Final Report Melter Tests with AZ-101 HLW Simulant Using a DuraMelter 100 Vitrification System VSL-01R10N0-1, Rev. 1, 2/25/02

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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**Melter Tests with AZ-101 HLW Simulant
Using a DuraMelter 100 Vitrification System**

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Duratek, Inc.

and

Bechtel National, Inc.

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Other:

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Date

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List of Acronyms

ADS	Air Displacement Slurry
BBI	Best Basis Inventory
DCP	Direct Current Plasma
DM10	DuraMelter 10
DM100	DuraMelter 100
DM1000	DuraMelter 1000
DM1200	DuraMelter 1200
EPA	Environmental Protection Agency
FTIR	Fourier Transform Infrared Spectroscopy
HEPA	High Efficiency Particulate Arrestor
HLW	High-Level Waste
LAW	Low-Activity Waste
RCRA	Resource Conservation and Recovery Act
RPP-WTP	River Protection Project-Waste Treatment Plant
SEM	Scanning Electron Microscopy
Scfh	Standard Cubic Feet per Hour
TWRS-OUP	Tank Waste Remediation System Operation and Utilization Plan
TOC	Total Organic Carbon
TCLP	Toxicity Characteristic Leaching Procedure
UTS	Universal Treatment Standard
VSL	Vitreous State Laboratory
WVDP	West Valley Demonstration Project
XRF	X-Ray Fluorescence

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SECTION 1.0 INTRODUCTION

This report provides data, analyses, and conclusions from a series of tests that were conducted at the Vitreous State Laboratory of The Catholic of America (VSL) to determine the processing rates that are achievable with AZ-101 HLW simulants and corresponding melter feeds on a DuraMelter 100 (DM100) vitrification system.

One of the most critical pieces of information in determining the required size of the RPP-WTP HLW melter is the specific glass production rate in terms of the mass of glass that can be produced per unit area of melt surface per unit time. The specific glass production rate together with the waste loading (essentially, the ratio of waste-in to glass-out, which is determined from glass formulation activities) determines the melt area that is needed to achieve a given waste processing rate with due allowance for system availability. Tests conducted during Part B1 (VSL-00R2590-2) on the DM1000 vitrification system installed at the Vitreous State Laboratory of The Catholic University of America showed that, without the use of bubblers, glass production rates with AZ-101 and C-106/AY-102 simulants were significantly lower than the Project design basis rate of $0.4 \text{ MT/m}^2/\text{d}$ [1]. Conversely, three-fold increases over the design basis rate were demonstrated with the use of bubblers [1]. Furthermore, an un-bubbled control-test using a replica of the melter feed used in cold commissioning tests at West Valley reproduced the rates that were observed with that feed on the WVDP production melter. More recent tests conducted on the DM1200 system, which more closely represents the present RPP-WTP design, are in general agreement with these earlier results [2].

Screening tests conducted on the DM10 system have provided good indications of the larger-scale processing rates *with bubblers* (for both HLW and LAW feeds) but significantly overestimated [3] the DM1000 *un-bubbled* rate observed for C-106/AY-102 melter feeds [1]. This behavior is believed to be a consequence of the role of heat transfer in rate attainment and the much greater role of wall effects in heat transfer when the melt pool is not agitated. The DM100 melter used for the present tests has a surface area of 0.108 m^2 , which is approximately 5 times larger than that of the DM10 (0.021 m^2) and approximately 11 times smaller than that of the DM1000 (1.2 m^2) (the DM1000 has since been replaced by a pilot-scale prototypical HLW melter, designated the DM1200, which has the same surface area as the DM1000). Testing on smaller melters is the most economical method for obtaining data over a wide range of operating conditions (particularly at extremes) and for guiding the more expensive tests that are performed at pilot-scale. Thus, one objective of these tests was to determine whether the DM100 melters are sufficiently large to reproduce the un-bubbled melt rates observed at the DM1000 scale, or to determine the extent of any off-set. DM100-scale tests can then be used to screen feed chemistry variations that may serve to increase the un-bubbled production rates prior to confirmation at pilot scale.

Finally, extensive characterization data obtained on simulated HLW melter feeds formed

from various glass forming additives [4] indicated that there may be advantages in terms of feed rheology and stability to the replacement of some of the hydroxides by carbonates. A further objective of the present tests was therefore to identify any deleterious processing effects of such a change before adopting the carbonate feed as the baseline.

Data from the WVDP melter using acidified (nitrated) feeds, and without bubbling, showed productions rates that are higher than those observed with the alkaline RPP feeds at the VSL. Therefore, the effect of feed acidification on production rate also was investigated.

This work was performed under Test Specification, "TSP-W375-00-00019, Rev 0, "HLW-DM10 and DM100 Melter Tests" dated November 13, 2000 and the corresponding Test Plan [5]. It should be noted, however, that the RPP-WTP Project directed a series of changes to the Test Plan as the results from previous tests were reported. As a result, the test matrix that was executed differs from that in the Test Plan, as is discussed below.

1.1 Test Objectives and Overview

DM100 melter tests using RPP feeds, with and without melt agitation by bubbling, were conducted to determine their processing characteristics. The principal objectives of this work were to:

- Obtain glass production rate data for a simulated AZ-101 HLW stream combined with pretreatment products and suitable glass forming additives using a DuraMelter 100 vitrification system to determine the effect of melter scale on un-bubbled production rates.
- Obtain processing data for a simulated AZ-101 HLW stream combined with additives as either carbonates or hydroxides to determine the effect of additive form on foaming, feed handling, cold cap characteristics, and processing rates.
- Obtain processing data for a simulated, nitrated AZ-101 HLW stream combined with additives to determine the effect of an acid, nitrated melter feed on foaming, feed handling, cold cap characteristics, and processing rates.
- Obtain data on the effects of other variables (feed water content, plenum heaters, and glass bubbling rate) on glass production rates.

Secondary objectives included:

- Collect data to characterize the melter off-gas emissions for all feed constituents, including iodine and cesium.

- Collect data on product glass composition and product quality.
- Collect data on mass balance across the melter.
- Collect operating data with a simulated ADS melter feed system (i.e., intermittent, pulsed flow of feed to the melter).

To meet these objectives, a series of tests was conducted for the primary purpose of determining throughput rates with an RPP-WTP AZ-101 HLW simulant over a range of operating conditions using the DM100-BL installed at the VSL. This melter is a scaled early RPP-WTP baseline design with fixed bottom-entering bubblers in addition to facilities for top-entering bubblers. (A second DM100 unit, the DM100-WV, which is based on the West Valley design, is also installed at the VSL).

Sufficient feed was supplied by an outside vendor to produce 3200 kg of glass, from which, approximately 2300 kg was used in the nine tests described in this report. An additional 420 kg of glass was produced in changing the glass inventory to the desired composition. Since the majority of the glass produced during the composition turnover period was produced when only the bottom electrode pair was used, well over 3 melter volumes turnover was achieved. Subsequent melter tests were conducted using both the top and bottom pair of electrodes. During the turnover period, scoping data with respect to parameters such as feed characteristics, cold-cap stabilization times, effects of melt bubbling and melt temperature, and general system operating characteristics were collected.

Nine tests were conducted with durations ranging from 56 to 120 hours to investigate the effects of bubbling rate, feed water content, feed nitration, reductant (sugar) concentration in the feed, plenum heaters, and lithium source (carbonate vs. hydroxide) on glass production rates. (Note that substitution of lithium hydroxide by lithium carbonate does not change the final glass composition because only lithium oxide is present in the product glass). Variables held constant for all of the tests included melt temperature (1150°C), cold cap coverage, the waste simulant composition, and the target glass composition. The feed rate was increased to the point that a constant, essentially complete cold cap was achieved, as an indicator of a maximized feed rate for each test. At the end of each test, the feed to the melter was stopped and the time taken to consume the cold cap was measured. Off-gas characteristics and system operational parameters throughout the melter system were recorded for each test.

All of the tests described here were conducted using the DM100-BL installed at the VSL. As noted above, the test matrix completed in this study is a departure from that originally proposed in the Test Plan [5], as shown in Table 1.1. The original test matrix included tests on the DM100-WV system, which has the advantage of a bubbling rate that can rigorously be set to zero. In contrast, the DM100-BL system has a minimum bubbling rate that is very low but not zero (< 0.2 scfh). However, the RPP-WTP Project elected not to perform the DM100-WV tests, in part due to the low production rates observed at the lowest achievable bubbling rate on the DM100-BL. The depth of the DM100-BL melter (which is greater than that of the DM100-WV) makes it well suited to the investigation of melt foaming and for the effect of immersion depth on bubbler performance. The latter issue has important implications for HLW bubbler

replacement and the mitigation of potential electrical effects within the melt pool and was, therefore, addressed in the test matrix of the Test Plan [5]. However, as shown in Table 1.1, the RPP-WTP Project elected instead to replace these tests with a series of tests to define the relationship between bubbling rate and glass production rate. Another addition to the test matrix was a test to determine whether plenum heaters would increase production rates when bubblers are not used. Finally, the nearly identical production rates obtained in the first two tests with carbonate and hydroxide additives permitted the use of carbonate additives throughout the remaining tests.

1.2 Melter System Description

1.2.1 Feed System

The melter feed is introduced in batches into a feed container that is mounted on a load cell for 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 mechanical timer-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 mixed feed enters the melter through a water-cooled, vertical feed tube.

1.2.2 Melter System

Cross-sectional diagrams of the DM100-BL melter are shown in Figure 1.1. The DM100-BL unit is a ceramic refractory-lined melter fitted with a total of five electrodes; two pairs of opposing Inconel 690 plate electrodes as well as a bottom electrode. Power can be supplied in either three-phase or single-phase configurations. All of the tests in the present work were performed with the upper and lower electrodes on each side connected together and powered by a single-phase supply; the bottom electrode was not powered. Melt pool agitation is achieved by either a removable lance entering from the top of the melter or a permanent bubbler installed through the bottom electrode. The glass product is removed from the melter by means of an airlift discharge system. The melter has a melt surface area of 0.108 m^2 and a variable glass inventory between 110 kg, when only the bottom pair of electrodes is used and about 170 kg when both pairs of electrodes are used.

1.2.3 Off-Gas Systems

For operational simplicity, the DM 100s are equipped with dry off-gas treatment systems involving gas filtration operations only. Figure 1.2 shows a schematic diagram of the off-gas system. 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, 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 equipped with internal coarse filter elements followed by conventional pre-filters and HEPA filters. The temperature of the cyclonic filters and the HEPAs are held above 100°C to prevent moisture condensation. For each melter, the entire train of gas filtration operations is duplicated and each train is used alternately. An induced draft fan completes the system.

1.3 Quality Assurance

This work was conducted under an NQA-1 (1994)-based quality assurance program that was in place at VSL. (This has since been changed to an NAQ-1 (1989) and NQA-2a (1990) Part 2.7 based quality assurance program. All of the work described in this report was conducted prior to this change). The program has been reviewed and audited by Duratek, Inc. and representatives of the RPP-WTP Project. This program is supplemented by a Quality Assurance Project Plan for RPP-WTP work that is conducted at VSL, which includes the correlation of the VSL QA program with the contractually imposed 10-CFR-830.120.

SECTION 2.0

WASTE SIMULANT, GLASS FORMULATION, AND FEED ANALYSIS

2.1 Waste Simulants

The nominal AZ-101 HLW feed simulant that was used for these tests was the same as that used for the DM1000 tests [1] and has deliberately not been modified with any more recent information in order to retain the ability to compare the results between these melter tests. The AZ-101 simulant is based on waste compositions provided in the Tank Waste Remediation System Operation and Utilization Plan (TWRS-OUP) [6]. The TWRS-OUP provides inventory information on 24 major waste components, which is, for the most part identical to that found in the Best Basis Inventory (BBI) database [7]; the exceptions are mercury, which is omitted in the TWRS-OUP, and strontium, for which the higher of the two values was assumed in this work. The TWRS-OUP, in addition to total inventories, provides the information on the partitioning of those inventories into solid and supernatant fractions that is needed to define waste simulants. The chemical wash factors that are provided in the TWRS-OUP were applied to the solid fractions in defining the AZ-101 simulant. For waste components that are not tracked in the TWRS-OUP or the BBI, data from the HLW Feed Staging Plan [8] based on the recommended number of in-tank sludge washings were used. No radionuclides or noble metals were included and all constituents present at less than 0.05 wt% (waste oxide basis) were omitted. In addition, all of the TOC was assumed to be oxalate and the small amounts of boron, lithium, and zinc were omitted since much greater amounts are present in the glass forming additives.

A total of 32 chemical components are present in the resulting simulant for the washed AZ-101 HLW (Table 2.1). This HLW material must then be blended with the projected products from LAW pretreatment to complete the waste simulant formulation. These pretreatment processes (Cs and Tc removal by ion exchange and Sr/TRU removal by Sr/permanaganate precipitation) lead to increases in the amounts of cesium, technetium, sodium, nitrate, strontium, and manganese in the HLW material. The pretreatment products from technetium removal, which contribute technetium, sodium, and nitrate, were neglected in the simulant since the impact on nitrate is relatively small (75 liters of Tc concentrate vs. 3,811 liters of Cs concentrate [9]. These data may be revised at the direction of the Project for future feeds to be used in melter tests.) and sodium is used as a glass forming additive. The quantities of pretreatment products to be combined with the AZ-101 HLW material were calculated based on References [9] and [10]. In particular, 7.71% of the total Sr/TRU precipitate from pretreatment of Envelope C waste is to be added to AZ-101 waste, which is equivalent to $(78 \text{ MT} \times 0.0771) = 6.01 \text{ MT}$ of strontium and $(38 \text{ MT} \times 0.0771) = 2.93 \text{ MT}$ of manganese. The strontium precipitate will probably consist of a combination of carbonate and hydroxide. We have assumed that the carbonate is predominant and have included 3 g of carbonate per 100 g of oxides in the simulant (no carbonate is present in the washed HLW material as a consequence of the assumed 100% wash factor for carbonate [6]). The composition of the resulting AZ-101 simulant mixed with pretreatment products is summarized in Table 2.1.

Recent WTP waste feed sequences do not result in the blending of Sr/TRU pretreatment

products with AZ-101 HLW solids. Therefore, for future melter tests, assumptions regarding waste composition including blending of pretreatment products will be revised as directed by the Project.

2.2 Glass and Melter Feed Formulations

The same glass formulation, HLW98-31, that was used for the DM1000 tests [1] was used in these tests and is presented in Table 2.1. This formulation accommodates the AZ-101 waste and LAW pretreatment products and meets all of the processing and product quality requirements. On an oxide basis, this glass incorporates 27.0 wt% of Envelope D waste and 3.5 wt% of pretreatment products; the resulting content of MnO is 3.03 wt%. Crucible, DM10, and DM1000 tests have confirmed that this glass meets all processing and performance requirements. The measured viscosity and conductivity at 1150°C are 43 P and 0.41 S/cm, respectively. Heat treatment of HLW98-31 at 950°C for 70 hours resulted in 0.26 vol% of spinel while the glass was completely homogeneous after 66 hours at 1050°C. The glass also shows good TCLP performance: the Cd concentration in the TCLP leachate is 0.067 mg/l, compared to the Universal Treatment Standard (UTS) level of 0.11 mg/l, while all other constituents are below their respective UTS levels by much wider margins.

The additional constituents required to form HLW98-31 glass from the AZ-101 simulant are boron, lithium, sodium, silicon, and zinc. The corresponding chemical additives that are the sources for these elements were selected based upon cost and compatibility with the vitrification process. Feeds made using either lithium hydroxide monohydrate or lithium carbonate as the lithium source were evaluated in these tests. The theoretical glass yield of the resulting hydroxide feed was 0.39 kg of glass per kg of feed, which is equivalent to 0.57 kg of glass per liter of feed based on the typical density of the feed of 1.47 g/ml. This was the upper limit of the feed solids content that was tested in this work; that value is based upon rheological characterization and pumping tests that have been conducted with batches having various solids contents.

2.3 Preparation of Melter Feed

Early in B1 VSL solicited bids from vendors to collaborate in simulant and feed development and to supply material for the large-scale melter tests, which resulted in the selection of NOAH Technologies Corporation. NOAH Technologies' Quality Assurance program has been reviewed and approved by VSL. NOAH Technologies has produced the simulant and feed samples used in development and screening tests conducted to date at VSL and has provided the feed for the DM10 and DM1000 throughput tests, as well as the more recent DM1200 tests.

Table 2.2 lists the starting materials and amounts required to generate the target AZ-101 simulant and feed for 10 MT of glass. For the DM100 tests reported here, NOAH Technologies prepared two feed batches (about 8,000 kg) that produced 2336.9 kg of glass with approximately

2000 kg of feed remaining unused. The formulation was specified by VSL based on chemical assays of the raw materials provided by NOAH, or as necessary, assay samples of those materials performed by VSL. NOAH Technologies provided signed certificates of addition to VSL for each batch. A representative sample from the feed batch was shipped by express mail to VSL prior to shipment of that batch. The feed material sample was vitrified and the yield and composition of the resulting glass was determined by VSL using VSL SOPs. These data were then compared to the target composition to determine if the batch needed to be re-worked ("shimmed") prior to use. Additional testing and characterization were conducted on the feed after acceptance to support these tests. These tests included density, pH, water content, rheology, and glass conversion ratio.

As requested by the Project, the feed received from NOAH was spiked with a 7:1 ratio of iodide to iodate (sodium or potassium salts). The amount of the spike was sufficient to provide the equivalent of 0.1 wt% iodine in the glass, were it all incorporated.

The feed variants used for these tests involved either the replacement of the lithium carbonate shown in Table 2.1 by lithium hydroxide to give the same lithium oxide content; dilution of the feed with water to vary the glass yield; or nitration of the feed. Nitration of the feed was based on the approach employed at West Valley (WVDP). At West Valley, nitric acid is added to the feed to bring the pH into the range of 3 - 4 prior to feed concentration by evaporation. In the present work, the starting feed was prepared by adding glass-forming chemicals to the waste simulant to achieve a target glass yield after nitration of about 420 grams per liter. Sufficient concentrated nitric acid was then added to the feed to obtain a pH of about 3 to 4. Finally, sugar was added to the nitrated feed at a ratio of 0.5 with respect to feed nitrate (i.e., 1 mole of sugar per 16 moles of NO_x).

For convenience, the approximate glass yields (amount of glass produced per unit amount of feed) for each feed type are listed below (actual values for each test are tabulated and discussed in subsequent Sections):

- "Nominal" Feed: approx. 540 g/l, carbonate-based feed
- "High" glass yield: approx. 540 g/l
- "Low" glass yield: approx. 420 g/l
- "Nitrated" feed: approx. 420 g/l
- "Very Low" glass yield: approx. 350 g/l
- RPP-WTP AZ-101 Baseline: approx. 400 g/l
(assumes 20 wt% solids Envelope D feed from pretreatment)

2.4 Analysis of Feed Samples

2.4.1 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 2.3. Additional water was deliberately added to the AZ-101 feed for Tests 3 and 7 resulting in the observed lower densities and glass yields. The target glass yields of 410 g/l for Test 3 and 350 g/l for Test 7 were closely approximated for most of the testing periods. Tests 2, 5, 6, 8 and 9 used high-solids, as-received, carbonate-based feed with only the minimal water dilution required for mixing and transfer. The measured parameters for these tests fall into relatively narrow ranges: water percent (53-58), density (1.41-1.47 g/l) and glass yield (0.37-0.39 kg/kg or 534-575 g glass/l feed). Given this similarity, the average value (0.38 kg glass / kg of feed) was used in calculating production rates for these tests. The measured glass yield and density for the hydroxide based feed used in Test 1 was slightly lower than the carbonate feeds and therefore the measured value for that test sample was used to calculate production rates for that test as opposed to the average from all the high solids tests. Sufficient nitric acid was added to the feed for Test 4 to reduce the pH from approximately 10 to below 5. As expected, both the feed density and glass conversion ratio were reduced.

2.4.2 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 [4]. 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. It should be noted that this approach is somewhat different than the "flow curve" approach that is often used 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 arbitrarily 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 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 "true" yield stress can be quite different from the value that is often reported as the yield stress,

which is instead obtained simply 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 [4], which examined a range of temperatures, showed a relatively weak effect of temperature.

Rheograms for the melter feeds, which show the feed viscosity versus shear rate, are presented in Figures 2.1 and 2.2; measured values for viscosity at selected shear rates and the yield stress values are compared to previously measured values in Table 2.3. Notice that the highest viscosities were for the small-scale test batch with lithium hydroxide and the feed from Test 1, which was also made with lithium hydroxide. This agrees with previous observations [4] indicating that feed formulated with carbonates as opposed to hydroxides are much less viscous and more stable over long periods of time. The other observed and expected trend was lower viscosities for samples with lower solids content by dilution with either water (Tests 3 and 7) or nitric acid (Test 4). Acidification of the carbonate-based feed, especially at the lower solid contents, did not show a significant impact on its viscosity [4]. The higher yield stress and viscosity values for the samples from the earlier work [4] are very likely due to the small amount of water introduced in feed handling at the larger scale in the present work, as corroborated by the measured water contents.

2.4.3 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 either dissolved in an HF/HNO₃ acid mixture with the aid of a microwave oven to produce a solution for DCP analysis or analyzed directly by XRF. Boron and lithium oxide concentrations derived from the DCP procedure were used for normalizing the XRF data since those elements were not determined by XRF. The digested glass sample solutions were also analyzed for cesium using flame atomic absorption. Data from both methods are compared to the target composition for preapproval and feed line samples in Tables 2.4 and 2.5, respectively. These results generally corroborate the consistency of the feed composition and show good agreement with the target composition for the major elements. Some of the minor oxides which were targeted at less than 0.5 wt%, such as CaO and K₂O, were consistently above target sometimes by as much as a factor of two. This may be a result of their presence as impurities in the raw materials. Volatile minor elements such as selenium, cesium, and chlorine are below target due to loss during crucible melting. The sum of analyzed oxides for DCP is always below 100% because not all elements are determined and minor losses during glass dissolution. Conversely, the same sum for XRF is always slightly greater than 100%. Agreement between the two procedures is generally good with higher XRF values for silicon, iron, and sodium. Further comparison of XRF and DCP glass analyses is provided in Section 4.1.

SECTION 3.0 MELTER OPERATIONS

Nine melter tests were conducted on the DM100-BL with the AZ-101 simulant between 11/27/00 and 2/9/01, producing over 2300 kg of glass. Glass bubbling rate, feed water content, feed nitration, and plenum heat were varied, as shown in the test summaries in Table 3.1 for tests with minimal bubbling and in Table 3.2 for tests using typical bubbling rates. A detailed run chronology is provided in the Appendix.

