	Phase identification	Not measured
PCT B (g/m^2)	< 2.0 g/m^2	0.66 g/m^2
PCT Na (g/m^2)	< 2.0 g/m^2	0.72 g/m^2
PCT Si (g/m^2)	< 2.0 g/m^2	0.15 g/m^2
VHT at 200°C (g/m^2/day)	< 50 g/m^2/day	11 and 16 g/m^2/day (measurements on ORPLD and ORPLDS4 samples)
Viscosity (poise) at 1100°C	10 to 150 P	53 P
Conductivity (S/cm) at 1100°C	0.2 to 0.7 S/cm	0.291 S/cm
T_G (°C)	Report for modeling	Not measured

Table 2.39. Oxide Composition of AN-102 Simulant and ORPLD1 Glass Composition Used in Melter Tests (wt%).

Component	AN-102 waste contribution	Glass former additives	ORPLD1 (for AN-102)
Loading	24.9%	75.1%	-
Al_2O_3	1.588	8.56	10.15
B_2O_3	0.008	12.01	12.02
CaO	0.047	7.96	8.01
Cr_2O_3	0.022	0.48	0.50
Cs_2O	0.126	-	0.13
Fe_2O_3	-	1.00	1.00
K_2O	0.164	-	0.16
MgO	-	1.00	1.00
Na_2O[a]	19.374 + 0.852[1] + 0.774[2]	-	21.00
NiO	0.036	-	0.04
PbO	0.014	-	0.01
SiO_2	0.013	37.10	37.11
V_2O_5	-	1.00	1.00
ZnO	-	3.00	3.00
ZrO_2	-	3.00	3.00
Cl	0.331	-	0.33
F	0.172	-	0.17
P_2O_5	0.281	-	0.28
SO_3[b]	1.100[1]	-	1.10
SUM	24.9	75.1	100.0

(a) Simulant was ordered at a concentration of 19.37 wt% Na_2O and modified before each melter test with (1) Na_2SO_4 and (2) NaOH additions to obtain 21.0 wt% Na_2O in the glass.
(b) Concentration of SO_3 was increased in steps during the melter tests from 0.7 wt% SO_3 in the glass up to 1.3 wt%.
– Empty data field

Table 2.40a. Glass Former Additives for 1 Liter of AN-102 Simulant (8 M Na) and Corresponding Melter Feed Properties.

Additives Source	Feed ORPLD1
Additives in Glass (wt%)	75.10
Kyanite (Al_2SiO_5) 325 Mesh (Kyanite Mining) (g)	177.01
H_3BO_3 (US Borax – Technical Granular) (g)	252.66
Wollanstonite NYAD 325 Mesh (NYCO Minerals) (g)	198.69
Cr_2O_3 oxide	5.80[(1)]
Fe_2O_3 (Prince Manufacturing) (g)	8.51
Olivine (Mg_2SiO_4) 325 Mesh (#180 Unimin) (g)	21.42
SiO_2 (Sil-co-Sil 75 US Silica) (g)	235.82
V_2O_5 – Pulva Ground - Stratcor	11.82
ZnO (KADOX – 920 Zinc Corp. of America) (g)	35.48
Zircon $ZrSiO_4$ (Flour) Mesh 325 (AM. Mineral) (g)	53.23
Supplemental Na_2SO_4	Variable – Table 2.40b
Addition of Sucrose as Reductant (g)	37.86
Simulant Weight for 1 liter (g)	1315.10
Sum of Additives (g)	1038
Sum of Complete Batch (g)	2353
Target Final Volume (l)	1.38
Estimated Density (g/ml)	1.70
Target Glass Produced (g)	1181
Target Weight % Additives in Slurry	44
Target Glass Yield (g/kg of Feed)	502
Target Glass Yield (g/l of Feed)	853
Target Total Solids (g/l of Feed)	1068
Target Additives (g/l of Feed)	750

(1) Note that a Cr_2O_3 addition was cut down by 50% to account for K3-brick contribution.

Table 2.40b. NaOH and Na_2SO_4 Additions Required to Obtain 21 wt% Na_2O and Various SO_3 Concentrations Ranging from 0.0 to 1.3 wt% in the ORPLD1Glass.

Final SO_3 wt%	NaOH needed per kg of feed (grams)	Na_2SO_4 needed per kg of feed (grams)
0.0	21.41	-
0.7	13.77	6.20
0.8	12.79	7.08
0.9	11.81	7.96
1.0	10.82	8.85
1.1	9.84	9.73
1.2	8.85	10.62
1.3	7.87	11.50

Table 2.41. LAW Sub-Envelope B1 (AZ-101) Waste Simulant Recipe at 7.0 Molar Sodium.

Envelope Constituents	Simulant AZ-101 Including Pretreatment		Glass Oxides	LAW B1 Simulant as Oxides (wt%)	Waste Contribution to Glass	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
-	mg/L	M	Loading		19.57%	In 547 ml water add following compounds in the order listed below				
Al	8331	0.309	Al_2O_3	5.932	1.16	$Al(NO_3)_3.9H_2O$, 60% sol.	1	375.14	0.61	190.88
Cr	944	0.018	Cr_2O_3	0.520	0.102	$Na_2CrO_4.4H_2O$	6	234.04	0.99	4.31
Cs spike	1917	0.014	Cs_2O	0.766	0.150	$CsNO_3$	2	194.91	1.00	2.82
K	6139	0.157	K_2O	2.786	0.545	KOH	5	56.10	0.91	9.70
Na	160930	7.000	Na_2O	81.739	16.000	NaOH, 50% sol. d=1.53	4	40.00	0.50	334.82
Si	94	0.003	SiO_2	0.075	0.015	SiO_2	3	60.09	0.99	0.20
Cl	334	0.009	Cl	0.126	0.025	NaCl	7	58.45	0.99	0.56
F	2762	0.145	F	1.041	0.204	NaF	8	42.00	0.99	6.17
PO_4	2239	0.024	P_2O_5	0.631	0.123	$Na_3PO_4.12H_2O$	9	380.12	0.99	9.05
SO_4 (Nominal)	20327	0.212	SO_3	6.384	1.250	Na_2SO_4(varied content per run)	10	142.06	0.99	(See Table 2.50b)
NO_2	84374	1.834	NO_2	-	-	$NaNO_2$	13	69.00	1.00	127.20
NO_3	72354	1.167	NO_3	-	-	$NaNO_3$	14	84.99	0.99	19.42
Org.Carbon	702	0.0258	-	-	-	-	-	-	-	-
formate	689	0.015	-	-	-	Sodium Formate (C1)	11	68.01	0.99	1.05
Oxalate	1898	0.022	-	-	-	Sodium Oxalate (C2)	12	134.00	0.99	2.92
-	-	-	-	-	-	Target Glass Weight				1355.81
-	-	-	SUM	100	19.574	Total Simulant Weight				1286.35

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

Table 2.42. Target and Analyzed Compositions (wt%) of Twelve ORPLE Crucible Glasses.

GLASS	ORPLE1		ORPLE2		ORPLE3		ORPLE4		ORPLE5		ORPLE6	
Oxides	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*
Al_2O_3	7.60	8.06	10.01	10.23	10.01	10.19	7.64	7.78	7.60	7.85	7.60	7.86
B_2O_3	9.85	10.05	11.46	11.78	11.46	11.64	9.81	10.28	9.61	10.02	9.85	9.98
CaO	10.46	10.06	8.04	8.10	10.46	10.69	10.43	10.19	10.24	10.40	9.97	10.08
Cr_2O_3	0.10	0.12	0.10	0.14	0.10	0.14	0.11	0.15	0.13	0.17	0.50	0.624
Cs_2O (spike)	0.15	0.17	0.15	0.19	0.15	0.16	0.15	0.23	0.15	0.18	0.15	0.173
Fe_2O_3	0.24	0.26	0.24	0.27	0.24	0.29	0.23	0.29	0.23	0.29	0.24	0.293
K_2O	0.55	0.55	0.55	0.58	0.55	0.57	0.61	0.62	0.68	0.73	0.55	0.592
Li_2O	3.00	3.18	3.00	3.20	3.00	3.25	2.10	2.36	1.10	1.33	3.00	3.17
MgO	1.05	1.09	1.05	1.07	1.05	1.06	1.05	1.08	0.99	0.92	1.05	0.924
Na_2O	16.00	16.70	16.00	15.96	16.00	16.13	18.00	18.58	20.00	19.54	16.00	16.11
SiO_2	41.41	41.37	39.80	39.75	37.39	36.87	40.34	39.29	39.95	40.12	41.41	41.24
SnO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TiO_2	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.035
V_2O_5	1.25	1.25	1.25	1.31	1.25	1.36	1.21	1.30	1.18	1.26	1.25	1.33
ZnO	3.22	2.97	3.22	3.15	3.22	3.24	3.13	3.34	2.96	2.95	3.22	3.17
ZrO_2	3.54	3.08	3.54	3.32	3.54	3.38	3.53	3.75	3.51	3.33	3.62	3.28
Cl	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.019
F	0.20	NA	0.20	NA	0.20	NA	0.23	NA	0.25	NA	0.20	NA
P_2O_5	0.12	0.18	0.12	0.18	0.12	0.18	0.14	0.20	0.15	0.22	0.12	0.167
SO_3	1.25	1.13	1.25	1.09	1.25	1.11	1.25	1.08	1.25	1.15	1.25	1.13
SUM	100.0	100.5	100.0	100.6	100.0	100.5	100.0	100.8	100.0	100.8	100.0	100.4

* – Analyzed by X-ray fluorescence except for boron and lithium which were measured by DCP
NA – Not analyzed

Table 2.42. Target and Analyzed Compositions (wt%) of Twelve ORPLE Crucible Glasses (continued).

GLASS	ORPLE7		ORPLE8		ORPLE9		ORPLE10		ORPLE11		ORPLE12	
Oxides	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*	Target	Analyzed*
Al_2O_3	7.60	7.89	7.60	7.95	7.60	7.81	8.80	9.31	7.60	7.94	7.60	8.05
B_2O_3	9.85	9.65	9.45	9.47	9.05	9.00	10.46	10.26	9.85	9.75	9.85	9.80
CaO	10.46	10.50	10.05	10.18	9.65	9.80	9.25	9.49	10.46	10.45	10.05	10.21
Cr_2O_3	0.50	0.63	0.10	0.14	0.50	0.62	0.10	0.14	0.10	0.16	0.50	0.63
Cs_2O (spike)	0.15	0.18	0.15	0.17	0.15	0.18	0.15	0.16	0.15	0.16	0.15	0.16
Fe_2O_3	0.24	0.28	1.05	1.07	1.05	1.07	0.24	0.30	0.24	0.29	0.24	0.29
K_2O	0.55	0.59	0.55	0.60	0.55	0.58	0.55	0.62	0.55	0.58	0.55	0.61
Li_2O	2.60	2.71	3.00	3.16	3.00	3.10	3.00	3.08	2.50	2.61	2.50	2.57
MgO	1.05	0.94	1.05	0.89	1.05	0.97	1.05	0.88	1.05	0.95	1.05	0.86
Na_2O	16.00	16.20	16.00	16.23	16.00	16.14	16.00	15.28	16.00	16.52	16.00	15.74
SiO_2	41.41	41.14	41.41	41.16	41.41	41.17	40.81	40.79	41.41	41.00	41.41	41.41
SnO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0..00	0.01
TiO_2	0.00	0.03	0.00	0.03	0.00	0.03	0.00	0.04	0.00	0.03	0.00	0.03
V_2O_5	1.25	1.33	1.25	1.32	1.25	1.35	1.25	1.36	1.75	1.85	1.75	1.84
ZnO	3.22	3.18	3.22	3.20	3.22	3.20	3.22	3.24	3.22	3.14	3.22	3.20
ZrO_2	3.54	3.20	3.54	3.18	3.94	3.57	3.54	3.25	3.54	3.14	3.54	3.23
Cl	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03
F	0.20	NA	0.20	NA	0.20	NA	0.20	NA	0.20	NA	0.20	NA
P_2O_5	0.12	0.18	0.12	0.19	0.12	0.18	0.12	0.18	0.12	0.19	0.12	0.19
SO_3	1.25	1.13	1.25	1.13	1.25	1.13	1.25	1.33	1.25	1.11	1.25	1.05
SUM	100.0	100.0	100.0	100.3	100.0	100.1	100.0	100.0	100.0	100.1	100.0	100.1

* – Analyzed by X-ray fluorescence except for boron and lithium which was measured by DCP
NA – Not analyzed

Table 2.43. Descriptions of Twelve As-Melted and Heat Treated ORPLE Crucible Glasses.

Glass ID	As-melted glass	Glass remelted at 1200°C for 1 hour, heat treated for 20 hours at 850°C, and quenched.
ORPLE1	Clear glass	Clear glass. < 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE2	Clear glass	Clear glass. < 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE3	Clear glass	Clear glass. < 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE4	Clear glass	Clear glass. < 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE5	Clear glass	Clear glass. < 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE6	Clear glass	Clear glass. < 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE7	Clear glass	Clear glass. < 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE8	Clear glass	Clear glass. ~ 0.2 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE9	Clear glass	Clear glass. ~ 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE10	Clear glass	Clear glass. ~ 0.2 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE11	Clear glass	Clear glass. < 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.
ORPLE12	Clear glass	Clear glass. < 0.1 vol% sodalite (Na-Al silicate sulfate) at platinum crucible interface.

Table 2.44. Measured Sulfate Solubility Limits in Twelve ORPLE Crucible Glasses.

Sample ID	**SO_3 Content (wt%)** (Target Minimum = 0.8 to 1.4 wt%)		
	Batch Saturation		**Bubbling***
	As-Melted	**After Acid Wash**	
ORPLE1S4	1.68	1.66	1.66
ORPLE2S4	1.54	1.43	1.38
ORPLE3S4	1.61	1.24	1.51
ORPLE4S4	1.70	1.30	1.44
ORPLE5S4	1.29	1.18	-
ORPLE6S4	1.69	1.24	1.50
ORPLE7S4	1.51	1.23	1.52
ORPLE8S4	1.67	1.26	-
ORPLE9S4	1.70	1.19	1.44
ORPLE10S4	1.87	1.24	-
ORPLE11S4	1.49	1.29	-
ORPLE12S4	1.63	1.20	1.55

- Empty data field
* Starting glass for bubbling tests contained no SO_3.

Table 2.45. Results of 7-day PCT (at 90ºC) and VHT (at 200ºC for 24 Days) for Twelve ORPLE Crucible Glasses.

Glass ID	ORPLE1	ORPLE2	ORPLE3	ORPLE4	ORPLE5	ORPLE6	ORPLE7	ORPLE8	ORPLE9	ORPLE10	ORPLE11	ORPLE12
7-Day PCT, Stainless Steel Vessel; S/V=2000m^{-1} (ppm)												
B	16.67	25.44	21.03	16.97	21.83	13.68	13.13	7.06	9.48	14.70	9.57	15.42
Na	152.30	108.40	119.30	140.70	213.30	108.90	102.20	90.43	89.49	87.78	81.96	94.32
Si	59.71	49.62	43.90	52.62	65.85	48.96	46.69	37.63	36.34	10.03	35.61	45.91
Normalized Concentrations (g/L)												
B	0.54	0.71	0.59	0.56	0.73	0.45	0.43	0.24	0.34	0.45	0.31	0.50
Na	1.28	0.91	1.01	1.05	1.44	0.92	0.86	0.76	0.75	0.74	0.69	0.79
Si	0.31	0.27	0.25	0.28	0.35	0.25	0.24	0.19	0.19	0.05	0.18	0.24
pH	11.48	11.18	11.34	11.48	11.61	11.39	11.32	11.34	11.38	11.25	11.34	11.32
7-Day PCT Normalized Mass Loss (g/m^2)												
B	0.27	0.36	0.30	0.28	0.37	0.22	0.21	0.12	0.17	0.23	0.16	0.25
Na	0.64	0.46	0.50	0.53	0.72	0.46	0.43	0.38	0.38	0.37	0.35	0.40
Si	0.15	0.13	0.13	0.14	0.18	0.13	0.12	0.10	0.09	0.03	0.09	0.12
7-Day PCT Normalized Loss Rate (g/m^2/d)												
B	0.04	0.05	0.04	0.04	0.05	0.03	0.03	0.02	0.02	0.03	0.02	0.04
Na	0.09	0.07	0.07	0.08	0.10	0.07	0.06	0.05	0.05	0.05	0.05	0.06
Si	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.02
VHT Alteration (24 days at 200°C)												
Alteration Depth (µm)	180	264	171	376	950	221	368	315	248	293	285	277
Alteration Rate (g/m^2/day)*	19.9	29.2	18.9	41.5	104.9	24.4	40.6	34.8	27.4	32.4	31.5	30.6

* Alteration rates calculated using estimated density of 2.65 g/cc

Table 2.46. Viscosities and Electrical Conductivities of Twelve ORPLE Crucible Glasses.

Glass ID	ORPLE1	ORPLE2	ORPLE3	ORPLE4	ORPLE5	ORPLE6	ORPLE7	ORPLE8	ORPLE9	ORPLE10	ORPLE11	ORPLE12
Viscosity (poise)												
900°C	294	373	251	327	441	366	517	221	359	285	367	502
950°C	149	179	122	157	192	161	193	116	176	150	170	215
1000°C	82	95	67	84	98	81	88	66	94	84	90	106
1050°C	48	55	40	48	56	45	46	40	54	49	52	58
1100°C	30	34	25	30	35	27	27	26	33	31	33	34
1150°C	20	22	17	19	23	17	17	17	22	20	22	22
1200°C	13	15	12	13	16	12	12	12	15	13	15	14
1250°C	9	11	9	9	12	8	9	9	10	9	11	10
Electrical Conductivity (S/cm)												
900°C	0.131	0.148	0.147	0.150	0.159	0.150	0.159	0.144	0.138	0.151	0.135	0.187
950°C	0.175	0.195	0.193	0.196	0.206	0.197	0.214	0.194	0.189	0.206	0.178	0.241
1000°C	0.229	0.251	0.247	0.252	0.261	0.254	0.275	0.256	0.248	0.268	0.230	0.304
1050°C	0.294	0.316	0.310	0.318	0.326	0.320	0.341	0.330	0.313	0.337	0.291	0.376
1100°C	0.370	0.391	0.384	0.394	0.399	0.398	0.412	0.418	0.385	0.412	0.361	0.457
1150°C	0.458	0.477	0.467	0.481	0.482	0.486	0.485	0.520	0.463	0.492	0.442	0.547
1200°C	0.559	0.573	0.562	0.579	0.575	0.587	0.561	0.639	0.546	0.576	0.533	0.647
1250°C	0.674	0.680	0.667	0.689	0.678	0.699	0.637	0.773	0.633	0.663	0.636	0.755

Table 2.47. Results of K-3 Corrosion Testing for Ten ORPLE Crucible Glasses.

Glass ID	Neck loss (inches)	Depth of altered zone (inches)	Half-down loss (inches)
ORPLE1	0.059	0.028	0.003
ORPLE3	0.072	0.031	0.004
ORPLE4	0.087	0.026	0.006
ORPLE6	0.054	0.028	0.006
ORPLE7	0.033	0.028	0.001
ORPLE8	0.069	0.027	0.005
ORPLE9	0.048	0.027	0.004
ORPLE10	0.053	0.027	0.005
ORPLE11	0.060	0.026	0.008
ORPLE12	0.031	0.030	0.001

Table 2.48. Summary of Test Results for Selected ORPLE Glass Formulation ORPLE12 and Comparison to ILAW Requirements.

Test	**Requirement [45, 46]**	**Test Result for ORPLE12**
Density of glass	< 3.7 g/cc	Not measured
Crystalline Phase	Phase identification	Clear homogeneous glass with less than 0.1 vol% crystals after heat treatment at 850°C for 20 hours
Liquidus	< 950°C	< 950°C
Centerline Canister Cooling	Phase identification	Not measured
PCT B (g/m^2)	< 2.0 g/m^2	0.25 g/m^2
PCT Na (g/m^2)	< 2.0 g/m^2	0.40 g/m^2
PCT Si (g/m^2)	< 2.0 g/m^2	0.12 g/m^2
VHT at 200°C (g/m^2/day)	< 50 g/m^2/day	31 g/m^2/day
Viscosity (poise) at 1100°C	10 to 150 P	34 P
Conductivity (S/cm) at 1100°C	0.2 to 0.7 S/cm	0.457 S/cm
T_G (°C)	Report for modeling	Not measured

Table 2.49. Oxide Composition of AZ-101 Simulant and ORPLE12 Glass Composition Used in Melter Tests (wt%).

Component	AZ-101 waste contribution	Glass former additives	ORPLE12 (for AZ-101)
Loading	19.8%	80.2%	-
Al_2O_3	1.161	6.41	7.58
B_2O_3	-	9.82	9.82
CaO	-	10.02	10.02
Cr_2O_3	0.102	0.40	0.50
Cs_2O	0.150	-	0.15
Fe_2O_3	-	0.24	0.24
K_2O	0.545	-	0.55
Li_2O	-	2.49	2.49
MgO	-	1.04	1.04
Na_2O[(a)]	15.806 + 0.194[(1)]	-	16.00
SiO_2	0.015	41.26	41.27
TiO_2		0.01	0.01
V_2O_5	-	1.74	1.74
ZnO	-	3.21	3.21
ZrO_2	-	3.53	3.53
Cl	0.025	-	0.02
F	0.204	-	0.20
P_2O_5	0.123	-	0.12
SO_3[(b)]	1.500[(1)]	-	1.50
SUM	19.8	80.2	100.0

(a) Simulant was ordered at a concentration of 15.81 wt% Na_2O and modified before each melter test with (1) Na_2SO_4 and (2) NaOH additions to obtain 16.00 wt% Na_2O in the glass.
(b) Concentration of SO_3 was increased in steps during the melter tests from 1.25 wt% SO_3 in the glass up to 1.75 wt%.
– Empty data field

Table 2.50a. Glass Former Additives for 1 Liter of LAW AZ-101 Simulant (7 M Na) and Corresponding Melter Feed Properties.

Additives Source	Feed ORPLE12
Additives in Glass (wt%)	80.17
Kyanite (Al_2SiO_5) 325 Mesh (Kyanite Mining) (g)	147.81
H_3BO_3 (US Borax – Technical Granular) (g)	236.52
Wollanstonite NYAD 325 Mesh (NYCO Minerals) (g)	298.96
Cr_2O_3 oxide	5.55[(1)]
Fe_2O_3 (Prince Manufacturing) (g)	0.29
Li_2CO_3 (Chemetall Foote Co, Tech Grade)	84.35
Olivine (Mg_2SiO_4) 325 Mesh (#180 Unimin) (g)	24.58
SiO_2 (Sil-co-Sil 75 US Silica) (g)	305.82
V_2O_5 – Pulva Ground - Stratcor	25.09
ZnO (KADOX – 920 Zinc Corp. of America) (g)	43.48
Zircon $ZrSiO_4$ (Flour) Mesh 325 (AM. Mineral) (g)	72.14
Supplemental Na_2SO_4	Variable – Table 2.50b
Addition of Sucrose as Reductant (g)	62.48
Simulant Weight for 1 liter (g)	1286
Sum of Additives (g)	1307
Sum of Complete Batch (g)	2593
Target Final Volume (l)	1.53
Estimated Density (g/ml)	1.70
Target Glass Produced (g)	1356
Target Weight % Additives in Slurry	50
Target Glass Yield (g/kg of Feed)	523
Target Glass Yield (g/l of Feed)	889
Target Total Solids (g/l of Feed)	1185
Target Additives (g/l of Feed)	857

[(1)] Note that a Cr_2O_3 addition was cut down by 50% to account for K3-brick contribution.

Table 2.50b. NaOH and Na_2SO_4 Additions Required to Obtain 16 wt% Na_2O and Various SO_3 Concentrations Ranging from 1.25 to 1.75 wt% in the ORPLE12 Glass.

Final SO_3 wt%	NaOH needed per kg of feed (grams)	Na_2SO_4 needed per kg of feed (grams)
1.25	11.0	0
1.50	8.81	2.38
1.625	7.48	3.58
1.75	6.64	4.78

Table 2.51. Characteristics of Melter Feed Samples During DM10 ORP LAW Tests.

Tank Waste/ Sub-Envelope Identification	Test	Region	Date	Name	% Water	Density	Glass Yield		pH
						(g/ml)	(kg/kg)	(g/l)	
AZ-101/ Sub-Envelope B1	**1**	**E**	1/25/2007	Q10-F-134A	38.95	1.68	0.504	847	10.98
	Average (LAWB83) [23]				40.65	1.71	0.521	888	8.57
	(LAWB83) [18]				38.77	1.71	0.526	899	7.49
AN-105/ Sub-Envelope A1	**2**	**A**	6/6/2007	R10-F-95A	42.08	1.61	0.441	712	13.59
	Average (LAWA187) [6]				42.37	1.64	0.442	725	11.83
	Average (LAWA161) [2]				38.70	1.68	0.472	791	11.50
	High Temperature Test Average [3]				38.40	1.69	0.467	788	11.96
	DM1200 Average [48]				37.60	1.72	0.481	827	12.19
AN-107/ Sub-Envelope C1	**3**	**B**	6/15/2007	S10-F-9A	41.12	1.66	0.465	772	12.88
	Average (LAWC22) [22]				39.83	1.67	0.493	826	11.35
	DM1200 [49]				38.5	1.69	0.485	821	8.95
AN-104/ Sub-Envelope A3	**4**	**C**	7/3/2007	S10-F-73A	40.79	1.63	0.447	729	9.89
	Average (LAWA137) [24]				37.55	1.70	0.480	815	9.65
	Average (variation study) [17]				37.5	1.64	0.474	779	9.34
AN-102/ Sub-Envelope C2	**5**	**D**	7/10/2007	S10-F-136A	37.16	1.70	0.511	869	6.60
			7/18/2007	T10-F-23A	38.02	1.70	0.498	847	7.09
	Average (LAWC100) [5]				40.8	1.66	0.461	764	7.03
	Average (LAWC35) [24]				37.97	1.69	0.499	844	8.19
	Average (variation study) [21]				39.31	1.68	0.496	831	9.07

Table 2.52. Compositions of Vitrified Melter Feed Samples During DM10 ORP LAW Tests (wt%).

