

DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelope A2 and B1 Feeds in Support of the LAW Pilot Melter

(VSL-03R3410-1 March 28, 2003)

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

Office of River Protection

P.O. Box 450
Richland, Washington 99352

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Department of Energy - Office of River Protection

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VSL-03R3410-1

Final Report

**DuraMelter 100 Sub-Envelope Changeover Testing Using LAW
Sub-Envelope A2 and B1 Feeds in Support of the LAW Pilot Melter**

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prepared by

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Washington, DC 20064**

for

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For W. Tanosenti

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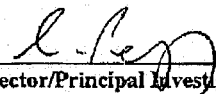
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R&T Focus Area(s): LAW Vitrification

Test Scoping Statement(s): VL-04

Completeness of Testing:

This report describes the results of work and testing specified by the above-listed Test Specification(s), Test Plan(s), and Text Exception(s). The work and any associated testing followed established quality assurance requirements and was conducted as authorized. The descriptions provided in this test report are an accurate account of both the conduct of the work and the data collected. Results required by the Test Plan are reported. Also reported are any unusual or anomalous occurrences that are different from the starting hypotheses. The test results and this report have been reviewed and verified.

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List of Abbreviations

AA	Atomic Absorption Spectroscopy
ADS	Air Displacement Slurry
DCP-AES	Direct Current Plasma Atomic Emission Spectroscopy
DF	Decontamination Factor
DM	DuraMelter®
DOE	Department of Energy
DRE	Destruction & Removal Efficiency
EPA	Environmental Protection Agency
FTIR	Fourier Transform Infrared Spectroscopy
GC	Gas Chromatography
HEPA	High-Efficiency Particulate Air Filter
HLW	High Level Waste
LAW	Low Activity Waste
QA	Quality Assurance
QAPjP	Quality Assurance Project Plan for Testing Programs Generating Environmental Regulatory Data
QAPP	Quality Assurance Project Plan
QC	Quality Control
RPP	River Protection Project
RPP-WTP	River Protection Project-Waste Treatment Plant
VSL	Vitreous State Laboratory
WTP	Waste Treatment and Immobilization Plant
XRF	X-Ray Fluorescence

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SUMMARY OF TESTING

A) Objectives

This report provides the results from tests that were performed on a DM100 system with LAW Sub-Envelope A2 and B1 feeds in support of the subsequent Pilot Melter tests.

The principal objectives of the DM100 tests were to determine the processing characteristics as the simulated melter feed transitioned from the LAW Sub-Envelope A2 to the Sub-Envelope B1 composition. Of particular interest was the presence or absence of secondary salt phases because of their potential deleterious effects on melter lifetime and product quality.

B) Conduct of Testing

The tests were performed using the DM100-WV vitrification system installed at the Vitreous State Laboratory. The LAW Sub-Envelope A2 feed was fed for a period of 50 hours followed by the LAW Sub-Envelope B1 feed for a further period of 50 hours. Key operating parameters including cold cap coverage, feed rate, and glass pool temperature were held constant to investigate the effects of each of the feeds on processing characteristics (including formation of a separate sulfate phase) and the product glass. The bubbling rate was adjusted to provide the desired feed rate with a near-complete cold cap (90-100% of melt surface covered with feed). Quantitative measurements of glass production rates, melter operating conditions (temperatures, pressures, power, flows, etc.), and off-gas characteristics (NO_x , SO_2 , CO , CO_2 , H_2 , gaseous iodine, particulate load and composition, and other acid gases) were made for each test.

The DM100-WV unit is a ceramic refractory-lined melter fitted with a pair of opposing Inconel 690 plate electrodes as well as a bottom electrode. A bubbler is used for stirring the melt pool; this bubbler enters from the top and is removable. The glass product is removed from the melter by means of an air-lift discharge system. The DM100-WV has a melt surface of 12 X 14 inches, giving a melt surface area of 0.108 m². The nominal depth of the melt pool is about 19 inches, which gives a typical glass inventory of between 115 and 120 kg. The plenum height is 27.5 inches. Temperatures are monitored by means of a series of thermocouples located in the melt pool, the electrodes, the plenum space, and the discharge chamber.

The DM100-WV 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. Consequently, under steady-state operating conditions, the exhaust gases passing through the transition line (between the melter and the first filtration device) can be sampled at constant temperature and airflow rate. The geometry of the transition line 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°C while

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the temperatures in the HEPAs are kept sufficiently high 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.

C) Results and Performance against Objectives

Tests were conducted on the DM100 vitrification system to assess the robustness of LAW formulations with respect to changeover from a Sub-Envelope A2 to a Sub-Envelope B1 composition. The results showed that the melt pool transition occurred without formation of a separated sulfate phase on the melt pool surface. A separate sulfate phase that did form prior to testing was easily removed by gently bubbling the melt pool while increasing the temperature back to 1150°C. The test results also showed that the system tolerated the glass pool compositional variations with respect to processing behavior, glass production rate, and product quality. The total particulate emissions from the melter were relatively high (0.89 wt. %) for the Sub-Envelope A2 as a result of the high feed concentration of volatile alkali halides. Melter DFs were determined for each element in the feed for both Sub-Envelope A2 and B1 feeds. Of the more volatile species, DFs for halogens and sulfur were less than 10. Good mass balance closure was obtained for volatile constituents including sulfur, chlorine, and iodine.

Based on the results of these tests, the feeds were accepted for subsequent larger-scale testing on the LAW Pilot Melter.

D) Quality Requirements

This work was conducted under an NQA-1 (1989) and NQA-2a (1990) Part 2.7 based quality assurance program that is in place at the VSL. This program is supplemented by a Quality Assurance Project Plan for RPP-WTP work that is conducted at VSL. The program is supported by VSL standard operating. This work is not subject to DOE/RW-0333P.

E) Issues

No significant issues were identified.

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SECTION 1.0 INTRODUCTION

The Vitreous State Laboratory at The Catholic University of America (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 [1]. 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) [2-9] and, ultimately, in the LAW Pilot Melter [10-16]. 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 pilot-scale tests and that the most effective use is made of that resource. The principal objective of the work described in this report was to collect the necessary small-scale melter test data to support a series of tests on the LAW Pilot Melter.

A previous series of tests on the LAW Pilot Melter was directed towards demonstration of the ability to process flow-sheet levels of sulfate following the decision to delete the sulfate removal process from pretreatment [10-16]. Those tests were based on supporting crucible and small-scale melter tests [1-9, 17]. Effects of variations in feed composition on processing also were evaluated during these tests. High-sulfate feeds based on tank compositions from each waste envelope (A, B, and C) were used for those tests. Another set of tests on the LAW Pilot Melter is intended to determine the processing characteristics of the feed as it transitions from one composition to the next [18]. The process should be able to accommodate these transitions without deleterious consequences such as the formation of a separate sulfate phase on the molten glass pool, unfavorable processing behavior, or adverse feed rheology or melt and glass product properties. The second of these tests on the LAW Pilot Melter was designed to evaluate the processing characteristics as the simulated melter feed transitions from the LAW Sub-Envelope A2 to the Sub-Envelope B1 composition [18]. The present report provides the results from tests that were performed on a DM100 system with LAW Sub-Envelope A2 and B1 feeds in support of the subsequent Pilot Melter tests. This work was performed under a corresponding Test Specification [18] and Test Plan [19].

1.1 Test Objectives and Success Criteria

The principal objectives of the DM100 tests were to determine the processing characteristics as the simulated melter feed transitioned from the LAW Sub-Envelope A2 to the Sub-Envelope B1 composition. The DM100-WV was used for all of the previous tests on LAW A, B, and C Sub-Envelopes [2-9] that were used to support the subsequent tests on the Pilot Melter [10-16]. The same melter was selected for the present tests in order to maintain

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comparisons between the data sets. In addition, the somewhat smaller glass volume for the same melt surface area means that more glass turnovers are achieved for a given test duration.

Two DM100 melter tests were conducted using the nominal LAW Sub-Envelope A2 and B1 feeds. Based on the results of these tests, the same feeds were used at a larger scale in subsequent Pilot Melter tests. Supporting crucible melt studies were performed at VSL to ensure that no sulfate phase separation was expected during this transition. However, one of the objectives of this test was to confirm that only single-phase glass was being produced prior to exposing the LAW Pilot Melter to these feeds. The melter was examined at the end of the feeding period to verify that no sulfate phase accumulation had occurred. The cost of the large-scale Pilot Melter tests, the capital investment in that asset, and the potential deleterious effects of either molten sulfate salts or reduced sulfides necessitate smaller-scale testing before advancing any approach to pilot-scale testing. Crucible-scale tests were conducted prior to the melter tests to confirm that the glasses and feeds are processable in the melter and that the glasses meet the waste form (ILAW) performance requirements. Crucible-scale tests were conducted using glass compositions at the two end-points and at 25%, 50%, and 75% composition turnover. The Test Specification [18] lists 24 objectives of which 9 were addressed fully or partially in this work. The remainder of the objectives will be accomplished at the LAW Pilot Melter, either during this test or in subsequent tests.

The major objectives of these tests were to:

- Perform analyses, laboratory and small-scale melter testing, as required, to assess and specify "working glass" compositions, and additives utilizing the estimated LAW feed composition in Appendix C of the Test Specification [18] (Test Specification Objective 1).
- Sample molten glass at least once per Sub-Envelope to ensure the absence of a separate sulfate layer (Test Specification Objective 10).
- Sample molten glass during melter composition changeover batch to ensure absence of secondary phase formation (Test Specification Objective 11).
- Obtain the necessary process measurements on the DM100 and DM3300 melters to enable melter scale-up. Operate the DM100 melter in a manner consistent with the DM3300, such that data are comparable for scale-up (Test Specification Objective 12).
- Quantify and document the occurrence and associated operating conditions of any melter off-gas volume surging events (Test Specification Objective 13).
- Characterize the chemical and physical characteristics of each batch of pretreated waste simulant and melter feed (Test Specification Objective 14).

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- Once each for Envelopes A, B, and C feeds and each melter platform (DM100, DM3300), complete physical and rheological characterization in accordance with 24590-WTP-GPG-RTD-001, *Guidelines for Performing Chemical, Physical, and Rheological Properties Measurement*. The samples and sample concentrations (i.e., sodium molarities) shall be selected such that the physical and rheological data are comparable with existing or planned actual waste data, simulant lab-scale data, simulant DM100 scale data and simulant DM3300 scale data (Test Specification Objective 15).
- Utilize only WTP Project approved glass former chemicals (GFCs) as defined in SRT-RPP-2002-00034, *Selection of HLW and LAW Glass Formers*, dated February 6, 2002 (Test Specification Objective 16).
- Collect and analyze discharged glass to determine sulfur retention in the glass and to complete mass balance for components of interest. Collect melter emissions data to determine the effect of composition on melter emissions and to complete mass balance for components of interest such as sulfur (Test Specification Objective 18).

The measures of success with respect to achieving these objectives are [18]:

- Completion of glass formulation and feed testing and recommendation of "working glass" compositions and feeds for melter tests using LAW Sub-Envelope A2 and B1 feeds. This included testing of the changeover glasses prepared at the crucible scale for compliance with ILAW performance requirements including PCT and VHT (Test Specification Objective 1).
- Collection of dip samples of the melter glass and their analysis to demonstrate the absence of a separate sulfate layer accumulation (Test Specification Objective 10).
- Collection of dip samples of the melter glass during composition changeover and their analysis to demonstrate the absence of secondary phase formation (Test Specification Objective 11).
- Collection of process data to enable melter scale-up. (Test Specification Objective 12).
- Documentation of operating conditions associated with any off-gas volume surging events (Test Specification Objective 13).
- Sampling and characterization of each batch of simulated melter feed obtained from Optima and characterization of waste simulant and melter feed prepared at the VSL (Test Specification Objective 14).

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- Submit data and analysis of complete physical and rheological characterization in accordance with 24590-WTP-GPG-RTD-001, *Guidelines for Performing Chemical, Physical, and Rheological Properties Measurements* for each Envelope (A, B, and C) and each melter platform (DM100, DM3300). Comparisons shall be made between actual waste data, simulant lab-scale data, simulant DM100 scale data and simulant DM3300 scale data and a judgment of the validation or adequacy of the LAW pretreated waste and melter feed simulants shall be rendered. This analysis may be presented in a separate, consolidated report for LAW simulant validation. (Test Specification Objective 15).
- Utilization of WTP Project approved GFC's in the preparation of simulated melter feed used in the DM100 melter tests (Test Specification Objective 16).
- Collection and analysis of glass samples to determine sulfur retention in the glass and completion of mass balance calculation for components of interest. Collection of supporting off-gas characterization data. (Test Specification Objective 18).

The tests were performed using the DM100-WV vitrification system installed at the Vitreous State Laboratory. The LAW Sub-Envelope A2 feed was fed for a period of 50 hours followed by the LAW Sub-Envelope B1 feed for a further period of 50 hours. Key operating parameters including cold cap coverage, feed rate, and glass pool temperature were held constant to investigate the effects of each of the feeds on processing characteristics (including formation of a separate sulfate phase) and the product glass. The bubbling rate was adjusted to provide the desired feed rate with a near-complete cold cap (90-100% of melt surface covered with feed). Quantitative measurements of glass production rates, melter operating conditions (temperatures, pressures, power, flows, etc.), and off-gas characteristics (NO_x , SO_2 , CO , CO_2 , H_2 , gaseous iodine, particulate load and composition, and other acid gases) were made for each test.

1.2 Quality Assurance

This work was conducted under an NQA-1 (1989) and NQA-2a (1990) Part 2.7 based quality assurance program that is in place at the VSL. This program is supplemented by a Quality Assurance Project Plan for RPP-WTP work [20] that is conducted at VSL. The program is supported by VSL standard operating procedures that were used for this work [21]. This work is not subject to DOE/RW-0333P.

1.3 Melter System Description

1.3.1 Feed System

A schematic diagram of the DM100 vitrification system is shown in Figure 1.1. The melter feed is introduced in batches into a feed container that is mounted on a load cell for

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weight monitoring. The feed is stirred with a variable speed mixer and constantly recirculated except for periodic, momentary interruptions during which the weight is recorded. The way in which the feed is introduced into the melter is designed to mimic the operation of an ADS pump, which is the present RPP-WTP baseline. The recirculation loop extends to the top of the melter where feed is diverted from the recirculation loop into the melter through a Teflon-lined feed line and water-cooled feed tube. Two computer operated pinch valves, one on the feed line and one on the recirculation loop, are activated in a timed sequence to introduce feed into the melter at the desired rate. The feed rate is regulated by adjusting the length of each pulse, the time between each pulse, and the pressure applied to the recirculation loop. A compressed air line is attached to the feed line and can be used to automatically clear the feed line into the melter after each pulse. The feed enters the melter through a water-cooled, vertical feed tube.

1.3.2 Melter System

Cross-sectional diagrams through the DM100-WV melter are shown in Figures 1.2a-c. The DM100-WV unit is a ceramic refractory-lined melter fitted with a pair of opposing Inconel 690 plate electrodes as well as a bottom electrode. The melter can be operated with either three-phase or single-phase power. However, the standard mode of operation, which was used for these tests, is single-phase with voltage applied to the side electrodes only. The bubbler used for stirring the melt pool enters from the top and is removable. The glass product is removed from the melter by means of an air-lift discharge system. The DM100-WV has a melt surface of 12 X 14 inches, giving a melt surface area of 0.108 m². The nominal depth of the melt pool is about 19 inches, which gives a typical glass inventory of between 115 and 120 kg. The plenum height is 27.5 inches. Temperatures are monitored by means of a series of thermocouples located in the melt pool, the electrodes, the plenum space, and the discharge chamber.

1.3.3 Off-Gas System

For operational simplicity, the DM100-WV 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. Consequently, under steady-state operating conditions, the exhaust gases passing through the transition line (between the melter and the first filtration device) can be sampled at constant temperature and airflow rate. The geometry of the transition line 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°C while the temperatures in the HEPAs are kept sufficiently high 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.

SECTION 2.0 WASTE SIMULANT AND GLASS FORMULATIONS

2.1 Waste Simulants

The Sub-Envelope A2 and B1 waste simulants are based on composition data for tanks AP-101 and AZ-101, respectively, given in the Test Specification [18]. The sodium concentration in the LAW Sub-Envelope A2 simulant was increased by 2.56% and the sodium concentration in the LAW Sub-Envelope B1 simulant was increased by 5.33% to account for sodium additions in pretreatment [1, 22]. The sulfate contents in both the simulants were then increased to represent recycle from the off-gas treatment system to the melter feed assuming that 15% and 30% of the sulfur in the feed reports to the off-gas stream for Sub-Envelopes A2 and B1, respectively [23]. The chlorine concentrations were increased by 111% and fluorine concentrations were increased by 19% to account for recycle [23]. Sulfur, chlorine, and fluorine from recycle streams were added as the respective sodium salts. The nominal feed concentration, expressed in terms of the sodium molarity, was determined on the basis of melter feed rheology tests on similar formulations [24]. The results of those tests led to the selection of 8.0 molar sodium as the nominal simulant concentration for Sub-Envelope A2 and 2.75 molar sodium as the nominal simulant concentration for Sub-Envelope B1. Since the waste loading for LAW Sub-Envelope B1 is low, large quantities of glass former chemicals need to be added to the melter feed. Therefore, it was necessary to start with a correspondingly more dilute simulant in order to produce a viable melter feed.