Prior to beginning the tests shown in Table 3.1, over 400 kg of glass was produced during the turnover of the melt pool composition. This was performed in a series of runs between 10/31/00 and 11/22/00.

The production rates summarized in Tables 3.1 and 3.2 are depicted in Figures 3.1 - 3.9. Note the slow rise in production rates at the beginning of many of the tests. For the tests with near-zero bubbling rates, the RPP-WTP Project directed that the feed rate be increased slowly over a period of about 10-20 hours, as opposed to building up the cold cap more quickly and then reducing the feed rate, which is our standard procedure. Based on the previous experience of ORP technical support staff with un-bubbled melters, a slow approach to maximum glass surface coverage was believed to avoid the onset of overfeeding. This alternative approach was therefore also evaluated as part of the testing program. In each of these graphs, both the cumulative and average over a ten-hour period are shown. Typically, by the end of each test, the cumulative production rate approximates the ten-hour average rate, indicating that steady-state rates have been approached. The primary exception is Test 4 for which the cumulative rate was biased by an overly conservative initial feed rate. While a longer test duration would have been preferable, the data suggest that the cumulative rate would likely have reached the steady-state rate of about 500 kg/m²/day.

Overall, the test variable with the greatest effect on production rate was bubbling. Figure 3.10 compares production rates of tests with nominal feed conducted at four different bubbling rates. Notice the three-fold increase in production rate as the bubbling rate is increased from 0.1 to 12 scfh. A similar increase in production rate with bubbling was observed for feed with higher water contents, as can be seen in Figure 3.11. Nominal and hydroxide-based feeds processed at approximately 400 kg/m²/day without bubbling. The production rate was enhanced by about 25% with the use of either plenum heaters or nitrated feed, as shown in Figure 3.12. As expected, processing rates decreased with increasing feed water content.

Cold cap behavior is somewhat difficult to accurately discern in smaller melters such as the DM100 but some general trends were apparent. The objective of attaining near complete coverage of the melt pool surface with a layer of partially melted feed or cold cap was achieved throughout the tests. However, dried feed would occasionally bridge from wall to wall creating a "shelf" which could be brought out of contact with molten glass upon discharging glass. This was particularly evident when plenum heaters were used (Test 6) due to foaming which tended to push feed material out of contact with the molten glass. These plenum deposits were perceived as

hard and as thick as 4 inches. Shelves were eliminated by delaying discharge events to allow the glass level to rise and incorporate the material, decreasing the feed rate, or "rodding" through the feed tube. With these measures, thinner more fluid cap cold caps were achieved which did not bridge the melt surface. In general, the cold cap material appeared relatively "crusty" in comparison to those formed when processing LAW feeds. Nitration of the feed did show some evidence of producing a somewhat more fluid cold cap.

A variety of operational measurements were made during these melter tests including temperatures throughout the melter system, which are given in Tables 3.3 - 3.4, and electrical properties in the glass pool, which are given in Table 3.5. The target glass temperature of 1150°C was successfully maintained for at least one portion of glass pool during each of the tests, as illustrated in Figures 3.13 - 3.21. In tests without bubbling, the top of the glass pool was typically at about 1150°C while temperatures deeper in the melt pool were progressively colder. A dramatic example is provided in Test 3 (Figure 3.15) where at the end of the test the glass at 11" from the bottom was at only 1050°C, while the glass at 5" from the bottom was at only about 850°C. It is unclear why this phenomenon was more pronounced in some unbubbled tests (e.g., Test 3) than in others (e.g., Test 2 in Figure 3.14). Glass temperatures throughout the pool during bubbled tests were significantly more uniform with temperature ranges of typically less than about 20°C, as shown in Figures 3.19-3.21. Plenum temperatures between 400 - 600°C were targeted and achieved for the steady-state portions of the tests. Since plenum temperature is a function of the extent to which the surface of the melt pool is covered by feed, plenum temperatures decrease over the course of each test as the cold cap develops, as shown in Figures 3.22 - 3.30. The higher plenum temperatures of around 700°C in Test 6 (Figure 3.27) were an intended consequence of using the plenum heaters for that test. Future tests are planned to assess the impact of normal and off-normal conditions on melter emissions. Gas temperatures at the film cooler typically averaged between 300 and 400°C, depending on the plenum temperature, the amount of added film cooler air, and the temperature of the added film cooler air. An approximate 65°C drop in gas temperature was observed across the transition line. Throughout the remainder of the off-gas filtration units, temperatures were maintained above 100°C to prevent water condensation. The system contains redundant HEPA filters and cyclones and therefore the units not in operation will drop well below the operating temperature. Lower gas temperatures were observed downstream of filtration units due to the lack of insulation and dilution from the blower.

Power was supplied to both electrode pairs (which were connected in parallel) but not to the bottom electrode in all nine tests. The supplied power was controlled and monitored throughout the tests. Power distribution data are provided in Table 3.5 and in Figures 3.31- 3.39. Approximately two thirds of the power is distributed to the bottom electrode pair and one-third to the top pair for tests with and without bubbling. This ratio is consistent with the relative surface areas of the upper and lower electrodes. The amount of power supplied to the electrodes depended on the feed rate, water content of the feed, and the use of plenum heaters. Tests with higher feed rates (e.g., bubbled tests) required more power; however, when normalized to glass production, they had the lowest power utilization per unit glass produced. As expected, tests with feeds with higher water contents resulted in higher power utilization and tests using plenum heaters required less electrode power than comparable tests where plenum heaters were not used.

SECTION 4.0 GLASS PRODUCT

Over 2300 kg of glass product was discharged from the melter periodically using an airlift system into 5-gallon cans. 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 and TCLP testing. Selected samples were also analyzed with Mössbauer spectroscopy and wet chemical techniques for iron redox state and with scanning electron microscopy with energy dispersive x-ray spectroscopy for secondary phases. Product glass masses, discharge date, and the analyses performed are listed in Table 4.1. Glass samples were also derived by "dipping" a rod into the glass pool at the beginning of most tests. These samples underwent total inorganic compositional analysis and are listed in Table 4.2.

4.1 Compositional Analysis

Discharge and dip glass samples were crushed and either dissolved in HF/HNO₃ acid mixtures with the aid of a microwave oven to produce a solution for DCP analysis or analyzed directly by XRF. Boron and lithium oxide concentrations derived from the DCP procedure were used for normalizing the XRF since those elements were not determined by XRF. Digested glass samples were also analyzed for cesium using flame atomic absorption. Analyzed glass compositions are provided in Table 4.3 for XRF analysis of discharged samples, Table 4.4 for DCP analysis of discharged samples, and Table 4.5 for analysis of dip samples using both methods. Compositional trends over the course of the tests are plotted for selected elements in Figures 4.1 - 4.3. The results were very similar to those for the feed samples given in Tables 2.4 and 2.5. Generally, there was good agreement with the target composition for the major elements, except for the un-normalized results of a few DCP analyses. These differences are most likely due to the low glass dissolution recoveries in a batch of about six DCP samples. Some of the minor oxides, targeted at less than 0.5 wt%, such as CaO and K₂O, were consistently above target, sometimes by as much as a factor of two. This is probably due to impurities in the raw materials. Unlike feed samples made into a glass via crucible melting, more of the volatile minor elements were retained in the glass product from the melter tests. As expected, selenium glass concentrations are well below target due to volatilization ranging from 7 to 50 percent (see Section 5). Results from the different methods of analyses agree well for the vast majority of elements, as was the case for feed sample analysis. Silica analyses using XRF are always higher and closer to target than the DCP analyses, presumably as a consequence of the dissolution step used for DCP analyses.

4.2 Iron Redox State

Glass samples from the six tests (see Table 4.1) were analyzed for iron redox state using two independent methods: Mössbauer spectroscopy and a wet-chemical method, which has greater sensitivity. Sample information including name, test and the amount of glass produced are given in Table 4.1. The wet-chemical method is a colorimetric technique that involves dissolving small amounts of glass with acid under a nitrogen atmosphere and addition of 1,10-phenanthroline during dilution. The method yields a detection limit of 0.5% divalent iron as opposed to about 3% from the Mössbauer technique. Samples from all of the tests without bubbling, except for the plenum-heater test, were selected since these had the greatest likelihood of exhibiting detectable reduced iron. In all cases, no divalent iron was detected using either method. This result is in keeping with prior testing on HLW glass formulations that were processed without the use of reductants such as sugar added to the feed.

4.3 Chemical Durability

A sample of the glass product was subjected to the EPA TCLP leach test (SW-846 Method 1311). In that procedure, a leachate solution is extracted from crushed glass with a sodium acetate buffer solution for 18 hours at 22°C with constant end-over-end agitation. The leachate concentrations were then measured by direct current plasma atomic emission spectroscopy (DCP-AES). Table 4.6 compares the results to the Universal Treatment Standard (UTS) limits, the results from a glass from the DM1000 AZ-101 tests [1], and the results for the original crucible melt glass HLW98-31 [11]. The measured leachate concentrations were all lower than the regulatory limits and, for many analytes, one to two orders of magnitude lower than the limits. Cadmium values, although below the UTS limit, came closest to the limit. There were no appreciable differences between the samples from the different melter systems other than barium values. Although the barium value for the DM100 glass is still more than 25 times less than the standard, the value of 0.83 ppm is curious given the low concentration of 0.04 wt% targeted in the glass product and in comparison to the earlier results.

4.4 Secondary Phases

Discharged glass is routinely examined microscopically for secondary phases. Samples were obtained from the tops of the 5-gallon pails into which glass was discharged and had, therefore, undergone relatively slow cooling. The glass examined, BLB-G-45A, contained approximately one volume percent spinels. In comparison, glasses produced from the DM1000 AZ-101 tests [1] exhibited less than 0.1 volume percent spinels. It should be noted that sample to sample variation of about one volume percent, in the crystal content of glass discharged from the melter, is not unusual. The spinels observed in BLB-G-45A ranged in size from 10-50 microns in diameter and consisted mainly of iron, nickel, and manganese. The MnO content of the spinels was about twice that of the surrounding glass matrix.

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 nominal operating conditions. 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. The collected materials were analyzed for the majority of the constituents present in the feed, including iodine. Summaries for melter exhaust sampling including sampling times, melter and feed conditions, stack air flow rates, air moisture content as well as complete elemental fluxes and partitioning are provided in Tables 5.1-5.3. 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 sample has passed through a 0.45 μm heated filter.

Particulate emissions from the melter were relatively low, averaging only 0.22% and did not exceed half a percent of feed solids. As expected, particulate and most elemental fluxes from the melter increased with increased melt pool bubbling. Figure 5.1 shows the emission of total solids and selected RCRA elements as a function of bubbling rate. It is unclear why the solids emissions percentage was higher for the 2 scfh test than those at 5 and 12 but this may have been the result of a surge due to cold cap break up. Increases in feed water content appear to cause smaller but discernable increases in particle emissions, particularly for tests without bubbling. Comparison of Tests 2 and 3 show an increase of 0.1 to 0.27 percent of feed solids emitted from the melter with increasing water content (53% vs. 62%, see Table 2.3). This trend would be expected if more solids are entrained with the increased amount of water boiling off from the feed and exiting the melter. Little difference was observed by varying the form of the lithium additive or by nitrating the feed. The feed element emitted as a highest percentage of feed was clearly selenium, with percentages between 8 and 60% depending primarily on bubbling. Other elements exhibiting volatile behavior include tellurium, sulfur, cesium, the halides and, to a lesser degree, boron and arsenic. Although, as expected, the halides exhibited high volatility, the relative percentages are difficult to evaluate due to their low concentrations in the feed and their prevalence as contaminants (e.g., even in water). Chlorine emissions increased as bubbling increased, but the measured emissions corresponded to greater than 100% of the target amount of chlorine in the feed. Only boron, sulfur, selenium, and the halides were detected in the impinger solutions collected downstream of the heated particle filter in the sampling train. These constituents, which constitute the "gas" fraction of the melter emissions, were also detected in the particulate fraction of the melter exhaust. Figure 5.2 shows the behavior of elements that

were detected as both particulate and as gas fractions as a function of bubbling rate. Notice that both gas and particulate species increase with bubbling except for particulate sulfur at higher bubbling rates. Sulfur emissions from high-sulfur LAW simulants tests were also divided between particulate and gaseous fractions with particulate percentages remaining roughly constant and the gaseous fraction being more sensitive to changing melter conditions [12].

The particulate filter from Test 7 was examined by SEM to determine particle morphology and to provide additional data on chemical composition. This filter was selected because measured emissions were relatively high during that test, which therefore provided sufficient material for analysis. Particles on the filter typically ranged from 0.2 to 30 μm in diameter with the majority being sub-micron. Agglomerations of particles rich in selenium and tellurium were most common with other particles being rich in sulfur and chlorine. Other feed constituents were also commonly observed, particularly iron and sodium. No iodine was observed in the particulate material. Silica concentrations were difficult to determine because the particles were sampled on a glass fiber filter. Furthermore, lighter elements such as boron and lithium could not be determined by the energy dispersive x-ray method. The SEM observations were generally corroborated by dissolution and analysis of the filters.

5.2 Gases Monitored by FTIR

Melter emissions were monitored in each test for a variety gaseous components, most notably CO and nitrogen species, by Fourier Transform Infrared Spectrometer (FTIR). The off-gas system temperature is maintained well above 100°C past the sampling port down stream 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 5.4. Concentrations of nitrogen species are plotted in Figures 5.3 - 5.11. The analytes listed in Table 5.4 are those that were thought likely to be observed during the test, based on previous work; however, FTIR is sensitive to many other species, which were not detected. The most abundant gas monitored was nitrogen oxide, which is consistent with numerous previous tests in which nitrates and nitrites were incorporated in the feed. The concentration of nitrogen oxide was five to twenty five times higher than that of nitrogen dioxide and significantly more than that for all other nitrogen species. As expected, nitrogen emissions for the test with nitrated feed (Test 4) exceeded any other test by more than an order magnitude. Gaseous emissions of species other than NO_x compounds were typically less than 1 ppm and always less than 6 ppm for every test other than the test with acidified feed (Test 4). In contrast to the Method 5-type sampling discussed earlier, gaseous chlorine and fluorine species were infrequently observed by FTIR. This is due to the impinger method being approximately 10 times more sensitive than the FTIR method and the low concentrations of halogens in the feed. As observed in several previous tests in which the feed contained high concentrations of nitrates and sugar, byproducts included significant amounts of carbon monoxide and measurable amounts of ammonia and HCN. A nitrogen mass balance is summarized in Table 5.5 and shown graphically for each test in Figures 5.12 - 5.20. Notice that NO emissions constitute anywhere from 43 to 81 percent of feed nitrogen, depending on feed and melter conditions. Tests featuring higher bubbling rates (and therefore higher feed rates), higher plenum temperatures (Test 6), and higher feed water contents appear to result in

higher proportions of nitrogen oxide emissions from feed. Although N_2O was detected in most of the tests, it did not play a significant part in the nitrogen mass balance. Feed nitrogen not accounted for by the measured compounds presumably was reduced to diatomic nitrogen. The feed nitrogen data are calculated from the instantaneous feed rate, which does vary considerably. The variations in emissions over the course of each test are due in part to the time at which the air is sampled with respect to the feed pulses and changes in instantaneous feed rates.

5.3 Iodine Emissions

The melter exhaust was sampled using a modified NIOSH Method 6005 train to determine gaseous iodine fluxes in the form of molecular iodine (I_2) and HI. The method involves pulling a melter exhaust side stream through 0.1 N sodium hydroxide solutions and then through absorption columns packed with coated charcoal. These are commercially available per the NIOSH Method and are stated as being "alkali treated." Other literature suggest that they are coated with potassium hydroxide. Iodine was eluted from the columns using a sodium carbonate solution, which was analyzed along with the basic impinger solutions for iodide by ion chromatographic or colorimetric methods. No iodine was detected in any of the solutions eluted from the charcoal columns. However, significant quantities, corresponding to anywhere from 25 to 90% of the feed flux, were detected in basic impinger solutions. Unfortunately, FTIR analysis provides no corroborative data since molecular iodine cannot be measured and HI is such a weak absorber it cannot be differentiated from other analytes. Careful examination of XRF spectra from glass analysis suggests that no measurable iodine remained in the glass (i.e., <0.01 wt%). Unfortunately, at present, no suitably matrix-matched XRF iodine standards are available to verify this finding with absolute certainty; however, the lack of iodine retention in glass is fully expected given its known volatility at high temperatures. The absence of iodine in the particulate material collected on the off-gas sampling filters (see Section 5.1) coupled with the measurements on glass and off-gas samples, results in a relatively poor closure of the mass balance for iodine. Efforts are ongoing to produce iodine standards for XRF, refine sampling methods for capturing iodine in exhaust streams, and improve methods for analyzing iodine in various matrices. All of the samples collected in this work have been retained for more detailed analysis, the results of which will be reported separately.

SECTION 6.0 SUMMARY AND CONCLUSIONS

Nine melter tests were conducted with the DM100 with the AZ-101 simulant producing over 2300 kg of glass. The measured glass production rates for these tests are summarized in Figure 6.1. Glass production rates ranged from 350 - 430 kg/m²/day without bubbling, depending on feed water content, and increased to about 500 kg/m²/day when using feed that was acidified with nitric acid (with corresponding sugar additions), and with the use of plenum heaters. Bubbling increased glass production rates by a factor of three to 1300 kg/m²/day. All three variables (nitrate + sugar, plenum heat, and bubbling) tend to improve the heat flow to the critical reaction zone in the cold cap region. As discussed previously [13, 3, 1], the combination of feed nitration with the addition of sugar provides a significant energy source in the cold cap region from the exothermic reaction between these compounds.

Tests conducted at a variety of bubbling rates and at different feed water contents show that the increase in production rate is directly proportional to the increase in glass pool bubbling rate for this system over the range of parameters investigated. It is convenient to scale the bubbling gas flow rate by the melt surface area for the purpose of subsequent comparisons. The results from the present work are plotted this way in Figure 6.2. Also shown in Figure 6.2 are similarly scaled data from tests on the DM1000 system [1] and the DM1200 system [2]. As discussed earlier, we believe that the inflation of the measured glass production rates as the melter scale is reduced (e.g., DM100 vs. DM1000) is a consequence of the role of wall effects in heat transport to the cold cap region. As the bubbling rate is increased, this effect plays a progressively smaller role, since heat (and mass) transport under the cold cap is facilitated. Consequently, the relative error in the large-scale production rate projected from small-scale melter tests decreases as the bubbling rate is increased. The net result is that while small-scale tests can provide reasonable estimates of the large-scale bubbled rates, they are rather poor predictors of values of the un-bubbled rates. It is, however, likely that the relative effects of parameter changes in small-scale tests are indicative of their effects at larger scale. Accordingly, while the results shown in Figure 6.1 illustrate the relative effects of the parameter changes, the effect of melter scale on the glass production rate (Figure 6.2) must also be considered in comparing these rates to the RPP-WTP HLW baseline value of 0.4 MT/m²/day.

A simple comparison of the glass production rates observed with comparable feeds on the DM100 and DM1000 systems without bubbling indicates that the former over-predicts the latter by about 38%. Since the melt rate increases observed with feed nitration or with plenum heaters were significantly less than this, neither of these variables are expected to make up the short-fall in glass production rates required to achieve the baseline rate of 0.4 MT/m²/day. Furthermore, although melt rates generally increase with the solids content of the feed (Figure 6.1), the range of solids contents evaluated in this work already extends considerably higher than is presently achievable with the existing RPP-WTP flow-sheet. Thus, while feeds with glass yields of up to about 550 g/l of feed were investigated, the expected solids content of Envelope D material from pretreatment (20 wt%) would correspond to a glass yield of only about 400 g/l for the AZ-101 composition. Nitration of such a feed by the addition of concentrated nitric acid would further reduce the glass yield of the feed unless an evaporator was added to the RPP-WTP HLW feed

make-up system.

Another important conclusion from Figure 6.2 is the relative sensitivity of the un-bubbled rate to glass composition (AZ-101 vs. C-106/AY-102) compared to the *insensitivity* of the corresponding bubbled rates. This is an extremely important consideration with respect to the robustness of melt rate attainment projections for the RPP-WTP facility in the face of potential variations in feed chemistry.

The glass products from these tests were consistently close to the intended composition and exhibited the expected TCLP performance. All of the glass were essentially fully oxidized with no measurable ferrous iron. Particulate emissions ranged from 0.09 to 0.48 wt% of feed solids, dependent primarily on the bubbling rate. The feed element emitted as a highest percentage of feed was clearly selenium, ranging between eight and sixty percent, depending primarily on bubbling. Other elements exhibiting volatile behavior include tellurium, sulfur, cesium, the halides and, to a lesser degree, boron and arsenic, dependent on bubbling rate. The majority of the iodine in the feed was released to the off-gas stream, none of which was detected in the particulate material. Although the mass balance for iodine was poor, there was no evidence for any significant retention in the glass. Analysis of samples for iodine is still in progress.

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Table 1.1. DM100 AZ-101 Test Matrix

Test #		Feed Type	Glass Yield	Bubbling		Objective
Actual	Test Plan			scfh	Location	
1	1	Hydroxide	High	< 0.2	Bottom electrode	Unbubbled rate vs. DM1000
2	5	Carbonate	High	< 0.2	Bottom electrode	Effect of carbonate
3	3*	Carbonate	Low	< 0.2	Bottom electrode	Effect of glass yield
4	4	Nitrated + sugar	Low	< 0.2	Bottom electrode	Effect of feed nitration
5	-	Carbonate	High	2	Bottom electrode	Effect of low bubbling
6	-	Carbonate	High	< 0.2	Bottom electrode	Effect of plenum heaters
7	-	Carbonate	Very Low	12	Bottom electrode + deep lance	Effect of bubbling and low glass yield
8	-	Carbonate	High	12	Bottom electrode + deep lance	Effect of bubbling
9	-	Carbonate	High	5	Bottom electrode + deep lance	Effect of moderate bubbling
TNC	6	Carbonate	High	12	Bottom electrode	Effect of bottom bubbling
TNC	7	Carbonate	High	12	Deep lance	Effect of bubbler depth
TNC	8	Carbonate	High	12	Shallow lance	Effect of bubbler depth

TNC - Test Not Conducted/ replaced.

* - Low glass yield test in Test Plan was planned with hydroxide feed.

Note: Approximate glass yields:

High	540 g/l
Low	420 g/l
Very Low	350 g/l
Nominal	540 g/l, carbonate-based feed.

