Final Report Integrated DM1200 Melter Testing of Bubbler Configurations Using HLW AZ-101 Simulants

VSL-04R4800-4, Rev. 0, 10/5/04

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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Further Dissemination Unlimited**

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K. S. Matlack
Vitreous State Laboratory,
The Catholic University of America

A. A. Kruger
Department of Energy - Office of River Protection

W. Gong
T. Bardakci
N. A. D'Angelo
W. Lutze
R. A. Callow
M. Brandys
W. K. Kot
I. L. Pegg
Vitreous State Laboratory,
The Catholic University of America

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Final Report

Integrated DM1200 Melter Testing of Bubbler Configurations Using HLW AZ-101 Simulants

prepared by

**Keith S. Matlack, Weiliang Gong, Tefvik Bardakci, Nicholas D'Angelo,
Werner Lutze, Richard A. Callow, Marek Brandys,
Wing K. Kot, and Ian L. Pegg**

**Vitreous State Laboratory
The Catholic University of America
Washington, DC 20064**

for

Duratek, Inc.

and

Bechtel National, Inc.

10/15/04
for W. Tansciti

ACCEPTED FOR

PROJECT USE

August 16, 2004

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Document Number and Revision: VSL-04R4800-4, Rev. 0
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Test Specification: 24590-HLW-TSP-RT-02-015, Rev 0
Test Exceptions: 24590-HLW-TEF-RT-03-038, 24590-HLW-TEF-RT-03-046
Test Plan: VSL-03T3800-1, Rev. 0
R&T Focus Area(s): HLW Vitrification, HLW Off-Gas
Test Scoping Statement(s): VH-4, VHO-3, VHO-2, VH-5

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.

I.L. Pegg: **Date:** 10/5/04
VSL Program Director/Principal Investigator

I. Joseph: **Date:** 10/5/04
Duratek Sub-Contract Manager

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List of Abbreviations

AA	Atomic Absorption Spectroscopy
ACM	Aspen Custom Modeler
AC-S	Sulfur Impregnated Activated Carbon
ADS	Air Displacement Slurry
AOD	Air Operated Diaphragm
BBI	Best Basis Inventory
CFR	Code of Federal Regulation
CPVC	Chlorinated Polyvinyl Chloride
DCP	Direct Current Plasma Emission Spectroscopy
DF	Decontamination Factor
DM	DuraMelter®
DOE	Department Of Energy
FTIR	Fourier Transform Infrared Spectroscopy
HEME	High-Efficiency Mist Eliminator
HEPA	High-Efficiency Particulate Air Filter
HLW	High Level Waste
i.d.	Inside Diameter
ISE	Ion Selective Electrode
LAW	Low Activity Waste
MS	Microsoft
MT	Metric Ton
ORP	Office of River Protection
PBS	Packed Bed Scrubber
PLC	Programmable Logic Controller
PTFE	Polytetrafluoroethylene
QAPjP	Quality Assurance Project Plan for Testing Programs Generating Environmental Regulatory Data
QCGR	Qualified Glass Composition Region
RPP	River Protection Project
RPP-WTP	River Protection Project-Waste Treatment Plant
SBS	Submerged Bed Scrubber
SCR	Selective Catalytic Reduction
TCO	Thermal Catalytic Oxidizer
TDS	Total Dissolved Solids
TFCOUP	Tank Farm Contractor Operation and Utilization Plan
TRU	Transuranic
TSS	Total Suspended Solids
VOC	Volatile Organic Compound
VSL	Vitreous State Laboratory
W.C.	Water Column
WESP	Wet Electrostatic Precipitator
WTP	Waste Treatment Plant
XRF	X-Ray Fluorescence

SUMMARY OF TESTING

This report documents melter and off-gas performance results obtained on the DM1200 HLW Pilot Melter during processing of AZ-101 HLW simulants. The tests reported herein are a subset of six tests from a larger series of tests described in the Test Plan for the work; results from the other tests have been reported separately. The solids contents of the melter feeds were based on the WTP baseline value for the solids content of the feeds from pretreatment which changed during these tests from 20% to 15% undissolved solids resulting in tests conducted at two feed solids contents. Based on the results of earlier tests with single outlet “J” bubblers, initial tests were performed with a total bubbling rate of 65 lpm. The first set of tests (Tests 1A-1E) addressed the effects of skewing this total air flow rate back and forth between the two installed bubblers in comparison to a fixed equal division of flow between them. The second set of tests (2A-2D) addressed the effects of bubbler depth. Subsequently, as the location, type and number of bubbling outlets were varied, the optimum bubbling rate for each was determined. A third (3A-3C) and fourth (8A-8C) set of tests evaluated the effects of alternative bubbler designs with two gas outlets per bubbler instead of one by placing four bubblers in positions simulating multiple-outlet bubblers. Data from the simulated multiple outlet bubblers were used to design bubblers with two outlets for an additional set of tests (9A-9C). Test 9 was also used to determine the effect of small sugar additions to the feed on ruthenium volatility. Another set of tests (10A-10D) evaluated the effects on production rate of spiking the feed with chloride and sulfate. Variables held constant to the extent possible included melt temperature, plenum temperature, cold cap coverage, the waste simulant composition, and the target glass composition. The feed rate was increased to the point that a constant, essentially complete, cold cap was achieved, which was used as an indicator of a maximized feed rate for each test. The first day of each test was used to build the cold cap and decrease the plenum temperature. The remainder of each test was split into two- to six-day segments, each with a different bubbling rate, bubbler orientation, or feed concentration of chloride and sulfur.

A) Objectives

The principal objectives of the DM1200 melter testing were to determine the achievable glass production rates for simulated HLW feeds using a variety of bubbler configurations and operational strategies; characterize melter off-gas emissions; characterize the performance of the prototypical off-gas system components as well as their integrated performance; characterize the feed, glass product, and off-gas effluents; and perform pre- and post test inspections of system components. The specific objectives (including test success criteria) of this testing, along with how each objective was met, are outlined in the following table. Test objectives are numbered from 1 to 14 and success criteria are listed as “a” through “k”.

Test Objective	Objective Met?	Discussion Section
1. Define melter testing matrices that provide sufficient coverage of the testing variables defined in Section 6, Test Conditions [8]. The test matrix for each variable is to be provided in the test plan. The test plan shall define each test variable and is to include a discussion of test variable development and basis by which the testing strategy and approach will provide a sufficient technical basis for WTP HLW melter processing constraints. The order in which the testing variables are performed should be done to optimize the testing and take into consideration predecessor activities such as glass formulation support and the maturity of the QGCR boundary definitions.	Yes	See Test Plan [13] and following Test Exception [14].
2. Define the laboratory, small-scale melter (DM10 and DM100) and DM1200 pilot melter testing that are required for each variable defined in Section 6, Test Conditions. The maximum melter scale proposed should be based on the data quality requirements and the scale necessary to achieve that quality of data. (a) When completed, the test results data shall sufficiently define the effects of the test variables on melter throughput attainment and any deleterious processing conditions.	Yes	Tables 3.1-3.6 provide glass production rate data and summary data for DM1200 melter testing.
3. Perform DM10, DM100 and DM1200 melter testing and associated feed handling and off-gas treatment equipment testing. The duration of each campaign or test period shall be sufficient to satisfy the objectives defined in the test plan. (a) When completed, the test results data shall sufficiently define the effects of the test variables on melter throughput attainment and any deleterious processing conditions.	Yes	This report is limited to DM1200 testing. DM1200 data are provided in Tables 3.1-3.6 and Figure 3.1.
4. Continue to assess the HLW bubbler design, operating life, modes of bubbler failure, and if necessary, alternative designs required to achieve a minimum two-month operating life. (b) Document the performance of the HLW bubbler design and placement recommended by the Duratek design staff and recommend alternative design or placement alternatives if deemed to be superior. Provide a mean time to failure estimate of the Inconel-690 bubbler or alternate design if used.	Yes (partially) (future)	The recommended bubbler design and placement was employed for these tests as described in Section 1.4.5. Performance with respect to production is provided in Tables 3.1-3.6. Information on bubbler operating lifetimes will be reported separately when it is available.

Test Objective	Objective Met?	Discussion Section
<p>5. For each test, establish and maintain melter throughput rates at the maximum steady state rate.</p> <p>(a) When completed, the test results data shall sufficiently define the effects of the test variables on melter throughput attainment and any deleterious processing conditions.</p>	<p>Yes</p>	<p>Data are provided in Tables 3.1-3.6 and Figure 3.1. Tests using four outlets either as four lances simulating two double-outlet bubblers or two actual double-outlet bubblers resulted in production rates between 1200 and 1400 kg/m²/day for feed containing 400 g glass per liter. This result was obtained with four lances simulating two double-outlet bubblers with either 8" or 14" separation between the outlets. Production rates dropped from 1300 to 1100 kg/m²/day when the number of bubbler outlets was reduced from four to two. A 25°C increase in glass temperature did not produce a large rate increase as a result of power supply limitations; however, a production rate of 1450 kg/m²/day was obtained in that test with 23% less bubbling than in the comparable test at 1150°C. Increasing bubbler depth increased production rate; however, the only test systematically evaluating that variable was complicated as a result of bubbler orientation (parallel to the electrode as opposed to diagonally pointing towards the melter center, which placed the bubble flow closer to the wall), which had a larger effect than did the depth. A smaller but discernable production rate increase was observed as a result of varying the flow between two bubblers while keeping the total flow constant (skewing). The effect of the chemical additives sodium chloride and sodium sulfate on production rate was unclear in these tests. Sodium chloride and sodium sulfate alone appeared to dramatically decrease production rate while the two combined appeared to increase production rate. However, it is believed that these decreases in production rate may be attributable to cold-cap ridges that built up in the first two test segments that were burned off prior to the last segment.</p>

Test Objective	Objective Met?	Discussion Section
<p>6. Characterize the melter emissions (particulate, aerosol, and gaseous) under nominal steady-state operating conditions for inorganics and organic compounds. Measurement of organic compounds can be satisfied through the use of Fourier Transform Infra-Red Spectroscopy (FTIR), H₂ and CO monitors. Silver mordenite characterization will include assessment of the effects of off-gas stream constituents that can affect column performance, e.g., halides, acid gases, etc.</p> <p>(c) Obtain, report and assess melter emissions (particulate, aerosol, and gaseous) data under nominal steady state operating conditions for each test.</p>	Yes	Section 7.0 provides data and detailed description of melter emissions.
<p>7. Quantify and document the occurrence and associated operating conditions of any melter off-gas volume surging events.</p> <p>(d) Document the occurrence and associated operating conditions of any melter off-gas volume surging events.</p>	Yes	Section 5.0 provides melter pressure data and control air flow rates during testing. Occasional pressure spikes were observed during processing. These transient spikes were typically associated with breakup and rapid incorporation of cold cap sections into the melt.
<p>8. Characterize the performance of the primary off-gas treatment equipment (SBS, WESP and HEME) to remove particulate, aerosol and gas phase emissions under steady state melter conditions. Measurement of organic compounds can be satisfied through the use of FTIR, H₂ and CO monitors.</p> <p>(e) Obtain, report and assess the ability of the primary off-gas treatment equipment (SBS, WESP and HEME) to remove particulate, aerosol and gas phase emissions under steady state melter conditions.</p>	Yes	Section 5.0 provides operational details of off-gas system components. Section 7.0 provides data and detailed description of SBS and WESP emissions as well as DF values for these components.
<p>9. Characterize the performance of the secondary off-gas treatment equipment (SCR, TCO and small-scale silver mordenite column) to treat NO_x and capture iodine emissions under steady state melter conditions. Measurement of organic compounds can be satisfied through the use of FTIR, H₂ and CO monitors. (A sulfur-impregnated activated carbon system is being added and will be similarly characterized.)</p> <p>(g) Measure and document the performance of the secondary off-gas treatment equipment (SCR, TCO and small-scale silver mordenite column) to treat NO_x and capture iodine emissions under steady state melter conditions. (A sulfur-impregnated activated carbon system is being added and will be similarly characterized.)</p>	Yes	See Sections 5.0 and 7.0. Data are presented for the SCR, TCO, and small-scale sulfur-impregnated activated carbon column. The silver mordenite system was not used during these tests; its performance was reported previously [17].

Test Objective	Objective Met?	Discussion Section
10. Characterize the chemical and physical characteristics of the aqueous streams (feed, SBS, WESP, and caustic scrubber). (f) Measure and document the chemical and physical characteristics of the aqueous streams (feed, SBS, WESP and caustic scrubber).	Yes	Section 2.2 provides detailed feed analysis. Section 5.2 provides detailed off-gas fluid analyses.
11. Obtain the necessary process measurements to provide mass and energy balances throughout the systems, including process monitoring of power, voltage, current, resistance, temperatures, pressures, flow rates, and cooling water and air flows and inlet and outlet temperatures. (h) Document process measurements that provide mass, and energy balances throughout the systems, including process monitoring of power, voltage, current, resistance, temperatures, pressures, flow rates, and cooling water and air flows and inlet and outlet temperatures.	Yes	Data for measured melter parameters are provided in Section 3.0 and data for measured off-gas parameters are in Section 5.0. Energy balances for the melter and SBS are given in Section 4.0.
12. Document general equipment operations (reliability, availability, maintainability, etc.); especially non-routine equipment failure and replacement activities. (i) Assess and document general equipment operations (reliability, availability, maintainability, etc.), especially non-routine equipment failure and replacement activities.	Yes	Data are presented and discussed in Sections 3.0, and 5.0.
13. Perform pre- and post-test inspections of key equipment and process lines to monitor for solids accumulations and corrosion/erosion of materials, especially ammonium nitrate downstream of the SCR. (j) Document pre- and post-test inspections of key equipment and process lines to monitor for solids accumulations and corrosion/erosion of materials.	Yes	Inspection information for off-gas equipment is provided in Section 5.0. Inspection downstream of the SCR was covered in a previous report [22].
14. Operate the melter plenum pressure control using the variable air-injection control method. Assess and document control stability (melter plenum and off-gas system pressure versus time) as a function of instrument controller settings. (k) Document the performance of the melter plenum pressure control using the variable air-injection control method. Document control stability (melter plenum and off-gas system pressure versus time) as a function of instrument controller settings.	Yes	Section 5.0 discusses melter pressure data and control air flow rates during testing.