The nominal simulant formulations for LAW Sub-Envelope A2 and B1 are shown in Tables 2.1 and 2.2, respectively. The resulting Sub-Envelope A2 simulant is a solution of predominantly sodium, potassium, aluminum, hydroxide, and nitrite. The Sub-Envelope B1 simulant is mainly a solution of sodium, aluminum, hydroxide, nitrite, and nitrate. Samples of the simulant were prepared according to Tables 2.1 and 2.2 and tested at VSL.

2.2 Glass Formulation

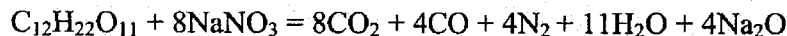
The feed additives were selected on the basis of glass formulation studies, which included optimization with respect to sulfate incorporation and prevention of formation of a separate sulfate phase [1-17], and rheological testing [24]. Project-directed glass forming chemicals [25] were used in the tests. LAWA126 has been identified as a suitable glass composition for the Sub-Envelope A2, AP-101 waste. LAWB83 has been selected as the composition for the Sub-Envelope B1, AZ-101 waste. The compositions of LAWA126 and LAWB83 glasses are shown in Table 2.3. The additive sources are shown in Tables 2.4 and 2.5 for Sub-Envelope A2 and Sub-Envelope B1, respectively. Glass formulations used in this work include the two end compositions, LAWA126 and LAWB83, along with those at 25%, 50% and 75% composition changeover, as shown in Table 2.3.

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2.3 Sugar Additions

The addition of reductants to high nitrate feeds 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 Duratek 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 RPP-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 ratio" of 1.0 as a result of concerns for over-reducing the melt. Such a reaction, using sodium salts as an example, is:



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 Sub-Envelope A2 feed to achieve a sugar ratio of 0.5 proceeds as follows:

- One liter of simulant contains 1.263 moles of nitrite and 2.953 moles of nitrate, giving a total of 4.216 moles of NO_x (see Table 2.1)
- Required total amount of organic carbon for a sugar ratio of 0.5 is $4.216 \times 0.75 = 3.162$ moles
- One liter of simulant contains 0.227 moles of organic carbon (see Table 2.1)
- Therefore, $3.162 - 0.227 = 2.935$ moles of organic carbon must be added.

Since the molecular weight of sucrose is 342 g per mole, $2.935 \times 342/12 = 83.66$ g sugar must be added per liter of simulant, as shown in Table 2.4.

2.4 Preparation of Melter Feed

Optima Chemicals, which has supplied all of the LAW simulants for the previous DM100 and LAW Pilot Melter studies, prepared the simulant and added most of the glass forming chemicals for the feed before shipment to VSL in 55-gallon drums. Sugar was added at VSL. Potassium iodide (KI) at sufficient concentration to provide 0.1 wt% in the product glass (if all of it were retained in the glass) was added to the feed to determine the partitioning of iodine between the glass phase and the gas phase.

2.5 Analysis of Feed Samples

2.5.1 General Properties

Feed samples were analyzed from each received feed batch and from each test that was conducted to confirm physical properties and chemical composition. Sample names, sampling dates, and measured properties are provided in Table 2.6. Average analyses from other Sub-Envelope A2 and B1 melter feed samples are provided for comparison [7, 8]. Measured values for glass yield were less than 10 percent below target and the water contents were similar percentages above target values (see Tables 2.4 and 2.5). In view of the small difference, the target values were used in all of the production rate calculations. Although the glass composition for the previous and current LAW Sub-Envelope B1 formulations are the same, the most recent waste composition promulgated by the Project [18] has a higher hydroxide concentration hence a higher pH. The Sub-Envelope A2 15%-variation values for glass conversion ratios, water content, and pH bracket the current nominal concentration despite the recent change in waste composition.

2.5.2 Rheology

Samples of the melter feeds that were used for these tests were also subjected to rheological characterization. The results from rheological characterization of a variety of other melter feeds and waste simulants, as well as the effects of a range of test variables, are described in detail in a separate report [24]. Melter feeds were characterized using a Haake RS75 rheometer, which was equipped with either a Z40DIN or a FL22-SZ40 sensor. A typical set of measurements consists of identifying the flow characteristics of the slurry by measuring the shear stress on the slurry at controlled shear rates and temperatures. In these measurements, the shear rate values are preset and are increased stepwise from 0.01 s^{-1} to 200 s^{-1} (70 s^{-1} for FL22-SZ40) with a sufficient delay (typically 15 to 30 seconds) between steps to ensure that shear stress is allowed to fully relax and therefore measured at equilibrium. This approach is somewhat different than the "flow curve" approach in which the shear rate is ramped up to some maximum value and then ramped back down to produce a hysteresis curve that is dependent on the selected ramp rate. In contrast, the present measurements are equilibrium values of the shear stress at each measured shear rate. The viscosity of the sample as a function of the shear rate is then calculated as the ratio of the shear stress to the shear rate. The yield stress data for the melter

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feeds were measured using a controlled-stress mode in which the torque on the rotor was slowly increased while the resulting deformation of the fluid was monitored. The discontinuity in the measured deformation-torque curve was identified as the yield stress. It should be noted that this direct measurement of the yield stress can be quite different from the value that is often reported as the yield stress, which is obtained by extrapolation of the shear stress-shear rate curve to zero shear rate. All of the measurements in this work were made at 25°C; previous work [24], which examined a range of temperatures, showed a relatively weak effect of temperature.

Rheograms for the present and previous [7,8] DM100 melter feeds which show the feed viscosity versus shear rate, are compared in Figure 2.1; measured values for viscosity at selected shear rates and the yield stress values are shown in Table 2.6. The LAW Sub-Envelope B1 feed samples from the current melter tests are less viscous than the corresponding samples from the previous tests. The decreased viscosity and yield stress are presumably due to the higher water content and increased hydroxide content. The current LAW Sub-Envelope A2 feed samples have similar rheological properties to the previous + 15% simulant variation although the water content is more similar to the previous - 15% simulant variation. Again, this difference is likely attributable to the difference in hydroxide contents. No problems were encountered in pumping, mixing, or processing either of the feeds.

2.5.3 Chemical Composition

The chemical compositions of the feed samples were determined by first making a glass from the feed via crucible melt. The glass was subsequently crushed and analyzed directly by X-Ray Fluorescence Spectroscopy (XRF). Boron and lithium oxide target values were used for normalizing the XRF data since those elements were not determined by XRF. The data are compared to the target compositions in Table 2.7. These results generally corroborate the consistency of the feed composition and show good agreement with the target composition for the major elements. Two oxides with a target composition greater than one percent have a deviation greater than 10% for both feed compositions. The 18.5% excess in TiO₂ was observed in both formulations as well as glasses produced during the melter tests (see Section 4.1). A surplus in titanium has been documented in previous melter feeds [4-9]. The magnesium deficiency in the LAW Sub-Envelope A2 feed samples as well as the sodium surplus in the LAW Sub-Envelope B2 feed samples were also observed in the product glasses (1.27 wt.% MgO as opposed to the target 1.47 wt.% MgO and 6.76 wt.% Na₂O as opposed to the target 5.47 wt.% Na₂O, see Section 4.1) corroborating the feed analysis. The deviations from the target values are not considered significantly large to impact the test objectives. For both feeds, volatile minor elements such as sulfur, cesium, and halogens are below target due to loss during crucible melting of the feed samples.

2.5.4 Nitrate and Nitrite Analysis

The Test Plan specifies that nitrate and nitrite concentrations be measured in selected feed samples. This was accomplished by diluting an aliquot of feed with de-ionized water and

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subjecting the filtered diluted feed sample to ion chromatography. The method is based on the assumption that the ions in question are completely soluble and do not form any appreciable amounts of insoluble species in the feed. The results of this procedure are compared to the target values in Table 2.8. There is reasonable agreement between measured and target values, particularly for nitrite. Measured values for the LAW Sub-Envelope B1 were somewhat above the target values, whereas the opposite trend was observed for the LAW Sub-Envelope A2 sample.

SECTION 3.0 MELTER OPERATIONS

Melter tests were conducted on the DM100-WV with the LAW Sub-Envelope A2 and B1 simulants between 10/28/02 and 11/3/02, producing almost 900 kg of glass from approximately 1,700 kg of feed. All of the tests used nominal feed compositions and a sugar ratio of 0.5. The tests were divided as follows:

- Test 1A: LAW Sub-Envelope A2, bubbling to achieve 2000 kg/m²/day, 50 hrs
- Test 1B: LAW Sub-Envelope B1, bubbling to achieve 2000 kg/m²/day, 50 hrs

Table 3.1 provides summaries for each of the tests. Attempts were made to replicate the melter configuration and operating conditions used for the corresponding tests conducted earlier [2, 3], as well as the previous LAW Sub-Envelope [4-9] tests. These conditions include a near complete cold cap, which is between 80-95% melt surface coverage for the DM100, since a 100% cold cap tends to lead to "bridging" in smaller melters. Feeding was interrupted four times during testing. Three were brief interruptions to perform repairs (discharge air lift, film cooler air heaters, and bubbler), which had minimal impact on the test. Conversely, a building-wide water outage resulted in an idling period of over 30 hours during the first test segment. Temperatures throughout the plenum area increased during this period necessitating about an hour of water feeding to cool down the plenum prior to re-introduction of feed. Despite the interruptions, the target production rate of 2000 kg/m²/day was approximated during feeding for both segments, as depicted in Figure 3.1. As typically observed, production rates vary from the target at the onset of feeding while the cold cap becomes established; in addition, instantaneous rates varied by about 25% as a result of variable feed pulse sizes. The feeds and glass formulations met the acceptance criteria in that the required processing rates were achieved, no processing problems were observed, and a secondary sulfate phase was not observed at the end or during the changeover tests. The LAW Sub-Envelope B1 feed required noticeably longer mixing periods prior to use and had a greater tendency to settle solids in the feed tank; however, no interruptions were experienced due to feed system clogging. The feeds and changeover protocol were, therefore, accepted for further tests on the LAW Pilot Melter.

The results of various operational measurements that were made during these tests are given in Table 3.2. Glass temperatures are shown in Figure 3.2, plenum temperatures in Figure 3.3, and electrode and bubbler temperatures in Figure 3.4. Glass temperatures near the middle of the pool (10" from the floor) were close to the target glass temperature of 1150°C, averaging between 1142 and 1146°C for the two tests. Glass temperatures at the top of the melt pool are not reliable indicators of bulk glass temperatures as a result of their sensitivity to variations in the level of glass in the melter and gradients near the melt surface. Plenum temperatures typically ranged from 550 to 650°C, within the 450 to 650°C target. This is deliberately somewhat higher than for the larger melters (DM1200 and LAW Pilot Melter) in order to reduce cold cap bridging that occurs in the smaller melters. Temperatures in the glass near the surface as well as the plenum rose during feeding interruptions, as expected. The East and West electrode temperatures were within 10°C of each other and the glass temperature, while the bottom electrode was

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typically about 200°C cooler. The bubbler temperature was about 25°C higher than the side electrodes. About 10% less power was required to process the LAW Sub-Envelope A2 feed than for the Sub-Envelope B1 feed as a result of the higher nitrate + nitrite and, therefore, carbon content of the Sub-Envelope A2 feed. Power supplied to the electrodes typically varied within only 2 kW from the average value during feeding periods. Decreases in power are evident during the maintenance interruptions (e.g., at 114 hours run time) and during idling (at 20-45 hours run time).

Gas temperatures at the film cooler typically averaged between 308 and 318°C, depending on the plenum temperature, the amount of added film cooler air, and the temperature of the added film cooler air. Little or no drop in gas temperature was observed across the (insulated) transition line.

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SECTION 4.0 GLASS PRODUCTS

Almost 900 kg of glass was produced during these tests. The glass was periodically discharged from the melter into 5-gallon pails by use of 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. Product glass masses, discharge date, and analyses performed are given 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 as well as during the changeover to the LAW Sub-Envelope B1 composition. These "dip samples" underwent visual examinations to detect the presence of a separate sulfate phase on the glass surface as well as total inorganic compositional analysis.

4.1 Compositional Analysis

Discharge and dip glass samples were crushed and analyzed directly by XRF. 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 discharged glass samples are provided in Table 4.2. Analysis results for dip samples by XRF are provided in Table 4.3. All discharged glass samples were subjected to XRF analysis. Average percentages and percent deviation from target are calculated for each formulation after the melt pool was turned over with 300 kg of glass (about three times the glass inventory). The majority of the XRF analysis results compared very favorably to their corresponding target values. Deviations from target were similar to those observed in the feed samples: excess titanium for both formulations, low magnesium in the LAW Sub-Envelope A2 glasses, and excess sodium in the LAW Sub-Envelope B1 glasses. Unlike the feed samples, calcium concentrations in the LAW Sub-Envelope B1 glasses were slightly more than 10% below target. Compositional trends for selected oxides shown in Figures 4.1-4.3 illustrate the closeness to target and the consistency once the steady-state composition was reached. As the glass pool transitions from the LAW Sub-Envelope A1 composition present in the melt pool at the start of the test [29] to the LAW Sub-Envelope A2 composition, the only significant changes observed are in iron and potassium due to the similarity of the two LAW Sub-Envelope A feeds. Conversely as the melt pool transitions to the LAW Sub-Envelope B1 composition, more significant changes are evident, including increases in calcium, silicon, magnesium, and zinc at the expense of sodium and potassium. Several oxides derived from additives are common to most LAW formulations and are present at similar concentrations, including Al_2O_3 , TiO_2 , and ZrO_2 , and these, therefore, vary little during melt pool changeovers.

The concentrations of chlorine, cesium, and sulfur, all of which are relatively volatile, are plotted over the course of the tests in Figure 4.4. Sulfur concentrations rise over the course of testing in response to the increase feed sulfur content. The concentrations of SO_3 are near target during most of the LAW Sub-Envelope A2 processing and about 30% below target during most of LAW Sub-Envelope B1 processing. Cesium concentrations increased gradually over the

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course of testing but remained at or near target. The chlorine concentrations experienced the largest changes over testing due in part to the large difference in its concentration in the two formulations. Note the dramatic decrease in chlorine concentration while processing the low chlorine LAW Sub-Envelope B1 feed. Also notice the dip in chlorine concentration at about 150 kg of glass production, which is associated with the 30-hour idling period. Iodine was not detected in any of the glasses produced during processing of the LAW Sub-Envelope B1 feed but reached 0.03 wt% in the product glass (30% of target) while processing the LAW Sub-Envelope A2 feed. This trend is in keeping with results of previous studies showing the positive correlation of iodine retention and glass alkali content [4-9].

Glass dip samples were obtained at the beginning and end of each test, as well as after about 0.7 turnovers into the Sub-Envelope B1 test, primarily to ascertain whether a secondary sulfate layer had formed on the surface of the glass melt at the compositional midpoint of the changeover. Table 4.3 provides a listing of all of the dip samples together with their analyzed compositions and whether or not a separated salt phase was evident. Dip samples taken immediately after and during both changeover tests (WVM-D-144A, WVM-D-152A and WVN-D-32A) were all free of secondary phases, whereas dip samples taken after a period of idling at about 1050°C prior to testing (WVM-D-85B, WVM-D-85C) showed clear visual evidence of sulfate, indicating that a salt layer was present on the melt surface. After the secondary phase was detected, the melt pool was bubbled at about 2 lpm for approximately two hours while increasing the temperature to 1150°C. Additional dip samples taken after this process (WVM-D-85D) indicated that the sulfate on the melt surface had been reincorporated into the glass pool or had volatilized.

The sample taken after about 0.7 turnovers (WVM-D-152A) is consistent with the expected midpoint composition of the changeover, as is most clearly evident for the major oxides that show significant compositional changes, most notably CaO, K₂O, MgO, Na₂O and ZnO. The midpoint composition was also observed for chlorine and sulfur after accounting for volatilization.

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SECTION 5.0 MONITORED OFF-GAS EMISSIONS

5.1 Particulate Sampling

The melter exhaust was sampled for metals/particles according to 40-CFR-60 Methods 3, 5, and 29 at steady-state operating conditions during each test segment. The concentrations of off-gas species that are present as particulates and gaseous species that are collected in impinger solutions were derived from laboratory data on solutions extracted from air samples (filters and various solutions) together with measurements of the volume of air sampled. Particulate collection required isokinetic sampling, which entails removing gas from the exhaust at the same velocity that the air is flowing in the duct (40-CFR-60, Methods 1-5). Typically, a sample size of 30 dscf was taken at a rate of between 0.5 and 0.75 dscfm. Total particulate loading was determined by combining gravimetric analysis of the standard particle filter and chemical analysis of probe rinse solutions. An additional impinger containing 2 N NaOH was added to the sampling train to ensure complete scrubbing of all acid gases. The collected materials were analyzed using the following: direct current plasma atomic emission spectroscopy (DCP-AES) for the majority of the constituents, atomic absorption spectroscopy (AA) for cesium, and ion chromatography (IC) for anions. Melter emission fluxes are compared to feed fluxes in Table 5.1. Notice the distinction that is made between constituents sampled as particles and as "gas". The "gaseous" constituents are operationally defined as those species that are scrubbed in the impinger solutions after the air stream has passed through a 0.45 μm heated filter. Calculated isokinetic percentages for both samples were 91.1% and 94.1%, within the 90-110% prescribed by the method.

