Final Report DuraMelter 100 HLW Simulant Validation Tests with C-106/AY-102 Feeds VSL-05R5710-1, Rev. 0, 6/2/05

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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VSL-05R5710-1

Final Report

DuraMelter 100 HLW Simulant Validation Tests with C-106/AY-102 Feeds

prepared by

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for

Duratek, Inc.

and

Bechtel National, Inc.

6/14/05
for W. Tamosaites

ACCEPTED FOR

WTP PROJECT USE

April 18, 2005

Rev. 0, 6/2/05

*The Catholic University of America
Vitreous State Laboratory*

*DM100 HLW Simulant Validation Tests with C-106/AY-102 Feeds
Final Report, VSL-05R5710-1, Rev. 0*

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Completeness of Testing:

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

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List of Abbreviations

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

SUMMARY OF TESTING

A) Objectives

The principal objectives of the DM100 tests were to determine the processing characteristics of several C-106/AY102 feeds derived from simulants prepared by different methods, which result in different physical characteristics of the feed. The VSL simulant used in a previous test was prepared by the direct hydroxide method, which was the method used for feed preparation in the bulk of previous VSL melter testing. The NOAH Technologies Corporation modified-rheology simulant was prepared to the same composition as the VSL simulant using a method that resulted in rheological properties closer to those of certain actual waste samples. The SIPP simulant was produced by processing a co-precipitated waste simulant through a non-radioactive pilot scale semi-integrated pretreatment facility. The general intent of these tests was to provide a basis for determining whether the variations in rheology or other feed physical characteristics arising from the different methods of simulant preparation have significant effects on the processing characteristics of the feed in the melter. Completion of the test objectives is detailed in the following table:

Test Objective	Objective Met?	Discussion Section
Characterize the chemical (i.e., XRF, DCP-AES, TOC, pH) and physical (i.e., density, % water, glass yield) characteristics of the as-received SIPP simulant.	Yes	Section 2.0. Samples of the SIPP simulants (pre-test and from each received drum) were characterized with respect to chemical composition and physical properties.
Utilize only WTP Project approved glass former chemicals (GFCs) as defined in SRT-RPP-2002-00034, Selection of HLW and LAW Glass Formers, dated February 6, 2002.	Yes	Section 2.0 Glass formers used are given Tables 2.3 and 2.7.
Characterize the chemical (i.e., composition, pH) and physical (i.e., density, % water, dissolved solids, suspended solids, rheology, glass yield) characteristics of the melter feed from each test segment.	Yes	Section 2.0. Samples of the melter feeds were characterized with respect to chemical composition and physical properties, including rheology.
Demonstrate acceptable processing (glass production rate, feed distribution across molten glass, glass redox, offgas characteristics, melter feed mixing/pumping) of the SIPP simulant with glass forming chemical additives at nominal operating conditions with a constant bubbling rate (Test 2) and compare these characteristics to simulants of the same composition made by direct hydroxide addition (Test 1) and NOAH Technologies Corporation modified-rheology simulant (Test 3) for nominal operating conditions at constant bubbling rate.	Yes	Section 3.0. Feed was successfully processed at a constant bubbling rate without any processing problems. Differences in production rates and cold cap characteristics are reported in Section 3.0. Results from analysis of the glass product are reported in Section 4.0. Results from off-gas characterization are reported in Section 5.0.

Test Objective	Objective Met?	Discussion Section
Sample molten glass at end of each test segment to ensure absence of secondary phases such as sulfate and spinels. Other samples may be taken as needed (e.g., prior to test).	Yes	Section 4.0. Dip samples were taken at the end of each test segment and no separate phases were detected.
Sample and characterize discharge glass samples at end of each test segment. Examine selected samples microscopically for secondary phases such as spinels.	Yes	Section 4.0. Analyzed glass product data are provided for glass redox state and oxide composition for each test.
Monitor offgas constituents (N ₂ O, NO, NO ₂ , NH ₃ , CO ₂ , CO, SO ₂) by FTIR and H ₂ by gas chromatography during each test segment.	Yes	Section 5.0. Data were collected for each test.
Quantify and document the occurrence and associated operating conditions of any melter off-gas volume surging events.	Yes	Section 3.0. Operational data are provided for each test.

B) Test Exceptions

WTP Test Exception 24590-WTP-TEF-RT-05-00001, Rev. 000 added physical and rheological characterization of melter feed samples that had been diluted to 5 wt% total solids.

C) Results and Performance Against the Objectives

The DM100 HLW simulant validation melter tests met their objective in that three different feeds were processed at the target bubbling rate of 9 lpm without any major processing problems or discernable secondary phase formation. Glass production rates for the three feeds differed by less than 6% suggesting that there was no significant impact of the feed preparation methods or rheological properties on the processing rate. The cold cap produced from the feed containing the SIPP simulant was more fluid and stable than cold cap originating from other HLW simulants. Feed and SIPP simulant samples were characterized for an array of physical, chemical, and rheological properties. Analysis of the simulant, feed, and glass samples showed their compositions to be in good agreement with the target. Melter emissions data were collected during the steady-state portions of all three test segments. Total particulate carry-over from the melter was 0.61 to 0.81 percent, which is within the range measured previously on the DM100 when processing HLW simulants. Melter DFs were determined for most elements in the feed for all three tests performed. The most volatile species was sulfur. Halogens were measured in the melter exhaust, presumably originating in the feed as contaminants. Particulate emissions from all three tests were similar, suggesting that simulant preparation method does not affect particulate emissions. Gaseous emissions of nitrogen oxides and byproducts of incomplete combustion, such as carbon monoxide and ammonia, were very low due to the lack of nitrates and organic carbon in the feed. An exception was the test with the SIPP simulant in which nitrogen oxide and carbon monoxide concentrations were ten times higher than in the other tests due to the higher levels of nitrates/nitrites and organics in the simulant.

D) Quality Requirements

This work was conducted under a quality assurance program based on NQA-1 (1989) and NQA-2a (1990) Part 2.7 that is in place at the VSL. This program is supplemented by a VSL Quality Assurance Project Plan (QAPP) for RPP-WTP work. Test and procedure requirements by which the testing activities are planned and controlled are also defined in this plan. The program is supported by VSL standard operating procedures that were used for this work. This work was not subject to DOE/RW-0333P or the WTP QAPjP for environmental regulatory data.

E) R&T Test Conditions

Melter tests were conducted using the DM100-BL melter, which has a melt surface area of 0.108 m². The DM100-BL is a continuously fed, ceramic refractory-lined melter equipped with a lance bubbler for glass pool agitation. The glass-melt is joule-heated using two pairs of opposing Inconel electrodes. Feed was introduced into the melter with a peristaltic pump to provide consistent feed introduction into the melter. For operational simplicity the melter is equipped with a dry off-gas treatment system involving gas filtration operations only.

Three tests using three different HLW C-106/AY-102 feeds were conducted on the DM100-BL over a period of 7 days to determine processing rates as well as feed and melter conditions (off-gas characteristics, melter feed mixing/pumping, etc.) at constant bubbling rate. Melter feed targeting the high-waste-loading C-106/AY-102 glass formulation was prepared by three different methods: direct hydroxide addition using the same method as used in previous tests; the modified-rheology method used by NOAH; and by combining HLW SIPP simulant generated at SRNL with glass forming chemicals (GFCs) at VSL. Production rates, feed distribution across molten glass, off-gas characteristics, and melter feed mixing/pumping behavior were determined at a nominal bubbling rate (9 lpm) for feed containing simulants prepared by each of the three methods. Dip samples were collected from the melt pool at the end of each test; these samples and discharge glass samples were tested to determine whether separate phases had formed on the melt surface or in the poured glass. Glass samples were analyzed for composition to calculate elemental mass balances. Glass samples were also analyzed for their divalent iron concentration to determine the effect of simulant preparation method on glass oxidation state.

Melter emissions data were collected during the steady-state portions of all three tests. The melter exhaust was sampled for metals/particles according to 40-CFR-60 Methods 3, 5, and 29. Particulate collection required isokinetic sampling. Melter emissions were monitored for a variety of gaseous components, notably CO and nitrogen species, by Fourier Transform Infra-Red Spectroscopy (FTIR). Feed samples and melter glass samples (both discharged glass samples and dip samples) were analyzed for their chemical composition. Rheological properties of the feed samples were measured.

F) Simulant Use

The C-106/AY-102 HLW simulant that was used in the current tests is based on the analytical data for actual wastes, which were previously provided by the WTP Project for developing HLW glass formulations to support vitrification testing of actual C-106/AY-102 waste. The simulants for two of the three tests were produced by NOAH Technologies; the simulant for the third test was produced by the Semi-Integrated Pilot Plant at SRNL. The SIPP demonstrated the pretreatment operations of the WTP flow-sheet by processing HLW and LAW feed simulants through feed evaporation, ultrafiltration, cesium ion exchange, and treated feed evaporation.

G) Issues and Follow-On Tests

None.

SECTION 1.0 INTRODUCTION

The Vitreous State Laboratory at The Catholic University of America (VSL) is developing and testing glass formulations for the River Protection Project – Waste Treatment Plant (RPP-WTP) waste envelopes to provide data to meet the RPP-WTP contract requirements and to support system design activities [1, 2]. That work is based upon small-scale batch melts (“crucible melts”) using waste simulants. Selected formulations have also been tested in small-scale continuously-fed joule-heated melters (DM100) [3, 4] and in the High Level Waste (HLW) Pilot Melter (DM1200) [5-12]. Such melter tests provide information on key process factors such as feed processing behavior, dynamic effects during processing, processing rates, off-gas amounts and compositions, foaming control, etc., that cannot be reliably obtained from crucible melts. All of this melter testing has been performed with projected pretreated feed compositions with adjustments to account for recycle streams and, in the case of certain C-106/AY-102 formulations, products from Sr/TRU removal from the LAW stream [6].

Testing on a Semi-Integrated Pilot Plant (SIPP) has been performed at the Savannah River National Laboratory (SRNL) to demonstrate the integration of the WTP pretreatment operations for the production of simulants as feed streams to the WTP Vitrification facility. HLW and Low Activity Waste (LAW) feed simulants were processed through the pilot-scale operations of feed evaporation, ultrafiltration, cesium ion exchange, and treated feed evaporation. Recycle streams were generated and added to feed batches two through four of a four-campaign test. The pretreated simulants were then delivered to VSL for vitrification in the DM-100 melter. The vitrification of these feeds completed the integration of the WTP flow-sheet and provided a more comprehensive incorporation of recycle contributions and process additives (e.g., NaOH and anti-foam) in the feed than has been the case for previous feeds tested at the VSL. The LAW simulant prepared in the Semi-Integrated Pilot Plant was combined with feed additives and processed in the DM100 melter at VSL [13]. This report describes melter tests that processed feed prepared by combining HLW simulant prepared in the Semi-Integrated Pilot Plant with glass former additives, as well as feeds of similar composition that were produced by different methods in order to provide comparisons. The objectives and methodology for these tests are prescribed in the Test Plan for this work [14].

The overall WTP strategy for HLW simulant validation [15, 16] includes testing of both AZ-102 and C-106/AY-102 simulants using both the DM100 and DM1200 melters. Previous testing as part of the HLW simulant validation strategy is defined in an earlier Test Plan [17]. These tests included comparison of simulants used in earlier DM1200 tests [8, 9] with simulants prepared by a modified method intended to better reproduce the rheology of an actual waste sample. Analysis of results from the previous HLW simulant validation tests is ongoing. The testing described in this Final Report allows comparison of results from DM100 testing of C-106/AY-102 simulant feed prepared by three methods:

- (1) The direct hydroxide method, which is the method typically used for generating HLW feed that has been processed in VSL melter tests [3-12].

- (2) The modified-rheology method developed by NOAH Technologies Corporation and VSL. This preparation method produces a material that better represents the rheology of some of the more viscous WTP actual waste samples.
- (3) The co-precipitated simulant employed in the Semi-Integrated Pilot Plant. This simulant was used in a non-radioactive pilot plant facility to demonstrate the integration of the WTP pretreatment operations. The material therefore includes recycle streams from simulated operations instead of assumed amounts from process modeling.

The results from DM100 testing reported here provide a basis for comparison of melter performance with feed prepared by the above three methods. All tests used simulants with 20 wt% un-dissolved solids from pretreatment, which should accentuate rheological differences, in order to most easily determine any differences in processing behavior between the three feed types.

1.1 Test Objectives

The principal objectives of the DM100 tests are to determine the processing characteristics of several C-106/AY102 feeds derived from simulants prepared by different methods, which result in different physical characteristics of the feed. The VSL simulant used in a previous test was prepared by the direct hydroxide method, which was the method used for feed preparation in the bulk of previous VSL testing. The NOAH Technologies Corporation modified-rheology simulant was prepared to the same composition as the VSL simulant using a method resulting in rheological properties that are closer to those of actual waste samples. The SIPP simulant results from processing a co-precipitated waste simulant through a non-radioactive pilot scale semi-integrated pretreatment facility. The general intent of these tests was to provide a basis for determining whether the variations in rheology or other feed physical characteristics arising from the different methods of simulant preparation have significant effects on the processing characteristics of the feed in the melter.

The test objectives are provided in summary form in the Test Specification for this work [15] and subsequently issued Project directives [16]. Specific test objectives and test success criteria provided in this section are consistent with the referenced objectives, but are based on the more detailed objectives provided in the Test Specification for the LAW SIPP testing [18], and have been modified to be applicable to the HLW simulant testing. Thus, the major objectives of these tests were to:

- Characterize the chemical (i.e., X-Ray Fluorescence (XRF), Direct Current Plasma – Atomic Emission Spectroscopy (DCP-AES), Total Organic Carbon (TOC), pH and physical (i.e., density, % water, glass yield in g-oxide/L)) characteristics of the as-received SIPP simulant.

- Utilize only WTP Project approved glass forming chemicals (GFCs) as defined in SRT-RPP-2002-00034, Selection of HLW and LAW Glass Formers, dated February 6, 2002.
- Characterize the chemical (i.e., XRF, pH) and physical (i.e., density, % water, dissolved solids, suspended solids, rheology, glass yield in g-oxide/L) characteristics of the melter feed from each test segment (i.e., from each of the three feed types).
- Demonstrate acceptable processing (glass production rate, feed distribution across molten glass, glass redox, off-gas characteristics, melter feed mixing/pumping) of the SIPP simulant with glass forming chemical additives at nominal operating conditions with a constant bubbling rate (Test 2) and compare these characteristics to simulants of the same composition made by direct hydroxide addition (Test 1) and NOAH Technologies Corporation modified-rheology simulant (Test 3) for nominal operating conditions at constant bubbling rate.
- Sample molten glass at the end of each test segment to ensure absence of secondary phases such as sulfate and spinels. Other samples may be taken as needed (e.g., prior to test).
- Sample and characterize discharge glass samples at the end of each test segment. Examine selected samples microscopically for secondary phases such as spinels.
- Monitor off-gas constituents (N₂O, NO, NO₂, NH₃, CO₂, CO, SO₂) by Fourier Transform Infrared Spectroscopy (FTIR) and H₂ by gas chromatography during each test segment.
- Quantify and document the occurrence and associated operating conditions of any melter off-gas volume surging events.

1.2 Quality Assurance

This work was conducted under a quality assurance program based on NQA-1 (1989) and NQA-2a (1990) Part 2.7 that is in place at the VSL. This program is supplemented by a VSL Quality Assurance Project Plan (QAPP) for RPP-WTP work [19]. Test and procedure requirements by which the testing activities are planned and controlled are also defined in this plan. The program is supported by VSL standard operating procedures that were used for this work [20].