B) Test Exceptions

Test Exception	Description
24590-HLW-TEF-RT-03-038	Modified some tests of the complete series to reflect new bubbler configurations.
24590-HLW-TEF-RT-03-046	Added small-scale S-AC bed in the secondary off-gas treatment equipment train

C) R&T Testing Conditions

Testing was performed using flow-sheet based AZ-101 composition provided by the WTP Project, from which suitable simulants were developed for this work. Supporting glass formulation work was performed to develop compliant glass formulations. Based on these results, melter feed simulants for these tests were prepared by a chemical vendor.

The following tests are discussed in this report:

- Test 2: Nine-day test using an AZ-101 composition (target glass yield = 0.375 kg/kg or 530 g/l) to determine cold-cap-limited glass production rates at three bubbler depths (on the melter floor, 6" from the floor, and 12" from the floor). Constant bubbling at 65 lpm from two lance bubblers oriented parallel to electrodes.
- Test 1: Seven-day test using an AZ-101 composition (target glass yield = 0.375 kg/kg or 530 g/l) to determine cold-cap-limited glass production rates using three bubbler skewing schemes; skewing refers to varying the amount of air flowing through each bubbler while maintaining constant total flow. Total bubbling constant at 65 lpm from two lance bubblers located 6" from the bottom, placed in the corners, and pointed towards the melt pool center.
- Test 3: Seven-day test using an AZ-101 composition (target glass yield = 0.315 kg/kg or 400 g/l) to determine cold-cap-limited glass production rates for prototypical bubbling patterns with two and four outlets. Bubbling adjusted to obtain the maximum rate from lance bubblers on the melter floor, 8" apart on East and West side, one bubbler 11.3" from feed tube.
- Test 8: Eight-day test using an AZ-101 composition (target glass yield = 0.315 kg/kg or 400 g/l) to determine cold-cap-limited glass production rates with four bubblers on the melter floor, one in each corner, 14" apart on East and West side at glass temperatures of 1150°C and 1175°C. Bubbling rate adjusted to obtain the maximum rate.
- Test 10: Seven-day test with three, two-day run segments using an AZ-101 composition (target glass yield = 0.315 kg/kg or 400 g/l) and variable amounts of sodium chloride or sodium sulfate to determine cold-cap-limited glass production rates. Constant bubbling at 80 lpm from two lance bubblers with outlets on the melter floor, one bubbler 11.3" from feed tube.

- **Test 9:** Nine-day test using an AZ-101 composition (target glass yield = 0.315 kg/kg or 400 g/l with 3.8 g sugar/liter) to determine cold-cap-limited glass production rates for prototypical double outlet bubblers with 8" between outlets. Bubbling adjusted to obtain 1050 kg/m²/day and the maximum rate from lance bubblers on the melter floor, one bubbler 11.3" from feed tube. Ruthenium retention and volatilization under slightly reducing conditions also was determined in this test.

The DM1200 HLW Pilot Melter is a Joule-heated melter with Inconel 690 electrodes. The melter shell is water-cooled and incorporates a jack-bolt thermal expansion system. The footprint of the melter is approximately 8 ft. by 6.5 ft. with a 4 ft. by 2.3 ft. air-lift discharge chamber appended to one end; the melter shell is almost 8 ft. tall. The melt surface area and the melt pool height are approximately 32 percent and 57 percent, respectively, of the corresponding values for the full-scale HLW melter. The discharge riser and trough are full-scale to verify pouring performance. The surface of the glass pool is about 1.2 m², and the volume is about 849 liters, corresponding to about 2 metric tonnes. The feed system consists of a mix tank and a feed tank, both of which are 750-gallon polyethylene tanks with conical bottoms that are fitted with mechanical agitators. The feed tank is also fitted with baffles to improve mixing and calibrated load cells that were electronically monitored to determine the feed rate to the melter. The feed is introduced into the melter using an air-displacement-slurry (ADS) pump, which is the present RPP-WTP baseline. Feed from the ADS pump flows into the melter through a prototypic un-cooled feed nozzle that is located above the center of the glass pool. The melter and entire off-gas treatment system are maintained under negative pressure by two Paxton external induced draft blowers. This negative pressure is necessary to direct the gases from the melter to the prototypical off-gas system. The off-gas treatment system consists of a submerged bed scrubber (SBS); a wet electrostatic precipitator (WESP); a high-efficiency mist eliminator (HEME), a high-efficiency particulate air (HEPA) filter; a thermal catalytic oxidation unit (TCO); a NO_x removal system (SCR); a packed-bed caustic scrubber (PBS); and a second HEME. A sulfur impregnated activated carbon column was used to treat a slip stream of about 10% of the off-gas stream exiting the SCR before returning it prior to the PBS. The second HEME is used to limit entrained particle carryover into the balance of the VSL ventilation system; the PBS and the second HEME are not part of the WTP off-gas train, which effectively ends at the SCR.

The following table outlines the specific testing conditions established in the Test Plan:

R&T Test Condition (from Test Plan [13])	Status
Melter	--
Bulk glass temperature target - 1150°C (typically allowed to vary $\pm 25^\circ\text{C}$ before power input changes are initiated). The bulk glass temperature is taken as the average of the readings from thermocouples located 13, 15.5, and 18 in. from the bottom.	Satisfied. See Tables 3.7 - 3.12.

R&T Test Condition (from Test Plan [13])	Status
The total bubbling rate for tests outlined in the Test Plan [13] will be 65 lpm (64 from lances) in all tests except 3D. Bubbling rates in tests specified in a subsequent Test Exception [14] and other Project directives [15] were optimized to achieve maximum production rate.	Satisfied. Values reported in Tables 3.7 - and 3.12.
Plenum temperature - 400°C – 450°C (this is a dependent variable whose actual value is the result of cold cap coverage, air inleakage and other conditions).	Values were generally higher than target as reported in Tables 3.7 - 3.12.
Feed rate – as-required to achieve plenum temperature range. This is expected to require a cold cap coverage of 80 to 90% of the glass surface.	Values reported in Tables 3.1- 3.6.
Melter plenum pressure is controlled by the air injection method described in Section 2.3. The air flow rate will be as required to maintain stable plenum pressure control without exceeding maximum SBS non-condensable gas flow rate. If compatible with melter and SBS operations, an air rate that is based on ~3X the melter condensable rate (essentially the steam rate) would be used to most closely simulate WTP assumptions. The typical control air flow rate on the DM1200 system is about 40 scfm.	Air injection method was used for plenum pressure control. Formation of cold cap mounds and ridges resulted in processing problems and occasional pressure spikes. See discussions in Sections 3.0 and 5.0.
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Film cooler: No special constraints; typically 70 scfm of air at about 100°C. Air flow to the film cooler will be maintained during idling or, alternatively, the film cooler will be removed. During operations, the film cooler will be washed down with water spray periodically (as directed by the operating procedures, presently every 12 hours). During Test 9, per Project direction [15], the film cooler was washed once a day to facilitate photography of film cooler blockages.	Typical flow rates for the film cooler were about 70 scfm. The film cooler was periodically rinsed.
SBS	--
Tank temperature - 50°C unless condensation downstream requires lowering the temperature. Based on previous test results, a nominal sump temperature of 40°C is expected to be necessary to prevent downstream condensation.	Average SBS water temperatures ranged between 40-50°C as reported in Table 5.2.
Liquid level – utilize lower overflow point.	Satisfied.
Condensate purge rate – 100 to 150 gallons per day. This parameter is intended to simulate the expected SBS condensate dissolved and undissolved solids concentrations for the full-scale facility. To achieve this purge rate, a separate water supply is in place to meter make-up water into the SBS, as needed. This average purge rate will be accomplished in blow-downs of about 40 gallons, as needed. The variation in the purge rate should be within about +/- 20 gallons per day.	Average SBS blow-down rates for the tests were as follows: Test 2: 205 gal/day Test 1: 396 gal/day Test 3: 551 gal/day Test 8: 663 gal/day Test 10: 333 gal/day Test 9: 560 gal/day

R&T Test Condition (from Test Plan [13])	Status
All SBS blow-downs will be via the solids removal "square" pick-up wand to help minimize solids accumulation. Accumulation of solids on the bottom of the SBS tank will be assessed after each test. Any solids deposits will be allowed to remain between tests to determine whether the accumulation volume remains static or increases with time.	SBS blow-downs were via the pick-up wand. Infrared inspections of the SBS down-comer were performed after each test. Refer to Table 5.1 for inspection and cleanout summary.
Solids sparger lances will be operated on a timer cycle (10 seconds on, 20 seconds off, with lances operated in opposing pairs) throughout the tests.	Satisfied.
Perforated down-comer extension pipe that was in place for the preceding AZ-101 and AZ-102 tests will be removed for the present tests in order to evaluate the SBS behavior without it installed. However, the Project may later direct its reinstallation or the installation of an alternative design for testing.	A flared down-comer extension piece was added prior to these tests [17].
Inspect off-gas inlet pipe for accumulated solids. Due to the relatively short duration of each DM1200 campaign, R&T has directed VSL not to remove solids accumulations in the down-comer pipe so that longer-term buildups can be observed. However, if it is determined that continued accumulation will lead to unacceptable SBS performance (excessive pressure drop or plugging and melter pressurization, solids removal is permitted, following inspection and documentation of the buildup (e.g., by portable camera).	Infrared inspections of the SBS down-comer were performed after each test. Refer to Table 5.1 for inspection and cleanout summary.
WESP	--
Operate at maximum current to achieve maximum voltage without sparking. Based on previous experience this would be about 17 milliamps and 31 - 33 kilovolts.	WESP performance is discussed in Section 5.1.3. Average operating values were: Test 2: 23.4 kV, 17.0 mA Test 1: 28.6 kV, 16.9 mA Test 3: 29.1 kV, 17.0 mA Test 8: 29.7 kV, 17.0 mA Test 10: 29.6 kV, 17.0 mA Test 9: 29.9 kV, 16.9 mA
Inlet water spray – 2 gph ± 0.2 gph.	Satisfied. Data reported in Section 5.1.3.
As a part of normal operation for the first test that is conducted (Test 4), the WESP electrodes will be deluged with water from the internal overhead nozzle once a day at the nominal rate of 20 gpm for 2 minutes. This is being done to compare previous operation to spraying with a new spray nozzle (with a smaller spray angle). The nozzle was replaced to attempt to minimize water spray in the WESP tower areas housing the insulator standoffs. For the second test that is conducted (Test 5), the deluge will be conducted once every three days. For the third test that is conducted (Test 6), the deluge will be conducted at the end of the test. The time delay before being able to reinstate the initial voltage and current settings for stable operation will be recorded.	The WESP was deluged daily at a nominal rate of 12 gpm for 3.3 minutes. The spray was turned off immediately before and after deluges. See Section 5.1.3. The time delays for reinstatement of stable operation are documented in Tables 5.6 - 5.11.

R&T Test Condition (from Test Plan [13])	Status
At end of each melter feeding test, inspect WESP internals prior to and after typical wash-down operation.	Discussion and photos provided. See Section 5.1.3.
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HEME: Operate with ~1 gph continuous water spray or per manufacturer's recommendations (< 50 mg/acfm of entrained liquid water).	HEME #1 operated with 0.2 gph spray. See Section 5.1.4.
HEPA Pre-heater: Operate to achieve a temperature rise between 10-20°C. Do not exceed a 20°C temperature rise unless condensation in the HEPA housing or downstream of the HEPA or increased pressure drop across the HEPA indicate higher temperatures are required to maintain stable operation.	HEME #1 outlet and HEPA outlet temperatures are reported in Table 5.2. Test average temperature rise values for these tests was between 16-23°C.
TCO: Bed temperature per the catalyst manufacturer's recommendation and previous test results (approximately 400°C). Based on previous tests, the gas residence time is about 0.16 sec.	TCO and SCR inlet temperatures are reported in Table 5.2. Units were not used during Test 8C. Average TCO inlet temperatures ranged from 462-477°C. Average SCR inlet (TCO bed outlet) temperatures ranged from 391-412°C.
SCR: Bed temperature – per the catalyst manufacturer's recommendation (350-400°C).	SCR inlet and outlet temperatures are reported in Table 5.2. Average SCR inlet temperatures ranged from 391-412°C. Average SCR outlet temperatures ranged from 370-401°C.
SCR: Ammonia slip (exit concentration) ≤ 25 ppm, if possible.	Ammonia slippages are discussed in Section 5.1.6. Ammonia SCR exit concentrations averaged less than 25 ppm and are presented in Tables 7.25 - 7.30.
All other melter and off-gas treatment system unit operation process and control parameters will be within standard limits and reported in the test summary report.	See Tables 3.1-3.6, and Table 5.2. No significant deviations from expected limits were observed.