Particulate emissions from the melter were only 0.15% of feed solids for the Sub-Envelope B1 test and considerably higher at 0.89% of feed solids for the Sub-Envelope A2 test. This trend was expected given the higher alkali content of the Sub-Envelope A2 feed and previous observations that particulate melter emissions increase with increasing feed alkali content [2-9]. As expected, the feed elements emitted at the lowest melter decontamination factors (DFs) were clearly halogens and sulfur, with DF values between 1 and 10. Iodine was detected exclusively as gaseous emissions in both tests. Chlorine emissions were difficult to evaluate in the Sub-Envelope B1 test due to the low feed concentrations. All of the feed sulfur that was emitted in the Sub-Envelope A2 test was emitted as particles, whereas the majority of the sulfur emitted in the Sub-Envelope B1 test was emitted as gaseous species. This trend of increasing proportions of gaseous sulfur with decreasing alkali content has also been documented in previous studies [2-9]. Other elements exhibiting volatile behavior include cesium, chromium, potassium, and to a lesser degree, sodium. Boron, sulfur, and the halides were the only elements detected in the impinger solutions collected downstream of the heated particle filter in the sampling train, which constitutes the "gas" fraction of the melter emissions.

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5.2 Gases Monitored by FTIR

Melter emissions were monitored in each test for a variety of gaseous components, most notably CO 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 to prevent analyte loss due to condensation prior to monitoring. A summary of average concentrations monitored during each test is provided in Table 5.2. Concentrations of select monitored species are plotted in Figures 5.1 and 5.2. The analytes listed in Table 5.2 are those that were thought likely to be observed during the test, based on previous work; no other species were detected in the off-gas stream by FTIR. The most abundant gas monitored was NO, which is consistent with previous tests in which nitrates and nitrites were present in the feed. The concentration of NO was about five times higher than that of NO₂ for the Sub-Envelope A2 test and about seventeen times higher for the Sub-Envelope B1 tests. Emissions were higher for the Sub-Envelope A2 tests due to the higher feed concentrations of nitrates, nitrites and, therefore, carbon in the form of sugar. Similar to previous DM100 LAW tests [4-9], little SO₂ was detected throughout testing. Gaseous sulfur emissions detected using 40-CFR-60 Methods are probably sulfuric acid or SO₂ which was oxidized prior to reaching the down stream FTIR sampling port. The variations in emissions over the course of each test segment are due in part to the pulsed feed system and changes in the melt pool cold cap. Hydrogen concentrations, monitored near the end of the tests with a gas chromatograph, were below detection levels for both tests.

A nitrogen mass balance is summarized in Table 5.3. In both tests, about half of the feed nitrogen oxides was reduced to diatomic nitrogen in keeping with expectations for feed with a sugar ratio of 0.5. No difference in the nitrogen mass balance was observed as a function of simulant composition.

5.3 Mass Balance of Volatile Constituents

Table 5.4 provides the percentages of volatile feed constituents with target glass concentrations greater than 0.1 wt% (chlorine, cesium, iodine, and sulfur) that were retained in the glass product or identified in the various off-gas stream samples for each of the tests. The total recovery of each of the volatile feed constituents exceeded 94% of that present in the batched feed. The total for each of four LAW Sub-Envelope A2 volatile species were within six percent of mass balance closure. Cesium was retained in the glass at a high rate for both formulations, with greater than target values reporting to the glass for the LAW Sub-Envelope B1 formulation. Mass balance closure for chlorine was excellent for the LAW Sub-Envelope A2 formulation due in part to the relatively high feed concentration, whereas a good mass balance was not achieved with the LAW Sub-Envelope B1 formulation due to low feed concentration and the ubiquity of chlorine as a contaminant. LAW Sub-Envelope A2 feed chlorine was nearly equally divided between glass and particulate emissions with very little being emitted as gaseous species, similar to previous tests with high-chlorine feeds [9]. Both tests had a total sulfur recovery within 12% of that present in the batched feed. The majority of the feed sulfur was retained in the glass, about a tenth was emitted as particles, and about one-third was emitted as gaseous species in the LAW Sub-Envelope B1 test. Iodine was observed in the high-alkali LAW

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Sub-Envelope A2 product glasses but not in the lower-sodium LAW Sub-Envelope B1 glass. Iodine emissions were almost exclusively gaseous, accounting for as much as all of the feed iodine. The excellent mass balance closure result is in contrast to previous tests [4-7] where substantial percentages of feed iodine could not be accounted for in the glass product and emissions. The improved iodine recovery may be due to the increase in sodium hydroxide concentration from 0.1 N to 2 N in the sampling train impinger solution [9].

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SECTION 6.0 CONCLUSIONS

Tests were conducted on a DM100 vitrification system to assess the robustness of LAW formulations with respect to changeover from a Sub-Envelope A2 to a Sub-Envelope B1 composition. The results showed that the melt pool transition occurred without formation of a separated sulfate phase on the melt pool surface. A separate sulfate phase that did form prior to testing was easily removed by gently bubbling the melt pool while increasing the temperature back to 1150°C. The test results also showed that the system tolerated the glass pool compositional variations with respect to processing behavior, glass production rate, and product quality. The total particulate emissions from the melter were relatively high (0.89 wt. %) for the Sub-Envelope A2 as a result of the high feed concentration of volatile alkali halides. Melter DFs were determined for each element in the feed for both Sub-Envelope A2 and B1 feeds. Of the more volatile species, DFs for halogens and sulfur were less than 10. Good mass balance closure was obtained for volatile constituents including sulfur, chlorine, and iodine.

The completion of the Test Objectives for this work is summarized in Table 6.1. Based on the results of these tests, the changeover feeds were accepted for subsequent larger-scale testing on the LAW Pilot Melter.

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- [18] "LAW Pilot Melter and DM-100 Sub-Envelope Changeover Testing," E.V. Morrey, WTP Test Specification, 24590-LAW-TSP-RT-02-012, Rev. 0, August 13, 2002.
- [19] "DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelopes A2 and B1 Feeds in Support of the LAW Pilot Melter," K.S. Matlack, I.S. Muller, and I.L. Pegg, Test Plan, VSL-02T62N0-4, Rev. 0, 10/23/02.
- [20] "Quality Assurance Project Plan for RPP-WTP Support Activities Conducted by VSL," Vitreous State Laboratory, QAPP Rev. 4, 8/2/01.
- [21] "Master List of Controlled VSL Manuals and Standard Operating Procedures in Use," QA-MLCP, Rev. 3, May 7, 2002.
- [22] "Basis of Design," BNFL report, DB-W375-EG00001, Rev. 0, November 23, 1998.
- [23] "Halide Recycle," e-mail from E. Morrey to I. Joseph, 8/7/02.
- [24] "Physical and Rheological Properties of Waste Simulants and Melter Feeds for RPP-WTP LAW Vitrification," Final Report, I.S. Muller, H. Gan, and I.L. Pegg, VSL-00R3520-1, Rev. 0, 1/16/01.
- [25] "Selection of HLW and LAW Glass Formers," R.F. Schumacher, E.K. Hansen, SRT-RPP-2002-00034, 2/6/02.

Table 2.1. LAW Sub-Envelope A2 Simulant Recipe at 8 Molar Sodium.

Envelope Constituents	Simulant AP-101 Including Pretreatment		Glass Oxides	LAW A2 Simulant as Oxides (wt%)	Waste Contribution to Glass	Source in Simulant	Order for Addition	Formula Weight	Assay	Target Weight (g)
	mg/L	Molarity								
-			Loading		24.54 %	In 459.03 ml water add following compounds in the order listed below				
Al	9625	0.357	Al ₂ O ₃	5.455	1.339	Al(NO ₃) ₃ ·9H ₂ O, 60% sol.	7	375.14	0.61	220.51
B	12	0.001	B ₂ O ₃	0.011	0.003	H ₃ BO ₃	3	61.83	0.99	0.07
Cr	198	0.004	Cr ₂ O ₃	0.087	0.021	Na ₂ CrO ₄ ·4H ₂ O	1	234.04	0.99	0.91
Cs spike	1900	0.014	Cs ₂ O	0.604	0.148	CsNO ₃	2	194.91	1.00	2.79
K	43270	1.107	K ₂ O	15.634	3.837	KOH	6	56.10	0.91	68.37
Na	183920	8.000	Na ₂ O	74.363	18.250	NaOH, 50% sol. d=1.53	5	40.00	0.50	337.96
Si	157	0.006	SiO ₂	0.101	0.025	SiO ₂	4	60.09	0.99	0.34
Cl	2746	0.077	Cl	0.824	0.202	NaCl	9	58.45	0.99	4.57
F	4022	0.212	F	1.206	0.296	NaF	10	42.00	0.99	8.98
PO ₄	1415	0.015	P ₂ O ₅	0.317	0.078	Na ₃ PO ₄ ·12H ₂ O	8	380.12	0.99	5.72
SO ₄	5589	0.058	SO ₃	1.397	0.343	Na ₂ SO ₄	11	142.06	0.99	8.35
NO ₂	58110	1.263	NO ₂	-	-	NaNO ₂	15	69.00	1.00	87.60
NO ₃	183067	2.953	NO ₃	-	-	NaNO ₃	16	84.99	0.99	160.33
Org. Carbon	2718	0.227	-	-	-	-	-	-	-	-
Acetate	3025	0.051	-	-	-	Sodium Acetate (C2)	12	136.08	0.99	7.04
Formate	2213	0.049	-	-	-	Sodium Formate (C1)	13	68.01	0.99	3.38
Oxalate	3321	0.038	-	-	-	Sodium Oxalate (C2)	14	134.00	0.99	5.11
-	-	-	-	-	-	Target Glass Weight				1358.47
-	-	-	SUM	100.000	24.54	Total simulant Weight				1381.06

- denotes empty field

Table 2.2. LAW Sub-Envelope B1 Simulant Recipe at 2.75 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		6.71 %	In 832.96 ml water add following compounds in the order listed below				
Al	3273	0.121	Al ₂ O ₃	5.808	0.390	Al(NO ₃) ₃ ·9H ₂ O, 60% sol.	1	375.14	0.61	74.99
Cr	371	0.007	Cr ₂ O ₃	0.509	0.034	Na ₂ CrO ₄ ·4H ₂ O	6	234.04	0.99	1.70
Cs spike	2250	0.017	Cs ₂ O	2.240	0.150	CsNO ₃	2	194.91	1.00	3.31
K	2412	0.062	K ₂ O	2.728	0.183	KOH	5	56.10	0.91	3.81
Na	63223	2.750	Na ₂ O	80.037	5.372	NaOH, 50% sol. d=1.53	4	40.00	0.50	131.18
Si	37	0.001	SiO ₂	0.074	0.005	SiO ₂	3	60.09	0.99	0.08
Cl	131	0.004	Cl	0.123	0.008	NaCl	7	58.45	0.99	0.22
F	1085	0.057	F	1.019	0.068	NaF	8	42.00	0.99	2.42
PO ₄	880	0.009	P ₂ O ₅	0.617	0.041	Na ₃ PO ₄ ·12H ₂ O	9	380.12	0.99	3.56
SO ₄	8742	0.091	SO ₃	6.843	0.459	Na ₂ SO ₄	10	142.06	0.99	13.06
NO ₂	33147	0.721	NO ₂	-	-	NaNO ₂	13	69.00	1.00	49.97
NO ₃	28425	0.458	NO ₃	-	-	NaNO ₃	14	84.99	0.99	6.66
Org. Carbon	276	0.023	-	-	-	-	-	-	-	-
formate	270	0.006	-	-	-	Sodium Formate (C1)	11	68.01	0.99	0.41
Oxalate	746	0.008	-	-	-	Sodium Oxalate (C2)	12	134.00	0.99	1.15
-	-	-	-	-	-	Target Glass Weight				1586.42
-	-	-	SUM	100	6.71	Total Simulant Weight				1125.48

- denotes empty field

Table 2.3. Oxide Compositions of LAW Sub-Envelope A2 (AP-101) and B1 (AZ-101) Glasses and the ¼, ½, and ¾ Points in the Changeover.

GLASS	100% AP-101 (LAWA126)	Turnover Glass ¾ AP101 ¼ AZ101	Turnover Glass ½ AP101 ½ AZ101	Turnover Glass ¼ AP101 ¾ AZ101	100% AZ-101 (LAWB83)
Loading*	24.54 %	N/A	N/A	N/A	6.71 %
Al ₂ O ₃	5.617	5.754	5.892	6.030	6.168
B ₂ O ₃	9.821	9.867	9.914	9.960	10.007
CaO	1.987	3.180	4.374	5.567	6.761
Cr ₂ O ₃	0.021	0.024	0.027	0.031	0.034
Cs ₂ O	0.149	0.150	0.150	0.151	0.151
Fe ₂ O ₃	5.531	5.467	5.402	5.337	5.272
K ₂ O	3.811	2.904	1.996	1.088	0.180
Li ₂ O	0.000	1.074	2.148	3.222	4.296
MgO	1.476	1.851	2.226	2.601	2.976
Na ₂ O	18.462	15.214	11.967	8.719	5.472
SiO ₂	43.987	45.117	46.247	47.377	48.507
TiO ₂	1.986	1.838	1.690	1.543	1.395
ZnO	2.938	3.413	3.887	4.361	4.835
ZrO ₂	2.961	3.011	3.061	3.111	3.162
Cl	0.424	0.322	0.220	0.119	0.017
F	0.350	0.283	0.215	0.148	0.080
P ₂ O ₅	0.077	0.068	0.059	0.050	0.041
SO ₃	0.401	0.462	0.524	0.585	0.646
SUM	100.000	100.000	100.000	100.000	100.000

* Loading denotes the wt% of waste oxides in the glass product.

**Table 2.4 Glass Forming Additives for 1 Liter of 8 Molar LAW Sub-Envelope A2
Simulant (Nominal) and Corresponding Feed Properties.**

Additives Source	Feed LAW126
Additives in Glass (wt%)	75.46%
Kyanite (Al ₂ SiO ₅) 325 Mesh (Kyanite Mining) (g)	99.98
H ₃ BO ₃ (US Borax – Technical Granular) (g)	238.52
Wollanstonite NYAD 325 Mesh (NYCO Minerals) (g)	59.77
Fe ₂ O ₃ (Prince Mfg.) (g)	72.18
Olivine (Mg ₂ SiO ₄) 325 Mesh (#180 Unimin) (g)	41.46
SiO ₂ (Sil-co-Sil 75 US Silica) (g)	490.66
TiO ₂ (Rutile Airfloated) (g)	28.82
ZnO (KADOX – 920 Zinc Corp. of America) (g)	40.18
Zircon ZrSiO ₄ (Flour) Mesh 325 (AM. Mineral) (g)	61.07
Addition of sucrose as reductant (g)	83.66
Na ₂ SO ₄ recycled (g)	1.47
NaCl recycled (g)	5.08
NaF recycled (g)	1.71
KI spike (g)	1.78
Simulant weight (g)	1381
Sum of Additives (g)	1216
Sum of complete batch (less sugar) (g)	2607
Final Volume (l)	1.50
Density - measured (g/ml)	1.74
Expected Glass yield	1359
Weight % Water in slurry	34.3%
Weight % Additives in slurry	46.6%
Glass Yield (g/kg of feed)	521
Glass Yield (g/l of feed)	907
Total Solids (g/l of feed)	1143
Additives - estimated (g/l of feed)	812

**Table 2.5 Glass Forming Additives for 1 Liter of 2.75 Molar LAW Sub-Envelope B1
Simulant (Nominal) and Corresponding Feed Properties.**

Additives Source	Feed LAW83
Additives in Glass (wt%)	93.29%
Kyanite (Al_2SiO_5) 325 Mesh (Kyanite Mining) (g)	156.10
H_3BO_3 (US Borax - Technical Granular) (g)	282.85
Wollanstonite NYAD 325 Mesh (NYCO Minerals) (g)	236.73
Fe_2O_3 (Prince Mfg.) (g)	75.82
Li_2CO_3 (Chemetall Foote Co. Technical grade) (g)	170.61
Olivine (Mg_2SiO_4) 325 Mesh (#180 Unimin) (g)	95.57
SiO_2 (Sil-co-Sil 75 US Silica) (g)	516.51
TiO_2 (Rutile Airfloated) (g)	23.52
ZnO (KADOX - 920 Zinc Corp. of America) (g)	76.96
Zircon ZrSiO_4 (Flour) Mesh 325 (AM. Mineral) (g)	75.89
Addition of sucrose as reductant (g)	24.55
Na_2SO_4 recycled (g)	5.60
NaCl recycled (g)	0.24
NaF recycled (g)	0.46
KI spike (g)	2.08
Simulant weight (g)	1125
Sum of Additives (g)	1735
Sum of complete batch (less sugar) (g)	2869
Final Volume (l)	1.66
Density - measured (g/ml)	1.73
Expected Glass yield	1586
Weight % Water in slurry	37.5 %
Weight % Additives in slurry	60.5 %
Glass Yield (in g/kg of feed)	553
Glass Yield (g/l of feed)	957
Total Solids (g/l of feed)	1170
Additives - estimated (g/l of feed)	1046

Table 2.6. DM100 LAW Sub-Envelope A2-B1 Changeover Feed Properties.

Date	Sample Name	% Water	Density (g/ml)	Glass Yield		pH	Yield Stress (Pa)	Viscosity (Poise)		
				kg/kg	g/l			@1/s	@10/s	@100/s
10/28/02	WVM-F-97A	36.32	1.73	0.496	858	12.47	0.4	2.45	0.55	0.34
10/30/02	WVM-F-119A	35.84	1.73	0.429	741	12.56	NA	NA	NA	NA
10/30/02	WVM-F-122A	35.88	1.73	0.498	861	12.48	NA	NA	NA	NA
	Average	36.01	1.73	0.474	820	12.50	0.4	2.45	0.55	0.34
Previous [7] Formulation	+15%	42.19	1.63	0.449	733	12.96	0.5	4.29	0.61	0.24
	-15%	35.71	1.72	0.509	877	11.76	5.7	37.3	5.22	0.89
11/01/02	WVM-F-151A	38.85	1.70	0.542	922	8.51	1.9	13.5	1.53	0.50
11/02/02	WVN-F-16A	42.44	1.71	0.500	854	8.63	NA	NA	NA	NA
	Average	40.65	1.71	0.521	888	8.57	1.9	13.5	1.53	0.50
Previous Formulation [8]		38.77	1.71	0.526	899	7.49	13.8	23.2	4.4	1.4

NA - Not Analyzed.