Region	E			A			B			C			D		
Test	1			2			3			4			5		
Name	Q10-F-134A			R10-F-95A			S10-F-9A			S10-F-73A			T10-F-23A		
Constituent	Target	XRF	%Dev.	Target	XRF	%Dev.	Target	XRF	%Dev.	Target	XRF	%Dev.	Target	XRF	%Dev.
Al_2O_3	7.57	7.10	-6.28	9.51	9.63	1.26	10.02	10.08	0.57	10.01	10.61	6.01	10.12	9.62	-4.90
B_2O_3	9.82	9.82*	NC	8.65	8.65*	NC	8.51	8.51*	NC	8.49	8.49*	NC	11.99	11.99*	NC
CaO	10.02	10.41	3.82	3.34	3.33	-0.29	1.90	2.01	5.76	1.90	1.91	0.21	7.99	7.89	-1.18
Cl	0.02	<0.01	NC	0.68	0.27	NC	0.11	0.05	NC	0.62	0.25	NC	0.33	0.02	NC
Cr_2O_3	0.50	0.38	NC	0.50	0.34	NC	0.53	0.06	NC	0.53	0.09	NC	0.50	0.35	NC
Cs_2O	0.15	0.17	NC	0.15	0.07	NC	0.14	0.08	NC	0.14	0.10	NC	0.13	0.08	NC
F	0.20	0.20*	NC	§	<0.01*	NC	0.47	0.47*	NC	0.01	0.01*	NC	0.17	0.17*	NC
Fe_2O_3	0.24	0.28	NC	0.93	1.00	NC	0.96	1.15	NC	0.97	1.03	NC	1.00	1.07	7.30
I	§	<0.01	NC	§	0.09	NC	§	0.03	NC	§	0.04	NC	§	<0.01	NC
K_2O	0.54	0.60	NC	0.54	0.53	NC	0.11	0.31	NC	0.54	0.53	NC	0.16	0.34	NC
Li_2O	2.49	2.49*	NC	§	<0.01*	NC	§	<0.01*	NC	§	<0.01*	NC	§	<0.01*	NC
MgO	1.04	0.63	-39.78	0.93	0.98	NC	0.93	1.06	NC	0.93	1.01	NC	1.00	0.92	-7.49
MnO	§	0.01	NC	§	0.01	NC	0.05	0.04	NC	§	<0.01	NC	§	0.01	NC
Na_2O	16.00	17.21	7.58	24.00	24.25	1.02	24.00	22.55	-6.07	23.57	22.39	-5.00	21.00	17.50	-16.68
NiO	§	0.00	NC	§	0.01	NC	0.04	0.05	NC	§	0.01	NC	0.04	0.04	NC
P_2O_5	0.12	0.17	NC	§	0.02	NC	0.22	0.29	NC	0.18	0.27	NC	0.28	0.34	NC
PbO	§	<0.01	NC	§	0.01	NC	§	<0.01	NC	§	<0.01	NC	0.01	0.01	NC
SiO_2	41.28	40.73	-1.32	39.52	39.44	-0.19	40.01	41.18	2.92	39.95	41.89	4.86	37.01	41.94	13.33
SnO_2	§	<0.01	NC	2.75	3.22	16.90	1.00	1.22	21.97	1.00	1.13	13.84	§	0.01	NC
SO_3	1.50	1.23	-18.04	0.10	0.14	NC	0.60	0.05	NC	0.80	0.02	NC	1.30	0.48	-63.43
TiO_2	0.01	0.15	NC	§	0.11	NC	§	0.25	NC	§	0.12	NC	§	0.20	NC
V_2O_5	1.74	2.12	21.79	§	<0.01	NC	2.00	2.22	10.97	1.99	2.18	9.30	1.00	1.08	8.15
ZnO	3.21	3.36	4.71	2.45	2.49	1.47	2.37	2.46	3.77	2.36	2.39	1.17	2.99	3.06	2.39
ZrO_2	3.53	2.94	-16.71	5.95	5.41	-9.07	6.03	5.90	-2.18	6.02	5.53	-8.10	2.99	2.88	-3.72
Sum	100.00	100.00	NC	100.00	100.00	NC	100.00	100.00	NC	100.00	100.00	NC	100.00	100.00	NC

* - Target values; § - Not a target constituent; NC – not calculated

Table 3.1. Summary of Region E Test Conditions and Results.

Tank Waste/Sub-Envelope Identification: AZ-101/Sub-Envelope B1						
Na_2O wt.%: Test Plan Target – 16.0, Melter Glass Target – 16.0						
Target Minimum SO_3 Concentration in Glass, wt%: 1.25						
Test Segment		1A	1B	1C	1D	1E
Time	Feed Start	1/23/07 17:45	1/24/07 9:30	1/25/07 0:30	1/25/07 16:00	1/26/07 06:30
	Feed End	1/24/07 7:30	1/24/07 23:00	1/25/07 14:27	1/26/07 5:00	1/26/07 19:20
	Net Slurry Feeding (hr)	13.9	13.5	13.9	13.0	12.8
Feed	wt% SO_3 as glass	1.25	1.50	1.50	1.75	1.625
	Feed Used (kg)	49.0	51.1	52.2	47.1	47.3
Average Production Rate ($kg/m^2/day$)*		2110	2249	2232	2153	2196
Average Bubbling Rate (lpm)		1.8	1.9	2.3	2.5	2.6
Average Temperatures (°C)	Glass, 2” from floor	1152	1153	1153	1151	1152
	Glass, 4” from floor	1122	1116	1126	1131	1127
	Electrode	1090	1085	1090	1100	1097
	Plenum, thermowell	494	508	519	564	555
	Plenum, exposed	464	490	486	548	542
Product	Secondary Phases on Melt Surface at Test End	Yes	Yes	No	Yes	Yes
	Measured wt% SO_3	1.06	1.40	1.38	1.59	1.65
	% Feed Sulfur in Glass Product	85	93	92	91	102
Average Concentrations monitored in stack exhaust by FTIR (ppmv)	NO	289	294	281	290	291
	NO_2	29.0	24.1	24.8	22.6	23.4
	CO	5.6	5.4	5.8	6.8	6.6
	NH_3	42.5	41.4	44.6	38.5	39.8

* – Glass production rates calculated from feed data

Table 3.2. Summary of Region A Test Conditions and Results.

Tank Waste/Sub-Envelope Identification: AN-105/Sub-Envelope A1						
Na_2O wt.%: Test Plan Target – 25.0, Melter Glass Target – 24.0						
Target Minimum SO_3 Concentration in Glass, wt%: 0						
Test Segment		2A	2B	2C	2D	2E
Time	Feed Start	6/6/07 7:28	6/6/07 23:00	6/7/07 13:15	6/8/07 6:18	6/11/07 20:40
	Feed End	6/6/07 21:45	6/7/07 12:00	6/8/07 4:40	6/8/07 22:00	6/12/07 9:11
	Net Slurry Feeding (hr)	14.3#	13.0	15.4	15.7@	12.5
Feed	wt% SO_3 as glass	0.1	0.2	0.3	0.4	0.5
	Feed Used (kg)	34.6	52.9	53.7	52.4	46.4
Average Production Rate ($kg/m^2/day$)*		1300	2186	1883	1793	1994
Average Bubbling Rate (lpm)		2.3	4.5	6.3	5.6	6.4
Average Temperatures (°C)	Glass, 2” from floor	1148	1150	1151	1148	1150
	Glass, 4” from floor	1107	1145	1150	1135	1147
	Electrode	1097	1080	1072	1055	1089
	Plenum, thermowell	581	363	580	514	509
	Plenum, exposed	531	349	499	466	475
Product	Secondary Phases on Melt Surface at Test End	No	No	No	No	No
	Measured wt% SO_3	0.10	0.19	0.29	0.37	0.50
	% Feed Sulfur in Glass Product	100	95	97	93	100
Average Concentrations monitored in stack exhaust by FTIR (ppmv)	NO	577	530	494	496	NM
	NO_2	87.1	96.2	72.5	75.2	NM
	CO	25.8	17.6	18.5	16.2	NM
	NH_3	11.2	26.5	26.4	30.9	NM

* – Glass production rates calculated from feed data
# – Net time reflects the total time interval including half hour down time.
@ – Net time reflects the total time interval including 112 minute down time.
NM – Not Measured.

Table 3.2. Summary of Region A Test Conditions and Results (continued).

Tank Waste/Sub-Envelope Identification: AN-105/Sub-Envelope A1		
Na_2O wt.%: Test Plan Target – 25.0, Melter Glass Target – 24.0		
Target Minimum SO_3 Concentration in Glass, wt%: 0		
Test Segment		2F
Time	Feed Start	6/14/07 10:25
	Feed End	6/15/07 4:07
	Net Slurry Feeding (hr)	17.7@
Feed	wt% SO_3 as glass	0.6
	Feed Used (kg)	50.8
Average Production Rate ($kg/m^2/day$)*		1542
Average Bubbling Rate (lpm)		6.5
Average Temperatures (°C)	Glass, 2” from floor	1150
	Glass, 4” from floor	1129
	Electrode	1043
	Plenum, thermowell	521
	Plenum, exposed	527
Product	Secondary Phases on Melt Surface at Test End	No
	Measured wt% SO_3	0.52
	% Feed Sulfur in Glass Product	87
Average Concentrations monitored in stack exhaust by FTIR (ppmv)	NO	371
	NO_2	68.6
	CO	13.0
	NH_3	2.8

* – Glass production rates calculated from feed data
@ – Net time reflects the total time interval including 168 minute down time.

Table 3.3. Summary of Region B Test Conditions and Results.

Tank Waste/Sub-Envelope Identification: AN-107/Sub-Envelope C1					
Na_2O wt.%: Test Plan Target – 25.0, Melter Glass Target – 24.0					
Target Minimum SO_3 Concentration in Glass, wt%: 0.35					
Test Segment		3A	3B	3C	3D
Time	Feed Start	6/15/07 7:00	6/28/07 17:10	6/29/07 15:30	7/2/07 7:50
	Feed End	6/15/07 20:30	6/29/07 10:12	6/30/07 4:31	7/2/07 20:00
	Net Slurry Feeding (hr)	13.5	17.0@	13.0	12.2
Feed	wt% SO_3 as glass	0.6	0.7	0.85	1.0
	Feed Used (kg)	48.9	53.2	51.4	52.6
Average Production Rate ($kg/m^2/day$)*		1946	1681	2124	2316
Average Bubbling Rate (lpm)		5.6	3.2	5.2	5.1
Average Temperatures (°C)	Glass, 2” from floor	1150	1148	1142	1130
	Glass, 4” from floor	1145	1143	1135	1125
	Electrode	1062	1086	1082	1074
	Plenum, thermowell	457	547	483	492
	Plenum, exposed	430	537	476	498
Product	Secondary Phases on Melt Surface at Test End	No	No	No	Yes
	Measured wt% SO_3	0.6	0.68	0.81	1.0
	% Feed Sulfur in Glass Product	100	97	95	100
Average Concentrations monitored in stack exhaust by FTIR (ppmv)	NO	388	458	543	581
	NO_2	77.7	63.9	88.9	97.3
	CO	11.5	11.0	13.8	15.0
	NH_3	35.2	58.9	61.5	65.9

* – Glass production rates calculated from feed data
@ – Net time reflects the total time interval including 112 minute down time.
NM – Not Measured.

Table 3.4. Summary of Region C Test Conditions and Results.

Tank Waste/Sub-Envelope Identification: AN-104/Sub-Envelope A3						
Na_2O wt.%: Test Plan Target – 25.0, Melter Glass Target – 23.6						
Target Minimum SO_3 Concentration in Glass, wt%: 0.65						
Test Segment		4A	4B	4C	4D	4E
Time	Feed Start	7/3/07 0:03	7/3/07 21:04	7/5/07 8:00	7/6/07 3:02	7/6/07 21:26
	Feed End	7/3/07 14:00	7/4/07 3:13	7/6/07 2:00	7/6/07 17:00	7/7/07 2:15
	Net Slurry Feeding (hr)	14.0	6.5	18.0@	14.0	4.9
Feed	wt% SO_3 as glass	0.8	0	0.7	0.9	0
	Feed Used (kg)	55.7	27.1	54.9	56.3	16.3
Average Production Rate ($kg/m^2/day$)*		2092	2192	1603	2114	1749
Average Bubbling Rate (lpm)		5.6	6.2	5.2	5.4	5.7
Average Temperatures (°C)	Glass, 2” from floor	1147	1152	1151	1148	1153
	Glass, 4” from floor	1143	1151	1148	1144	1143
	Electrode	1078	1063	1055	1074	1069
	Plenum, thermowell	467	332	511	501	481
	Plenum, exposed	480	397	448	469	416
Product	Secondary Phases on Melt Surface at Test End	Yes	No	No	Yes	No
	Measured wt% SO_3	0.88	0.39	0.61	0.97	0.40
	% Feed Sulfur in Glass Product	110	NC	87	108	NC
Average Concentrations monitored in stack exhaust by FTIR (ppmv)	NO	614	499	451	597	451
	NO_2	115	91.8	76.4	104	76.2
	CO	21.1	16.3	14.7	22.2	14.9
	NH_3	51.4	78.4	47.9	51.3	50.4

* – Glass production rates calculated from feed data
@ – Net time reflects the total time interval including 66 minute down time.
NC – Not Calculated.

Table 3.5. Summary of Region D Test Conditions and Results.

Tank Waste/Sub-Envelope Identification: AN-102/Sub-Envelope C2					
Na_2O wt.%: Test Plan Target – 25.0, Melter Glass Target – 21.0					
Target Minimum SO_3 Concentration in Glass, wt%: 1.0					
Test Segment		5A	5B	5C	5D
Time	Feed Start	7/9/07 19:17	7/10/07 12:10	7/17/07 7:30	7/17/07 20:50
	Feed End	7/10/07 11:05	7/11/07 1:30	7/17/07 19:50	7/18/07 9:30
	Net Slurry Feeding (hr)	15.8	13.3	12.3	12.7
Feed	wt% SO_3 as glass	0.7	0.9	1.1	1.3
	Feed Used (kg)	54.2	46.6	46.1	49.9
Average Production Rate ($kg/m^2/day$)*		2039	2082	2227	2335
Average Bubbling Rate (lpm)		5.0	5.7	3.7	4.3
Average Temperatures (°C)	Glass, 2” from floor	1144	1152	1152	1152
	Glass, 4” from floor	1146	1150	1147	1148
	Electrode	1067	1076	1095	1085
	Plenum, thermowell	559	553	574	552
	Plenum, exposed	543	517	567	545
Product	Secondary Phases on Melt Surface at Test End	No	No	No	Yes
	Measured wt% SO_3	0.69	0.77	0.89	1.25
	% Feed Sulfur in Glass Product	99	86	81	96
Average Concentrations monitored in stack exhaust by FTIR (ppmv)	NO	609	619	539	574
	NO_2	130	127	118	133
	CO	27.4	34.5	30.6	35.7
	NH_3	24.8	25.8	11.3	17.9

* – Glass production rates calculated from feed data
NM – Not Measured.

Table 4.1. Listing of DM10 Glasses Discharged, Masses, Target Sulfur Contents and Analysis Performed.

Test	Region	Target SO_3	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1A	**E**	1.25%	1/23/07	Q10-G-104B	-	-	-
				Q10-G-104C	XRF	5.60	5.60
				Q10-G-113A	-	-	-
				Q10-G-113B	XRF	5.58	11.18
			1/24/07	Q10-G-114A	-	-	-
				Q10-G-115A	XRF	5.26	16.44
				Q10-G-115B	-	-	-
				Q10-G-118A	XRF	4.50	20.94
				Q10-G-118B	-	-	-
				Q10-G-119A	XRF	4.28	25.22
1B		1.50%		Q10-G-120A	-	-	-
				Q10-G-120B	XRF	4.86	30.08
				Q10-G-120C	-	-	-
				Q10-G-120D	XRF	5.12	35.20
				Q10-G-122A	-	-	-
				Q10-G-122B	XRF	5.52	40.72
				Q10-G-122C	-	-	-
				Q10-G-122D	XRF	4.12	44.84
				Q10-G-122E	-	-	-
1C		1.50%	1/25/07	Q10-G-127A	XRF	4.00	48.84
				Q10-G-128A	-	-	-
				Q10-G-130A	XRF	6.84	55.68
				Q10-G-130B	-	-	-
				Q10-G-130C	XRF	5.36	61.04
				Q10-G-130D	-	-	-
				Q10-G-130E	XRF	4.88	65.92
				Q10-G-131A	-	-	-
				Q10-G-131B	XRF	4.70	70.62
				Q10-G-134A	XRF F VHT PCT DCP	2.86	73.48
1D		1.75%		Q10-G-136A	-	-	-
				Q10-G-136B	XRF	5.06	78.54
				Q10-G-136C	-	-	-
				Q10-G-136D	XRF	5.52	84.06
				Q10-G-137A	-	-	-
				Q10-G-137B	XRF	4.96	89.02
1E		1.625%	1/26/07	Q10-G-137C	-	-	-
				Q10-G-137D	XRF	5.28	94.30
				Q10-G-141A	-	-	-
				Q10-G-141B	XRF	3.96	98.26
				Q10-G-142A	-	-	-
				Q10-G-142B	XRF	4.80	103.06
				Q10-G-142C	-	-	-
				Q10-G-142D	XRF	4.90	107.96

"-" Empty data field

Table 4.1. Listing of DM10 Glasses Discharged, Masses, Target Sulfur Contents and Analysis Performed (continued).

Test	Region	Target SO_3	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1E	E	1.625%	1/26/07	Q10-G-142E	-	-	-
				Q10-G-142F	XRF	4.90	112.86
				Q10-G-147A	-	-	-
				Q10-G-147B	XRF	4.74	117.60
				Q10-G-147C	-	-	-
				Q10-G-148A	XRF	4.84	122.44
2A	A	0.10%	6/6/07	R10-G-89A	-	-	-
				R10-G-89B	XRF	3.24	125.68
				R10-G-89C	-	-	-
				R10-G-89D	XRF	2.82	128.5
				R10-G-90A	-	-	-
				R10-G-90B	XRF	3.74	132.24
				R10-G-90C	-	-	-
				R10-G-90D	-	-	-
				R10-G-90E	XRF	4.68	136.92
				R10-G-91A	-	-	-
				R10-G-91B	XRF	4.18	141.10
				R10-G-91C	-	-	-
				R10-G-91D	-	-	-
				R10-G-91E	XRF	5.08	146.18
				R10-G-95A	-	-	-
2B		0.20%	6/7/07	R10-G-96A	XRF	3.20	149.38
				R10-G-96B	-	-	-
				R10-G-98A	XRF	4.12	153.50
				R10-G-98B	-	-	-
				R10-G-99A	XRF	4.58	158.08
				R10-G-99B	-	-	-
				R10-G-99C	XRF	3.20	161.28
				R10-G-100A	-	-	-
				R10-G-100B	XRF	4.08	165.36
				R10-G-101A	-	-	-
				R10-G-101B	XRF	3.64	169.00
2C		0.30%		R10-G-104A	-	-	-
				R10-G-104B	XRF	4.74	173.74
				R10-G-105A	-	-	-
				R10-G-105B	XRF	3.32	177.06
				R10-G-105C	-	-	-
				R10-G-105D	XRF	3.02	180.08
				R10-G-105E	-	-	-
				R10-G-107A	XRF	3.58	183.66
				R10-G-107B	-	-	-
			6/8/07	R10-G-107C	XRF	3.02	186.68

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Table 4.1. Listing of DM10 Glasses Discharged, Masses, Target Sulfur Contents and Analysis Performed (continued).

Test	Region	Target SO_3	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
2C	**A**	0.30%	6/8/07	R10-G-111A	XRF	3.80	190.48
				R10-G-112A	XRF	3.26	193.74
2D		0.40%		R10-G-112B	-	-	-
				R10-G-112C	XRF	3.76	197.50
				R10-G-112D	-	-	-
				R10-G-114A	XRF	3.98	201.48
				R10-G-118A	-	-	-
				R10-G-119A	XRF	4.04	205.52
				R10-G-119B	-	-	-
				R10-G-119C	XRF	3.76	209.28
				R10-G-119D	-	-	-
				R10-G-119E	-	-	-
				R10-G-119F	XRF	4.60	213.88
2E		0.50%	6/11/07	R10-G-129A	-	-	-
				R10-G-129B	XRF	3.24	217.12
				R10-G-129C	XRF	3.32	220.44
			6/12/07	R10-G-134A	-	-	-
				R10-G-134B	XRF	3.02	223.46
				R10-G-134C	-	-	-
				R10-G-134D	XRF	3.56	227.02
				R10-G-134E	-	-	-
				R10-G-135A	XRF	3.62	230.64
				R10-G-135B	XRF	4.18	234.82
2F		0.60%	6/14/07	R10-G-148A	XRF	4.02	238.84
				R10-G-148B	XRF	3.56	242.40
				R10-G-149A	XRF	2.62	245.02
				R10-G-150A	-	-	-
				R10-G-153A	XRF	3.56	248.58
				R10-G-153B	-	-	-
			6/15/07	R10-G-153C	XRF	3.92	252.50
				R10-G-155A	XRF F VHT PCT DCP	2.88	255.38
				R10-G-155B	XRF	1.64	257.02
3A		0.60%	6/15/07	S10-G-14A	-	-	-
				S10-G-14B	XRF	2.42	259.44
				R10-G-14C	-	-	-
				S10-G-15A	XRF	5.94	265.38
				S10-G-15B	-	-	-
				S10-G-15C	XRF	5.62	271.00
				S10-G-16A	-	-	-
				S10-G-16B	XRF	4.26	275.26
				S10-G-22A	XRF	3.70	278.96
3B		0.70%	6/28/07	S10-G-30A	XRF	3.98	282.94
			6/29/07	S10-G-31A	XRF	4.60	287.54

"-" Empty data field

Table 4.1. Listing of DM10 Glasses Discharged, Masses, Target Sulfur Contents and Analysis Performed (continued).

Test	Region	Target SO_3	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
3B	**B**	0.70%	6/29/07	S10-G-32A	XRF	4.74	292.28
				S10-G-33A	-	-	-
				S10-G-33B	XRF	3.52	295.80
				S10-G-36A	-	-	-
				S10-G-36B	XRF	3.54	299.34
				S10-G-36C	XRF	1.86	301.20
3C		0.85%		S10-G-37A	-	-	-
				S10-G-37B	XRF	2.06	303.26
				S10-G-39A	-	-	-
				S10-G-39B	XRF	4.24	307.50
				S10-G-42A	-	-	-
				S10-G-42B	XRF	3.86	311.36
				S10-G-42C	-	-	-
			6/30/07	S10-G-42D	XRF	4.42	315.78
				S10-G-44A	-	-	-
				S10-G-44B	XRF	3.98	319.76
				S10-G-44C	-	-	-
				S10-G-44D	-	-	-
				S10-G-45A	XRF F VHT PCT DCP	5.70	325.46
3D		1.00%	7/2/07	S10-G-53A	-	-	-
				S10-G-53B	XRF	3.76	329.22
				S10-G-57A	-	-	-
				S10-G-57B	XRF	4.44	333.66
				S10-G-57C	-	-	-
				S10-G-57D	XRF	3.70	337.36
				S10-G-58A	-	-	-
				S10-G-58B	XRF	4.26	341.62
				S10-G-58C	-	-	-
				S10-G-59A	XRF	3.88	345.50
				S10-G-59B	XRF F	2.32	347.82
4A	**C**	0.80%	7/3/07	S10-G-70A	XRF	3.88	351.70
				S10-G-71A	-	-	-
				S10-G-72A	XRF	3.12	354.82
				S10-G-72B	-	-	-
				S10-G-73A	XRF	3.62	358.44
				S10-G-73B	-	-	-
				S10-G-73C	XRF	2.98	361.42
				S10-G-73D	-	-	-
				S10-G-73E	XRF	4.42	365.84
				S10-G-76A	-	-	-
				S10-G-76B	XRF	4.44	370.28
				S10-G-76C	XRF	1.74	372.02

"-" Empty data field

Table 4.1. Listing of DM10 Glasses Discharged, Masses, Target Sulfur Contents and Analysis Performed (continued).

Test	Region	Target SO_3	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
4B	**C**	0.00%	7/3/07	S10-G-81A	-	-	-
			7/4/07	S10-G-81B	-	-	-
				S10-G-82A	XRF	3.56	375.58
				S10-G-83A	XRF	2.90	378.48
4C		0.70%	7/5/07	S10-G-94A	XRF	4.06	382.54
				S10-G-94B	XRF	3.04	385.58
				S10-G-95A	-	-	-
				S10-G-95B	XRF	3.56	389.14
				S10-G-95C	-	-	-
				S10-G-96A	XRF	4.00	393.14
				S10-G-97A	XRF	3.00	396.14
				S10-G-97B	-	-	-
4D		0.90%	7/6/07	S10-G-101A	XRF	4.20	400.34
				S10-G-101B	XRF F VHT PCT DCP	3.22	403.56
				S10-G-102A	-	-	-
				S10-G-103A	XRF	3.92	407.48
				S10-G-103B	-	-	-
				S10-G-103C	XRF	3.34	410.82
				S10-G-106A	-	-	-
				S10-G-106B	XRF	3.04	413.86
				S10-G-106C	-	-	-
				S10-G-106D	XRF	3.34	417.20
				S10-G-106E	-	-	-
				S10-G-109A	XRF	4.20	421.40
				S10-G-109B	XRF	4.22	425.62
				S10-G-111A	XRF	1.28	426.90
4E		0.00%	7/7/07	S10-G-113A	-	-	-
				S10-G-113B	XRF	2.86	429.76
				S10-G-116A	-	-	-
				S10-G-117A	XRF	2.56	432.32
5A	**D**	0.70%	7/9/07	S10-G-132A	XRF	3.56	435.88
				S10-G-132B	XRF	3.28	439.16
				S10-G-133A	-	-	-
			7/10/07	S10-G-134A	XRF	4.32	443.48
				S10-G-135A	-	-	-
				S10-G-135B	XRF	3.48	446.96
				S10-G-136A	-	-	-
				S10-G-136B	XRF	5.16	452.12
				S10-G-136C	-	-	-
				S10-G-136D	XRF	3.76	455.88
				S10-G-139A	XRF	2.96	458.84
5B		0.90%		S10-G-141A	-	-	-
				S10-G-141B	XRF	5.02	463.86

"-" Empty data field

Table 4.1. Listing of DM10 Glasses Discharged, Masses, Target Sulfur Contents and Analysis Performed (continued).

Test	Region	Target SO_3	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
5B	**D**	0.90%	7/10/07	S10-G-141C	-	-	-
				S10-G-144A	XRF	3.80	467.66
				S10-G-144B	-	-	-
				S10-G-144C	XRF	3.04	470.70
				S10-G-144D	-	-	-
				S10-G-145A	XRF	3.22	473.92
				S10-G-145B	-	-	-
			7/11/07	S10-G-145C	XRF	4.52	478.44
				S10-G-145D	-	-	-
				S10-G-148A	XRF	2.50	480.94
5C		1.10%	7/17/07	T10-G-12A	-	-	-
				T10-G-13A	XRF	6.68	487.62
				T10-G-13B	-	-	-
				T10-G-13C	XRF	5.48	493.10
				T10-G-13D	-	-	-
				T10-G-13E	XRF	4.54	497.64
				T10-G-13F	-	-	-
				T10-G-16A	XRF F VHT PCT DCP	4.92	502.56
5D		1.30%		T10-G-16B	-	-	-
				T10-G-18A	XRF	4.84	507.40
			7/18/07	T10-G-18B	-	-	-
				T10-G-18C	XRF	5.16	512.56
				T10-G-18D	-	-	-
				T10-G-19A	XRF	3.92	516.48
				T10-G-19B	-	-	-
				T10-G-19C	XRF	4.68	521.16
				T10-G-23A	-	-	-
				T10-G-23B	XRF	4.24	525.40
				T10-G-23C	XRF	1.86	527.26

"-" Empty data field

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%).