This work did not generate data to support waste form qualification activities; nor did it generate data to support environmental regulatory data to support permitting activities. Therefore, this work is not subject to DOE/RW-0333P or the WTP QAPjP [21] for environmental regulatory data.

1.3 Melter System Description

1.3.1 Feed System

A schematic diagram of the DM100 vitrification system is shown in Figure 1.1. The melter feed is introduced in batches into a feed container that is mounted on a load cell for 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. Feed is normally introduced into the melter via a system designed to mimic the operation of an ADS pump, which is the present RPP-WTP baseline; however, a peristaltic pump was used in these tests to facilitate observations of any differences in processing rates and feed behavior. In this system, a recirculation loop extends to the top of the melter where feed is diverted from the recirculation loop to the peristaltic pump and subsequently into the melter through a Teflon-lined feed line and water-cooled, vertical feed tube.

1.3.2 Melter System

Cross-sectional diagrams of the DM100-BL melter are shown in Figures 2.2.a-c. 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 and 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. In these tests the lance bubbler was used. 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 m² and a variable glass inventory of between 110 kg, when only the bottom pair of electrodes is used and about 170 kg when both pairs of electrodes are used, which was the case in the present tests.

1.3.3 Off-Gas System

For operational simplicity, the DM100-BL is equipped with a dry off-gas treatment system involving gas filtration operations only. Exhaust gases leave the melter plenum through a film cooler device that minimizes the formation of solid deposits. The film-cooler air has constant flow rate and its temperature is thermostatically controlled. Consequently, under steady-state operating conditions, the exhaust gases passing through the transition line (between the melter and the first filtration device) can be sampled at constant temperature and airflow rate. The geometry of the transition line conforms to the requirements of the 40-CFR-60 air sampling techniques. Immediately downstream of the transition line are cyclonic filters followed by conventional pre-filters and HEPA filters. The temperature of the cyclonic filters is maintained above 150°C while the temperatures in the HEPAs are kept sufficiently high to prevent moisture condensation. The entire train of gas filtration operations is duplicated and each train is used alternately. An induced draft fan completes the system.

SECTION 2.0 WASTE SIMULANT AND GLASS FORMULATIONS

2.1 C-106/AY-102 Waste Simulant

The C-106/AY-102 HLW simulant that was used in the current tests is based on the analytical data for actual wastes, which were previously provided by the WTP Project for developing HLW glass formulations to support vitrification testing of actual C-106/AY-102 waste [22]. This section describes the actual waste data and the derivation of the HLW simulant.

Samples of C-106/AY-102 actual waste solids were shipped to Savannah River National Laboratory (SRNL) where they were combined and the composite sample analyzed. Washing and caustic leaching were the HLW pretreatments performed before analysis. Table 2.1 lists the analyzed composition of the C-106/AY-102 waste in terms of non-volatile oxides, as approved and provided by the WTP Project [23]. Table 2.1 also lists the analyzed composition of the cesium eluate (average of six sets of data) from LAW pretreatment of AW-101 waste [24], which needs to be blended with the C-106/AY-102 solids to give the HLW simulant. The blending ratio was determined from the WTP dynamic process flow-sheet model (G2), with the mass ratio of ^{137}Cs in the AW-101 eluate to iron in the C-106/AY-102 sludge equal to 2.09×10^{-5} [23]. This blending ratio corresponds to a mass ratio of AW-101 oxides to C-106/AY-102 oxides of about 5.9×10^{-4} . The blended composition is given in Table 2.1. As can be seen, the AW-101 cesium ion-exchange eluate is composed essentially of a solution of sodium (nitrate) and boron, together with smaller amounts of other alkalis and selected metal ions, including barium, cerium, copper, nickel, and tin. The blended waste composition is very similar to that of the C-106/AY-102 waste, primarily because of the low blending ratio.

The blended waste in Table 2.1 contains 32 non-volatile components and is modified to give the HLW waste simulant for the current tests. The modifications are made to keep the number of components at a manageable level and they include: i) omitting the minor components (i.e., components that make up < 0.05 wt% in glass, which corresponds to about 0.12 wt% in waste, on an oxide basis); ii) omitting silver, which was not included in earlier C-106/AY-102 melter tests; and iii) substituting sodium for potassium, lanthanum for gadolinium, and zirconium for uranium (to eliminate the use of radioactive materials). Renormalization after these modifications results in the HLW waste simulant (in terms of non-volatile oxide), the composition of which is given in Table 2.1.

To complete the formulation of the HLW waste simulant, non-volatile components need to be defined. No analytical data on the actual wastes were provided since they did not affect glass formulations [22, 23]. Consequently, concentrations of carbonate, nitrate, nitrite, and total organic carbon (TOC) from previous C-106/AY-102 melter tests are adopted [6]. The complete HLW waste simulant is listed in Table 2.2.

2.2 C-106/AY-102 Glass Formulation and Melter Feed Formulation

After definition of the composition of the blended C-106/AY-102 waste, new glass formulations were developed and tested at VSL to support actual waste testing [22]. The glass composition selected as the basis to vitrify actual C-106/AY-102 waste, HLW04-09, is presented in Table 2.2. The same glass formulation, with modifications including those made in defining the simulant described above, was used for the present tests. On an oxide basis, HLW04-09 has a total waste loading of 37.10 wt%, practically all of which is Envelope D waste (37.08 wt%). These can be compared with the respective values of 51.00 wt% and 39.42 wt% for HLW98-34, the C-106/AY-102 reference glass used in Part B1 [25]. The difference is primarily due to the presence of much more Na_2O in the Part B1 waste simulant (20.61 wt% vs. 14.68 wt% for the current simulant). The reduced amount of sodium in the current *waste* formulation explains the lower total waste oxide waste loading (which includes waste sodium) associated with the glass formulation HLW04-09. The current target glass (HLW09-04) is also different from HLW98-34 in that it meets the contract minimum component limit by incorporating 14.01 wt% of Fe_2O_3 , instead of > 21 wt% of $(\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 + \text{ZrO}_2)$ [25].

Crucible melts of HLW04-09 and related formulations have been prepared and tests performed to determine that the target glass meets the necessary processing and performance requirements [22]. Heat treatment of HLW04-09 using the HLW canister-centerline-cooling temperature profile results in a homogeneous dark brown glass that contains only 0.1 vol% of spinel crystals. In addition, heat treatment of HLW04-07, which has a composition very similar to HLW04-09, at 950°C for 70 hours results in about 0.2 vol% of spinel crystals. The viscosity measured for HLW04-07 is 45 P at 1150°C. Finally, the normalized PCT leach rates of HLW04-09 are (in $\text{g}/(\text{m}^2\text{-day})$) 0.039, 0.043, 0.040 and 0.024, respectively for B, Li, Na and Si; these values can be compared with those for the reference glass (SRL-EA): 1.17, 0.71, 0.80 and 0.27. The target glass formulation to be used for the present tests, as given in Table 2.2, is very similar to HLW04-09 and has a total waste loading of 36.80 wt%.

The additional constituents required to form the target test glass from the HLW simulant are boron, lithium, sodium, silicon, and zinc (see Table 2.2). They were added in the same proportions as those used in HLW04-09, with the exception of zinc, which was added at 1.00 wt%, with respect to glass (oxide basis), compared to 0.70 wt% in HLW04-09 [22]. The raw materials that are the sources for the glass forming additives were selected based on previous testing and with direction of the WTP Project. Table 2.3 lists the starting materials and amounts required to produce the target C-106/AY-102 simulant and melter feed. Note that all of the TOC is assumed to be oxalate. The undissolved solids concentration in the *simulant* is assumed to be 20 wt%, which is equivalent to 21.49 wt% total solids, based on the data from AZ-102 testing [10]. The theoretical glass yield of the resulting C-106/AY-102 feed is 327 g of glass/kg of feed (about (415-480) g/l of feed, depending on feed density).

Simulants and melter feeds with different viscosities have been prepared for AZ-102 and C-106/AY-102 compositions and subsequently processed in the DM1200 [17]. The same process was used to generate feed for the C-106/AY-102 formulation to be used in this study for the second two-day test segment. These melter feeds were produced by NOAH Technologies

Corporation, the supplier of simulant and feed samples used in previous testing on the DM1200 melter system.

2.3 SIPP HLW Simulant and Glass Forming Additives

The HLW SIPP simulant for the third segment of this test was provided by SRNL. The SIPP was used to demonstrate the pretreatment operations of the WTP flow-sheet by processing HLW and LAW simulants through feed evaporation, ultrafiltration, cesium ion exchange, and treated feed evaporation. The projected composition of the SIPP simulant [26] is shown in Table 2.4. Based on the projected simulant composition [26], HLW04-09 was selected as the target glass composition. Table 2.5 shows the projected oxide composition of the SIPP simulant, the glass forming additives, and the projected target glass formulation; this is compared with the glass composition used in previous HLW melter studies [2-12], which is the same as the melter glass that will be processed in the other test segments. Note that the waste loading of the SIPP material was selected to achieve the same Fe_2O_3 content (14.03 wt%) in the target glass. The glass compositions are very similar with the exception of the changes made to the melter glass discussed in Section 2.1: inclusion of minor elements, such as silver, omitted in the melter glass; inclusion of potassium; and lower concentrations of zirconium.

Pre-test SIPP simulant samples were received at VSL, sampled and analyzed. These samples were sub-samples of the SIPP material that were shipped to VSL for “preview” analysis prior to receipt of the drums of SIPP material that were used for the melter tests. The preliminary analyzed composition of the simulant on an oxide basis is provided in Table 2.6 along with the oxide contribution from additives and the target glass composition; again, the waste loading is selected to achieve an Fe_2O_3 content of 14.03 wt% in the target glass. The analyzed simulant composition differs only slightly from the projected composition [26], which is reflected in minor changes in glass forming additives and the proportion of SIPP simulant to additives. Therefore, the target glass compositions in Tables 2.5 and 2.6 are very close. The amounts of SIPP simulant and additives required to produce 100 kg of glass based on the composition in Table 2.6 are given in Table 2.7.

2.4 Analysis of SIPP Simulant

Each of the three drums of SIPP simulant delivered to VSL was homogenized and then sampled to provide material for analysis. Measured physical properties of the simulant are compared to projected values [27] in Table 2.8. Samples were subjected to total dissolved solids (TDS) and total suspended solids (TSS) determinations by gravimetric analysis of filtered material and the evaporated filtrate. Total organic carbon (TOC) was measured using a Shimadzu Model TOC-VWP carbon analyzer. Prior to analysis, the samples were acidified with phosphoric acid and sparged to convert the inorganic carbon in the sample to carbon dioxide which is purged prior to TOC determination. The remaining material is then heated under UV illumination to convert the non-purgeable organic carbon (NPOC) in the sample to carbon dioxide, which flows with the carrier gas via the dehumidifier into the non-dispersive infrared (NDIR) sample cell. The area of the carbon dioxide peak signal was measured and this peak area was converted to

carbon concentration using a pre-prepared calibration curve. This procedure is appropriate for liquids and, therefore, the analysis was performed on the supernatant fraction of settled feed samples. The analyzed TOC concentrations in the SIPP simulant are two orders of magnitude higher than in the nominal simulant recipe used for the first two tests. The difference may be partly attributable to organic compounds present in the SBS condensate sent from VSL to SRNL for generating the SIPP material and the antifoam added to the simulant at SRNL, neither of which were accounted for in the SRNL nominal composition. The projected analysis provided by SRNL indicates most of the TOC is oxalate presumably added in the generation of the SIPP simulant. The measured total solids deviated by only four percent from the projected value; however, a much greater proportion of the solids was measured as dissolved solids. This might be attributable to dissolution of suspended material in the time between analysis and differing methods of segregating the solids for analysis. Little variation in simulant density, pH, TSS, TDS, and TOC was observed in samples from the three drums.

The chemical composition of the simulant was determined by homogenizing, fusing in a platinum crucible, and grinding the fused product to less than 200 mesh for chemical analysis. The concentration of the majority of the elements was then determined by microwave dissolution of the ground material in mixed acids followed by DCP analysis of the resulting solutions. This procedure was performed in duplicate for each of the three ground samples. Additional data were provided by direct analysis by XRF for elements not measured by DCP, and those prone to precipitation in the presence of high fluoride concentrations or subject to a low bias by the DCP. The results of the combined analysis for samples from each drum are provided in Table 2.9. The analyzed compositions are the same or very similar to those obtained on pre-test samples given in Table 2.6. The only element to vary significantly between the two sets of analysis was sulfur which increased by 36% (from 0.11 to 0.15 wt% SO₃). The compositional data also confirms the consistency over the three drums of simulant received.

2.5 Analysis of Feed Samples

2.5.1 General Properties

Feed samples from each test as well as feed made with pretest SIPP samples were analyzed to confirm physical properties and chemical composition. Samples were taken during melter testing from an inline sampling port. Sample names, sampling dates, and measured properties are given in Table 2.10. Also included is a feed sample from the test using SIPP simulant diluted to a target of 5 percent totals solids as specified by a WTP Test Exception [27]. Measured water content, density, glass yield and pH were similar for all undiluted samples. Feed made with SIPP simulant had glass yields marginally higher than other feed samples. As expected, the density of the diluted sample was close to one.

2.5.2 Rheology

Samples of the melter feeds that were used for these tests were also subjected to rheological characterization. The results from rheological characterization of a variety of other melter feeds and waste simulants, as well as the effects of a range of test variables, are described

in detail in a separate report [28]. 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 the shear stress is allowed to fully relax and therefore is measured at equilibrium. This approach is somewhat different from the "flow curve" approach in which the shear rate is ramped up to some maximum value and then ramped back down to produce a hysteresis curve that is dependent on the selected ramp rate. 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 yield stress can be quite different from the value that is often reported as the yield stress, which is obtained by extrapolation of the shear stress-shear rate curve to zero shear rate. All of the measurements in this work were made at 25°C ; previous work [28], 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 Figure 2.1; measured values for viscosity at selected shear rates and the yield stress are shown in Table 2.10. Notice that melter feed prepared using the SIPP simulant has similar rheological properties to the feed adjusted by NOAH to be more viscous. Also, both of these feeds were considerably more viscous than the melter feed produced by NOAH using the direct hydroxide method. The yield stress values exhibited the same trends as those described for the viscosity at low shear rates.

Comparisons of rheological properties of diluted and undiluted feed from the tests using the SIPP simulant are given in Figure 2.2 and Table 2.10. As expected, the feed containing only about five percent total solids is considerably less viscous than the undiluted feed. The rise at high shear rates may be due in part to re-suspension of settled material. Viscosity is typically measured after 20 minutes of "relaxation" during which settling can occur. In light of the rapid settling rates of the diluted sample, additional measurements were made immediately after stirring. The results of the measurements made on stirred and unstirred samples suggest the amount of solids that settles during the "relaxation" period had little effect on the rheology measurements, as depicted in Figure 2.3. The settling rate of solids in the diluted sample was further investigated using VSL SOPs, which are based on WTP Project and standard methods [29, 30]; the results of these procedures are shown in Figure 2.4. Approximately half the solids settled out of the feed in 30 minutes and settling was complete after about 180 minutes. Samples were monitored for an additional 12 hour period beyond the data presented in Figure 2.4 with no additional settling observed.