Table 2.1. Composition Summary of AZ-101 Waste, LAW Pretreatment Products, AZ-101 Simulant Plus Pretreatment Products, Glass Additives, and HLW98-31 Glass.

	AZ-101 Envelope D Waste	Pretreatment Products (as wt% of total AZ-101 oxides)	AZ-101 Simulant (Envelope D + Pretreatment Products)	Additives (as wt% of glass)	HLW98-31 Glass Composition
Al ₂ O ₃	27.41%		24.27%		7.40%
As ₂ O ₃	0.15%		0.13%		0.04%
B ₂ O ₃				10.00%	10.00%
BaO	0.16%		0.14%		0.04%
CaO	0.91%		0.81%		0.25%
CdO	1.38%		1.22%		0.37%
CeO ₂	0.31%		0.27%		0.08%
Cl	0.03%		0.02%		0.01%
Cr ₂ O ₃	0.16%		0.14%		0.04%
Cs ₂ O	0.01%	0.3%	0.27%		0.08%
CuO	0.10%		0.09%		0.03%
F	0.14%		0.12%		0.04%
Fe ₂ O ₃	38.49%		34.08%		10.39%
K ₂ O	0.63%		0.55%		0.17%
La ₂ O ₃	1.20%		1.06%		0.32%
Li ₂ O				6.00%	6.00%
MgO	0.24%		0.21%		0.06%
MnO	7.76%	3.5%	9.94%		3.03%
Na ₂ O	1.46%	0.8%	1.96%	6.00%	6.59%
NiO	1.99%		1.76%		0.54%
P ₂ O ₅	0.47%		0.42%		0.13%
PbO	0.56%		0.50%		0.15%
SO ₃	0.93%		0.82%		0.25%
Sb ₂ O ₃	0.78%		0.69%		0.21%
SeO ₂	0.55%		0.49%		0.15%
SiO ₂	0.08%		0.07%	45.51%	45.53%
SrO	0.16%	8.6%	7.60%		2.32%
TeO ₂	0.53%		0.47%		0.14%
TiO ₂	0.23%		0.21%		0.06%
ZnO				2.00%	2.00%
ZrO ₂	13.19%		11.68%		3.56%
Total	100%	13.16%	100%	69.61%	100%
Total Oxides (kg)	82,997	10,920	93,917	214,108	308,025
Volatiles,g/100 g oxides					
CO ₂	0.00	4.96*	3.00		
NO ₂	1.08		0.95		
NO ₃	0.61	1.63	1.97		
TOC	1.50		1.32		

* If all Sr in pretreatment is precipitated as SrCO₃

Table 2.2. Composition of Melter Feed Simulant to Produce 10 Metric Tons of HLW98-31 Glass from AZ-101 Waste Plus Pretreatment Products.

AZ-101+ Pretreatment Products		Glass-Forming Additives	
Starting Materials	Target Weight, kg	Starting Materials	Target Weight, kg
Al(OH) ₃	1131.6		
Na ₂ HAsO ₄	7.5		
Ba(OH) ₂ *8H ₂ O	8.7		
CaCO ₃	44.1		
CdO	37.2		
Ce(OH) ₄	10.1		
Cr ₂ O ₃ *1.5H ₂ O	5.2		
CsOH (50% Solution)	17.5		
CuSO ₄ *5H ₂ O	8.8		
NaF	8.4		
Fe(OH) ₃ Slurry	10553.5		
KNO ₃	36.3		
La(OH) ₃ *3H ₂ O	48.5		
Li ₂ CO ₃		Li ₂ CO ₃	1484.1
(MgCO ₃) ₄ (Mg(OH) ₂ *5H ₂ O)	15.1		
MnO ₂	371.5		
NaOH (50% Solution)	12.8		
		Na ₂ B ₄ O ₇ *10H ₂ O	2738.7
Ni(NO ₃) ₂ *6H ₂ O			
Ni(OH) ₂	66.7		
FePO ₄ (80%)	33.8		
PbCO ₃ *Pb(OH) ₂	17.3		
Na ₂ SO ₄	39.4		
Sb ₂ O ₅	21.1		
SeO ₂	14.9		
SiO ₂	2.2	SiO ₂	4551.8
Sr(NO ₃) ₂	57.3		
Sr(OH) ₂ *8H ₂ O	522.2		
TeO ₂	14.2		
TiO ₂	6.3		
ZnO		ZnO	200.0
ZrOOH(CO ₃) _{0.5} (50%)	570.9		
Zr(OH) ₄ (50%)	330.8		
KCl	1.5		
Na ₂ CO ₃		Na ₂ CO ₃	264.3
NaNO ₂	63.6		
NaNO ₃			
C ₂ H ₂ O ₄ *2H ₂ O	208.1		
H ₂ O	1897.6		
Total	16,184.8	Total	9238.9
		FEED TOTAL	25,423.7

Note: Iodine (iodide/iodate) spike was added, as described in the text.

Table 2.3. Measured Feed Samples Properties From DM100, AZ-101 Tests.

Sampling Date		Sample Name	Wt. % Water	Density (g/ml)	Glass Yield (kg/kg)	Glass Yield (g/l)	pH	Yield Stress (Pa)	Viscosity (poise)		
									@ 1/s	@ 10/s	@ 100/s
NOAHF9 (Target, Li ₂ CO ₃) [4]			51.57	1.51	0.392	592	9.95	4.5	63.8	21.8	2.7
NOAHF11 (Target, LiOH) [4]			53.2	1.52	0.390	593	12.4	45.0	396	177	12.3
Preapproval Samples		NF11-100A	55.7	1.45	0.371	538	12.4	NM	NM	NM	NM
		NF9-100E	51.9	1.46	0.398	581	9.9	NM	NM	NM	NM
As Received Acidified Feed		NF11-100C	54.5	1.38	0.301	415	5.6	NM	NM	NM	NM
		NF11-100D	55.2	1.35	0.301	406	4.6	NM	NM	NM	NM
1	11/28/00	BLT-F-53A	57.1	1.39	0.370	514	10.3	1.1	110	37.4	4.0
2	12//00	BLA-F-138A	53.0	1.41	0.381	537	10.3	0.4	18	1.87	0.35
3	12/11/00	BLB-F-12A	59.5	1.35	0.335	452	9.9	0.3	9.5	1.07	0.22
	12/12/00	BLB-F-23A	62.5	1.30	0.312	406	10.1	0.4	7.0	0.75	0.15
	12/16/00	BLB-F-62A	62.0	1.31	0.312	409	10.0	NE	8.0	0.84	0.15
4	12/18/00	BLB-F-67A	54.3	1.37	0.307	421	5.0	NE	7.0	0.82	0.15
	12/21/00	BLB-F-101A	54.4	1.39	0.296	411	4.7	NE	2.7	0.39	0.10
5	1/4/01	BLB-F-136A	53.1	1.46	0.385	562	10.0	0.7	30	2.74	0.46
6	1/10/01	BLC-F-32A	53.2	1.41	0.385	543	9.9	NE	23	2.6	0.43
7	1/17/01	BLC-F-85A	65.7	1.26	0.278	350	10.0	NE	3.5	0.42	0.10
	1/19/01	BLC-F-113A	69.1	1.23	0.253	311	10.0	NE	7.0	0.77	0.13
8	1/30/01	BLC-F-125A	53.8	1.41	0.379	534	10.0	1.2	50	8.15	1.10
9	2/3/01	BLD-F-13A	53.0	1.41	0.385	542	10.1	0.8	52	6.0	0.9

NM = Not Measured

NE = Not Evident

Table 2.4. Analyzed Compositions of “Preapproval” Samples.
(wt%)

	Target	NF11-100A		NF11-100C	NF11-100D			NF9-100E	
		DCP	DCP	DCP	DCP	DCP	XRF*	DCP	XRF*
Al ₂ O ₃	7.40	8.02	7.93	6.01	8.22	7.86	8.54	7.54	8.21
As ₂ O ₃	0.04	0.03	0.04	0.03	0.05	0.08	0.04	0.05	0.03
B ₂ O ₃	10.00	10.68	10.50	10.99	10.61	10.29	10.61	10.62	10.62
BaO	0.04	0.05	0.05	0.07	0.08	0.08	ND	0.07	ND
CaO	0.25	0.49	0.46	0.47	0.40	0.37	0.37	0.29	0.36
CdO	0.37	0.32	0.33	0.37	0.38	0.37	0.41	0.30	0.32
CeO ₂	0.08	NA	NA	NA	NA	NA	0.07	NA	0.07
Cl	0.01	NA	NA	NA	NA	NA	ND	NA	0.01
Cr ₂ O ₃	0.04	0.05	0.05	0.05	0.06	0.06	0.05	0.04	0.05
Cs ₂ O	0.08	NA	NA	NA	NA	NA	0.07	NA	0.05
CuO	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.03
F	0.04	NA	NA	NA	NA	NA	ND	NA	ND
Fe ₂ O ₃	10.39	9.59	9.95	10.35	9.90	10.17	10.87	9.89	10.67
K ₂ O	0.17	0.22	0.21	0.26	0.22	0.18	0.28	0.20	0.29
La ₂ O ₃	0.32	NA	NA	NA	NA	NA	0.31	NA	0.26
Li ₂ O	6.00	5.50	5.48	6.30	5.74	5.51	5.74	5.45	5.45
MgO	0.06	0.14	0.13	0.12	0.10	0.10	ND	0.08	ND
MnO	3.03	2.61	2.62	2.99	2.55	2.51	2.86	2.65	2.95
Na ₂ O	6.59	6.61	6.59	6.70	6.56	6.29	7.02	6.17	7.12
NiO	0.54	0.48	0.49	0.59	0.50	0.48	0.48	0.46	0.47
P ₂ O ₅	0.13	0.26	0.32	0.25	0.31	0.09	0.15	0.25	0.23
PbO	0.15	0.17	0.17	0.21	0.14	0.15	0.13	0.16	0.12
SO ₃	0.25	NA	NA	NA	NA	NA	0.15	NA	0.19
Sb ₂ O ₅	0.21	0.18	0.17	0.22	0.19	0.23	0.16	0.21	0.14
SeO ₂	0.15	0.04	0.05	0.01	0.05	0.03	0.03	0.09	0.03
SiO ₂	45.53	43.89	43.78	45.57	41.06	41.53	44.25	43.16	46.06
SrO	2.32	2.01	2.21	2.31	2.20	2.10	2.15	1.93	1.88
TeO ₂	0.14	0.14	0.17	0.09	0.18	0.24	0.09	0.14	0.09
TiO ₂	0.06	0.12	0.12	0.12	0.09	0.08	0.10	0.08	0.06
ZnO	2.00	1.93	1.92	2.00	2.40	2.32	2.28	1.91	1.82
ZrO ₂	3.56	3.60	3.51	4.00	3.77	3.55	3.81	3.40	3.38
Total	99.98	97.16	97.25	100.10	95.83	94.69	101.06	95.19	100.96

NA - Not Analyzed

ND - Not Detected

* - Li₂O and B₂O₃ values taken from DCP analysis for purposes of normalization

Table 2.5. DM100 AZ101 Analyzed Feed Sample Compositions. (wt%)

		BLA-F-53A		BLA-F-138A		BLB-F-12A		BLB-F-23A		BLB-F-62A		BLB-F-67A	
Test #		1		2		3		3		3		4	
Target		XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP
Al ₂ O ₃	7.40	7.91	8.01	7.61	7.49	8.11	7.72	8.31	7.78	7.95	7.79	5.50	5.28
As ₂ O ₃	0.04	0.03	0.03	0.04	0.05	0.04	0.03	0.04	0.05	0.04	0.07	0.04	0.05
B ₂ O ₃	10.00	11.38	11.38	10.27	10.27	9.81	9.81	10.31	10.31	10.30	10.30	9.96	9.96
BaO	0.04	ND	0.07	ND	0.07	ND	0.07	ND	0.06	ND	0.05	ND	0.07
CaO	0.25	0.42	0.43	0.44	0.47	0.42	0.46	0.41	0.43	0.38	0.34	0.40	0.45
CdO	0.37	0.39	0.34	0.43	0.37	0.41	0.35	0.39	0.32	0.39	0.31	0.43	0.37
CeO ₂	0.08	0.07	0.02	0.06	0.02	0.07	0.02	0.06	0.01	0.08	0.03	0.08	0.01
Cl	0.01	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
Cr ₂ O ₃	0.04	0.04	0.05	0.05	0.06	0.05	0.06	0.05	0.05	0.04	0.05	0.05	0.05
Cs ₂ O	0.08	0.07	0.06	0.07	0.06	0.08	0.07	0.06	0.07	0.07	0.07	0.07	0.08
CuO	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.06	0.04	0.04	0.03
F	0.04	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
Fe ₂ O ₃	10.39	10.00	9.20	10.78	9.65	11.01	9.85	10.58	9.57	10.70	9.93	11.15	10.05
K ₂ O	0.17	0.30	0.29	0.30	0.25	0.29	0.25	0.30	0.25	0.30	0.23	0.29	0.25
La ₂ O ₃	0.32	0.31	NA	0.41	NA	0.33	NA	0.31	NA	0.31	NA	0.31	NA
Li ₂ O	6.00	5.76	5.76	5.41	5.41	4.94	4.94	5.11	5.11	5.46	5.46	5.63	5.63
MgO	0.06	0.03	0.11	0.04	0.10	0.02	0.11	ND	0.10	ND	0.09	0.03	0.11
MnO	3.03	2.97	2.74	3.13	2.67	3.05	2.60	2.92	2.64	3.04	2.71	3.38	2.90
Na ₂ O	6.59	6.66	6.91	6.77	6.30	6.79	6.06	6.83	6.06	7.47	6.47	7.45	6.24
NiO	0.54	0.46	0.54	0.50	0.50	0.50	0.52	0.48	0.52	0.49	0.47	0.53	0.55
P ₂ O ₅	0.13	0.17	0.33	0.17	0.24	0.17	0.27	0.17	0.28	0.17	0.22	0.18	0.22
PbO	0.15	0.13	0.19	0.14	0.16	0.13	0.17	0.13	0.12	0.14	0.17	0.14	0.13
SO ₃	0.25	0.14	NA	0.18	NA	0.17	NA	0.15	NA	0.16	NA	0.08	NA
Sb ₂ O ₅	0.21	0.19	0.21	0.18	0.20	0.19	0.22	0.17	0.20	0.18	0.21	0.19	0.21
SeO ₂	0.15	0.02	<0.01	0.04	0.03	0.04	0.01	0.03	0.00	0.03	0.05	0.01	<0.01
SiO ₂	45.53	46.46	44.00	45.61	44.16	46.07	43.86	46.36	42.23	45.23	42.72	46.48	43.48
SrO	2.32	1.97	2.26	2.13	1.99	2.12	2.03	2.02	2.05	2.08	2.05	2.22	2.12
TeO ₂	0.14	0.09	0.10	0.11	0.15	0.10	0.13	0.07	0.12	0.09	0.09	0.07	0.12
TiO ₂	0.06	0.07	0.10	0.08	0.09	0.07	0.10	0.07	0.10	0.06	0.09	0.07	0.10
ZnO	2.00	1.78	1.96	2.00	1.94	2.00	1.95	1.91	2.08	1.96	1.96	2.01	2.02
ZrO ₂	3.56	3.80	3.98	3.98	3.60	3.96	3.65	3.72	3.65	3.82	3.58	3.88	3.55
Sum	99.98	101.67	99.06	100.94	96.26	100.94	95.27	100.97	94.12	100.98	95.48	100.64	93.97

NA = Not Analyzed

ND = Not Detected

NOTES: Li₂O and B₂O₃ values taken from DCP analysis for purposes of normalization

Cs₂O values reported under DCP heading are from AA analysis; Cs₂O values reported under XRF heading are from XRF analysis.

Table 2.5. DM100 AZ101 Analyzed Feed Sample Compositions. (wt%) (continued)

		BLB-F-101A		BLB-F-136A		BLC-F-32A		BLC-F-85A		BLC-F-113A		BLC-F-125A		BLD-F-13A	
Test #		4		5		6		7		7		8		9	
Target		XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP
Al ₂ O ₃	7.40	7.58	7.13	7.98	7.89	7.88	7.94	8.10	8.04	8.25	8.00	7.88	6.81	8.02	6.75
As ₂ O ₃	0.04	0.04	NA	0.04	0.05	0.03	0.02	0.04	0.07	0.04	0.06	0.04	0.15	0.04	0.08
B ₂ O ₃	10.00	10.59	10.59	10.53	10.53	10.25	10.25	10.30	10.30	10.78	10.78	9.78	9.78	9.62	9.62
BaO	0.04	ND	0.06	ND	0.05	ND	0.05	ND	0.05	ND	0.06	ND	0.07	ND	0.07
CaO	0.25	0.37	0.32	0.37	0.32	0.40	0.39	0.40	0.33	0.35	0.30	0.34	0.33	0.34	0.34
CdO	0.37	0.45	0.34	0.41	0.30	0.40	0.33	0.33	0.29	0.34	0.27	0.29	0.30	0.32	0.33
CeO ₂	0.08	0.07	0.02	0.07	0.03	0.08	0.02	0.06	0.03	0.06	0.02	0.07	0.01	0.08	0.02
Cl	0.01	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	0.01	NA	0.01	NA
Cr ₂ O ₃	0.04	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.05	0.04	0.04	0.04	0.04
Cs ₂ O	0.08	0.09	0.06	0.07	0.06	0.07	0.06	0.06	0.06	0.07	0.07	0.06	0.07	0.05	0.06
CuO	0.03	0.04	NA	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.04
F	0.04	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
Fe ₂ O ₃	10.39	10.88	9.65	10.63	9.48	10.69	9.74	11.21	9.94	11.52	10.55	11.50	10.43	11.34	10.43
K ₂ O	0.17	0.28	0.22	0.29	0.23	0.30	0.24	0.29	0.22	0.31	0.24	0.29	0.22	0.29	0.23
La ₂ O ₃	0.32	0.29	NA	0.32	NA	0.31	NA	0.33	NA	0.32	NA	0.29	NA	0.28	NA
Li ₂ O	6.00	5.64	5.64	5.50	5.50	5.63	5.63	5.58	5.58	5.27	5.27	4.70	4.70	4.95	4.95
MgO	0.06	0.00	0.09		0.09	0.02	0.10	0.04	0.09	0.03	0.08	ND	0.08	NA	0.09
MnO	3.03	3.07	2.68	3.06	2.73	3.08	2.80	2.85	2.51	2.65	2.41	3.15	2.46	3.14	2.48
Na ₂ O	6.59	7.23	6.38	6.84	6.44	6.74	6.57	6.70	6.46	7.39	6.79	6.94	5.73	6.94	5.70
NiO	0.54	0.49	0.47	0.49	0.46	0.56	0.50	0.50	0.43	0.52	0.48	0.52	0.48	0.50	0.50
P ₂ O ₅	0.13	0.16	0.21	0.17	0.23	0.18	0.29	0.17	0.24	0.17	0.26	0.17	0.18	0.16	0.21
PbO	0.15	0.13	0.17	0.13	0.17	0.14	0.19	0.13	0.17	0.12	0.17	0.13	0.18	0.13	0.19
SO ₃	0.25	0.15	NA	0.18	NA	0.17	NA	0.16	NA	0.14	NA	0.17	NA	0.16	NA
Sb ₂ O ₃	0.21	0.19	NA	0.18	0.18	0.18	0.22	0.16	0.19	0.16	0.20	0.13	0.21	0.13	0.21
SeO ₂	0.15	0.03	NA	0.04	0.05	0.04	0.01	0.03	0.00	0.02	0.01	0.04	0.11	0.03	0.11
SiO ₂	45.53	44.85	41.48	45.62	42.57	45.61	43.49	45.33	42.22	44.71	41.90	46.71	44.49	46.71	43.80
SrO	2.32	2.13	2.05	2.08	2.07	2.10	2.10	2.12	2.11	1.97	2.04	1.96	1.79	1.97	1.80
TeO ₂	0.14	0.11	NA	0.12	0.10	0.07	0.08	0.08	0.10	0.08	NA	0.08	0.34	0.06	0.31
TiO ₂	0.06	0.07	0.09	0.07	0.09	0.07	0.09	0.07	0.09	0.09	0.09	0.06	0.09	0.06	0.10
ZnO	2.00	1.98	1.94	1.94	1.88	1.98	1.95	2.02	1.97	1.98	1.94	2.03	1.92	2.02	1.92
ZrO ₂	3.56	4.03	3.67	3.89	3.68	3.96	3.62	3.85	3.68	3.59	3.51	3.52	3.10	3.50	3.08
Sum	99.98	100.99	93.24	101.06	95.18	101.01	96.71	100.98	95.19	101.00	95.54	100.93	94.07	100.92	93.41

NA = Not Analyzed

ND = Not Detected

NOTES: Li₂O and B₂O₃ values taken from DCP analysis for purposes of normalization

Cs₂O values reported under DCP heading are from AA analysis; Cs₂O values reported under XRF heading are from XRF analysis.

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**Table 3.1. Summary of DM 100 AZ-101 Throughput Tests with Minimal Bubbling.
(0.1-0.2 scfh)**

Test #		1	2	3	4	6
Time	Feed Start	11/27/00 18:52	12/4/00 09:17	12/11/00 13:45	12/18/00 08:06	1/8/01 09:34
	Feed End	12/2/00 18:52	12/9/00 09:17	12/16/00 13:45	12/22/00 05:00	1/13/01 09:28
	Interval	120 hr	120 hr	120 hr	93 hr	120 hr
Cold Cap Burn		5 hr	4 hr	2 hr	2.5 hr	0.5 hr
Total		125 hr	124 hr	122 hr	95.5 hr	120.5 hr
Plenum Heaters		No	No	No	No	Yes
Feed	Characteristics	LiOH	Nominal	High Water	Nitric acid + Sugar	Nominal
	Used	605 kg	607 kg	608 kg	510 kg	755 kg
	Glass Yield	514 g/l	537 g/l	413 g/l	417 g/l	543 g/l
		0.370 kg/kg	0.380 kg/kg	0.315 kg/kg	0.302 kg/kg	0.380 kg/kg
	Average Rate	4.84 kg/hr	4.90 kg/hr	4.98 kg/hr	5.34 kg/hr	6.27 kg/hr
Glass Produced	Poured	191.9 kg	231.6 kg	195.8 kg	154.0 kg	278.2 kg
	Average Rate ^s	341 kg/m ² /day	415 kg/m ² /day	357 kg/m ² /day	358 kg/m ² /day	513 kg/m ² /day
	Average Rate [*]	398 kg/m ² /day	414 kg/m ² /day	349 kg/m ² /day	358 kg/m ² /day	529 kg/m ² /day
	Steady State Rate [*]	415 kg/m ² /day	430 kg/m ² /day	350 kg/m ² /day	490 kg/m ² /day	530 kg/m ² /day
	Average Power Use	8.0 kW.hr/kg glass	8.4 kW.hr/kg glass	9.1 kW.hr/kg glass	8.6 kW.hr/kg glass	5.5 kW.hr*/kg glass

^s - Rates calculated from glass poured.