Test	1A					1B					1C
Region	E										
Target SO_3	1.25					1.50					1.50
Glass (kg)	5.60	11.18	16.44	20.94	25.22	30.08	35.20	40.72	44.84	48.84	55.68
Constituent	Q10-G-104C	Q10-G-113B	Q10-G-115A	Q10-G-118A	Q10-G-119A	Q10-G-120B	Q10-G-120D	Q10-G-122B	Q10-G-122D	Q10-G-127A	Q10-G-130A
Al_2O_3	6.31	6.65	7.10	7.25	7.15	7.52	7.50	7.49	7.34	7.27	7.34
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	9.72	9.78	9.81	9.82	9.83	9.83	9.83	9.82	9.82	9.82	9.82
CaO	4.49	6.68	8.03	8.63	9.02	9.39	9.64	9.97	10.06	10.63	10.21
Cl	0.23	0.13	0.07	0.07	0.06	0.05	0.04	0.04	0.04	0.03	0.03
Cr_2O_3	0.88	0.86	0.83	0.81	0.80	0.80	0.76	0.76	0.76	0.80	0.64
Cs_2O	0.05	0.10	0.11	0.13	0.14	0.17	0.17	0.17	0.17	0.17	0.19
F*	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Fe_2O_3	4.99	3.32	2.10	1.64	1.34	0.94	0.77	0.64	0.55	0.51	0.54
I	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K_2O	3.71	2.64	1.81	1.52	1.33	1.06	0.90	0.83	0.79	0.77	0.68
La_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Li_2O*	1.07	1.68	2.02	2.19	2.30	2.37	2.42	2.45	2.47	2.48	2.48
MgO	1.24	1.06	1.04	1.01	0.92	0.92	0.98	0.96	0.98	0.83	0.91
MnO	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Na_2O	17.31	16.30	16.06	15.82	16.38	15.78	15.88	14.90	15.62	14.48	15.61
Nd_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NiO	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	2.38	1.54	1.00	0.77	0.64	0.47	0.35	0.28	0.27	0.22	0.20
PbO	0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO_2	39.23	40.01	40.73	40.78	40.69	41.07	41.00	41.50	40.82	41.15	40.99
SnO_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SO_3	0.63	0.83	0.92	1.01	1.06	1.17	1.26	1.33	1.33	1.40	1.33
SrO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO_2	1.05	0.73	0.50	0.41	0.35	0.27	0.23	0.21	0.20	0.20	0.18
V_2O_5	0.59	1.13	1.46	1.61	1.72	1.81	1.87	1.93	1.96	2.13	2.01
ZnO	3.15	3.30	3.22	3.23	3.19	3.18	3.14	3.22	3.28	3.50	3.30
ZrO_2	2.74	3.02	2.97	3.02	2.84	2.96	3.04	3.27	3.31	3.36	3.30
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model

§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	1C				1D					1E	
Region	E										
Target SO_3	1.50				1.75					1.625	
Glass (kg)	61.04	65.92	70.62	73.48	78.54	84.06	89.02	94.30	98.26	103.06	107.96
Constituent	Q10-G-130C	Q10-G-130E	Q10-G-131B	Q10-G-134A	Q10-G-136B	Q10-G-136D	Q10-G-137B	Q10-G-137D	Q10-G-141B	Q10-G-142B	Q10-G-142D
Al_2O_3	7.23	7.28	7.57	7.58	7.39	7.21	7.16	7.32	7.25	7.45	7.30
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	9.82	9.82	9.82	9.82	9.81	9.80	9.80	9.80	9.80	9.80	9.80
CaO	10.24	10.15	10.01	10.16	10.39	10.18	10.19	10.25	10.44	9.95	10.19
Cl	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.03
Cr_2O_3	0.57	0.52	0.49	0.48	0.48	0.45	0.45	0.44	0.44	0.42	0.44
Cs_2O	0.18	0.17	0.16	0.16	0.19	0.19	0.20	0.19	0.15	0.18	0.21
F*	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Fe_2O_3	0.45	0.41	0.42	0.43	0.38	0.37	0.37	0.36	0.37	0.39	0.38
I	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K_2O	0.67	0.64	0.64	0.63	0.63	0.60	0.60	0.60	0.62	0.62	0.63
La_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Li_2O*	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.49
MgO	0.94	1.01	0.98	0.95	0.92	1.03	0.98	0.96	0.77	0.78	0.98
MnO	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02
Na_2O	15.69	15.94	15.46	15.45	15.08	16.02	16.11	15.58	15.40	16.23	15.35
Nd_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NiO	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	0.22	0.19	0.21	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.18
PbO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO_2	41.10	41.08	41.82	41.59	41.59	41.09	40.90	41.36	41.47	41.46	41.58
SnO_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SO_3	1.40	1.37	1.39	1.38	1.45	1.52	1.58	1.59	1.63	1.48	1.56
SrO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO_2	0.17	0.17	0.17	0.17	0.17	0.16	0.17	0.17	0.16	0.16	0.16
V_2O_5	2.02	2.01	1.94	1.98	2.02	2.00	2.01	2.01	2.07	1.94	1.99
ZnO	3.27	3.24	3.12	3.18	3.29	3.22	3.24	3.21	3.35	3.15	3.24
ZrO_2	3.27	3.25	3.05	3.09	3.26	3.25	3.32	3.25	3.16	3.04	3.27
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	1E			2A						2B	
Region	E			A							
Target SO_3	1.625			0.10						0.20	
Glass (kg)	112.86	117.60	122.44	125.68	128.50	132.24	136.92	141.10	146.18	149.38	153.50
Constituent	Q10-G-142F	Q10-G-147B	Q10-G-148A	R10-G-89B	R10-G-89D	R10-G-90B	R10-G-90E	R10-G-91B	R10-G-91E	R10-G-96A	R10-G-98A
Al_2O_3	7.25	7.38	7.34	5.85	7.30	7.80	8.32	8.63	8.75	9.02	9.03
As_2O_5	<0.01	<0.01	<0.01	0.12	0.10	0.07	0.05	0.04	0.03	0.02	0.01
B_2O_3*	9.80	9.81	9.81	9.15	9.03	8.91	8.82	8.76	8.72	8.70	8.68
CaO	10.17	10.11	10.14	0.68	1.46	1.80	2.27	2.67	2.85	3.20	3.15
Cl	0.03	0.03	0.02	0.09	0.20	0.27	0.36	0.42	0.46	0.46	0.46
Cr_2O_3	0.44	0.42	0.45	0.24	0.24	0.27	0.31	0.35	0.40	0.45	0.49
Cs_2O	0.18	0.23	0.22	0.05	0.09	0.08	0.10	0.11	0.10	0.12	0.12
F*	0.20	0.20	0.20	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe_2O_3	0.36	0.39	0.39	10.95	8.55	7.03	5.22	4.29	3.28	2.64	2.40
I	<0.01	<0.01	<0.01	<0.01	0.03	0.03	0.06	0.07	0.06	0.08	0.09
K_2O	0.61	0.58	0.61	0.15	0.27	0.33	0.40	0.46	0.48	0.54	0.52
La_2O_3	<0.01	<0.01	<0.01	0.21	0.16	0.13	0.09	0.07	0.07	0.05	0.05
Li_2O*	2.49	2.49	2.49	1.81	1.36	0.94	0.59	0.39	0.23	0.17	0.11
MgO	0.99	1.00	0.94	1.13	1.11	1.08	0.94	0.98	0.96	0.93	0.94
MnO	0.01	0.01	0.02	3.31	2.38	1.92	1.37	1.06	0.76	0.53	0.48
Na_2O	15.49	15.85	15.79	11.17	15.53	17.50	19.44	19.87	21.59	21.08	21.85
Nd_2O_3	<0.01	<0.01	<0.01	0.14	0.10	0.08	0.06	0.04	0.03	0.03	0.02
NiO	0.02	0.02	0.02	0.17	0.12	0.09	0.07	0.06	0.06	0.05	0.05
P_2O_5	0.18	0.17	0.19	0.12	0.09	0.08	0.06	0.05	0.05	0.03	0.04
PbO	<0.01	<0.01	<0.01	0.11	0.09	0.08	0.05	0.04	0.03	0.03	0.03
Sb_2O_3	<0.01	<0.01	<0.01	0.25	0.21	0.15	0.10	0.08	0.05	0.04	0.03
SeO_2	<0.01	<0.01	<0.01	0.21	<0.01	0.01	0.01	0.00	0.01	0.00	0.01
SiO_2	41.52	40.99	41.07	50.38	45.62	44.77	43.56	42.47	41.67	40.59	40.24
SnO_2	<0.01	<0.01	<0.01	<0.01	1.07	1.34	1.81	2.20	2.29	2.97	3.08
SO_3	1.60	1.63	1.65	0.38	0.08	0.08	0.09	0.10	0.11	0.12	0.14
SrO	<0.01	<0.01	<0.01	0.74	0.58	0.45	0.32	0.25	0.16	0.12	0.10
TiO_2	0.16	0.16	0.16	0.22	0.19	0.18	0.15	0.15	0.13	0.13	0.12
V_2O_5	2.01	1.98	2.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ZnO	3.22	3.19	3.20	1.93	2.13	2.13	2.23	2.41	2.40	2.63	2.57
ZrO_2	3.28	3.37	3.28	0.41	1.90	2.39	3.14	4.00	4.28	5.26	5.21
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	2B				2C						
Region	A										
Target SO_3	0.20				0.30						
Glass (kg)	158.08	161.28	165.36	169.00	173.74	177.06	180.08	183.66	186.68	190.48	193.74
Constituent	R10-G-99A	R10-G-99C	R10-G-100B	R10-G-101B	R10-G-104B	R10-G-105B	R10-G-105D	R10-G-107A	R10-G-107C	R10-G-111A	R10-G-112A
Al_2O_3	9.14	9.47	9.40	9.55	9.51	9.53	9.49	9.36	9.54	9.62	9.51
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	8.66	8.66	8.65	8.65	8.64	8.64	8.64	8.63	8.63	8.63	8.63
CaO	3.42	3.28	3.30	3.28	3.42	3.29	3.37	3.40	3.49	3.39	3.48
Cl	0.49	0.49	0.50	0.47	0.44	0.43	0.43	0.43	0.42	0.40	0.45
Cr_2O_3	0.51	0.49	0.47	0.47	0.49	0.44	0.45	0.44	0.46	0.44	0.42
Cs_2O	0.12	0.13	0.11	0.12	0.12	0.09	0.10	0.11	0.10	0.10	0.10
F*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe_2O_3	2.02	1.75	1.46	1.33	1.36	1.17	1.20	1.17	1.19	1.11	1.08
I	0.09	0.09	0.08	0.11	0.10	0.09	0.09	0.08	0.08	0.09	0.08
K_2O	0.56	0.55	0.55	0.54	0.56	0.53	0.53	0.53	0.56	0.53	0.55
La_2O_3	0.01	0.03	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
Li_2O*	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01
MgO	0.95	1.00	1.01	0.83	0.75	0.96	0.85	0.97	0.98	0.96	0.82
MnO	0.33	0.27	0.19	0.15	0.16	0.11	0.10	0.09	0.09	0.08	0.07
Na_2O	21.63	21.52	22.67	23.58	22.89	24.21	23.18	23.41	22.42	23.38	23.61
Nd_2O_3	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NiO	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
P_2O_5	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.02	<0.01
PbO	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01
Sb_2O_3	0.02	0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
SiO_2	39.93	40.64	40.77	40.03	40.03	40.20	40.34	39.93	40.38	39.98	40.20
SnO_2	3.15	3.14	2.82	3.12	3.36	2.75	3.09	3.02	3.02	3.10	3.05
SO_3	0.16	0.16	0.17	0.19	0.21	0.24	0.25	0.26	0.26	0.26	0.29
SrO	0.07	0.05	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01
TiO_2	0.13	0.12	0.11	0.11	0.11	0.09	0.10	0.10	0.11	0.11	0.10
V_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ZnO	2.72	2.54	2.45	2.47	2.63	2.38	2.50	2.54	2.57	2.52	2.56
ZrO_2	5.69	5.42	5.10	4.84	5.08	4.72	5.18	5.44	5.64	5.22	4.96
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	2D					2E					
Region	A										
Target SO_3	0.40					0.50					
Glass (kg)	197.50	201.48	205.52	209.28	213.88	217.12	220.44	223.46	227.02	230.64	234.82
Constituent	R10-G-112C	R10-G-114A	R10-G-119A	R10-G-119C	R10-G-119F	R10-G-129B	R10-G-129C	R10-G-134B	R10-G-134D	R10-G-135A	R10-G-135B
Al_2O_3	9.60	9.63	9.33	9.40	9.28	9.47	9.37	9.50	9.38	9.49	9.47
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	8.63	8.63	8.62	8.62	8.62	8.62	8.61	8.61	8.61	8.61	8.61
CaO	3.42	3.29	3.39	3.37	3.44	3.38	3.34	3.34	3.39	3.43	3.39
Cl	0.39	0.61	0.46	0.45	0.43	0.19	0.28	0.31	0.37	0.40	0.38
Cr_2O_3	0.44	0.45	0.48	0.46	0.47	0.57	0.53	0.52	0.51	0.49	0.51
Cs_2O	0.11	0.11	0.11	0.12	0.12	0.06	0.08	0.09	0.09	0.11	0.09
F*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe_2O_3	1.09	1.02	1.09	1.06	1.06	1.38	1.30	1.23	1.18	1.13	1.09
I	0.11	0.09	0.10	0.09	0.09	0.09	0.08	0.08	0.09	0.09	0.07
K_2O	0.56	0.58	0.54	0.54	0.54	0.53	0.53	0.54	0.55	0.56	0.55
La_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.02
Li_2O*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	0.84	1.12	1.02	1.03	1.09	0.89	0.93	0.94	1.05	0.99	0.91
MnO	0.07	0.06	0.05	0.05	0.04	0.17	0.13	0.12	0.09	0.08	0.06
Na_2O	23.82	24.10	23.62	23.31	22.91	23.15	22.90	22.50	23.18	22.18	22.82
Nd_2O_3	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	0.01	<0.01	0.01	0.01
NiO	0.03	0.03	0.03	0.03	0.03	0.06	0.05	0.04	0.04	0.03	0.03
P_2O_5	0.03	<0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
PbO	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01
SeO_2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01
SiO_2	39.60	39.71	39.72	40.01	39.95	40.34	40.42	40.86	40.28	40.98	40.78
SnO_2	3.35	2.88	3.08	3.09	3.24	2.99	3.06	3.02	2.86	2.96	2.90
SO_3	0.29	0.33	0.35	0.35	0.37	0.36	0.41	0.44	0.48	0.47	0.50
SrO	0.01	0.01	<0.01	0.01	<0.01	0.03	0.02	0.02	0.01	0.01	0.01
TiO_2	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11
V_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01
ZnO	2.54	2.38	2.49	2.48	2.58	2.50	2.50	2.45	2.50	2.48	2.48
ZrO_2	4.98	4.87	5.38	5.37	5.57	5.06	5.26	5.24	5.21	5.37	5.17
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	2F							3A			
Region	A							B			
Target SO_3	0.60							0.60			
Glass (kg)	238.84	242.40	245.02	248.58	252.50	255.38	257.02	259.44	265.38	271.00	275.26
Constituent	R10-G-148A	R10-G-148B	R10-G-149A	R10-G-153A	R10-G-153C	R10-G-155A	R10-G-155B	S10-G-14B	S10-G-15A	S10-G-15C	S10-G-16B
Al_2O_3	9.38	9.40	9.45	9.51	9.24	9.35	9.47	9.73	9.84	9.78	9.60
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	8.61	8.60	8.60	8.60	8.60	8.60	8.60	8.58	8.55	8.53	8.52
CaO	3.45	3.44	3.48	3.40	3.51	3.49	3.61	2.92	2.61	2.48	2.17
Cl	0.26	0.28	0.40	0.43	0.39	0.39	0.42	0.23	0.19	0.17	0.16
Cr_2O_3	0.49	0.48	0.40	0.39	0.37	0.33	0.37	0.39	0.40	0.41	0.41
Cs_2O	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.13	0.12
F*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	0.27	0.35	0.39
Fe_2O_3	1.16	1.16	1.19	1.07	1.14	1.05	1.15	1.02	1.05	1.08	1.02
I	0.08	0.08	0.10	0.09	0.09	0.08	0.09	0.06	0.05	0.05	0.04
K_2O	0.55	0.54	0.56	0.55	0.55	0.56	0.58	0.49	0.43	0.42	0.35
La_2O_3	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Li_2O*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	0.87	0.97	1.05	1.10	1.11	0.99	0.86	1.05	1.13	1.07	1.19
MnO	0.09	0.08	0.06	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Na_2O	23.13	23.26	23.10	23.46	23.58	23.76	23.27	24.60	24.13	23.56	24.69
Nd_2O_3	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	0.01
NiO	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.04	0.05	0.05	0.05
P_2O_5	0.03	0.01	0.03	0.03	0.02	0.01	0.02	0.09	0.16	0.19	0.22
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01
SiO_2	40.05	39.93	39.53	39.63	39.15	39.49	39.19	39.42	39.74	39.65	39.58
SnO_2	3.22	3.17	3.25	3.05	3.19	3.09	3.37	2.58	1.94	1.89	1.49
SO_3	0.46	0.47	0.50	0.56	0.50	0.51	0.52	0.53	0.54	0.56	0.54
SrO	0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO_2	0.10	0.10	0.09	0.10	0.11	0.11	0.10	0.13	0.17	0.20	0.21
V_2O_5	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.55	1.09	1.41	1.66
ZnO	2.56	2.57	2.53	2.50	2.60	2.59	2.76	2.43	2.39	2.46	2.32
ZrO_2	5.33	5.27	5.52	5.31	5.65	5.39	5.42	4.88	5.11	5.51	5.22
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	3A	3B						3C			
Region	B										
Target SO_3	0.60	0.70						0.85			
Glass (kg)	278.96	282.94	287.54	292.28	295.80	299.34	301.20	303.26	307.50	311.36	315.78
Constituent	S10-G-22A	S10-G-30A	S10-G-31A	S10-G-32A	S10-G-33B	S10-G-36B	S10-G-36C	S10-G-37B	S10-G-39B	S10-G-42B	S10-G-42D
Al_2O_3	9.69	9.93	9.83	9.94	9.98	10.02	9.87	9.92	9.85	9.92	9.69
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	8.52	8.51	8.51	8.50	8.50	8.50	8.50	8.50	8.49	8.49	8.49
CaO	2.20	2.45	2.44	2.25	2.07	2.04	2.04	1.94	2.03	1.99	2.03
Cl	0.18	0.05	0.03	0.09	0.11	0.13	0.13	0.11	0.12	0.12	0.13
Cr_2O_3	0.43	0.77	0.78	0.66	0.56	0.55	0.53	0.53	0.58	0.52	0.57
Cs_2O	0.15	0.07	0.06	0.10	0.12	0.13	0.12	0.13	0.13	0.13	0.14
F*	0.42	0.43	0.45	0.46	0.46	0.46	0.46	0.47	0.47	0.47	0.47
Fe_2O_3	1.05	1.40	1.39	1.27	1.13	1.16	1.13	1.04	1.14	1.10	1.15
I	0.04	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.03
K_2O	0.37	0.42	0.41	0.38	0.36	0.36	0.36	0.34	0.35	0.35	0.34
La_2O_3	<0.01	<0.01	0.02	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Li_2O*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	0.83	0.89	0.87	0.83	0.94	0.90	1.00	1.08	0.90	1.04	0.99
MnO	0.03	0.13	0.14	0.09	0.06	0.06	0.05	0.04	0.04	0.04	0.04
Na_2O	23.74	22.98	23.32	23.30	23.29	23.41	23.77	24.33	23.06	23.70	22.97
Nd_2O_3	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01
NiO	0.05	0.14	0.15	0.11	0.08	0.09	0.08	0.09	0.10	0.09	0.09
P_2O_5	0.25	0.23	0.22	0.24	0.27	0.29	0.29	0.29	0.28	0.29	0.29
PbO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01
SiO_2	40.33	39.93	39.72	39.90	40.23	39.85	40.22	40.27	40.10	39.97	39.56
SnO_2	1.49	1.58	1.66	1.45	1.28	1.29	1.16	1.11	1.19	1.07	1.18
SO_3	0.60	0.55	0.55	0.60	0.63	0.65	0.68	0.68	0.80	0.75	0.89
SrO	<0.01	0.01	0.02	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO_2	0.20	0.20	0.21	0.22	0.22	0.23	0.22	0.21	0.24	0.23	0.24
V_2O_5	1.83	1.59	1.53	1.81	1.92	1.98	2.02	1.92	2.12	2.10	2.21
ZnO	2.38	2.51	2.48	2.43	2.37	2.41	2.35	2.21	2.44	2.37	2.54
ZrO_2	5.20	5.16	5.18	5.29	5.33	5.44	4.98	4.78	5.51	5.22	5.96
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model

§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	3C		3D						4A		
Region	B								C		
Target SO_3	0.85		1.00						0.80		
Glass (kg)	319.76	325.46	329.22	333.66	337.36	341.62	345.50	347.82	351.7	354.82	358.44
Constituent	S10-G-44B	S10-G-45A	S10-G-53B	S10-G-57B	S10-G-57D	S10-G-58B	S10-G-59A	S10-G-59B	S10-G-70A	S10-G-72A	S10-G-73A
Al_2O_3	9.82	9.59	9.84	9.71	9.78	9.72	9.87	9.71	9.90	9.74	9.95
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	8.48	8.48	8.48	8.47	8.47	8.47	8.47	8.47	8.47	8.48	8.48
CaO	1.97	2.03	1.98	2.01	1.95	1.91	1.91	1.92	1.99	2.00	1.97
Cl	0.14	0.14	0.09	0.11	0.13	0.13	0.14	0.15	0.18	0.34	0.35
Cr_2O_3	0.49	0.50	0.58	0.53	0.59	0.52	0.44	0.45	0.47	0.65	0.59
Cs_2O	0.14	0.16	0.14	0.15	0.15	0.16	0.16	0.16	0.17	0.18	0.14
F*	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.32	0.24	0.17
Fe_2O_3	1.08	1.13	1.12	1.13	1.08	1.06	1.11	1.05	1.11	1.14	1.12
I	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04
K_2O	0.34	0.34	0.35	0.35	0.34	0.33	0.33	0.32	0.39	0.46	0.48
La_2O_3	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.02	<0.01
Li_2O*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	0.98	0.99	0.97	0.93	0.92	1.03	0.92	0.95	0.84	0.84	0.95
MnO	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02
Na_2O	23.19	24.12	23.77	23.68	23.45	24.07	23.50	24.17	22.61	22.88	22.32
Nd_2O_3	<0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	0.01	0.01	0.01
NiO	0.08	0.09	0.14	0.11	0.09	0.08	0.07	0.07	0.07	0.06	0.05
P_2O_5	0.30	0.30	0.30	0.28	0.30	0.29	0.29	0.29	0.29	0.28	0.27
PbO	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01	0.01
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	0.01	0.01	0.01	<0.01	0.01	0.01	<0.01	0.01	0.01	<0.01	0.01
SiO_2	40.18	38.90	39.72	39.59	39.75	39.32	40.39	39.57	40.24	38.99	40.06
SnO_2	1.13	1.21	1.22	1.21	1.15	1.21	1.15	1.15	1.28	1.36	1.21
SO_3	0.84	0.81	0.77	0.86	1.15	1.04	0.89	1.00	0.90	1.14	1.01
SrO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO_2	0.24	0.24	0.23	0.23	0.24	0.22	0.23	0.23	0.23	0.20	0.17
V_2O_5	2.11	2.30	2.19	2.21	2.16	2.13	2.10	2.17	2.27	2.30	2.29
ZnO	2.36	2.55	2.41	2.44	2.38	2.34	2.30	2.38	2.49	2.57	2.51
ZrO_2	5.58	5.58	5.15	5.44	5.36	5.40	5.18	5.27	5.66	6.07	5.80
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	4A				4B		4C				
Region	C										
Target SO_3	0.80				0.00		0.70				
Glass (kg)	361.42	365.84	370.28	372.02	375.58	378.48	382.54	385.58	389.14	393.14	396.14
Constituent	S10-G-73C	S10-G-73E	S10-G-76B	S10-G-76C	S10-G-82A	S10-G-83A	S10-G-94A	S10-G-94B	S10-G-95B	S10-G-96A	S10-G-97A
Al_2O_3	10.13	10.12	10.23	10.20	10.45	10.61	10.76	10.42	10.39	10.28	10.46
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	8.48	8.48	8.49	8.49	8.53	8.56	8.54	8.53	8.52	8.51	8.51
CaO	1.89	1.87	1.85	1.91	1.95	1.93	1.86	1.90	1.95	1.95	1.96
Cl	0.37	0.47	0.43	0.43	0.30	0.33	0.32	0.37	0.40	0.42	0.44
Cr_2O_3	0.55	0.81	0.55	0.51	0.41	0.41	0.41	0.45	0.51	0.55	0.53
Cs_2O	0.13	0.15	0.13	0.13	0.11	0.12	0.10	0.12	0.12	0.13	0.12
F*	0.13	0.08	0.06	0.05	0.04	0.03	0.02	0.02	0.02	0.01	0.01
Fe_2O_3	1.05	1.05	1.03	1.06	1.09	1.09	1.04	1.05	1.10	1.12	1.14
I	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03
K_2O	0.48	0.54	0.52	0.53	0.55	0.57	0.55	0.56	0.58	0.58	0.57
La_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Li_2O*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	0.99	0.96	0.98	0.91	0.81	0.82	0.86	0.83	0.90	0.88	0.91
MnO	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01
Na_2O	23.33	22.61	23.34	23.08	22.83	22.48	23.25	23.14	22.54	22.23	22.49
Nd_2O_3	0.01	0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
NiO	0.04	0.04	0.03	0.03	0.04	0.05	0.05	0.05	0.05	0.04	0.04
P_2O_5	0.28	0.28	0.26	0.26	0.26	0.27	0.26	0.28	0.26	0.26	0.27
PbO	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	<0.01	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	<0.01
SiO_2	40.36	39.63	40.20	40.39	41.08	41.16	41.17	41.03	40.94	40.59	40.50
SnO_2	1.04	1.13	1.11	1.12	1.08	1.12	1.01	1.09	1.07	1.14	1.05
SO_3	0.94	1.57	0.99	0.88	0.45	0.39	0.42	0.48	0.59	0.67	0.60
SrO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO_2	0.16	0.15	0.14	0.14	0.14	0.13	0.13	0.12	0.13	0.13	0.14
V_2O_5	2.13	2.18	2.13	2.18	2.19	2.19	2.12	2.17	2.25	2.26	2.26
ZnO	2.33	2.35	2.31	2.39	2.42	2.47	2.32	2.35	2.46	2.54	2.53
ZrO_2	5.13	5.45	5.18	5.24	5.22	5.23	4.73	4.98	5.18	5.64	5.39
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	4C		4D							4E	
Region	C										
Target SO_3	0.70		0.90							0.00	
Glass (kg)	400.34	403.56	407.48	410.82	413.86	417.2	421.4	425.62	426.9	429.76	432.32
Constituent	S10-G-101A	S10-G-101B	S10-G-103A	S10-G-103C	S10-G-106B	S10-G-106D	S10-G-109A	S10-G-109B	S10-G-111A	S10-G-113B	S10-G-117A
Al_2O_3	10.55	10.50	10.47	10.10	10.60	10.45	10.02	10.22	10.45	10.47	10.68
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	8.51	8.50	8.50	8.49	8.49	8.48	8.48	8.48	8.48	8.52	8.55
CaO	1.90	1.96	1.99	2.05	1.93	1.86	1.91	1.87	1.91	1.91	1.97
Cl	0.43	0.41	0.42	0.49	0.47	0.45	0.62	0.49	0.41	0.29	0.38
Cr_2O_3	0.51	0.53	0.54	0.91	0.54	0.52	1.16	0.68	0.60	0.43	0.37
Cs_2O	0.12	0.11	0.12	0.15	0.11	0.13	0.15	0.15	0.14	0.13	0.11
F*	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fe_2O_3	1.07	1.10	1.14	1.23	1.09	1.03	1.08	1.03	1.08	1.11	1.11
I	0.03	0.03	0.04	0.04	0.03	0.04	0.03	0.03	0.04	0.04	0.03
K_2O	0.56	0.59	0.59	0.63	0.58	0.56	0.64	0.57	0.57	0.56	0.58
La_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Li_2O*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	0.85	0.84	0.86	0.88	0.94	0.86	0.90	0.92	0.93	0.95	1.00
MnO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Na_2O	22.74	22.45	21.60	21.78	22.00	22.99	21.89	22.81	22.02	22.17	21.29
Nd_2O_3	0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01
NiO	0.03	0.04	0.03	0.04	0.02	0.02	0.03	0.02	0.02	0.03	0.03
P_2O_5	0.26	0.25	0.26	0.26	0.27	0.25	0.28	0.25	0.26	0.26	0.27
PbO	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01
SiO_2	40.78	40.88	40.88	38.98	40.92	40.35	39.24	39.81	40.43	40.87	41.69
SnO_2	1.05	1.04	1.13	1.18	1.01	1.10	1.07	1.11	1.16	1.17	1.04
SO_3	0.64	0.61	0.70	1.06	0.84	0.88	1.99	1.31	0.97	0.57	0.40
SrO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO_2	0.12	0.14	0.13	0.14	0.13	0.12	0.13	0.12	0.14	0.13	0.13
V_2O_5	2.18	2.28	2.29	2.50	2.24	2.15	2.36	2.18	2.20	2.19	2.27
ZnO	2.42	2.56	2.61	2.80	2.47	2.36	2.48	2.37	2.44	2.45	2.50
ZrO_2	5.21	5.17	5.68	6.26	5.29	5.36	5.53	5.52	5.70	5.72	5.59
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model