2.5.3 Chemical Composition

The chemical compositions of the feed samples were determined by first making a glass from the feed via crucible melt. The glass was subsequently crushed and analyzed directly by X-Ray Fluorescence Spectroscopy (XRF). The boron and lithium oxide target values were used for normalizing the XRF data since their concentrations were not determined by XRF. Data are compared to the target composition in Table 2.11. These results generally corroborate the consistency of the feed composition and show good agreement with the target composition for the major elements. All oxides with target compositions greater than one percent deviated less than 10% from target for feed samples from material produced by NOAH. Aluminum and zinc showed deviations that were greater than 10 percent for the feed produced from the SIPP material. The absolute deviation for zinc is only 0.12 percent and therefore may be due to sampling variations. Conversely, the absolute surplus of aluminum is over one percent in the SIPP feed indicating an actual surplus. Glass from the end of the melter tests (see Section 4.1) also displayed an excess of aluminum although not to the same degree since the glass pool was only partially turned over to the SIPP glass composition. The disparity in aluminum might be attributable to sampling biases or contamination of additives blended with the SIPP simulant. Aluminum is different from most other elements in that it is soluble at both low and high pH. Also, precipitated aluminum is typically very fine grained. The SIPP dissolved and undissolved portions measured at SRNL and VSL are different although the total measured solids are similar. This suggests that constituents may be dissolving over time, which could reduce the consistency between different samples collected over an extended period of time. Lanthanum is present in each feed recipe at 0.07 to 0.08 wt% oxide but was only detected in the feed containing the SIPP simulant. Low concentrations of titanium and potassium were measured in feed blended by NOAH even though they are not included in the target composition. Elements such as these are often observed in melter feeds even when omitted from the recipe due to their ubiquity in the raw materials used to make up the simulants and in the glass forming additives.

SECTION 3.0 MELTER OPERATIONS

Melter tests were conducted on the DM100-BL between 10/27/04 and 11/02/04. These tests produced nearly 800 kg of glass from almost two and a half metric tons of feed. The tests were divided as follows:

- 3 day test with nominal feed produced by NOAH Technologies Corporation.
- 2 day test with adjusted rheology feed produced by NOAH Technologies Corporation.
- 33.6 hour test with HLW SIPP simulant from SRNL and glass formers added at VSL; the test duration was the maximum achievable with the amount of SIPP material that was available.

The first test included an additional day to cool the melter plenum and build a steady-state cold cap. The third test was shorter than the planned two-day duration due to the amount of SIPP simulant received from SRNL. Summaries of the three tests are provided in Table 3.1. Attempts were made to replicate the melter configuration and operating conditions used for previous tests with HLW simulants [3-7, 17]. These conditions include a near complete cold cap, which is between 80-95% melt surface coverage for the DM100 since a 100% cold cap tends to lead to "bridging" in smaller melters. The bubbling rate was fixed at 9 lpm and the feed rate was adjusted to maintain a complete cold cap; this is in contrast to previous tests where the production rate was fixed between 1000 to 1050 kg/m²/day and the bubbling rate was adjusted to maintain the complete cold cap. The approach used in the present tests permits the direct comparison of each feed stream with respect to production rate, as shown in Figure 3.1. Glass production rates increased gradually over the course of testing, which may be partly attributable to changes in the feed streams. Conversely, the average rate from the first test is less than six percent lower than that for the third test, suggesting that the differences between the three feeds do not have a substantial effect on processing rates. The differences between production rates calculated from glass poured and feed processed can be attributed to variations in the amount of glass in the melt pool, which affects the calculated rate based on the amount of glass poured but not the rate based on the amount of feed processed. Another reason for the difference is that the actual glass yield is higher than the targeted yield for the feed containing the SIPP simulant (see Section 2.5).

Cold cap conditions during the first two tests were very similar to each other and previous tests with HLW feeds [3-7, 17] whereas the feed with SIPP simulant formed a more fluid cold cap which spread more evenly across the melt surface and was less likely to adhere to melter walls, thus not forming shelves and bridges. Interruptions between the tests required to change over to the new feed and to take required glass samples were limited to less than 45 minutes each in an effort to provide a seamless transition between the tests. However, spikes in feed rate often occurred immediately after feed transfers due to adjustments in tank mixer speeds and pump settings. Feeding was paused momentarily several times during testing to adjust the feed line in the peristaltic pump as a result of wear from the pump rollers. There was also a brief power outage which required rebooting the computers and resulted in a brief pause in feeding. The melter feed tube required one to three rod outs per test as a result of blockages.

Some of these blockages in the latter part of testing may be attributed to the deterioration of the Teflon liner during preceding rod outs and/or heat from melter. The infrequent blockages of the feed tube were an artifact of the DM100 system and have not been encountered on the DM1200. The DM100 feed flow rates are lower than for the DM1200, particularly when the peristaltic pump is used. Also, the DM100 plenum is much hotter than the DM1200 and the feed tube tip much closer to the glass surface, which increases the tendency for drying of feed on the tip of the feed tube. The film cooler only required one rod out, which occurred near the end of the tests. Although the film cooler blockage occurred while processing feed containing SIPP simulant, it is not clear if that particular feed stream exclusively contributed to the blockage. It was often difficult to discern the glass level and therefore the glass level was allowed to rise to the top of riser overflow. Once auto-discharging was observed, air was introduced for a set amount of time to discharge glass. Thus, the intentional auto-discharging in these tests is in stark contrast to the unintentional auto discharging observed with LAW feeds that had high reductant contents during recent tests on the WV-DM100 [18]. No foamy glass was observed in the glass discharge and no foam was observed on the melt pool surface or cold cap.

The results of various operational measurements that were made during these tests are given in Table 3.2. Glass bubbling rates are shown in Figure 3.2, glass temperatures are shown in Figure 3.3, plenum temperatures in Figure 3.4, and electrode temperatures in Figure 3.5; electrode power is included in two of the figures. Throughout testing, the target glass bubbling rate was maintained. The test average glass temperature for the entire glass pool (1143-1146°C) approximated the target glass temperature of 1150°C. Adjusting power to achieve this temperature was a balance between the bottom and top halves of the melt pool with the upper portion of the melt pool being 20-25°C cooler. Plenum temperatures typically ranged from 450 to 600°C, which is lower than the 550 to 650°C target. These lower temperatures were the consequence of maintaining a more complete cold cap. Similar to the glass pool, the lower pair of electrodes was a little hotter than the upper pair of electrodes. There was little temperature difference across the melter between the East and West electrodes. The bottom electrode, which was not powered, had a temperature of about 800°C. Power supplied to the electrodes typically varied between 24 and 25 kW. As expected, more power was required in the latter portion of testing as the production rate increased.

The gas temperature at the film cooler averaged between 281-289°C and depended on the plenum temperature, the amount of added film cooler air, and the temperature of the added film cooler air. A small drop of about five degrees in gas temperature was observed across the (insulated) transition line; the high temperature is maintained in order to prevent condensation in the downstream filtration units.

SECTION 4.0 GLASS PRODUCTS

Almost 800 kg of glass was produced in these tests. The glass was discharged from the melter periodically into 5-gallon carbon steel pails using an airlift system. The discharged product glass was sampled at the end of each test by removing sufficient glass from the top of the cans for total inorganic analysis. Product glass masses, discharge date, and analysis performed are given in Table 4.1. Glass samples were also obtained by dipping a rod into the glass pool at the beginning and end of each test. These "dip samples" underwent visual examinations to detect the presence of a separate sulfate phase on the glass surface as well as total inorganic compositional analysis on select samples.

4.1 Compositional Analysis

Discharge glass samples were crushed and analyzed directly by XRF. The target value for boron and lithium oxides, which are not determined by XRF, were used for normalizing the XRF data to 100 wt%. The XRF analyzed compositions of discharged glass samples are provided in Table 4.2. All discharged glass samples were subjected to XRF analysis. The majority of the XRF analysis results compared very favorably to their corresponding target values. All oxides with a target concentration greater than 1 weight percent had a less than 10% deviation from target values for the feed received from NOAH Technologies Corporation. Glass from the end of the test using the SIPP material had manganese and aluminum oxide concentrations that deviated by more than 10% from their respective target values. This was attributable in part to the fact that only one turnover of the melt pool was completed during the test due to the limited amount of HLW SIPP that was available for these tests. The excess of aluminum was also observed in feed and simulant samples (see Section 2) and therefore the surplus in the product glass was anticipated. Also similar to feed sample analysis, potassium and titanium, which are not in the target composition, were measured at low concentrations in the glass produced from the NOAH feeds. Lanthanum was only measured in glasses at the beginning of the tests, suggesting it was present in the glass pool prior to testing but not in any of the melter feeds. These data are at odds with the SIPP simulant and feed analysis (see Sections 2.4 and 2.5.3), which indicate the feed should produce a glass containing 0.07 wt% La_2O_3 .

Corroborative analysis using DCP on solutions of acid dissolved glass was performed on select glasses produced from each test; the results are compared to the XRF analysis in Table 4.3. Values for all the major oxides compare favorably with the XRF analysis and target composition except for sodium, which often exhibits a low bias using this procedure [13]. The closeness of the DCP boron and lithium analysis to the target (deviations less than 10%) validates the use of the target boron and lithium concentrations for normalizing the XRF data.

Compositional trends for selected oxides shown in Figures 4.1-4.5 illustrate the closeness to target from the beginning and the consistency throughout testing. The melt pool composition at the start of testing was the same as the target composition for the first two tests and therefore

no compositional changes indicative of turnover occurred. Compositional changes that occurred during the test using HLW SIPP simulant were as follows: a small decrease in silicon concentration, increases in aluminum concentration, decreases in sulfur and zirconium concentrations due to decreases in feed concentrations, increases in the concentration of elements such as silver, copper, neodymium, and praseodymium that are present only in the SIPP simulant, and a peculiar dip in the concentrations of several metals including iron, nickel, lead, and zinc. The latter can be observed during the test with SIPP simulants in Figures 4.2 and 4.3 as an increase in concentration during the first 50 kg of production, a decrease during the next 100 kg of production and a return to the higher concentration during the last 50 kg of production. We have no explanation for this unusual behavior.

Several discharge samples, including one from near the end of each test, were examined with an optical microscope for secondary phases. The method permits determination of crystalline phases as small as 0.1 micron. The results showed that no sample contained more than 0.1 volume percent crystalline phases including spinels.

Glass dip samples were obtained primarily to ascertain whether secondary phases had formed on the surface of the glass melt. No secondary phases were observed prior to or subsequent to any of the tests. Table 4.4 provides analyzed compositions of select dip samples. The compositions of the samples taken at the end of each test are comparable to discharge glass samples from the end of each test.

4.2 Iron Redox State

The iron oxidation states for glass samples from all three tests were measured using colorimetric methods. The method detection limit of 0.3% divalent iron reported here is dependent on several factors including the level (14 wt%) of Fe_2O_3 in the target glass. Sample information including name, test, and the amount of glass produced for all samples analyzed for divalent iron are given in Table 4.5. Divalent iron concentrations were characteristically low during the first test at less than two percent of total iron, increased to almost seven percent during the second test and decreased to four and half percent during the test using SIPP simulants. The increase during the second test was unexpected since the glass composition did not change and no additional organic matter was added to the feed. The amount of iron reduction observed in the test using SIPP simulants is within the range measured for HLW feeds containing similar TOC concentrations [4, 11].

SECTION 5.0 MONITORED OFF-GAS EMISSIONS

5.1 Particulate Sampling

The melter exhaust was sampled for metals/particles according to 40-CFR-60 Methods 3, 5, and 29 at steady-state operating conditions during each test segment. The concentrations of off-gas species that are present as particulates and gaseous species that are collected in impinger solutions were derived from laboratory data on solutions extracted from air samples (filters and various solutions) together with measurements of the volume of air sampled. Particulate collection required isokinetic sampling, which entails removing gas from the exhaust at the same velocity that the air is flowing in the duct (40-CFR-60, Methods 1-5). Typically, a sample size of 30 dscf was taken at a rate of between 0.5 and 0.75 dscfm. Total particulate loading was determined by combining gravimetric analysis of the standard particle filter and chemical analysis of probe rinse solutions. An additional impinger containing 2 N NaOH was added to the sampling train to ensure complete scrubbing of all acid gases and, particularly, iodine. The collected materials were analyzed using direct current plasma atomic emission spectroscopy (DCP-AES) for the majority of the constituents and ion chromatography (IC) for anions. Melter emission fluxes are compared to feed fluxes in Table 5.1. Notice the distinction that is made between constituents sampled as particles and as "gas". The "gaseous" constituents are operationally defined as those species that are scrubbed in the impinger solutions after the air stream has passed through a 0.3 μm heated filter. All three samples are well within the 90 – 110% limits for isokinetic sampling. Percent elemental carry-over for aluminum and sulfur during the test with SIPP simulant was calculated using the measured simulant concentrations due to the large disparity between the projected and analyzed compositions for these elements.

Particulate emissions from the melter constituted 0.61 to 0.81 percent of feed solids. This level of carry-over is at the low end of that measured for HLW AZ-102 simulants (0.57 - 1.47 percent) processed on the same melter [4]. As expected, the feed element emitted at the lowest melter DF was clearly sulfur. Other elements exhibiting volatile behavior include chromium and boron. Chromium carry-over from the melter ranged from 1.49 to 2.08 percent, which is comparable to that for previous tests on the DM100 (1.49 to 2.08%) [3] and slightly higher than measured during DM1200 tests with C-106/AY-102 simulants (1.1 to 1.18%) [6, 17]. However, it should be noted that the percentages relative to the chromium content in the feed are inflated because the melter component materials (K3 refractory, Inconel) are also sources of chromium. In addition, although Cr(III), such as is present in the K3 refractory, is not particularly volatile, it can be oxidized to Cr(VI), which is much more volatile. Emissions of the halogens chlorine, fluorine, and iodine were measured during all three tests even though they were not included in simulant recipes or in analyzed compositions. Chlorine and fluorine have frequently been observed in melter emissions when not present in feed recipe or at levels exceeding the amount in the feed recipe due to their ubiquity in raw materials, presence in tap water, and their high volatility at glass melting temperatures. Iodine was only measured in significant quantity during the test with SIPP simulant. For SIPP simulant preparation at SRNL, VSL provided SBS

condensate from tests performed on the DM1200 to study iodine emissions; therefore, it is not surprising that iodine was observed in tests using HLW and LAW SIPP simulants [13] even though it was not present in the nominal SRNL composition. Emission trends were similar for all three tests suggesting that feed rheology and preparation method do not have a large effect on melter emissions. The sulfur particulate emission rates for all three tests are similar, although the target sulfur concentration for the SIPP feed is one-fourth of that of the other two. The measured concentration for the SIPP feed is higher than the target but still one-third of that in the other feeds. Since the measured value for the feed sample was obtained by first making a glass from feed via crucible melt, which results in partial volatilization of species like sulfur, the actual feed concentration is probably higher than the measured sulfur concentration, which in turn would result in higher sulfur DF values. Boron, sulfur, and the halides were the only elements detected in the impinger solutions collected downstream of the heated particle filter in the sampling train, which constitutes the “gas” fraction of the melter emissions.