D) Results and Performance Against Objectives

Melter tests were conducted on the DM1200 to determine the effects of bubbler operation and configuration on glass production rate and off-gas system performance while processing the HLW AZ-101 feed composition. Six tests of durations between seven and nine days were conducted using a variety of bubbler configurations, operational strategies, and bubbling rates. An additional test was also conducted with sodium chloride and sulfate spikes to determine the effects of the addition of these salts on production rate. Ruthenium was added to the feed during the last test to investigate its behavior at low feed sugar concentrations. Each of the tests began with a day of feeding to establish the cold cap before determining the production rate during the two- to four-day test segments. Of the test variables investigated, the number of bubbler outlets and their locations had the greatest impact on processing rate. Tests using four outlets either as four lances simulating two double-outlet bubblers or two actual double-outlet bubblers resulted in production rates between 1200 and 1400 kg/m²/day for feed containing 400 g glass per liter. This result was obtained with four lances simulating two double-outlet bubblers with either 8” or 14” separation between the outlets. Production rates dropped from 1300 to 1100 kg/m²/day when the number of bubbler outlets was reduced from four to two. A 25°C increase in glass

temperature did not produce a large rate increase as a result of power supply limitations; however, a production rate of 1450 kg/m²/day was obtained in that test with 23% less bubbling than in the comparable test at 1150°C. Increasing bubbler depth increased production rate; however, the only test systematically evaluating that variable was complicated as a result of bubbler orientation (parallel to the electrode as opposed to diagonally pointing towards the melter center, which placed the bubble flow closer to the wall), which had a larger effect than did the depth. A smaller but discernable production rate increase was observed as a result of varying the flow between the two bubblers while keeping the total flow constant (skewing). The effect of the chemical additives sodium chloride and sodium sulfate on production rate was unclear in these tests. Sodium chloride and sodium sulfate alone appeared to decrease production rate while the two combined appeared to increase production rate. However, it is believed that these decreases in production rate may be attributable to cold-cap ridges that built up in the first two test segments that were burned off prior to the last segment.

Since the WTP expectations for the solids content in the feed from pretreatment was revised from 20% to about 15% undissolved solids, the production rate demands on the HLW melter have increased accordingly. Previous tests with the same AZ-101 feed at 15% undissolved solids from pretreatment and the previous nominal bubbler configuration (two single-outlet bubblers, 6 in. from the melter floor, 65 lpm) produced glass at only 750 kg/m²/day [9], which is significantly below the WTP requirement. Consequently, an important result of this work is that the new bubbler configuration (two double-outlet bubblers on the melter floor) yielded significantly higher glass production rates that meet the WTP requirement, even with the more dilute feed.

The general performance of the DM1200 melter and off-gas treatment system was good. However, the results of post-test inspections showed that solids accumulation in the SBS down-comer continued to be an issue for the first five of these tests. Design modifications to the internals of the SBS directed by the Project to address this issue were completed and implemented prior to the last of the present series of tests. Limited testing (one nine-day test) suggested that the build-up of deposits in the down-comer may be less extensive as a result of the modifications. Numerous film cooler blockages requiring mechanical clean-out occurred throughout several of the tests. Transition line clogs between the film cooler and SBS inlet also occurred and, on one occasion, required removal of part of the line to remove the occluding material. The ADS pump worked well throughout testing, although the actuator solenoid valve had to be replaced twice during the tests. Extensive sets of process engineering data were collected during the six tests. Energy balances were conducted for select test segments around the melter and SBS with excellent closure. The glass product was close to the intended composition once the melt inventory was turned over for all elements except zirconium, which did not impact testing. The amount of divalent iron was within the 5 to 10 percent target range for the test evaluating ruthenium behavior in the cold cap and melt pool.

Isokinetic particulate samples were taken at the outlets of the melter and SBS for each bubbler operational setting and once during most of the tests at the WESP outlet. The purpose of these samples was to determine the effects of changes in bubbler operation on emissions, as well as to determine the efficiency of off-gas system components. Particulate carryover from the

melter increased with increasing bubbling rate but was unaffected by bubbler configuration. The composition of the melter emissions was unchanged by differences in bubbling rate and operation. Elemental DF values were determined across the melter, SBS, and WESP. Calculated DFs across the primary off-gas system components were higher for most of these tests as compared to previous tests that included the WESP deluges during the exhaust sampling interval. Modifications of the SBS made prior to the last test did not result in discernable changes in particle removal efficiency. Additional emissions data collected during the tests were particle size distributions of the melter emissions, concentrations of various gaseous species throughout the off-gas system by FTIR, and hydrogen concentrations by gas chromatography at the WESP outlet.

The volumes of processing solutions generated in the SBS, WESP, HEME, and PBS were documented during testing and representative samples were subjected to chemical analysis. The SBS solutions were close to neutral pH, due in large part to the lack of acid gases in the exhaust stream. The major dissolved species were halogens, boron, and alkali metals, while the suspended species closely resembled the feed composition. The measured TSS and TDS concentrations in the SBS ranged between 2 to 5 g/L. The WESP sump fluid was also in the neutral pH region but had negligible suspended solids. The WESP solutions contained significant concentrations of boron, sulfate, and alkali halides. The WESP inlet spray was operated continuously at 2.0 gph during these tests and was deluged with 40 gallons of water once daily, resulting in a daily blow-down volume of between 80 and 120 gallons. The 23,330 gallons of liquid that accumulated in the SBS during testing originated from the condensation of water from the melter feed.

The TCO and a slip stream carbon column were evaluated for removal of trichloroethylene and chlorobenzene during one of the tests; the former by spiking these compounds into the melter feed and the latter by injecting the inlet air of the slip stream with these organic compounds. Measured TCO destruction efficiencies of 93% for chlorobenzene, 77% for trichloroethylene, and 97% for total hydrocarbons were very similar to those measured during tests with LAW feeds. The carbon column tested on a 10% slip stream taken upstream of the catalyst was evaluated for removal of HCl, trichloroethylene, and chlorobenzene. Column breakthrough at points one-third and two-thirds into the carbon was demonstrated. Removal of chlorine by the column was about 90%.

One of the tests used feed spiked with ruthenium and an yttrium tracer to determine the retention and volatilization of ruthenium under mildly reducing conditions (iron redox ratio around 0.06 - 0.1). Sugar was added to the feed at a concentration of 3.5 g/L, which is less than the lowest concentration, 7.5 g/L, added in previous testing at reducing conditions. The fraction of ruthenium lost to the off-gas stream was between 2.5 and 10%, which is less than was found under oxidizing conditions. Retention of ruthenium in the melter was relatively high (17.83%) and in the same range as previously observed (13.3 to 20.9%) under oxidizing conditions, and significantly less than observed under more reducing conditions (90%). With the small sugar addition to the feed, a relatively small fraction of ruthenium was reduced to the metallic state. Metallic ruthenium was found at the bottom of the melter, but most of the ruthenium in the glass and at the bottom of the melter occurred as RuO₂. The particle morphology of RuO₂ was

different from that observed under oxidizing conditions. Long thin needles were observed before (oxidizing conditions) whereas short thick rods were observed in this test (mild reducing conditions). This shape difference is likely to affect settling rates.

E) Quality Requirements

This work was conducted under a quality assurance program that is in place at the VSL that is based on NQA-1 (1989) and NQA-2a (1990) Part 2.7. This program is supplemented by a Quality Assurance Project Plan for RPP-WTP work that is conducted at VSL. 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 requirements of the RPP-WTP QAPjP for environmental testing.

F) Simulant Use

This testing used HLW AZ-101 simulant with a composition described in Section 2.0; this composition was defined in the BNI Test Specification [25].

G) Issues

These tests showed that significant improvements in glass production rates could be achieved by employing modified bubbler configurations. These improvements appear to be sufficient to more than make up for the production rate short-fall brought about by the reduction in the solids content in the feed from pretreatment from 20 wt% to 15 wt% undissolved solids. However, further reduction in solids content or increases in waste loading (which increases the water content in the melter feed) could again challenge rate attainment.

The modified SBS design appeared to show less tendency for clogging than did the previous design, but longer test durations are needed to confirm this.

Film cooler and transition line clogging continued to be a significant operational problem; their frequency appeared to increase with bubbling rate and glass production rate.

Maintaining a cold cap limited feed rate during DM1200 tests is dependent on frequent visual monitoring of conditions in the melter plenum. Planned operation of the WTP melter based on only non-visual data, such as plenum temperature, could lead to either under feeding of the melter resulting in lower than attainable production rates or over feeding of the melter resulting in excessive cold-cap buildup as well as other operational difficulties. Testing under such conditions is therefore recommended.

SECTION 1.0 INTRODUCTION

The RPP-WTP Project has undertaken a "tiered" approach to vitrification development testing involving computer-based glass formulation, glass property-composition models, crucible melts, and continuous melter tests of increasing, more realistic scales. Melter systems ranging from 0.02 to 1.2 m² installed at VSL have been used for this purpose, which, in combination with the 3.3 m² LAW Pilot Melter at Duratek, Inc., span more than two orders of magnitude in melt surface area. In this way, less-costly small-scale tests can be used to define the most appropriate tests to be conducted at the larger scales in order to extract maximum benefit from the large-scale tests. For HLW vitrification development, a key component in this approach is the one-third scale DuraMelter™ 1200 (DM1200) HLW Pilot Melter system that has been installed at VSL with an integrated prototypical off-gas treatment system. That system has replaced the DM1000 system that was used for HLW throughput testing during Part B1 [1]. Both melters have similar melt surface areas (1.2 m²), but the DM1200 is prototypical of the present RPP-WTP HLW melter design whereas the DM1000 was not. In particular, the DM1200 system provides for testing on a vitrification system with the specific train of unit operations that has been selected for both HLW and LAW RPP-WTP off-gas treatment [2].

Previous testing with HLW simulants on the DM1000 [1] and DM1200 [3-6] indicated that while processing rates considerably above the project baseline (0.4 MT/m²/d) were possible with bubbling, the baseline rate was not achieved in tests performed without bubblers. As a result of this testing, it was concluded that the current WTP HLW melter design is not capable of achieving the baseline production rate of 1.5 MT/d without the use of bubblers [7]. Testing has shown that the use of bubblers could also provide ORP the "performance enhancement" necessary to achieve the future expanded capacity per melter of 3.0 Mt/d, which is the present requirement under the so-called "2+2" revised baseline [8]. Following the Project decision to include bubblers in the reference HLW design, recent DM1200 testing has been conducted to determine the processing rates achievable with bubbling for each of the Phase 1 HLW feed compositions [9-12].

Per the WTP Test Specification [8], the next phase of DM1200 testing was intended to address bubbler configuration variations to optimize throughput and a variety of flow-sheet issues. This Final Report is the second of two reports on the results of tests that are described in a Test Plan [13] that was prepared in response to that Test Specification [8]. That Test Plan is one in a series responding to the Test Specification; consequently, only part of the scope described in the Test Specification [8] was addressed in the Test Plan. The Test Plan addresses bubbler configuration and operation effects and glass redox effects, including the effects of higher flow-sheet nitrate levels and ruthenium volatility; the results from tests designed to investigate bubbler placement and production rate enhancement are the subject of the present report. Summary level results from all of the tests conducted per the Test Plan [13] and subsequent Test Exception [14] and direction [15] have been presented previously [16]. A final report was submitted previously

detailing the results and conclusions from tests evaluating flow sheet changes and reductant levels [17].

1.1 Test Objectives

As listed in the Test Specification for this work [8], the principal objectives of these tests are identified below. Section 6 of the Test Specification ("Test Conditions") [8] describes test "Variability Parameters" in the following nine areas:

- (1) *Effect of REDOX on throughput*
- (2) *Effect of "troublesome" components on processability and off-gas emissions*
- (3) *Assess impact of waste loading or $\pm 15\%$ GFCs variability on processability*
- (4) *Evaluate impact of 2+2 compositions and transitions on throughput*
- (5) *Simulant vs. precipitated hydroxide recipe methods on melt rate and/or throughput*
- (6) *Assess impact of different GFC sources (borax and Na_2CO_3) for B_2O_3 and Na_2O on melt stability and production rate*
- (7) *Assess impact of high viscosity glass on melt rate for HLW*
- (8) *Assess glass liquidus (T_L) vs. volume percent crystals criterion in terms of production rate or waste throughput*
- (9) *System configuration assessments*

The scope of the pertinent Test Plan included only areas (1), and (9), above. This final report addresses only area (9).

The objectives from the Test Specification [8] addressed fully or partially during tests described in this Final Report are:

1. Define melter testing matrices that provide sufficient coverage of the testing variables defined in Section 6, Test Conditions [8]. The test matrix for each variable is to be provided in the Test Plan. The Test Plan shall define each test variable and is to include a discussion of test variable development and basis by which the testing strategy and approach will provide a sufficient technical basis for WTP HLW melter processing constraints. The order in which the testing variables are performed should be done to optimize the testing and take into consideration predecessor activities such as glass formulation support and the maturity of the QGCR boundary definitions.
2. Define the laboratory, small-scale melter (DM10 and DM100) and DM1200 pilot melter testing that are required for each variable defined in Section 6, Test Conditions. The maximum melter scale proposed should be based on the data quality requirements and the scale necessary to achieve that quality of data.
3. Perform DM10, DM100 and DM1200 melter testing and associated feed handling and off-gas treatment equipment testing. The duration of each campaign or test period shall be sufficient to satisfy the objectives defined in the test plan.
4. Continue to assess the HLW bubbler design, operating life, modes of bubbler failure, and if necessary, alternative designs required to achieve a minimum two-month operating life.