§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	5A							5B			
Region	D										
Target SO_3	0.70							0.90			
Glass (kg)	435.88	439.16	443.48	446.96	452.12	455.88	458.84	463.86	467.66	470.7	473.92
Constituent	S10-G-132A	S10-G-132B	S10-G-134A	S10-G-135B	S10-G-136B	S10-G-136D	S10-G-139A	S10-G-141B	S10-G-144A	S10-G-144C	S10-G-145A
Al_2O_3	10.72	10.40	10.31	10.29	10.37	10.12	10.19	10.18	9.94	10.06	9.56
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	9.61	10.30	10.93	11.27	11.60	11.75	11.84	11.92	11.96	11.99	12.01
CaO	2.81	3.72	4.59	5.88	6.45	7.08	7.41	7.51	7.32	7.33	7.56
Cl	0.24	0.26	0.26	0.28	0.27	0.27	0.27	0.25	0.25	0.25	0.26
Cr_2O_3	0.46	0.46	0.49	0.54	0.55	0.59	0.61	0.56	0.50	0.51	0.52
Cs_2O	0.11	0.11	0.11	0.12	0.14	0.13	0.15	0.13	0.13	0.13	0.13
F*	0.06	0.09	0.12	0.13	0.15	0.16	0.16	0.16	0.17	0.17	0.17
Fe_2O_3	1.12	1.12	1.06	1.12	1.14	1.17	1.17	1.10	1.06	1.04	1.09
I	0.02	0.02	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K_2O	0.52	0.50	0.44	0.43	0.42	0.39	0.40	0.38	0.34	0.35	0.36
La_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Li_2O*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.02	1.02	1.08	1.05	1.03	0.98	0.90	0.90	0.98	0.97	0.92
MnO	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Na_2O	21.43	20.69	21.33	20.00	19.27	19.24	19.57	18.80	19.35	18.46	18.61
Nd_2O_3	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NiO	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.06
P_2O_5	0.27	0.30	0.31	0.33	0.35	0.36	0.35	0.39	0.39	0.36	0.35
PbO	<0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO_2	40.49	40.29	39.33	39.14	38.75	38.26	37.85	39.15	39.62	40.38	40.13
SnO_2	0.98	0.81	0.58	0.41	0.35	0.24	0.18	0.13	0.08	0.07	0.05
SO_3	0.47	0.50	0.55	0.62	0.65	0.68	0.69	0.73	0.76	0.77	0.78
SrO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO_2	0.14	0.15	0.16	0.18	0.20	0.19	0.20	0.19	0.19	0.19	0.19
V_2O_5	1.94	1.87	1.62	1.51	1.42	1.39	1.31	1.21	1.12	1.12	1.12
ZnO	2.47	2.63	2.60	2.86	3.02	3.20	3.19	3.04	2.89	2.86	3.05
ZrO_2	4.99	4.68	4.03	3.74	3.78	3.70	3.47	3.16	2.89	2.89	3.03
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent

Table 4.2. XRF Analyzed Compositions for DM10 Discharged Glass Samples (wt%) (continued).

Test	5B		5C				5D					
Region	D											
Target SO_3	0.90		1.10				1.30					
Glass (kg)	478.44	480.94	487.62	493.1	497.64	502.56	507.4	512.56	516.48	521.16	525.4	527.26
Constituent	S10-G-145C	S10-G-148A	T10-G-13A	T10-G-13C	T10-G-13E	T10-G-16A	T10-G-18A	T10-G-18C	T10-G-19A	T10-G-19C	T10-G-23B	T10-G-23C
Al_2O_3	9.65	9.71	9.79	9.58	9.43	9.32	9.45	9.69	9.47	9.53	9.54	9.23
As_2O_5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B_2O_3*	12.02	12.03	12.03	12.03	12.03	12.02	12.01	12.00	12.00	12.00	12.00	12.00
CaO	7.41	7.45	7.26	7.30	7.54	7.69	7.61	7.27	7.43	7.26	7.29	7.26
Cl	0.26	0.25	0.13	0.19	0.22	0.23	0.23	0.23	0.23	0.24	0.28	0.31
Cr_2O_3	0.50	0.46	0.48	0.45	0.44	0.42	0.41	0.39	0.41	0.38	0.40	0.46
Cs_2O	0.14	0.15	0.11	0.11	0.12	0.13	0.11	0.11	0.14	0.11	0.14	0.12
F*	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Fe_2O_3	1.05	1.04	1.12	1.08	1.15	1.12	1.08	1.08	1.07	0.99	1.07	1.05
I	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K_2O	0.34	0.34	0.36	0.34	0.34	0.34	0.35	0.34	0.33	0.32	0.32	0.32
La_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Li_2O*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	0.94	0.94	0.89	0.87	0.98	0.93	0.98	1.00	0.97	1.04	1.05	1.02
MnO	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Na_2O	18.67	18.63	18.05	18.24	18.04	18.11	17.65	18.42	17.96	18.42	18.21	18.99
Nd_2O_3	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NiO	0.06	0.05	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.05
P_2O_5	0.36	0.34	0.34	0.35	0.33	0.34	0.35	0.34	0.35	0.35	0.35	0.35
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01
Sb_2O_3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO_2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO_2	40.49	40.59	41.10	41.27	40.70	40.67	41.42	41.19	41.31	41.50	41.26	40.29
SnO_2	0.04	0.03	0.11	0.08	0.05	0.05	0.03	0.02	0.02	0.02	0.02	0.01
SO_3	0.79	0.77	0.78	0.86	0.87	0.89	0.96	0.98	1.06	1.09	1.25	1.83
SrO	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO_2	0.19	0.19	0.19	0.19	0.20	0.20	0.19	0.19	0.19	0.19	0.18	0.18
V_2O_5	1.09	1.06	1.14	1.09	1.13	1.12	1.09	1.03	1.07	1.02	0.99	1.01
ZnO	2.93	2.91	2.91	2.86	3.05	3.09	2.99	2.83	2.92	2.72	2.76	2.79
ZrO_2	2.87	2.86	2.92	2.84	3.08	3.07	2.83	2.63	2.82	2.57	2.67	2.53
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent

Table 4.3. Compositions of Discharged Glass Samples During DM10 ORP LAW Tests with Maximum Sulfur Concentrations without Secondary Phases (wt%).

Test Segment	1C			2F			3C		
Region	E			A			B		
Target SO_3	1.50			0.60			0.85		
Name	Q10-G-134A			R10-G-155A			S10-G-45A		
Constituent	Target	XRF	%Dev.	Target	XRF	%Dev.	Target	XRF	%Dev.
Al_2O_3	7.57	7.58	-0.04	9.45	9.35	-1.02	9.98	9.59	-4.00
As_2O_5	§	<0.01	NC	§	<0.01	NC	§	<0.01	NC
B_2O_3	9.82	9.82*	NC	8.60	8.60*	NC	8.48	8.48*	NC
CaO	10.02	10.16	1.08	3.32	3.49	5.23	1.89	2.03	7.16
Cl	0.02	0.03	NC	0.68	0.39	NC	0.11	0.14	NC
Cr_2O_3	0.50	0.48	NC	0.49	0.33	NC	0.53	0.50	NC
Cs_2O	0.15	0.16	NC	0.14	0.11	NC	0.14	0.16	NC
F	0.20	0.20*	NC	§	<0.01*	NC	0.47	0.47*	NC
Fe_2O_3	0.24	0.43	NC	0.92	1.05	NC	0.96	1.13	NC
I	§	<0.01	NC	§	0.08	NC	§	0.04	NC
K_2O	0.54	0.63	NC	0.54	0.56	NC	0.11	0.34	NC
La_2O_3	§	<0.01	NC	§	<0.01	NC	§	<0.01	NC
Li_2O	2.49	2.49*	NC	§	<0.01*	NC	§	<0.01*	NC
MgO	1.04	0.95	-8.73	0.92	0.99	NC	0.93	0.99	NC
MnO	§	0.01	NC	§	0.04	NC	0.05	0.03	NC
Na_2O	16.00	15.45	-3.44	24.00	23.76	-1.01	24.00	24.12	0.50
Nd_2O_3	§	<0.01	NC	§	0.01	NC	§	<0.01	NC
NiO	§	0.02	NC	§	0.03	NC	0.04	0.09	NC
P_2O_5	0.12	0.19	NC	§	0.01	NC	0.22	0.30	NC
PbO	§	<0.01	NC	§	0.01	NC	§	0.01	NC
Sb_2O_3	§	<0.01	NC	§	<0.01	NC	§	<0.01	NC
SeO_2	§	<0.01	NC	§	<0.01	NC	§	0.01	NC
SiO_2	41.28	41.59	0.76	39.25	39.49	0.59	39.88	38.90	-2.46
SnO_2	§	<0.01	NC	2.73	3.09	12.93	1.00	1.21	21.36
SO_3	1.50	1.38	-8.06	0.60	0.51	NC	0.85	0.81	NC
SrO	§	<0.01	NC	§	<0.01	NC	§	<0.01	NC
TiO_2	0.01	0.17	NC	§	0.11	NC	§	0.24	NC
V_2O_5	1.74	1.98	13.72	§	<0.01	NC	1.99	2.30	15.34
ZnO	3.21	3.18	-0.92	2.43	2.59	6.29	2.36	2.55	7.92
ZrO_2	3.53	3.09	-12.47	5.91	5.39	-8.78	6.01	5.58	-7.17
Sum	100.00	100.00	NC	100.00	100.00	NC	100.00	100.00	NC

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent
NC – not calculated

Table 4.3. Compositions of Discharged Glass Samples During DM10 ORP LAW Tests with Maximum Sulfur Concentrations without Secondary Phases (wt%) (continued).

Test Segment	4C			5C		
Region	C			D		
Target SO_3	0.70			1.10		
Name	S10-G-101B			T10-G-16A		
Constituent	Target	XRF	%Dev.	Target	XRF	%Dev.
Al_2O_3	10.02	10.50	4.78	10.15	9.32	-8.10
As_2O_5	§	<0.01	NC	§	<0.01	NC
B_2O_3	8.50	8.50*	NC	12.02	12.02*	NC
CaO	1.91	1.96	2.73	8.01	7.69	-3.98
Cl	0.62	0.41	NC	0.33	0.23	NC
Cr_2O_3	0.53	0.53	NC	0.50	0.42	NC
Cs_2O	0.14	0.11	NC	0.13	0.13	NC
F	0.01	0.01*	NC	0.17	0.17*	NC
Fe_2O_3	0.97	1.10	NC	1.00	1.12	11.82
I	§	0.03	NC	§	<0.01	NC
K_2O	0.54	0.59	NC	0.16	0.34	NC
La_2O_3	§	<0.01	NC	§	<0.01	NC
Li_2O	§	<0.01*	NC	§	<0.01*	NC
MgO	0.93	0.84	NC	1.00	0.93	-6.98
MnO	§	0.01	NC	§	0.02	NC
Na_2O	23.57	22.45	-4.77	21.00	18.11	-13.76
Nd_2O_3	§	<0.01	NC	§	0.01	NC
NiO	§	0.04	NC	0.04	0.06	NC
P_2O_5	0.18	0.25	NC	0.28	0.34	NC
PbO	§	<0.01	NC	0.01	0.01	NC
Sb_2O_3	§	<0.01	NC	§	<0.01	NC
SeO_2	§	<0.01	NC	§	<0.01	NC
SiO_2	40.01	40.88	2.18	37.11	40.67	9.60
SnO_2	1.00	1.04	4.65	§	0.05	NC
SO_3	0.70	0.61	NC	1.10	0.89	NC
SrO	§	<0.01	NC	§	<0.01	NC
TiO_2	§	0.14	NC	§	0.20	NC
V_2O_5	2.00	2.28	14.21	1.00	1.12	11.71
ZnO	2.36	2.56	8.27	3.00	3.09	3.08
ZrO_2	6.03	5.17	-14.20	3.00	3.07	2.43
Sum	100.00	100.00	NC	100.00	100.00	NC

* - Target values calculated based on simple well-stirred tank model
§ - Not a target constituent
NC – not calculated

Table 4.4. DCP Analyzed Compositions of Discharged Glass Samples During DM10 ORP LAW Tests with Maximum Sulfur Concentrations without Secondary Phases (wt%)

Test	**1C**			**2F**			**3C**		
Region	**E**			**A**			**B**		
Target SO_3	**1.50**			**0.60**			**0.85**		
Name	Q10-G-134A			R10-G-155A			S10-G-45A		
Constituent	Target	XRF	DCP	Target	XRF	DCP	Target	XRF	DCP
Al_2O_3	7.59	7.58	6.82	9.45	9.35	8.74	9.98	9.59	8.86
As_2O_5	§	<0.01	0.03	§	<0.01	<0.01	§	<0.01	<0.01
B_2O_3	9.85	9.82*	9.76	8.60	8.60*	8.92	8.48	8.48*	8.56
CaO	10.05	10.16	10.15	3.32	3.49	3.37	1.89	2.03	1.96
Cl	0.02	0.03	0.03	0.68	0.39	NA	0.11	0.14	NA
Cr_2O_3	0.25	0.48	0.39	0.49	0.33	0.27	0.53	0.50	0.37
Cs_2O	0.15	0.16	0.15**	0.14	0.11	0.07**	0.14	0.16	0.11**
F	0.20	0.20*	NA	§	<0.01*	NA	0.47	0.47*	NA
Fe_2O_3	0.24	0.43	0.44	0.92	1.05	1.09	0.96	1.13	1.09
I	§	<0.01	NA	§	0.08	NA	§	0.04	NA
K_2O	0.54	0.63	0.69	0.54	0.56	0.64	0.11	0.34	0.40
La_2O_3	§	<0.01	NA	§	<0.01	NA	§	<0.01	NA
Li_2O	2.50	2.49*	2.85	§	<0.01*	0.08	§	<0.01*	0.05
MgO	1.05	0.95	1.02	0.92	0.99	1.10	0.93	0.99	0.92
MnO	§	0.01	0.02	§	0.04	0.04	0.05	0.03	0.03
Na_2O	16.00	15.45	13.66	24.00	23.76	20.11	24.00	24.12	20.07
Nd_2O_3	§	<0.01	NA	§	0.01	NA	§	<0.01	NA
NiO	§	0.02	0.03	§	0.03	0.03	0.04	0.09	0.09
P_2O_5	0.12	0.19	0.32	§	0.01	0.25	0.22	0.30	0.25
PbO	§	<0.01	0.01	§	0.01	0.01	§	0.01	0.01
Sb_2O_3	§	<0.01	0.05	§	<0.01	0.04	§	<0.01	0.04
SeO_2	§	<0.01	0.01	§	<0.01	<0.01	§	0.01	0.04
SiO_2	41.41	41.59	40.52	39.25	39.49	39.70	39.88	38.90	39.44
SnO_2	§	<0.01	0.03	2.73	3.09	2.83	1.00	1.21	1.14
SO_3	1.50	1.38	NA	0.60	0.51	NA	0.85	0.81	NA
SrO	§	<0.01	0.01	§	<0.01	0.01	§	<0.01	0.01
TiO_2	0.01	0.17	0.17	§	0.11	0.12	§	0.24	0.23
V_2O_5	1.75	1.98	1.84	§	<0.01	0.02	1.99	2.30	2.03
ZnO	3.22	3.18	3.21	2.43	2.59	2.45	2.36	2.55	2.33
ZrO_2	3.54	3.09	3.10	5.91	5.39	5.14	6.01	5.58	5.05
Sum	100.00	100.00	95.31	100.00	100.00	95.03	100.00	100.00	93.08

§ - Not a target constituent
* - Target values calculated based on simple well-stirred tank model
** - Analyzed by Atomic Absorption
NA – Not analyzed
NC – Not calculated

Table 4.4. DCP Analyzed Compositions of Discharged Glass Samples During DM10 ORP LAW Tests with Maximum Sulfur Concentrations without Secondary Phases (wt%) (continued).

Test	**4C**			**5C**		
Region	**C**			**D**		
Target SO_3	0.70			1.10		
Name	S10-G-101B			T10-G-16A		
Constituent	Target	XRF	DCP	Target	XRF	DCP
Al_2O_3	10.02	10.50	9.59	10.15	9.32	8.61
As_2O_5	§	<0.01	<0.01	§	<0.01	<0.01
B_2O_3	8.50	8.50*	8.47	12.02	12.02*	12.27
CaO	1.91	1.96	1.87	8.01	7.69	7.07
Cl	0.62	0.41	NA	0.33	0.23	NA
Cr_2O_3	0.53	0.53	0.41	0.50	0.42	0.32
Cs_2O	0.14	0.11	0.10**	0.13	0.13	0.08**
F	0.01	0.01*	NA	0.17	0.17*	NA
Fe_2O_3	0.97	1.10	1.06	1.00	1.12	1.04
I	§	0.03	NA	§	<0.01	NA
K_2O	0.54	0.59	0.67	0.16	0.34	0.38
La_2O_3	§	<0.01	NA	§	<0.01	NA
Li_2O	§	<0.01*	0.04	§	<0.01*	0.06
MgO	0.93	0.84	0.90	1.00	0.93	1.04
MnO	§	0.01	0.01	§	0.02	0.02
Na_2O	23.57	22.45	19.30	21.00	18.11	15.47
Nd_2O_3	§	<0.01	NA	§	0.01	NA
NiO	§	0.04	0.05	0.04	0.06	0.06
P_2O_5	0.18	0.25	0.28	0.28	0.34	0.26
PbO	§	<0.01	0.01	0.01	0.01	0.03
Sb_2O_3	§	<0.01	0.05	§	<0.01	0.05
SeO_2	§	<0.01	0.04	§	<0.01	0.05
SiO_2	40.01	40.88	40.35	37.11	40.67	40.45
SnO_2	1.00	1.04	1.14	§	0.05	0.05
SO_3	0.70	0.61	NA	1.10	0.89	NA
SrO	§	<0.01	<0.01	§	<0.01	0.01
TiO_2	§	0.14	0.14	§	0.20	0.19
V_2O_5	2.00	2.28	2.06	1.00	1.12	0.99
ZnO	2.36	2.56	2.32	3.00	3.09	2.72
ZrO_2	6.03	5.17	4.96	3.00	3.07	2.71
Sum	100.00	100.00	93.82	100.00	100.00	93.93

§ - Not a target constituent
* - Target values calculated based on simple well-stirred tank model
** - Analyzed by Atomic Absorption
NA – Not analyzed
NC – Not calculated

Table 4.5. Listing of Dip Samples and Presence of Sulfate Layer During DM10 Melter Tests.

Test	Region	Sampling Date	Target (wt%)					Sample Name	Secondary Phase Observed
			SO_3	F	Cl	Cr_2O_3	P_2O_5		
1A	**E**	1/24/07	1.25	0.20	0.02	0.50	0.12	Q10-D-118A	YES
								Q10-D-118B	YES
								Q10-D-118C	NO
								Q10-D-118D	YES
								Q10-D-119A	YES
								Q10-D-119B	NO
1B			1.50	0.20	0.02	0.50	0.12	Q10-D-127A	NO
								Q10-D-127B	NO
								Q10-D-127C	YES
								Q10-D-127D	TRACE
		1/25/07						Q10-D-127E	NO
1C			1.50	0.20	0.02	0.25	0.12	Q10-D-134A	NO
								Q10-D-134B	NO
								Q10-D-134C	NO
1D		1/26/07	1.75	0.20	0.02	0.25	0.12	Q10-D-141A	NO
								Q10-D-141B	NO
								Q10-D-141C	YES
								Q10-D-141D	YES
								Q10-D-141E	NO
1E		1/26/07	1.625	0.20	0.02	0.25	0.12	Q10-D-148A	NO
								Q10-D-148B	NO
								Q10-D-148C	YES
								Q10-D-148D	NO
2A	**A**	6/6/07	0.10	0.20	0.02	0.50	0.12	R10-D-95A	NO
								R10-D-95B	NO
								R10-D-95C	NO
2B		6/7/07	0.20	0.20	0.02	0.50	0.12	R10-D-101A	NO
								R10-D-101B	NO
								R10-D-101C	NO
2C		6/8/07	0.30	0.00	0.68	0.49	0.00	R10-D-111A	NO
								R10-D-111B	NO
								R10-D-111C	NO
2D			0.40	0.00	0.68	0.49	0.00	R10-D-122A	NO
								R10-D-122B	NO
								R10-D-122C	NO
								R10-D-122D	NO
2E		6/12/07	0.50	0.00	0.68	0.49	0.00	R10-D-136A	NO
								R10-D-136B	NO
								R10-D-136C	NO
								R10-D-136D	NO
								R10-D-136E	NO
								R10-D-136F	NO

Table 4.5. Listing of Dip Samples and Presence of Sulfate Layer During DM10 Melter Tests (continued).

Test	Region	Sampling Date	Target (wt%)					Sample Name	Secondary Phase Observed
			SO_3	F	Cl	Cr_2O_3	P_2O_5		
2F	**A**	6/14/07	0.60	0.00	0.68	0.49	0.00	R10-D-147A	NO
		6/15/07						R10-D-155A	NO
								R10-D-155B	NO
								R10-D-155C	NO
3A	**B**		0.60	0.47	0.11	0.53	0.22	S10-D-16A	NO
								S10-D-16B	NO
								S10-D-16C	NO
3B		6/29/07	0.70	0.47	0.11	0.53	0.22	S10-D-36A	NO
								S10-D-36B	NO
								S10-D-36C	NO
3C		6/30/07	0.85	0.47	0.11	0.53	0.22	S10-D-45A	NO
								S10-D-45B	NO
								S10-D-45C	NO
3D		7/2/07	1.00	0.47	0.11	0.53	0.22	S10-D-45D	NO
								S10-D-59A	YES
								S10-D-59B	YES
								S10-D-59C	YES
								S10-D-60A	NO
								S10-D-60B	TRACE
								S10-D-60C	YES
								S10-D-60D	TRACE
								S10-D-60E	TRACE
								S10-D-60F	NO
								S10-D-60G	NO
4A	**C**	7/3/07	0.80	0.01	0.62	0.53	0.18	S10-D-76A	YES
								S10-D-76B	YES
								S10-D-76C	YES
								S10-D-77A	NO
								S10-D-77B	TRACE
								S10-D-77C	NO
								S10-D-77D	YES
								S10-D-77E	TRACE
								S10-D-77F	YES
								S10-D-77G	NO
								S10-D-78A	YES
								S10-D-78B	YES
								S10-D-78C	YES
								S10-D-78D	NO
								S10-D-78E	NO
								S10-D-78F	YES
								S10-D-78G	NO
								S10-D-78H	TRACE
								S10-D-78I	YES

Table 4.5. Listing of Dip Samples and Presence of Sulfate Layer During DM10 Melter Tests (continued).