^{*} - Rates calculated from feed data.

* Average power reported for Test 6 does not include the power supplied to the plenum heater.

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Table 3.2. Summary of DM 100 AZ-101 Throughput Tests with Bubbling.

Test #		5	7	8	9
Time	Feed Start	1/3/01 08:11	1/16/01 10:36	1/30/01 08:26	2/5/01 08:31
	Feed End	1/5/01 16:16	1/19/01 10:36	2/2/01 15:38	2/9/01 18:00
	Interval	56 hr	72 hr	79.2	105.5
Cold Cap Burn		0.8	2 hr	1.8 hr	3 hr
Total		56.8 hr	74 hr	81 hr	108.5 hr
Bubbling Rate		2 scfh	12 scfh	12 scfh	5 scfh
Plenum Heaters		No	No	No	No
Feed	Characteristics	Nominal	Very High Water	Nominal	Nominal
	Used	432 kg	1046 kg	1183 kg	1044 kg
	Glass yield	562 g/l	350 g/l	534 g/l	542 g/l
		0.380 kg/kg	0.278 kg/kg	0.380 kg/kg	0.380 kg/kg
	Avg. Rate	7.6 kg/hr	14.1 kg/hr	14.6 kg/hr	9.6 kg/hr
Glass Produced	Poured	155.4 kg	294.1 kg	442.0 kg	368.0 kg
	Avg. Rate ^{\$}	609 kg/ m ² /day	883 kg/ m ² /day	1233 kg/ m ² /day	811 kg/ m ² /day
	Avg. Rate [*]	643 kg/ m ² /day	873 kg/ m ² /day	1233 kg/ m ² /day	811 kg/ m ² /day
	Steady State Rate [*]	650 kg/ m ² /day	900 kg/ m ² /day	1300 kg/ m ² /day	800 kg/ m ² /day
	Avg. Power Use	6.0 kW.hr/ kg glass	6.1 kW.hr/ kg glass	4.4 kW.hr/ kg glass	5.2 kW.hr/ kg glass

\$ - Rates calculated from glass poured.

* - Rates calculated from feed data.

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Table 3.3. Temperatures from DM100, AZ-101 Tests Without Bubbling (°C).

			Test 1			Test 2			Test 3			Test 4			Test 6		
			Avg.	Min.	Max	Avg.	Min.	Max	Avg.	Min.	Max	Avg.	Min.	Max	Avg.	Min.	Max
TC-024	Electrode	Bottom	878	801	941	943	930	971	706	586	951	717	670	879	955	933	968
TC-011		West Lower	1054	1002	1089	1078	1068	1106	976	902	1087	979	943	1041	1078	1055	1092
TC-012		West Upper	1089	1000	1107	1098	1083	1122	1104	1091	1125	1106	1069	1120	1086	975	1130
TC-008-29	Glass Pool	1" from upper elec.	994	683	1159	1063	611	1173	1049	690	1173	1074	867	1174	988	841	1180
TC-009-5		5" from bottom	1072	1005	1125	1111	1091	1122	950	856	1138	960	911	1066	1112	1092	1141
TC-002-11		11" from bottom	1130	1084	1157	1146	1123	1168	1100	1039	1162	1110	1058	1141	1150	1132	1167
TC-014-20	Plenum	20" from bottom	1144	1102	1171	1138	1098	1168	1146	1121	1180	1146	1083	1163	1147	1105	1178
TC-004-24		24" from bottom	1151	1073	1194	1150	1081	1177	1153	1127	1186	1153	1082	1184	1128	925	1181
TC-007-18		11" from top	468	107	725	584	310	869	580	461	874	626	526	864	699	540	771
TC-005-24		17" from top	483	142	981	623	287	947	612	446	938	662	542	931	640	118	927
TC-001	Discharge		894	757	978	882	801	1022	872	775	1007	901	782	1011	940	816	991
TC-035	Film Cooler		342	322	395	358	262	472	347	243	487	358	304	458	340	160	460
TC-030	Transition Line Outlet		285	247	333	295	167	368	282	188	367	278	179	350	276	203	348
TC-027	Cyclone Outlet 1		148	139	169	149	47	183	138	98	170	152	34	169	156	82	194
TC-029	Cyclone Outlet 2		194	184	232	196	61	236	186	142	228	165	51	224	174	75	235
TC-033	HEPA Inlet 2		123	30	139	119	38	145	115	84	140	113	32	139	117	56	157
TC-034	HEPA Inlet 1		38	33	135	35	28	38	34	32	36	35	29	38	35	30	39
TC-031	Blower Inlet		73	51	91	70	33	87	63	48	79	61	29	79	65	36	86
TC-032	Stack		NM	NM	NM	29	26	32	29	25	32	32	26	36	30	27	34

NM – Not Measured

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Table 3.4. Temperatures from DM100, AZ-101 Tests With Bubbling (°C).

			Test 5			Test 7			Test 8			Test 9		
			Avg.	Min.	Max	Avg.	Min.	Max	Avg.	Min.	Max	Avg.	Min.	Max.
TC-024	Electrode	Bottom	979	947	990	1005	965	1019	1005	947	1016	985	963	997
TC- 011		West Lower	1082	1053	1089	1086	1059	1096	1092	1059	1107	1074	1059	1089
TC- 012		West Upper	1115	1093	1122	1110	1078	1126	1111	1092	1125	1091	1069	1112
TC- 008-29	Glass Pool	1" from upper elec.	1010	815	1132	1019	794	1115	1039	600	1170	1056	821	1139
TC- 009-5		5" from bottom	1129	1104	1152	1133	1108	1159	1147	1122	1171	1149	1133	1162
TC- 002-11		11" from bottom	1153	1137	1172	1141	1116	1170	1146	1117	1173	1150	1130	1165
TC- 014-20		20" from bottom	1136	1116	1160	1122	1099	1152	1136	1096	1167	1132	1106	1154
TC- 004-24	Plenum	24" from bottom	1133	1110	1169	1125	1097	1152	1141	1105	1175	1129	1093	1160
TC- 007-18		11" from top	611	401	904	600	507	933	600	491	913	535	439	902
TC- 005-24		17" from top	644	455	954	580	219	973	568	139	939	509	122	916
TC- 001	Discharge		915	856	995	946	896	1013	912	820	996	864	766	973
TC- 035	Film Cooler		329	252	441	350	309	494	338	270	476	314	82	464
TC- 030	Transition Line Outlet		269	221	326	289	180	354	272	150	347	250	146	359
TC- 027	Cyclone Outlet 1		155	88	168	148	56	185	145	48	173	110	44	187
TC- 029	Cyclone Outlet 2		169	82	195	181	48	205	188	63	226	180	57	246
TC- 033	HEPA Inlet 2		121	61	137	63	29	142	31	28	33	33	25	88
TC- 034	HEPA Inlet 1		35	29	37	92	30	133	117	43	140	115	40	157
TC- 031	Blower Inlet		65	38	77	77	31	90	76	37	93	71	31	98
TC- 032	Stack		29	28	31	32	28	35	32	30	34	30	27	32

Table 3.5. Electrical Data from DM100 AZ-101 Tests.

		Electrode Voltage (V)	Total Power (kW)	Resistance (ohms)	Total Current (A)	Top Current (A)	Top Electrode Power (kW)	Bottom Electrode Power (kW)	Top Resistance (ohms)	Bottom Resistance (ohms)
Test 1	Avg.	31.4	14.1	0.07	488	155	4.8	10.4	0.20	0.09
	Min.	0.5	0.1	<0.01	453	145	4.1	8.8	0.19	0.09
	Max.	51.4	35.8	0.08	543	178	6.1	12.4	0.21	0.10
Test 2	Avg.	30.7	15.7	0.06	514	159	4.9	10.9	0.63	0.13
	Min.	<0.1	<0.1	<0.01	463	133	3.9	9.1	0.55	0.12
	Max.	36.1	21.0	0.07	555	174	5.5	12.7	0.78	0.13
Test 3	Avg.	30.8	14.2	0.07	471	171	5.3	9.3	0.50	0.16
	Min.	16.4	4.0	0.05	400	145	4.0	6.5	0.39	0.12
	Max.	37.1	19.9	0.08	542	214	7.8	12.0	0.65	0.22
Test 4	Avg.	30.1	13.8	0.07	453	173	5.2	8.4	0.46	0.17
	Min.	<0.1	<0.1	<0.01	403	144	3.7	6.7	0.38	0.15
	Max.	39.2	21.9	0.08	498	187	5.8	10.1	0.59	0.20
Test 5	Avg.	30.9	17.2	0.06	554	172	5.3	11.9	0.58	0.12
	Min.	11.8	2.5	0.05	211	62	0.7	1.8	0.54	0.11
	Max.	38.2	24.9	0.06	655	202	7.7	17.2	0.72	0.12
Test 6	Avg.	28.3	13.2	0.06	468	125	3.5	9.7	1.05	0.11
	Min.	3.4	0.3	0.04	86	18	0.1	0.2	0.54	0.06
	Max.	38.6	25.6	0.07	663	204	7.8	17.7	6.71	0.13
Test 7	Avg.	37.3	23.8	0.06	639	197	7.4	16.5	0.61	0.12
	Min.	<0.1	<0.1	<0.01	497	158	5.2	11.1	0.59	0.11
	Max.	40.3	26.2	0.08	681	210	8.0	18.2	0.76	0.17
Test 8	Avg.	37.7	24.2	0.06	641	200	7.5	16.6	0.61	0.12
	Min.	0.7	0.1	0.01	99	4	<0.1	0.1	0.54	0.01
	Max.	46.5	36.9	0.06	793	256	11.9	25.0	5.08	0.13
Test 9	Avg.	33.1	18.8	0.06	568	181	6.0	12.8	0.58	0.13
	Min.	31.1	16.9	0.06	534	166	5.3	11.5	0.53	0.12
	Max.	39.1	26.2	0.06	671	212	8.3	17.9	0.67	0.13

Table 4.1. Glass Discharge for DM100 AZ-101 Test.

	Discharge Date	Glass Name	Analysis Performed	Measured Mass (kg)	Overall Cumulative Mass (kg)	Mass per Test (kg)
TEST 1	11-28-00	BLA-G-53A		8.7	8.7	191.4
	11-28-00	BLA-G-55A				
	11-28-00	BLA-G-55B	MD/DCP XRF	11.5	20.2	
	11-29-00	BLA-G-58A				
	11-29-00	BLA-G-58B		20.7	40.9	
	11-29-00	BLA-G-62A				
	11-29-00	BLA-G-63A		13.4	54.3	
	11-29-00	BLA-G-63B				
	11-30-00	BLA-G-67A		13.8	68.1	
	11-30-00	BLA-G-67B				
	11-30-00	BLA-G-72A		14	82.1	
	11-30-00	BLA-G-72B				
	12-1-00	BLA-G-72C	MD/DCP XRF	12.5	94.6	
	12-1-00	BLA-G-72D				
	12-1-00	BLA-G-76A		20	114.6	
	12-1-00	BLA-G-81A				
	12-2-00	BLA-G-81B		14.5	129.1	
	12-2-00	BLA-G-83A				
	12-2-00	BLA-G-83B		11.7	140.8	
	12-2-00	BLA-G-90A				
	12-2-00	BLA-G-91A		18.5	159.3	
	12-2-00	BLA-G-91B				
	12-2-00	BLA-G-93A	MD/DCP XRF,Fe ⁺⁺ /Fe ⁺⁺⁺	18.4	190.7	
	12-4-00	BLA-G-93B				
				0.7	191.4	

Table 4.1. Glass Discharge for DM100 AZ-101 Test (continued).

	Discharge Date	Glass Name	Analysis Performed	Measured Mass (kg)	Overall Cumulative Mass (kg)	Mass per Test (kg)
TEST 2	12-4-00	BLA-G-103A	MD/DCP XRF	27.2	218.6	231.6
	12-5-00	BLA-G-108A				
	12-5-00	BLA-G-110A		30.9	249.5	
	12-5-00	BLA-G-117A				
	12-6-00	BLA-G-117B	MD/DCP XRF	16.4	265.9	
	12-6-00	BLA-G-120A	MD/DCP XRF, Fe ⁺⁺ /Fe ⁺⁺⁺	15.7	281.6	
	12-6-00	BLA-G-122A		11.2	292.8	
	12-6-00	BLA-G-132A				
	12-7-00	BLA-G-127A	MD/DCP XRF	20.1	312.9	
	12-7-00	BLA-G-128A				
	12-7-00	BLA-G-131A		24.8	337.7	
	12-8-00	BLA-G-133A	MD/DCP XRF	13.5	351.2	
	12-8-00	BLA-G-136A				
	12-8-00	BLA-G-138A		19.4	370.6	
	12-8-00	BLA-G-142A		15.9	386.5	
	12-8-00	BLA-G-142B				
	12-9-00	BLA-G-146A		22.7	409.2	
	12-9-00	BLA-G-147A	MD/DCP XRF	13.8	423	

Table 4.1. Glass Discharge for DM100 AZ-101 Test (continued).

	Discharge Date	Glass Name	Analysis Performed	Measured Mass (kg)	Overall Cumulative Mass (kg)	Mass per Test (kg)
TEST 3	12-11-00	BLA-G-13A				195.8
	12-12-00	BLB-G-17A		27.4	450.4	
	12-12-00	BLB-G-19A				
	12-12-00	BLB-G-23A		22	472.4	
	12-12-00	BLB-G-25A				
	12-13-00	BLB-G-25B		11.9	484.3	
	12-13-00	BLB-G-29A				
	12-13-00	BLB-G-34A	MD/DCP, XRF	28.7	513	
	12-14-00	BLB-G-36A		21	534	
	12-14-00	BLB-G-40A		12.8	546.8	
	12-15-00	BLB-G-44A	MD/DCP, XRF	15	561.8	
	12-15-00	BLB-G-45A	MD/DCP, XRF, SEM	3.5	565.3	
	12-15-00	BLB-G-52A		13.8	579.1	
	12-16-00	BLB-G-57A		23.7	602.8	
	12-16-00	BLB-G-64A	MD/DCP, XRF, Fe ⁺⁺ /Fe ⁺⁺⁺	16	618.8	
TEST 4	12-18-00	BLB-G-80A				154.0
	12-19-00	BLB-G-82A		18.7	637.5	
	12-19-00	BLB-G-86A				
	12-19-00	BLB-G-86B		19.9	657.4	
	12-19-00	BLB-G-90A				
	12-20-00	BLB-G-92A	MD/DCP XRF	14.9	672.3	
	12-20-00	BLB-G-96A	MD/DCP XRF	20	692.3	
	12-20-00	BLB-G-100A				
	12-21-00	BLB-G-101A		26.3	718.6	
	12-21-00	BLB-G-101B				
	12-21-00	BLB-G-108A		25.5	744.1	
	12-21-00	BLB-G-108B				
	12-22-00	BLB-G-109A	MD/DCP XRF, Fe ⁺⁺ /Fe ⁺⁺⁺	28.7	772.8	

Table 4.1. Glass Discharge for DM100 AZ-101 Test (continued).

	Discharge Date	Glass Name	Analysis Performed	Measured Mass (kg)	Overall Cumulative Mass (kg)	Mass per Test (kg)
TEST 5	1-3-01	BLB-G-127A		22	794.8	155.4
	1-3-01	BLB-G-128A	MD/DCP XRF	10.9	805.7	
	1-3-01	BLB-G-128B				
	1-4-01	BLB-G-128C		22.4	828.1	
	1-4-01	BLB-G-128D				
	1-4-01	BLB-G-136A		28.2	856.3	
	1-4-01	BLB-G-136B				
	1-4-01	BLB-G-139A	MD/DCP XRF	17.6	873.9	
	1-2-01	BLB-G-139B				
	1-5-01	BLB-G-142A		36.5	910.4	
	1-5-01	BLB-G-142B				
	1-5-01	BLB-G-142C	MD/DCP XRF, Fe ⁺⁺ /Fe ⁺⁺⁺	17.8	928.2	
TEST 6	1-8-01	BLC-G-14A				278.2
	1-8-01	BLC-G-14B	MD/DCP XRF	18.9	947.1	
	1-8-01	BLC-G-18A				
	1-9-01	BLC-G-20A	MD/DCP XRF	21.3	968.4	
	1-9-01	BLC-G-18B		8.6	977	
	1-9-01	BLC-G-23A				
	1-10-01	BLC-G-26A		25.1	1002.1	
	1-10-01	BLC-G-26B				
	1-10-01	BLC-G-29A	MD/DCP XRF	16.7	1018.8	
	1-10-01	BLC-G-32A		19.8	1038.6	
	1-10-01	BLC-G-37A		15.9	1054.5	
	1-10-01	BLC-G-37B				
	1-10-01	BLC-G-39A	MD/DCP XRF	21	1075.5	

Table 4.1. Glass Discharge for DM100 AZ-101 Test (continued).

	Discharge Date	Glass Name	Analysis Performed	Measured Mass (kg)	Overall Cumulative Mass (kg)	Mass per Test (kg)
TEST 6	1-10-01	BLC-G-41B				
	1-11-01	BLC-G-45A	MD/DCP XRF	14.3	1089.8	
	1-11-01	BLC-G-46B	MD/DCP XRF	16.4	1106.2	
	1-11-01	BLC-G-48B		10	1116.2	
	1-11-01	BLC-G-51A				
	1-12-01	BLC-G-51B	MD/DCP XRF	10	1126.2	
	1-12-01	BLC-G-51C				
	1-12-01	BLC-G-51D		24.9	1151.1	
	1-12-01	BLC-G-56A				
	1-12-01	BLC-G-56B	MD/DCP XRF	18.2	1169.3	
	1-12-01	BLC-G-60A				
	1-13-01	BLC-G-60B		13.9	1183.2	
	1-13-01	BLC-G-62A				
	1-13-01	BLC-G-62B	MD/DCP XRF	23.2	1206.2	
TEST 7	1-16-01	BLC-G-69A		5.3	1211.7	299.4
	1-16-01	BLC-G-69B				
	1-16-01	BLC-G-78A		32.1	1243.8	
	1-16-01	BLC-G-81A				
	1-16-01	BLC-G-84A	MD/DCP XRF	21.3	1265.1	
	1-16-01	BLC-G-84B				
	1-17-01	BLC-G-85A		20.9	1286	
	1-17-01	BLC-G-87A				
	1-17-01	BLC-G-90A		33.6	1319.6	
	1-17-01	BLC-G-90B				
	1-17-01	BLC-G-93A		18.6	1338.2	

Table 4.1. Glass Discharge for DM100 AZ-101 Test (continued).

	Discharge Date	Glass Name	Analysis Performed	Measured Mass (kg)	Overall Cumulative Mass (kg)	Mass per Test (kg)
TEST 7	1-17-01	BLC-G-93B				
	1-18-01	BLC-G-93C	MD/DCP XRF	25.2	1363.4	
	1-18-01	BLC-G-96A				
	1-18-01	BLC-G-98A		24.1	1387.5	
	1-18-01	BLC-G-99A				
	1-18-01	BLC-G-100A		31	1418.5	
	1-18-01	BLC-G-105A				
	1-18-01	BLC-G-105B	MD/DCP XRF	22.1	1440.6	
	1-19-01	BLC-G-109A				
	1-19-01	BLC-G-109B		21.3	1461.9	
	1-19-01	BLC-G-109C				
	1-19-01	BLC-G-110A		20.9	1482.8	
	1-19-01	BLC-G-110B	MD/DCP XRF, Fe ⁺⁺ /Fe ⁺⁺⁺	23	1505.8	
TEST 8	1-30-01	BLC-G-125A				405.1
	1-30-01	BLC-G-125B		34	1539.8	
	1-31-01	BLC-G-127A				
	1-31-01	BLC-G-127B		27.6	1567.4	
	1-31-01	BLC-G-127C				
	1-31-01	BLC-G-131A	MD/DCP XRF	20.4	1587.8	
	1-31-01	BLC-G-131B				
	1-31-01	BLC-G-131C		22	1609.8	
	1-31-01	BLC-G-131D				
	1-31-01	BLC-G-131E		35.7	1645.5	
	1-31-01	BLC-G-136A				
	1-31-01	BLC-G-136B		39.1	1684.6	

Table 4.1. Glass Discharge for DM100 AZ-101 Test (continued).

	Discharge Date	Glass Name	Analysis Performed	Measured Mass (kg)	Overall Cumulative Mass (kg)	Mass per Test (kg)
TEST 8	1-31-01	BLC-G-140A				
	2-1-01	BLC-G-140B	MD/DCP XRF	28.2	1712.8	
	2-1-01	BLC-G-140C				
	2-1-01	BLC-G-140D		27.2	1740	
	2-1-01	BLC-G-140E		24.9	1764.9	
	2-1-01	BLC-G-144A				
	2-1-01	BLC-G-144B		22.7	1787.6	
	2-1-01	BLC-G-144C				
	2-1-01	BLC-G-146A		24.9	1812.5	
	2-1-01	BLC-G-146B				
	2-1-01	BLC-G-146C	MD/DCP XRF	34.6	1847.1	
	2-2-01	BLC-G-150A				
	2-2-01	BLC-G-150B		18.4	1865.5	
	2-2-01	BLC-G-150C		16.8	1882.3	
	2-2-01	BLC-G-150D				
	2-2-01	BLC-G-150E	MD/DCP XRF	28.6	1910.9	
	2-2-01	BLD-G-10B		23.6	1934.5	
	2-2-01	BLD-G-10C	MD/DCP XRF	13.3	1947.8	
TEST 9	2-5-01	BLD-G-22A		21.7	1969.5	389.1
	2-5-01	BLD-G-22B				
	2-5-01	BLD-G-22C		25.5	1995	
	2-5-01	BLD-G-26A				
	2-6-01	BLD-G-26B	MD/DCP XRF	28.8	2023.8	
	2-6-01	BLD-G-26C				
	2-6-01	BLD-G-29A		25.1	2048.9	
	2-6-01	BLD-G-29B				
	2-6-01	BLD-G-33A		25.8	2074.7	

Table 4.1. Glass Discharge for DM100 AZ-101 Test (continued).