5.2 Gases Monitored by FTIR

Melter emissions were monitored in each test for a variety of gaseous components, most notably CO and nitrogen species, by Fourier Transform Infra-Red Spectroscopy (FTIR). The off-gas system temperature is maintained well above 100°C beyond the sampling port downstream of the HEPA filter to prevent analyte loss due to condensation prior to monitoring. A summary of average concentrations monitored during each test is provided in Table 5.2. Concentrations of two of the monitored species are plotted in Figures 5.1 - 5.2. The analytes listed in Table 5.2 are those that were thought likely to be observed during the test based on previous work; no other species were detected in the off-gas stream by FTIR. Emissions are very low as a result of the low concentrations of nitrogen, organic carbon, ammonia, and halogens in the feed. The most abundant nitrogen species monitored was NO, which is consistent with previous tests in which nitrates and nitrites were present in the feed. Little or no nitrogen was detected as other species, including NO₂. Nitrogen oxide and carbon monoxide concentrations increased by about an order of magnitude during the test with SIPP simulant as result of nitrates/nitrites and TOC concentrations being four and one hundred times higher in the SIPP simulant, respectively (see Tables 2.2, 2.4 and 2.8). Hydrogen emissions were highest during the second test even though the feed organic content was the same as the first test and considerably less than the tests using SIPP simulant. Consistent with the low gaseous chlorine and fluorine concentrations observed using the Method 5-type sampling discussed earlier, no HF or HCl were observed by FTIR. The variations in emissions over the course of each test segment are due in part to changes in the melt pool cold cap.

SECTION 6.0

SUMMARY AND CONCLUSIONS

Three tests using three different HLW C-106/AY-102 feeds were conducted on the DM100-BL over a period of 7 days to determine processing rates as well as feed and melter conditions (off-gas characteristics, melter feed mixing/pumping, etc.) at constant bubbling rate. Melter feed targeting the high-waste-loading C-106/AY-102 formulation was prepared by three different methods: direct hydroxide addition using the same method as used in previous tests; the modified-rheology method used by NOAH; and by combining HLW SIPP simulant generated at SRNL with glass forming chemicals (GFCs) at VSL. Production rates, feed distribution across molten glass, off-gas characteristics, and melter feed mixing/pumping behavior were determined at a nominal bubbling rate (9 lpm) for feed containing simulants prepared by each of the three methods. Steady state processing rates were achieved for tests with each simulant type without any significant problems. Glass production rates for the three feeds differed by less than 6% suggesting that there was no significant impact of the simulant preparation methods or rheological properties on the processing rate. The cold cap produced from the feed containing the SIPP simulant was more fluid and stable than cold cap originating from other HLW simulants. Feed and SIPP simulant samples were characterized for an array of physical, chemical, and rheological properties. Testing of dip samples collected from the melt pool at the end of each test and discharge glass samples indicated that no separate phases had formed on the melt surface or in the poured glass. Glass samples were analyzed for composition to calculate elemental mass balances. Glass samples were also analyzed for divalent iron concentration to determine the effect of simulant preparation on glass oxidation state; less than 7% of the iron was present in the divalent form in the glass samples obtained from the three tests.

Total particulate carry-over from the melter was 0.61 to 0.81 percent, which is within the range measured previously on the DM100 when processing HLW simulants. Melter DFs were determined for most elements in the feed for all three tests performed. The most volatile species was sulfur. Halogens were measured in the melter exhaust, presumably originating in the feed as contaminants. Particulate emissions from all three tests were similar, suggesting that simulant preparation does not affect particulate emissions. Gaseous emissions of nitrogen oxides and byproducts of incomplete combustion, such as carbon monoxide and ammonia, were very low due to the lack of nitrates and organic carbon in the feed. An exception was the test with the SIPP simulant in which nitrogen oxide and carbon monoxide concentrations were ten times higher than in the other tests due to the higher levels of nitrates/nitrites and organics in the simulant.

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Table 2.1. Compositional Summary (Oxide Basis) of the C-106/AY-102 Actual Waste, AW-101 Cesium-Eluate, Blended Waste, and the HLW Simulant.

Oxide (wt%)	Analyzed C-106/AY-102 Solid	Analyzed AW-101 Cesium-Eluate	Blended C-106/AY-102 Actual Waste	HLW Simulant
Ag ₂ O	0.50%	—	0.50%	—
Al ₂ O ₃	13.17%	—	13.16%	13.29%
B ₂ O ₃	0.70%	33.18%	0.73%	0.74%
BaO	0.20%	1.68%	0.20%	0.20%
CaO	1.23%	—	1.23%	1.24%
CdO	0.03%	0.38%	0.03%	—
Ce ₂ O ₃	0.27%	4.91%	0.27%	0.27%
Cr ₂ O ₃	0.60%	0.69%	0.60%	0.61%
Cs ₂ O	—	3.36%	0.00%	0.00%
CuO	0.09%	2.57%	0.09%	—
Fe ₂ O ₃	37.78%	0.41%	37.74%	38.12%
Gd ₂ O ₃	0.02%	—	0.02%	—
K ₂ O	0.03%	—	0.03%	—
La ₂ O ₃	0.20%	0.85%	0.20%	0.22%
Li ₂ O	0.11%	7.34%	0.12%	0.12%
MgO	0.39%	—	0.39%	0.39%
MnO	7.61%	—	7.60%	7.68%
MoO ₃	0.09%	—	0.09%	—
Na ₂ O	14.48%	35.73%	14.50%	14.68%
NiO	1.11%	1.36%	1.11%	1.12%
P ₂ O ₅	1.51%	—	1.51%	1.53%
PbO	1.46%	—	1.46%	1.47%
SO ₃	0.51%	—	0.51%	0.52%
Sb ₂ O ₅	0.11%	—	0.11%	—
SiO ₂	14.28%	—	14.27%	14.41%
SnO ₂	0.16%	6.83%	0.17%	0.17%
SrO	0.46%	0.71%	0.46%	0.46%
TiO ₂	0.09%	—	0.09%	—
U ₃ O ₈	1.40%	—	1.40%	—
V ₂ O ₅	0.04%	—	0.04%	—
ZnO	0.08%	—	0.08%	0.08%
ZrO ₂	1.25%	—	1.25%	2.68%
TOTAL	99.96%	100.00%	99.96%	100.00%

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Table 2.2. Compositional Summary (Oxide Basis) of the HLW Simulant, Glass Forming Additives, Target Test Glass, and the Reference Glass (HLW04-09).

Oxide (wt%)	HLW Simulant	Glass Former (as wt% of glass)	Melter Test Target Glass	HLW04-09
Ag ₂ O	—	—	—	0.19%
Al ₂ O ₃	13.29%	—	4.89%	4.88%
B ₂ O ₃	0.74%	10.00%	10.27%	10.27%
BaO	0.20%	—	0.07%	0.07%
CaO	1.24%	—	0.46%	0.46%
CdO	—	—	—	0.01%
Ce ₂ O ₃	0.27%	—	0.10%	0.10%
Cr ₂ O ₃	0.61%	—	0.22%	0.22%
Cs ₂ O	0.00%	—	0.00%	0.00%
CuO	—	—	—	0.03%
Fe ₂ O ₃	38.12%	—	14.03%	14.01%
Gd ₂ O ₃	—	—	—	0.01%
K ₂ O	—	—	—	0.01%
La ₂ O ₃	0.22%	—	0.08%	0.07%
Li ₂ O	0.12%	2.60%	2.64%	2.64%
MgO	0.39%	—	0.14%	0.14%
MnO	7.68%	—	2.82%	2.82%
MoO ₃	—	—	—	0.03%
Na ₂ O	14.68%	7.15%	12.55%	12.53%
NiO	1.12%	—	0.41%	0.41%
P ₂ O ₅	1.53%	—	0.56%	0.56%
PbO	1.47%	—	0.54%	0.54%
SO ₃	0.52%	—	0.19%	0.19%
Sb ₂ O ₅	—	—	—	0.04%
SiO ₂	14.41%	42.45%	47.75%	47.75%
SnO ₂	0.17%	—	0.06%	0.06%
SrO	0.46%	—	0.17%	0.17%
TiO ₂	—	—	—	0.03%
U ₃ O ₈	—	—	—	0.52%
V ₂ O ₅	—	—	—	0.01%
ZnO	0.08%	1.00%	1.03%	0.73%
ZrO ₂	2.68%	—	0.98%	0.46%
TOTAL	100.00%	63.20%	100.0%	100.0%
Volatiles (g/100 g glass)	—	—	—	—
Carbonate	4.650	—	—	—
Nitrite	0.012	—	—	—
Nitrate	0.784	—	—	—
TOC	0.026	—	—	—

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Table 2.3. Composition of Melter Feed to Produce 1 Metric Ton of Target Glass from C-106/AY-102 HLW Simulant (20 wt% undissolved solids).

C-106/AY-102 HLW Simulant		Glass-Forming Additives	
Starting Materials	Target Weight (kg)*	Starting Materials	Target Weight (kg)
Al(OH) ₃	78.78	—	—
B ₂ O ₃	4.87	Na ₂ B ₄ O ₇ ·10H ₂ O	276.66
BaCO ₃	0.97	—	—
CaCO ₃	8.33	—	—
CeO ₂	1.06	—	—
Cr ₂ O ₃	2.25	—	—
Fe(OH) ₃ (13% slurry)	1378.96	—	—
La(OH) ₃ ·3H ₂ O	1.24	—	—
Li ₂ CO ₃	1.13	Li ₂ CO ₃	65.95
Mg(OH) ₂	2.12	—	—
MnO ₂	34.97	—	—
Na ₂ OH	6.82	Na ₂ CO ₃	46.62
Ni(OH) ₂	5.31	—	—
FePO ₄ ·xH ₂ O (80%)	14.91	—	—
PbO	5.48	—	—
Na ₂ SiO ₃ ·5H ₂ O	125.47	—	—
SiO ₂	18.75	SiO ₂	428.79
Na ₂ SO ₄	3.40	—	—
SnO ₂	0.64	—	—
SrCO ₃	2.46	—	—
ZnO	0.30	ZnO	10.10
Zr(OH) ₄ ·xH ₂ O (50%)	25.45	—	—
Na ₂ CO ₃	17.83	—	—
NaNO ₂	0.07	—	—
NaNO ₃	3.97	—	—
H ₂ C ₂ O ₄ ·2H ₂ O	0.51	—	—
Water	481.25	—	—
TOTAL	2227.30	TOTAL	828.12
—	—	FEED TOTAL	3055.42

*Target weights adjusted for assay information of starting materials

—" Empty data field

Table 2.4. Summary of Projected SIPP Simulated Waste Composition [26].

Element	Concentration in SIPP Simulant (mg/L)	Oxide	Concentration in SIPP Simulant (mg oxide /L)	Concentration in SIPP Simulant (wt% oxide)
Ag	975.7	Ag ₂ O	1047.9	0.41%
Al	15472.1	Al ₂ O ₃	29229.7	11.57%
B	<182	B ₂ O ₃	—	—
Ba	480.5	BaO	536.5	0.21%
Ca	2360.3	CaO	3302.1	1.31%
Cd	73.5	CdO	84.0	0.03%
Ce	603.1	Ce ₂ O ₃	706.4	0.28%
Co	<16.1	CoO	—	—
Cr	723.9	Cr ₂ O ₃	1057.8	0.42%
Cs (AA)	<20.3	Cs ₂ O	—	—
Cu	149.3	CuO	186.8	0.07%
Fe	66743.0	Fe ₂ O ₃	95420.7	37.77%
K (AA)	3858.9	K ₂ O	4648.5	1.84%
La	468.4	La ₂ O ₃	549.3	0.22%
Li	105.2	Li ₂ O	226.5	0.09%
Mg	697.2	MgO	1155.6	0.46%
Mn	14805.0	MnO	19116.6	7.57%
Mo	<20.3	MoO ₃	—	—
Na average	33256.0	Na ₂ O	44823.3	17.74%
Nd	1395.5	Nd ₂ O ₃	1627.7	0.64%
Ni	2038.7	NiO	2594.7	1.03%
P	339.2	P ₂ O ₅	777.1	0.31%
Pb	3240.0	PbO	3490.0	1.38%
Pr	373.0	Pr ₆ O ₁₁	450.6	0.18%
S	593.4	SO ₃	1481.7	0.59%
Si	17727.4	SiO ₂	37922.4	15.01%
Sn	—	SnO ₂	—	—
Sr	519.4	SrO	614.2	0.24%
Ti	15.7	TiO ₂	26.1	0.01%
Y	109.0	Y ₂ O ₃	138.4	0.05%
Zn	168.7	ZnO	209.9	0.08%
Zr	831.2	ZrO ₂	1122.8	0.44%
Br	<27.9	Br	—	—
Cl	99.4	Cl	99.4	0.04%
F	19.0	F	19.0	0.01%
TOTAL	168241.7	TOTAL	252665.7	100.00%
Nitrate	7874.7	Nitrate	—	3.117*
Nitrite	2314.8	Nitrite	—	0.916*
TOC	6070.0	TOC	—	2.402*
Carbonate	5100.0	Carbonate	—	2.018*

*Units of volatiles in g/100 g of waste oxide. "—" Empty Data Field.

Table 2.5. Compositional Summary (in non-volatile oxides) of Projected SIPP Simulated Waste, Glass Forming Additives, Projected SIPP Target Glass, and C-106/AY-102 Melter Glass.

Oxide	Projected SIPP Simulant (wt%)	Glass Forming Additives (as wt% of Glass)	Projected SIPP Target Glass (wt%)	C-106/AY-102 Melter Glass
Ag ₂ O	0.41%	—	0.15%	—
Al ₂ O ₃	11.57%	—	4.30%	4.89%
B ₂ O ₃	—	9.97%	9.97%	10.27%
BaO	0.21%	—	0.08%	0.07%
CaO	1.31%	—	0.49%	0.46%
CdO	0.03%	—	0.01%	—
Ce ₂ O ₃	0.28%	—	0.10%	0.10%
CoO	—	—	—	—
Cr ₂ O ₃	0.42%	—	0.16%	0.22%
Cs ₂ O	—	—	—	0.00%
CuO	0.07%	—	0.03%	—
Fe ₂ O ₃	37.77%	—	14.03%	14.03%
K ₂ O	1.84%	—	0.68%	—
La ₂ O ₃	0.22%	—	0.08%	0.08%
Li ₂ O	0.09%	2.59%	2.62%	2.64%
MgO	0.46%	—	0.17%	0.14%
MnO	7.57%	—	2.81%	2.82%
MoO ₃	—	—	—	—
Na ₂ O	17.74%	6.00%	12.59%	12.55%
Nd ₂ O ₃	0.64%	—	0.24%	—
NiO	1.03%	—	0.38%	0.41%
P ₂ O ₅	0.31%	—	0.11%	0.56%
PbO	1.38%	—	0.51%	0.54%
Pr ₆ O ₁₁	0.18%	—	0.07%	—
SO ₃	0.59%	—	0.22%	0.19%
SiO ₂	15.01%	43.30%	48.88%	47.75%
SnO ₂	—	—	—	0.06%
SrO	0.24%	—	0.09%	0.17%
TiO ₂	0.01%	—	<0.01%	—
Y ₂ O ₃	0.05%	—	0.02%	—
ZnO	0.08%	1.00%	1.03%	1.03%
ZrO ₂	0.44%	—	0.17%	0.98%
Br	—	—	—	—
Cl	0.04%	—	0.01%	—
F	0.01%	—	<0.01%	—
TOTAL	100.0%	62.86%	100.0%	100.0%

"—" Empty Data Field.

Table 2.6. Compositional Summary (Oxide Basis) of the SIPP Simulant, Glass Forming Additives, and Target SIPP Glass Based on VSL Simulant Analysis of Pre-Test Samples.