Test	Region	Sampling Date	Target (wt%)					Sample Name	Secondary Phase Observed
			SO_3	F	Cl	Cr_2O_3	P_2O_5		
4B	**C**	7/4/07	0.00	0.01	0.63	0.00	0.19	S10-D-83A	NO
								S10-D-83B	NO
								S10-D-83C	NO
4C		7/5/07	0.70	0.01	0.62	0.53	0.18	S10-D-83D	NO
		7/6/07						S10-D-101A	NO
								S10-D-101B	NO
								S10-D-101C	NO
4D			0.90	0.01	0.61	0.53	0.18	S10-D-110A	YES
								S10-D-110B	YES
								S10-D-110C	YES
								S10-D-110D	TRACE
								S10-D-110E	YES
								S10-D-110F	YES
								S10-D-110G	TRACE
								S10-D-110H	TRACE
								S10-D-110I	YES
								S10-D-111A	TRACE
								S10-D-111B	YES
								S10-D-111C	YES
								S10-D-111D	NO
								S10-D-111E	NO
								S10-D-111F	TRACE
4E		7/7/07	0.00	0.01	0.63	0.00	0.19	S10-D-117A	NO
								S10-D-117B	NO
								S10-D-117C	NO
5A	**D**	7/9/07	0.70	0.17	0.33	0.50	0.29	S10-D-117D	NO
								S10-D-117E	NO
								S10-D-117F	NO
		7/10/07						S10-D-139A	NO
								S10-D-139B	NO
								S10-D-139B	NO
5B		7/11/07	0.90	0.17	0.33	0.50	0.29	S10-D-148A	NO
								S10-D-148B	NO
								S10-D-148C	NO
5C		7/17/07	1.10	0.17	0.33	0.50	0.28	T10-D-12A	NO
								T10-D-12B	NO
								T10-D-12C	NO
								T10-D-16A	NO
								T10-D-16B	NO
								T10-D-16C	NO

Table 4.5. Listing of Dip Samples and Presence of Sulfate Layer During DM10 Melter Tests (continued).

Test	Region	Sampling Date	Target (wt%)					Sample Name	Secondary Phase Observed
			SO_3	F	Cl	Cr_2O_3	P_2O_5		
5D	**D**	7/18/07	1.30	0.17	0.33	0.50	0.28	T10-D-23A	YES
								T10-D-23B	YES
								T10-D-23C	YES
								T10-D-24A	YES
								T10-D-24B	TRACE
								T10-D-24C	YES
								T10-D-24D	YES
								T10-D-24E	NO
								T10-D-24F	YES
								T10-D-24G	YES
								T10-D-24H	NO
								T10-D-24I	NO
								T10-D-25A	TRACE
								T10-D-25B	NO
								T10-D-25C	NO

Table 4.6. Results of PCT Leaching Procedure (ASTM C1285, 7-days at 90ºC, Stainless Steel Vessel; S/V=2000m^{-1}) for Crucible Glass and Corresponding Melter Glass Samples that Contain the Maximum Sulfur Content Without Formation of Secondary Phases During DM10 ORP LAW Tests.

Region		E		A		B	
Tank Waste/Sub-Envelope Identification		AZ-101/Sub-Envelope B1		AN-105/Sub-Envelope A1		AN-107/Sub-Envelope C1	
Sample Type		Crucible Glass	Melter Glass	Crucible Glass	Melter Glass	Crucible Glass	Melter Glass
Sample I.D.		ORPLE12	Q10-G-134A	ORPLA15	R10-G-155A	ORPLB4	S10-G-45A
7-Day PCT Concentration in mg/L	B	15.42	15.48	35.39	49.84	37.18	43.02
	Na	94.32	88.65	242.40	292.80	236.30	251.90
	Si	45.91	48.39	69.91	75.35	69.70	68.79
7-Day PCT Normalized Concentrations, g/L	B	0.50	0.51	1.32	1.87	1.41	1.63
	Na	0.79	0.77	1.36	1.66	1.33	1.41
	Si	0.24	0.25	0.38	0.41	0.37	0.38
	pH	11.32	11.32	11.58	11.58	11.53	11.42
7-Day PCT Normalized Mass Loss (g/m^2)	B	0.25	0.25	0.66	0.93	0.70	0.82
	Na	0.40	0.39	0.68	0.83	0.66	0.70
	Si	0.12	0.12	0.19	0.20	0.19	0.19
7-Day PCT Normalized Loss Rate, g/d/m^2	B	0.04	0.04	0.09	0.13	0.10	0.12
	Na	0.06	0.06	0.10	0.12	0.09	0.10
	Si	0.02	0.02	0.03	0.03	0.03	0.03

Table 4.6. Results from PCT Leaching Procedure (ASTM C1285, 7-days at 90ºC, Stainless Steel Vessel; S/V=2000m^{-1}) for Crucible Glass and Corresponding Melter Glass Samples that Contain the Maximum Sulfur Content Without Formation of Secondary Phases During DM10 ORP LAW Tests (continued).

Region		C		D		ANL-LRM-2	WTP Contract Limit
Tank Waste/Sub-Envelope Identification		AN-104/Sub-Envelope A3		AN-102/Sub-Envelope C2			
Sample Type		Crucible Glass	Melter Glass	Crucible Glass	Melter Glass		
Sample I.D.		ORPLC5	S10-G-101B	ORPLD1	T10-G-16A		
7-Day PCT Concentration in mg/L	B	44.97	35.64	49.32	25.66	29.08	-
	Na	260.50	201.40	223.60	106.30	165.70	-
	Si	67.71	61.94	53.61	44.04	81.61	-
7-Day PCT Normalized Concentrations, g/L	B	1.70	1.35	1.32	0.69	1.17	-
	Na	1.49	1.21	1.44	0.79	1.12	-
	Si	0.36	0.32	0.31	0.23	0.32	-
	pH	11.38	11.28	11.45	10.65	11.08	-
7-Day PCT Normalized Mass Loss (g/m^2)	B	0.85	0.67	0.66	0.34	0.59	< 2.0
	Na	0.74	0.60	0.72	0.40	0.56	< 2.0
	Si	0.18	0.16	0.15	0.12	0.16	< 2.0
7-Day PCT Normalized Loss Rate, g/d/m^2	B	0.12	0.10	0.09	0.05	0.08	-
	Na	0.11	0.09	0.10	0.06	0.08	-
	Si	0.03	0.02	0.02	0.02	0.02	-

- Empty data field

Table 4.7. VHT Results (24 Day) for Crucible Glass and Corresponding Melter Glass Samples that Contain the Maximum Sulfur Content Without Formation of Secondary Phases During DM10 ORP LAW Tests.

Region		**E**		**A**			
Tank Waste/Sub-Envelope Identification		AZ-101/Sub-Envelope B1		AN-105/Sub-Envelope A1			
Sample Type		Crucible Glass	Melter Glass	Crucible Glass	Melter Glass		
Sample I.D.		ORPLE12	Q10-G-134A	ORPLA15	R10-G-91E (low sulfur)	R10-G-155A (Heavily foamed)	R10-G-155A Re-melted
Based on Layer Thickness	**Alteration depth (μm)**	375	350	275	325	Coupon fully reacted	395
	Rate ($g/m^2/d$)	41	39	30	36		44
	Compared to limit of 50 $g/m^2/d$	82%	78%	60%	72%		88%
Based on Remaining Glass	**Alteration depth (μm)**	277	301	230	554		751
	Rate ($g/m^2/d$)	31	33	25	61		83
	Compared to limit of 50 $g/m^2/d$	62%	66%	50%	122%		166%

Rates calculated with an average density of 2.65 g/cm^3
NC – Not calculated

Table 4.7. VHT Results (24 Day) for Crucible Glass and Corresponding Melter Glass Samples that Contain the Maximum Sulfur Content Without Formation of Secondary Phases During DM10 ORP LAW Tests (continued).

Region		**B**			**C**			**D**	
Tank Waste/Sub-Envelope Identification		AN-107/Sub-Envelope C1			AN-104/Sub-Envelope A3			AN-102/Sub-Envelope C2	
Sample Type		Crucible Glass	Melter Glass		Crucible Glass	Melter Glass		Crucible Glass	Melter Glass
Sample I.D.		ORPLB4	S10-G-45A	S10-G-45A Re-melted	ORPLC5	S10-G-101B	S10-G-101B Re-melted	ORPLD1	T10-G-16A
Based on Direct Layer	**Alteration depth (μm)**	450	417	401	318	300	232	175	163
	Rate (g/m^2/d)	50	46	44	35	33	26	19	18
	Compared to limit of 50 g/m^2/d	100%	92%	88%	70%	66%	52%	38%	36%
Based on Remaining Glass	**Alteration depth (μm)**	369	481	604	362	292	240	99	99
	Rate (g/m^2/d)	41	53	67	40	32	27	11	11
	Compared to limit of 50 g/m^2/d	82%	106%	134%	80%	64%	54%	22%	22%

Rates calculated with an average density of 2.65 g/cm3

Table 5.1. Maximum Sodium and Sulfur Oxide Concentrations Achieved in Crucible and Melter Tests (wt% in Glass).

Region		A	B	C	D	E
Tank Waste/ Sub-Envelope Identification		AN-105/ Sub-Envelope A1	AN-107/ Sub-Envelope C1	AN-104/ Sub-Envelope A3	AN-102/ Sub-Envelope C2	AZ-101/ Sub-Envelope B1
Crucible Studies	Na_2O	24.0	24.0	23.57	21.0	16.0
	SO_3 (batching)	0.27	0.52	0.56	0.70	1.20
	SO_3 (bubbling)	NM	0.70	NM	NM	1.55
Melter Studies	Target Feed Na_2O	24.0	24.0	23.57	21.0	16.0
	Target Feed SO_3	0.6	0.85	0.70	1.10	1.50
	Measured Na_2O	23.76	24.12	22.45	18.11	15.45
	Measured SO_3	0.52	0.68	0.61	0.89	1.38
Previous Melter Studies	Target Feed Na_2O	23.0 [6]			20.0 [5]	10.0 [6]*
	Target Feed SO_3	1.0			1.125	1.5
	Measured Na_2O	22.0			19.9	10.7
	Measured SO_3	0.88			1.07	1.33

* - Previous tests with LAW Sub-Envelope B2 waste.

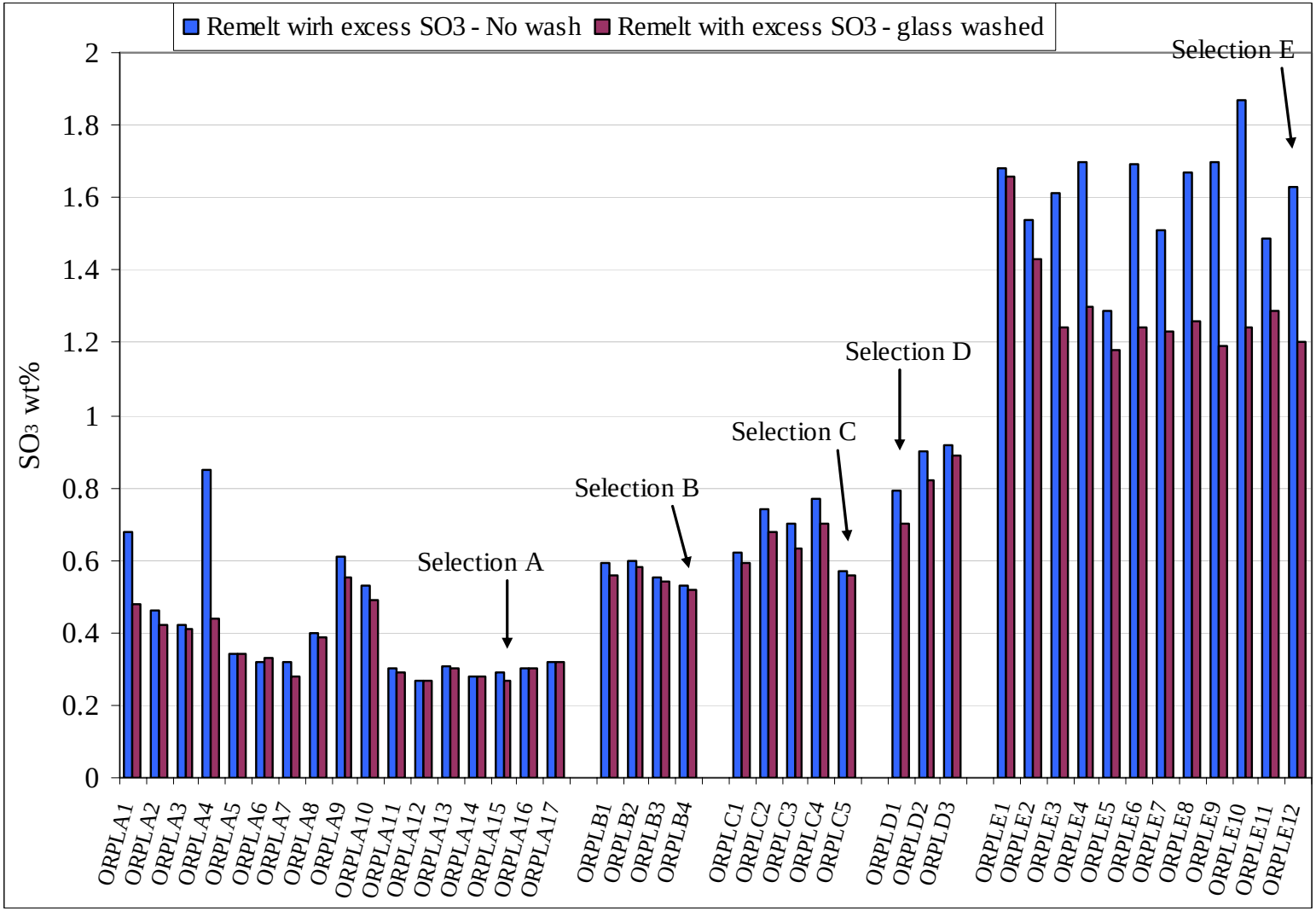


Figure 2.1. Sulfate solubility determined by remelting with excess SO_3 for forty one new ORP LAW crucible glasses.

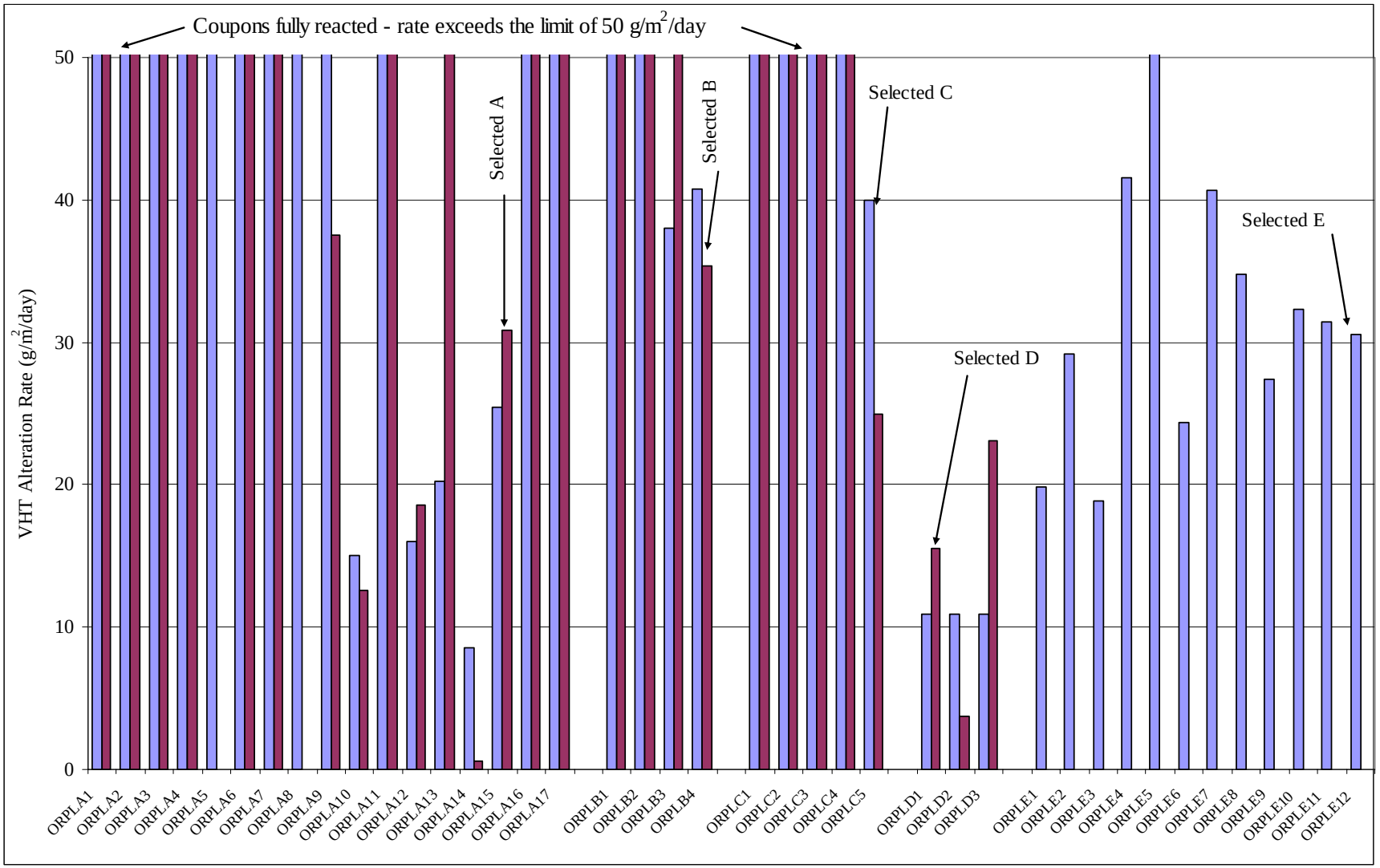


Figure 2.2. VHT results for forty one new ORP LAW crucible glasses.

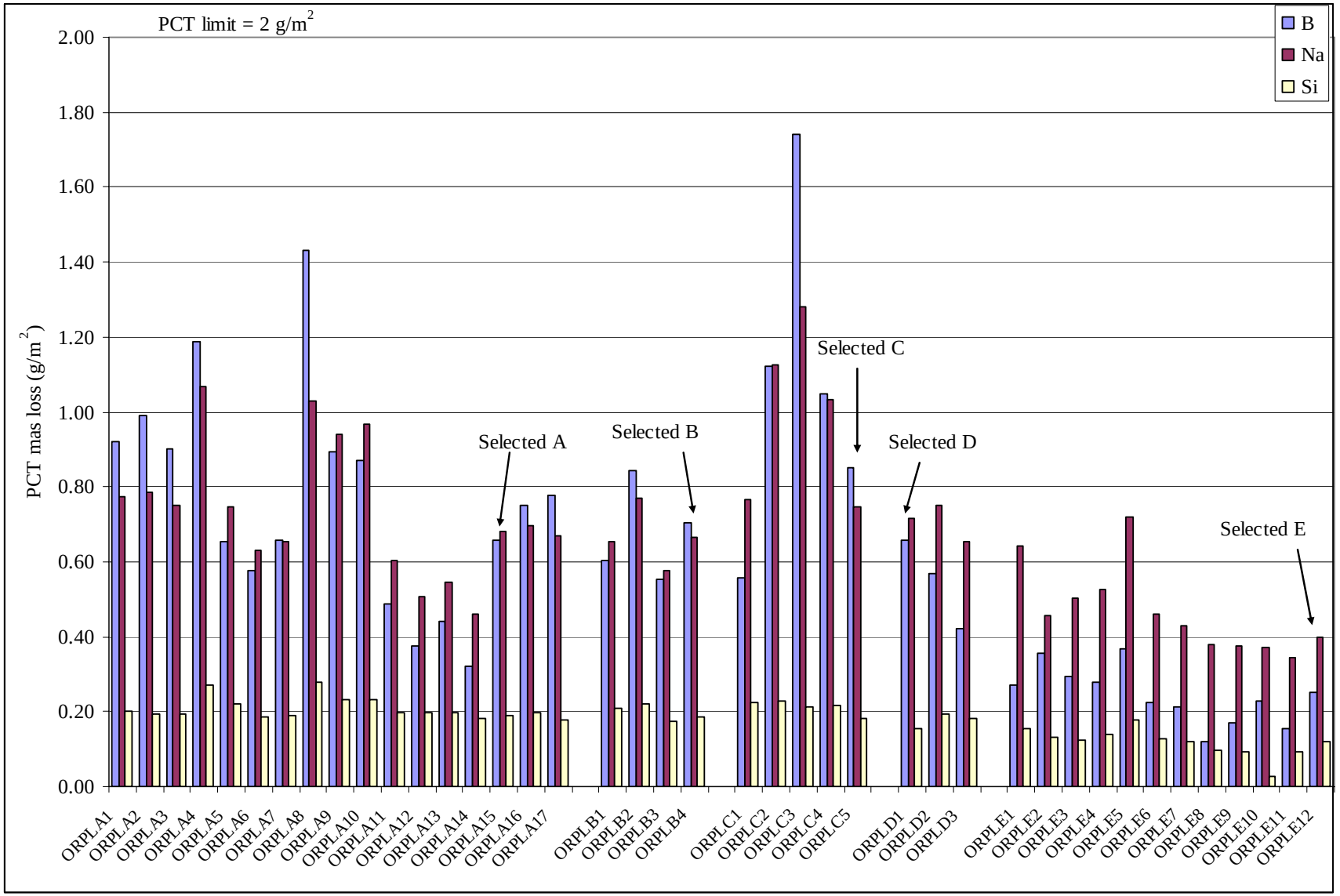


Figure 2.3. Normalized PCT releases for forty one new ORP LAW crucible glasses.

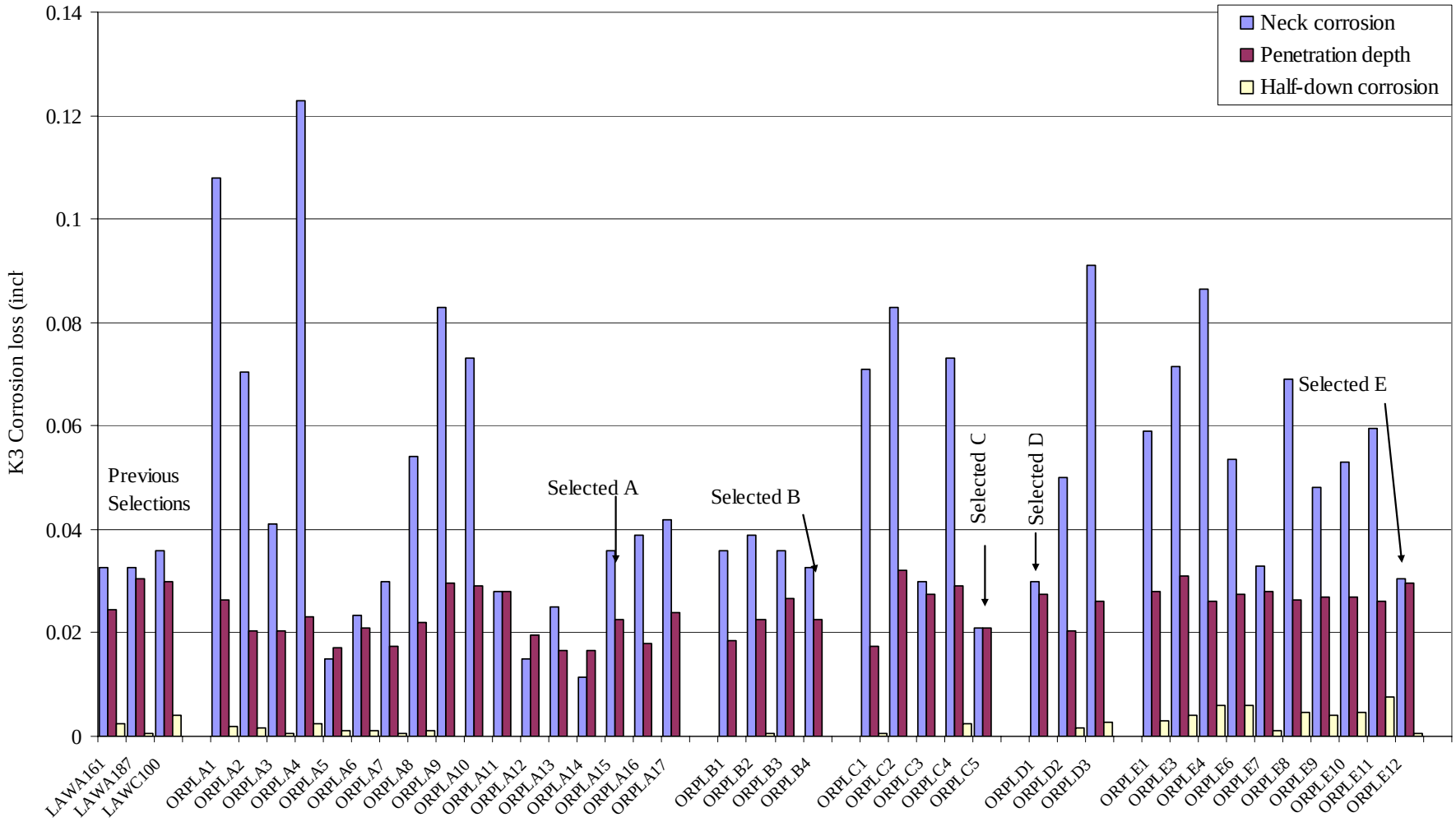


Figure 2.4. K3 Corrosion results for thirty eight new ORP LAW crucible glasses and three old LAW formulations.