	Discharge Date	Glass Name	Analysis Performed	Measured Mass (kg)	Overall Cumulative Mass (kg)	Mass per Test (kg)
TEST 9	2-6-01	BLD-G-33B		25.3	2100	
	2-7-01	BLD-G-33C	MD/DCP XRF			
	2-7-01	BLD-G-37A		25	2125	
	2-7-01	BLD-G-37B				
	2-7-01	BLD-G-37C		22.6	2147.6	
	2-7-01	BLD-G-41A				
	2-7-01	BLD-G-41B		14.5	2162.1	
	2-7-01	BLD-G-43A				
	2-7-01	BLD-G-43B		17.4	2179.5	
	2-8-01	BLD-G-43C	MD/DCP XRF			
	2-8-01	BLD-G-43D		23.6	2203.1	
	2-8-01	BLD-G-46A				
	2-8-01	BLD-G-50A		22.3	2225.4	
	2-8-01	BLD-G-50B				
	2-8-01	BLD-G-52A		22	2247.4	
	2-8-01	BLD-G-52B	MD/DCP XRF			
	2-9-01	BLD-G-55A		20.3	2267.7	
	2-9-01	BLD-G-55B				
	2-9-01	BLD-G-55C		24.2	2291.9	
	2-9-01	BLD-G-57A				
	2-9-01	BLD-G-57B		18.7	2310.6	
	2-9-01	BLD-G-62A				
	2-9-01	BLD-G-62B		21.3	2331.9	
	2-9-01	BLD-G-62C				
	2-12-01	BLD-G-63A	MD/DCP XRF	5	2336.9	

Table 4.2. DM100 AZ-101 Dip Samples.

Test #	Sampling Date	Glass Name	Analysis Performed
2	12-04-00	BLA-D-93A	MD/DCP, XRF
3	12-11-00	BLA-D-148A	MD/DCP, XRF
4	12-18-00	BLB-D-67A	MD/DCP, XRF
5	01-03-01	BLB-D-115A	MD/DCP, XRF
6	01-08-01	BLB-D-146A	MD/DCP, XRF
	01-13-01	BLC-D-68A	MD/DCP, XRF
7	01-19-01	BLC-D-113A	MD/DCP, XRF
	01-21-01	BLD-D-113B	MD/DCP, XRF
8	01-30-01	BLD-D-115A	MD/DCP, XRF
	02-03-01	BLD-D-13A	MD/DCP, XRF
9	02-12-01	BLD-D-63A	MD/DCP, XRF

Table 4.3. XRF Analysis of DM100, AZ-101 Glass Samples (wt%).

Elements	Target	BLA-G-72C	BLA-G-93A	BLA-G-103A	BLA-G-117B	BLA-G-120A	BLA-G-127A	BLA-G-133A	BLA-G-147A
Test #		1	1	2	2	2	2	2	2
Cumulative (kg)		94.6	190.7	218.6	265.9	281.6	312.9	351.2	423
Al ₂ O ₃	7.40	7.95	8.02	7.93	7.83	7.96	7.88	7.78	7.74
As ₂ O ₃	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.04
B ₂ O ₃ *	10.00	10.930	11.13	11.18	10.99	10.72	11.44	10.43	10.91
BaO	0.04	ND	ND	ND	ND	ND	ND	ND	ND
CaO	0.25	0.51	0.46	0.44	0.43	0.42	0.41	0.48	0.40
CdO	0.37	0.32	0.35	0.38	0.37	0.38	0.37	0.41	0.40
CeO ₂	0.08	0.054	0.06	0.07	0.06	0.06	0.08	0.07	0.06
Cl	0.01	ND	0.01	0.01	0.01	0.01	0.02	0.01	0.01
Cr ₂ O ₃	0.04	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.07
Cs ₂ O	0.08	0.10	0.10	0.11	0.10	0.09	0.09	0.10	0.10
CuO	0.03	0.03	0.05	0.03	0.03	0.04	0.03	0.03	0.03
F	0.04	ND	ND	ND	ND	ND	ND	ND	ND
Fe ₂ O ₃	10.39	10.16	9.90	10.04	10.22	10.14	10.05	10.53	10.23
K ₂ O	0.17	0.35	0.32	0.32	0.32	0.31	0.32	0.31	0.30
La ₂ O ₃	0.32	0.33	0.34	0.34	0.29	0.35	0.29	0.33	0.37
Li ₂ O*	6.00	5.21	5.15	5.28	5.63	5.36	5.94	5.30	5.67
MgO	0.06	0.18	0.11	0.01	0.09	0.06	0.06	0.11	ND
MnO	3.03	2.94	2.88	2.91	2.98	2.97	2.93	3.07	2.99
Na ₂ O	6.59	7.36	7.50	7.44	6.95	7.54	7.16	6.99	7.23
NiO	0.54	0.39	0.40	0.41	0.43	0.40	0.43	0.47	0.45
P ₂ O ₅	0.13	0.28	0.24	0.23	0.20	0.21	0.20	0.19	0.19
PbO	0.15	0.13	0.12	0.12	0.13	0.12	0.12	0.13	0.13
SO ₃	0.25	0.20	0.24	0.24	0.25	0.25	0.25	0.27	0.27
Sb ₂ O ₅	0.21	0.14	0.15	0.17	0.17	0.17	0.17	0.17	0.18
SeO ₂	0.15	0.04	0.06	0.06	0.07	0.07	0.07	0.07	0.08
SiO ₂	45.53	45.74	45.88	45.48	45.56	45.55	44.98	45.45	45.40
SrO	2.32	1.93	1.88	1.93	2.00	1.96	1.95	2.08	1.98
TeO ₂	0.14	0.10	0.12	0.13	0.14	0.13	0.13	0.14	0.14
TiO ₂	0.06	0.07	0.078	0.07	0.06	0.07	0.06	0.06	0.07
ZnO	2.00	1.93	1.86	1.86	1.91	1.89	1.88	2.01	1.89
ZrO ₂	3.56	3.56	3.54	3.67	3.75	3.72	3.68	3.93	3.75
Total	99.98	101.02	101.05	101.02	101.04	101.04	101.09	101.02	101.04

ND = None Detected

* - Li₂O and B₂O₃ values taken from DCP analysis for purposes of normalization

Table 4.3. XRF Analysis of DM100, AZ-101 Glass Samples (wt%) (continued).

Elements	Target %	BLB-G-34A	BLB-G-44A	BLB-G-45A	BLB-G-64A	BLB-G-92A	BLB-G-96A	BLB-G-109A	BLB-G-128A	BLB-G-139A	BLB-G-142C	BLC-G-14B
Test #		3	3	3	3	4	4	4	5	5	5	6
Cumulative (kg)		513	561.8	565.3	618.8	672.3	692.3	772.8	805.7	873.9	928.2	947.1
Al ₂ O ₃	7.40	7.87	7.98	7.87	7.96	7.46	7.72	7.46	7.34	7.85	7.67	7.57
As ₂ O ₃	0.04	0.04	0.04	0.04	0.04	0.04	0.045	0.04	0.04	0.04	0.04	0.04
B ₂ O ₃ *	10.00	10.36	10.18	10.14	10.30	10.56	10.36	10.47	10.46	10.26	10.42	11.09
BaO	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CaO	0.25	0.40	0.40	0.40	0.40	0.39	0.39	0.38	0.38	0.37	0.38	0.37
CdO	0.37	0.40	0.36	0.41	0.43	0.41	0.38	0.43	0.46	0.42	0.43	0.41
CeO ₂	0.08	0.07	0.06	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.08	0.07
Cl	0.01	0.02	0.02	0.01	0.02	0.01	ND	0.03	ND	ND	ND	ND
Cr ₂ O ₃	0.04	0.07	0.06	0.07	0.06	0.07	0.07	0.06	0.07	0.07	0.07	0.07
Cs ₂ O	0.08	0.09	0.08	0.08	0.09	0.08	0.08	0.10	0.10	0.09	0.07	0.09
CuO	0.03	0.03	0.03	0.03	0.04	0.05	0.04	0.03	0.03	0.04	0.04	0.04
F	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fe ₂ O ₃	10.39	10.45	10.45	10.58	10.56	10.39	10.28	10.40	10.59	10.16	10.65	10.33
K ₂ O	0.17	0.30	0.31	0.30	0.30	0.29	0.32	0.30	0.28	0.29	0.29	0.29
La ₂ O ₃	0.32	0.33	0.38	0.32	0.33	0.32	0.31	0.31	0.37	0.31	0.37	0.32
Li ₂ O*	6.00	5.24	5.11	5.22	5.13	5.59	5.48	5.63	5.78	5.78	5.73	5.93
MgO	0.06	0.03	ND	ND	ND	ND	0.02	ND	ND	0.00	ND	ND
MnO	3.03	3.05	3.00	3.05	3.02	3.00	3.00	3.09	3.11	2.98	3.13	3.01
Na ₂ O	6.59	6.98	7.50	7.04	7.38	7.16	7.29	6.89	6.49	7.21	6.40	7.00
NiO	0.54	0.41	0.37	0.34	0.45	0.44	0.45	0.46	0.46	0.45	0.49	0.46
P ₂ O ₅	0.13	0.19	0.29	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.17
PbO	0.15	0.13	0.13	0.14	0.13	0.13	0.16	0.14	0.13	0.14	0.14	0.13
SO ₃	0.25	0.28	0.18	0.28	0.29	0.27	0.26	0.28	0.22	0.22	0.22	0.23
Sb ₂ O ₅	0.21	0.17	0.15	0.18	0.19	0.17	0.17	0.19	0.20	0.18	0.18	0.18
SeO ₂	0.15	0.08	0.07	0.08	0.07	0.05	0.05	0.06	0.02	0.03	0.03	0.02
SiO ₂	45.53	45.92	45.87	45.87	45.49	45.97	46.09	45.94	45.94	46.12	45.75	45.27
SrO	2.32	2.06	2.05	2.14	2.10	2.04	2.03	2.08	2.10	1.99	2.11	2.03
TeO ₂	0.14	0.14	0.12	0.14	0.15	0.13	0.13	0.15	0.15	0.14	0.14	0.14
TiO ₂	0.06	0.06	0.08	0.06	0.06	0.07	0.07	0.07	0.08	0.07	0.08	0.06
ZnO	2.00	1.93	1.94	1.98	1.93	1.89	1.87	1.89	1.93	1.84	1.95	1.88
ZrO ₂	3.56	3.88	3.77	4.00	3.92	3.77	3.67	3.89	3.97	3.73	3.97	3.82
Total	99.98	100.98	100.98	100.99	101.03	100.98	100.95	100.96	100.93	101	101.00	101.02

* - Li₂O and B₂O₃ values taken from DCP analysis for purposes of normalization

ND = None Detected

Table 4.3. XRF Analysis of DM100, AZ-101 Glass Samples (wt%) (continued).

Elements	Target	BLC-G-20A	BLC-G-29A	BLC-G-39A	BLC-G-45A	BLC-G-51B	BLC-G-56B	BLC-G-62B	BLC-G-84A	BLC-G-93C	BLC-G-105B
Test #		6	6	6	6	6	6	6	7	7	7
Cumulative (kg)		968.4	1018.8	1075.5	1089.8	1126.2	1169.3	1206.2	1265.1	1363.4	1440.6
Al ₂ O ₃	7.40	7.62	7.59	7.58	7.45	7.80	7.87	7.86	7.75	7.87	7.92
As ₂ O ₃	0.04	0.03	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04
B ₂ O ₃ *	10.00	11.09	10.91	10.48	10.99	11.11	10.70	10.59	11.27	10.34	10.36
BaO	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CaO	0.25	0.38	0.39	0.39	0.40	0.38	0.37	0.37	0.37	0.53	0.36
CdO	0.37	0.42	0.40	0.41	0.39	0.37	0.38	0.38	0.40	0.32	0.33
CeO ₂	0.08	0.07	0.07	0.06	0.07	0.08	0.07	0.07	0.06	0.08	0.08
Cl	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	ND	ND	ND
Cr ₂ O ₃	0.04	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.07	0.07	0.07
Cs ₂ O	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.08	0.08	0.05	0.06
CuO	0.03	0.03	0.03	0.04	0.05	0.04	0.04	0.03	0.04	0.04	0.04
F	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fe ₂ O ₃	10.39	10.26	10.35	10.33	10.25	10.40	10.35	10.28	10.38	10.76	10.62
K ₂ O	0.17	0.31	0.28	0.29	0.27	0.31	0.30	0.30	0.31	0.32	0.30
La ₂ O ₃	0.32	0.32	0.33	0.33	0.31	0.32	0.31	0.32	0.32	0.31	0.31
Li ₂ O*	6.00	6.17	6.83	5.86	6.07	6.10	5.79	5.75	6.17	5.59	5.83
MgO	0.06	0.00	0.04	0.05	0.02	ND	0.01	ND	0.04	ND	0.06
MnO	3.03	3.03	3.04	3.03	3.00	3.05	3.04	3.02	3.04	3.08	3.04
Na ₂ O	6.59	6.85	6.83	7.20	7.16	6.68	6.75	6.92	6.50	6.88	6.96
NiO	0.54	0.45	0.47	0.46	0.46	0.47	0.47	0.47	0.48	0.49	0.48
P ₂ O ₅	0.13	0.16	0.16	0.17	0.17	0.16	0.16	0.17	0.18	0.50	0.16
PbO	0.15	0.13	0.13	0.13	0.13	0.13	0.15	0.14	0.18	0.13	0.13
SO ₃	0.25	0.23	0.25	0.26	0.27	0.26	0.28	0.28	0.21	0.18	0.17
Sb ₂ O ₅	0.21	0.19	0.17	0.18	0.17	0.16	0.16	0.17	0.17	0.12	0.14
SeO ₂	0.15	0.03	0.04	0.05	0.05	0.06	0.06	0.07	0.02	0.02	0.02
SiO ₂	45.53	45.23	45.33	45.57	45.28	45.05	45.70	45.78	45.04	45.61	45.96
SrO	2.32	2.03	2.03	2.03	2.01	2.05	2.01	2.01	2.03	2.02	1.96
TeO ₂	0.14	0.14	0.14	0.14	0.14	0.12	0.13	0.14	0.13	0.09	0.09
TiO ₂	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.06	0.06
ZnO	2.00	1.87	1.90	1.89	1.88	1.92	1.91	1.87	1.90	1.97	1.91
ZrO ₂	3.56	3.79	3.82	3.82	3.77	3.81	3.78	3.77	3.84	3.63	3.53
Total	99.98	101.04	101.75	101.00	101.01	101.05	101.03	101.01	101.07	101.09	100.99

* - Li₂O and B₂O₃ values taken from DCP analysis for purposes of normalization

ND = None Detected

Table 4.3. XRF Analysis of DM100, AZ-101 Glass Samples (wt%) (continued).

Elements	Target	BLC-G-110B	BLC-G-131C	BLC-G-140B	BLC-G-146C	BLC-G-150E	BLD-G-10C	BLD-G-26B	BLD-G-33C	BLD-G-43C	BLD-G-52B	BLD-G-63A
Test #		7	8	8	8	8	8	9	9	9	9	9
Cumulative (kg)		1505.8	1567.4	1712.8	1847.1	1910.9	1947.8	2023.8	2100	2179.5	2247.4	2336.9
Al ₂ O ₃	7.40	7.90	8.06	7.89	8.13	7.97	8.68	7.98	8.30	8.23	7.84	7.88
As ₂ O ₃	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
B ₂ O ₃ *	10.00	10.59	10.50	10.30	9.53	10.35	9.76	9.55	9.56	9.61	10.21	10.33
BaO	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CaO	0.25	0.36	0.34	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.33	0.33
CdO	0.37	0.38	0.30	0.32	0.32	0.32	0.32	0.31	0.29	0.29	0.27	0.30
CeO ₂	0.08	0.08	0.06	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07
Cl	0.01	0.01	0.01	0.07	ND	0.01	0.01	0.01	0.02	0.01	0.01	0.01
Cr ₂ O ₃	0.04	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06
Cs ₂ O	0.08	0.07	0.06	0.06	0.06	0.07	0.07	0.06	0.04	0.05	0.05	0.06
CuO	0.03	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.03	0.04
F	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fe ₂ O ₃	10.39	11.22	10.66	10.84	11.11	10.96	11.02	11.61	11.42	11.33	11.06	11.15
K ₂ O	0.17	0.30	0.33	0.30	0.30	0.29	0.32	0.31	0.31	0.31	0.29	0.30
La ₂ O ₃	0.32	0.30	0.28	0.28	0.33	0.34	0.27	0.29	0.29	0.28	0.28	0.34
Li ₂ O*	6.00	5.85	5.59	5.46	4.92	4.94	4.99	4.89	4.88	4.87	5.43	5.49
MgO	0.06	ND	0.02	0.03	ND	ND	ND	0.01	ND	ND	ND	ND
MnO	3.03	3.18	2.99	3.07	3.12	3.07	3.06	3.23	3.17	3.15	3.07	3.09
Na ₂ O	6.59	5.95	6.98	6.88	7.13	6.80	6.62	6.63	6.57	6.78	7.30	6.74
NiO	0.54	0.51	0.48	0.48	0.5	0.48	0.47	0.51	0.52	0.50	0.50	0.40
P ₂ O ₅	0.13	0.16	0.17	0.18	0.17	0.16	0.18	0.17	0.17	0.18	0.18	0.17
PbO	0.15	0.13	0.12	0.12	0.13	0.13	0.13	0.14	0.13	0.14	0.12	0.13
SO ₃	0.25	0.17	0.18	0.17	0.19	0.20	0.18	0.22	0.22	0.22	0.23	0.22
Sb ₂ O ₅	0.21	0.16	0.13	0.13	0.14	0.14	0.14	0.13	0.12	0.13	0.12	0.13
SeO ₂	0.15	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
SiO ₂	45.53	45.42	46.27	46.31	46.71	46.56	46.65	46.31	46.72	46.63	46.11	46.13
SrO	2.32	2.09	1.89	1.98	1.96	1.97	1.95	2.06	1.97	1.97	1.89	1.96
TeO ₂	0.14	0.12	0.09	0.09	0.09	0.10	0.10	0.09	0.09	0.09	0.09	0.10
TiO ₂	0.06	0.07	0.06	0.06	0.08	0.08	0.080	0.06	0.08	0.08	0.07	0.10
ZnO	2.00	2.02	1.89	1.95	1.98	1.96	1.96	2.09	2.06	2.02	1.96	2.00
ZrO ₂	3.56	3.83	3.38	3.48	3.52	3.52	3.49	3.68	3.45	3.51	3.32	3.46
Sum	99.98	101.02	100.98	100.95	100.97	100.97	101.00	100.91	100.93	100.98	100.96	101.02

* - Li₂O and B₂O₃ values taken from DCP analysis for purposes of normalization

Table 4.4. DCP Analysis of DM100, AZ-101 Glass Samples (wt%).

Element	Target	BLA-G-72C	BLA-G-93A	BLA-G-103A	BLA-G-117B	BLA-G-120A	BLA-G-127A	BLA-G-133A	BLA-G-147A
Test #		1	1	2	2	2	2	2	2
Cumulative (kg)		94.6	190.7	218.6	265.9	281.6	312.9	351.2	423
Al ₂ O ₃	7.40	8.16	7.73	7.81	8.16	7.72	8.45	8.04	8.00
As ₂ O ₃	0.04	0.04	0.04	0.04	0.03	0.04	0.06	0.02	0.04
B ₂ O ₃	10.00	10.93	11.13	11.18	10.99	10.72	11.44	10.43	10.91
BaO	0.04	0.11	0.09	0.09	0.08	0.08	0.08	0.08	0.08
ClO	0.25	0.51	0.47	0.45	0.43	0.41	0.43	0.48	0.46
CdO	0.37	0.29	0.30	0.30	0.31	0.29	0.33	0.33	0.37
CeO ₂	0.08	NA	NA	NA	NA	NA	NA	NA	NA
Cl	0.01	NA	NA	NA	NA	NA	NA	NA	NA
Cr ₂ O ₃	0.04	0.07	0.06	0.07	0.06	0.06	0.07	0.07	0.08
Cs ₂ O*	0.08	0.13	0.11	0.10	0.11	0.10	0.09	0.11	0.11
CuO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	10.39	9.67	9.52	9.59	9.89	9.42	10.16	9.27	9.78
K ₂ O	0.17	0.29	0.28	0.28	0.27	0.26	0.27	0.26	0.28
La ₂ O ₃	0.32	NA	NA	NA	NA	NA	NA	NA	NA
Li ₂ O	6.00	5.21	5.15	5.28	5.63	5.36	5.94	5.30	5.67
MgO	0.06	0.26	0.21	0.21	0.18	0.17	0.17	0.18	0.16
MnO	3.03	2.75	2.69	2.73	2.80	2.69	2.91	2.65	2.75
Na ₂ O	6.59	7.41	6.83	6.87	7.12	6.71	7.28	6.48	6.79
NiO	0.54	0.41	0.44	0.45	0.45	0.44	0.47	0.46	0.50
P ₂ O ₅	0.13	0.38	0.31	0.29	0.30	0.33	0.23	0.24	0.31
PbO	0.15	0.18	0.17	0.17	0.19	0.17	0.18	0.16	0.16
SO ₃	0.25	NA	NA	NA	NA	NA	NA	NA	NA
Sb ₂ O ₅	0.21	0.17	0.20	0.19	0.19	0.20	0.19	0.18	0.19
SeO ₂	0.15	0.05	0.03	0.03	0.06	0.05	0.07	0.04	0.05
SiO ₂	45.53	44.08	43.13	44.07	44.59	42.51	46.08	43.14	45.14
SrO	2.32	2.08	2.03	2.08	2.13	2.03	2.22	1.97	2.07
TeO ₂	0.14	0.10	0.11	0.14	0.13	0.14	0.13	0.14	0.16
TiO ₂	0.06	0.08	0.09	0.09	0.08	0.08	0.09	0.09	0.10
ZnO	2.00	1.94	1.93	1.91	1.92	1.86	1.97	1.89	2.02
ZrO ₂	3.56	3.73	3.69	3.78	3.86	3.71	4.01	3.54	3.75
Sum	99.98	98.92	96.67	98.13	99.88	95.51	103.23	95.48	99.85

NA = Analyzed

*Cs₂O from AA analysis

Table 4.4. DCP Analysis of DM100, AZ-101 Glass Samples (wt%) (continued).