Table 2.7. XRF Analyzed Composition of Melter Feed Samples (wt.%).

Test	LAW A2						LAW B1				
	Target	WVM-F-97A	WVM-F-119A	WVM-F-122A	Avg.	% Dev.	Target	WVM-F-151A	WVN-F-16A	Avg.	% Dev.
Al ₂ O ₃	5.61	5.34	5.42	5.14	5.30	-5.56	6.16	5.53	6.15	5.84	-5.21
B ₂ O ₃ *	9.81	9.81	9.81	9.81	NC	NC	10.00	10.00	10.00	NC	NC
BaO	<0.01	<0.01	0.05	0.04	0.03	NC	<0.01	0.04	0.04	0.04	NC
CaO	1.99	2.08	2.04	2.04	2.05	3.25	6.75	6.08	6.37	6.23	-7.81
Cl	0.42	0.06	0.06	0.07	0.06	NC	0.02	0.02	0.02	0.02	NC
Cr ₂ O ₃	0.02	0.03	0.14	0.22	0.13	NC	0.03	0.28	0.12	0.20	NC
Cs ₂ O	0.15	0.08	0.08	0.08	0.08	NC	0.15	0.18	0.15	0.17	NC
F	0.35	NA	NA	NA	NC	NC	0.08	NA	NA	NC	NC
Fe ₂ O ₃	5.53	6.08	6.17	6.36	6.20	6.20	5.27	5.89	5.51	5.70	8.23
I	0.10	0.00	0.00	0.01	0.01	NC	0.10	0.00	0.00	0.00	NC
K ₂ O	3.81	3.56	3.44	3.42	3.47	3.47	0.18	0.61	0.37	0.49	NC
Li ₂ O*	<0.01	NA	NA	NA	NC	NC	4.29	4.29	4.29	NC	NC
MgO	1.47	0.90	0.95	1.12	0.99	-32.76	2.97	2.61	2.99	2.80	-5.78
MnO	<0.01	0.00	0.01	0.01	0.01	NC	<0.01	0.02	0.02	0.02	NC
Na ₂ O	18.44	18.03	18.35	18.31	18.23	-1.18	5.47	7.93	5.65	6.79	24.21
NiO	<0.01	<0.01	<0.01	0.02	0.01	NC	<0.01	0.04	0.02	0.03	NC
P ₂ O ₅	0.08	0.10	0.11	0.11	0.11	MC	0.04	0.08	0.09	0.09	NC
SiO ₂	43.94	44.94	44.65	44.39	44.66	1.63	48.46	46.41	48.27	47.34	-2.31
SO ₃	0.40	0.27	0.26	0.28	0.27	NC	0.65	0.41	0.40	0.41	NC
TiO ₂	1.98	2.36	2.31	2.28	2.32	16.84	1.39	1.62	1.62	1.62	16.38
ZnO	2.94	3.11	3.05	3.06	3.07	4.56	4.83	4.67	4.66	4.67	-3.42
ZrO ₂	2.96	3.23	3.10	3.24	3.19	7.85	3.16	3.27	3.25	3.26	3.34
Sum	100.00	100.00	100.00	100.00	100.00	NC	100.00	100.00	100.00	100.00	NC

NA = Not analyzed
NC = Not Calculated
* Target values
< = less than

Table 2.8. Analyzed Nitrate and Nitrite Concentrations in Feed Samples (mg/l).

		Sub-Envelope A2	Sub-Envelope B1
Nitrite	Measured	19,600	13,400
	Target	21,594	11,454
	% dev (from target)	-9.2	17.0
Nitrate	Measured	56,000	13,100
	Target	68,029	9,822
	% dev (from target)	-17.7	33.4

Table 3.1. Summary of Test Conditions and Results for Changeover from LAW Sub-Envelope A2 to Sub-Envelope B1.

		Test 1A	Test 1B
Sub-Envelope		A2	B1
LAW Simulant		AP-101	AZ-101
Nominal Target Glass Formulation		LAWA126	LAWB83
Glass	Target wt% SO ₃	0.40	0.65
	Target wt% Na ₂ O	18.46	5.47
	Target wt% Cl	0.42	0.017
	Target wt% I	0.10	0.10
Time	Feed Start	10/28/02, 12:26	11/1/02, 00:23
	Feed End	10/31/02, 23:24	11/3/02, 03:30
	Water Feeding (hr)	1.03 + 1.10	NA
	Feeding Interruptions	10/28/02, 15:00 – 16:50 10/29/02, 08:27-10/30/02, 09:30 10/31/02, 04:27 – 08:41	11/2/02, 06:31 – 07:30
	Total Feeding Interruptions (hr)	31.1	1.0
	Net Slurry Feeding (hr)	49.7	50.1
	Cold Cap Burn-Off (hr)	NA	1.5
Reductant Ratio:		0.5	0.5
Glass Yield (g/l of feed)		907	957
Total Feed Processed (kg)		857	823
Average Production Rate (kg/m ² /day)		1978	1996
Target Production Rate (kg/m ² /day)		2000	2000
Product	Measured wt% SO ₃	0.34	0.46
	Measured wt% Cl	0.22	0.03
	Measured wt% I	0.03	< 0.01
	% Feed Sulfur in Glass Product	85	71
	% Feed Chlorine in Glass Product	52	> 100
	% Feed Iodine in Glass Product	30	< 10
Gaseous Emissions	% of Feed Sulfur	< 0.1	32
	% of Feed Chlorine	0.4	> 100
	% of Feed Iodine	63	102
Separate Sulfate Phase During or at Test End?		No	No

NA = Not applicable

Table 3.2. Summary of Measured Melter Parameters During Feeding.

		LAW A2			LAW B1			
		Avg	Min	Max	Avg	Min	Max	
Temperature (C)	Electrode	East	1142	1111	1159	1139	1101	1160
		West	1152	1121	1167	1144	1100	1172
		Bottom	947	915	956	944	920	962
	Glass	19" from bottom	959	633	1058	914	678	1042
		16" from bottom	1103	984	1148	1088	1047	1133
		10" from bottom	1146	1107	1172	1142	1103	1181
		4" from bottom	1134	1101	1157	1130	1078	1151
	Plenum	Thermowell	622	559	818	591	519	723
		Exposed	614	166	809	589	499	718
	Bubbler		1173	1149	1209	1173	302	1267
	Discharge	Chamber	1027	988	1051	1023	1004	1043
		Air Lift	1112	989	1162	1111	1038	1164
	Film Cooler Outlet		308	173	391	318	297	340
	Transition Line Outlet		307	190	397	307	295	320
Lance Bubbling (lpm)		15.58	1.78	22.39	14.27	0	20.72	
Electrode Voltage (V)		40.73	36.06	45.10	52.69	0.20	60.05	
Total Power (kW)		21.73	19.09	26.34	23.28	0.28	26.20	

Table 4.1. List of Glass Discharged, Masses, and Analysis Performed.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1A (LAWA2)	10/28/02	WVM-G-99A	-	22.98	22.98
		WVM-G-99B	XRF		
		WVM-G-99C	-	25.40	48.38
		WVM-G-100A	XRF		
		WVM-G-100B	-		
		WVM-G-101A	XRF		
	10/29/02	WVM-G-103A	XRF	22.70	100.48
		WVM-G-103B	-	26.10	126.58
		WVM-G-106A	XRF		
		WVM-G-107A	-		
	10/30/02	WVM-G-119A	XRF	27.80	154.38
		WVM-G-120A	-		
		WVM-G-121A	XRF	33.00	187.38
		WVM-G-122A	-		
		WVM-G-122B	XRF		
		WVM-G-124A	-	27.80	245.48
		WVM-G-124B	XRF		
		WVM-G-128A	-	24.20	269.68
		WVM-G-130A	XRF		
		10/31/02	WVM-G-130B	-	27.10
	WVM-G-131A		XRF		
	WVM-G-136A		-	38.78	335.56
	WVM-G-137A		XRF		
	WVM-G-137B		-		
WVM-G-138A	XRF		26.60	362.16	
WVM-G-138B	-				
WVM-G-142A	XRF		26.90	389.06	
WVM-G-142B	-				
WVM-G-142C	XRF				
WVM-G-142D	-				
1B (LAWBI)	11/01/02	WVM-G-144A	XRF	29.40	439.06
		WVM-G-148A	-	20.20	459.26
		WVM-G-148B	XRF		
		WVM-G-150A	-	21.60	480.86
		WVM-G-151A	XRF		
		WVM-G-151B	-	23.20	504.06
		WVM-G-152A	XRF		
		WVM-G-154A	-	27.20	531.26
		WVM-G-155A	XRF		
		WVN-G-8A	-	22.90	554.16
		WVN-G-8B	XRF		
		WVN-G-8C	-	27.10	581.26
		WVN-G-11A	XRF		
		WVN-G-11B	-	28.90	610.16
		WVN-G-11C	XRF		
		WVN-G-12A	-	28.80	638.96
	11/02/02	WVN-G-12B	XRF		

Table 4.1. List of Glass Discharged, Masses, and Analysis Performed (continued).

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1B (LAWB1)	11/02/02	WVN-G-16A	-	24.90	663.86
		WVN-G-16B	XRF		
		WVN-G-17A	-	27.10	690.96
		WVN-G-18A	XRF		
		WVN-G-21A	-	30.00	720.96
		WVN-G-21B	XRF		
		WVN-G-21C	-	27.50	748.46
		WVN-G-24A	XRF		
		WVN-G-24B	-	25.10	773.56
		WVN-G-24C	XRF		
		WVN-G-27A	-	22.30	795.86
		WVN-G-27B	XRF		
		WVN-G-27C	-	28.10	823.96
		WVN-G-28A	XRF		
	11/03/02	WVN-G-28B	-	24.30	848.26
		WVN-G-32A	XRF		
WVN-G-32B		XRF	11.60	859.86	

- denotes empty field

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

Test	LAWA2															
	22.98	48.38	77.78	100.48	126.58	154.38	187.38	217.68	245.48	269.68	296.78	335.56	362.16			
Glass (kg)	WVM-G-99B	WVM-G-100A	WVM-G-101A	WVM-G-103A	WVM-G-106A	WVM-G-120A	WVM-G-121A	WVM-G-122B	WVM-G-124B	WVM-G-130A	WVM-G-131A	WVM-G-137A	WVM-G-138A			
Element	Target	5.61	9.81	1.99	0.42	0.02	0.15	0.35	5.53	9.81	1.99	0.42	0.02			
Al ₂ O ₃	6.34	9.25	2.04	0.26	0.18	0.10	0.12	0.14	0.13	0.13	0.13	0.13	0.13			
B ₂ O ₃ *	9.12	2.04	0.26	0.18	0.10	0.12	0.14	0.13	0.13	0.13	0.13	0.13	0.13			
CaO	2.04	0.26	0.18	0.10	0.12	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13			
Cl	0.42	0.02	0.15	0.35	5.53	9.81	1.99	0.42	0.02	0.15	0.35	5.53	9.81			
Cr ₂ O ₃	0.02	0.18	0.10	0.12	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13			
Cs ₂ O	0.15	0.35	5.53	9.81	1.99	0.42	0.02	0.15	0.35	5.53	9.81	1.99	0.42			
F	0.35	5.53	9.81	1.99	0.42	0.02	0.15	0.35	5.53	9.81	1.99	0.42	0.02			
Fe ₂ O ₃	5.53	9.81	1.99	0.42	0.02	0.15	0.35	5.53	9.81	1.99	0.42	0.02	0.15			
I	0.10	0.01	0.96	<0.01	1.81	1.74	1.54	1.79	1.52	1.98	1.52	1.98	1.52			
K ₂ O	3.81	<0.01	1.81	1.74	1.54	1.79	1.52	1.98	1.52	1.98	1.52	1.98	1.52			
Li ₂ O*	<0.01	1.81	1.74	1.54	1.79	1.52	1.98	1.52	1.98	1.52	1.98	1.52	1.98			
MgO	1.47	18.38	0.05	0.02	0.06	0.04	44.98	0.25	2.18	2.19	2.19	2.19	2.19			
Na ₂ O	18.44	0.05	0.02	0.06	0.04	44.98	0.25	2.18	2.19	2.19	2.19	2.19	2.19			
NiO	<0.01	0.05	0.02	0.06	0.04	44.98	0.25	2.18	2.19	2.19	2.19	2.19	2.19			
P ₂ O ₅	0.08	0.02	0.29	0.40	0.29	2.17	2.94	2.96	3.28	3.27	3.06	3.07	3.07			
SiO ₂	43.94	44.95	44.98	45.11	45.10	44.76	44.65	44.78	44.35	45.33	44.83	45.35	45.30			
SO ₃	0.40	0.29	0.40	0.29	0.30	0.32	0.31	0.32	0.34	0.35	0.34	0.35	0.36			
TiO ₂	1.98	2.17	2.18	2.19	2.21	2.19	2.26	2.29	2.28	2.17	2.16	2.22	2.23			
ZnO	2.94	2.94	2.94	2.81	2.92	3.05	3.08	3.07	3.06	2.88	2.82	2.91	2.91			
ZrO ₂	2.96	3.28	3.27	3.06	3.17	3.22	3.25	3.29	3.29	3.06	2.97	3.08	3.10			
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	100.00			

*Target values. Target values for compositions of discharged glass were calculated based on a simple well-stirred tank model
NA - Not Analyzed.
< - less than

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

Test	LAWA2			LAWB1									
	389.06 WVM-G-142A	409.66 WVM-G-142C	Average (336-410 kg)	%DEV	Target	439.06 WVM-G-144A	459.26 WVM-G-148B	480.86 WVM-G-151A	504.06 WVM-G-152A	531.26 WVM-G-155A	554.16 WVM-G-8B	581.26 WVM-G-11A	610.16 WVM-G-11C
Element	Target	Target			Target								
Al ₂ O ₃	5.61	5.53	5.51	-1.57	6.16	5.31	5.13	5.65	5.70	5.37	5.39	5.48	5.82
B ₂ O ₃ *	9.81	9.78	9.78	NC	10.00	9.99	10.00	10.00	10.00	10.00	10.00	10.00	10.00
CaO	1.99	1.98	1.90	1.08	6.75	2.10	2.59	3.20	3.78	4.33	4.51	4.89	5.08
Cl	0.42	0.25	0.24	NC	0.02	0.21	0.18	0.14	0.11	0.08	0.07	0.05	0.04
Cr ₂ O ₃	0.02	0.14	0.14	NC	0.03	0.17	0.35	0.14	0.14	0.31	0.35	0.29	0.12
Cs ₂ O	0.15	0.14	0.13	NC	0.15	0.13	0.15	0.14	0.13	0.16	0.16	0.15	0.15
F	0.35	NA	NA	NC	0.08	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	5.53	5.80	5.54	4.33	5.27	5.80	6.45	5.54	5.54	6.17	6.08	5.99	5.47
I	0.10	0.03	0.03	NC	0.10	0.03	0.03	0.01	0.01	<0.01	<0.01	<0.01	<0.01
K ₂ O	3.81	3.51	3.44	-9.27	0.18	3.38	3.10	2.58	2.16	1.85	1.58	1.39	1.25
Li ₂ O*	<0.01	<0.01	<0.01	NC	4.29	0.93	1.45	1.92	2.34	2.73	3.00	3.26	3.48
MgO	1.47	1.25	1.29	-14.18	2.97	1.42	1.43	1.70	2.00	2.10	2.34	2.52	2.54
Na ₂ O	18.44	17.53	18.88	-2.89	5.47	17.62	16.08	14.12	12.81	11.62	11.34	10.07	9.40
NiO	<0.01	<0.01	<0.01	NC	<0.01	0.01	0.05	<0.01	<0.01	0.05	0.06	0.05	<0.01
P ₂ O ₅	0.08	0.10	0.09	NC	0.04	0.10	0.10	0.10	0.09	0.09	0.09	0.08	0.08
SiO ₂	43.94	45.47	44.87	2.97	48.46	44.23	43.70	46.04	46.31	45.42	45.66	46.16	47.11
SO ₃	0.40	0.36	0.36	NC	0.65	0.36	0.38	0.43	0.46	0.45	0.45	0.46	0.46
TiO ₂	1.98	2.21	2.14	10.79	1.39	2.17	2.18	1.98	1.93	1.93	1.78	1.80	1.74
ZnO	2.94	2.88	2.74	2.62	4.83	2.94	3.33	3.28	3.50	3.97	3.93	4.11	4.07
ZrO ₂	2.96	3.05	2.91	2.70	3.16	3.11	3.33	3.04	2.99	3.37	3.22	3.26	3.17
Sum	100.00	100.00	100.00	NC	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

*Target values. Target values for compositions of discharged glass were calculated based on a simple well-stirred tank model.

NA - Not Analyzed.

NC - Not Calculated.