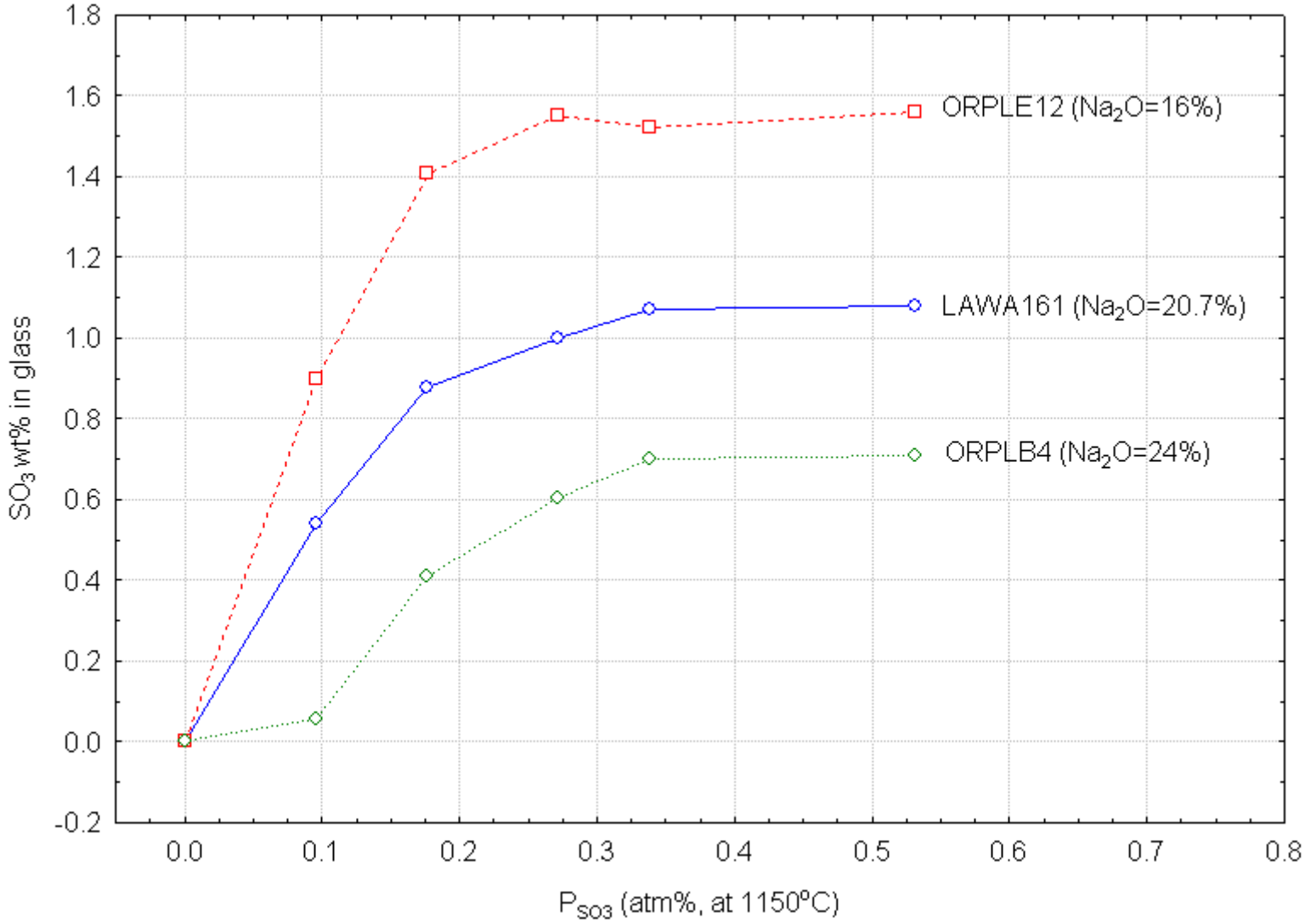


Figure 2.5. Results of SO_2/O_2 gas bubbling tests on the new ORP LAW glasses ORPLB4 and ORPLE12 and the previous ORP Envelope A glass LAWA161 at 1150°C showing the partial pressure of SO_3 vs. the SO_3 concentration in the glass melt. The horizontal portions indicate the solubility limits while the slopes at lower concentrations provide measures of the activity coefficient of SO_3 in the melt.

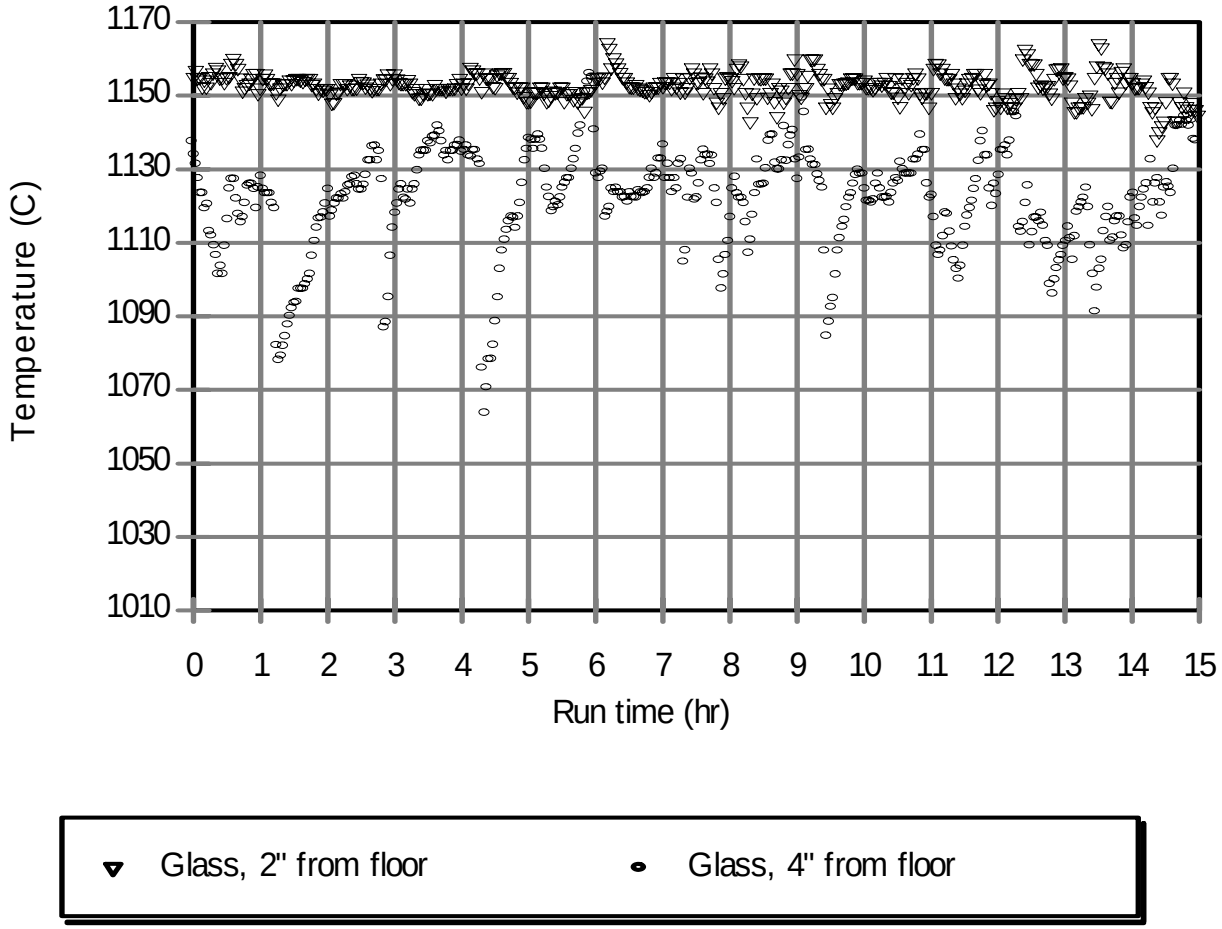


Figure 3.1. Representative plot of glass pool temperatures during DM10 tests. This plot is from the first test performed (Region E, Test 1A) and a portion of the idling period prior to Test 1B. The temperatures at 2" above the floor, which are most representative of the bilk glass temperature, closely approximate the target of 1150°C.

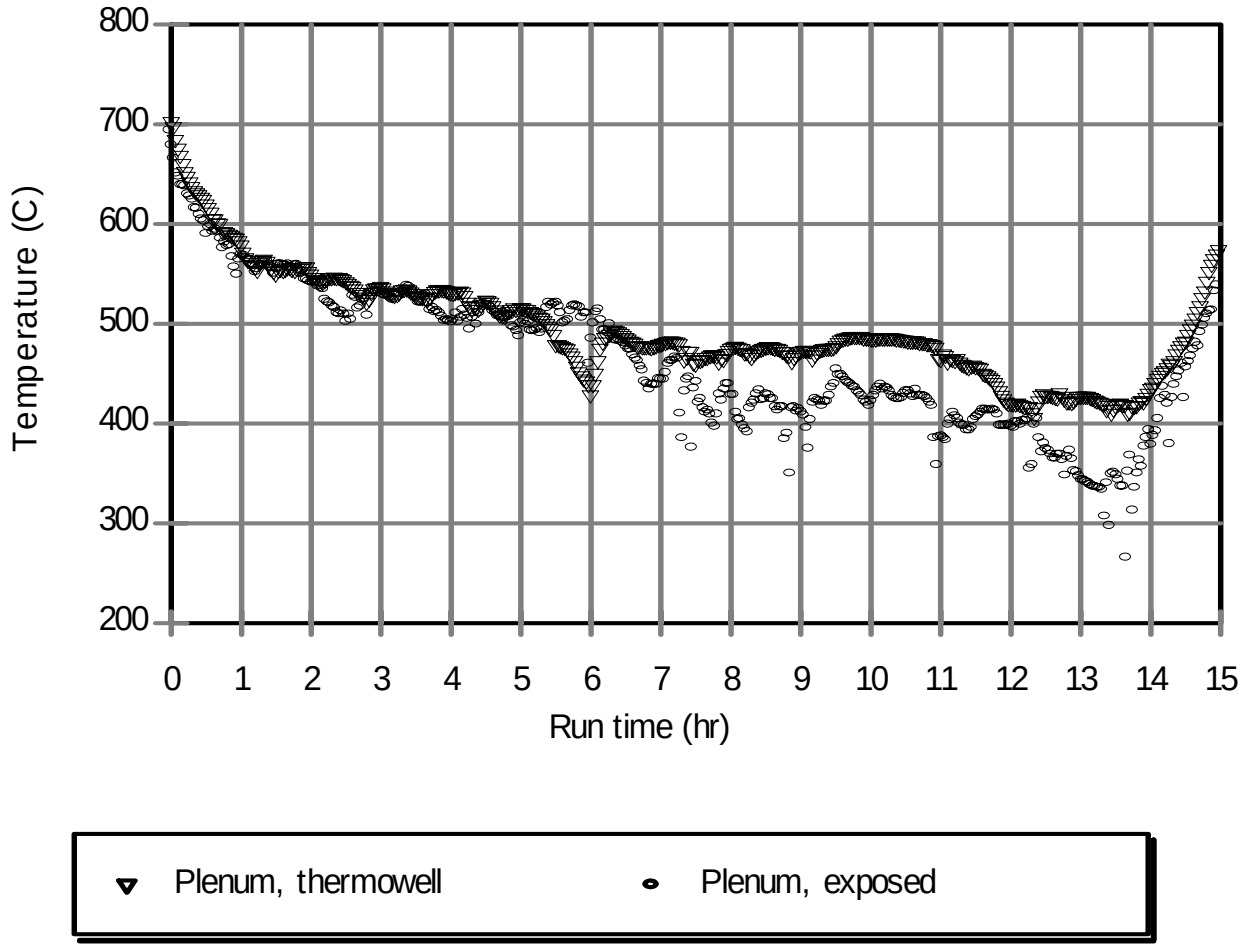


Figure 3.2. Representative plot of plenum temperatures during DM10 tests. This plot is from the first test performed (Region E, Test 1A) and a portion of the idling period prior to Test 1B. The temperatures fall into the 550 to 400°C range after about 2 hours of feeding and increase again during idling.

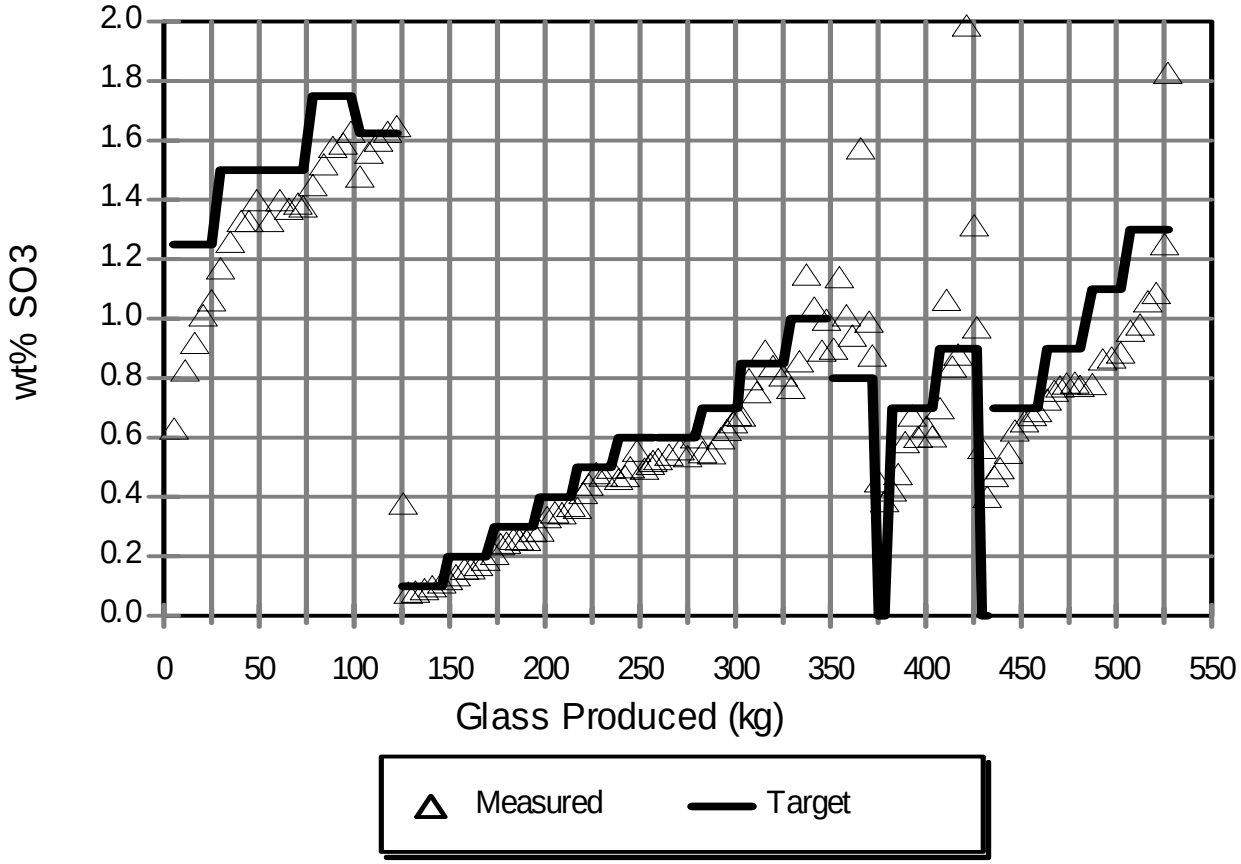


Figure 3.3. XRF analysis of sulfur in DM10 product glasses.

Figure 4.1. Secondary sulfur phases on discharge glass S10-G-109B from the end of Test 4D.

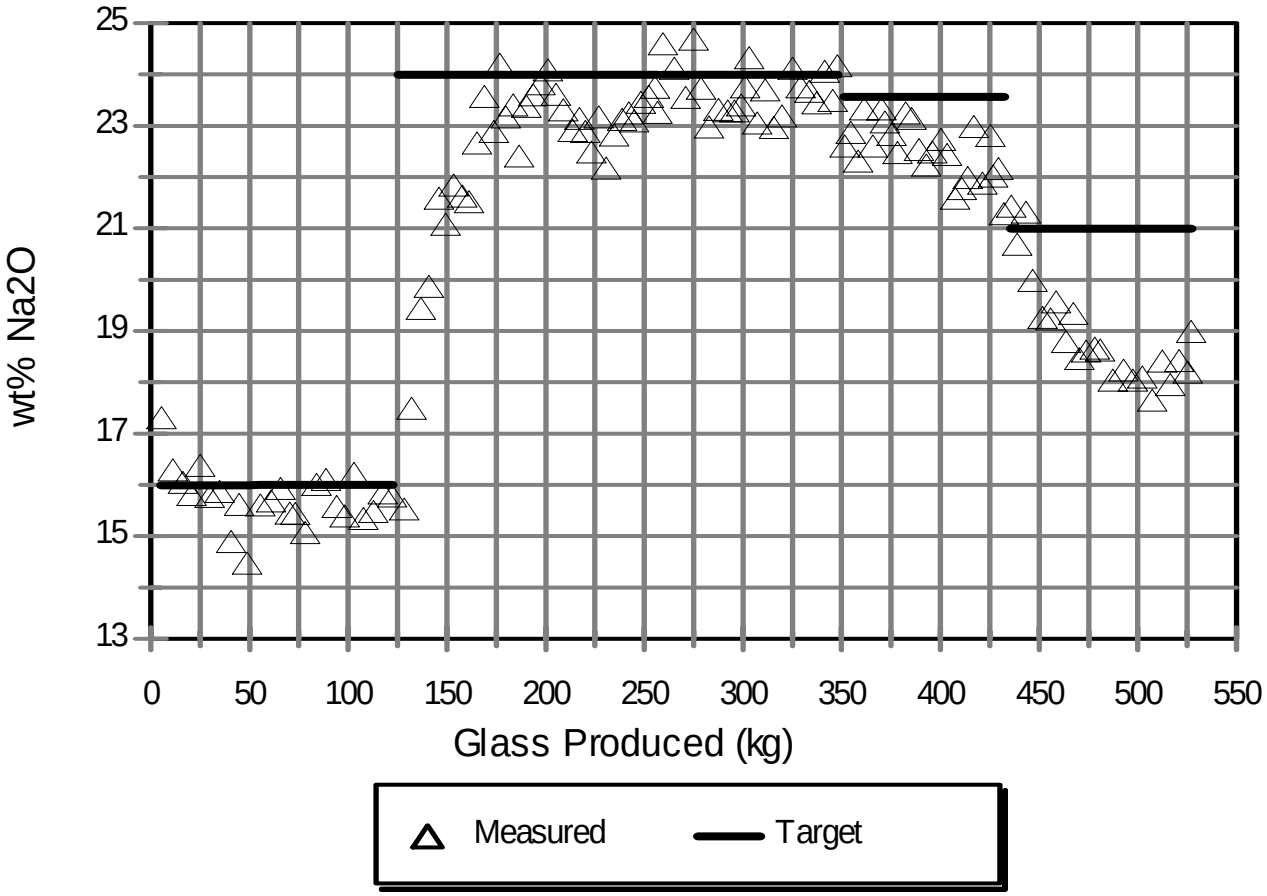


Figure 4.2. XRF analysis of sodium in DM10 product glasses.

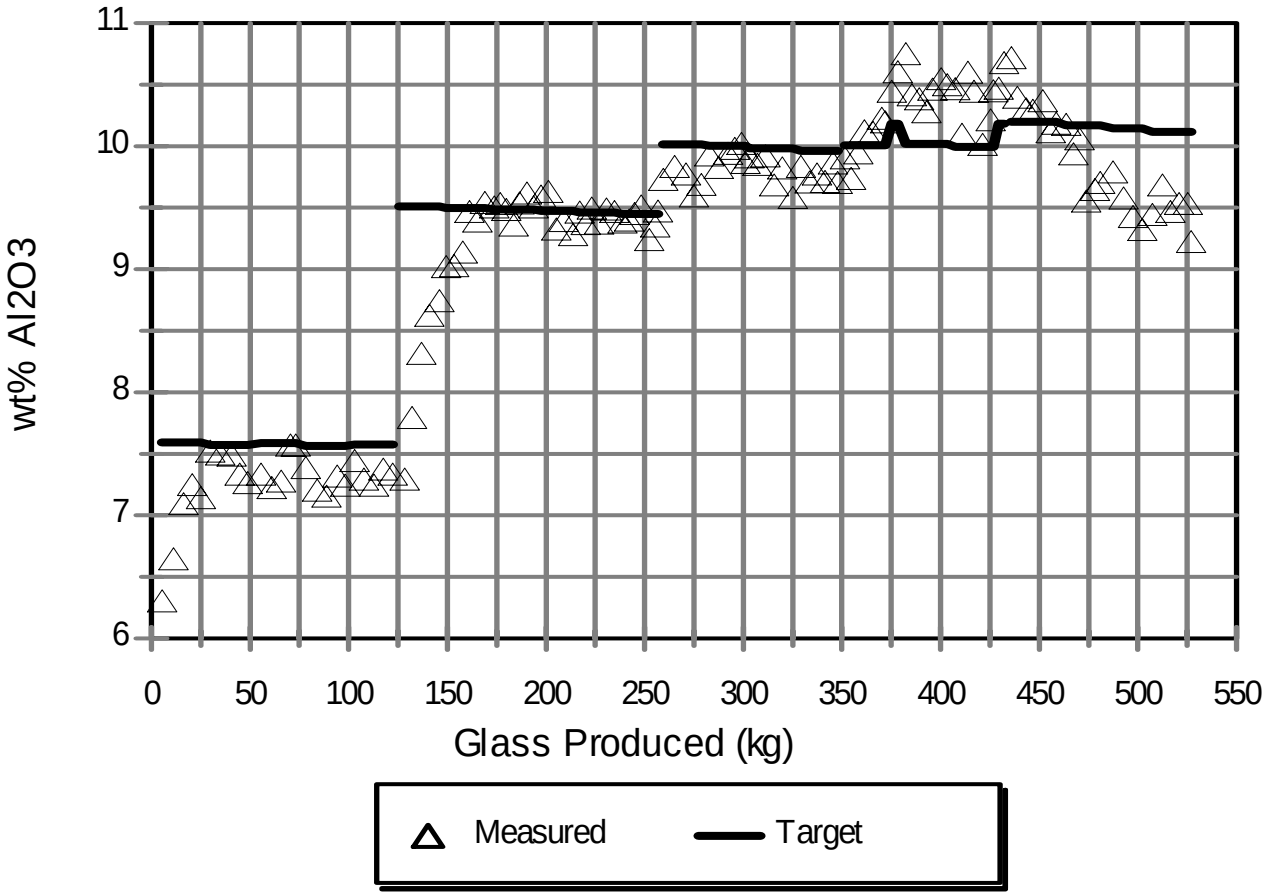


Figure 4.3. XRF analysis of aluminum in DM10 product glasses.

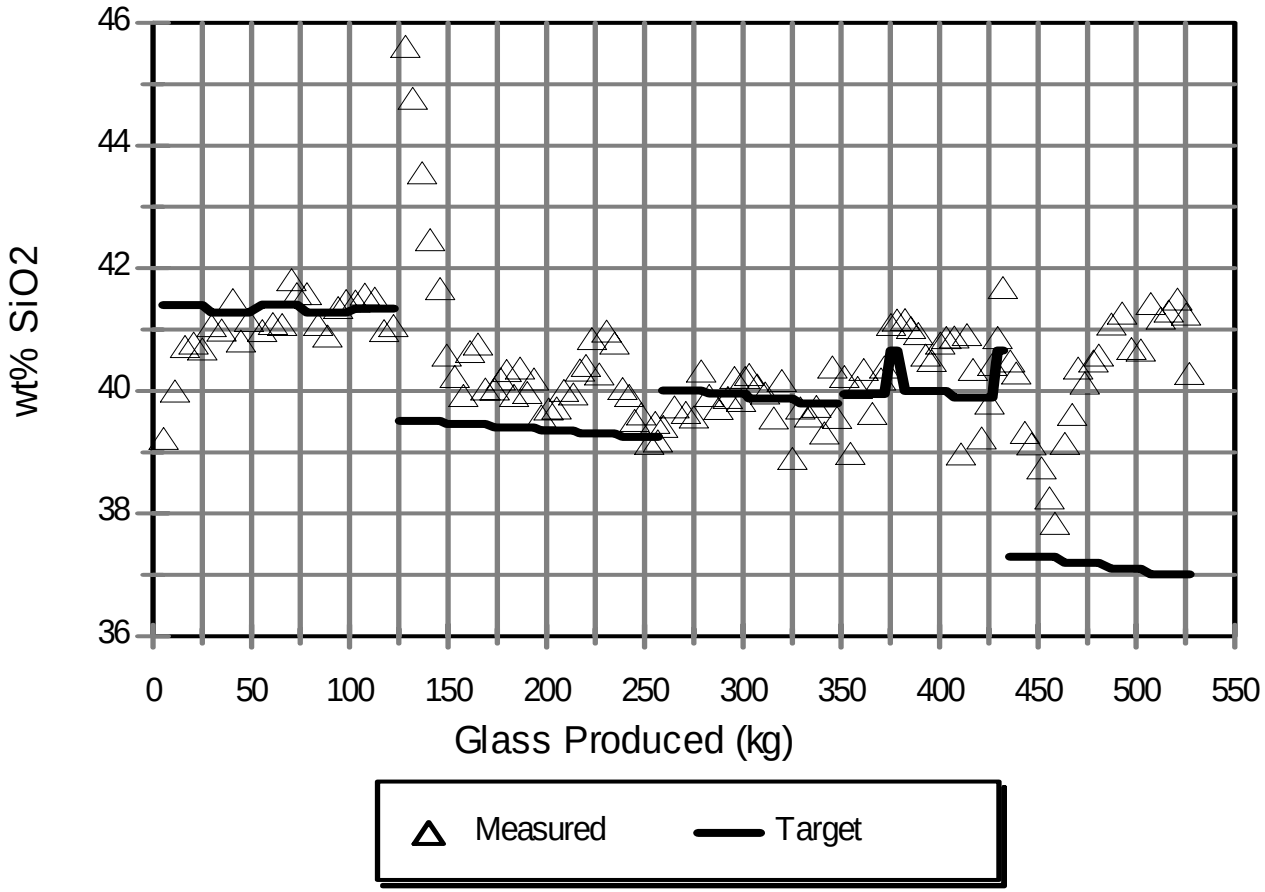


Figure 4.4. XRF analysis of silicon in DM10 product glasses.

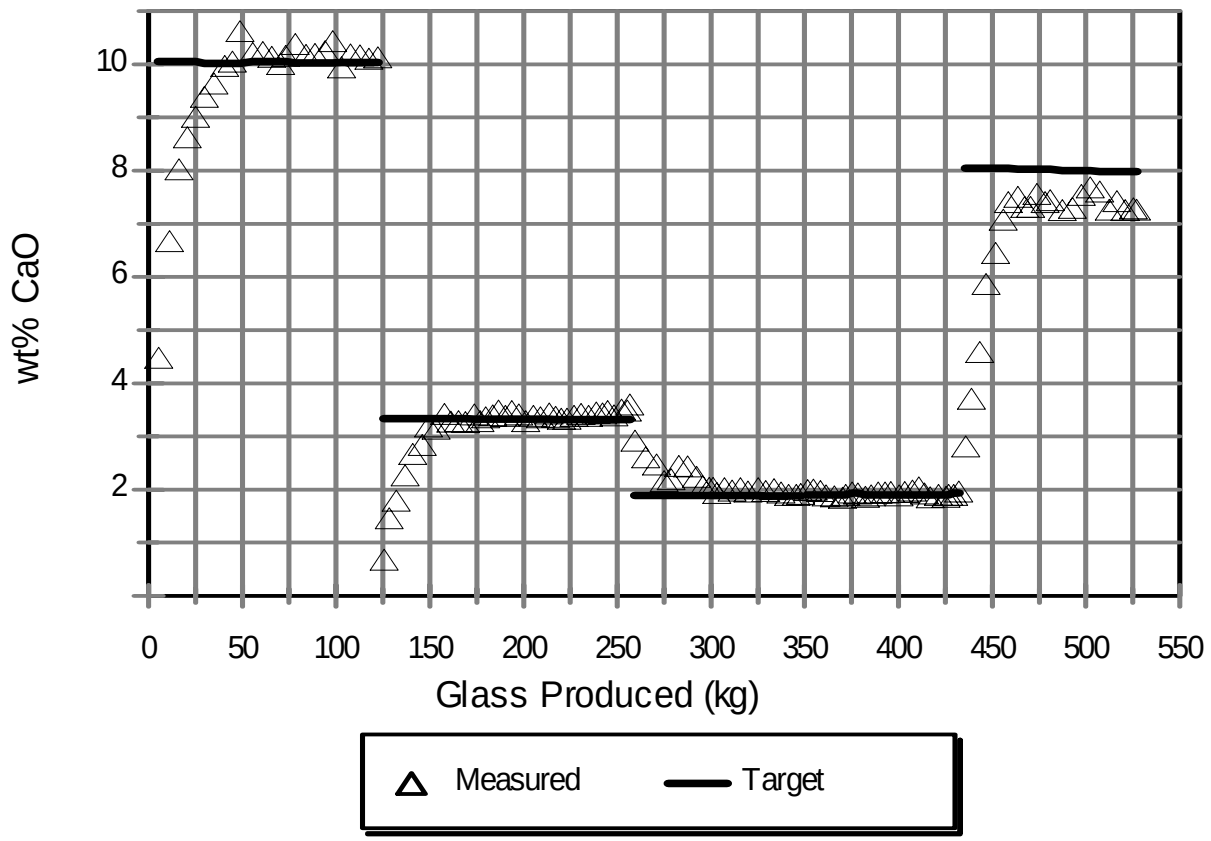


Figure 4.5. XRF analysis of calcium in DM10 product glasses.