Element	Target	BLB-G-34A	BLB-G-44A	BLB-G-45A	BLB-G-64A	BLB-G-92A	BLB-G-96A	BLB-G-109A	BLB-G-128A	BLB-G-139A	BLB-G-142C	BLC-G-14B
Test #		3	3	3	3	4	4	4	5	5	5	6
Cumulative (kg)		513	561.8	565.3	618.8	672.3	692.3	772.8	805.7	873.9	928.2	947.1
Al ₂ O ₃	7.40	7.55	7.38	7.50	7.38	7.26	7.16	7.38	7.53	7.71	7.70	8.05
As ₂ O ₃	0.04	0.06	0.05	0.04	0.06	0.04	0.10	0.06	0.08	0.07	0.08	0.07
B ₂ O ₃	10.00	10.36	10.18	10.14	10.30	10.02	10.36	10.47	10.46	10.26	10.42	10.83
BaO	0.04	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
CaO	0.25	0.43	0.42	0.43	0.46	0.37	0.46	0.36	0.37	0.36	0.37	0.36
CdO	0.37	0.34	0.31	0.32	0.34	0.35	0.33	0.34	0.33	0.33	0.35	0.36
CeO ₂	0.08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cl	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cr ₂ O ₃	0.04	0.07	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07
Cs ₂ O*	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.10	0.07	0.07	0.08
CuO	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	10.39	9.29	9.25	9.31	9.50	10.01	10.14	9.94	9.94	9.70	9.81	9.99
K ₂ O	0.17	0.26	0.26	0.27	0.26	0.23	0.23	0.23	0.23	0.23	0.24	0.23
La ₂ O ₃	0.32	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Li ₂ O	6.00	5.24	5.11	5.22	5.13	5.52	5.48	5.63	5.78	5.78	5.73	6.00
MgO	0.06	0.14	0.13	0.14	0.13	0.12	0.12	0.13	0.13	0.12	0.12	0.12
MnO	3.03	2.62	3.09	2.53	2.59	2.82	2.86	2.90	2.87	2.80	2.83	2.97
Na ₂ O	6.59	6.30	6.10	6.23	6.12	6.47	6.43	6.56	6.70	6.66	6.66	6.93
NiO	0.54	0.48	0.47	0.49	0.48	0.47	0.47	0.46	0.47	0.47	0.50	0.49
P ₂ O ₅	0.13	0.22	0.25	0.20	0.21	0.19	0.23	0.22	0.27	0.22	0.26	0.26
PbO	0.15	0.17	0.18	0.11	0.17	0.19	0.20	0.20	0.19	0.20	0.19	0.20
SO ₃	0.25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sb ₂ O ₅	0.21	0.18	0.19	0.20	0.20	0.20	0.19	0.19	0.18	0.20	0.17	0.20
SeO ₂	0.15	0.07	0.03	0.05	0.08	0.08	0.05	0.06	0.04	0.04	0.05	0.04
SiO ₂	45.53	42.59	41.86	42.45	43.21	44.41	44.34	44.64	43.85	43.49	44.18	43.89
SrO	2.32	1.98	1.94	1.98	1.96	2.14	2.13	2.16	2.16	2.12	2.12	2.22
TeO ₂	0.14	0.17	0.16	0.17	0.15	0.14	0.18	0.17	0.27	0.17	0.17	0.16
TiO ₂	0.06	0.09	0.09	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09
ZnO	2.00	1.85	1.93	2.03	1.88	1.92	1.89	1.87	1.91	1.93	1.92	1.97
ZrO ₂	3.56	3.57	3.51	3.55	3.50	3.63	3.63	3.69	3.65	3.65	3.66	3.81
Sum	99.98	94.12	93.04	93.62	94.38	96.85	97.25	97.90	97.68	96.76	97.80	99.40

NA = Not Analyzed

*Cs₂O from AA analysis

Table 4.4. DCP Analysis of DM100, AZ-101 Glass Samples (wt%). (continued).

Element	Target	BLC-G-20A	BLC-G-29A	BLC-G-39A	BLC-G-45A	BLC-G-51B	BLC-G-56B	BLC-G-62B	BLC-G-84A	BLC-G-93C	BLC-G-105B
Test #		6	6	6	6	6	6	6	7	7	7
Cumulative (kg)		968.4	1018.8	1075.5	1089.8	1126.2	1169.3	1206.2	1265.1	1363.4	1440.6
Al ₂ O ₃	7.40	8.29	8.14	7.88	8.17	8.41	7.90	7.85	8.69	7.87	8.08
As ₂ O ₃	0.04	0.07	0.06	0.04	0.06	0.06	0.07	0.06	0.08	0.04	0.07
B ₂ O ₃	10.00	11.09	10.91	10.48	10.99	11.11	10.70	10.59	11.27	10.34	10.36
BaO	0.04	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.06	0.06	0.06
CaO	0.25	0.37	0.38	0.38	0.40	0.38	0.35	0.34	0.38	0.51	0.35
CdO	0.37	0.36	0.35	0.34	0.35	0.35	0.34	0.33	0.37	0.35	0.34
CeO ₂	0.08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cl	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cr ₂ O ₃	0.04	0.07	0.07	0.06	0.07	0.06	0.06	0.06	0.07	0.07	0.06
Cs ₂ O*	0.08	0.08	0.08	0.09	0.08	0.09	0.08	0.07	0.08	0.07	0.06
CuO	0.03	0.04	0.04	0.04	0.05	0.04	0.03	0.04	0.04	0.04	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	10.39	10.20	9.98	9.60	9.95	10.12	9.63	9.55	10.50	9.81	9.89
K ₂ O	0.17	0.24	0.23	0.23	0.23	0.25	0.23	0.22	0.28	0.24	0.24
La ₂ O ₃	0.32	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Li ₂ O	6.00	6.17	6.10	5.86	6.07	6.10	5.79	5.75	6.17	5.59	5.83
MgO	0.06	0.12	0.12	0.12	0.13	0.12	0.11	0.10	0.12	0.11	0.10
MnO	3.03	3.02	2.97	2.83	2.96	3.01	2.88	2.87	3.10	2.83	2.82
Na ₂ O	6.59	7.16	7.06	6.74	7.07	7.14	6.70	6.69	7.19	6.49	6.69
NiO	0.54	0.50	0.49	0.48	0.49	0.49	0.47	0.46	0.50	0.49	0.50
P ₂ O ₅	0.13	0.30	0.22	0.22	0.27	0.22	0.21	0.21	0.20	0.30	0.24
PbO	0.15	0.20	0.20	0.19	0.20	0.21	0.23	0.20	0.27	0.19	0.19
SO ₃	0.25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sb ₂ O ₃	0.21	0.20	0.18	0.24	0.19	0.21	0.20	0.19	0.20	0.19	0.25
SeO ₂	0.15	0.06	0.04	0.08	0.07	0.07	0.09	0.06	0.06	0.02	0.03
SiO ₂	45.53	45.62	44.52	43.59	44.81	46.91	43.45	43.07	47.48	43.78	44.22
SrO	2.32	2.27	2.23	2.12	2.22	2.25	2.14	2.12	2.30	2.10	2.10
TeO ₂	0.14	0.14	0.16	0.15	0.19	0.14	0.16	0.14	0.18	0.10	0.13
TiO ₂	0.06	0.09	0.09	0.09	0.10	0.09	0.09	0.09	0.10	0.09	0.09
ZnO	2.00	2.03	2.01	1.89	2.01	2.03	1.99	1.92	2.07	1.91	1.89
ZrO ₂	3.56	3.89	3.84	3.65	3.85	3.87	3.70	3.68	3.96	3.57	3.60
Sum	99.98	102.57	100.46	97.38	100.94	103.70	97.57	96.66	105.63	97.10	98.17

NA = Not Analyzed

*Cs₂O values from AA analysis

Table 4.4. DCP Analysis of DM100, AZ-101 Glass Samples (wt%). (continued).

Element	Target	BLC-G-110B	BLC-G-131C	BLC-G-140B	BLC-G-146C	BLC-G-150E	BLD-G-10C	BLD-G-26B	BLD-G-33C	BLD-G-43C	BLD-G-52B	BLD-G-63A
Test #		7	8	8	8	8	8	9	9	9	9	9
Cumulative (kg)		1505.8	1567.4	1712.8	1847.1	1910.9	1947.8	2023.8	2100	2179.5	2247.4	2336.9
Al ₂ O ₃	7.40	8.22	7.74	7.36	6.79	6.78	7.09	6.75	6.82	6.78	7.18	7.45
As ₂ O ₃	0.04	0.02	0.05	0.06	0.08	0.12	0.11	0.11	0.14	0.08	0.05	0.03
B ₂ O ₃	10.00	10.59	10.50	10.30	9.53	10.35	9.76	9.55	9.56	9.61	10.21	10.33
BaO	0.04	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
ClO	0.25	0.35	0.30	0.30	0.33	0.32	0.34	0.34	0.32	0.32	0.30	0.31
CdO	0.37	0.33	0.30	0.29	0.30	0.31	0.31	0.31	0.30	0.30	0.33	0.33
CeO ₂	0.08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cl	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cr ₂ O ₃	0.04	0.06	0.06	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.07
Cs ₂ O*	0.08	0.07	0.06	0.07	0.09	0.09	0.08	0.07	0.07	0.07	0.08	0.07
CuO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	10.39	10.05	9.73	9.97	10.15	10.03	10.39	10.29	10.62	10.09	10.17	10.28
K ₂ O	0.17	0.23	0.24	0.24	0.23	0.22	0.24	0.24	0.23	0.23	0.22	0.23
La ₂ O ₃	0.32	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Li ₂ O	6.00	5.85	5.59	5.46	4.92	4.94	4.99	4.89	4.88	4.87	5.43	5.49
MgO	0.06	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08
MnO	3.03	2.87	2.64	2.68	2.42	2.46	2.50	2.43	2.44	2.42	2.51	2.55
Na ₂ O	6.59	6.76	6.41	6.19	5.67	5.70	5.79	5.67	5.62	5.59	6.14	6.25
NiO	0.54	0.49	0.45	0.47	0.49	0.48	0.50	0.50	0.48	0.47	0.47	0.48
P ₂ O ₅	0.13	0.20	0.25	0.28	0.24	0.20	0.23	0.21	0.19	0.21	0.25	0.20
PbO	0.15	0.19	0.17	0.17	0.20	0.19	0.19	0.19	0.19	0.19	0.18	0.18
SO ₃	0.25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sb ₂ O ₅	0.21	0.28	0.22	0.21	0.19	0.19	0.21	0.22	0.20	0.19	0.18	0.18
SeO ₂	0.15	0.04	0.04	0.06	0.11	0.06	0.17	0.19	0.18	0.09	0.03	0.07
SiO ₂	45.53	44.44	43.02	44.13	43.67	43.45	44.55	44.10	44.23	43.29	43.90	44.76
SrO	2.32	2.12	1.97	1.96	1.78	1.80	1.82	1.78	1.76	1.76	1.95	1.99
TeO ₂	0.14	0.11	0.15	0.14	0.37	0.34	0.48	0.44	0.41	0.34	0.13	0.13
TiO ₂	0.06	0.09	0.08	0.09	0.09	0.09	0.10	0.09	0.10	0.09	0.09	0.09
ZnO	2.00	1.88	1.81	1.89	1.92	1.90	1.87	1.89	1.85	1.86	1.94	1.91
ZrO ₂	3.56	3.64	3.43	3.43	3.06	3.10	3.12	3.05	3.04	3.03	3.37	3.41
Sum	99.98	99.01	95.35	95.95	92.79	93.26	95.01	93.52	93.82	92.04	95.26	96.89

NA = Not Analyzed

* Cs₂O from AA analysis

Table 4.5. Compositions of DM100, AZ-101 Dip Samples (wt%).

	Target	BLA-D-93A		BLA-D-148A		BLB-D-67A		BLB-D-115A		BLB-D-146A	
Test #		2		3		4		5		6	
		XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP
Al ₂ O ₃	7.40	8.00	7.62	7.72	7.54	7.98	7.66	7.71	7.71	7.97	7.64
As ₂ O ₃	0.04	0.03	0.03	0.03	0.06	0.04	0.05	0.04	0.08	0.04	0.03
B ₂ O ₃	10.00	10.73	10.73	10.70	10.70	10.65	10.65	10.46	10.46	10.09	10.09
BaO	0.04	ND	0.08	ND	0.07	ND	0.07	ND	0.07	ND	0.06
CaO	0.25	0.44	0.44	0.42	0.45	0.39	0.44	0.38	0.39	0.38	0.38
CdO	0.37	0.35	0.30	0.39	0.34	0.41	0.35	0.39	0.35	0.38	0.34
CeO ₂	0.08	0.06	NA	0.07	NA	0.07	NA	0.06	NA	0.07	NA
Cl	0.01	0.01	NA	0.01	NA	0.01	NA	ND	NA	0.01	NA
Cr ₂ O ₃	0.04	0.06	0.06	0.07	0.07	0.06	0.07	0.06	0.06	0.07	0.07
Cs ₂ O	0.08	0.10	0.09	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.08
CuO	0.03	0.05	0.04	0.10	0.07	0.04	0.03	0.03	0.03	0.04	0.04
F	0.04	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
Fe ₂ O ₃	10.39	9.55	9.59	10.37	9.32	10.48	9.42	9.91	9.60	10.36	9.64
K ₂ O	0.17	0.31	0.26	0.30	0.26	0.29	0.26	0.30	0.28	0.31	0.25
La ₂ O ₃	0.32	0.33		0.32	NA	0.36	NA	0.30	NA	0.36	NA
Li ₂ O	6.00	5.19	5.19	5.28	5.28	5.19	5.19	5.72	5.72	5.56	5.56
MgO	0.06	0.12	0.20	0.00	0.16	0.00	0.14	0.03	0.14	0.02	0.13
MnO	3.03	2.79	2.67	3.01	2.66	3.00	2.58	2.92	2.84	3.03	2.75
Na ₂ O	6.59	7.93	6.77	7.56	6.42	7.24	6.27	7.10	6.68	7.14	6.46
NiO	0.54	0.39	0.43	0.46	0.47	0.45	0.49	0.40	0.47	0.45	0.49
P ₂ O ₅	0.13	0.25	0.30	0.19	0.30	0.17	0.08	0.18	0.26	0.16	0.22
PbO	0.15	0.11	0.16	0.14	0.16	0.13	0.13	0.13	0.20	0.12	0.19
SO ₃	0.25	0.24	NA	0.26	NA	0.27	NA	0.23	NA	0.23	NA
Sb ₂ O ₃	0.21	0.15	0.18	0.17	0.19	0.18	0.20	0.18	0.19	0.17	0.19
SeO ₂	0.15	0.06	0.04	0.08	0.04	0.05	0.06	0.01	0.04	0.02	0.04
SiO ₂	45.53	46.71	43.25	45.13	42.60	45.42	42.35	46.81	43.79	46.03	43.67
SrO	2.32	1.78	2.03	2.03	1.99	2.06	1.99	1.95	2.16	2.04	2.05
TeO ₂	0.14	0.12	0.10	0.13	0.15	0.14	0.23	0.13	0.14	0.12	0.09
TiO ₂	0.06	0.07	0.09	0.06	0.09	0.08	0.09	0.06	0.09	0.09	0.10
ZnO	2.00	1.78	1.92	2.12	2.06	1.92	2.03	1.79	1.91	1.89	1.91
ZrO ₂	3.56	3.34	3.68	3.82	3.54	3.86	3.58	3.61	3.65	3.77	3.54
Sum	99.98	101.04	96.15	101.02	94.99	101.02	94.41	100.94	97.31	100.98	95.93

NA = Not Analyzed

ND = None Detected

NOTES: Li₂O and B₂O₃ values taken from DCP analysis for purposes of normalization

Cs₂O values reported under DCP heading are from AA analysis; Cs₂O values reported under XRF heading are from XRF analysis.

Table 4.5. Compositions of DM100, AZ-101 Dip Samples (wt%) (continued).

		BLC-D-68A		BLC-D-113A		BLC-D-113B		BLC-D-115A		BLD-D-13A		BLD-D-63A	
Test #		6		7		7		8		8		9	
	Target	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP
Al ₂ O ₃	7.40	7.92	7.97	8.16	8.04	8.04	8.19	8.03	7.86	8.15	6.54	8.05	7.36
As ₂ O ₃	0.04	0.04	0.00	0.04	0.03	0.04	0.05	0.04	NA	0.04	0.09	0.04	0.03
B ₂ O ₃	10.00	10.39	10.39	10.43	10.43	10.43	10.43	10.57	10.57	9.33	9.33	10.06	10.06
BaO	0.04	ND	0.06	ND	0.06	ND	0.06	ND	0.06	ND	0.07	ND	0.07
CaO	0.25	0.50	0.51	0.36	0.34	0.35	0.34	0.36	0.31	0.34	0.34	0.33	0.29
CdO	0.37	0.35	0.34	0.30	0.33	0.34	0.34	0.32	0.31	0.28	0.30	0.29	0.33
CeO ₂	0.08	0.08	NA	0.07	NA	0.07	NA	0.07	NA	0.08	NA	0.07	NA
Cl	0.01	0.02	NA	0.01	NA	0.01	NA	0.01	NA	0.01	NA	0.01	NA
Cr ₂ O ₃	0.04	0.07	0.06	0.06	0.06	0.07	0.06	0.07	0.06	0.07	0.06	0.06	0.05
Cs ₂ O	0.08	0.08	0.07	0.05	0.07	0.05	0.07	0.06	0.07	0.05	0.07	0.06	0.07
CuO	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	NA	0.04	0.03	0.03	0.03
F	0.04	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA
Fe ₂ O ₃	10.39	10.28	9.82	10.69	9.98	10.60	10.08	10.72	9.60	11.40	10.06	10.98	9.67
K ₂ O	0.17	0.31	0.25	0.30	0.23	0.28	0.23	0.30	0.23	0.32	0.24	0.25	0.21
La ₂ O ₃	0.32	0.31	NA	0.29	NA	0.29	NA	0.30	NA	0.34	NA	0.28	NA
Li ₂ O	6.00	5.71	5.71	5.68	5.68	5.75	5.75	5.65	5.65	4.72	4.72	5.46	5.46
MgO	0.06	0.07	0.15	0.09	0.10	0.02	0.10	0.00	0.10	ND	0.09	0.00	0.08
MnO	3.03	3.01	2.83	3.03	2.81	3.03	2.83	3.07	2.67	3.19	2.40	3.04	2.53
Na ₂ O	6.59	7.17	6.65	6.83	6.57	6.88	6.70	7.02	6.54	7.01	5.49	7.15	6.13
NiO	0.54	0.48	0.50	0.48	0.49	0.47	0.48	0.47	0.44	0.50	0.49	0.52	0.44
P ₂ O ₅	0.13	0.17	0.23	0.12	0.26	0.18	0.22	0.16	0.21	0.16	0.24	0.17	0.27
PbO	0.15	0.13	0.19	0.13	0.19	0.12	0.18	0.13	0.17	0.35	0.18	0.12	0.18
SO ₃	0.25	0.30	NA	0.17	NA	0.19	NA	0.19	NA	0.13	NA	0.26	NA
Sb ₂ O ₅	0.21	0.16	0.30	0.13	0.31	0.14	0.29	0.13	NA	0.12	0.20	0.12	0.19
SeO ₂	0.15	0.07	0.07	0.03	0.05	0.02	0.04	0.01	NA	0.03	0.05	0.02	0.02
SiO ₂	45.53	45.70	44.28	46.14	43.85	46.12	44.24	45.84	42.49	46.58	43.38	46.24	42.71
SrO	2.32	1.96	2.10	1.91	2.08	1.95	2.11	1.93	2.02	1.99	1.73	1.92	1.97
TeO ₂	0.14	0.12	0.15	0.09	0.10	0.10	0.10	0.09	NA	0.08	0.36	0.09	0.13
TiO ₂	0.06	0.07	0.10	0.07	0.09	0.07	0.10	0.07	0.09	0.08	0.09	0.07	0.09
ZnO	2.00	1.88	1.90	1.93	1.89	1.89	1.92	1.96	1.82	2.06	1.86	1.94	1.95
ZrO ₂	3.56	3.66	3.67	3.40	3.59	3.48	3.62	3.45	3.53	3.51	2.96	3.40	3.23
Sum	99.98	101.02	98.24	101.02	97.60	100.99	98.47	101.03	94.74	100.95	91.32	101.00	93.47

NA = Not Analyzed

ND = None Detected

NOTES: Li₂O and B₂O₃ values taken from DCP analysis for purposes of normalization

Cs₂O values reported under DCP heading are from AA analysis; Cs₂O values reported under XRF heading are from XRF analysis.

Table 4.6 TCLP Results for AZ-101 Glasses.
(mg/l)

	Sample ID	As	Ba	Cd	Cr	Cu	Ni	Pb	Sb	Se	Zn
	UTS Limit	5.00	21.00	0.11	0.60		11.00	0.75	1.15	5.70	4.30
DM100	BLD-G-63A	<0.05	0.83	0.07	0.01	0.10	0.04	0.03	0.04	<0.05	0.58
DM1000	AZ2-G-45B	<0.05	0.02	0.08	<0.01	0.02	0.08	0.03	<0.04	<0.05	0.40
Crucible melt	HLW98-31	<0.05	0.03	0.07	0.02	-	0.09	0.03	<0.04	0.09	0.33
	Detection Limits	0.05	<0.01	<0.01	<0.01	<0.01	0.01	0.02	0.04	0.05	<0.01

Table 5.1. Melter Emissions for DM100 AZ101 Tests 1-3.