5. For each test, establish and maintain melter throughput rates at the maximum steady state rate.
6. Characterize the melter emissions (particulate, aerosol, and gaseous) under nominal steady-state operating conditions for inorganics and organic compounds. Measurement of organic compounds can be satisfied through the use of Fourier Transform Infra-Red Spectroscopy (FTIR), H₂ and CO monitors. Silver mordenite characterization will include assessment of the effects of off-gas stream constituents that can affect column performance, e.g., halides, acid gases, etc.
7. Quantify and document the occurrence and associated operating conditions of any melter off-gas volume surging events.
8. Characterize the performance of the primary off-gas treatment equipment (SBS, WESP and HEME) to remove particulate, aerosol and gas phase emissions under steady state melter conditions. Measurement of organic compounds can be satisfied through the use of FTIR, H₂ and CO monitors.
9. Characterize the performance of the secondary off-gas treatment equipment (SCR, TCO and small-scale silver mordenite column) to treat NO_x and capture iodine emissions under steady state melter conditions. Measurement of organic compounds can be satisfied through the use of FTIR, H₂ and CO monitors. (A sulfur-impregnated activated carbon system is being added and will be similarly characterized.)
10. Characterize the chemical and physical characteristics of the aqueous streams (feed, SBS, WESP and caustic scrubber).
11. Obtain the necessary process measurements to provide mass, and energy balances throughout the systems, including process monitoring of power, voltage, current, resistance, temperatures, pressures, flow rates, and cooling water and air flows and inlet and outlet temperatures.
12. Document general equipment operations (reliability, availability, maintainability, etc.); especially non-routine equipment failure and replacement activities.
13. Perform pre- and post-test inspections of key equipment and process lines to monitor for solids accumulations and corrosion/erosion of materials, e.g., film cooler, off-gas jumper, SBS downcomer and tank (sump), WESP internals, post TCO/SCR lines for ammonium nitrate deposits, etc.
14. Operate the melter plenum pressure control using the variable air-injection control method. Assess and document control stability (melter plenum and off-gas system pressure versus time) as a function of instrument controller settings.

1.2 Test Overview

The tests were performed with an AZ-101 HLW simulant [9]. The solids contents of the melter feeds were based on the WTP baseline value for the solids content of the feeds from pretreatment which changed during these tests from 20% to 15% undissolved solids, resulting in tests conducted at two feed solids contents. Based on the results of earlier tests with single-outlet "J" bubblers, initial tests were performed with a total bubbling rate of 65 lpm. The first set of tests (Tests 1A-1E) addressed the effects of skewing this total air flow rate back and forth between the two installed bubblers in comparison to a fixed equal division of flow between them.

The second set of tests (2A-2D) addressed the effects of bubbler depth. Subsequently, as the location, type and number of bubbling outlets were varied, the optimum bubbling rate for each was determined. A third (3A-3C) and fourth (8A-8C) set of tests evaluated the effects of alternative bubbler designs with two gas outlets per bubbler instead of one by placing four bubblers in positions simulating multiple-outlet bubblers. Data from the simulated multiple-outlet bubblers was used to design bubblers with two outlets for an additional set of tests (9A-9C). Another set of tests (10A-10D) evaluated the effects of spiking the feed with chloride and sulfate on production rate. Variables held constant to the extent possible included melt temperature, plenum temperature, cold cap coverage, the waste simulant composition, and the target glass composition. The feed rate was increased to the point that a constant, essentially complete, cold cap was achieved, which was used as an indicator of a maximized feed rate for each test. The first day of each test was used to build the cold cap and decrease the plenum temperature. The remainder of each test was split into two- to six-day segments, each with a different bubbling rate, bubbler orientation, or feed concentration of chloride and sulfur. All of the data collected was intended for engineering and system design use and, therefore, no environmental sampling was performed during these tests.

1.3 Quality Assurance

This work was conducted under a quality assurance program that is in place at the VSL that is based on NQA-1 (1989) and NQA-2a (1990) Part 2.7. This program is supplemented by a Quality Assurance Project Plan for RPP-WTP work [18] that is conducted at VSL. 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 [19].

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 was not subject to DOE/RW-0333P or the WTP Quality Assurance Project Plan (QAPjP) [20] for environmental and regulatory data.

1.4 Melter System Description

1.4.1 Feed System

The feed material for these tests was prepared and controlled according to VSL specifications by a chemical supplier, as detailed in Section 2. Each batch of feed slurry was shipped to VSL in lined 55-gallon drums (approximately 16 per shipment), which were staged for unloading into the mix tank. Both the mix tank and the feed tank are 750-gallon polyethylene tanks with conical bottoms that are fitted with mechanical agitators; the feed tank is also fitted with baffles to improve mixing. Five calibrated load cells directly mounted on the legs of the feed tank were used to measure additions to and removal from the feed tank and were electronically monitored to determine the feed rate to the melter. The requisite amount of feed is pumped into the feed tank from the mix tank; measured amounts of water were combined by

weight with the feed at this point to adjust the concentration of the melter feed. The material in the feed tank is constantly recirculated from the feed tank discharge outlet, at the tank bottom, to the tank inlet at the top, which provided additional mixing.

The feed is introduced into the melter using an ADS pump, which is the present WTP baseline. The feed transfer line extends from the outlet of the ADS pump in the feed tank to the top of the melter. Feed is introduced into the melter through a prototypic uncooled feed nozzle that is located above the center of the glass pool. Only one feed tube is used to represent the planned number of feed tubes per unit melt surface area in the full-scale WTP HLW melter. The operation of the ADS pump is controlled from the melter computer control system. The ADS pump works by opening the pump reservoir to the feed tank using a double-acting air cylinder and mechanical link to actuate the poppet. The reservoir is filled with slurry by gravity. After sufficient time is allowed to fill the reservoir (a few seconds), the poppet is toggled to close the reservoir to the tank and open the transfer line. After a two-second delay time, the reservoir is pressurized with air to transfer the slurry (about 1.6 liter/shot) to the melter. This cycle is repeated at the rate required to provide the desired feed rate.

When necessary, a backup system is used to introduce feed into the melter with an air operated diaphragm (AOD) pump system that simulates the pulsed feeding action of an ADS pump. The recirculation loop extends to the top of the melter where feed is diverted from the recirculation loop into the melter through a Teflon-lined feed line and water-cooled feed tube. Two computer-operated pinch valves, one on the feed line and one on the recirculation loop, are activated in a timed sequence to introduce feed into the melter at the desired rate. The feed rate is regulated by adjusting the length of each pulse, the time between each pulse, and the pressure applied to the recirculation loop. A compressed air line is attached to each of the feed lines and can be used to automatically clear the feed line into the melter after each pulse; air at 40 psi is flowed for 3 seconds through the 0.275" i.d. line for this purpose.

1.4.2 Melter System

The DuraMelter™ 1200 (DM1200), which is the HLW Pilot Melter, was used for these tests. Cross-sectional diagrams of the melter illustrating the discharge chamber and electrode configuration are provided in Figures 1.1 and 1.2. The DM1200 is a Joule-heated melter with Inconel 690 electrodes and thus has an upper operating temperature of about 1200°C. The melter shell is water-cooled and incorporates a jack-bolt thermal expansion system. The footprint of the melter is approximately 8 ft. by 6.5 ft. with a 4 ft. by 2.3 ft. air-lift discharge chamber appended to one end; the melter shell is almost 8 ft. tall. The melt surface area and the melt pool height are approximately 32 percent and 57 percent, respectively, of the corresponding values for the full-scale HLW melter. The discharge riser and trough are full-scale to verify pouring performance. Other aspects of the discharge system are also prototypical such as the chamber ventilation scheme. The glass contact refractory is Monofrax® K-3, while the plenum area walls are constructed of Monofrax® H refractory. The surface of the glass pool is 34" by 54" with a glass depth of nominally 25". The resultant melt volume is approximately 45,000 cubic inches (735 liters), which represents a glass tank capacity of more than 1.7 metric tons of glass. However, since the typical operating glass level is closer to 29 inches, the effective glass volume during

testing is actually about 849 liters, giving an inventory of about 2.0 metric tons, which is larger than had been previously assumed [21]. The DM1200 is fitted with one pair of electrodes placed high on opposite walls of the melter as well as one bottom electrode. The side electrodes are 11" by 34" giving an electrode area for the pair of about 750 sq. in. Depending on the glass level, the plenum space extends about 33" to 36" above the melt surface, resulting in a plenum volume ranging from about 43 to 46 ft³.

The single-phase power supply to the melter electrodes (250 kW design power) is derived from the DuraMelter™ 1000 transformers by wiring them in parallel and using a single large silicon controlled rectifier. Current can be passed either from the side electrodes to the bottom electrode or between the two side electrodes only, by rearranging jumpers; only side-to-side operation was used for the present tests. Programmable process controllers are installed and can be used to control temperature or power. The melt temperature is controlled by configuring the process controller to maintain constant power and adjusting the power set-point as needed to maintain the desired operating temperature. Alarms can be set to detect out-of-range temperatures or power in the melter. Backup process controllers are installed to be used in case of failure of the main controllers. The entire system is supported by a back-up generator that is tripped on in the event of a power outage.

The DM1200 has several other features. The lid refractory is prototypic and also includes a two-piece construction, which simulates the seam needed for the LAW lid that was planned to be fabricated in three pieces. Nozzles are provided for the off-gas film cooler, a standby off-gas port, discharge airlift, along with 11 ports available for top-entering bubblers, start-up heaters and other components as needed. In addition, a bubbler arrangement is installed in the bottom electrode with the objective of developing permanent bubblers for possible use on future melters. For the present tests, two top-entering bubblers in different configurations were used.

1.4.3 Lance Bubblers

Three types of lance bubblers, placed in a variety of locations and orientations, were evaluated during these tests for the effect on processing rate. The three types of bubblers used, single-outlet "J", single-outlet "L", and double-outlet "J", are shown in Figures 1.3, 1.4 and 1.5, respectively. In previous tests with HLW simulants [3-6, 9-12, 17], two single-outlet "J" bubblers were used, located in opposite corners, pointing towards the center, six inches from the melter floor. Tests evaluating bubbler air flow skewing and bubbler depth used the "J" bubblers in these locations. For the first test evaluating bubbler depth, the bubblers were rotated parallel to the electrodes to avoid current channeling and the height of the bubblers from the floor was varied. In previous tests with LAW simulants [21-23], four single-outlet "L" bubblers were used, located in opposite corners, six inches from the melter floor. Combinations of "J" and "L" bubblers were used in some of the tests reported herein to simulate the locations of bubbling outlets of proposed double-ported bubblers, as illustrated in Figures 1.6 and 1.7. Direction provided by the Duratek design group resulted in the bubbler arrangement shown in Figure 1.6: bubblers on the melter floor, one bubbler outlet 11.3 inches from the feed tube (in the plane of the melt surface), and eight inches separation between bubbling outlets on each side of the

melter. Direction provided by the Project resulted in an alternate bubbler arrangement, as shown in Figure 1.7: bubblers on the melter floor and fourteen inches separation between bubbling outlets on each side of the melter, placed at the maximum distance from the feed tube with a minimum distance from the wall of 8 inches. Figure 1.8 shows a schematic of the prototypical double-outlet bubbler design that was based on the combination of the results from these DM1200 tests and room-temperature tests that were performed in transparent fluid simulating the properties of the glass melt [24]. These bubblers have outlets 8 inches apart and were placed on the melter floor. The orientation of the bubblers in the melter, as shown in Figure 1.9, results in one of the bubbling outlets being 11.3 inches from the feed tube.

1.4.4 Off-Gas System

The melter and entire off-gas treatment system are maintained under negative pressure by two Paxton external induced draft blowers. The two blowers operate in series: the first located upstream of the thermal catalytic oxidizer, and the second located downstream of the packed-bed scrubber. Most of the components of the off-gas system are functionally prototypical. The system, shown schematically in Figure 1.10, consists of a submerged bed scrubber (SBS), a wet electrostatic precipitator (WESP), a high-efficiency mist eliminator (HEME), a high-efficiency particulate air (HEPA) filter, a thermal catalytic oxidation unit (TCO), a NO_x removal system (SCR), a packed-bed caustic scrubber (PBS), and a second HEME. The second HEME is used to limit entrained particle carryover into the balance of the VSL ventilation system. The PBS and the second HEME are not parts of the WTP off-gas train. Subsequent to the AZ-101 and AZ-102 tests [9, 10], the system was modified to direct a 10% slip stream of the SCR/TCO exhaust through a silver mordenite column that was installed to obtain data on its iodine capture efficiency; a sulfur impregnated carbon column (for mercury and organics removal) was also added into the slip-stream system prior to Test 3, but was not used for the preceding tests (Test 2 and Test 1). The DM1200 off-gas can be functionally divided into four subsystems:

Particulate Removal:

Components from the submerged bed scrubber (SBS) through the HEPA remove the particulate matter entrained within the gas stream with an estimated removal efficiency greater than 99.9999% for particles larger than 0.3 μm. In the RPP-WTP facility, this provision serves to segregate the radioactive from the non-radioactive components in the system for maintenance and handling purposes.

VOC Control/Acid Gas:

The thermal catalytic oxidation unit is designed to oxidize any hazardous organics that are present in the off-gas stream. This is followed by a SCR to remove NO_x gases and a packed-bed scrubber to remove remaining acidic gases.

Stack System:

Both the primary and the emergency/bypass exhaust system with its separate HEPA filter vent into the atmosphere through the building stack.

Liquid Processing: Components such as water spray lines, liquid sampling and water storage tanks, as well as the effluent evaporator, function to sample and process the system liquids for recycle or discharge.

As noted above, with minor exceptions the DM1200 off-gas system processing sequence used for the present tests follows the proposed design for the full-scale WTP HLW installation.

Initial quenching of the melter exhaust gas stream takes place in the film cooler, which is designed to eliminate deposition of solids in the melter off-gas exit nozzle. Immediately downstream of the film cooler is the injection point for control air, which is used to regulate slow fluctuations (i.e., occurring in the time scale of several seconds or more) in melter pressure. At the film cooler exit the off-gas stream is in the temperature range of 250 to 350°C and its flow rate is between 100-250 scfm, of which about 10-80 scfm is water vapor. The off-gas is then rapidly quenched by percolation through a submerged packed column in the SBS, which also removes large particulate and many water-soluble species from the gas stream. The piping between the film cooler and SBS has a high superficial gas velocity (~80 ft/s) to minimize particulate deposition. The gas stream leaving the SBS is at a temperature between 40-50°C. Heat is removed from the SBS by means of two banks of internal cooling coils and an external cooling jacket connected in series to a chilled water system. Further mist and particulate removal takes place in the WESP, the HEME, and the HEPA. The TCO and SCR follow the particle removal components and serve to destroy organic compounds and nitrogen oxides. Finally, the PBS provides acid gas removal. Water sprays located in the WESP, the HEMEs, and the PBS drain into their respective collection sumps from which they can be sampled. The system components are fabricated from corrosion resistant materials including AL6XN (SBS and TCO), 316/316L stainless steel, and various plastics (mostly CPVC) at low-temperature locations. There are extensive provisions for sampling of both the gas and the liquid streams throughout the system.