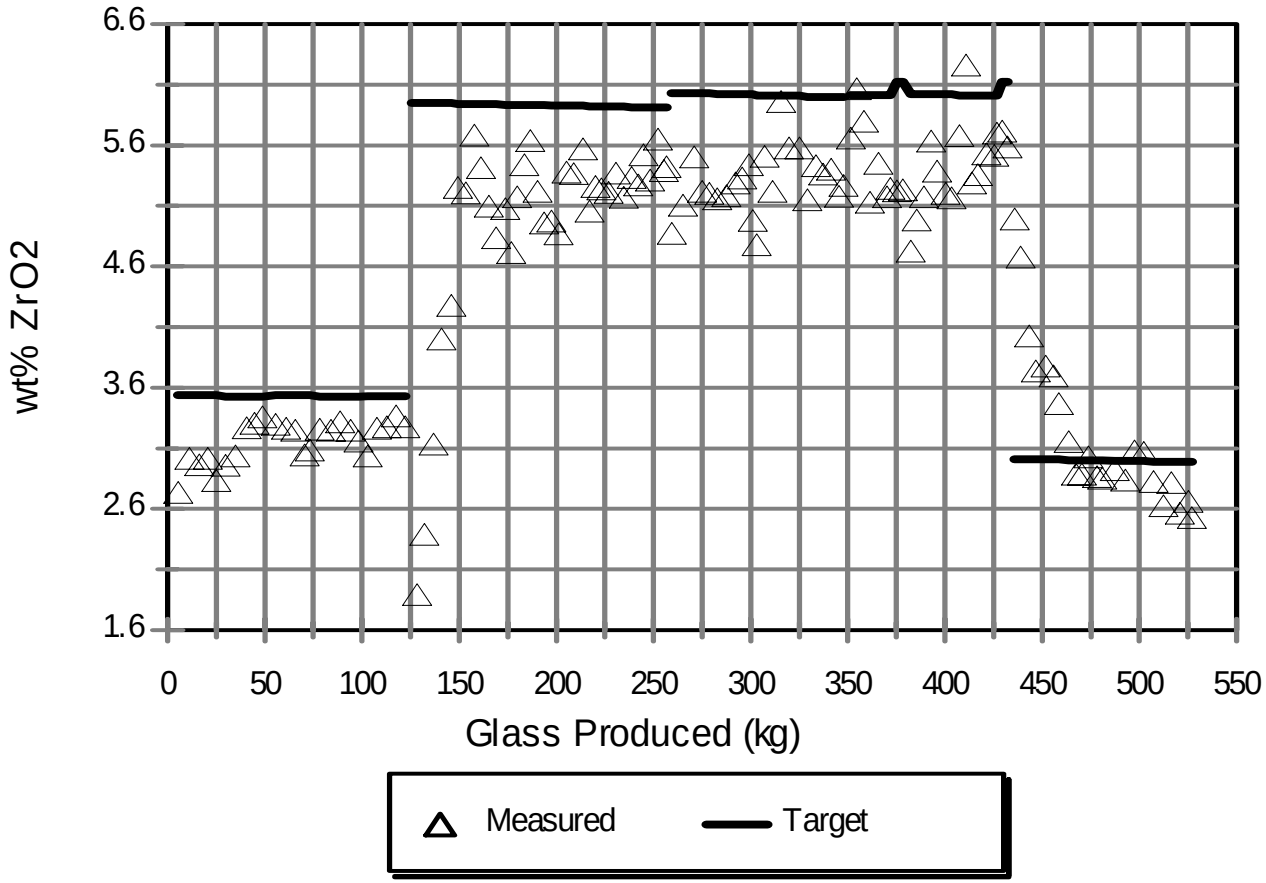


Figure 4.6. XRF analysis of zirconium in DM10 product glasses.

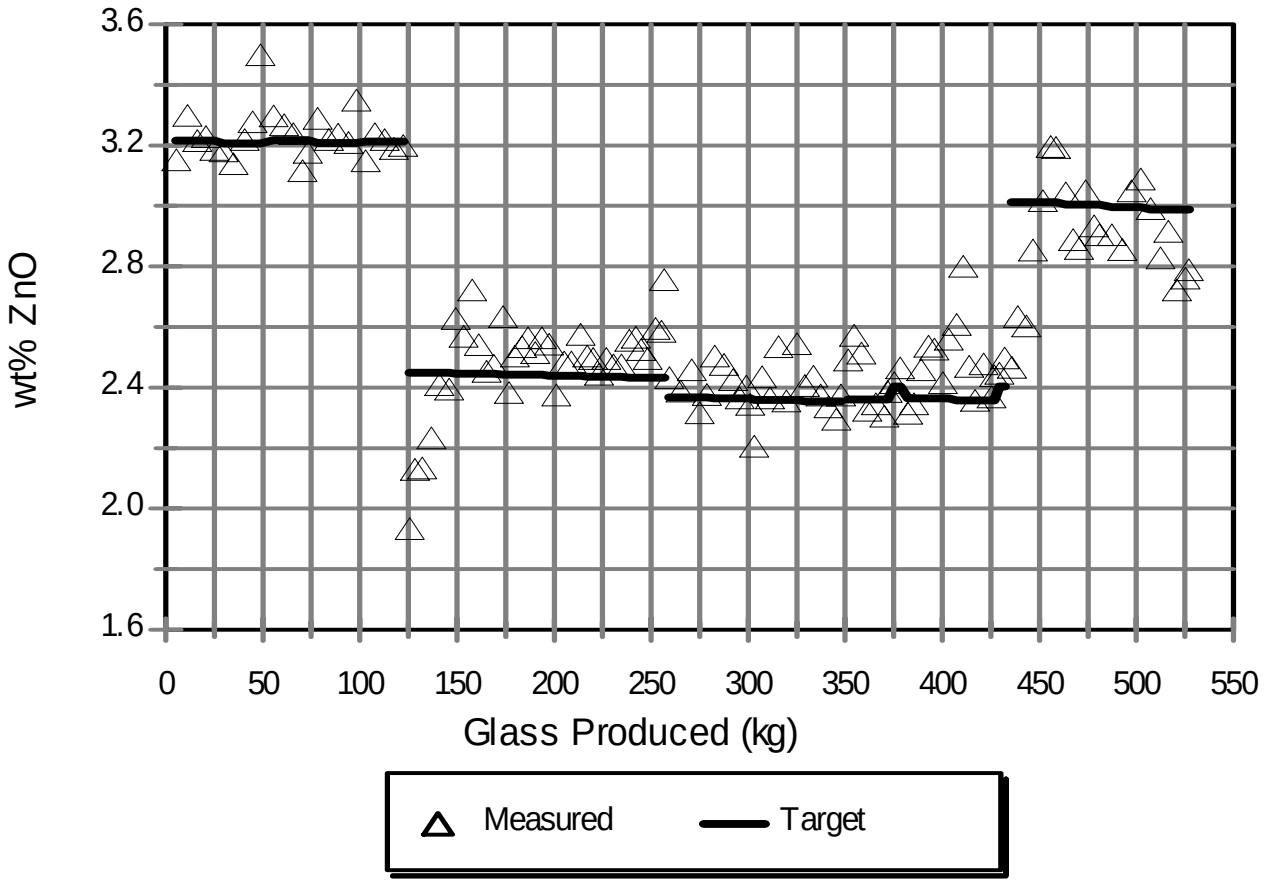


Figure 4.7. XRF analysis of zinc in DM10 product glasses.

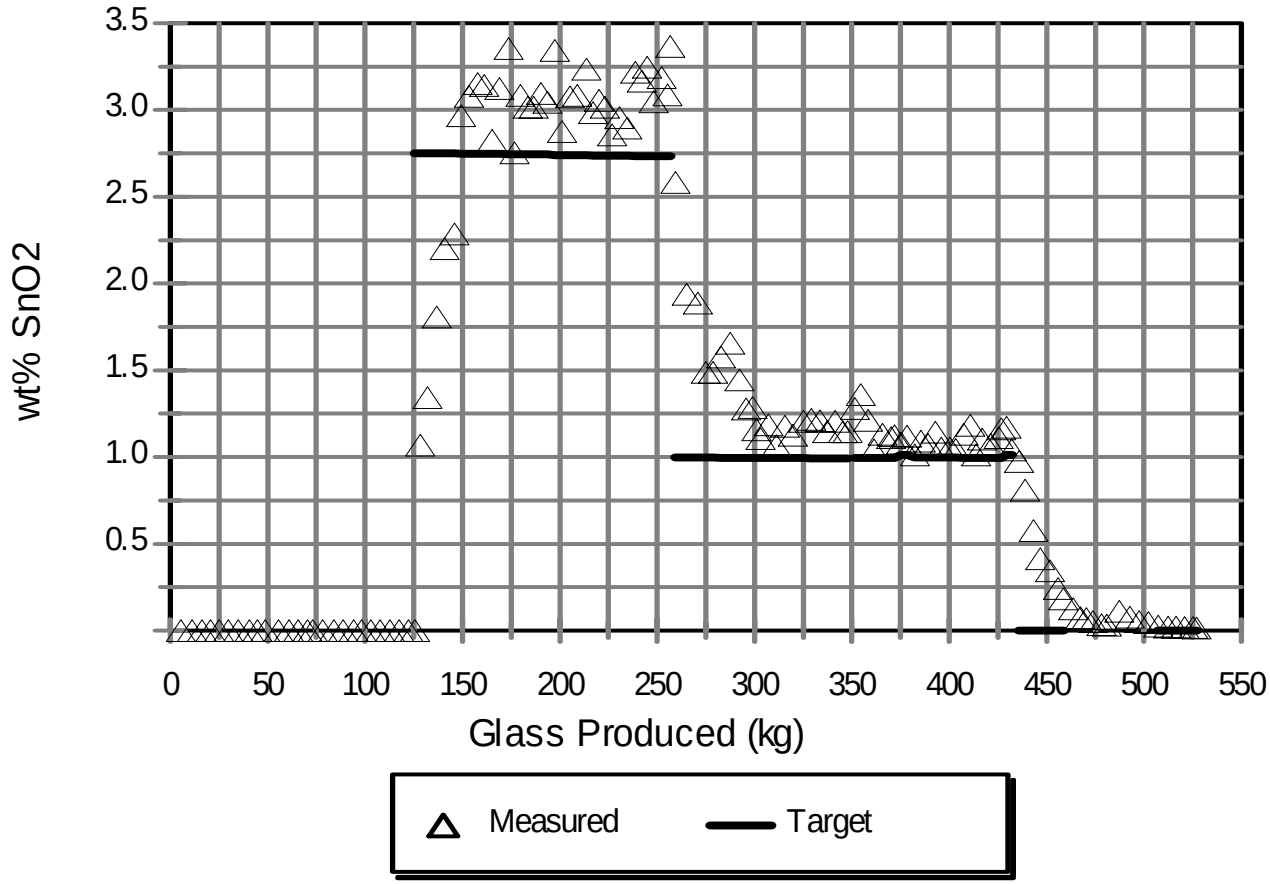


Figure 4.8. XRF analysis of tin in DM10 product glasses.

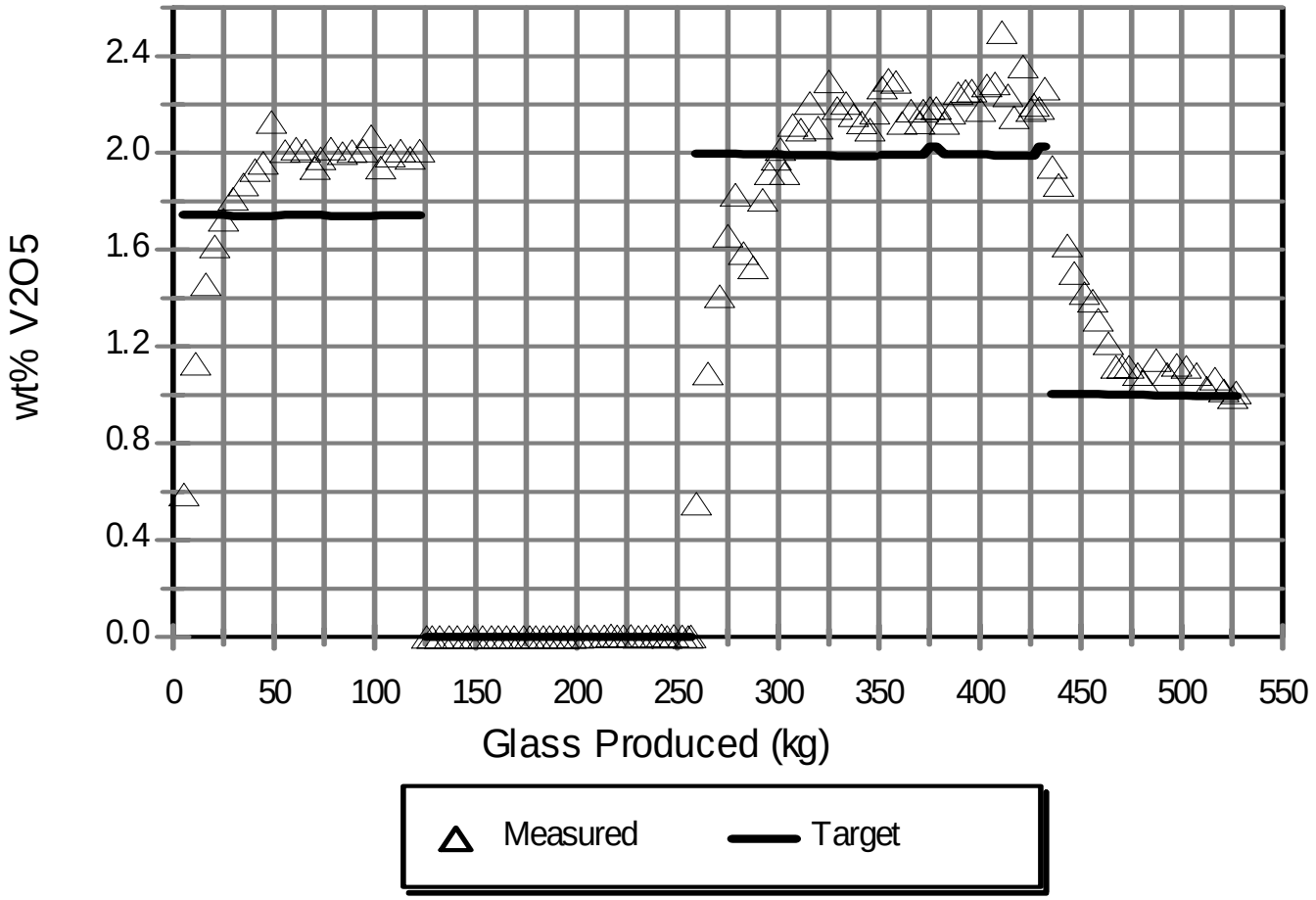


Figure 4.9. XRF analysis of vanadium in DM10 product glasses.

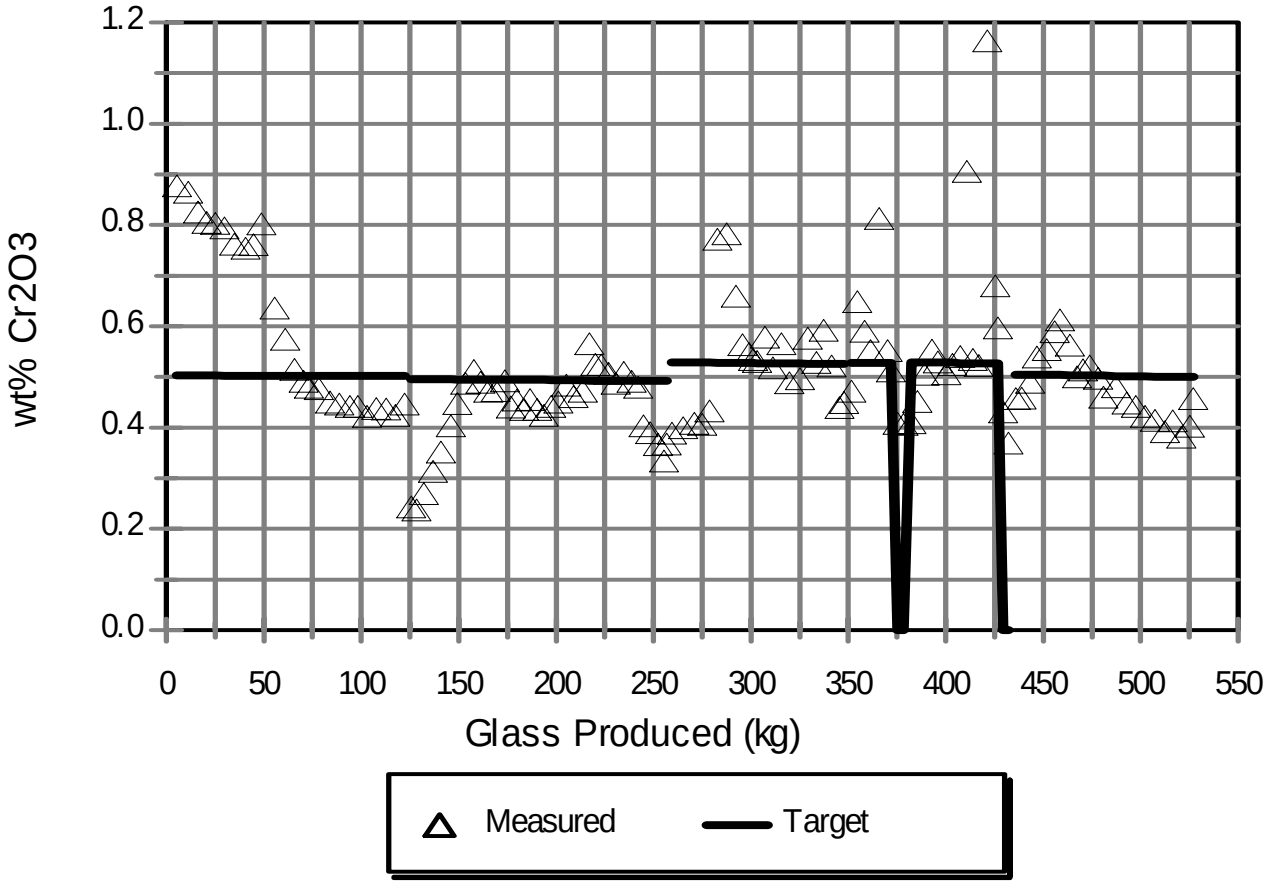


Figure 4.10. XRF analysis of chromium in DM10 product glasses.

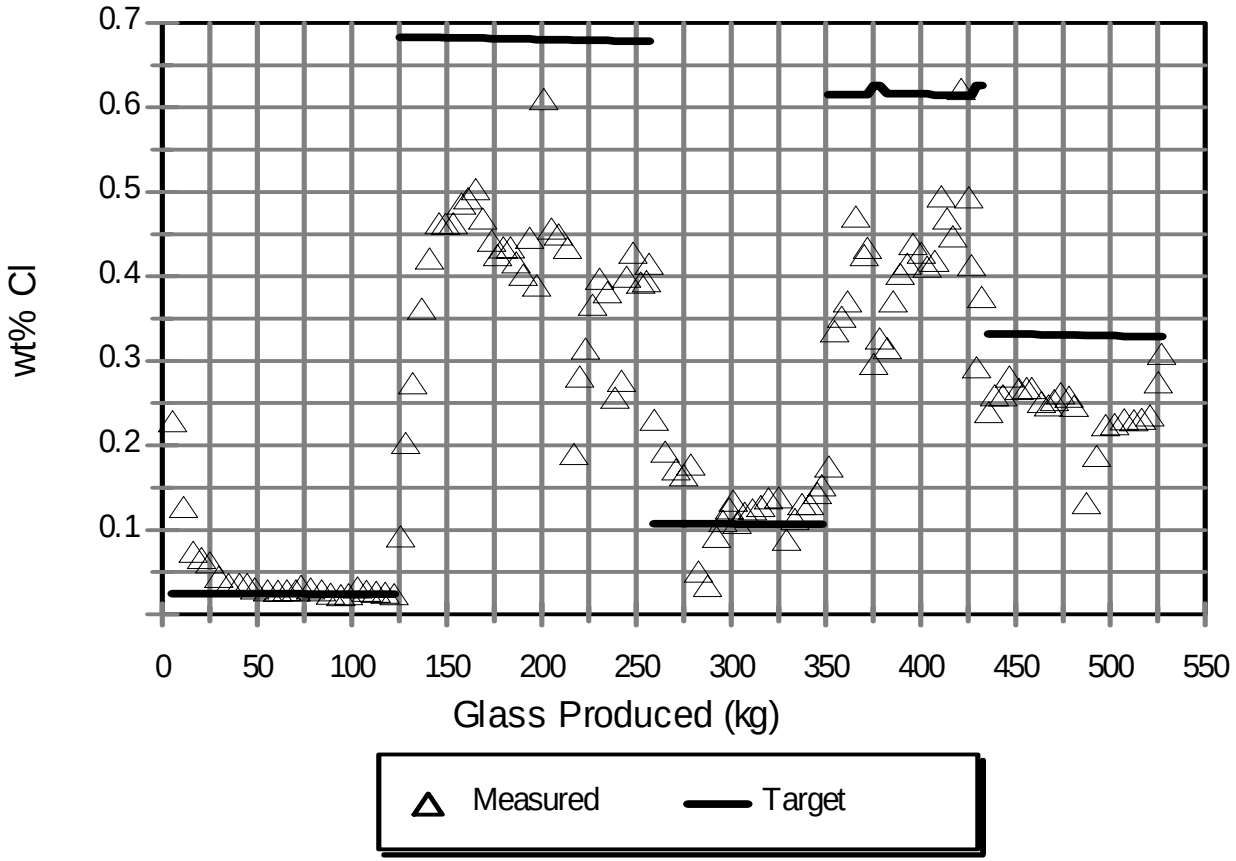


Figure 4.11. XRF analysis of chlorine in DM10 product glasses.

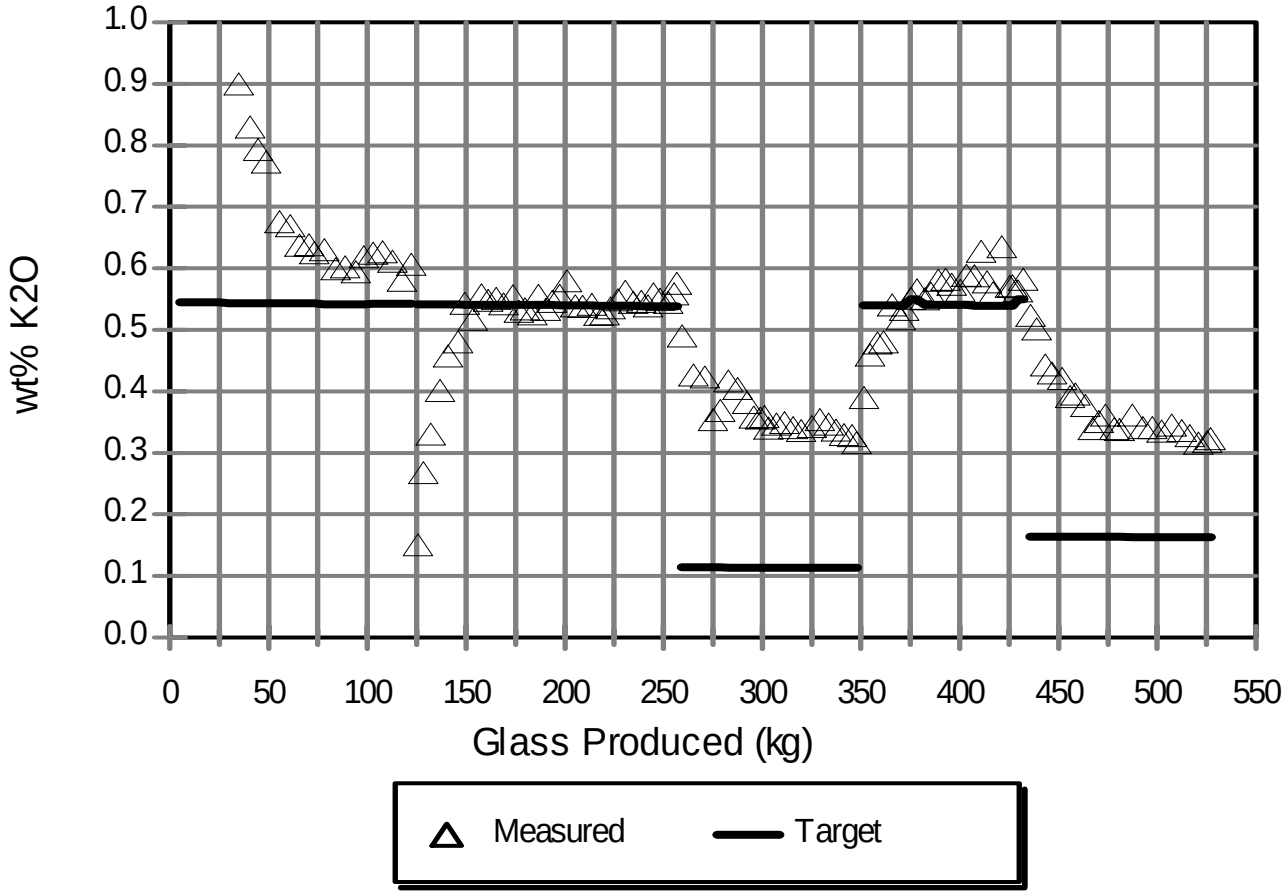


Figure 4.12. XRF analysis of potassium in DM10 product glasses.