Wt%	VSL SIPP Simulant Analysis of Pre-test Samples	Glass Former (as wt% of glass)	SIPP Target Glass Based on Preliminary VSL Analysis (wt%)
Ag ₂ O	0.41%	—	0.16%
Al ₂ O ₃	12.41%	—	4.87%
B ₂ O ₃	0.12%	10.20%	10.25%
BaO	0.26%	—	0.10%
CaO	1.29%	—	0.51%
CdO	0.04%	—	0.02%
Ce ₂ O ₃	0.35%	—	0.14%
CoO	0.01%	—	0.00%
Cr ₂ O ₃	0.43%	—	0.17%
CuO	0.08%	—	0.03%
Fe ₂ O ₃	35.70%	—	14.01%
K ₂ O	1.36%	—	0.53%
La ₂ O ₃	0.18%	—	0.07%
Li ₂ O	0.11%	2.60%	2.64%
MgO	0.57%	—	0.22%
MnO	7.01%	—	2.75%
MoO ₃	0.01%	—	—
Na ₂ O	17.46%	5.70%	12.55%
Nd ₂ O ₃	0.79%	—	0.31%
NiO	1.09%	—	0.43%
P ₂ O ₅	0.74%	—	0.29%
PbO	1.29%	—	0.51%
Pr ₆ O ₁₁	0.19%	—	0.08%
SO ₃	0.11%	—	0.04%
SiO ₂	16.96%	41.25%	47.91%
SnO ₂	0.05%	—	0.02%
SrO	0.28%	—	0.11%
TiO ₂	0.03%	—	0.01%
Y ₂ O ₃	0.04%	—	0.02%
ZnO	0.09%	1.00%	1.04%
ZrO ₂	0.53%	—	0.21%
TOTAL	100.0%	60.75%	100.0%

"—" Empty data field.

Table 2.7. Composition of Melter Feed To Produce 100 kg of Target Glass from SIPP Simulant (Oxide Content = 20.525 wt%).

SIPP Simulant	Glass-Forming Additives	
Target Weight (kg)	Starting Materials	Target Weight (kg) *
191.23	Na ₂ B ₄ O ₇ ·10H ₂ O	28.22
	Li ₂ CO ₃	6.60
	Na ₂ CO ₃	2.00
	SiO ₂	41.67
	ZnO	1.01
	TOTAL	79.49
	FEED TOTAL	270.72

*Target weights adjusted for assay information of starting materials

Table 2.8 Measured Properties of HLW SIPP Simulant.

—	BLJ-I-79A	BLJ-I-79B	BLJ-I-79C	Average	Projected [26]
Density	1.12	1.15	1.13	1.13	1.214
pH	13.16	13.11	13.12	13.13	-
TSS (mg/L)	209974	225927	208171	214691	-
TDS (mg/L)	92818	99389	101806	98004	-
TOC (mg/L)	4257	4445	3901	4201	6070
% Undissolved Solids	18.75	19.65	18.42	19.00	22.22
% Dissolved Solids	8.29	8.64	9.01	8.67	5.59
% Total Solids	27.04	28.29	27.43	27.67	26.56

"—" Empty data field

Table 2.9. DCP and XRF Analyzed Composition for SIPP Waste Simulant (wt%).

—		BLJ-I-80B		BLJ-I-80C		BLJ-I-80D		Average	Normalized
DCP	Ag ₂ O	0.43	0.44	0.32	0.33	0.43	0.43	0.40	0.40
	Al ₂ O ₃	12.82	12.29	12.40	12.08	12.18	11.60	12.23	12.39
	B ₂ O ₃	0.08	0.13	0.16	0.18	0.07	0.10	0.12	0.12
	BaO	0.27	0.24	0.27	0.24	0.27	0.24	0.26	0.26
	CaO	1.25	1.36	1.20	1.33	1.16	1.32	1.27	1.29
	CdO	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04
	CoO	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01
	Cr ₂ O ₃	0.43	0.41	0.44	0.41	0.44	0.41	0.42	0.43
	CuO	0.09	0.08	0.08	0.08	0.09	0.08	0.08	0.08
	Fe ₂ O ₃	35.95	33.80	36.31	34.20	36.75	33.99	35.17	35.62
	K ₂ O	1.26	1.31	1.28	1.37	1.33	1.46	1.34	1.35
	Li ₂ O	0.11	0.11	0.11	0.10	0.11	0.10	0.11	0.11
	MgO	0.58	0.54	0.58	0.53	0.58	0.52	0.56	0.56
	MnO	7.26	6.98	7.00	6.85	6.82	6.53	6.91	7.00
	MoO ₃	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
	NiO	1.09	1.09	1.07	1.05	1.06	1.05	1.07	1.08
	P ₂ O ₅	0.72	0.72	0.67	0.91	0.58	0.79	0.73	0.74
	PbO	1.32	1.31	1.10	1.09	1.39	1.38	1.27	1.28
	SiO ₂	16.86	16.56	16.68	16.77	16.74	16.62	16.71	16.92
	SnO ₂	0.05	0.04	0.05	0.05	0.04	0.04	0.05	0.05
	SrO	0.30	0.26	0.30	0.26	0.30	0.26	0.28	0.28
	TiO ₂	0.03	0.04	0.02	0.03	0.02	0.04	0.03	0.03
	Y ₂ O ₃	0.04	0.03	0.04	0.04	0.04	0.02	0.04	0.04
	ZnO	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
	ZrO ₂	0.54	0.52	0.54	0.50	0.53	0.50	0.52	0.53
XRF	Ce ₂ O ₃	0.35		0.37		0.37		0.36	0.37
	La ₂ O ₃	0.18		0.22		0.20		0.20	0.20
	Na ₂ O	17.78		17.26		17.12		17.39	17.61
	Nd ₂ O ₃	0.75		0.77		0.76		0.76	0.77
	Pr ₆ O ₁₁	0.16		0.19		0.19		0.18	0.18
	SO ₃	0.15		0.15		0.14		0.15	0.15
	Sum	NC		NC		NC		98.71	100.00

"—" Empty data field

Table 2.10. Measured Properties of Melter Feed Samples.

—	Date	Name	% Water	Density (g/ml)	Glass Yield		pH	Yield Stress (Pa)	Viscosity (Poise) [#]		
					(kg/kg)	(g/l)			1 /10	1 /100	1 /1000
Nominal Melter Feed	10/26/04	BLJ-F-81A	56.7	1.31	0.332	435	11.16	NA	NA	NA	NA
Nominal Melter Feed	10/26/04	BLJ-F-81B	61.9	1.26	0.326	411	10.10	10.9	3.58	0.41	0.22
Adjusted Rheology Feed	10/30/04	BLJ-F-135A	62.0	1.34	0.325	436	11.34	37.8	17.4	1.64	0.28
Feed made from HLW SIPP	11/01/04	BLK-F-17A	58.3	1.38	0.362	500	11.12	23.4	11.4	1.64	0.34
Diluted BLK-F-17A (120 g feed + 880 g water)	1/24/05	BLK-F-17AD	95.6	1.03	—	—	—	0.2	0.07	0.02	0.03*
Feed made from Pretest SIPP Sample			60.1	1.34	0.354	475	9.46	19.6	9.98	1.50	0.32
Feed made from Pretest SIPP Sample			58.9	1.37	0.340	466	11.03	49.9	22.8	3.03	0.47

"-" Empty data field

NA – Not analyzed

- Viscosity at three different shear rates (in reciprocal seconds).

* Increase may be due to re-suspension of settled solids

Table 2.11. XRF-Analyzed Compositions of Feed Samples (wt%).

—	Nominal Melter Feed			Modified Rheology Melter Feed			Melter Feed Made From HLW SIPP		
Sample I.D.	BLJ-F-81A			BLJ-F-135A			BLK-F-17A		
Constituent	XRF	Target	%Dev.	XRF	Target	%Dev.	XRF	Target	%Dev.
Ag ₂ O	0.01	§	NC	<0.01	§	NC	0.21	0.16	NC
Al ₂ O ₃	5.07	4.89	3.71	5.00	4.89	2.26	5.96	4.87	22.39
B ₂ O ₃ *	10.27	10.27	NC	10.27	10.27	NC	10.25	10.25	NC
BaO	0.12	0.07	NC	0.11	0.07	NC	0.13	0.10	NC
CaO	0.55	0.46	NC	0.50	0.46	NC	0.52	0.51	NC
CdO	<0.01	§	NC	<0.01	§	NC	<0.01	0.02	NC
CeO ₂	0.10	0.10	NC	0.11	0.10	NC	0.15	0.14	NC
Cl	<0.01	§	NC	0.01	§	NC	<0.01	§	NC
Cr ₂ O ₃	0.24	0.22	NC	0.23	0.22	NC	0.18	0.17	NC
Cs ₂ O	<0.01	§	NC	<0.01	§	NC	<0.01	§	NC
CuO	<0.01	§	NC	<0.01	§	NC	0.03	0.03	NC
Fe ₂ O ₃	13.26	14.04	-5.53	12.96	14.04	-7.68	13.42	14.01	-4.21
K ₂ O	0.12	§	NC	0.13	§	NC	0.65	0.53	NC
La ₂ O ₃	<0.01	0.08	NC	<0.01	0.08	NC	0.07	0.07	NC
Li ₂ O*	2.64	2.64	NC	2.64	2.64	NC	2.64	2.64	NC
MgO	0.14	0.14	NC	0.09	0.14	NC	0.07	0.22	NC
MnO	2.88	2.82	2.00	2.73	2.82	-3.25	2.97	2.75	8.01
Na ₂ O	13.02	12.56	3.72	13.52	12.56	7.68	12.31	12.55	-1.84
Nd ₂ O ₃	<0.01	§	NC	<0.01	§	NC	0.30	0.31	NC
NiO	0.37	0.41	NC	0.37	0.41	NC	0.37	0.43	NC
P ₂ O ₅	0.63	0.56	NC	0.64	0.56	NC	0.24	0.29	NC
PbO	0.64	0.54	NC	0.62	0.54	NC	0.60	0.51	NC
Pr ₆ O ₁₁	<0.01	§	NC	<0.01	§	NC	0.08	0.08	NC
SiO ₂	47.33	47.77	-0.91	47.53	47.77	-0.50	47.54	47.91	-0.73
SnO ₂	0.07	0.06	NC	0.08	0.06	NC	0.01	0.02	NC
SO ₃	0.14	0.19	NC	0.18	0.19	NC	0.06	0.04	NC
SrO	0.16	0.17	NC	0.15	0.17	NC	0.10	0.11	NC
TiO ₂	0.06	§	NC	0.05	§	NC	<0.01	0.01	NC
Y ₂ O ₃	<0.01	§	NC	<0.01	§	NC	0.02	0.02	NC
ZnO	0.93	1.03	-9.71	0.93	1.03	-9.71	0.92	1.04	-11.54
ZrO ₂	1.25	0.98	NC	1.17	0.98	NC	0.22	0.21	NC
Sum	100.00	100.00	NC	100.00	100.00	NC	100.00	100.00	NC

* Target values

§ - Not a target constituent

NC – Not calculated

"—" Empty data field

Table 3.1. Summary of Test Conditions and Results.

HLW Simulant		C-106/AY-102		
Nominal Target Glass Formulation		HLW04-09		
Target Glass	kg per kg feed	0.327		
	wt% Fe ₂ O ₃	14.03		
	wt% Na ₂ O	12.55		
—		Nominal	Adjusted Rheology	SIPP Simulant
Time	Feed Start	10/27/04, 11:00	10/30/04, 11:42	11/01/04, 13:25
	Feed End	10/30/04, 11:00	11/01/04, 13:00	11/02/04, 23:00
	Water Feeding (hr)	1.0	NA	NA
	Net Slurry Feeding (hr)	71.0	49.2	33.6
	Cold Cap Burn-Off (hr)	NA	NA	1.2
Average Bubbling Rate (lpm)		8.9	9.1	9.1
Feed Processed (kg)		1091	777	547
Glass Poured (kg)		349	255	186
Average Production Rate (kg/m ² /day)	From feed consumed	1117	1148	1183
	From glass poured	1092	1152	1230
Average Plenum Temperature (C°)	Thermowell	504	526	526
	Exposed	531	559	573
Average Power Supplied to Electrodes (kW)		24.1	24.7	24.5

"—" Empty data field
NA - Not Applicable
ND - Not Determined

Table 3.2. Summary of Measured Melter Parameters.

—			Test 1			Test 2			Test 3		
			AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
T E M P E R A T U R E (C)	Electrode	East Upper	1106	1077	1119	1110	1090	1123	1104	1092	1118
		West Upper	1109	1098	1133	1107	1097	1123	1112	1100	1127
		West Lower	1120	1100	1128	1121	1112	1131	1125	1114	1135
		Bottom	809	804	814	803	791	815	813	804	818
	Glass	27" from bottom	1137	1098	1173	1134	1110	1160	1132	1109	1163
		16" from bottom	1139	1115	1177	1139	1121	1163	1136	1117	1170
		10" from bottom	1158	1132	1180	1159	1145	1176	1160	1147	1183
		5" from bottom	1151	1108	1163	1146	1134	1159	1145	1131	1152
		Average	1146	1113	1173	1145	1128	1165	1143	1126	1167
	Plenum	Exposed	531	480	693	559	521	746	573	510	690
		Thermowell	504	447	676	526	492	677	526	503	570
	Discharge	Chamber	1055	674	1071	1060	544	1093	1063	928	1082
		Air Lift	1034	988	1112	1043	1028	1110	1039	997	1112
	Film Cooler Outlet		289	277	321	281	276	286	281	258	326
	Transition Line Outlet		283	255	323	277	250	289	276	261	288

"—" Empty data field

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

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1 (Nominal)	10/27/04	BLJ-G-94A	—	19.7	19.7
		BLJ-G-94B	XRF		
		BLJ-G-95A	—	20.4	40.2
		BLJ-G-96A	XRF		
		BLJ-G-96B	—	21.68	61.8
	10/28/2004	BLJ-G-100A	XRF		
		BLJ-G-101A	—		
		BLJ-G-102A	XRF	26.4	113.1
		BLJ-G-104A	—		
		BLJ-G-104B	XRF	28.4	141.5
		BLJ-G-107A	—		
		BLJ-G-108A	XRF	20.6	162.1
		BLJ-G-109A	—		
		BLJ-G-111A	XRF	10/29/2004	22.04
	BLJ-G-111B	—			
	BLJ-G-115A	XRF	22.5		206.7
	BLJ-G-116A	—			
	BLJ-G-117A	XRF	22.6		229.3
	BLJ-G-117B	—			
	BLJ-G-118A	XRF	21.6		250.9
	BLJ-G-119A	—			
	BLJ-G-119B	XRF	20.5		271.4
	BLJ-G-123A	—			
	BLJ-G-124A	XRF	30.09	301.5	
	BLJ-G-124B	—			
	10/30/2004	BLJ-G-128A	XRF	26.68	328.2
		BLJ-G-129A	—		
		BLJ-G-131A	XRF	20.9	349.1
		BLJ-G-132A	—		
		BLJ-G-132B	XRF, DCP, Microscopy, Fe ²⁺	22.6	371.7
		BLJ-G-136A	—		
		BLJ-G-137A	XRF		
		BLJ-G-137B	—		
		BLJ-G-138A	XRF		
10/31/2004	BLJ-G-138B	—	23.7	395.4	
	BLJ-G-139A	XRF			
	BLJ-G-140A	—	24.72	420.1	
	BLJ-G-146A	XRF			
	BLJ-G-146B	—	23.6	443.7	
	BLJ-G-150A	XRF, DCP, Microscopy, Fe ²⁺			
	BLJ-G-151A	—	25.92	469.6	
BLJ-G-151B	XRF				
2 (Adjusted Rheology)	10/31/2004	BLJ-G-151B	XRF	23	492.6
		BLJ-G-151A	—		
		BLJ-G-150A	XRF, DCP, Microscopy, Fe ²⁺	23	492.6
		BLJ-G-146B	—		
		BLJ-G-146A	XRF	23.6	443.7
	BLJ-G-140A	—			
	BLJ-G-139A	XRF	24.72	420.1	
BLJ-G-138B	—				
10/30/2004	BLJ-G-138A	XRF	23.7	395.4	
	BLJ-G-137B	—			
	BLJ-G-137A	XRF	22.6	371.7	
	BLJ-G-136A	—			
	BLJ-G-132B	XRF, DCP, Microscopy, Fe ²⁺	20.9	349.1	
BLJ-G-132A	—				
BLJ-G-131A	XRF	26.68	328.2		
BLJ-G-129A	—				
BLJ-G-128A	XRF	30.09	301.5		
BLJ-G-124B	—				
BLJ-G-124A	XRF	20.5	271.4		
BLJ-G-123A	—				
BLJ-G-119B	XRF	21.6	250.9		
BLJ-G-119A	—				
BLJ-G-118A	XRF	22.6	229.3		
BLJ-G-117B	—				
BLJ-G-117A	XRF	22.5	206.7		
BLJ-G-116A	—				
BLJ-G-115A	XRF	22.04	184.2		
BLJ-G-111B	—				
BLJ-G-111A	XRF	20.6	162.1		
BLJ-G-109A	—				
BLJ-G-108A	XRF	28.4	141.5		
BLJ-G-107A	—				
BLJ-G-104B	XRF	26.4	113.1		
BLJ-G-104A	—				
BLJ-G-102A	XRF	24.9	86.7		
BLJ-G-101A	—				
BLJ-G-100A	XRF	21.68	61.8		
BLJ-G-96B	—				
BLJ-G-96A	XRF	20.4	40.2		
BLJ-G-95A	—				
BLJ-G-94B	XRF	19.7	19.7		
BLJ-G-94A	—				