< - less than

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

Test Element	LAWBI														Average (748-860 kg)	%DEV
	Target	638.96 WVN-G- 12B	663.86 WVN-G- 16B	690.96 WVN-G- 18A	720.96 WVN-G- 21B	748.46 WVN-G- 24A	773.56 WVN-G- 24C	795.86 WVN-G- 27B	823.96 WVN-G- 28A	848.26 WVN-G- 32A	859.86 WVN-G- 32B					
Al ₂ O ₃	6.16	5.85	6.02	5.99	5.54	5.63	6.12	6.14	6.02	6.07	5.99	6.00	-2.70			
B ₂ O ₃ *	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	NC			
CaO	6.75	5.38	5.41	5.59	5.88	5.79	5.89	5.91	6.05	6.10	6.08	5.97	-11.60			
Cl	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	NC			
Cr ₂ O ₃	0.03	0.11	0.11	0.11	0.25	0.27	0.10	0.10	0.09	0.10	0.10	0.12	NC			
Cs ₂ O	0.15	0.17	0.16	0.15	0.18	0.16	0.15	0.18	0.18	0.17	0.17	0.17	NC			
F	0.08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NC			
Fe ₂ O ₃	5.27	5.51	5.31	5.39	6.03	5.96	5.40	5.33	5.44	5.50	5.42	5.51	4.55			
I	0.10	0.01	<0.01	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01	<0.01	0.01	NC			
K ₂ O	0.18	1.10	0.96	0.89	0.78	0.67	0.70	0.62	0.59	0.57	0.55	0.62	NC			
Li ₂ O*	4.29	3.66	3.77	3.88	3.97	4.04	4.08	4.12	4.15	4.18	4.19	3.90	NC			
MgO	2.97	2.67	2.71	2.74	2.77	2.87	2.83	2.88	2.95	2.93	2.99	2.91	-2.10			
Na ₂ O	5.47	8.16	8.35	7.95	7.43	7.62	6.78	6.87	6.35	6.30	6.63	6.76	23.63			
NiO	<0.01	<0.01	<0.01	<0.01	0.04	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	NC			
P ₂ O ₅	0.04	0.09	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	NC			
SiO ₂	48.46	47.59	47.76	47.71	46.88	46.94	48.26	48.30	48.34	48.26	48.13	48.04	-0.87			
SO ₃	0.65	0.48	0.46	0.47	0.48	0.47	0.45	0.46	0.46	0.45	0.46	0.46	NC			
TiO ₂	1.39	1.75	1.66	1.69	1.72	1.64	1.64	1.60	1.63	1.63	1.61	1.62	16.51			
ZnO	4.83	4.20	4.10	4.21	4.57	4.49	4.34	4.30	4.45	4.48	4.45	4.42	-8.57			
ZrO ₂	3.16	3.24	3.10	3.13	3.39	3.29	3.15	3.09	3.19	3.19	3.15	3.18	0.56			
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	NC			

*Target values. Target values for compositions of discharged glass were calculated based on a simple well-stirred tank model.

NA - Not Analyzed.

NC - Not Calculated.

< - less than

Table 4.3. XRF Analyzed Compositions for Glass Dip Samples (wt%).

Test	LAWA2					LAWB1		
	Glass (kg)	0.00	0.00	0.00	-	439.06	-	504.06
Date	10/28/02	10/28/02	10/28/02	LAWA2 Target	10/31/02	LAWB1 Target	11/01/02	11/03/02
Element	WVM-D-85B	WVM-D-85C	WVM-D-85D		WVM-D-144A		WVM-D-152A	WVN-D-32A
Al ₂ O ₃	6.62	6.50	6.63	5.61	5.42	6.16	5.62	6.07
B ₂ O ₃ *	8.97	8.97	8.97	9.81	9.78**	10.00	10.00**	10.00**
CaO	1.96	1.97	1.96	1.99	1.95	6.75	3.93	6.09
Cl	0.44	1.00	0.29	0.42	0.25	0.02	0.11	0.02
Cr ₂ O ₃	0.14	0.16	0.15	0.02	0.14	0.03	0.14	0.10
Cs ₂ O	0.09	0.09	0.08	0.15	0.14	0.15	0.14	0.16
F	NA	NA	NA	0.35	NA	0.08	NA	NA
Fe ₂ O ₃	6.90	6.89	6.82	5.53	5.58	5.27	5.65	5.45
I	0.01	<0.01	0.01	0.10	0.03	0.10	0.01	<0.01
K ₂ O	0.56	0.54	0.52	3.81	3.49	0.18	2.07	0.57
Li ₂ O*	<0.01	<0.01	<0.01	<0.01	<0.01**	4.29	2.34**	4.19**
MgO	2.00	1.99	1.93	1.47	1.31	2.97	1.98	2.89
Na ₂ O	18.61	19.17	19.15	18.44	18.44	5.47	12.25	6.45
NiO	0.05	0.05	0.05	<0.01	<0.01	<0.01	<0.01	<0.01
P ₂ O ₅	0.02	0.02	0.01	0.08	0.09	0.04	0.09	0.08
SiO ₂	45.45	44.47	45.36	43.94	45.16	48.46	46.37	48.20
SO ₃	0.22	0.21	0.21	0.40	0.36	0.65	0.46	0.47
TiO ₂	2.09	2.07	2.06	1.98	2.15	1.39	1.93	1.62
ZnO	2.77	2.79	2.74	2.94	2.78	4.83	3.70	4.48
ZrO ₂	3.09	3.11	3.04	2.96	2.93	3.16	3.20	3.18
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Secondary Sulfate?	Yes	Yes	No	-	No	-	No	No

NA - Not Analyzed

* Target values

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

< - less than

Table 5.1. Melter Off-Gas Emission Rates.

		Test 1A, 10/31/02				Test 1B, 11/02/02			
		91.1% Isokinetic, 20% Moisture				94.1% Isokinetic, 18.3% Moisture			
		Feed Flux (mg/min)	Emitted (mg/min)	Percent of Feed	DF Across Melter	Feed Flux (mg/min)	Emitted (mg/min)	Percent of Feed	DF Across Melter
Particles	Total ^S	184333	1633.56	0.89	112.8	164000	249.57	0.15	657.1
	Al	5482	7.53	0.14	727.8	5355	1.77	0.03	3026.4
	B	5618	78.51	1.40	71.6	5093	10.27	0.20	496.1
	Ca	2618	2.92	0.11	896.8	7926	3.06	0.04	2593.1
	Cl*	782	403.59	51.61	1.9	28	10.03	35.82	2.8
	Cr	26	4.14	15.64	6.4	38	0.74	1.93	51.8
	Cs	259	37.88	14.62	6.8	234	10.42	4.46	22.4
	F*	645	126.89	19.67	5.1	131	18.07	13.79	7.3
	Fe	7129	15.50	0.22	459.9	6046	5.29	0.09	1143.7
	I*	184	1.95	1.06	94.4	164	< 0.10	< 0.01	> 1640
	K	5832	195.55	3.35	29.8	245	7.83	3.19	31.3
	Li	0	0.33	NC	NC	3273	4.50	0.14	726.5
	Mg	1641	0.38	0.02	4262.9	2943	0.21	0.01	13897.2
	Na	25249	298.13	1.18	84.7	6658	30.15	0.45	220.9
	P	62	1.72	2.77	36.1	29	< 0.10	< 0.01	> 290
	S*	296	28.29	9.56	10.5	425	37.08	8.72	11.5
	Si	37903	21.30	0.06	1779.8	37188	12.00	0.03	3099.1
	Ti	2195	6.00	0.27	365.9	1372	1.56	0.11	881.0
	Zn	4351	10.92	0.25	398.5	6370	7.19	0.11	886.2
Zr	4041	0.71	0.02	5729.9	3839	0.22	0.01	17277.4	
Gas	B	5618	14.91	0.27	376.7	5093	49.04	0.96	103.9
	Cl	782	2.99	0.38	261.8	28	44.21	158.57	0.6
	F	645	5.05	0.78	127.7	131	48.51	36.97	2.7
	I	184	115.86	62.85	1.6	164	166.80	101.71	1.0
	S	296	< 0.10	< 0.01	> 2960	425	134.75	31.74	3.2

*- Calculation based on water dissolution of filter particulate

^S- From gravimetric analysis of filters and nitric rinses

Calculated values in this table should be considered to have a maximum of three significant figures accuracy.

< - less than

> - greater than

Table 5.2. Average Concentrations [ppmv] of Selected Species in Off-Gas Measured by FTIR Spectroscopy.

Analyte	LAWA2	LAWB1
N ₂ O	130	52
NO	1600	400
NO ₂	340	23
NH ₃	18	9.7
H ₂ O	5.5%	5.7%
CO ₂	2900	3200
HNO ₂	3.0	< 1.0
HNO ₃	1.3	< 1.0
HCN	< 1.0	< 1.0
SO ₂	2.3	1.5
CO	64	24
HCl	< 1.0	< 1.0
HF	< 1.0	1.1
H ₂ *	< 5.0	< 5.0

* Value obtained by gas chromatography.

< - less than

Table 5.3. Average NO_x Fluxes in Melter Off-Gas Measured by FTIR Spectroscopy.

Test	Feed [mol/h]	Sugar Ratio	Emissions [mol/h]			% Feed NO _x Emitted as Nitrogen Oxides
			N ₂ O [mol/h]	NO [mol/h]	NO ₂ [mol/h]	
1A	28.2	0.5	0.9	11.2	2.4	51.4
1B	6.75	0.5	0.4	2.8	0.2	50.4

Table 5.4. Mass Balance for Volatile Constituents (% of Feed).

	Analyte	Test 1A, LAW A2	Test 1B, LAW B1
Glass	Cl	52	> 100
	Cs	87	> 100
	I	30	< 10
	S	85	71
Particulate Emissions	Cl	51.6	35.8
	Cs	14.6	4.5
	I	1.1	< 0.1
	S	9.6	8.7
Gaseous Emissions	Cl	0.4	> 100
	Cs	< 0.1	< 0.1
	I	63	102
	S	< 0.1	32
Total	Cl	104	> 100
	Cs	101.6	> 100
	I	94.1	102
	S	94.6	111.7

< - less than
 > - greater than

Table 6.1. Completion of Test Objectives.

Test Objective	Objective Met?	Discussion Section
Completion of glass formulation and feed testing and recommendation of "working glass" compositions and feeds for melter tests using LAW Sub-Envelope A2 and B1 feeds.	Yes	Section 2.0 provides "working glass" compositions and feed formulations.
Collection of dip samples of the melter glass and their analysis to demonstrate the absence of a separate sulfate layer accumulation.	Yes	Section 3.0. No separate sulfate phase was detected at the end or during the changeover tests. A separate phase was detected after idling at 1050°C prior to the first test but was readily removed by bubbling at low rates for a few hours. Section 4.0 provides analyses of dip samples.
Collection of dip samples of the melter glass during composition changeover and their analysis to demonstrate the absence of secondary phase formation.	Yes	Section 3.0. No separate sulfate phase was detected during changeover testing. Section 4.0 provides analyses of dip samples.
Collection of process data to enable melter scale-up. For Tests 1A and 1B, the DM100 should be operated to achieve a processing rate of $\approx 2000 \text{ kg/m}^2/\text{day}$ of glass production at a nominal operating temperature of 1150°C and plenum temperature of 350 to 600°C.	Yes	Section 3.0. Nominal operating temperature maintained and target glass production rate achieved.
Documentation of operating conditions associated with any off-gas volume surging events.	Yes	Section 3.0. No surging events were observed.
Sampling and characterization of each batch of simulated melter feed obtained from Optima and characterization of waste simulant and melter feed prepared at the VSL.	Yes	Section 2.0. Samples of the melter feeds were characterized with respect to chemical composition and physical properties, including rheology
Submit data and analysis of complete physical and rheological characterization in accordance with 24590-WTP-GPG-RTD-001, <i>Guidelines for Performing Chemical, Physical, and Rheological Properties Measurements</i> for each Envelope (A, B, and C) and each melter platform (DM100, DM3300). Comparisons shall be made between actual waste data, simulant lab-scale data, simulant DM100 scale data and simulant DM3300 scale data and a judgment of the validation or adequacy of the LAW pretreated waste and melter feed simulants shall be rendered. This analysis may be presented in a separate, consolidated report for LAW simulant validation.	No	Samples of the present A2 and B1 Sub-Envelope feeds have been retained. The B1 sample will undergo complete physical and rheological characterization and results will be reported separately.
Utilization of WTP Project approved GFC's in the preparation of simulated melter feed used in the DM100 melter tests.	Yes	Section 2.0
Collection of supporting off-gas characterization data. Samples of the off-gas particulate, semi-volatile, and condensable emissions will be collected during steady-state operation. Data on feed and process flows (flow rate, humidity, etc.) that are necessary to relate the off-gas sample data to the process operations will also be collected.	Yes	Section 5.0. Particulate and gaseous emissions were determined for a variety of species and DF values computed.
Collection and analysis of glass samples to determine sulfur retention in the glass and completion of mass balance calculation for components of interest.	Yes	Section 4.0. The analyzed glass product compositions agreed well with the target compositions. Sulfur retention was measured.

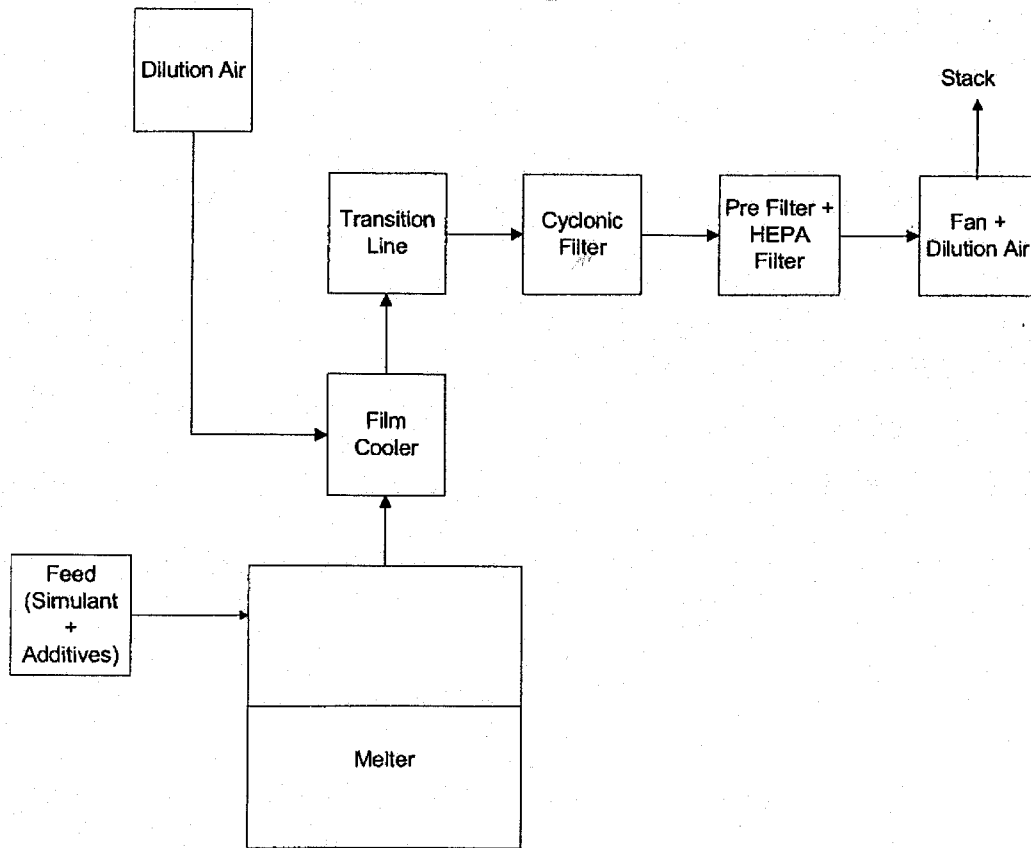
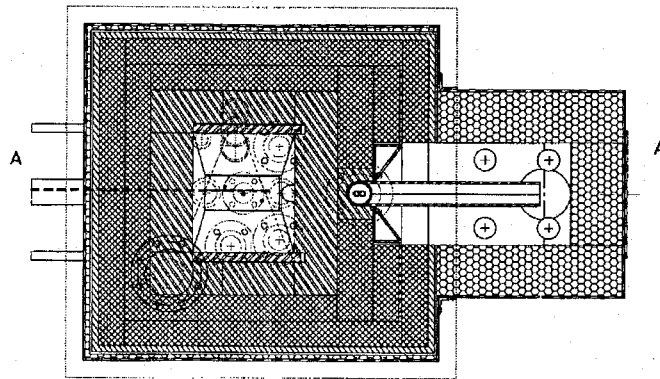


Figure 1.1. Schematic diagram of DuraMelter 100-WV vitrification system.



SECTION B-B
(BACKGROUND OMITTED)

Figure 1.2(a). Cross-section through the DM100-WV melter—Plan View.