Test #		1			2			3		
Sampling Interval		11/30/00 13:50-14:50			12/7/00 15:52-16:52			12/14/00 11:05-12:05		
Conditions		< 0.2 scfh bubbling, LiOH			< 0.2 scfh bubbling, Li ₂ CO ₃			< 0.2 scfh bubbling, Li ₂ CO ₃ , low solids		
Steady State Glass Production Rate		415 kg/m ² /day			430 kg/m ² /day			350 kg/m ² /day		
Stack Flow Rate		40.2 dscfm			35.2 dscfm			37.0 dscfm		
Sample Volume		40.701 dscf			39.710 dscf			39.541 dscf		
Moisture		6.3%			13.0%			11.5%		
Fluxes		Feed (g/hr)	Emitted (mg/min)	%	Feed (g/hr)	Emitted (mg/min)	%	Feed (g/hr)	Emitted (mg/min)	%
PARTICLE	Solids	2165.00	48.30	0.13	2393.0	41.10	0.10	1918.0	85.30	0.27
	As	0.6	0.07	0.69	0.6	<0.01	<0.10	0.5	<0.01	<0.12
	B	58.0	3.49	0.36	60.1	2.27	0.23	48.9	4.77	0.59
	Ba	0.7	0.05	0.41	0.7	0.02	0.18	0.6	0.04	0.40
	Cd	6.2	0.16	0.15	6.4	0.15	0.14	5.2	0.31	0.35
	Cl	0.2	0.35	10.50	0.2	0.46	13.80	0.2	0.73	21.90
	Cr	0.5	0.03	0.37	0.5	0.05	0.56	0.4	0.08	1.14
	Cs	1.15	0.13	0.54	1.5	0.12	0.49	1.2	0.15	0.72
	Cu	0.4	0.02	0.25	0.5	0.02	0.27	0.4	0.03	0.53
	F	0.7	<0.01	<0.09	0.8	0.11	0.83	0.6	0.37	3.70
	Fe	135.7	7.33	0.32	140.6	7.11	0.30	114.4	12.89	0.68
	K	2.6	0.27	0.61	2.7	0.16	0.35	2.2	0.32	0.86
	Li	52.0	2.90	0.33	53.9	0.79	0.09	43.9	1.87	0.26
	Mn	43.8	0.32	0.04	45.4	0.15	0.02	37.0	0.53	0.09
	Na	91.3	6.17	0.41	94.6	5.02	0.32	77.0	7.99	0.62
	Ni	7.9	0.13	0.09	8.2	0.13	0.09	6.7	0.24	0.22
	P	27.4	0.19	0.04	28.4	0.25	0.05	23.1	0.23	0.06
	Pb	2.6	0.09	0.21	2.7	0.08	0.18	2.2	0.18	0.48
	S	1.9	<0.01	<0.09	1.9	0.18	0.57	1.6	0.24	0.90
	Sb	3.0	0.03	0.07	3.1	0.03	0.06	2.5	0.05	0.12
	Se	2.0	2.42	7.27	2.1	3.82	11.10	1.7	6.95	24.82
	Sr	36.6	1.42	0.23	38.0	1.46	0.23	30.9	2.55	0.50
	Te	2.1	0.06	0.17	2.2	0.10	0.27	1.8	0.19	0.66
	Ti	0.7	0.01	0.10	0.7	<0.01	0.12	0.6	<0.01	<0.04
	Zn	30.0	1.35	0.27	31.1	1.32	0.25	25.3	2.37	0.56
	Zr	49.2	0.50	0.06	51.0	0.19	0.02	41.5	0.85	0.12
GAS	B	58.0	0.80	0.08	60.1	4.05	0.40	48.9	6.16	0.76
	Cl	0.2	<0.01	<0.3	0.2	<0.01	<0.3	0.2	<0.01	<0.3
	F	0.7	<0.01	<0.09	0.8	<0.01	<0.08	0.6	<0.01	<0.1
	Se	2.0	0.03	0.09	2.1	0.12	0.34	1.7	0.10	0.35
	S	1.9	0.01	0.03	1.9	0.02	0.06	1.6	<0.01	<0.04

Table 5.2 . Melter Emissions for DM100 AZ101 Tests 4-6.

Test #		4			5			6		
Sampling Interval		12/20/00 10:44-11:44			1/4/01 12:47-13:47			1/12/01 14:30-15:30		
Conditions		< 0.2 scfh bubbling, Li ₂ CO ₃ , nitrated feed with sugar			2 scfh bubbling, Li ₂ CO ₃			< 0.2 scfh bubbling, Li ₂ CO ₃ , plenum heaters		
Steady State Glass Production Rate		490 kg/m ² /day			650 kg/m ² /day			530 kg/m ² /day		
Stack Flow Rate		36.2 dscfm			33.0 dscfm			32.0 dscfm		
Sample Volume		35.547 dscf			34.014 dscf			34.014 dscf		
Moisture		5.7%			10.8%			8.5%		
Fluxes		Feed (g/hr)	Emitted (mg/min)	%	Feed (g/hr)	Emitted (mg/min)	%	Feed (g/hr)	Emitted (mg/min)	%
PARTICLE	Solids	3359.0	50.00	0.09	3618.0	290.00	0.48	2950.0	53.30	0.11
	As	0.7	0.03	0.26	0.9	0.16	1.09	0.7	0.05	0.40
	B	68.4	4.73	0.41	90.8	10.55	0.70	74.0	3.43	0.28
	Ba	0.8	0.06	0.45	1.0	0.14	0.78	0.9	0.02	0.17
	Cd	7.3	0.30	0.25	9.7	1.06	0.65	7.9	0.25	0.19
	Cl	0.2	0.48	14.40	0.3	1.92	38.40	0.2	0.33	9.90
	Cr	0.6	0.05	0.45	0.8	0.24	1.77	0.7	0.06	0.54
	Cs	1.7	0.13	0.47	2.1	0.65	1.88	1.9	0.12	0.38
	Cu	0.5	0.09	1.02	0.7	0.08	0.71	0.6	0.03	0.35
	F	0.9	0.17	1.13	1.2	0.83	4.15	1.0	<0.01	<0.06
	Fe	160.2	5.75	0.22	212.5	27.37	0.77	173.3	10.18	0.35
	K	3.1	0.20	0.39	4.1	0.87	1.27	3.4	0.14	0.25
	Li	61.5	2.09	0.20	81.5	3.99	0.29	66.5	0.99	0.09
	Mn	51.7	0.59	0.07	68.6	2.67	0.23	56.0	0.53	0.06
	Na	107.8	5.09	0.28	143.0	20.35	0.85	116.6	6.25	0.32
	Ni	9.4	0.18	0.11	12.4	0.99	0.48	10.1	0.21	0.12
	P	32.3	0.23	0.04	42.9	0.79	0.11	35.0	0.40	0.07
	Pb	3.1	0.09	0.17	4.1	0.61	0.90	3.3	0.19	0.34
	S	2.2	0.13	0.35	2.9	1.59	3.29	2.4	0.11	0.28
	Sb	3.5	0.01	0.01	4.6	0.31	0.41	3.8	0.07	0.11
	Se	2.4	3.26	8.32	3.1	24.34	46.77	2.5	7.23	17.05
	Sr	43.3	1.31	0.18	57.4	6.02	0.63	46.8	2.04	0.26
	Te	2.5	0.06	0.15	3.3	2.58	4.74	2.7	0.36	0.80
	Ti	0.8	0.00	0.03	1.1	0.10	0.55	0.9	0.00	0.02
	Zn	35.4	1.00	0.17	47.0	5.84	0.75	38.3	1.97	0.31
	Zr	58.1	0.66	0.07	77.1	4.98	0.39	62.9	0.77	0.07
GAS	B	68.4	3.96	0.35	90.8	9.58	0.63	74.0	7.42	0.60
	Cl	0.2	<0.01	<0.3	0.3	2.01	40.20	0.2	<0.01	<0.3
	F	0.9	<0.01	<0.07	1.2	3.03	15.15	1.0	<0.01	<0.06
	Se	2.4	0.11	0.28	3.1	1.58	3.06	2.5	1.77	4.25
	S	2.2	0.61	1.66	2.9	4.51	9.33	2.4	0.17	0.43

Table 5.3. Melter Emissions for DM100 AZ101 Tests 7-9.

Test #		7			8			9		
Sampling Interval		1/18/01 15:15-16:15			1/31/01 13:53-14:53			2/7/01 10:40-11:40		
Conditions		12 scfh bubbling, Li ₂ CO ₃ , low solids			12 scfh bubbling, Li ₂ CO ₃			5 scfh bubbling, Li ₂ CO ₃		
Steady State Glass Production Rate		900 kg/m ² /day			1300 kg/m ² /day			800 kg/m ² /day		
Stack Flow Rate		30.1 dscfm			37.5 dscfm			39.2 dscfm		
Sample Volume		35.018 dscf			37.682 dscf			36.534 dscf		
Moisture		24.5%			18.7%			11.1%		
Fluxes		Feed (g/hr)	Emitted (mg/min)	%	Feed (g/hr)	Emitted (mg/min)	%	Feed (g/hr)	Emitted (mg/min)	%
PARTICLE	Solids	4946.0	241.50	0.29	7236.0	309.8	0.26	4453.0	157.7	0.21
	As	1.2	0.53	2.59	1.8	0.56	1.88	1.1	0.24	1.31
	B	125.7	5.58	0.27	181.6	7.39	0.24	111.7	4.77	0.26
	Ba	1.5	0.10	0.40	2.1	0.12	0.34	1.3	0.10	0.48
	Cd	13.4	1.49	0.66	19.4	1.80	0.56	11.9	0.76	0.38
	Cl	0.4	1.63	24.45	0.6	1.56	15.60	0.4	1.67	25.05
	Cr	1.1	0.38	2.08	1.6	0.52	1.96	1.0	0.25	1.49
	Cs	3.1	1.29	2.48	4.37	1.69	2.32	2.7	0.67	1.49
	Cu	1.0	0.07	0.41	1.4	0.06	0.25	0.9	0.04	0.29
	F	1.6	1.00	3.75	2.3	1.02	2.66	1.4	1.36	5.83
	Fe	294.2	19.46	0.40	425.0	21.75	0.31	261.5	12.54	0.29
	K	5.7	0.95	1.00	8.3	1.21	0.88	5.1	0.77	0.91
	Li	112.9	4.96	0.26	163.0	5.13	0.19	100.3	2.83	0.17
	Mn	95.0	0.65	0.04	137.3	1.33	0.06	84.5	0.74	0.05
	Na	198.0	14.76	0.45	286.0	18.75	0.39	176.0	11.36	0.39
	Ni	17.2	1.04	0.36	24.8	1.29	0.31	15.3	0.69	0.27
	P	59.4	0.28	0.03	85.8	1.17	0.08	52.8	0.84	0.10
	Pb	5.6	0.51	0.54	8.1	0.67	0.49	5.0	0.35	0.42
	S	4.1	4.57	6.69	5.9	4.80	4.88	3.6	4.16	6.93
	Sb	6.4	0.30	0.28	9.2	0.35	0.23	5.7	0.22	0.23
	Se	4.3	34.18	47.44	6.2	48.51	46.61	3.8	23.92	37.35
	Sr	79.5	3.86	0.29	114.8	4.27	0.22	70.6	2.67	0.23
	Te	4.5	6.79	8.99	6.5	8.75	8.02	4.0	3.60	5.36
	Ti	1.5	0.00	0.00	2.1	0.02	0.05	1.3	0.01	0.05
	Zn	65.1	3.84	0.35	94.0	4.38	0.28	57.8	2.75	0.28
	Zr	106.7	0.84	0.05	154.2	2.19	0.09	94.9	1.24	0.08
GAS	B	125.7	31.79	1.52	181.6	36.19	1.20	111.7	13.36	0.72
	Cl	0.4	19.06	>100	0.6	21.43	>100	0.4	8.51	>100
	F	1.6	14.21	53.29	2.3	17.68	46.12	1.4	7.21	30.90
	Se	4.3	3.79	5.29	6.2	11.84	11.46	3.8	2.56	4.04
	S	4.1	12.92	18.92	5.9	21.12	21.48	3.6	8.30	13.83

Table 5.4. Average Gaseous Emission as Monitored by FTIR.
(ppm)

Test #	1	2	3	4	5	6	7	8	9
N ₂ O	< 1.0	1.7	< 1.0	100.4	5.4	3.9	2.0	3.0	2.7
NO ₂	3.2	15.7	17.3	494.1	23.0	15.3	8.5	16.6	22.2
NO	49.1	79.0	78.7	2326.2	189.1	154.1	188.1	268.6	172.0
SO ₂	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	3.8	4.5	< 1.0
Acetonitrile	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Acrylonitrile	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HCN	< 1.0	< 1.0	1.0	9.8	1.1	< 1.0	< 1.0	1.5	< 1.0
CO	< 1.0	< 1.0	< 1.0	202.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HCl	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.6	< 1.0
HF	< 1.0	< 1.0	< 1.0	1.2	< 1.0	< 1.0	2.2	5.8	3.0
HNO ₂	< 1.0	< 1.0	< 1.0	11.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HNO ₃	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.2	1.1	< 1.0
NH ₃	< 1.0	< 1.0	< 1.0	4.8	1.6	< 1.0	1.5	< 1.0	< 1.0
CO ₂ (%)	0.1	0.2	0.1	0.5	0.3	0.2	0.3	0.4	0.3
H ₂ O (%)	3.7	4.1	4.2	7.8	8.9	7.0	14.6	12.7	9.8

Table 5.5. Mass Balance for Nitrogen Compounds.

Test #		1	2	3	4	5	6	7	8	9
Fluxes (mol/hr)	NO	0.157	0.181	0.181	7.34	0.455	0.351	0.477	0.670	0.424
	NO ₂	0.038	0.036	0.040	1.48	0.055	0.034	0.022	0.041	0.053
	N ₂ O	<0.005	0.004	<0.005	0.34	0.013	0.009	0.005	0.008	0.006
	Feed NOx	0.300	0.330	0.279	16.95	0.902	0.433	0.640	0.914	0.614
% of Feed	NO	52.3	54.8	64.9	43.3	50.4	81.0	74.5	73.3	69.1
	NO ₂	12.7	10.9	14.3	8.7	6.1	7.9	3.4	4.5	8.6
	N ₂ O	<1.7	1.2	<1.7	2.0	1.4	2.1	0.8	0.8	1.0
	Total NOx	65.0	66.9	79.2	54.0	57.9	91.0	78.7	78.6	78.7

Figure 1.1a. Schematic diagram showing cross-section through the DM100-BL melter.

Figure 1.1b. Schematic diagram showing cross-section through the DM100-BL melter.

Figure 1.1c. Schematic diagram showing cross-section through the DM-100-BL-melter. Plan view showing locations of lid ports.

Figure 1.2. Schematic diagram of the DM100-BL-off-gas system (best available copy).

Figure 2.1. Rheograms comparing AZ-101 high solids feed (570 g/l) using nominal additives (Li_2CO_3) and LiOH.

Figure 2.2. Rheograms comparing AZ-101 melter feeds with various solids contents; high water (350-450 g/l), acidified (420 g/l) and nominal (570 g/l).

Figure 3.1. Production rates for DM100 AZ-101 Test 1 (see Table 1.1 for test matrix).

Figure 3.2. Production rates for DM100 AZ-101 Test 2 (see Table 1.1 for test matrix).

Figure 3.3. Production rates for DM100 AZ-101 Test 3 (see Table 1.1 for test matrix).

Figure 3.4. Production rates for DM100 AZ-101 Test 4 (see Table 1.1 for test matrix).

Figure 3.5. Production rates for DM100 AZ-101 Test 5 (see Table 1.1 for test matrix).

Figure 3.6. Production rates for DM100 AZ-101 Test 6 (see Table 1.1 for test matrix).

Figure 3.7. Production rates for DM100 AZ-101 Test 7 (see Table 1.1 for test matrix).

Figure 3.8. Production rates for DM100 AZ-101 Test 8 (see Table 1.1 for test matrix).

Figure 3.9. Production rates for DM100 AZ-101 Test 9 (see Table 1.1 for test matrix).

Figure 3.10. Ten-hour average production rates for DM100 AZ-101 tests with variable bubbling rate (see Table 1.1 for test matrix).

Figure 3.11. Ten-hour average production rates for DM100 AZ-101 tests with feeds other than nominal composition (see Table 1.1 for test matrix).

Figure 3.12. Ten-hour moving average production rates for AZ-101 DM100 tests without bubbling (see Table 1.1 for test matrix).

Figure 3.13. Glass temperatures and total electrode power for DM100 AZ-101 Test 1 (see Table 1.1 for test matrix).

Figure 3.14. Glass temperatures and total electrode power for DM100 AZ-101 Test 2 (see Table 1.1 for test matrix).

Figure 3.15. Glass temperatures and total electrode power for DM100 AZ-101 Test 3 (see Table 1.1 for test matrix).

Figure 3.16. Glass temperatures and total electrode power for DM100 AZ-101 Test 4 (see Table 1.1 for test matrix).

Figure 3.17. Glass temperatures and total electrode power for DM100 AZ-101 Test 5 (see Table 1.1 for test matrix).

Figure 3.18. Glass temperatures and total electrode power for DM100 AZ-101 Test 6 (see Table 1.1 for test matrix).

Figure 3.19. Glass temperatures and total electrode power for DM100 AZ-101 Test 7 (see Table 1.1 for test matrix).

Figure 3.20. Glass temperatures and total electrode power for DM100 AZ-101 Test 8 (see Table 1.1 for test matrix).

Figure 3.21. Glass temperatures and total electrode power for DM100 AZ-101 Test 9 (see Table 1.1 for test matrix).

—△— 11" from top —●— 17" from top — Total Electrode Power

Figure 3.22. Plenum temperature and total electrode power for DM100 AZ-101 Test 1 (see Table 1.1 for test matrix).

Figure 3.23. Plenum temperature and total electrode power for DM100 AZ-101 Test 2 (see Table 1.1 for test matrix).

Figure 3.24. Plenum temperature and total electrode power for DM100 AZ-101 Test 3 (see Table 1.1 for test matrix).

Figure 3.25. Plenum temperature and total electrode power for DM100 AZ-101 Test 4 (see Table 1.1 for test matrix).

Figure 3.26. Plenum temperature and total electrode power for DM100 AZ-101 Test 5 (see Table 1.1 for test matrix).

Figure 3.27. Plenum temperature and total electrode power for DM100 AZ-101 Test 6 (see Table 1.1 for test matrix).

Figure 3.28. Plenum temperature and total electrode for DM100 AZ-101 Test 7 (see Table 1.1 for test matrix).

Figure 3.29. Plenum temperature and total electrode power for DM100 AZ-101 Test 8 (see Table 1.1 for test matrix).

Figure 3.30. Plenum temperature and total electrode power for DM100 AZ-101 Test 9 (see Table 1.1 for test matrix).

Figure 3.31. Electrode power and melt resistance for DM100 AZ-101 Test 1 (see Table 1.1 for test matrix).

Figure 3.32. Electrode power and melt resistance for DM100 AZ-101 Test 2 (see Table 1.1 for test matrix).

Figure 3.33. Electrode power and melt resistance for DM100 AZ-101 Test 3 (see Table 1.1 for test matrix).

Figure 3.34. Electrode power and melt resistance for DM100 AZ-101 Test 4 (see Table 1.1 for test matrix).

Figure 3.35. Electrode power and melt resistance for DM100 AZ-101 Test 5 (see Table 1.1 for test matrix).

Figure 3.36. Electrode power and melt resistance for DM100 AZ-101 Test 6 (see Table 1.1 for test matrix).

Figure 3.37. Electrode power and melt resistance for DM100 AZ-101 Test 7 (see Table 1.1 for test matrix).

Figure 3.38. Electrode power and melt resistance for DM100 AZ-101 Test 8 (see Table 1.1 for test matrix).

Figure 3.39. Electrode power and melt resistance for DM100 AZ-101 Test 9 (see Table 1.1 for test matrix).

Figure 4.1. Analyzed product glass compositions for major oxides during DM100 AZ-101 tests.

Figure 4.2. Analyzed product glass compositions for major oxides (including Band Li) during DM100 AZ-101 tests.

Figure 4.3. Analyzed heavy metal oxide compositions from DM100 AZ-101 tests.

Figure 5.1. Heavy metal particulate emissions as a function of bubbling rate during DM100 AZ-101 tests.

Figure 5.2. Select particulate and gaseous emissions during DM100 AZ-10 tests as a function of bubbling rate.

Figure 5.3. FTIR monitored gaseous nitrogen emission during DM100 AZ-101 Test 1 (see Table 1.1 for test matrix).

Figure 5.4. FTIR monitored gaseous nitrogen emission during AZ-101 DM100 Test 2 (see Table 1.1 for test matrix).

Figure 5.5. FTIR monitored gaseous nitrogen emissions during DM100 AZ-101 Test 3 (see Table 1.1 for test matrix).

Figure 5.6. FTIR monitored gaseous nitrogen emissions during DM100 AZ-101 Test 4 (see Table 1.1 for test matrix).

Figure 5.7. FTIR monitored gaseous nitrogen emissions during DM100 AZ-101 Test 5 (see Table 1.1 for test matrix).

Figure 5.8. FTIR monitored gaseous nitrogen emissions during DM100 AZ-101 Test 6 (see Table 1.1 for test matrix).

Figure 5.9. FTIR monitored gaseous emissions during DM100 AZ-101 Test 7 (see Table 1.1 for test matrix).

Figure 5.10. FTIR monitored gaseous nitrogen emissions during DM100 AZ-101 Test 8 (see Table 1.1 for test matrix).

Figure 5.11. FTIR monitored gaseous nitrogen emissions during DM100 AZ-101 Test 9 (see Table 1.1 for test matrix).

Figure 5.12. Nitrogen fluxes during DM100 AZ-101 Test 1 (see Table 1.1 for test matrix).

Figure 5.13. Nitrogen fluxes during DM100 AZ-101 Test 2 (see Table 1.1 for test matrix).

Figure 5.14. Nitrogen fluxes during DM100 AZ-101 Test 3 (see Table 1.1 for test matrix).

Figure 5.15. Nitrogen fluxes during DM100 AZ-101 Test 4 (see Table 1.1 for test matrix).

Figure 5.16. Nitrogen fluxes during DM100 AZ-101 Test 5 (see Table 1.1 for test matrix).

Figure 5.17. Nitrogen fluxes during DM100 AZ-101 Test 6 (see Table 1.1 for test matrix).

Figure 5.18. Nitrogen fluxes during DM100 AZ-101 Test 7 (see Table 1.1 for test matrix).

Figure 5.19. Nitrogen fluxes during DM100 AZ-101 Test 8 (see Table 1.1 for test matrix).

Figure 5.20. FTIR monitored gaseous nitrogen emissions during DM100 AZ-101 Test 9 (see Table 1.1 for test matrix).

Figure 6.1. Summary of glass production rates from AZ101 tests on the DM100 melter. "Nominal" = Carbonate feed, not acidified, no plenum heaters, very low bubbling (aprox. zero) , low water (550 g/l); "High water" = 420 g/l; acidified = 420 g/l; "High water with bubbling" = 350 g/l.

Figure 6.2. Comparison of glass production rates on DM100, DM1000, and DM1200 melter systems using AZ-101 and C-106/AY-102 HLW feeds. The rates are plotted against the bubbling rate normalized to the melt surface area.

Perez, Joseph

From: Larson, Donald
Sent: Tuesday, October 16, 2001 2:34 PM
To: Perez, Joseph
Cc: Howell, John F.; Hyman, Marve; Carl, Daniel; Larson, Donald
Subject: RE: Review of subcontractor test data report submittal

Could not send you filled in DRR as it was read only.

First class job on document. Congradulate them. Only nits I had was no Table of Contents and no List of Acronyms and Abbreviations.