The off-gas system maintains the melter plenum under slightly negative pressure, typically -3 to -5 in. W.C. The plenum pressure is controlled by means of an air injection system that introduces a controlled air flow into the off-gas jumper just downstream of the film cooler. The air is supplied by a blower through a diverter valve. The position of the diverter valve, and therefore the air flow rate, is proportionally controlled by a feedback signal from a melter pressure transducer. Loss of vacuum on the plenum causes the air injection flow rate to decrease, which restores the pressure to the set-point level. Conversely, the control air flow rate increases when the plenum pressure becomes too low.

As noted above, a silver mordenite system was installed to obtain engineering data on iodine capture efficiency. This system treats a slip-stream of up to about 10% of the off-gas stream entering the SCR, which is then returned to the PBS. The slip-stream system was later modified (after Tests 2 and 1 and prior to Test 3) to add a sulfur-impregnated activated carbon column (AC-S) ahead of the silver mordenite column. A schematic diagram of the combined slip-stream system is shown in Figure 1.11. The slip-stream gas is heated before entering the top of a glass column loaded with 1/16" pellets of C-Chem Ag-900 silver-impregnated zeolite

(“silver mordenite”). The active bed is a cylinder, 32” long and 6” in diameter containing about 30 lb of the zeolite material (57.4 lb/ft³ bulk density). C-Chem specifications claim an external void fraction of 37% for this material. Temperatures at both the inlet and the outlet, the differential pressure across the column, and the flow at the outlet of the column are monitored continuously. The gas exiting at the bottom of the column is cooled to protect the down-stream blower. Design ranges of flow conditions at specific points along the system are indicated in Figure 1.11. There are four analytical sampling ports provided in each column: one at the inlet, one each located at 1/3 and 2/3 of the column length, and one at the outlet of the column. The sulfur impregnated activated carbon column, with dimensions identical to those of the silver mordenite column, is packed with 4 mm Calgon HGR media.

1.4.5 Modifications to the SBS prior to Test 9

During this test series, prior to Test 9, a modified SBS was placed into service. The significant modifications to the SBS are:

- The diameter of the bed was increased by 40% to make the superficial flow velocity closer to its prototypical value.
- The water level above the packing was lowered by several inches such that the nominal level is now equal to the prototypical level of 3 inches above the top of the bed packing. This change reduces the pressure drop across the SBS. It also results in a prototypical SBS plenum height (21 inches) from the top of the liquid to the off-gas entry and exit points. The DM1200 SBS plenum volume is, however, smaller than prototypical due to the difference in SBS diameters.
- The overflow nozzle design was changed to the prototypical funnel-like shape.
- The down-comer annular pipe was changed to the prototypical open-ended type.
- An additional ring of the inner cooling coil was added, making a total of two coils in the DM1200 system as compared to three in the WTP SBS. This change improves the heat transfer efficiency enabling the support of higher feed rates to the melter.

Figure 1.12 shows a schematic side view of the modified SBS internals. The gas inlet labeled A1 is redundant and normally not used. The horizontal dotted line above the cooling coils indicates the nominal water level. Photographs of the new SBS before installation are shown in Figures 1.13 to 1.16. Figure 1.13 provides an overall view, Figures 1.14 and 1.15 provide views of the diffuser plate from the top and bottom, and Figure 1.16 provides a view of the top of the packing grate. The new down-comer exterior outfitted with thermocouples is shown in Figure 1.17.

In addition to the physical modifications of the SBS, the cooling piping and heat exchanger system serving the SBS were modified. These changes are described in Section 4 where their effect on energy transfer and SBS cooling are discussed.

SECTION 2.0

WASTE SIMULANT AND GLASS FORMULATIONS

The AZ-101 waste data, blending assumptions, and glass formulation used for these tests are the same as those used in previous melter tests [9]. The composition of the AZ-101 HLW simulant was derived and specified in a corresponding BNI Test Specification [25]. This section summarizes the composition of the AZ-101 simulant and describes the corresponding glass formulation selected for melter testing.

2.1 AZ-101 Waste Simulant

Formulation of the AZ-101 waste simulant makes use of inventory data from the TFCOUP Rev. 3A [26], calculated data from ACM modeling, and analytical data on Cs- and Tc-removal eluates¹ from LAW pretreatment [25].

The composition of the AZ-101 Envelope D solids (Stream FRP02) is based on the inventory data found in Revision 3A of the TFCOUP [26]. As seen in Table 2.1, in addition to updated information, Revision 3A of the TFCOUP also provides information on minor components that were not included in earlier revisions [27] and the Best Basis Inventory (BBI) database (e.g., cadmium). The use of other data sources (e.g., HLW Feed Staging Plan [28]) to supplement the TFCOUP, as was done in previous tests, is therefore no longer necessary. The ACM model calculates the composition of the recycle stream (PWD01), which is then blended with the Envelope D solids based on the expected daily processing rates (i.e., 1.30E+04 lb/day for Envelope D solids and 1.28E+03 lb/day for the recycle stream on a dry solid basis). The resulting material is concentrated and pretreated before ultra-filtration to produce the pretreated HLW solids. The separation factors due to HLW pretreatment and ultra-filtration are given in Table 2.1.

To complete the simulant formulation, the pretreated HLW solids must be blended with wastes from LAW pretreatment. In contrast to the blending scenario used in Part B1 tests, Sr/TRU removal products from pretreatment of Envelope C wastes will be omitted since the current processing schedule indicates that AN-102 (first Envelope C tank) waste will be processed after AZ-101. Analytical data on eluates from Cs- and Tc-removal on an Envelope B sample (AZ-102) [25] provide the compositional bases for the respective feed streams CNP12 and TEP12. The blending proportions are determined by the projected daily processing rate of sodium in the eluates (i.e., 1.71E+01 lb/day for Cs-removal and 3.32E-01 lb/day for Tc-removal). It can be seen in Table 2.1 that incorporation of these streams primarily leads to increase of sodium and nitrate in the HLW simulant.

¹ It is recognized that technetium removal in pretreatment is no longer part of the WTP flow-sheet; however, for practical purposes, this stream has a negligible impact on the overall melter feed composition.

The calculated composition of the blended HLW solids (HLP09b) is shown in Table 2.1, which lists a total of 53 components. Similar to the approach taken during previous testing, radionuclides, noble metals (including silver), and minor components (< 0.05 wt% oxide basis) are omitted from the simulant formulations. Exceptions include cesium, which is included for analytical purpose, and praseodymium, which is replaced with another rare earth element, neodymium. Iodine, added for analytical purposes in previous HLW tests [9-12], was *not* spiked into the feed procured for these tests². The resulting HLW simulant formulation, which is given in Table 2.2, consists of 28 components, 24 of which are non-volatile (compared with 32 and 28, respectively, for the previous AZ-101 simulant). Note that, as detailed in Section 8, ruthenium and yttrium were spiked into the feed to track ruthenium volatility during Test 9. Also, chloride and sulfate were spiked into the feed in Test 10 to assess any effects of these components on production rate.

2.2 AZ-101 Glass and Melter Feed Formulations

With the elimination of Sr/TRU pretreatment products from the HLW AZ-101 simulant, new glass formulations have been developed and tested at VSL to support these tests. The glass composition selected as the basis for these tests, HLW98-77, is presented in Table 2.2. On an oxide basis, this glass incorporates 24.65 wt% of Envelope D waste and 25.25 wt% of all wastes. These can be compared with the respective values of 27.00 wt% and 30.49 wt% for HLW98-31, the AZ-101 reference glass used in Part B1. The difference is due to the increased limiting component ($\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 + \text{ZrO}_2$) in the new HLW simulant (84 wt% vs. 79 wt%). The glass HLW98-77 meets the contract specification by incorporating 21.20 wt% of ($\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 + \text{ZrO}_2$) from Envelope D waste.

Crucible melts of HLW98-77 have been prepared and tested to confirm that it meets the necessary processing requirements. The measured viscosity and conductivity at 1150°C are 50 P and 0.36 S/cm, respectively. Heat treatment of HLW98-77 at 950°C results in <0.5 vol% of spinel crystals. The target glass formulation for these tests, which is also given in Table 2.2, differs slightly from HLW98-77 by the removal of silver and the addition of small amounts of barium from the projected waste composition.

The additional constituents required to form the target test glass from the AZ-101 HLW simulant are boron, lithium, sodium, silicon, and zinc. The corresponding chemical additives that are the sources for these elements were selected based on previous testing and with direction of the RPP-WTP Project. Table 2.3 lists the starting materials and amounts required to produce the target AZ-101 simulant and melter feed. Note that all of the TOC is assumed to be oxalate and that more carbonate (0.429 g/100 g oxide) is present in the simulant than that required per the basis documents (0.106 g/100 g oxide). The small excess in carbonate is not expected to impact the tests since much greater amounts are present in the glass forming additives. The theoretical

² Note, however, that the early part of the turn-over employed leftover AZ-101 feed of the same composition but which *was* spiked with iodine. Consequently, iodine was found in the early SBS fluid samples, as discussed in Section 5.2.

glass yield of the resulting feed is 375 g of glass/kg of feed (about 485-550 g/l of feed, dependent on feed density), when the total solids content of the *simulant* is assumed to be 20 wt%.

Melter feeds were produced by NOAH Technologies Corporation, the supplier of simulant and feed samples used in previous testing on the DM100 and DM1200 melter systems. Sugar and additional water to achieve the target glass yield of 400 g glass per liter were added to the feed at VSL.

2.3 Analysis of Feed Samples

2.3.1 General Properties

Feed samples were analyzed from each distinct feed tank charging, or at least once per day of operation, to confirm the chemical composition and physical properties. Sample names, sampling dates, and measured properties are provided for all feed samples in Table 2.4. Data from samples with the same target composition and water contents [9, 17] are provided for comparison. All samples were taken from the feed line immediately upstream of the entrance point to the melter. The average measured glass yields were within one and one half percent of the two target glass yields of 375 and 314.5 g of glass per kg of feed. Average glass yields expressed in g glass per liter of feed were also equally close to target values (530 vs. 517 and 400 vs. 413). The target glass yields were therefore used for calculating glass production rates. For each test, all measured parameters, including glass conversion ratio, water content, density, and pH, fall within narrow ranges, confirming the relative consistency of the melter feed within each test as well as within each feed solids content. All measured parameters were also very similar to previous tests conducted with the same feeds at the same solids contents [9, 17]. The expected differences in measured feed properties were observed as a consequence of the intended changes in feed solids content: feed water content was lower, feed pH was slightly higher, and feed density was higher at the higher feed solids content.

2.3.2 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 [29]. Melter feeds were characterized using a Haake RS75 rheometer, which was equipped with either a Z40DIN or a FL22-SZ40 sensor. A typical set of measurements consists of identifying the flow characteristics of the slurry by measuring the shear stress on the slurry at controlled shear rates and temperatures. In these measurements, the shear rate values are preset and are increased stepwise from 0.01 s^{-1} to 200 s^{-1} (70 s^{-1} for FL22-SZ40) with a sufficient delay (typically 15 to 30 seconds) between steps to ensure that shear stress is allowed to fully relax and therefore measured at equilibrium. 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. All of the measurements in this work were made at 25°C ; previous work [29], which examined a range of temperatures, showed a relatively weak effect of temperature.

Rheograms showing the feed viscosity versus shear rate for feed targeted at 400 g glass/liter are presented in Figure 2.1. Included in the figure for comparison are data from previously reported [9, 17] feed samples of the same composition and solids content. Measured values for viscosity at selected shear rates and the yield stress values are shown in Table 2.5. Rheological properties for samples from this study were all very similar, further attesting to the uniformity of the feed. Measured values are also similar to those measured in other studies, with the exception of samples that contain higher concentrations of sugar, which have slightly reduced feed viscosity [17].

2.3.3 Chemical Composition

Feed samples collected during these tests were subjected to chemical analysis using x-ray fluorescence (XRF). The chemical compositions of the feed samples from the tests were determined by first making a glass from the feed samples via crucible melt. The glass was subsequently crushed and analyzed directly by XRF. Target values for boron and lithium oxide were used for normalizing the XRF data since they were not determined by XRF. The data are presented in Table 2.6 and are compared to the target composition. Elements spiked into the feed during portions of Test 10 (sulfur and chloride) and Test 9 (ruthenium and yttrium) were not factored into the target composition due to the low spike concentrations and to facilitate comparisons of data from each test.