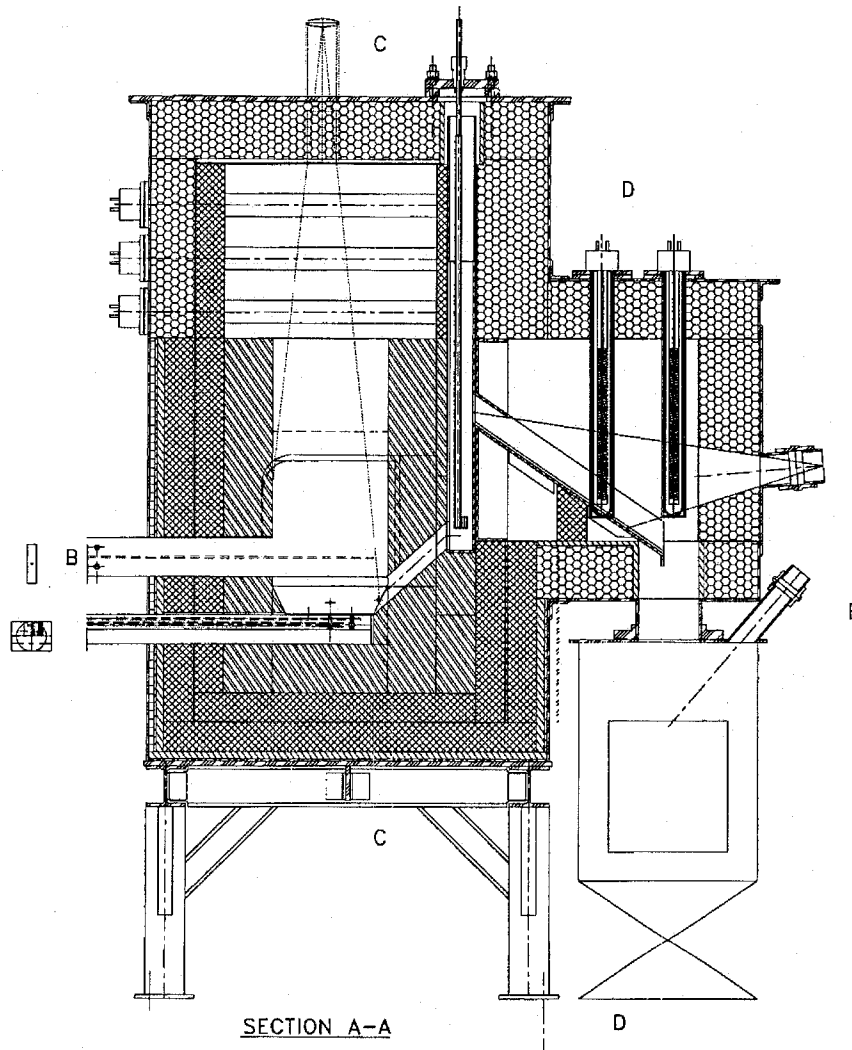


Figure 1.2(b). Cross-section through the DM100-WV melter—Section AA.

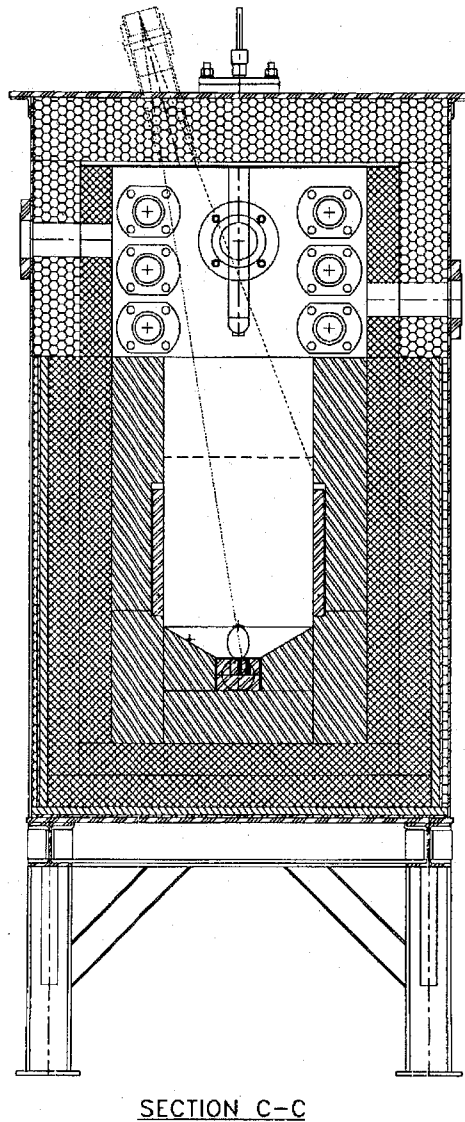


Figure 1.2(c). Cross-section through the DM100-WV melter—Section CC.

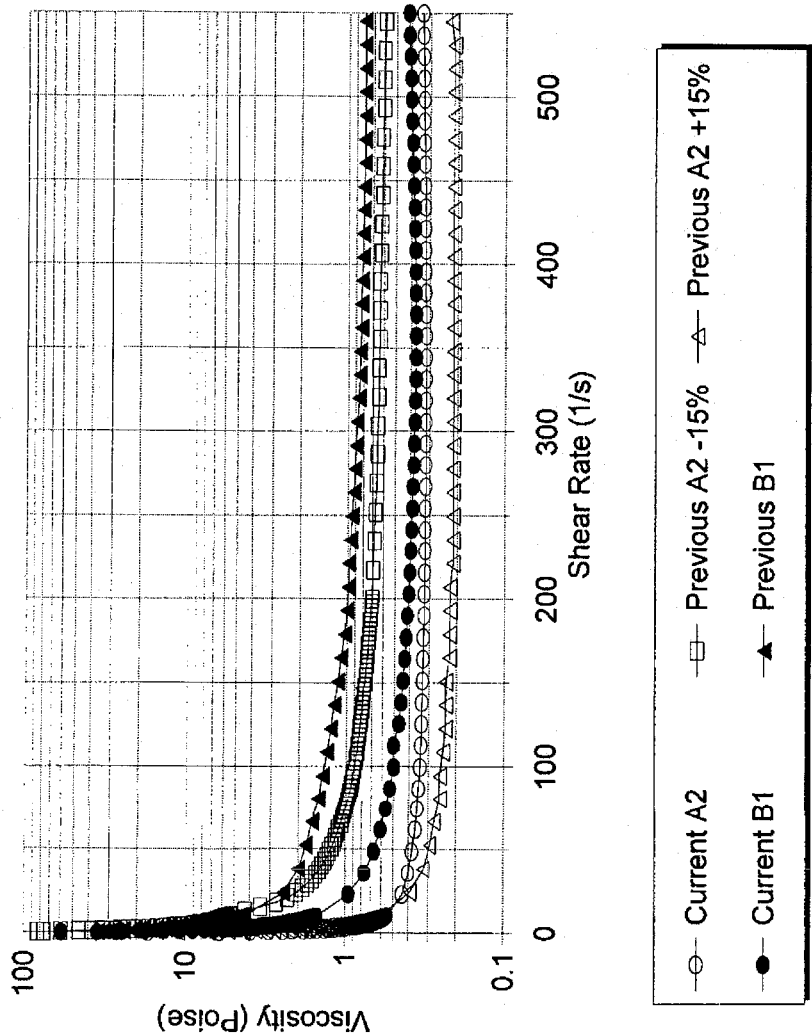


Figure 2.1. Measured viscosity of melter feed samples.

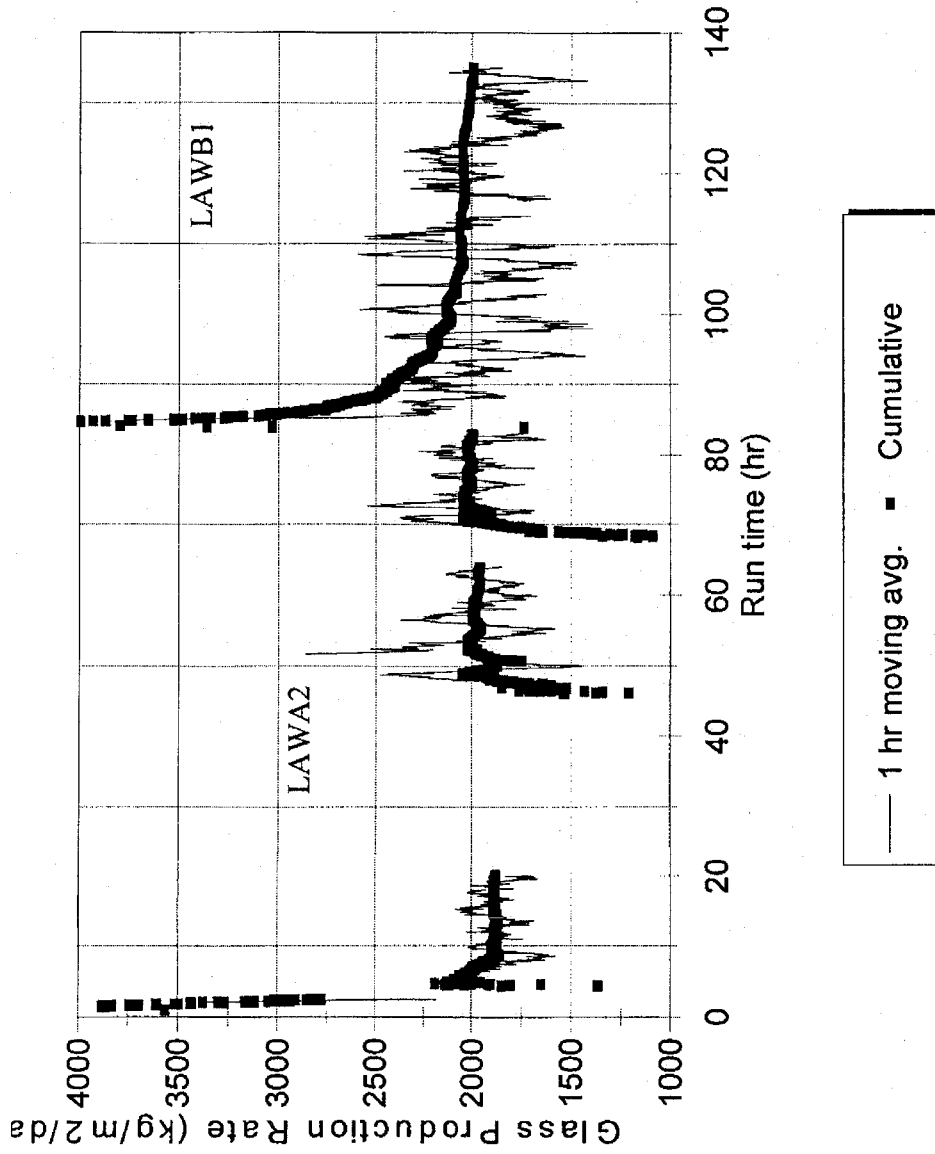


Figure 3.1. Glass production rates for LAW A2 to LAW B1 changeover test.

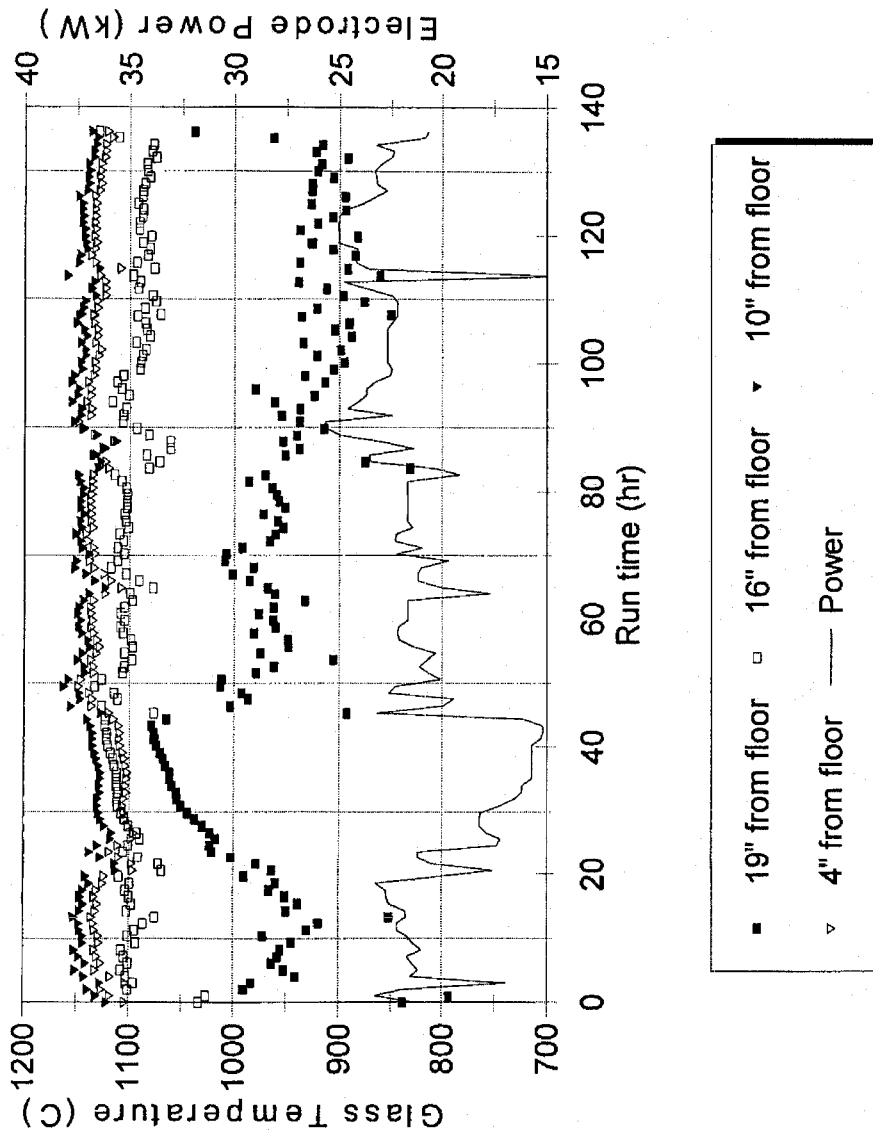


Figure 3.2. Glass temperatures and electrode power for LAW A2 to LAW B1 changeover test.

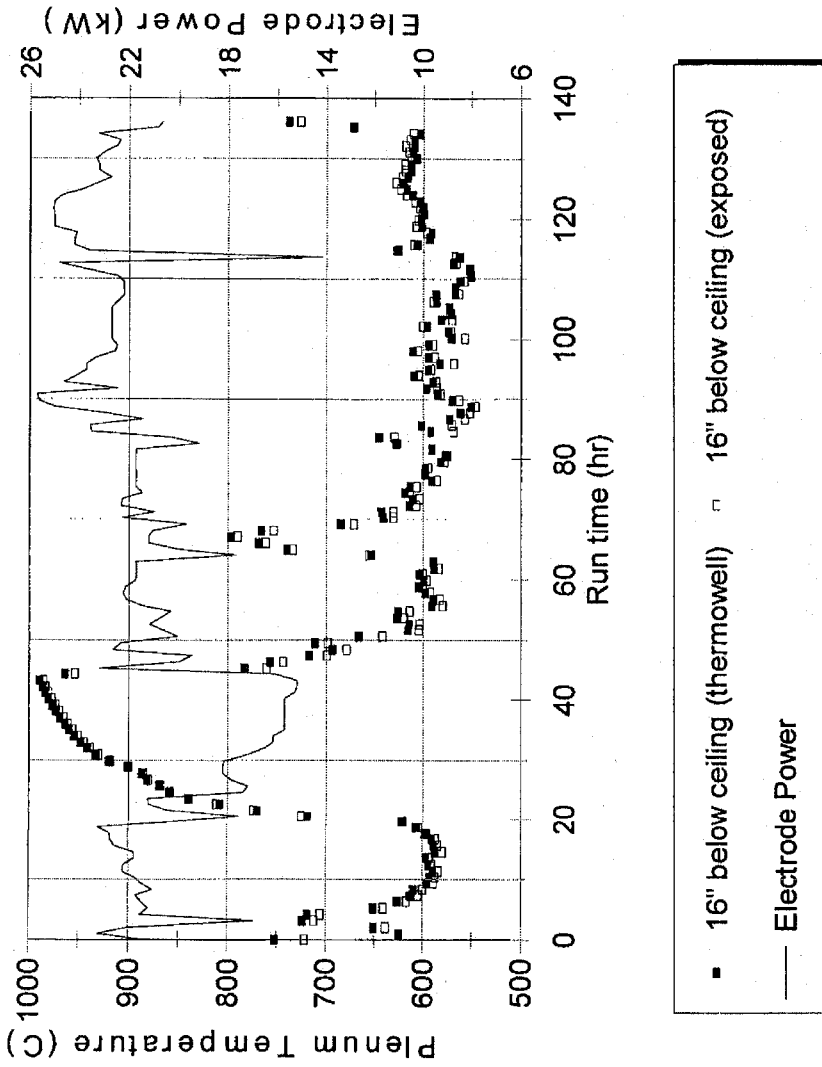


Figure 3.3. Plenum temperatures and electrode power for LAW A2 to LAW B changeover test.