Don

-----Original Message-----

From: Howell, John F.
Sent: Friday, October 12, 2001 10:45 AM
To: Peters, Richard D. (WTP); Larson, Donald
Cc: Beary, Mickey; Rouse, James; Hyman, Marve
Subject: FW: Review of subcontractor test data report submittal

Please review and send comments to Joe. Copy Marve & me on comments.

Thanks,
 Fred

-----Original Message-----

From: Hyman, Marve
Sent: Wednesday, October 10, 2001 2:43 PM
To: Howell, John F.
Cc: Papp, Ivan
Subject: FW: Review of subcontractor test data report submittal

Fred, Ivan: I just noticed that Joe Perez's email below skipped you. I talked to Joe today and he will be certain in the future to get these documents addressed to Ivan.

Note that the document is available for viewing on a share drive and that Joe asked for comments this Friday Oct. 12. However, that is our normal Friday off and he will accept comments early next week.

Marve

original e-mail 6/11/03

-----Original Message-----

From: Perez, Joseph
Sent: Wednesday, September 26, 2001 12:04 PM
To: Barnes, Steven; Morrey, Eugene; Kelly, Sam; Hyman, Marve; Winkler, Clifford; Block, Oliver; Maxwell, Robert; Saucedo, Ermelinda; Vukovich, Peter; Schuetz, Phillip
Subject: Review of subcontractor test data report submittal

Duratek has submitted the test report, "DuraMelter 100 Tests with AZ-101 Final Report", VSL-00R10N0-1, rev. 0, data August 31, 2001 for project review, comment, and acceptance. This report documents small-melter (DM-100) testing that was performed in support of the HLW vitrification facility. Testing was initiated under the CHG period of the WTP contract and completed under the BNI contract. Testing was primarily to assess the effects of chemical and process parameters on melter throughput attainment. This work has continued under a new test plan as well as testing being conducted on the DM1200 pilot-scale HLW melter at CUA-VSL.

The report and the controlling project work documents, the Project Test Specification and the VSL test plan (latest revision) have been posted to the R&T share drive that everyone has access to. The folder address is:
 //Wtps0027/R&t/Vitrification/HLW Mltr Tstg/DM100

The comment review form is on the share drive site and also attached to this e:mail message. Comments are due to be submitted by me Friday, October 12, 2001.

The review guidance can be found at the end of the Document Review Record sheet. For clarify it is reproduced

here:

Review Guidance:

- The report has been written to document results for testing conducted under the test plan titled, "Melter Tests with AZ-101 HLW Simulants Using DuraMelter 100 Vitrification Systems," VSL-00T10N0-1, rev. 1 dated November 30, 2001.
- Review comments regarding technical details, discussions of results, and extension of results must be provided within this context. Comments that do not "fit" within the test scope will not be forwarded to the subcontractor.
- This review record form has been adapted from project procedure K13P023. However, the review is being conducted under the Project procedure, "Supplier/Subcontractor Data Submittal," K13P008.
- The report and test plan are stored electronically in the R&T share drive file, //WTPS0027/R&t/Vitrification/HLW Mltr Tstg/DM100. All project staff have "Read Access" to this share drive.
- Comments shall be documented on this review record. If comments written on a paper copy of the report are submitted they will be addressed at the discretion of the review coordinator.
- Comments should provide a basis or explanation for their comment to assist the subcontractor in addressing comments.
- As this is a subcontractor data submittal, the emphasis is on the data provided and the discussions surrounding the results. Together with the test plan they should provide a clear record of the test objectives, test conditions, test equipment arrangement, and sample and analyses requirements. Comments should focus on these areas. It is not expected that information in the test plan be automatically reproduced in the test report.
- Reviewers should feel compelled to make extensive editorial comments. Unless the text commented on is determined and concurred on by the review coordinator to be misleading or grammatically wrong editorial comments will not be forwarded to the subcontractor.

Please call if you have questions.

Joe Perez
R&T/WTP
Ph.: 509.371.5188
Fax: 509.371.5163

This document was reviewed by the following ES&H discipline(s):

Document Number: YSL-00T10NO-1

Environmental	Comments
J. Markillie	
J. Su-coker	
M. Proctor	
J. Sipkowski	
J. Brown	
C. Haas	
P. Berlin	
S. Hill	
J. Lesser	
G. Hendricks	
B. Dubiel	
S. Fahey	
C. Strand	
B. Haggard	
L. Bostic	NO
E. Savage	
P. Peistrup	
J. Cook	NO
B. Curn	

Regulatory Safety

M. Platt	
E. Smith	
D. Smith	

ISMS

J. Carlson	
B. Gaydosh	
G. Von Nieda	

IH&S	Comments
T. Meagher	
S. Marko	
M. Rosenthal	
J. Morse	
S. Walter	

Radiation Protection

M. Perks	
R. Miles	NO
S. Larson	
J. Rathbun	
S. Henry	
T. DeGarmo	
R. Winslow	

Safety Analysis

R. Garrett	
P. Lowry	
C. Lindquist	
D. Cresci	
S. Johnson	
M. Higuera	
R. Crowe	
J. Christiansen	
B. Oberg	
N. Hunt	
J. Hinckley	
S. Sontag	

Comments, as attached/marked, must be dispositioned in accordance with project procedures with procedures for each indicated discipline. Contact Emmy Saucedo for information on specific comments.

Fred Beranek, ES&H Manager

10/15/07
Date

No DRR was provided. Email transmittal.
ES&H had no or minor comments as noted
herein. Emmy will return this package to author

Tracking #: 588	Document # VSL-00T10N0-1	Rev 0	Information only
Title DURAMELTER 100 TESTS WITH AZ-101 FINAL REPORT			
Date Recieved 09/26/2001	Preparer JOSEPH PEREZ	Due Date 10/12/2001	Reviewer FRED
Environmental: BOSTIC, COOK	EC ☐	Regulatory Safety: ☐	RSC ☐
Safety Analysis: LOWRY			
Radiation Protection: MILES	RPC ☐	IHS: ☐	IHC ☐
ISMS: ☐		I ☐	
For Signature: 10/11/2001	Date Returned	Form of Return:	
Notes/Comments BOSTIC, Cook			

ES&H Tracking #

588

Environmental	Review
J. Markillie	
J. Su-coker	
M. Proctor	
J. Sipkowski	
J. Brown	
C. Haas	
P. Berlin	
S. Hill	
J. Lesser	
G. Hendricks	
B. Dubiel	
S. Fahey	
C. Strand	
B. Haggard	
L. Bostic	✓
E. Savage	
P. Peistrup	
J. Cook	✓
B. Curn	

Regulatory Safety	
M. Platt	
E. Smith	
D. Smith	

ISMS

J. Carlson	
B. Gaydosh	
G. Von Nieda	

IH&S	Review
T. Meagher	
S. Marko	
M. Rosenthal	
J. Morse	
S. Walter	

Radiation Protection	
M. Perks	
R. Miles	✓
S. Larson	
J. Rathbun	
S. Henry	
T. DeGarmo	
R. Winslow	

Safety Analysis

R. Garrett	
P. Lowry	X
C. Lindquist	
D. Cresci	
S. Johnson	
M. Higuera	
R. Crowe	
J. Christiansen	
B. Oberg	
N. Hunt	
J. Hinckley	
S. Sontag	

Please return to Emmy in N116.

EMMY - I HAVE NO COMMENTS
ON THIS DOCUMENT

[Signature]
10/11/01

ES&H Tracking #

588

Environmental	Review
J. Markillie	
J. Su-coker	
M. Proctor	
J. Sipkowski	
J. Brown	
C. Haas	
P. Berlin	
S. Hill	
J. Lesser	
G. Hendricks	
B. Dubiel	
S. Fahey	
C. Strand	
B. Haggard	✓
L. Bostic	✓
E. Savage	
P. Peistrup	
J. Cook	✓
B. Curn	

Regulatory Safety	
M. Platt	
E. Smith	
D. Smith	

ISMS

J. Carlson	
B. Gaydosh	
G. Von Nieda	

IH&S	Review
T. Meagher	
S. Marko	
M. Rosenthal	
J. Morse	
S. Walter	

Radiation Protection	
M. Perks	
R. Miles	✓
S. Larson	
J. Rathbun	
S. Henry	
T. DeGarmo	
R. Winslow	

Safety Analysis

R. Garrett	
P. Lowry	X
C. Lindquist	
D. Cresci	
S. Johnson	
M. Higuera	
R. Crowe	
J. Christiansen	
B. Oberg	
N. Hunt	
J. Hinckley	
S. Sontag	

Please return to Emmy in N116.

*No comments
Lee Bostic
10/3/01*

ES&H Tracking #

580

Environmental	Review
J. Markillie	
J. Su-coker	
M. Proctor	
J. Sipkowski	
J. Brown	
C. Haas	
P. Berlin	
S. Hill	
J. Lesser	
G. Hendricks	
B. Dubiel	
S. Fahey	
C. Strand	
B. Haggard	
L. Bostic	✓
E. Savage	
P. Peistrup	
J. Cook	✓
B. Curn	

Regulatory Safety	
M. Platt	
E. Smith	
D. Smith	

ISMS

J. Carlson	
B. Gaydosh	
G. Von Nieda	

IH&S	Review
T. Meagher	
S. Marko	
M. Rosenthal	
J. Morse	
S. Walter	

Radiation Protection	
M. Perks	
R. Miles	✓
S. Larson	
J. Rathbun	
S. Henry	
T. DeGarmo	
R. Winslow	

Safety Analysis

R. Garrett	
P. Lowry	X
C. Lindquist	
D. Cresci	
S. Johnson	
M. Higuera	
R. Crowe	
J. Christiansen	
B. Oberg	
N. Hunt	
J. Hinckley	
S. Sontag	

No comments.

2 1 Observation:

It might be very useful to have information on the partitioning of mercury across the melter. I note there is no mercury included in the simulant. Is it possible to add?

*John Cook
10/10/01*

Please return to Emmy in N116.

Perez, Joseph

From: Hyman, Marve
Sent: Thursday, February 14, 2002 3:47 PM
To: Perez, Joseph
Subject: FW: DM100 comment resolution form

Joe: All of Process Engineering's comments are now resolved. Let me know if you need any signed-off hard copy documentation.

Marve Hyman for I. Papp

P.S.: I am curious about comment No. 12, which was purely editorial, but some of the edits are really needed for clarity and correctness. Did you or someone in R&T review/incorporate any of the edits?

-----Original Message-----

From: Perez, Joseph
Sent: Thursday, February 14, 2002 11:07 AM
To: Perez, Joseph; Hyman, Marve
Subject: RE: DM100 comment resolution form

Marve, used this one please - I added the comment responders' names, etc.

VSL

DM100-AZ101-com-resp2 papp.

Joe Perez
 R&T/WTP
 Ph.: 509.371.5188
 Fax: 509.371.5242

-----Original Message-----

From: Perez, Joseph
Sent: Thursday, February 14, 2002 10:40 AM
To: Hyman, Marve
Subject: DM100 comment resolution form
Importance: High

Marve, VSL has finally gotten to responding to comments made on the DM100 test report that was reviewed by the Project in late

October. Please review the attached form and responses and tell me if they are acceptable. This has been on the top of ORP's R&T document watch list for some time. I hate to ask since its been over two months since they were given to VSL but could you let me know by say next Wed. if they are acceptable. Thanks

<< File: VSL DM100-AZ101-com-resp2 papp.doc.dot >>

Joe Perez
 R&T/WTP
 Ph.: 509.371.5188
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DOCUMENT REVIEW RECORD

Sheet 1 of 3

Return to: JM Perez (Rm. 524B, Sigma 4, H4-02)

Comments Due: October 12, 2001

Document Title: DuraMelter 100 Tests with AZ-101 Final Report		Document No. VSL-00R10N0-1		Revision: 0	Date: August 31, 2001
Reviewer: JM Perez	Date: 11/01/01	Response by: Ian Pegg	Date: 2/14/02	Comments Resolved: <i>[Signature]</i> 2/15/02	Date:

Item No.	Section/ Paragraph	Comment	Response	Significance	Resolution	Incorporated?
1	Tables 2.3 and 2.4	Was Cs analyzed by AA or by the methods indicated?	Presumably, you are referring to Tables 2.4 and 2.5 (there are no Cs data in Table 2.3). The only Cs data in Table 2.4 are in the XRF column, which was indeed the method of analysis. The footnote to Table 2.5 states that: "Cs ₂ O is from AA analysis, not DCP" This is potentially ambiguous for the "XRF" columns (for which the Cs data were from XRF) and will be clarified.	M		
2	Table 3.1	Did the Test 6 average power use include the plenum heater power? If not, this should be somehow indicated.	No. This will be indicated on the table.	M		
3	Table 5.1	In future reports include a calculated DF value from the information provided next to the % column.	Agreed.	M		
4	Figure 2.2	Acidification of the feed did not affect the viscosity of the melter feed. This is unexpected based on previous DOE experience. Does VSL have a hypothesis regarding the physical/chemical behavior of these feeds that makes them insensitive to acid "treatment"	This is discussed in VSL-00R2520-1. Dilution of hydroxide-based feed with nitric acid does indeed reduce the viscosity more rapidly than does the corresponding dilution with water. However, the difference is much smaller with the carbonate-based feed, especially at the lower solids contents. This result was part of the basis of the decision to	M		

ORP-51436, Rev. 0

Perez, Joseph

From: Jian-Shun_Shuen@RL.gov
Sent: Wednesday, March 20, 2002 9:13 AM
To: Barnes, Steven; Perez, Joseph
Cc: Lupfer, Jennifer S; Damerow, Frederick W; Jian-Shun_Shuen@rl.gov;
Rodolfo_Rudy_Carreon@rl.gov
Subject: ORP Acceptance of DRR Response to ORP Comments on DM 100 Test Report VSL-01R10N0-1

Joe and Steve,

ORP has reviewed the DRR response to our comments on the subject Test Report and found them acceptable. Please incorporate comment dispositions in the Report and submit to ORP for verification and record as soon as practicable.

As to your question regarding another round of review because a new test was added to the Test Report since the Report was issued for review. Since the comments from ORP were global rather than on specific tests and, as you stated in our earlier conversation, the result from the last test didn't raise issues that were significantly different from other tests already included in the Report, ORP doesn't believe there is a need for another round of review.

For your question of parallel ORP and WTP Project review for the subject Test Report, ORP accepts it as having been reviewed. When you transmit the final Test Report, please identify significant revisions to the Report due to Project comments.

Thanks,
Jian-Shun

P.S.: I would like to have a copy of reference 11, VSL-01R2540-2, 2/16/01, either hard copy or electronic, if you have it handy.

Research and Technology Completion Form

Page 1 of 3

R&T Scoping Statement(s): VH-5; HLW - Melter Tests - Small Scale

Test Specification Number/Title: TSP-W375-00-00019, Rev. 0, "HLW-DM1- and DM100 Melter Tests

Test Plan Number/Title: VSL-00T10N0-2, Rev. 1, "Melter Tests with AZ-101 HLW Simulants Using DuraMelter 100 Vitrification Systems

Test Report Number/Title: VSL-01R10N0-1, Rev. 1, "Melter Tests with AZ-101 HLW Simulant Using a DuraMelter 100 Vitrification System, 2/25/01 02. *7/3/03*

Prepared by: J. M. Perez Date: 6/10/03

List Test Objectives:	State how objectives were met:
1) Obtain glass production rate data for a simulated AZ-101 HLW stream combined with pretreatment products and suitable glass forming additives using a DuraMelter 100 vitrification system to determine the effect of melter scale on un-bubbled production rates.	Nine melter tests were conducted on the DM100-BL with the AZ-101 simulant between 11/27/00 and 2/9/01. Section 3 of the report discusses the results. Glass production rates ranged from 350 - 430 kg/m ² /day without bubbling, depending on feed water content, and increased to about 500 kg/m ² /day when using feed that was acidified with nitric acid (with corresponding sugar additions), and with the use of plenum heaters. Bubbling increased glass production rates by a factor of three to 1300 kg/m ² /day. Tests conducted at a variety of bubbling rates and at different feed water contents show that the increase in production rate is directly proportional to the increase in glass pool bubbling rate for this system over the range of parameters investigated. See Section 3 and Tables 3.1 and 3.2 and associated figures. See also Figures 6.1 and 6.2 for summary comparison plots of throughput versus feed variable.
2) Obtain processing data for a simulated AZ-101 HLW stream combined with additives as either carbonates or hydroxides to determine the effect of additive form on foaming, feed handling, cold cap characteristics, and processing rates.	The use of lithium hydroxide rather than lithium carbonate resulted in feeds with higher yield stress and viscosity (Section 2.4.2, Rheology, and Table 2.3). Process rates and conditions were comparable when hydroxide and carbonate was used (Table 3.1). No significant differences in cold cap appearance were noted; however, this would be difficult to discern in a system the size of the DM100.
3) Obtain processing data for a simulated, nitrated AZ-101 HLW stream combined with additives to determine the effect of an acid, nitrated melter feed on foaming, feed handling, cold cap characteristics, and processing rates.	Nitrated feed resulted in a 25% increase over the nominal case (Table 3.1 and Figure 3.12).

Research and Technology Completion Form

R&T Scoping Statement(s): VH-5; HLW - Melter Tests - Small Scale

Test Specification Number/Title: TSP-W375-00-00019, Rev. 0, "HLW-DM1- and DM100 Melter Tests

Test Plan Number/Title: VSL-00T10N0-2, Rev. 1, "Melter Tests with AZ-101 HLW Simulants Using DuraMelter 100 Vitrification Systems

Test Report Number/Title: VSL-01R10N0-1, Rev. 1, "Melter Tests with AZ-101 HLW Simulant Using a DuraMelter 100 Vitrification System, 2/25/01 02 *LC 7/31/03*

List Test Objectives:	State how objectives were met:
4) Obtain data on the effects of other variables (feed water content, plenum heaters, and glass bubbling rate) on glass production rates.	Glass production rates ranged from 350 - 430 kg/m ² /day without bubbling, depending on feed water content and with the use of plenum heaters. Bubbling increased glass production rates by a factor of three to 1300 kg/m ² /day. See Section 3 and Tables 3.1 and 3.2 and associated figures. See also Figures 6.1 and 6.2 for summary comparison plots of throughput versus feed variable.
5) Collect data to characterize the melter off-gas emissions for all feed constituents, including iodine and cesium.	Section 5 and Table 5.1 through 5.5 provide off-gas emissions data.
6) Collect data on product glass composition and product quality.	Section 4 and Tables 4.1 through 4.6 provide composition and TCLP data.
7) Collect data on mass balance across the melter.	Feed and glass sample data (Tables 2.3, 3.2, 2.5, 4.3) and off-gas sample data (Tables 5.1 through 5.5) provide the data necessary to perform a mass balance.
8) Collect operating data with a simulated ADS melter feed system (i.e., intermittent, pulsed flow of feed to the melter).	Testing was conducted using a system of pinch valves and timers to simulate ADS pump operation.
List any Test Exceptions:	Did exceptions impact the objective? ☐ Yes ☒ No (Explain)
1) None	
List Success Criteria	Did the test meet the criteria? ☒ Yes ☐ No (Explain)
1) Verify that candidate feeds have acceptable processing behavior prior to DM1200 testing	Each feed was successfully tested and verified to be acceptable for testing at the larger scale. On exception was that plenum temperature variations could not be attempted in the DM1200 without modification of the DM1200 to provide supplemental heating.
2) Obtain sufficient data to allow comparison between melter scales.	Testing provided production rates and processing characteristics to permit direct correlation to the DM1200.
List QA Requirements:	Did the subcontractor meet the requirements? ☒ Yes ☐ No (Explain)

Research and Technology Completion Form

Page 3 of 3

R&T Scoping Statement(s): VH-5; HLW - Melter Tests - Small Scale

Test Specification Number/Title: TSP-W375-00-00019, Rev. 0, "HLW-DM1- and DM100 Melter Tests

Test Plan Number/Title: VSL-00T10N0-2, Rev. 1, "Melter Tests with AZ-101 HLW Simulants Using DuraMelter 100 Vitrification Systems

Test Report Number/Title: VSL-01R10N0-1, Rev. 1, "Melter Tests with AZ-101 HLW Simulant Using a DuraMelter 100 Vitrification System, 2/25/02 *LC 7/31/03*

- 1) 1. Work to be performed under a NQA-1 approved quality assurance plan. This work was conducted under an NQA-1 (1994)-based quality assurance program that was in place at VSL during the testing period. Subsequently, the requirements were changed to an NQA-1 (1989) and NQA-2a (1990) Part 2.7 based quality assurance program. All of the work described in this report was conducted prior to this change). There are no limitations on the use of these data.

List R&T Test Conditions: Were test conditions followed? ☒ Yes ☐ No (Explain)

1) Glass Temperature: nominal operating temperature is set at 1150°C.	Set point was 1150°C for each test with actual values ranging between 1125°C and 1155°C near the cold cap.
2) Cold Cap Coverage: 100% cold cap will be maintained in all the tests.	Maximum steady-state feeding was adhered to for all tests.
3) Plenum Temperature: temperature of 400-600°C is targeted except when plenum heaters are used.	Average plenum temperatures without plenum heaters varied from 460°C to 662°C.

Was testing performed with simulants? If yes, discuss how results compare to radioactive tests. ☒ Yes ☐ No

The AZ101 composition was based on previously approved TF COUP and BBI data provided by CHG and BNFL prior to the BNI WTP Contract period. Rheological and vitrification data on actual pretreated AZ101HLW sludge or melter feed was not available at the time this work was performed. The data was recently generated by Battelle and a draft report is in process, but the data is not yet approved for project use. Pilot-scale simulant data will be compared to actual waste data, when it is approved, and the results of the comparison will be included in a separate simulant verification report.

Are all discrepancies resolved? If no, explain. ☒ Yes ☐ No

Are all subcontractor signoffs completed? ☒ Yes ☐ No

This work is acceptable to complete the indicated: ☒ Test Specification(s) ☐ Scoping Statement(s)
If Other, please explain what the report completes. ☒ Test Plan(s) ☐ Other

Does the Testing or Report suggest any follow-on work? If yes, describe the suggested activity ☐ Yes ☒ No and, if appropriate, attach a Request for Technology Development (RTD).

Additional comments:

R&T added to the final subcontractor report; 1) the phrase, "(best available copy)" to figure caption 1.2, and 2) "(see Table 1.1 for test matrix)" to figure captions 3.1 through 3.39, inclusive, and 5.3 through 5.20, inclusive, for clarity.

Approved by R&T Manager or Designee:

Date:

[Signature]

7/31/2003