The compositional analysis results can be discussed by dividing the elements into four categories: major elements with measured oxide concentrations greater than 3%, intermediate elements with measured oxide concentrations between 0.5 and 3%, minor elements with target concentrations less than 0.5%, and contaminants that are not in the target composition. The major elements constitute the bulk of the glass and, therefore, largely determine its properties. The average measured concentration for all the major elements in the AZ-101 formulation (Al, Fe, Na, Si, and Zr) were within 10 percent of the target composition except for zirconium, which was about twenty-five percent above its target throughout the tests. The zirconium surplus observed in the feed samples was also observed in glass discharge samples as well as in previous HLW tests [9, 10, 12, 17] for both feed samples and product glasses. This uniform excess indicates that the purity of the zirconium used by NOAH was somewhat higher than assumed. However, the absolute deviations amounted to only about 1 wt% and therefore the effect on the glass properties is expected to be small and inconsequential with respect to meeting the test objectives. There were two elements in the intermediate concentration range (Ni and Zn) and both were within 10% of their target values. The large number of minor elements (Ba, Ca, Cd, Cl, Cu, F, K, La, Mg, Mn, Nd, Pb, Ru, S, Sr, and Y) are all contributed by the simulated waste or spiked into the feed at low levels. Deviations were not calculated for these oxides due to the high volatility of many of the constituents and the uncertainty associated with deviation calculations on very low concentrations. Common elements such as calcium and potassium, which are typical impurities in bulk chemicals, are over-represented when the constituent is a minor component. Elements not included in the glass formulations but detected at low levels in the feed as impurities were chlorine, titanium, and phosphorus. It is to be expected that small amounts of

common elements such as chlorine, potassium, and phosphorus are present in additive sources. An excess in titanium oxide has been observed in previous studies [9-12, 17, 22, 23], suggesting that titanium is a common contaminant in the source chemicals.

SECTION 3.0 DM1200 OPERATIONS

Six tests with the HLW AZ-101 simulant were conducted between 5/28/03 and 4/1/04, producing over 56 metric tons of glass. The total testing duration, including the time for water feeding and cold-cap burn-off, was 1160 hours, during which over 168 metric tons of feed was processed. A summary of the test conditions and results is provided in Tables 3.1 – 3.6. The tests were designed to show the effects of various bubbler configurations, bubbler operational parameters, and feed additives on glass production rate, glass chemistry, and melter emissions. The tests are summarized below in the order that they were conducted:

- Test 2: Nine-day test using an AZ-101 composition (target glass yield = 0.375 kg/kg or 530 g/l) to determine cold-cap-limited glass production rates at three bubbler depths (on the melter floor, 6" from the floor, and 12" from the floor). Constant bubbling at 65 lpm from two lance bubblers oriented parallel to electrodes.
- Test 1: Seven-day test using an AZ-101 composition (target glass yield = 0.375 kg/kg or 530 g/l) to determine cold-cap-limited glass production rates using three bubbler skewing schemes; skewing refers to varying the amount of air flowing through each bubbler while maintaining constant total flow. Total bubbling constant at 65 lpm from two lance bubblers located 6" from the bottom, placed in the corners, and pointed towards the melt pool center.
- Test 3: Seven-day test using an AZ-101 composition (target glass yield = 0.315 kg/kg or 400 g/l) to determine cold-cap-limited glass production rates for bubbling patterns with two and four outlets. Lance bubblers on the melter floor, 8" apart on East and West side, one bubbler 11.3" from feed tube. Bubbling adjusted to obtain the maximum rate.
- Test 8: Eight-day test using an AZ-101 composition (target glass yield = 0.315 kg/kg or 400 g/l) to determine cold-cap-limited glass production rates with four bubblers on the melter floor, one in each corner, 14" apart on East and West side at glass temperatures of 1150°C and 1175°C. Bubbling rate adjusted to obtain the maximum rate.
- Test 10: Seven-day test with three, two-day run segments using an AZ-101 composition (target glass yield = 0.315 kg/kg or 400 g/l) and variable amounts of sodium chloride or sodium sulfate to determine cold-cap-limited glass production rates. Constant bubbling at 80 lpm from two lance bubblers with outlets on the melter floor, one bubbler 11.3" from feed tube.
- Test 9: Nine-day test using an AZ-101 composition (target glass yield = 0.315 kg/kg or 400 g/l with 3.8 g sugar/ liter) to determine cold-cap-limited glass production rates for two double-outlet bubblers with 8" between outlets. Bubbling adjusted to obtain 1050 kg/m²/day and the maximum rate from lance bubblers on the melter floor, one bubbler 11.3" from feed tube. Ruthenium retention and volatilization in a slightly reducing atmosphere also were determined during this test.

Immediately prior to these tests, a series of two tests using HLW C-106/AY-102 simulants was conducted to evaluate the effects of additions to the feed of reductants and nitrate on glass production rate and glass chemistry [17]. The change in melt pool composition from the HLW C-106/AY-101 to the HLW AZ-101 composition was not deemed to affect production rate and therefore no turnover was conducted. A test with the same AZ-101 feed used in the tests with reductants was conducted in between Test 8 and Test 10. During the nearly six-month interval between Test 10 and Test 9, a series of tests with LAW simulants was conducted [30]. Prior to Test 9, the melt pool was partially turned over to a mixed HLW composition most similar to the C-106/AY-102 composition [31].

The tests employed a prototypical ADS feed system, a single feed tube in the center of the melter, a nominal glass temperature of 1150°C for all tests but Test 8C, in which a glass temperature of 1175°C was targeted, and a side-to-side electrode firing pattern. In each test, the cold-cap-limited production rate was determined by visual observations of the cold cap and confirmed by the plenum temperature. The ADS feed system performed well throughout testing, causing no interruptions in feeding during most of the testing. The pump malfunctioned in Tests 1 and 8, resulting in downtimes of twenty to fifty minutes to replace the poppet actuator (solenoid valve). These failures are unrelated to the previous ADS pump failure, which occurred because of binding with the higher-solids-content LAW Sub-Envelope B1 feed [22, 32]. The problems may be related to an earlier failure which occurred with HLW feed [32] in which dried feed caused binding, and possibly accelerated wear, of an actuator rod.

Feeding was interrupted several times during Tests 1, 3, 8 and 9 for 1- to 8-minute intervals to remove blockages from the film cooler (see Section 5). The majority of the deposits were readily removed by running a rod from above the melter down through the film cooler. However, in one instance during Test 1, it was not possible to dislodge the blockage by that method and a rod had to be extended through a view port on the side of melter in order to access the blockage at the bottom of the film cooler. Transition line blockages during Tests 2, 1, 3, and 10 resulted in 2- to 7-minute interruptions during which the clogging material was dislodged by tapping on the outside of the transition line. A transition line clog during Test 3 required a one and a half hour feed interruption in order to remove the bellows upstream of the SBS and clear out the material blocking the line. These feeding hiatuses and those required to prepare the system for transitioning into subsequent test segments did not compromise the objective of determining a steady production rate for any of the test segments. Production rates were limited in portions of Tests 3 and 8 due to insufficient cooling capacity in the SBS. Cold cap conditions limited production rate in Tests 2 and 10 due to excessive mounding and large ridges, which prevent free flow of the aqueous feed slurry. Conditions were marginally improved during Test 10 by feed stoppages of about an hour and twenty minutes to allow the portions of the cold cap to diminish and be incorporated into the glass melt. Less extensive ridges formed during the other tests; however, bubbler skewing (Test 1) and the distribution of bubbling over multiple outlets prevented the phenomenon from limiting production rate. Foaming on the glass surface was not an issue.

The effect of bubbler configuration on glass production rates is illustrated in Figures 3.1.a – 3.1.f. The number of bubbler outlets and their locations had the biggest impact on processing

rate. Both tests using four lances (Tests 3 and 8) resulted in production rates between 1200 and 1400 kg/m²/day for feed containing 400 g glass per liter. The higher of these rates was repeated in Test 9 with two double-outlet bubblers. Also note that in Test 9 only 64 lpm of bubbler air was required to produce glass at 1050 kg/m²/day, whereas in previous tests with the same AZ-101 feed and single outlet bubblers, the same amount of bubbler air produced glass at only 750 kg/m²/day [9], a 40% increase in production rate. Sugar added to the feed at low concentrations (3.8 g/l) was intended to assess its effect on limiting ruthenium volatilization from the melter; as expected, the added sugar had no effect on production rates. The 25°C increase in glass temperature in Test 8 did not produce a large rate increase as a result of power supply limitations; however, a production rate of 1450 kg/m²/day was obtained in that test with 23% less bubbling than in the comparable test at 1150°C. Predictably, production rates dropped in Test 3, from 1300 to 1100 kg/m²/day (15%), when the number of bubbler outlets was reduced from four to two. It is difficult to discern a difference between the four-lance bubbler configurations given that the steady-state rates were within 10 percent of each other and the interruptions in chilled water supplied to the SBS during Test 3 periodically limited the rate. Increasing bubbler depth increased production rate by as much as 24%; however, the only test systematically evaluating that variable (Test 2) was complicated as a result of bubbler orientation (parallel to the electrode as opposed to diagonally pointing towards the melter center, which placed the bubble flow closer to the wall), which had a larger effect than did the depth. A smaller but discernable production rate increase of 11% was observed as a result of varying the flow between two bubblers while keeping the total flow constant (skewing) in Test 1. The effect of the chemical additives sodium chloride, and sodium sulfate on production rate was unclear in these tests. Sodium chloride and sodium sulfate alone appeared to decrease production rate, while the two combined appeared to increase production rate. However, it is believed that these decreases in production rate observed in Test 10 may be attributable to cold-cap ridges that built up in the first two test segments that were burned off prior to the last segment.

A variety of operational measurements recorded during these tests, including temperatures throughout the melter system, are given in Tables 3.7 – 3.12. The target glass temperature of 1150°C was successfully maintained for most of the glass pool during each test segment, as illustrated in Figures 3.2.a -3.2.f. Bulk glass temperatures were relatively constant throughout the glass pool except near the surface (27" from the floor), where temperatures were lower due to the thermocouples being in or near the cold cap. The fact that the thermocouple at 27" from the floor has high readings for part of Test 8 is not necessarily an indication of sensor failure. It is possible that the thermocouple was near an area of upwelling hot glass during parts of the test and, therefore, there is no reason to discount data from this thermocouple. One exception was in the latter portion of Test 8 where a glass temperature of 1175°C was targeted and obtained. Another was in the latter portion of Test 9 when the process was power (or current) limited during attempts to maximize production rates with the double-ported bubblers, resulting in glass temperatures about fifteen degrees below target. Plenum temperatures, given in Figures 3.3.a - 3.3.f, typically ranged from 400 to 700°C during the steady-state portion of the tests, which is higher than the 400 to 450°C target given in the Test Plan as a result of the small openings in the cold cap above the bubblers at sustainable feed rates. Plenum temperatures were higher in tests with more than two bubbling outlets (Tests 3 and 8) and in tests where difficulty was encountered in creating a uniform cold cap (Test 10). Plenum temperatures increased over

the course of Test 2 as the bubblers were moved deeper into the melt pool.

The east and west side electrode temperatures varied over the narrow range of 1078 – 1155°C after the cold cap was established, and typically varied no more than 35°C from each other during each test, as shown in Figures 3.4.a - 3.4.f. Conversely, the bottom electrode, which was not powered in these tests, experienced temperatures ranging from about 800 – 1100°C. The lowest bottom electrode temperature, and therefore the largest differential between the bottom and side electrode temperature, occurred during Test 2 when the bubblers were furthest from the floor. The discharge chamber and riser temperatures were largely maintained above 950°C throughout the tests. (The riser thermocouple is located about 4 inches above the bottom of the riser pipe, which is about 7.5 inches above the melter floor.) Gas temperatures after the film-cooler were 150 - 250°C lower than the plenum temperature as a result of film-cooler and control-air dilution. Also, the film cooler is cleaned by a water spray every 12 hours, resulting in a short-duration reduction to about 75°C in the film cooler outlet temperature.

Conditions in the glass pool are illustrated for electrical properties in Figures 3.5.a – 3.5.f, level and density in Figures 3.6.a – 3.6.f, and bubbling in Figures 3.7.a – 3.7.f. Power supplied to the electrodes was relatively constant during each test segment and increased with production rate for the six tests. The maximum amount of power supplied to the electrodes was about 225 kW at a glass target temperature of 1150°C (Tests 3 and 9) and 240 kW at a target glass temperature of 1175°C (Test 8). Glass resistance varied as a function of glass temperature and, to a lesser extent bubbling configuration, during the tests. The temperature effect is readily observed as a decrease in glass resistance with increasing temperature in Test 8, and an increase in glass resistance with decreasing glass temperature during Test 9. A dramatic decrease in glass resistance occurred during Test 2 as bubblers were moved progressively lower in the melter; however, the reason is uncertain. A drop in resistance was also observed in Test 3 when the number of bubblers used was reduced from four to two, and the bubbling flow rate was reduced. Tests with consistent bubbler operation and glass temperature, such as Test 10, had little change in glass resistance after the start-up period. The glass level was mostly within an inch of the intended average of about 30 inches from the floor in Tests 1 and 3, as well as in the initial portions of Tests 2, 8 and 10. The glass level was intentionally increased to the maximum heights of 33-34" from the floor to test bubblers at the maximum depths. Levels were also increased during portions of Tests 8 and 10 and most of Test 9 in an attempt to create the most favorable cold cap conditions. Glass pool density varied between 2.2 and 2.45 g/cc during these tests and decreased with increasing bubbling rate and bubbler depth. Tests using a constant bubbler rate and depth, such as Tests 1 and 10, experienced little change in glass density over the course of the test. The bubbling rates used throughout the tests are shown in Figures 3.7.a – 3.7.f. Since four bubbling outlets were intended to simulate two bubblers, each with two outlets, in Tests 3 and 8, the figures depict the sum of the pairs of outlets as a single bubbler. Target total bubbling rates of 65 lpm for Tests 1 and 2, as well as 80 lpm for Test 10, were maintained throughout each test. Lance bubbler flow rates were skewed slightly in Tests 2 and 10 to reduce excessive accumulations of feed in portions of the melt pool. The intentional systematic skewing conducted during Test 1 is observed in Figure 3.7 as two bubbling rates of 16 and 48 lpm for the step-change skewing and as a blur in between these values for the gradual-change skewing. Bubbling was adjusted in Tests 3, 8, and 9 to achieve the maximum cold cap limited production rate.