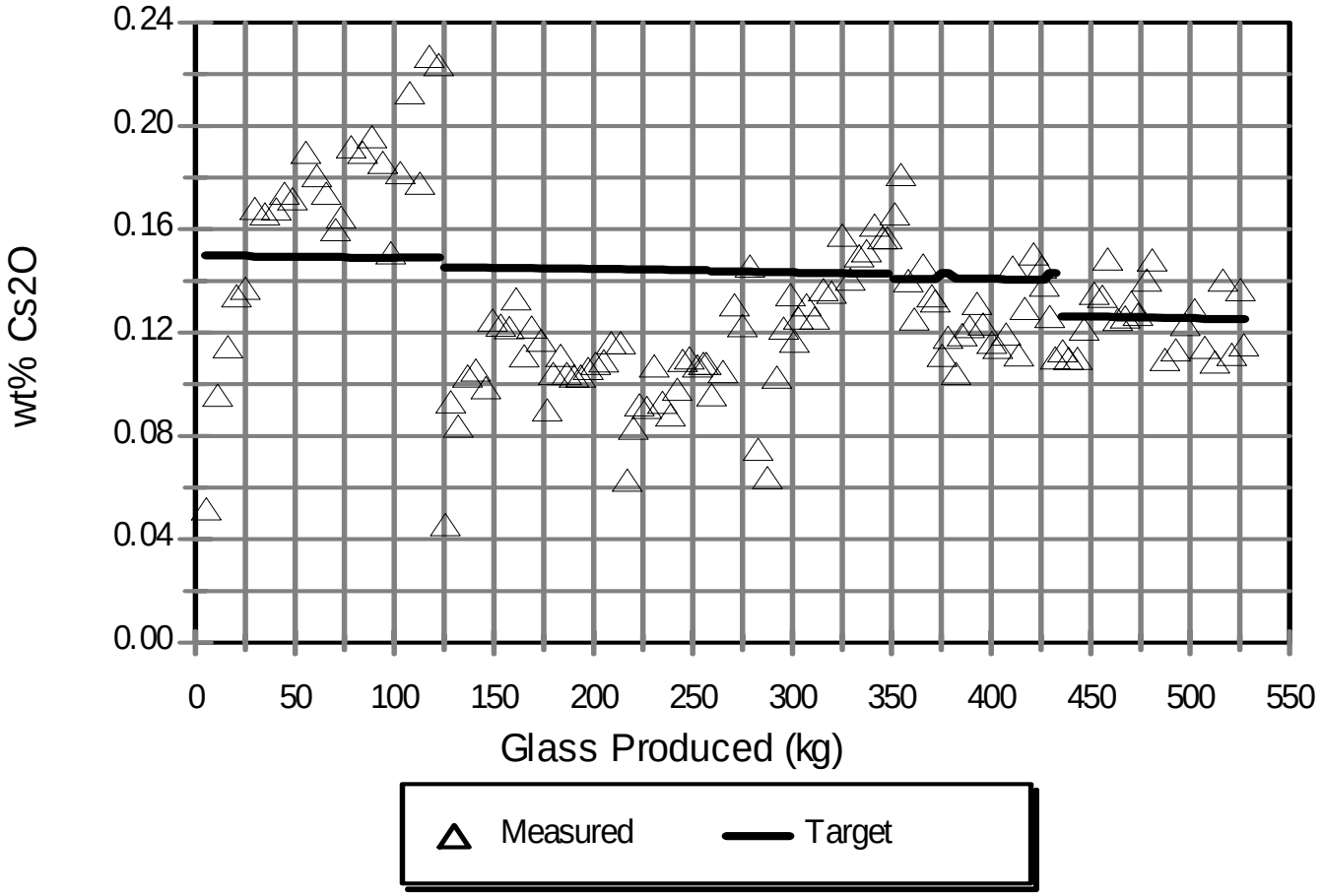


Figure 4.13. XRF analysis of cesium in DM10 product glasses.

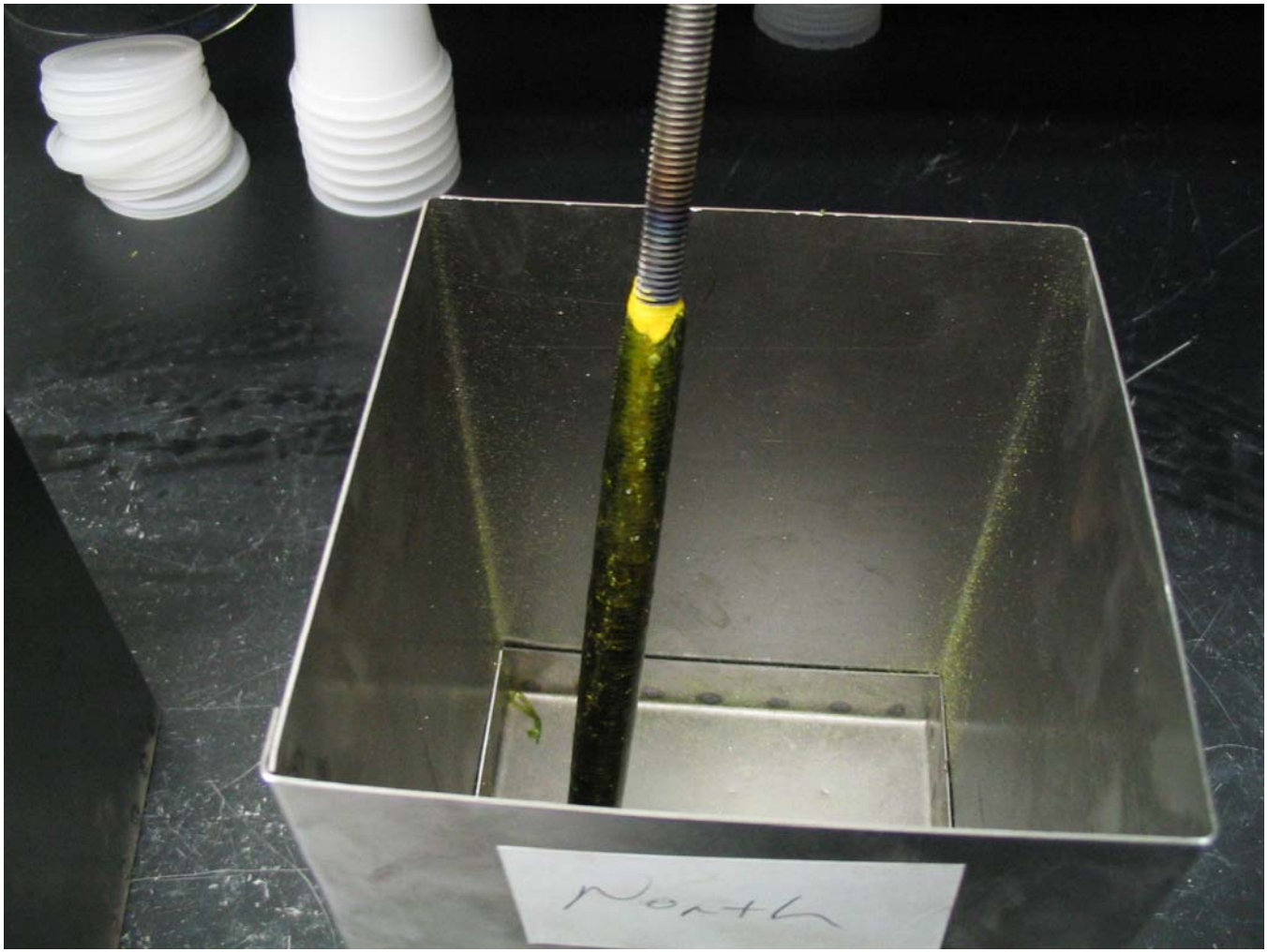
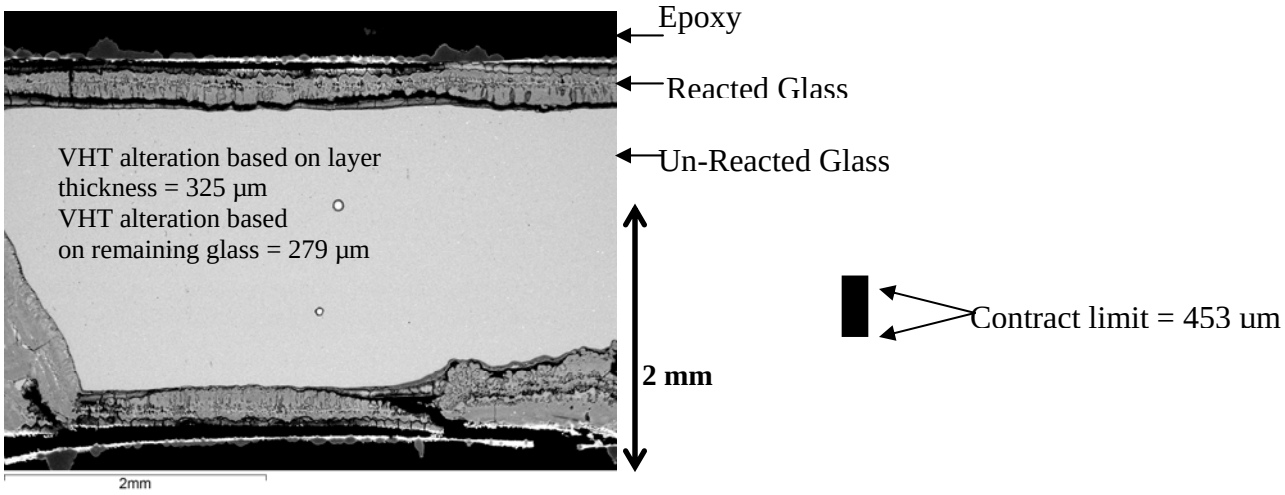


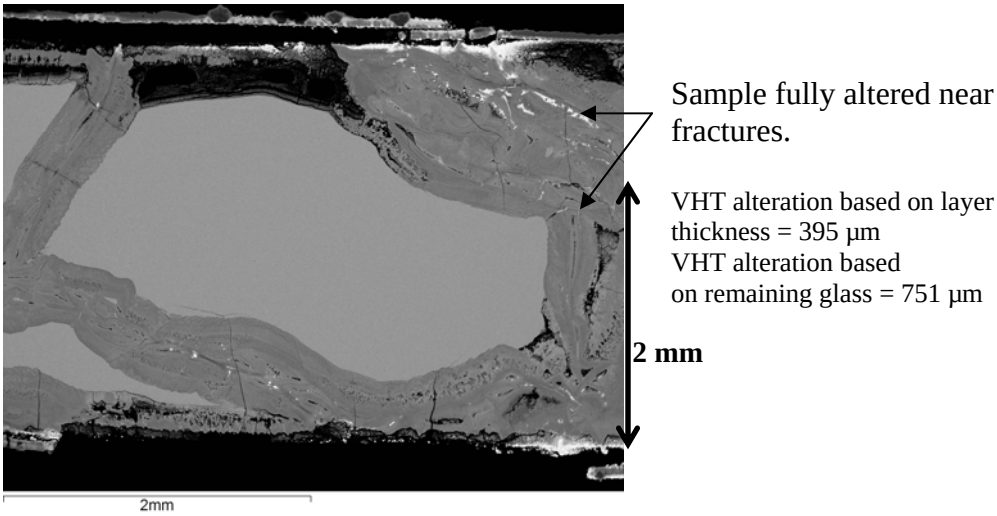
Figure 4.14. Secondary sulfur phases on dip sample Q10-D-148C from the end of Test 1D.

Figure 4.15. Secondary sulfur phases on dip samples S10-D-110A, B, and C from the end of Test 4D.

Figure 4.16. Secondary sulfur phases on dip sample T10-D-24D from the end of Test 5D.

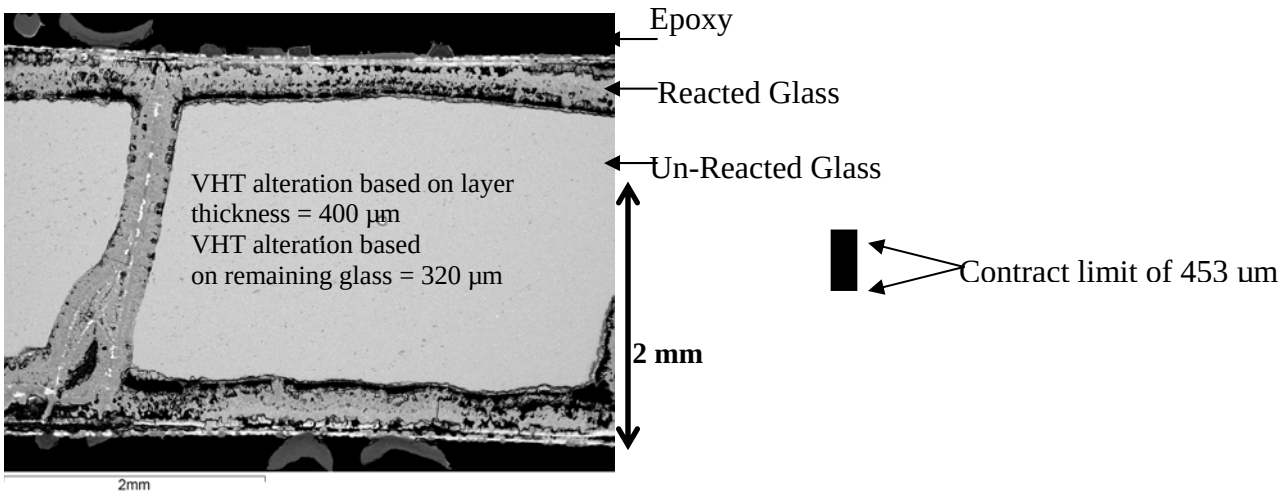


4.17 a. SEM image of cross section of crucible glass ORPLA15S4 after VHT

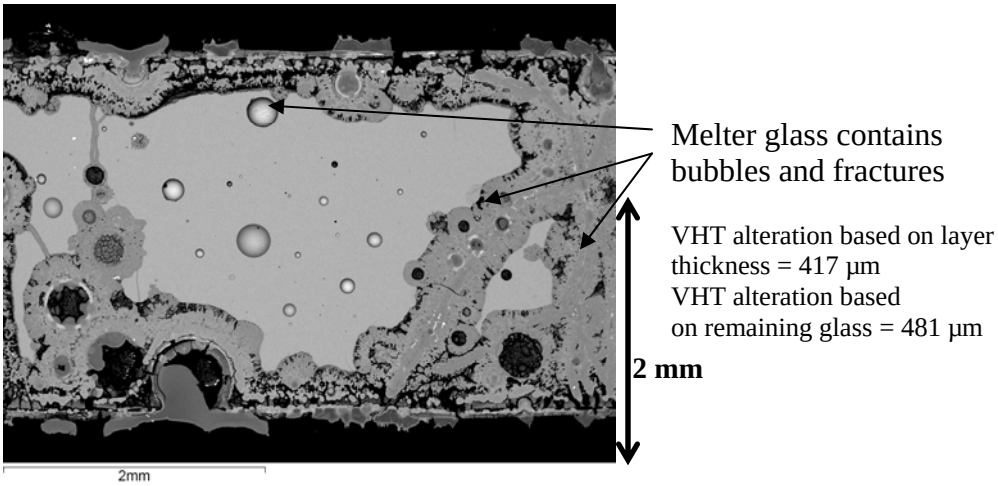


4.17 b. SEM image of cross section of DM10 melter glass R10-G-155A-remelt after VHT

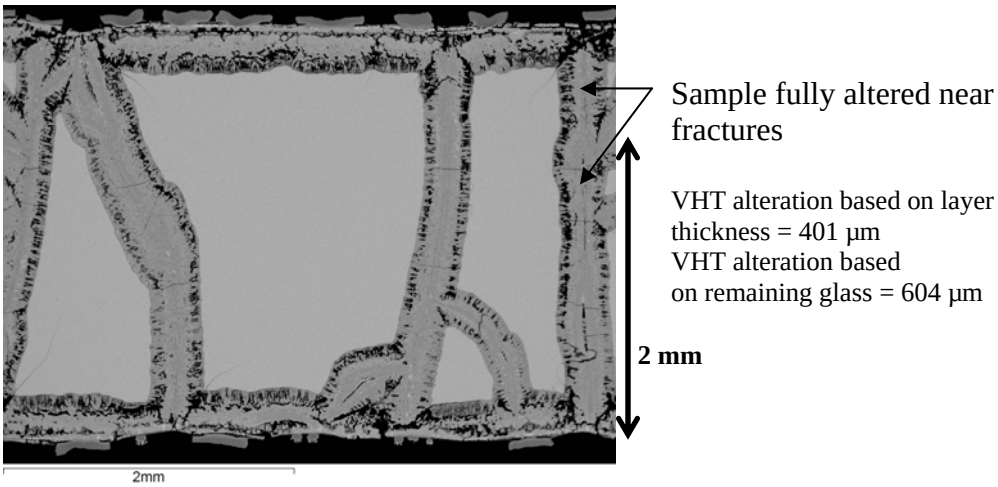
Figure 4.17. Comparison of VHT coupons for glass formulation ORPLA15.



4.18 a. SEM image of cross section of crucible glass ORPLB4S4 after VHT

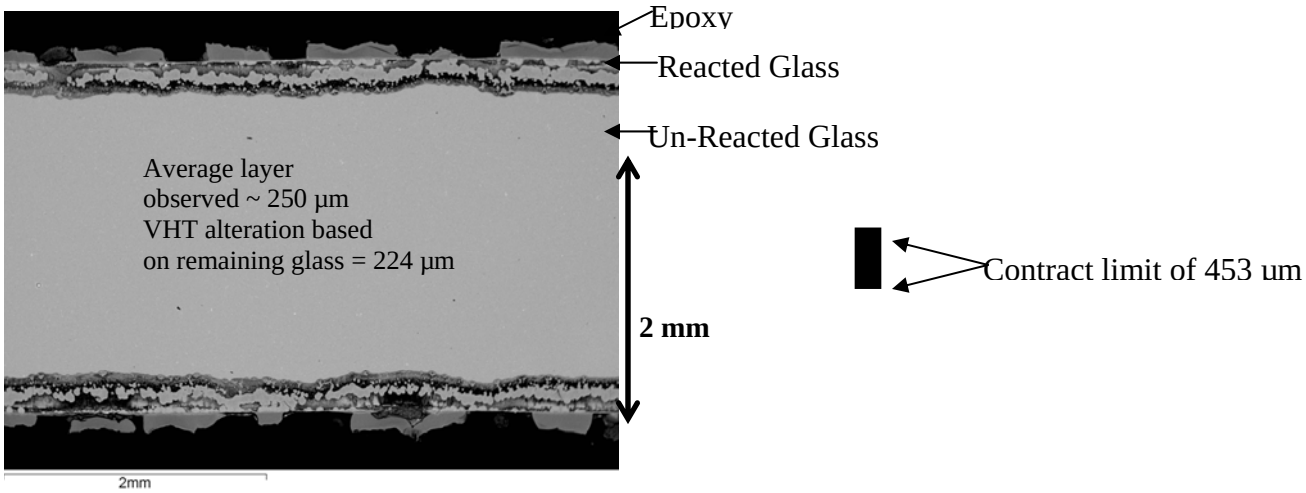


4.18 b. SEM image of cross section of DM10 melter glass S10-G-45A after VHT

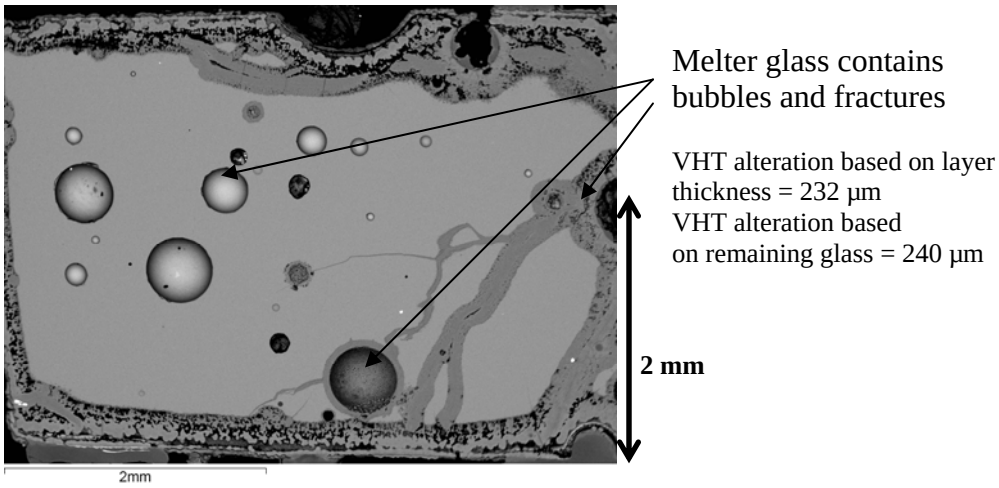


4.18 c. SEM image of cross section of DM10 melter glass S10-G-45A-remelt after VHT

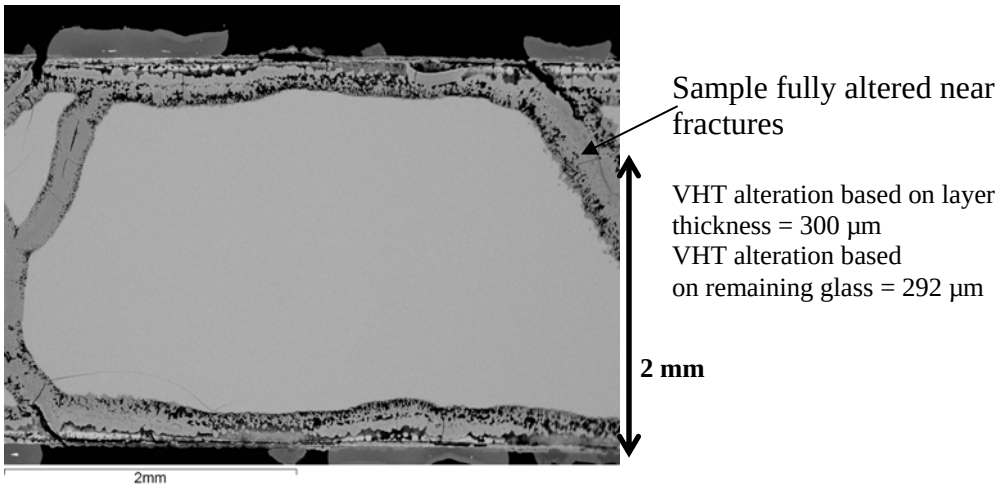
Figure 4.18. Comparison of VHT coupons for glass formulation ORPLB4.



4.19 a. SEM image of cross section of crucible glass ORPLC5S4 after VHT



4.19 b. SEM image of cross section of DM10 melter glass S10-G-110B after VHT



4.19 c. SEM image of cross section of DM10 melter glass S10-G-110B-remelt after VHT

Figure 4.19. Comparison of VHT coupons for glass formulation ORPLC5.

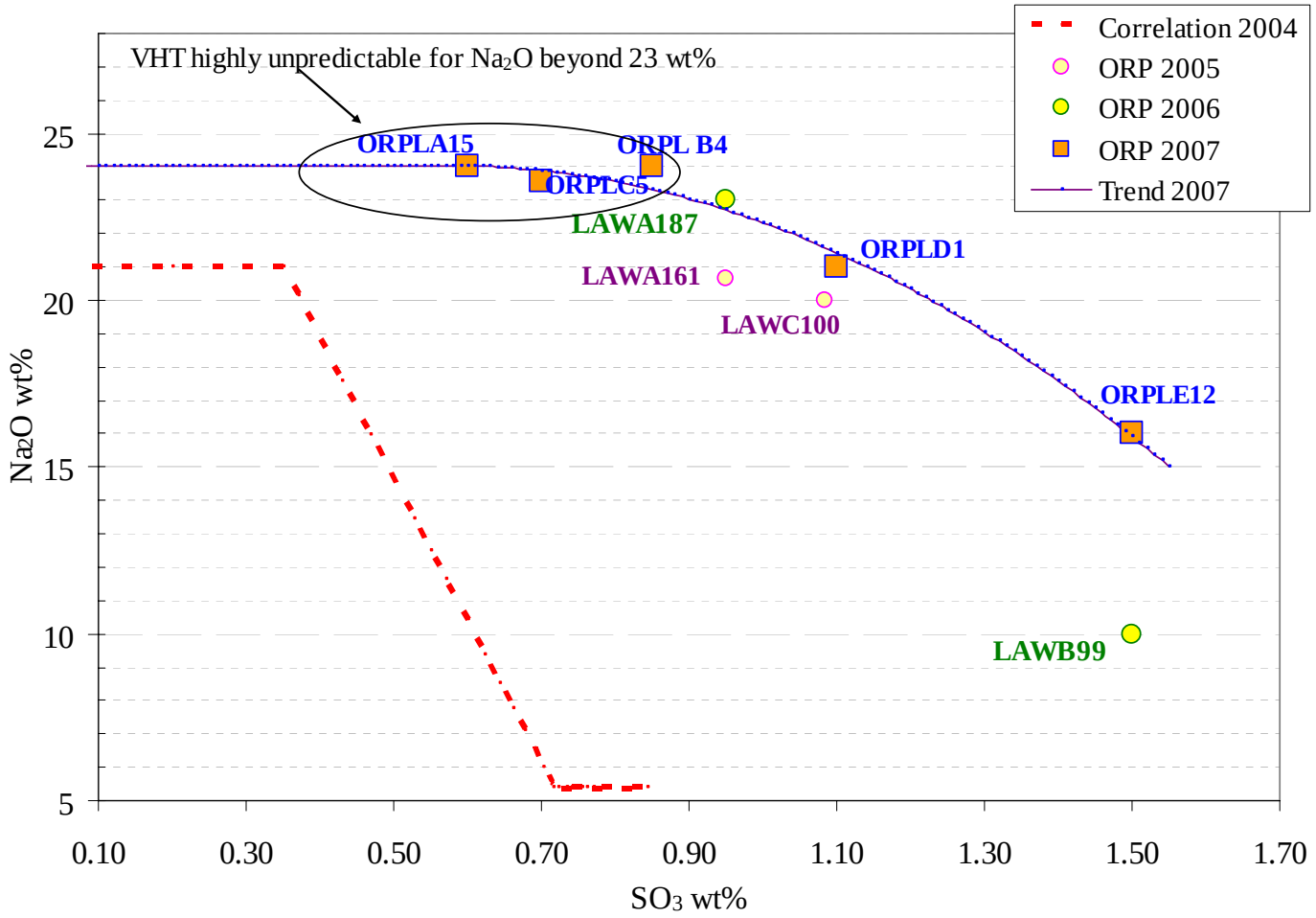


Figure 5.1. Overview of Na_2O and SO_3 loadings for WTP and ORP glasses.