"—" Empty data field

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

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
2 (Adjusted Rheology)	11/11/2004	BLJ-G-152A	—	24.5	517.1
		BLJ-G-152B	XRF		
		BLK-G-5A	—	27.12	544.2
		BLK-G-10A	XRF		
	11/1/2004	BLK-G-10B	—	23.5	567.7
		BLK-G-11A	XRF, DCP, Microscopy, Fe ²⁺		
		BLK-G-13A	—	22.3	590.0
		BLK-G-13B	XRF		
		BLK-G-17A	—	28.4	618.4
		BLK-G-18A	XRF		
		BLK-G-18B	—	25.6	644.0
		BLK-G-20A	XRF		
		BLK-G-21A	—	23.44	667.5
3 (SIPP Simulant)	11/2/2004	BLK-G-24A	XRF, DCP, Microscopy, Fe ²⁺	23.44	667.5
		BLK-G-24B	—	22.88	690.3
		BLK-G-26A	XRF		
		BLK-G-27A	—	26.44	716.8
		BLK-G-28A	XRF		
		BLK-G-28B	—	23.4	740.2
		BLK-G-28C	XRF		
		BLK-G-29A	—	25.9	766.1
		BLK-G-33A	XRF		
		BLK-G-33B	—	23.44	789.5
		BLK-G-33C	XRF, DCP, Microscopy, Fe ²⁺		
	11/3/2004	BLK-G-34A	XRF	8.24	797.8

"—" Empty data field

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

Test		1									
Glass (kg)		19.74	40.16	61.84	86.74	113.14	141.54	162.14	184.18	206.68	229.28
Constituent	Target	BLJ-G-94B	BLJ-G-96A	BLJ-G-100A	BLJ-G-102A	BLJ-G-104B	BLJ-G-108A	BLJ-G-111A	BLJ-G-115A	BLJ-G-117A	BLJ-G-118A
Ag ₂ O	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al ₂ O ₃	4.89	5.43	5.32	5.37	5.40	5.37	5.30	5.19	5.17	5.26	5.45
B ₂ O ₃ *	10.27	10.34	10.33	10.32	10.32	10.31	10.30	10.30	10.30	10.29	10.29
BaO	0.07	0.10	0.10	0.09	0.08	0.08	0.10	0.10	0.08	0.10	0.11
CaO	0.46	0.50	0.52	0.50	0.52	0.51	0.52	0.52	0.52	0.52	0.55
CdO	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ce ₂ O ₃	0.10	0.08	0.08	0.07	0.09	0.08	0.08	0.08	0.08	0.09	0.08
Cl	§	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cr ₂ O ₃	0.22	0.19	0.21	0.21	0.23	0.22	0.23	0.23	0.23	0.23	0.24
CuO	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe ₂ O ₃	14.04	12.85	13.33	12.80	13.38	12.60	13.12	13.47	13.22	13.14	13.46
K ₂ O	§	0.13	0.13	0.13	0.16	0.15	0.14	0.14	0.13	0.14	0.13
La ₂ O ₃	0.08	0.03	0.04	0.02	0.02	0.03	<0.01	<0.01	0.02	<0.01	<0.01
Li ₂ O*	2.64	2.66	2.66	2.66	2.66	2.65	2.65	2.65	2.65	2.65	2.65
MgO	0.14	0.14	0.16	0.13	0.17	0.19	0.17	0.18	0.16	0.18	0.15
MnO	2.82	2.53	2.65	2.58	2.73	2.62	2.75	2.83	2.78	2.78	2.86
Na ₂ O	12.56	13.16	12.86	13.28	12.73	13.43	12.95	12.75	13.31	12.75	12.46
Nd ₂ O ₃	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NiO	0.41	0.35	0.39	0.38	0.40	0.37	0.39	0.40	0.39	0.39	0.40
P ₂ O ₅	0.56	0.60	0.60	0.59	0.59	0.61	0.61	0.61	0.62	0.63	0.62
PbO	0.54	0.43	0.45	0.42	0.45	0.42	0.44	0.47	0.45	0.44	0.46
Pr ₆ O ₁₁	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.77	47.85	47.41	47.87	47.35	47.81	47.57	47.26	47.20	47.77	47.31
SnO ₂	0.06	0.08	0.09	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08
SO ₃	0.19	0.03	0.05	0.06	0.09	0.11	0.11	0.13	0.13	0.13	0.15
SrO	0.17	0.15	0.16	0.15	0.16	0.14	0.15	0.16	0.15	0.15	0.16
TiO ₂	§	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.07
Y ₂ O ₃	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ZnO	1.03	0.98	1.01	0.95	1.00	0.91	0.96	0.99	0.96	0.94	0.99
ZrO ₂	0.98	1.33	1.39	1.29	1.34	1.25	1.31	1.36	1.31	1.28	1.32
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Calculated based on simple well-mixed tank model

§ - Not a target constituent

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

Test		1					2				
Glass (kg)		250.88	271.38	301.42	328.10	349.00	371.60	395.30	420.02	443.62	469.54
Constituent	Target	BLJ-G-119B	BLJ-G-124A	BLJ-G-128A	BLJ-G-131A	BLJ-G-132B	BLJ-G-137A	BLJ-G-138A	BLJ-G-139A	BLJ-G-146A	BLJ-G-150A
Ag ₂ O	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al ₂ O ₃	4.89	5.20	5.21	5.26	5.22	5.13	5.10	5.32	5.23	5.13	5.11
B ₂ O ₃ *	10.27	10.29	10.29	10.28	10.28	10.28	10.28	10.28	10.28	10.28	10.28
BaO	0.07	0.10	0.10	0.12	0.10	0.09	0.10	0.11	0.09	0.07	0.10
CaO	0.46	0.53	0.51	0.53	0.52	0.52	0.53	0.64	0.52	0.51	0.52
CdO	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ce ₂ O ₃	0.10	0.09	0.09	0.08	0.09	0.08	0.08	0.08	0.08	0.09	0.10
Cl	§	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	0.01
Cr ₂ O ₃	0.22	0.24	0.23	0.23	0.24	0.23	0.23	0.23	0.23	0.23	0.24
CuO	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe ₂ O ₃	14.04	13.24	12.78	13.21	12.96	12.75	12.87	13.15	12.57	12.54	12.78
K ₂ O	§	0.13	0.13	0.13	0.14	0.12	0.12	0.18	0.13	0.12	0.12
La ₂ O ₃	0.08	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	0.08	<0.01	<0.01	<0.01
Li ₂ O*	2.64	2.65	2.65	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64
MgO	0.14	0.19	0.13	0.16	0.20	0.13	0.14	0.20	0.14	0.16	0.17
MnO	2.82	2.83	2.74	2.84	2.80	2.74	2.78	2.85	2.71	2.73	2.76
Na ₂ O	12.56	12.80	13.30	12.78	13.53	14.15	13.39	12.52	13.50	13.83	13.28
Nd ₂ O ₃	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NiO	0.41	0.39	0.37	0.38	0.37	0.36	0.38	0.39	0.36	0.36	0.36
P ₂ O ₅	0.56	0.64	0.64	0.63	0.61	0.64	0.64	0.62	0.66	0.65	0.65
PbO	0.54	0.46	0.43	0.45	0.44	0.43	0.45	0.46	0.43	0.43	0.44
Pr ₆ O ₁₁	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.77	47.54	47.75	47.58	47.20	47.15	47.66	47.55	47.94	47.78	47.89
SnO ₂	0.06	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.08
SO ₃	0.19	0.14	0.14	0.14	0.16	0.15	0.16	0.17	0.16	0.16	0.17
SrO	0.17	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.15
TiO ₂	§	0.06	0.07	0.07	0.06	0.06	0.06	0.08	0.05	0.06	0.05
Y ₂ O ₃	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ZnO	1.03	0.95	0.90	0.94	0.92	0.89	0.91	0.93	0.88	0.88	0.89
ZrO ₂	0.98	1.28	1.22	1.29	1.26	1.22	1.24	1.27	1.18	1.16	1.20
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Calculated based on simple well-mixed tank model

§ - Not a target constituent

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

Test		2					1&2	
Glass (kg)		492.54	517.04	544.16	567.66	589.96	540-590 kg	
Constituent	Target	BLJ-G-151B	BLJ-G-152B	BLK-G-10A	BLK-G-11A	BLK-G-13B	Average	%Dev.
Ag ₂ O	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Al ₂ O ₃	4.89	5.02	5.08	5.10	5.08	5.05	5.08	3.75
B ₂ O ₃ *	10.27	10.27	10.27	10.27	10.27	10.27	10.27	NC
BaO	0.07	0.10	0.10	0.09	0.09	0.10	0.09	NC
CaO	0.46	0.52	0.53	0.52	0.52	0.52	0.52	NC
CdO	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Ce ₂ O ₃	0.10	0.10	0.09	0.10	0.10	0.10	0.10	NC
Cl	§	0.01	0.01	0.01	0.01	<0.01	0.01	NC
Cr ₂ O ₃	0.22	0.24	0.25	0.24	0.24	0.25	0.24	NC
CuO	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Fe ₂ O ₃	14.04	13.11	13.19	13.10	12.95	13.30	13.12	-6.55
K ₂ O	§	0.11	0.14	0.12	0.12	0.12	0.12	NC
La ₂ O ₃	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Li ₂ O*	2.64	2.64	2.64	2.64	2.64	2.64	2.64	NC
MgO	0.14	0.10	0.11	0.11	0.11	0.08	0.10	NC
MnO	2.82	2.83	2.82	2.82	2.78	2.86	2.82	-0.09
Na ₂ O	12.56	12.99	12.88	13.04	12.95	13.00	13.00	3.51
Nd ₂ O ₃	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
NiO	0.41	0.38	0.38	0.38	0.37	0.39	0.38	NC
P ₂ O ₅	0.56	0.65	0.65	0.65	0.66	0.63	0.65	NC
PbO	0.54	0.46	0.47	0.45	0.44	0.46	0.45	NC
Pr ₆ O ₁₁	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
SiO ₂	47.77	47.84	47.76	47.81	48.10	47.56	47.83	0.12
SnO ₂	0.06	0.08	0.07	0.07	0.08	0.08	0.08	NC
SO ₃	0.19	0.16	0.17	0.16	0.18	0.17	0.17	NC
SrO	0.17	0.16	0.16	0.15	0.15	0.16	0.15	NC
TiO ₂	§	0.05	0.05	0.05	0.05	0.05	0.05	NC
Y ₂ O ₃	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
ZnO	1.03	0.93	0.94	0.93	0.91	0.95	0.93	-9.63
ZrO ₂	0.98	1.24	1.25	1.19	1.20	1.25	1.22	NC
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

* Calculated based on simple well-mixed tank model

§ - Not a target constituent

NC- Not calculated

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

Test		3									
Glass (kg)		618.36	643.96	667.40	690.28	716.72	740.12	766.02	789.46	797.70	%Dev
Constituent	Target	BLK-G-18A	BLK-G-20A	BLK-G-24A	BLK-G-26A	BLK-G-28A	BLK-G-28C	BLK-G-33A	BLK-G-33C	BLK-G-34A	(last sample)
Ag ₂ O	0.16	0.01	0.05	0.07	0.09	0.10	0.11	0.13	0.15	0.15	NC
Al ₂ O ₃	4.87	5.11	5.25	5.13	5.75	5.55	5.40	5.54	5.34	5.58	14.50
B ₂ O ₃ *	10.25	10.27	10.27	10.26	10.26	10.26	10.26	10.26	10.26	10.26	NC
BaO	0.10	0.08	0.12	0.11	0.10	0.12	0.13	0.13	0.13	0.14	NC
CaO	0.51	0.52	0.52	0.53	0.53	0.53	0.52	0.53	0.54	0.54	NC
CdO	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Ce ₂ O ₃	0.14	0.06	0.12	0.11	0.11	0.11	0.11	0.13	0.13	0.13	NC
Cl	§	0.01	0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01	<0.01	NC
Cr ₂ O ₃	0.17	0.24	0.24	0.24	0.23	0.22	0.21	0.22	0.22	0.22	NC
CuO	0.03	<0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	NC
Fe ₂ O ₃	14.01	13.06	13.51	14.06	13.35	13.15	12.95	13.49	14.31	14.26	1.75
K ₂ O	0.53	0.16	0.23	0.26	0.32	0.37	0.39	0.42	0.44	0.44	NC
La ₂ O ₃	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
Li ₂ O*	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	NC
MgO	0.22	0.10	0.12	0.05	0.13	0.13	0.11	0.13	0.08	0.09	NC
MnO	2.75	2.85	2.92	3.04	2.93	2.86	2.83	2.97	3.10	3.09	12.45
Na ₂ O	12.55	12.59	13.19	12.66	12.74	12.70	12.91	12.51	12.69	12.18	-2.95
Nd ₂ O ₃	0.31	<0.01	0.06	0.08	0.11	0.14	0.15	0.19	0.22	0.21	NC
NiO	0.43	0.38	0.40	0.41	0.37	0.37	0.36	0.38	0.40	0.41	NC
P ₂ O ₅	0.29	0.64	0.53	0.51	0.48	0.44	0.43	0.40	0.39	0.39	NC
PbO	0.51	0.44	0.49	0.49	0.45	0.44	0.42	0.45	0.48	0.48	NC
Pr ₆ O ₁₁	0.08	<0.01	<0.01	0.02	0.02	0.02	0.03	0.05	0.05	0.04	NC
SiO ₂	47.91	48.39	46.92	46.88	47.25	47.85	48.17	47.58	46.49	46.81	-2.29
SnO ₂	0.02	0.06	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.04	NC
SO ₃	0.04	0.16	0.12	0.12	0.10	0.10	0.09	0.07	0.07	0.07	NC
SrO	0.11	0.15	0.16	0.16	0.14	0.13	0.12	0.12	0.13	0.13	NC
TiO ₂	0.01	0.04	0.04	0.03	0.03	0.01	0.01	0.01	<0.01	0.01	NC
Y ₂ O ₃	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	NC
ZnO	1.04	0.92	0.95	1.01	0.95	0.91	0.90	0.94	1.02	1.02	-1.77
ZrO ₂	0.21	1.10	1.09	1.03	0.84	0.75	0.68	0.66	0.64	0.64	NC
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

* Calculated based on simple well-mixed tank model

Note: The XRF determination of the trace elements Br, Co, and Mo were below 0.01 wt%. The trace element F could not be determined by XRF

§ - Not a target constituent

NC - Not calculated

Table 4.3. XRF and DCP Analysis of Major Oxides in Selected Glass Samples (wt%).