Notice that the volume of air passed through the bubbler(s) on each side of the melter was the same and no skewing was permitted. Steady-state bubbling rates given in Tables 3.1 – 3.6 were calculated as an average for each steady-state production rate period. During testing where bubbling rates were varied to obtain the maximum glass production rate (i.e., Test 3), the bubbling rates during steady-state production were often varied significantly in response to changes in cold cap conditions.

It is worth noting that visual observation of the DM1200 melt pool is a key operational aspect of current DM1200 testing. In many instances where feeding was slowed or even stopped based on visual observations of cold cap ridges and mounds, non-visual data such as plenum temperature would not have identified the extent of the cold-cap buildup. In fact, high plenum temperatures can result from a high mound over a portion of the melt surface preventing feed from spreading across the melt surface and creating an opening on the glass surface. Without the visual evidence, an operator may conclude that feed rates should be increased, which could exacerbate the problem. It is likely that the maximum production rate for each set of test conditions would have been significantly impacted for most of the tests if the cold cap conditions were not monitored visually. Consequently, it is recommended that the ability to maintain production rates without use of visual information be evaluated, if that is the planned WTP operating mode.

SECTION 4.0 MELTER AND SBS ENERGY BALANCE

This section provides an analysis of the energy balance for the DM1200 based on data from the HLW AZ101 Tests 3, 8, and 9. The energy balance envelope includes the melter box, transition line, and SBS. An additional computation involving the melter box only is also reported. The SBS was modified during the course of the test series, and results from Test 9 are from the system with the modified SBS.

4.1 Introduction to Energy Balance

The purpose of the melter energy balance is to better understand the energy flow pathways in the DM1200 melter to underpin the basis for optimization of design, operation, and control of the WTP HLW melter. One specific potential application would be to determine the required electrode power and other required utilities for a given set of conditions such as the slurry type, slurry feed rate, air flow rates, melt pool and plenum temperatures, and SBS discharge temperatures. The objectives of this section are to document the details of the calculation and the results obtained together with an assessment of the sources and magnitudes of the associated uncertainties.

Energy balances around the DM1200 melter were constructed for tests with HLW AZ-101 feed (Tests 3, 8, and 9). Multiple test segments were included in the calculations for Tests 3 and 8. Because each test segment typically has operating conditions different from other test segments, e.g., feed rate, bubbling rate, melt pool temperature, or bubbler placement, separate energy balance calculations were done for each test segment. However, only the final 24 hours of Test 9 were included in its energy balance calculation. For each segment two separate calculations were performed, within different system boundaries, both of which compared the melter electrode power to the sum of all other heat gains and losses. The two energy balance envelopes considered were:

- a) Boundary including both the melter and the SBS. For Test 3, the overall agreement or closure between the electrode power and all of the other energy streams was 108%, based on information from all three of the test segments. For Test 8, the overall closure for the three segments was 111%. For Test 9 the closure for the test segment calculated (last 24 hours) was 112%.
- b) Melter only, with the boundary at the discharge from the film cooler. For Test 3, the overall agreement or closure between the electrode power and all of the other energy streams was 106%, based on information from the three test segments. For Test 8, the overall closure for the three segments was 110%. For Test 9, the closure for the test segment calculated (last 24 hours) was 110%.

4.2 Methodology

Figures 4.1 and 4.2 conceptually illustrate elements included in the melter energy balance calculations. Figure 4.1 shows the configuration for Tests 3 and 8, and Figure 4.2 shows the configuration for Test 9. The significant process change is the rerouting of the SBS cooling water, connecting the cooling coil and jacket in series. The SBS cooling coil was also modified, as discussed earlier, to improve heat transfer. The energy balance boundary (or “envelope”) surrounds the melter, transition line, and SBS; or, the melter only. In both cases (with or without inclusion of the transition line and SBS) the envelope excludes the discharge chamber of the melter while including in the balance the molten glass discharged from the melter melt pool. The role of the discharge chamber is to maintain discharging glass temperature constant, which has no net contribution to the overall heat balance.

The SBS is included within the energy balance herein, for two reasons:

- In its present configuration, overall system thermal capacity is limited by both melter and SBS utility subsystems. Approximately 50% of the melter electrode power is dissipated in the SBS during normal operating conditions. Therefore no significant change can be made to one of the components without affecting the other.
- The flow measurements made around the SBS allow a double check of the material balance, and hence, the energy balance of the melter. Furthermore, there is no continuous measurement allowing determination of the air leakage into the system earlier than the WESP exhaust.

The overall energy balance compares the melter electrode power to the sum of all of the other energy streams entering, leaving, consumed, and generated within the envelope. Some of these energy streams are associated with material flows, e.g. the melter slurry and air streams, or the SBS exhaust streams. Some of the energy streams are direct energy (non-material) transfers such as the melter electrode electrical power and skin convection losses to the surrounding air; some of the energy streams crossing the envelope border are indirect, such as cooling water; and finally, some of the energies are internal, such as combustion and other chemical reactions and phase transitions taking place within the melter.

An energy balance for each segment of each test, as well as the overall balance for each test is provided for Tests 3 and 8. (For Test 9, energy balance only for the final 24 hour segment is calculated.) A segment for the purpose of the energy balance calculation begins with the initiation and ends with the termination of the slurry feed to the melter. Data were excluded whenever an interruption in the slurry feed to the melter exceeded 30 minutes. The start-up water (i.e., water fed to the melter before the introduction of the feed slurry) is always included in the energy and material balances, since the first blow-down from the SBS never occurs until after the feed slurry has started.

The following is a list of all of the energy streams included in the energy balance:

- Electric power to melter electrodes.
- Air streams, including control air, film cooler air, melter inleakage. The temperatures of the inlet control air and film cooler air were measured continuously.
- SBS blow-down.
- Melter feed slurry (assumed at 80°F/26.7°C). Actual heats of reaction involved in the decomposition of the feed slurry components as well as phase transition energy required to form glass were calculated.
- SBS exhaust.
- Energy transferred to cooling water streams including the melter cooling panels, the SBS internal coil, and the SBS jacket. The actual cooling water flow rates and temperatures were measured.
- Discharged molten glass. Its temperature was taken as equal to the measured temperature at the bottom of the melt pool.
- Convection energy lost from the melter shell.
- Convection energy lost from the transition line.
- Combustion of organic feed components (such as sugar).

Implicit in the material streams listed above (and explicitly included in the energy balance) is the relative thermal energy of feed and product streams. For example, one component of the balance is the temperature difference between the water in the feed slurry and the water in the SBS blow-down. Similarly the difference in the temperatures in the air feed streams versus the temperature of the SBS exhaust (the “sensible” heat) is taken into consideration. The latent (i.e., phase transition) heat of the water that is fed into the melter as a liquid and leaves as water vapor is a major included component.

Table 4.1 provides more detailed information about the calculation method. The first column, *Calculated Value*, lists values required to assemble the energy balance. Column two, *Other Calculated or Recorded Information*, identifies the specific input information (either calculated or measured) immediately determining the magnitude of the value in column one. The subsequent columns show actual data sets from which column two values were derived.

4.2.1 Assumptions Used for Energy Balance Calculations

The assumptions associated with the energy balance model include:

1. The melter is assumed to be at steady state within each calculated energy balance segment. This means the melter is capable of processing all the feed at the given rate (i.e., there are no significant cold cap changes).
2. Gas streams are considered to be composed of air and water vapor only for the purpose of estimating heat transfer properties such as specific heat, density, or viscosity. The specific heat of the bone-dry air component of these streams is assumed constant at 0.25 cal/gram/°C. The specific heat of the water vapor portion of the gas streams is assumed constant at 0.5 cal/gram/°C.

3. Cooling water heat transfer properties were corrected for the measured ethylene glycol content.
4. Ambient air temperature of 26.7°C (80°F) and relative humidity of 30% were assumed for calculations involving air inleakage and convection. The actual inlet temperatures of the film cooler air and control air are considerably above 26.7°C, thus the measured temperatures were used in calculations, but taking the absolute water content as defined by 30% relative humidity at 26.7°C.
5. The heat carried away by the discharged glass was estimated by using the temperature at the bottom of the melt pool, the slurry feed temperature (assumed to be the ambient air temperature), and a calculated heat capacity of the glass. The calculation method for the heat capacity for a similar nuclear waste glass up to its glass transition temperature (T_g) is provided in Reference [33]:

$$C_p \text{ [Joules/(gram-atom x K)]} = 0.3119 (a + bT + c/T^2 + d/T^{1/2} + eT^2)$$

where the coefficients are:

$$a = 112.897 \quad b = 2.34243 \times 10^{-3} \quad c = -54243.9$$

$$d = -966.796 \quad e = 1.5 \times 10^{-7}$$

The above heat capacity equation is modified for its gram atom weight, since the gram-atom weight of glass in the above report [33] was 21.28 grams and the gram atom weight of the AZ-101 feed is 20.20 grams. The calculated (solid) glass heat capacity is increased by 5.1% to account for the difference in gram atom weight.

The sensible heat of the glass discharged from the melter relative to the feed slurry is calculated in two steps:

- a. Integrate the above expression for heat capacity, between the feed slurry temperature, 26.7°C, and T_g for AZ-101, 468°C, adjusted for the gram-atom weight.
- b. Utilize a constant heat capacity, 30.5 Joules/(gram-atom x K), from T_g to the melt-pool temperature, 1139° for Test 3, and 1154°C for Test 8, without adjustment for the gram-atom weight.

In typical engineering units, the integrated average heat capacity of the solid glass is 0.274 calories/(gram °C), and of the molten glass pool, 0.361 calories/(gram °C). A reference dealing with a different nuclear waste glass utilizes a melt pool heat capacity which is only 5% different from the VSL glass, while the gram atom weight is 13% different [34].

6. To calculate the melter shell convective heat loss, skin temperature measurements were done during idling. A linear relationship between this convection heat lost and the melter

plenum temperature was assumed (based on 970°C during idling and the actual plenum operating temperature, typically around 450-550°C, during operation).

7. Heat due to the feed decomposition reactions (an endothermic process) in the melter was calculated from standard formation enthalpies of various feed components using commonly accepted stoichiometries. The glass phase transition heat was estimated as well. The values obtained for the case of HLW AZ-101 feed were 1093 kJ/(kg of glass formed) and 53 kJ/(kg of glass formed) for the decomposition and phase transitions, respectively. All the reactions were assumed to proceed to completion.
8. No significant inleakage of air occurs from the transition line through the WESP. Inleakage of air between the top of the SBS and the WESP exhaust line would especially impact energy balance calculations.
9. Exhaust vapors from both the SBS and the WESP are saturated with water.
10. Empirical natural convection heat loss methodology, based on Nusselt, Grasshof, and Prandtl numbers [35, 36], was used for estimating the melter skin convective heat loss. These calculations were adjusted using values of the transition line heat loss, which could be calculated from available data.

4.2.2 Calculation Details

The dry air flow rate, as calculated from the WESP exhaust flow, temperature, and pressure measurements, is the critical tie-component in the melter energy balance evaluation. The WESP exhaust temperature was used to calculate the saturation pressure of water there. The assumption of water saturation and the total static pressure at the WESP exhaust determine the molar (volumetric) ratio of dry air to water vapor in this stream. This ratio and the wet gas flow rate (wscfm) yield the flow rate of dry air (dscfm). This dry air flow rate is assumed to be constant downstream of the film cooler.

Similar to the method used for the WESP exhaust stream, the temperature at the SBS exit is used to determine the water saturation pressure there. This, along with the dry air flow rate determined at the WESP, determine the water mass flow in the SBS exhaust stream. The SBS exhaust water, combined with the SBS blow-down, yields the total water mass flow from the melter. The result can be verified by comparison with the total water contained in the slurry feed and melter air streams. The proper water material balance is critical to the total energy balance, since about 1/3 of the melter electrode power dissipation is associated with water condensation and cooling in the SBS.

There are four sources of dry air in the melter:

- Film cooler air, containing the same amount of water vapor as ambient air but supplied at higher temperature due to the use of a regenerative blower.

- Control air, with the same water content as ambient air and elevated in temperature due to the use of a turbo-blower.
- Bubbling air, dehydrated (from a compressor) but supplied at ambient temperature.
- Ambient in-leakage air. Inleakage air is calculated by difference as (WESP Air – Film Cooler Air – Control Air – Bubbling Air).

The off-gas temperature at the entrance to the transition line is calculated assuming an adiabatic mixture of the control air, feed related emissions (at the plenum temperature), and the film cooler air.

Given the calculated transition line inlet temperature and the measured SBS inlet temperature along with the dry air and water vapor mass flow rates, the actual convective heat loss from the transition line can be estimated. Natural convection heat transfer calculations for the transition line (surface area: 2.6 m²) were performed assuming the transition line external skin temperature to be the same as the average internal gas temperature. This assumes that the internal film heat transfer coefficient, where there is high turbulence and mixing, is much higher than the external film heat transfer coefficient, where only natural convection is present. As an allowance for the surface area of flanges that are present on the transition line, as well as the impact of melter fans that force some external air flow along the transition line, the calculated convection heat transfer of the transition line was increased by 10%.

The convection heat lost from the melter skin was calibrated by the convection heat lost from the transition line. The determination of the calibration factor (142%) was documented in a previous report [17].

During a melter-idling period, 258 surface (skin) temperature measurements of the melter were systematically collected with a non-contact IR thermometer. An average of 1.5 measurements were made for every square foot of (superficial) surface area for the sides and 2 measurements per square foot were made for the top. “Superficial area” is defined here as the overall length times the width of the face. The bottom of the melter was assumed to be at 45°C, based on 100% coverage by cooling panels, with an average cooling water discharge temperature of 41°C. The convective heat loss was calculated, based on the average temperature from each melter face. An overall correction factor of 1.25 was used as an allowance for the melter shell geometry being more complex than a flat plane (i.e., 25% more convective heat loss than if calculated for a rectangular box the size of the melter). The 25% factor was a visual (not calculated) judgment of how much bracing structural members (angles and I-beams) and other structural support elements added to the superficial area of the melter box. The 25% factor includes also an allowance for the three discharge chamber fans that force air over the top and west faces of the melter. Figures 4.3 and 4.4 are photographs of the west and top sides of the DM1200 melter illustrating the surface complexity. The 142% calibration factor from the transition line convection was applied in addition to the 125% surface area correction.