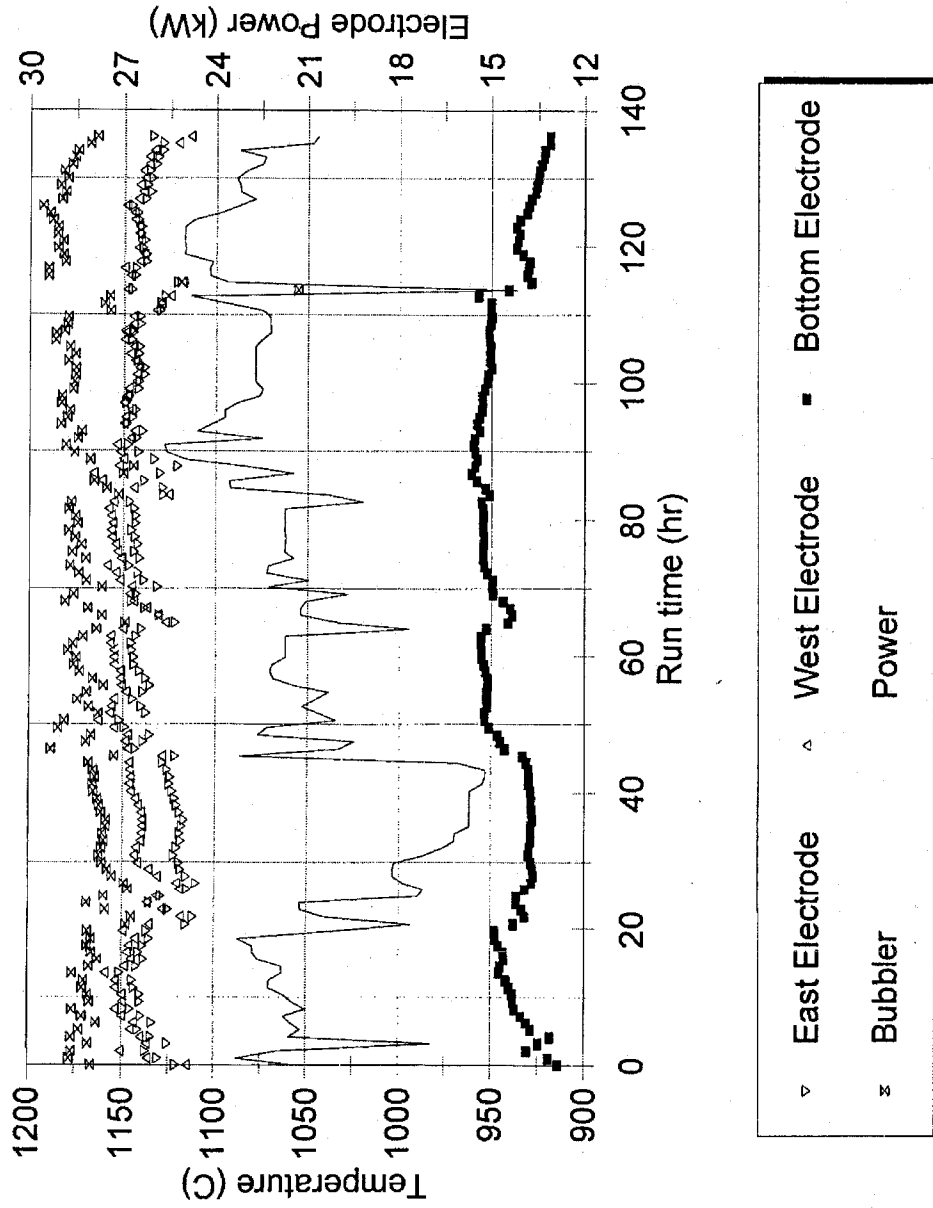


Figure 3.4. Electrode bubbler temperatures plus electrode power for LAWA2 to LAWBI changeover test.

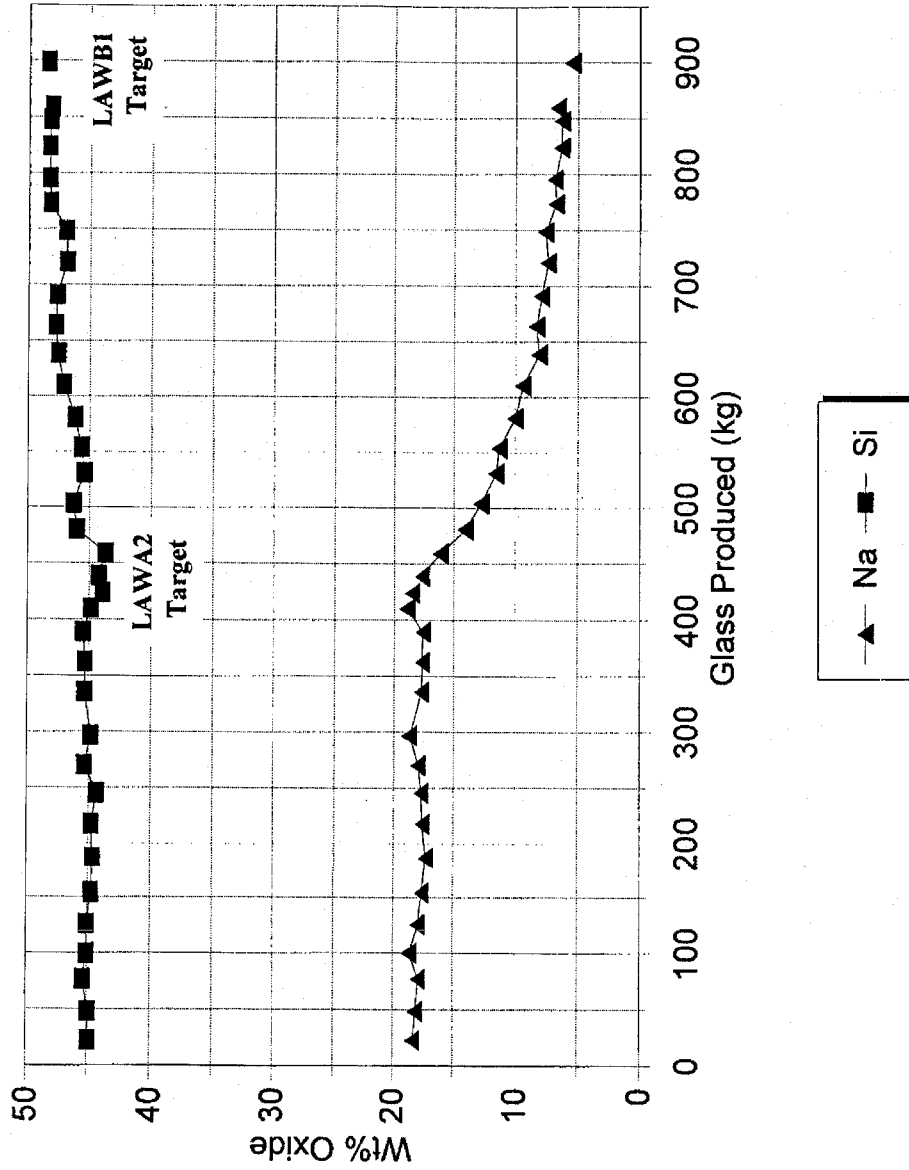


Figure 4.1. XRF analysis of Na₂O and SiO₂ in melter glasses.

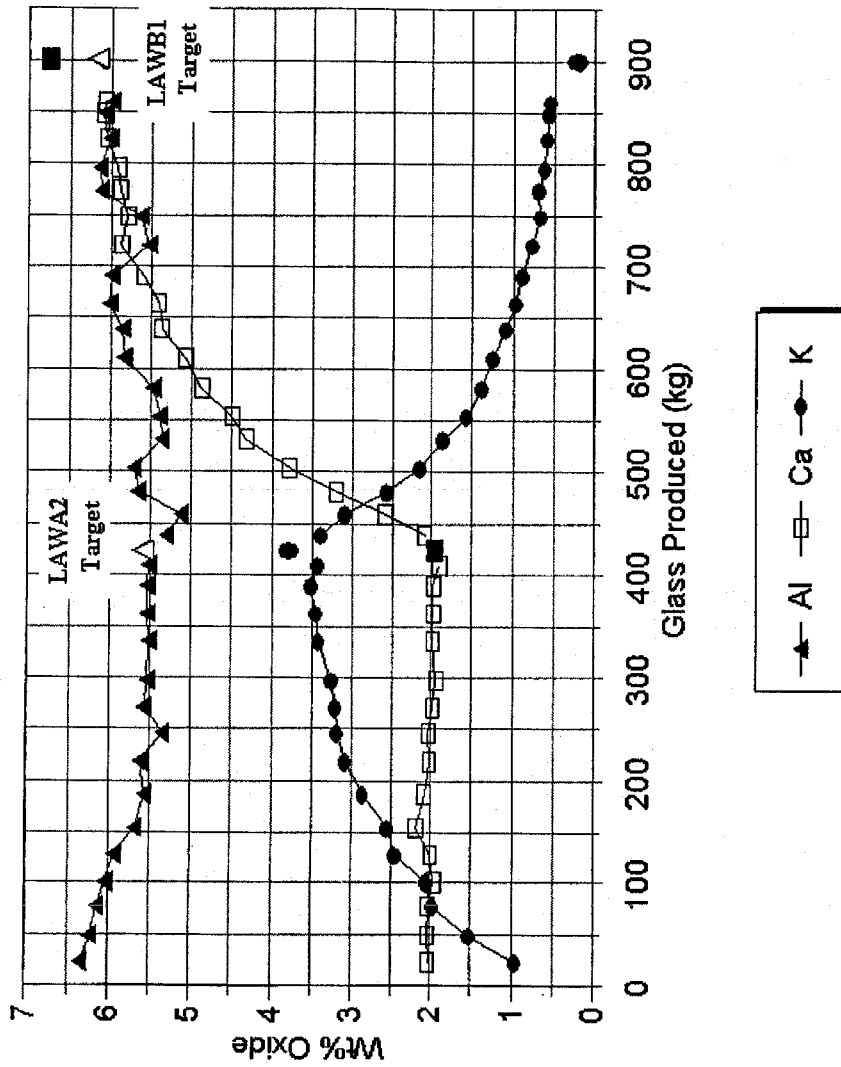


Figure 4.2. XRF analysis of aluminum, calcium, and potassium oxides in product glasses.

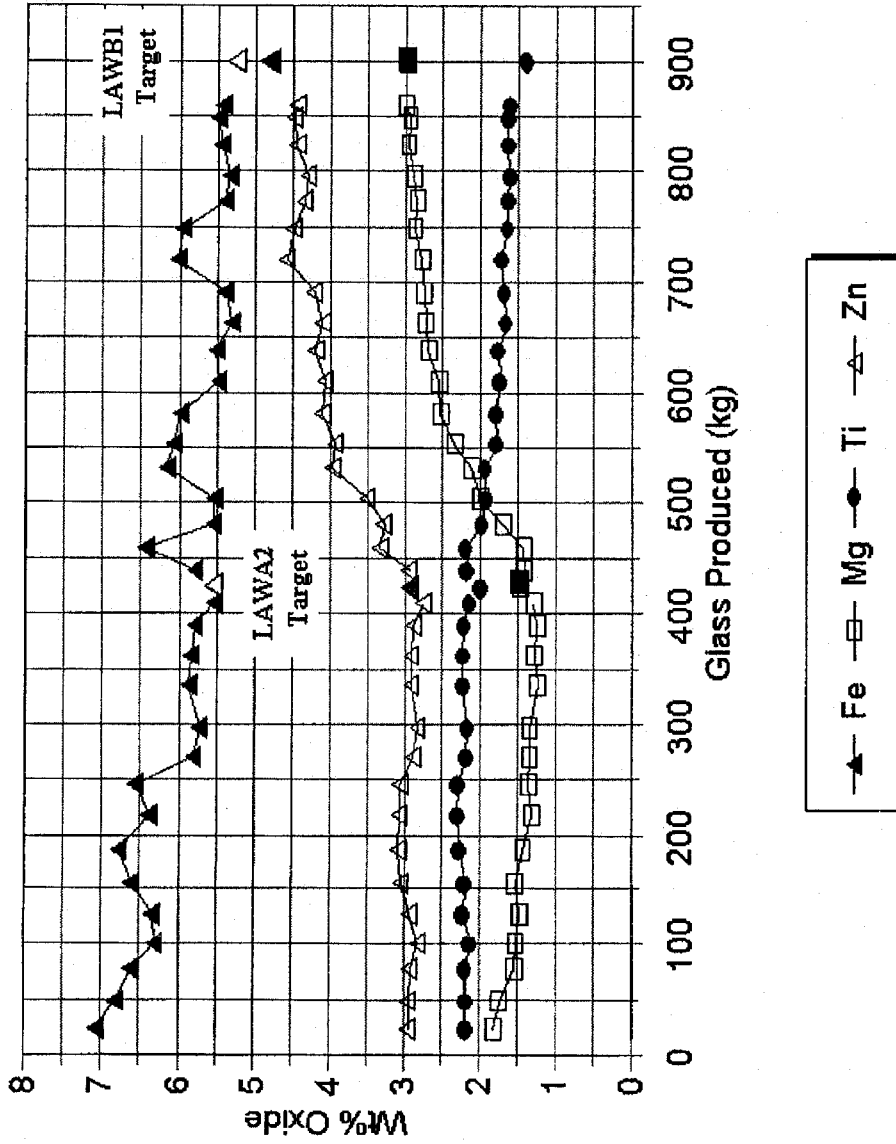


Figure 4.3. XRF analysis of select oxides in product glasses.

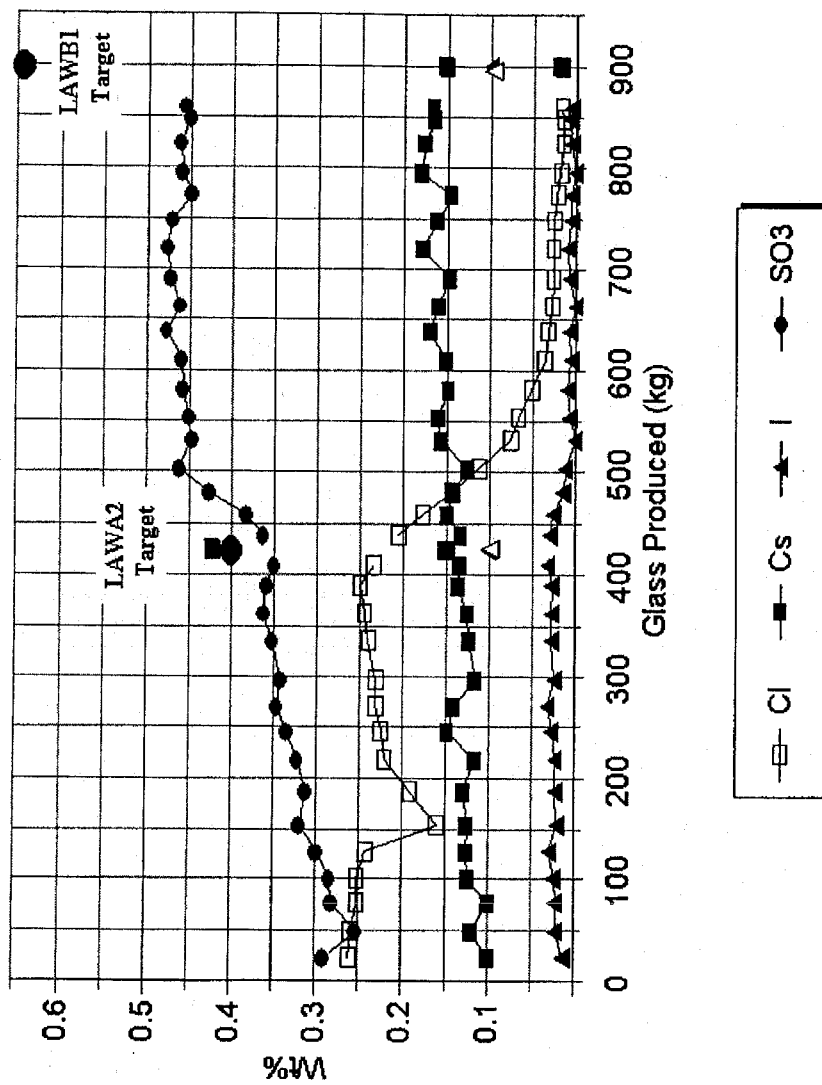


Figure 4.4. XRF analysis of volatile constituents in melter glasses.

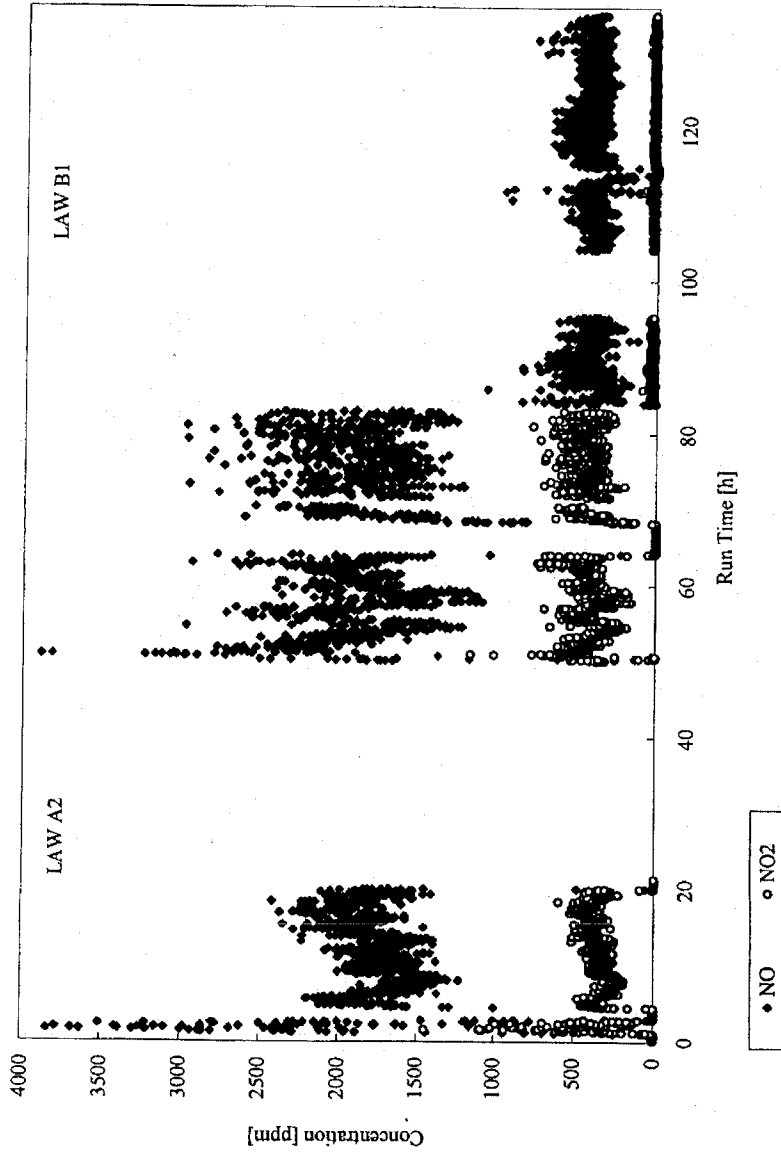


Figure 5.1. Nitrogen oxide emissions monitored by FTIR for LAW A2 to LAW B1 changeover tests.