Test		1		2				Target	3			
Glass (kg)		349.00		469.54		567.66			667.40		789.46	
Constituent	Target	BLJ-G-132B		BLJ-G-150A		BLK-G-11A			BLK-G-24A		BLK-G-33C	
		XRF	DCP	XRF	DCP	XRF	DCP		XRF	DCP	XRF	DCP
Al ₂ O ₃	4.89	5.13	5.20	5.11	4.99	5.08	4.93	4.87	5.13	5.20	5.34	5.30
B ₂ O ₃	10.27	10.28	10.50	10.28	10.97	10.27	10.86	10.25	10.26	10.78	10.26	10.38
CaO	0.46	0.52	0.55	0.52	0.53	0.52	0.53	0.51	0.53	0.53	0.54	0.52
Fe ₂ O ₃	14.04	12.75	13.51	12.78	13.50	12.95	13.22	14.01	14.06	13.30	14.31	13.15
Li ₂ O	2.64	2.64	2.54	2.64	2.41	2.64	2.42	2.64	2.64	2.42	2.64	2.41
MnO	2.82	2.74	2.67	2.76	2.61	2.78	2.56	2.75	3.04	2.66	3.10	2.61
Na ₂ O	12.56	14.15	11.30	13.28	11.13	12.95	11.20	12.55	12.66	10.89	12.69	11.00
NiO	0.41	0.36	0.40	0.36	0.39	0.37	0.40	0.43	0.41	0.39	0.40	0.38
P ₂ O ₅	0.56	0.64	0.63	0.65	0.61	0.66	0.57	0.29	0.51	0.51	0.39	0.34
PbO	0.54	0.43	0.64	0.44	0.64	0.44	0.63	0.51	0.49	0.63	0.48	0.59
SiO ₂	47.77	47.15	47.24	47.89	47.16	48.10	46.73	47.91	46.88	47.23	46.49	46.85
ZnO	1.03	0.89	1.00	0.89	0.98	0.91	0.97	1.04	1.01	0.99	1.02	0.97
ZrO ₂	0.98	1.22	1.27	1.20	1.21	1.20	1.22	0.21	1.03	0.93	0.64	0.57
Sum	98.97	98.90	97.45	98.80	97.13	98.87	96.24	97.97	98.65	96.46	98.30	95.07

Note: for XRF-analyzed compositions, target values for B₂O₃ and Li₂O were used which were calculated based on simple well-stirred tank model.

Table 4.4. XRF-Analyzed Composition of Select Dip Samples.

Test	Before		1		2	3	
Glass (kg)	0.00		349.00		589.96	797.70	
Date	10/26/04		10/30/04		11/01/04	11/02/04	
Constituent	Target	BLJ-D-81A	Target	BLJ-D-135A	BLK-D-14A	Target	BLK-D-34A
Ag ₂ O	§	<0.01	§	<0.01	<0.01	0.16	0.16
Al ₂ O ₃	4.89	5.32	4.89	5.34	5.22	4.87	5.78
As ₂ O ₃	§	<0.01	§	<0.01	<0.01	§	<0.01
B ₂ O ₃ *	10.27	10.27	10.27	10.28	10.27	10.25	10.26
BaO	0.07	0.10	0.07	0.10	0.09	0.10	0.11
CaO	0.46	0.51	0.46	0.55	0.52	0.51	0.53
CdO	§	<0.01	§	<0.01	<0.01	0.02	<0.01
Ce ₂ O ₃	0.10	0.07	0.10	0.09	0.09	0.14	0.13
Cl	§	<0.01	§	0.01	0.01	§	0.01
Cr ₂ O ₃	0.22	0.18	0.22	0.24	0.25	0.17	0.22
CuO	§	<0.01	§	<0.01	<0.01	0.03	0.02
Fe ₂ O ₃	14.04	13.38	14.04	13.22	13.44	14.01	13.83
K ₂ O	§	0.13	§	0.16	0.15	0.53	0.45
La ₂ O ₃	0.08	0.04	0.08	<0.01	<0.01	0.07	<0.01
Li ₂ O*	2.64	2.64	2.64	2.64	2.64	2.64	2.64
MgO	0.14	0.09	0.14	0.15	0.10	0.22	0.09
MnO	2.82	2.62	2.82	2.86	2.87	2.75	2.99
Na ₂ O	12.56	12.71	12.56	12.70	12.65	12.55	11.63
Nd ₂ O ₃	§	<0.01	§	<0.01	<0.01	0.31	0.20
NiO	0.41	0.37	0.41	0.39	0.39	0.43	0.39
P ₂ O ₅	0.56	0.60	0.56	0.62	0.63	0.29	0.39
PbO	0.54	0.46	0.54	0.46	0.47	0.51	0.46
Pr ₆ O ₁₁	§	<0.01	§	<0.01	<0.01	0.08	0.04
SiO ₂	47.77	47.73	47.77	47.08	47.43	47.91	47.49
SnO ₂	0.06	0.08	0.06	0.09	0.08	0.02	0.04
SO ₃	0.19	<0.01	0.19	0.15	0.16	0.04	0.13
SrO	0.17	0.16	0.17	0.16	0.16	0.11	0.13
TiO ₂	§	0.06	§	0.07	0.05	0.01	0.01
Y ₂ O ₃	§	<0.01	§	<0.01	<0.01	0.02	0.02
ZnO	1.03	1.06	1.03	1.33	1.03	1.04	1.24
ZrO ₂	0.98	1.41	0.98	1.31	1.28	0.21	0.61
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Secondary Phases Observed	-	No	-	No	No	-	No

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

§ – Not a target constituent

"—" Empty data field

Table 4.5. Measured Divalent Iron Content of Select Glass Samples.

Test	Date	Sample I.D.	Time	Cumulative Glass (kg)	% Fe ⁺² /Total Fe
1	10/30/04	BLJ-G-132B	08:18	301.42	1.8
2	10/31/04	BLJ-G-150A	11:46	469.54	6.8
	11/01/04	BLK-G-11A	06:45	567.66	6.0
3	11/02/04	BLK-G-24A	01:40	667.40	5.2
	11/02/04	BLK-G-33C	23:04	789.46	4.5

Table 5.1. Results from Melter Off-Gas Emission Samples.

		Test 1				Test 2				Test 3			
		Nominal Feed, 10/29/04				Modified Rheology, 11/01/04				HLW SIPP, 11/02/04			
		105% Isokinetic, 12.0% Moisture				96.4% Isokinetic, 12.9% Moisture				104% Isokinetic, 12.7% Moisture			
		Feed Rate# (mg/min)	Emissions Rate (mg/min)	% of Feed	DF	Feed Rate# (mg/min)	Emissions Rate (mg/min)	% of Feed	DF	Feed Rate# (mg/min)	Emissions Rate (mg/min)	% of Feed	DF
Particulate	Total ^{\$}	101000	619	0.61	163	106000	863	0.81	123	110000	699	0.64	157
	Al	2134	8.59	0.40	248.5	2231	11.20	0.50	199.1	2838 ⁺	18.94	0.67	149.8
	B	2629	35.33	1.34	74.4	2749	62.15	2.26	44.2	2863	37.63	1.31	76.1
	Ba	52	0.51	0.98	102.1	54	0.74	1.36	73.5	81	0.73	0.91	110.4
	Ca	271	2.81	1.04	96.5	284	3.38	1.19	84.0	328	2.71	0.83	121.0
	Cl*	0	27.44	NC	NC	0	26.11	NC	NC	0	9.94	NC	NC
	Cr	124	1.74	1.40	71.3	130	2.87	2.21	45.2	105	2.76	2.63	38.0
	Cu	0	< 0.10	NC	NC	0	< 0.10	NC	NC	22	0.20	0.91	110
	F*	0	< 0.1	NC	NC	0	6.09	NC	NC	0	7.81	NC	NC
	Fe	8099	61.73	0.76	131.2	8468	72.58	0.86	116.7	8817	67.73	0.77	130.2
	K	0	0.69	NC	NC	0	0.66	NC	NC	396	5.00	1.26	79.1
	Li	1012	5.84	0.58	173.2	1058	9.26	0.88	114.2	1104	5.31	0.48	207.8
	Mg	70	1.08	1.55	64.4	73	1.21	1.66	60.2	119	1.03	0.86	115.8
	Mn	1802	2.79	0.15	646.7	1884	3.88	0.21	484.9	1917	15.28	0.80	125.4
	Na	7688	71.63	0.93	107.3	8037	106.08	1.32	75.8	8380	67.06	0.80	125.0
	Ni	266	1.97	0.74	135.1	278	2.47	0.89	112.7	304	2.33	0.77	130.6
	P	202	0.86	0.43	234.6	211	1.25	0.59	169.1	114	0.45	0.40	252.8
	Pb	414	3.40	0.82	121.7	432	5.94	1.37	72.7	426	5.00	1.17	85.2
	Sn	39	0.34	0.88	113.4	41	0.46	1.12	89.4	14	0.26	1.80	55.5
	S*	63	13.25	21.03	4.8	66	19.06	28.9	3.5	21 ⁺	17.45	83.1	1.2
	Si	18423	66.03	0.36	279.0	19260	85.56	0.44	225.1	20157	62.47	0.31	322.6
Gaseous	Sr	119	1.19	1.00	99.8	124	1.88	1.52	66.0	84	0.77	0.92	108.9
	Zn	683	5.77	0.85	118.3	714	8.61	1.21	82.9	752	5.71	0.76	131.6
	Zr	599	2.32	0.39	257.6	626	2.83	0.45	221.3	140	1.25	0.89	112.3
	B	2629	24.21	0.92	108.6	2749	26.28	0.96	104.6	2863	29.05	1.01	98.6
	Cl	0	0.72	NC	NC	0	0.17	NC	NC	0	0.50	NC	NC
	F	0	< 0.10	NC	NC	0	< 0.10	NC	NC	0	0.38	NC	NC
	I	0	1.87	NC	NC	0	< 0.10	NC	NC	0	35.08	NC	NC
	S	63	16.13	25.67	3.9	66	25.37	38.63	2.6	21 ⁺	2.39	11.38	8.8

\$ - From gravimetric analysis of filters and front half nitric acid analytical results

* - Based on analysis of water dissolution of filter particulate and calculated proportion in acid rinse

- Elemental feed rates calculated from test average production rates and target compositions.

+ - Al and S feed rates based on analysis (see Table 2.11) and test average production rate.

NC - Not Calculated

"-" Empty data field

**Table 5.2. Average Concentration (ppmv) of Selected Species
in Off-Gas Measured by FTIR Spectroscopy.**

—	Normal			Adjusted Rheology			SIPP Simulant		
—	Avg.	Min.	Max	Avg.	Min.	Max	Avg.	Min.	Max
N ₂ O	< 1.0	< 1.0	1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.2
NO	13.7	< 1.0	24.5	11.7	< 1.0	18.7	100.5	4.1	150.4
NO ₂	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.1	< 1.0	2.6
NH ₃	< 1.0	< 1.0	2.0	< 1.0	< 1.0	< 1.0	1.6	< 1.0	3.9
H ₂ O (%)	5.5	0.9	8.3	5.9	1.0	9.3	5.9	1.6	8.4
CO ₂	900	100	1200	900	200	1200	1100	200	1600
Nitrous Acid	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Nitric Acid	< 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	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
SO ₂	1.0	< 1.0	2.5	1.9	< 1.0	3.6	< 1.0	< 1.0	1.3
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
CO	2.2	< 1.0	4.6	1.4	< 1.0	2.4	7.9	< 1.0	12.1
HCl	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HF	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
H ₂ *	8	6	9	26	16	85	11	6	17

* - Measured by gas chromatography

"—" Empty data field

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

**Figure 1.2.a. Schematic diagram showing cross-section through the DM100-BL-melter.
Plan view showing locations of lid ports.**

Figure 1.2.b. Schematic diagram showing cross-section through the DM100-BL melter.

Figure 1.2.c. Schematic diagram showing cross-section through the DM100-BL melter.

Figure 2.1. Measured viscosity of HLW DM100 feed samples.

Figure 2.2. Comparison of rheological behavior of HLW SIPP melter feed samples before and after dilution with water. (Note: Rise at high shear rates is likely due to re-suspension of partially settled solids in the diluted (5% solids) feed.)

Figure 2.3. Comparison of rheological behavior of HLW SIPP melter feed samples with and without stirring.

Figure 2.4. Settling rate of solids in diluted HLW SIPP Melter Feed Sample.

Figure 3.1. Glass production rates (hourly moving averages).

Figure 3.2. Melt pool bubbling rate.

Figure 3.3. Glass temperatures and electrode power.

▼ 17" from top, Thermowell

● 17" from top, Exposed

Figure 3.4. Plenum temperatures.

Figure 3.5. Electrode temperatures and power.

Figure 4.1. XRF analysis of Na₂O and SiO₂ in melter glasses. Note: The target concentrations depicted are for first two tests.

Figure 4.2. XRF analysis of select major oxides in product glasses. Note: The target concentrations depicted are for first two tests. Target for third test has $\text{ZrO}_2 = 0.21 \text{ wt}\%$

Figure 4.3. XRF analysis of select oxides in product glasses. Note: The target concentrations depicted are for first two tests.

Figure 4.4. Sulfur Concentration in Product glass determined by XRF. Note: The target sulfur concentration depicted is for first two tests. Target for third test has SO₃ = 0.04 wt%

Figure 4.5. XRF analysis of select oxides in product glasses produced from feed containing SIPP waste simulant.

Figure 5.1. Nitrogen oxide concentrations in off-gas from FTIR.

Figure 5.2. CO concentration in off-gas from FTIR.

R&T Subcontractor Document Review Record

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1) To Be Completed by Cognizant R&T Personnel			
Document Number VSL-05R5710-1	Revision A	Document Title DuraMelter 100 HLW Simulant Validation Tests with C-106/AY-102 Feeds	
Test Spec: 24590-HLW-TSP-RT-02-015, Rev. 0		Scoping Statement(s): VH-5	
R&T Contact: Lawrence Petkus		MS5-L	371-3258
Name (Print)		MSIN	Telephone Number
			April 18, 2005
			Date

Review Distribution			
Organization	Contact	MSIN	Required?
Process Operations	D McLaughlin	MS4-B2	Yes ☒ No ☐
Quality Assurance	M Mitchell	MS14-4B	Yes ☐ No ☒
Environmental and Nuclear Safety	E Saucedo	MS4-C1	Yes ☐ No ☒
Commissioning and Training	K Vacca	MS12-B	Yes ☐ No ☒
Engineering	M Ongpin	MS4-A2	Yes ☒ No ☐
R&T Functional Manager	S. Barnes	MS5-L	Yes ☒ No ☐
HLW Area	P. Schuetz	MS5-H	Yes ☐ No ☒
			Yes ☐ No ☐
			Yes ☐ No ☐
			Yes ☐ No ☐
Comments Due By: May 3, 2005 <i>Required Reviewers are required to respond to the R&T Contact.</i>			

2) To be Completed by Reviewer			
Reviewer _____			
Name (Print)		Organization	Date
☐	☐	☐	☐
Accepted, No Comments	Accepted, Comments Not Significant	Significant Comments, Form 24590-MGT-F00006 Attached	Significant Comments, Comments Marked on Document

3) To be Completed by Reviewer*		
My significant comments have been addressed.		
Acceptance: _____		
Print/Type Name	Signature	Date
<i>* An e-mail to the R&T contact stating that significant comments are addressed can substitute for this acceptance.</i>		

Petkus, Lawrence

From: Yorgesen, Jack
Sent: Monday, June 13, 2005 7:28 AM
To: Petkus, Lawrence
Subject: VSL-05R5710-1, " DM100 HLW Simulant Validation Tests with C-106/AY-102 Feeds"

The subject document has been reviewed and comments have been incorporated; therefore, Engineering gives its concurrence on the subject document.

Bret

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

From: Gimpel, Rod
Sent: Monday, June 13, 2005 7:18 AM
To: Petkus, Lawrence; Yorgesen, Jack
Subject: RE: Comment Response: VSL-05R5710-1, " DM100 HLW Simulant Validation Tests with C-106/AY-102 Feeds"

Comment resolution is OK.

Thanks,
Rod

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

From: Petkus, Lawrence
Sent: Wednesday, June 08, 2005 9:38 AM
To: Gimpel, Rod
Subject: Comment Response: VSL-05R5710-1, " DM100 HLW Simulant Validation Tests with C-106/AY-102 Feeds"

Rod,
I got a verbal OK from you, but no E-mail follow-up. Please respond to Yorgesen and I so that this report can be issued.

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

From: Petkus, Lawrence
Sent: Wednesday, May 18, 2005 1:14 PM
To: Gimpel, Rod; Carl, Daniel
Subject: Comment Response: VSL-05R5710-1, " DM100 HLW Simulant Validation Tests with C-106/AY-102 Feeds"

Rod, Dan

Attached are the responses to your comments on the subject report. Please let me know if these responses address your comments acceptably. Thank you.

Larry Petkus

R&T, Main L-179
Ph. 371-3258

<< File: HLW SIPP comresp Gimp.doc >> << File: HLW SIPP comresp Carl.doc >>

COMMENT RESOLUTION FORM

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Return to: L. Petkus

Comments Due: May 3, 2005

Document Title: DuraMelter 100 HLW Simulant Validation Tests with C-106/AY-102 Feeds		Document No. VSL-05R5710-1		Revision: A	Date: April 18, 2005
Reviewer: Rod F Gimpel, Engineering	Date: May 3, 2005	Response by:	Date:	Comments Resolved:	Date:

Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^b	Response	Resolution
RFG01	Sections 5 and 6	Table 5.1, <i>Results from Melter Off-Gas Emission Samples</i> , shows that almost all the sulfur from the SIPP feed is lost to the offgas as particulate. Whereas, this is not so with the other feeds. Please comment on this in Sections 5 and 6 and give some possible reasons why this happens. What is different in the feeds that would cause this? Which is more prototypical feed with the WTP melter feed expected?			Explanation will be added to section 5.1. In short, it appears that the sulfur content of the SIPP feed was significantly higher than the target value: The sulfur particulate emission rates for all three tests are similar. However, the target sulfur concentration for the SIPP feed is one-fourth of that of the other two. The measured concentration is higher than the target but still one-third of that in the other feeds. However, given that the measured value was obtained by first making a glass from feed via crucible melt, which results in partial volatilization of species like sulfur, the actual feed concentration is probably higher than the measured sulfur concentration. The higher feed concentration would result in higher DF values.	

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- ^a **Significance:** M = Mandatory; I = Improvement. Definitions for these terms are provided at the end of the form instructions and in Appendix B of procedure "WTP Document Administration".
- ^b Justification required for Mandatory Comments.

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COMMENT RESOLUTION FORM

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Return to: L. Petkus

Comments Due: May 3, 2005

Document Title: DuraMelter 100 HLW Simulant Validation Tests with C-106/AY-102 Feeds		Document No. VSL-05R5710-1		Revision: A	Date: April 18, 2005
Reviewer: D. E. Carl/Melter System	Date: 03MAY05	Response by:	Date:	Comments Resolved:	Date:

Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^b	Response	Resolution
01	1.3.1/1	Clarify if simulation of the ADS feed pump included a prototypic air purge of the feed line with each feed admission, and a periodic water flush.	M	Needed to interpret the feed line pluggages noted in 3/3.	R&T: Reviewer misunderstood text. Report goes on to state that a peristaltic pump was used for these tests, not the simulated ADS pump. Feed nozzle or line pluggages are therefore likely due to the slow continuous flow of slurry.	
02	2.1/4, and table 2.4 footnote	Change "non-volatile" to "volatile" components. Table 2.1 provided the non-volatile formulation.	I		Footnote will be changed as indicated.	
03	2.2/1	Better explain the difference between this and the B1 formulations. The text states that HLW09-04 (presumably this is a typo, intended to read HLW04-09) is 2.11 wt-% Na ₂ O, whereas table 2.2 shows the Na ₂ O concentration to be 12.53 wt-%.	I		The typo will be fixed. The number 2.11 wt% in the text is a typo and should be 14.68 wt% (as in the second column of Table 2.2). It refers to the amount of sodium in the waste and not the glass formulation. The reduced amount of sodium in the current waste formulation explains the lower waste loading associated with the glass formulation HLW04-09. The text will be modified to clarify the distinction.	
04	2.3/1	Check the Ag ₂ O and TiO ₂ concentrations: they should be 1029 and 26.2 mg/l for the	I		The numbers for Ag ₂ O and TiO ₂ as given in Table 2.4 are correct.	

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Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^b	Response	Resolution
		given elemental concentrations, assuming standard atomic weights.			With the standard atomic and molecular weights, respectively, for Ag (107.868) and Ag ₂ O (231.74), the calculated oxide concentration for 975.7 mg/l of Ag is 1048 mg/l of Ag ₂ O, compared with 1047.9 mg/l in Table 2.4. The minor difference is due to rounding of numbers, which also explains the difference found for TiO ₂ (the elemental concentration of Ti in the SIPP simulant is actually 15.651 mg/l, rounded to 15.7 mg/l in Table 2.4).	
05	2.4/1	The text states that significant organic carbon may have originated from the SBS condensate. Add statement regarding the basis for this - for example, TOC analyses of the condensate.	I		There is no available analysis of the condensate. The statement alluded to a <i>possible</i> source of TOC. It can be removed if desired by the Project.	
06	2.4/1	Clarify the interpretation regarding (TOC). Because most of the TOC originated during generation of the SIPP simulant (implied by the oxalate composition) should the reference waste (TOC) be increased by two orders of magnitude?	M	The waste (TOC) assumed for the process effects the nominal process design, such as the required sugar addition amount.	The simple point being made here is that the TOC content of the two feeds are quite different. The difference relates to two different waste bases and flow-sheet assumptions. We cannot comment on which, if any, should be used as the "reference waste."	
07	2.5.1/1	In table 2.10, clarify that the last three columns are for different shear rates.	I		Clarification will be added to the Table.	
08	2.5.1/1	Explain the difference for samples reported in table 2.10, between "Feed made from HLW SIPP" and "Feed made from Pretest SIPP Sample". Aren't these the same?	I		"Feed made from HLW SIPP" is a melter feed sample collected on the day indicated in the table. The Pretest samples were sub-samples of the SIPP material that were shipped to VSL for	

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Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^B	Response	Resolution
					"preview" analysis prior to receipt of the drums of SIPP material that were used for the melter tests. We will add text at the first mention of "pretest samples" to further clarify this distinction.	
09	2.5.2/3	Specify the ASTM method used for fig. 2.4.	M	Needed for reference.	The method reference will be added to the final report.	
10	2.5.3/1	Elaborate on the postulated sample bias that might have caused the excess aluminum in the feed and glass. Shouldn't other species, such as silicon, have had similar bias?	M	Understanding bias is necessary to interpret whether there was actually an excess of aluminum.	Aluminum is different from silicon and most other elements in that it is soluble at both low and high pH. Precipitated aluminum is typically very fine grained. The SIPP dissolved and undissolved portions measured at SRNL and VSL are different although the total measured solids are similar. This suggests that constituents are dissolving over time. The changing nature of the SIPP over time complicates consistent sampling occurring over an extended period of time. More speculation can be added to the text if desired.	
11	3/3	Expand on feed line blockages. For example, which test(s) required only one blockage to be cleared and which required three? Was the rate of blockage (that is, blockages per hour of feeding) for the nominal feed similar to the rate recorded for the previous tests? Can a conclusion be made that the blockages were due to the ADS simulation and not characteristics of the feed types?	M	Needed to understand need for water-cooled feed line, and to estimate feed line clearing activities during operation.	The infrequent blockages of the feed tube are an artifact of the DM100 system and have not been encountered on the DM1200. The DM100 feed rates are lower than the DM1200 particularly when the peristaltic pump is used. The DM100 plenum is much hotter than the DM1200 and the feed tube tip	

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Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^b	Response	Resolution
					much closer to the glass surface. The result of these factors is drying of feed on the tip of the feed tube.	
12	3/3	Elaborate on "minor auto discharging". Was the discharged glass that auto-discharged foamy? Did it result in glass fibers in the discharge section? Was the auto discharge due to the elevation difference between the nominal glass level and the riser overflow (that is, did bubbler-induced sloshing transfer glass)? Has this been typically observed?	M	Needed to understand potential for uncontrolled glass discharge.	Additional text will be added to clarify the difference between auto discharging in the two reports. On the WV-DM100, auto discharging was caused unintentionally by a foamy product that coincided with the use of high concentrations of reductants in LAW feeds. On the BL-DM100 with HLW glass, it can be difficult to discern the glass level and therefore the glass level is often allowed to rise to the top of riser overflow. Once auto-discharging is observed, air is introduced for a set amount of time to discharge glass. As stated in the text, no foam was observed in the glass product in the HLW tests.	
13	4.1/1	Elaborate on the lack of La in the glass. Has La typically been held up in the melter?	I		The same lack of La is evident in most of the feed samples, suggesting none was fed to the melter and therefore none was observed in the discharge glass.	
14	4.2/1	Expand on the different glass redox measurements for the different tests. Without specific data, I assume the simulant (TOC) for tests 1 and 2 are both ~0.026 wt-% (table 2.2) and the concentration for test 3 is 0.371 wt-% (table 2.8). Similarly, the ratio of (TOC) to the sum of (NO3) and (NO2) for tests 1 and 2 is 0.03 while it is	I		The mass ratio for NOx:TOC is about 30 for Tests 1+2 and < 2 for Test 3 (see response 15). Based on these data alone, a more reduced glass would result in Test 3, which is not the case. However, the absolute concentrations are uniformly low	

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Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^b	Response	Resolution
		0.60 for test 3. Is the interpretation that the results in table 4.5 are essentially data scatter?			and, evidently, low enough that no appreciable reduction was found. It is likely that the results in Table 4.5 are essentially data scatter.	
15	5.2/1	Confirm the differences noted between the NOAH and SIPP simulants. (NO ₂), (NO ₃), (NO ₂ + NO ₃), and (TOC) for the NOAH simulants are given in table 2.2 as 0.012, 0.784, 0.796, and 0.026, respectively. The same species for SIPP simulants are given in tables 2.4 and 2.8 as, 0.191, 0.649, 0.840, and 0.500 (or, 0.371 for TOC using table 2.8 alone), respectively. Nitrate/nitrite is not 4x greater for the SIPP simulants (the value is 0.840 / 0.796 = 1.06). Also, TOC is not 100x greater for the SIPP simulants (the value is either 0.500 / 0.026 = 19, or 0.371 / 0.026 = 14).	I		<p>It is not clear where the reviewer is getting the numbers cited. The values copied from the bottom of Tables 2.2 (NOAH) and 2.4 (SIPP) expressed as <i>Volatiles (g/100 g glass)</i> are</p> <p>Nitrate 0.784 vs. 3.117 Nitrite 0.012 vs. 0.916 TOC 0.026 vs. 2.402</p>	

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^a **Significance:** M = Mandatory; I = Improvement. Definitions for these terms are provided at the end of the form instructions and in Appendix B of procedure "WTP Document Administration".

^b Justification required for Mandatory Comments.

COMMENT RESOLUTION FORM

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Return to: L. Petkus

Comments Due: May 3, 2005

Document Title: DuraMelter 100 HLW Simulant Validation Tests with C-106/AY-102 Feeds		Document No. VSL-05R5710-1		Revision: A	Date: April 18, 2005
Reviewer: Larry Petkus for S. Barnes	Date: May 5, 2005	Response by:	Date:	Comments Resolved: <i>Lawrence Petkus</i>	Date: 6/13/05

Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^B	Response	Resolution
1	5.1 /2 - 4th sentence	"volatile behavior" Is there any reason why chromium, a non-volatile, is behaving as a volatile metal? This is not normal.	M	Address testing inconsistencies	Chromium can be volatile depending on the oxidation state. It is also leached from melter components as a volatile species.	
2	Table 2.1 and Section 5.3	Plan specified that feed samples obtained during testing would be analyzed for complete inorganic analyses using XRF and DCP. As such, boron and lithium values were expected to be provided for the feed samples; not target values. Provide the DCP results similar to the comparison presented in Table 4.3 on the glass.	M	Test plan requirement not fulfilled.	This analysis is listed in the Test Plan as an option for feed samples not a requirement. "The measures of success with respect to achieving these objectives are: <i>"Characterized the chemical (XRF, pH) and physical (i.e., density, % water, dissolved solids, suspended solids, rheology, glass yield in g-oxide/L) characteristics of the melter feed from each test segment."</i> The additional analysis can be performed and added to the final report if desired by the Project.	
3	Section 3, 3rd para.	This is the second consecutive DM100 test report that has reported auto discharging of glass. The first being the LAW test report VSL-05R5410-1. Here-to-fore, this has not been reported. Comment on the possible explanations (elaborating on what was	M	Test observation requiring further investigation.	Additional text will be added to the text to clarify the difference between auto discharging in the two reports. On the WV-DM100, auto discharging was caused unintentionally by a foamy	

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Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^B	Response	Resolution
		provided in VSL-05R5410-1), e.g., change in operating personnel, change in glass level monitoring, how glass pours are started and stopped, bubbler position, bottom area glass cooler than normal, etc.			product that coincided with the use of high concentrations of reductants in LAW feeds. On the BL-DM100 with HLW glass, it can be difficult to discern the glass level and therefore the glass level is often allowed to rise to the top of riser overflow. Once auto-discharging is observed, air is introduced for a set amount of time to discharge glass. As stated in the text, no foam was observed in the glass product in the HLW tests.	
4	General	Very good report.			Thank you.	

^a **Significance:** M = Mandatory; I = Improvement. Definitions for these terms are provided at the end of the form instructions and in Appendix B of procedure "WTP Document Administration".

^b Justification required for Mandatory Comments.

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R&T Technology Issues Summary

Test Report Title: Dura Melter 100 HLW Simulant Validation Tests with C-106/AY-102 Feeds

Test Report Number: VSL-05R5710-1

Prepared By: Lawrence Petkus

Date: June 13, 2005

Signature: Lawrence Petkus

Does the Testing or Report reveal any new discoveries, technology issues,
or suggest potential follow-on work?

Yes

No

☐☒

If yes, describe the suggested activity.

No Issues

If appropriate, is a Request for Technology Development attached.

Yes

No

☐☒

Additional comments (include researcher recommendations):

This report provides input to a separate simulant validation closure report.