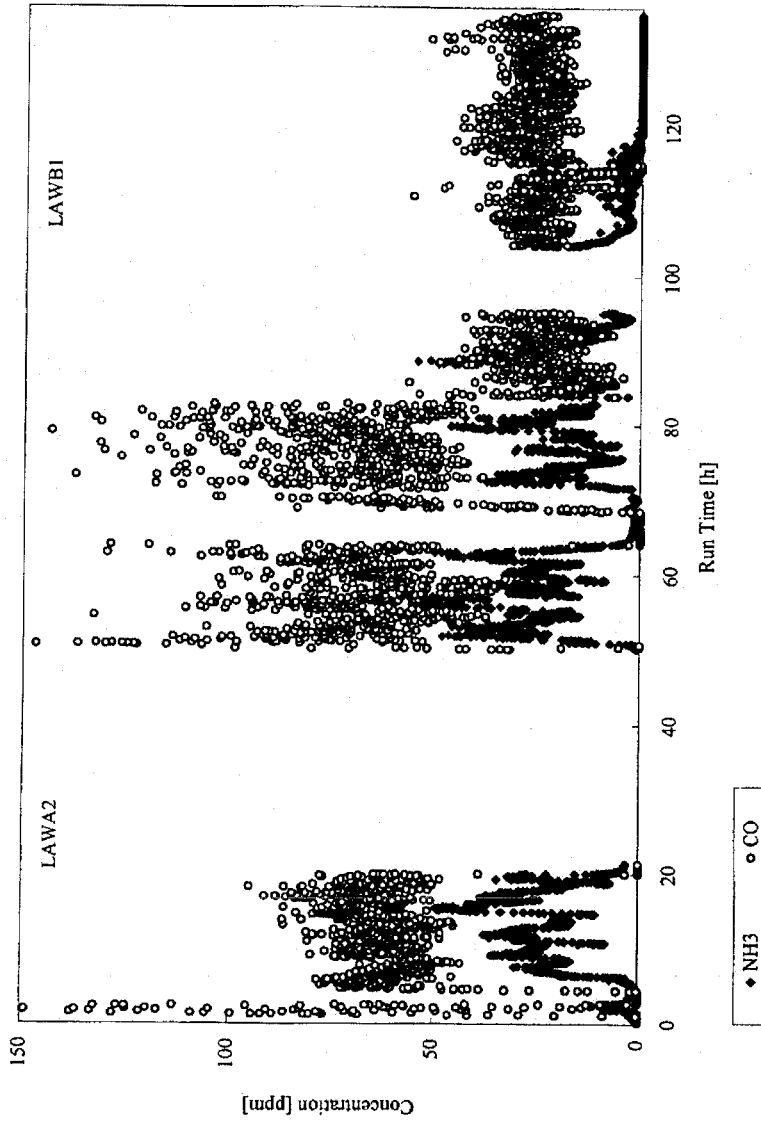


Figure 5.2. Ammonia and carbon monoxide for LAW2 to LAWBI changeover tests.



Duratek

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October 8, 2003
 L-12260

Bechtel National, Inc.
 WTP PDC, Submittal Coordinator
 2435 Stevens Center Place
 MSIN H4-02/MS11-B
 Richland, WA 99352

Attn: Mr. L. Scot Jenkins H4-02 (MS14-3A)

SUBCONTRACT NO. 24590-101-TSA-W000-0009
DURATEK FEDERAL SERVICES, INC. RESEARCH AND TECHNOLOGY SUPPORT,
TRANSMITTAL OF FINAL REPORT, APPROVED BY BNI R&T MANAGER FOR USE.

Dear Mr. Jenkins:

Please find attached the following Final Report approved by BNI R&T Manger for use on October 2, 2003:

- Final Report: DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelope A2 and B1 Feeds in Support of the LAW Pilot Melter VSL-03R3410-1, Rev. 0, dated 08/22/03

Should you have any questions and/or concerns, please contact the undersigned on 376-9942.

Sincerely,

P. K. Brockman
 Duratek Federal Services, Inc.
 Vice President / RPP Project Manager

Attachments

cc:	Steve Barnes w/o att	H4-02 (MS1-B)	Brad Bowan w/o att	Columbia
	Karen Hornbuckle w/o att	H4-02 (MS1-B)	Glenn Diener w/o att	Columbia
	Jeannette Doyle w/o att	H4-02 (MS1-B)	Karen Petro w/o att	Columbia
	Joe Perez w/o att	H4-02 (MS1-B)	Chris Chapman w/o att	H1-11
	Chris Musick w/o att	H4-02 (MS1-B)		
	Jerry Naaf w/o att	H4-02 (MS1-B)		
	David Knighton w/o att	H4-02 (MS1-B)		
	Scot Jenkins w/o att	H4-02 (MS14-3A)		
	Document Control file w/o att	Columbia	P. K. Brockman LB	

Attachment to
L-12260

**Final Report: DuraMelter 100 Sub-Envelope Changeover Testing Using
LAW Sub-Envelope A2 and B1 Feeds in Support of the LAW Pilot Melter**

VSL-03R3410-1, Rev. 0, dated 08/22/03



Research and Technology Completion Form

R&T Scoping Statement(s): VL-4

Test Specification Number/Title: 24590-LAW-TSP-RT-02-012, Rev. 0 / LAW Pilot Melter and DM-100 Sub-Envelope Changeover Testing

Test Plan Number/Title: VSL-02T62N0-4, Rev. 0 / Test Plan - DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelopes A2 and B1 Feeds in Support of the LAW Pilot Melter

Test Report Number/Title: VSL-03R3410-1, Rev. 0 / Final Report - DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelopes A2 and B1 Feeds in Support of the LAW Pilot Melter

Prepared by: Eugene Morrey **Date:** 9/29/03

List Test Objectives:	State how objectives were met:
1. Perform analyses, laboratory and small-scale melter testing, as required, to assess and specify "working glass" compositions, and additives utilizing the estimated LAW feed composition in Appendix C of the Test Specification.	A new glass formulation was not required to accommodate the updated LAW Sub-envelope B1 feed composition provided in Appendix C of the Test Specification. Due to the substantial increase in potassium in the updated A2 feed composition, additional laboratory glass formulation work was required for the updated A2 composition. Results from the laboratory testing will be placed in test report VSL-03R3460-2. The glass formulations used for the A2 Variation and Changeover test were LAWA88 and LAWA126, respectively. The glass formulations used for the B1 Variation and Changeover testing was LAWB83.
2. Sample molten glass at least once per Sub-Envelope to ensure the absence of a separate sulfate layer	Glass dip samples were analyzed for a separate sulfate layer before and after each sub-envelope test. (See Section 4.1 and Table 4.3) All dip samples taken immediately before and after the two sub-envelope transition runs were free from a separate sulfate phase. Samples taken prior to the first test under idling conditions at 1050°C and minimal bubbling and Sub-Envelope A1 composition in the melter yielded a separate sulfate phase. Bubbling at 2 lpm (1/3 nominal) and increasing the temperature back to 1150°C, resulted in re-incorporation of the sulfate back into the glass. This same result was observed in the A1 DM100 Variation test and in the C1-A1 DM100 Changeover test. It is interesting to note that the DM100 melter had been idling for 1-month and sulfate was still observed.
3. Sample molten glass during melter composition changeover batch to ensure absence of secondary phase formation	No indications of a separate sulfate layer were observed in the molten glass dip sample taken midpoint in the A2-B1 changeover. (See Section 4.1)
4. Quantify and document the occurrence and associated operating conditions of any melter off-gas volume surging events	No offgas volume surge events were experienced during these tests. (See Table 6.1)



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Test Report Number/Title:	VSL-03R3410-1, Rev. 0 / Final Report - DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelopes A2 and B1 Feeds in Support of the LAW Pilot Melter

List Test Objectives:	State how objectives were met:
5. Characterize the chemical and physical characteristics of each batch of melter feed.	Samples of each batch of melter feed were characterized chemically and physically. (See Table 2.6).
6. Once each for Envelopes A, B, and C feeds and each melter platform (DM-100, DM-3300), complete physical and rheological characterization in accordance with 24590-WTP-GPG-RTD-001, <i>Guidelines for Performing Chemical, Physical, and Rheological Properties Measurement</i> . The samples and sample concentrations (i.e., sodium molarities) shall be selected such that the physical and rheological data are comparable with existing or planned actual waste data, simulant lab-scale data, simulant DM-100 scale data and simulant DM-3300 scale data	A sample of the present B1 Sub-Envelope feed has been retained for physical and rheological characterization per the guideline. The results from this sample will be reported along with samples of A1 and C1 feeds in a separate report (report number not yet available). (See Table 6.1)
7. Utilize only WTP Project approved glass former chemicals (GFCs) as defined in SRT-RPP-2002-00034, <i>Selection of HLW and LAW Glass Formers</i> , dated February 6, 2002	Only WTP Project approved glass former chemicals were used in the preparation of melter feeds for these tests. (Section 2.2 and Table 6.1)
8. Collect melter emissions data to determine the effect of composition on melter emissions and to complete mass balance for components of interest such as sulfur	Melter emissions data were collected for each of the tests and mass balances were calculated for selected elements. (See Tables 5.1-5.4)
9. Collect and analyze discharged glass to determine sulfur retention in the glass and to complete mass balance for components of interest	Discharge glass samples were collected at approximately 30 kg glass intervals and analyzed for elemental analysis by XRF. (See Table 4.2)
List any Test Exceptions:	Did exceptions impact the objective? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No (Explain)
1) N/A	
List Success Criteria	Did the test meet the criteria? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No (Explain)



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<p>1) Completion of glass formulation and feed testing and recommendation of "working glass" compositions and feeds for melter tests using LAW Sub-Envelope C1 and A1 feeds. This will include testing of the changeover glasses (compositions given in Table 3.3) prepared at the crucible scale for compliance with ILAW performance requirements including PCT and VHT.</p>	<p>Criteria met. See Response to Objective 1 above.</p>
<p>2) Collection of dip samples of the melter glass and their analysis to demonstrate the absence of a separate sulfate layer accumulation.</p>	<p>Criteria partially met. Samples were analyzed for separate sulfate phase as required, and sulfate was not found in any of the Sub-Envelope A2 and B1 samples. Sulfate was found, however, prior to the test campaign after an extended idling period with Sub-Envelope A1 feed at 1050°C and low bubbling rate. See Response to Objective 2 above.</p>
<p>3) Collection of dip samples of the melter glass during composition changeover and their analysis to demonstrate the absence of secondary phase formation.</p>	<p>Criteria met- -see response to Objective 3 above.</p>
<p>4) Documentation of operating conditions associated with any off-gas volume surging events.</p>	<p>Criteria met- -see response to Objective 4 above.</p>
<p>5) Sampling and characterization of each batch of simulated melter feed obtained from Optima.</p>	<p>Criteria met- -see response to Objective 5 above.</p>
<p>6) Characterization of one sample each of the LAW Sub-Envelope A1 waste simulant, LAW Sub-Envelope A1 simulated melter feed, LAW Sub-Envelope C1 waste simulant, and LAW Sub-Envelope C1 simulated melter feed per 24590-WTP-GPG-RTD-001, <i>Guidelines for Performing Chemical, Physical, and Rheological Properties Measurement.</i></p>	<p>Objective net yet met- -see response to Objective 6 above.</p>



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7) Utilization of WTP Project approved GFC's in the preparation of simulated melter feed used in the DM100 melter tests.	Criteria met- -see response to Objective 7 above.
8) Collection of supporting off-gas characterization data. Samples of the off-gas particulate, semi-volatile, and condensable emissions will be collected during steady-state operation. Data on feed and process flows (flow rate, humidity, etc.) that are necessary to relate the off-gas sample data to the process operations will also be collected.	Criteria met- -see response to Objective 8 above.
9) Collection and analysis of glass samples to determine sulfur retention in the glass and completion of mass balance calculation for components of interest.	Criteria met- -Discharge glass samples were collected at 30 kg glass intervals and analyzed for elemental analysis by XRF. (See Table 4.2) Sulfur retention in the glasses were measured to be 85% for sub-envelope A2 and 71% for sub-envelope B1, which are consistent with prior results. (See Table 3.1)
List QA Requirements:	Did the subcontractor meet the requirements? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No (Explain)
1) Per the test plan, work is to be conducted according to NQA-1 (1994).	Work was conducted in accordance with a VSL Project Quality Assurance Project Plan (QAPP), which complies with NQA-1 (1989).
2) Per the test plan, software development is to be conducted in accordance with NQA-2a (1990) Part 2.7.	Software quality assurance was conducted in accordance with a VSL Project Quality Assurance Project Plan (QAPP) which complies with NQA-2a (1990) Part 2.7.
3) Verification of test conditions and properties determination.	Independent review of methods and results by VSL.
List R&T Test Conditions:	Were test conditions followed? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No (Explain)



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<p>1) Tests shall be conducted with the Sub-Envelope A2 and B1 feeds and glass compositions resulting from the transition between the two.</p>	<p>Sub-envelope A2 melter feed compositions as measured by XRF were within 10% of target for all elements except Mg and Ti, which are minor components. (See Table 2.7). This resulted in 0.5 wt% too little MgO and 0.3 wt% too much TiO₂ in the glass, which will not have a significant effect on glass properties.</p> <p>Sub-envelope B1 melter feed compositions as measured by XRF were within 10% of target for all elements except Na and Ti. (See Table 2.7). This resulted in 0.2 wt% too much TiO₂ in the glass, which will not have a significant affect on glass properties. The Na variation from target is +1.3 wt% Na₂O in the glass, which will effect glass properties at some level. Glass property models were run to determine the effect of increased Na in Sub-Envelope B1 glass and it was shown that an increase of at least 2.5 wt% Na₂O could be tolerated in the glass without adverse affects to glass properties. Therefore, the glass composition tested, although not ideal, is acceptable.</p>
<p>2) Glass Temperature: 1150°C</p>	<p>Bulk glass temperatures averaged between 1142°C – 1146°C for both feeds, very near the target of 1150°C. (Section 3.0, Figures 3.4-3.5).</p>
<p>3) Plenum Gas Temperature: 350-600°C</p>	<p>Plenum temperatures typically ranged between 550-650°C, within the 450-650°C target (Section 3.0).</p>
<p>4) Production Rate: 2000 kg /m2/day.</p>	<p>Average production rates for both tests within 1.5% of target. (Table 3.1)</p>
<p>Was testing performed with simulants? If yes, discuss how results compare to radioactive tests. <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No</p>	
<p>Rheological and physical properties data on actual pretreated waste and melter feed from Sub-envelope A2 (tank AP-101) does exist and is included in issued report WTP-RPT-064. Simulant data from this report (VSL-03R3410-1) will be compared to the actual waste data, and the results of the comparison will be included in a separate simulant verification report.</p>	
<p>Rheological and physical properties data on actual pretreated waste and melter feed from Sub-envelope B1 (tank AZ-101) does exist and is included in draft report WTP-RPT-095. Simulant data from this report (VSL-03R3410-1) will be compared to the actual waste data (when approved for project use), and the results of the comparison will be included in a separate simulant verification report.</p>	
<p>Are all discrepancies resolved? If no, explain. <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No</p>	



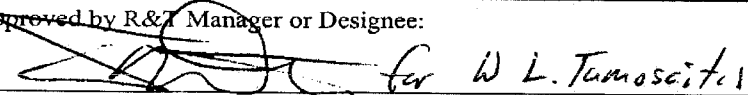
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Are all subcontractor signoffs completed? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
This work is acceptable to complete the indicated: If Other, please explain what the report completes.	
<input type="checkbox"/> Test Specification(s)	<input type="checkbox"/> Scoping Statement(s)
<input type="checkbox"/> Test Plan(s)	<input checked="" type="checkbox"/> Other
All of the test plan objectives were completed except for the physical/rheological analysis per the guideline, which will be reported in a separate report (report number not available yet).	
Does the Testing or Report suggest any follow-on work? If yes, describe the suggested activity and, if appropriate, attach a Request for Technology Development (RTD). <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	
The fact that a separate sulfate phase (although small) was observed in Sub-envelope A1 during idling at 1050°C and near zero bubbling rate suggests that there may be an issue with extremely low bubbling rates and/or reduced temperature during idle. This same phenomenon was not observed in the LAW pilot melter, which does not reduce bubbling rates during idle and maintains 1150°C for short duration idle periods (≤1 week). Engineering however is interested in reducing bubbling rates during idle to some acceptable level. A sulfate layer detector used for process control could tell operations real time how low a bubbling rate is acceptable or if reduced melt pool temperatures were problematic. Otherwise, we have not developed a solid basis for reducing bubbling rates during idle. This issue will be added to the "Recommendations and Issues List from R&T Reports" and monitored as we review upcoming LAW melter reports. The answer to this issue (assuming it is an issue) may reside in existing and near term melter testing results or test conditions could be worked into future melter tests at minimal costs.	
Additional comments:	
Approved by R&T Manager or Designee: 	Date: 10/2/03