4.3 Results of Energy Balance Analysis

4.3.1 Results Overview

One measure of the accuracy of the melter heat balance is its “closure”, defined as the sum of the heat generated, consumed, or lost in unit time, divided by the melter electrode power. The overall average closure for the “melter + SBS” energy balance for all of the test segments in Test 3 is 108%; the closure for the “melter-only” energy balance for this test is 106%. The overall average closure for the “melter + SBS” energy balance for all of the test segments in Test 8 is 111%; the closure for the “melter-only” energy balance for this test is 110%. For Test 9, during the last segment, the closure for the “melter + SBS” energy balance was 112%, and the closure for the “melter-only” energy balance was 110%.

Table 4.2 provides more details about the closure for the “melter + SBS” energy balance from each test, as well as the variability of the closure for each test segment.

During Tests 3 and 8, 54% of the total melter energy was exchanged within the SBS, and for the last 24-hour segment of Test 9, 57% of the melter energy was exchanged within the SBS. These values are typical for runs involving melter feed slurry, and the higher value for Test 9 is consistent with the intended improved heat transfer for the modified SBS. The SBS heat transfer value can be evaluated in two ways:

- a) From the process side, by determining the energy lost in the SBS by the off-gas stream.
- b) From the cooling side, by determining the energy absorbed by the two cooling water streams exchanging heat with the SBS.

Both methods should yield the same results, and within the precision of the available data the values are reasonably close. As shown in Table 4.3, the calculated energy absorbed by the cooling water side is about 1.5% higher than the energy lost by the process side, during Test 3. For Test 8, the calculated energy absorbed by the cooling water side is about 1.0% lower than the energy lost by the process side, and for the Test 9 segment the calculated energy absorbed by the cooling water side is about 2.1% higher than the energy lost by the process side. For the purpose of the model presented here, the cooling side calculations, which do not involve any phase transitions, are considered to be more accurate.

Water is a major component in the energy balance calculations, accounting for about 1/3 of the total energy flow in the melter/off-gas system. During typical runs, water vapor leaving the melter is partially condensed in the SBS. Consequently, the sum of the SBS blow-down stream and the water content of the SBS exhaust stream should equal the total water fed to the melter. Melter water includes both the feed slurry and the water vapor contained in various air streams. This air moisture typically adds about 3% to the overall melter water intake. The ambient conditions during operations were relatively constant at 80°F with 30% humidity. Table 4.4 provides a summary of the water balance between the feed water and the exiting water for both tests. The water balance closure values were 102% for Test 3, 116% for Test 8, and 108% for the last segment of Test 9.

An energy balance can be made at the discharge of the film cooler, using the water and dry air flow rates obtained from the foregoing analyses around the SBS. The latent and sensible heats for the water and air are estimated by utilizing the respective inlet and discharge temperatures: ambient temperature of 26.7°C, film cooler air temperatures around 82°C, and the measured film cooler discharge temperature (approximately 350 - 410°C) as the “envelope” discharge temperature. Table 4.5 illustrates the components of this calculation. The distinction is made between the “melter-only” and “melter + SBS” values. This is useful as an integrity check of the entire calculation method, since both values should equal each other. The first row of Table 4.5 is the melter electrode power. The second row shows the enthalpy change of the film cooler air, and the third row gives the enthalpy change of the bubbling air and inleakage air. Most (97%) of the water is fed to the melter as a liquid with the feed slurry at ambient temperature. Because of the large temperature change between the ambient air and the film cooler discharge, the heat capacity of the gaseous stream was not considered constant. The enthalpies were calculated utilizing heat capacities as a polynomial function of temperature [37].

The remaining rows in Table 4.5, e.g., the melter cooling panels, the sensible heat of the glass discharged from the melter (relative to the feed), combustion, etc., identify, for each test, the melter-only calculated heat losses, and compare the average values, when possible, to the average values for the “melter + SBS” calculation. Table 4.5 illustrates the comparison between the melter-only and melter + SBS energy balance for Test 3, Table 4.6 makes this comparison for Test 8, and Table 4.7 for Test 9.

Figure 4.5 is a conceptual representation of the energy transfer pathways around the SBS for Tests 3 and 8. Figures 4.6 and 4.7 illustrate that for Tests 3 and 8, the cooling coil accounts for about 70% of the total SBS heat load, and the energy transferred by the jacket amounts to about 30% of it, which is typical for most DM1200 runs. The bottom two rows of Table 4.8 indicate that for Test 3, the average approach temperature* in the coil is 7.2°C, and 21.3°C in the jacket. The bottom rows of Table 4.9 indicate similar temperature approaches in the coil (8.3°C) and jacket (23.6°C) for Test 8. These data indicate that the coil is more efficient at heat transfer than the jacket.

Figure 4.8, which is a conceptual representation of the energy transfer pathways around the SBS for Test 9, shows the simplified SBS cooling system arrangement in which the SBS coil water outlet is piped to the jacket cooling water inlet. The main process effect of the modified SBS can be seen in Table 4.10, which provides the overall melter and SBS duties for the Test 9 final segment and makes comparisons to the overall average values for all segments of Tests 3 and 8. In general, for all tests, the total melter electrode power tracks the glass production rate, as expected. The percentage of the total water-side heat removed in the SBS relative to the electrode power is 56.6% for Test 9 as compared to 53.7% for Test 3, and 54.1% for Test 8. As intended, the modified SBS is more effective in removing energy from the off-gas stream and transferring it to the cooling system. The effect of connecting the jacket side in series with the coil is also apparent in Table 4.10. For Test 9, with the coil and jacket in series, the coil removes 91% of the heat transferred to the cooling system, as compared to 72% for Test 3, and 74% for

* The *approach temperature* is defined as the difference in temperature between the discharge from a cooler and the inlet temperature of the cooling medium, usually air or water.

Test 8.

4.3.2 Energy Balance Results for Test 3

Figure 4.9 illustrates contributions of the various component energy pathways to the overall energy balance for this test. Table 4.8 lists the actual duties (kW) for each of the components, as well as details about the heat transfer within the SBS. Figure 4.6 shows the relative contributions of the two heat exchangers to the overall heat transfer in the SBS. Figure 4.10 illustrates the temperature histories during Test 3 of the items which have the highest “thermal inertia” within the energy balances, e.g., the melt pool (2 metric tons) and the water recirculating within the SBS (360 gallons). The most significant departures from steady state include:

- Two feed breaks, which occurred during Segment C. After the first feed break, at about 118 hours during the transition from Segment B to C, the SBS bed temperature increased from 33°C to 44.9°C. After the second feed break, at about 162 hours, the SBS bed temperature increased from about 22.8°C to about 46°C by the end of the test. These short-term deviations amount to an average additional duty, not included in the energy balances, of 0.8 kW, or 0.4% of the melter electrode power, during Segment C.
- Partially offsetting the SBS bed temperature increases of the third segment was a slight decrease in the average melt pool temperature, relative to the second segment. This amounts to a decrease in the average duty of 0.5 kW or 0.3% of the melter electrode power.

4.3.3 Energy Balance Results for Test 8

Figure 4.11 illustrates contributions of the various component energy pathways to the overall energy balance for this test. Table 4.9 lists the actual duties (kW) for each of the components, as well as details about the heat transfer within the SBS. Figure 4.7 shows the relative contributions of the two heat exchangers to the overall heat transfer in the SBS. Figure 4.12 illustrates the temperature histories during Test 8 of the items which have the highest “thermal inertia” within the energy balances, e.g., the melt pool (2 metric tons) and the water recirculating within the SBS (360 gallons). The most significant departures from steady state include:

- The increase in the SBS recirculating water temperature, from 23.9°C at the start to 44.8°C at the end of the first segment. This amounts to an average additional duty, not included in the energy balances, of 1.4 kW or 0.9% of the melter electrode power during this segment.
- The increase in the average melt pool temperature during the third segment, relative to the second segment. This amounts to an average additional duty, not included in the energy balances, of 0.8 kW or 0.4% of the melter electrode power during this segment.
- The increase in the SBS recirculating water temperature, from 26.2°C at the start of the third segment to 51.9°C at the end of the test. This amounts to an average additional duty,

not included in the energy balances, of 0.8 kW or 0.4% of the melter electrode power during this segment.

The inclusion of these items would affect the overall energy balance closures by only 0.2%.

4.3.4 Energy Balance Results for Test 9

For Test 9, only the final 24-hour segment was analyzed with a mass and energy balance calculation. The results for this analysis are presented in Table 4.10 where comparison is made to Tests 3 and 8. As discussed earlier, a primary process effect of the modified SBS is improved SBS capability to remove heat from the off-gas stream. This enhanced heat removal capability of the coil is the result of the design modification which provides a second coil pass with a corresponding increased heat transfer surface area. The SBS change also results in relatively more heat removed by the SBS cooling coil as compared to the SBS jacket. This is primarily due to the extra cooling from the additional length of cooling coil, as well as the fact that the jacket is connected in series with the coil instead of being part of a separate cooling loop as was the case previously.

4.4 Summary and Conclusions

Energy balances were made around the DM1200 melter for Tests 3, 8, and 9 with HLW AZ-101 feed. Since the operating conditions, such as bubbling rate, melt pool temperature, bubbler placement, or feed rate, typically change from segment to segment, separate energy balance calculations were performed for each segment of Tests 3 and 8. Energy balance calculations were performed for each segment of each test, as well as an overall average. For Test 9, which used the newly modified SBS, only the final 24-hour segment was analyzed. Two different system boundaries were considered, and for each system the melter electrode power was compared to the sum of all other heat gains and losses.

- a) An energy balance including both the melter and the SBS for Test 3 yielded a closure value of 108%, based on information from all three of the test segments. The analysis for Test 8 yielded a closure value of 111%, based on information from all three of the test segments. For Test 9 the closure for the test segment calculated (last 24 hours) was 112%.
- b) An energy balance around the melter only, with the boundary at the discharge from the film cooler, yielded an overall closure value for all three test segments of Test 3 of 106%. The overall closure value for all three test segments of Test 8 was 110%. For Test 9 the closure for the test segment calculated (last 24 hours) was 110%.

The energy balance closures for these tests are satisfactory, given the simplifying assumptions and accuracy of the data values used in the model calculations. The average accuracy of the acquired data was estimated to be on the order of 2-3%, based on nominal performance of the instrumentation used.

The main uncertainties of the model are:

- a) Water temperature measurements around the melter cooling panels. The precision of these measurements was 10-20%, or about 2-4% of the overall energy balance.
- b) Water temperature measurements around the SBS. The precision of these measurements are 5-10%, or about 1.5-4% of the overall energy balance.
- c) The melter shell convective heat loss, which does not appear to be verifiable to better than within a -20% to +100% interval. This represents 2-3% of the overall energy balance.

SECTION 5.0 OFF-GAS SYSTEM PERFORMANCE

The off-gas treatment system, shown schematically in Figure 1.10, consists of a submerged bed scrubber (SBS); a wet electrostatic precipitator (WESP); a high-efficiency mist eliminator (HEME #1); a heater; a high-efficiency particulate arrestor (HEPA); a TCO/SCR catalytic unit, which includes a heater, a thermal catalytic oxidation unit (TCO), and a selective catalytic reduction unit (SCR) equipped with an ammonia injection system; a packed-bed caustic scrubber (PBS); a second high-efficiency mist eliminator (HEME #2); and a second HEPA on the bypass off-gas system. A silver mordenite column and a sulfur-impregnated activated carbon bed were used to treat a slip stream of about 10% of the off-gas stream entering the TCO and return it prior to the PBS. The sulfur-impregnated activated carbon bed was installed on 7/14/03 right before Test 3. With the exception of the silver mordenite and sulfur-impregnated activated carbon systems, data on the off-gas system performance collected during the test with HLW AZ-101 feed are presented and discussed in this section. Data on performance of the columns are presented in Section 7.5.

The tests reported herein (Tests 2, 1, 3, 8, 10 and 9), together referred to as the “configuration tests”, represent a subset of the entire test series. For context, Table 5.1 provides an overview of the complete test series in the chronological sequence in which the tests were performed, and includes major post-test inspections and equipment modifications. The table also includes key operational events that affected the off-gas system during the tests.

5.1 Off-Gas System Test Results

Data for each of the off-gas system components, logged by the LabVIEW data acquisition and control software, were imported into MS Excel files for data manipulation and plotting. Time “0” on the x-axis of each data plot corresponds to the start of water feed into the melter at the beginning of each test. Where indicated, data were smoothed by time averaging instantaneous measurements logged at two-minute intervals to reduce data scatter and the number of data points for the plots. The average, minimum, and maximum values of the measured off-gas system parameters are given in Tables 5.2 and 5.3. Plots of the typical sequence of gas temperatures through the DM1200 off-gas system at various locations are given in Figures 5.1 through 5.6.

During the course of the above tests, equipment malfunctions resulted in test interruptions or modifications of normal equipment operating parameters a few times. The first interruption occurred during Test 1 between 44.2 and 44.8 hours of operation due to failure of the ADS pump poppet valve and subsequent rod out of the feed tube. During Test 3, between 72.8 and 73.3 hours, the feed was stopped to due to an observed slight excess of cold cap along with a small decrease of melt pool temperature below the target value. Again, feeding was secured between 116.8 and 117.8 hours while the air flow between the bubblers was adjusted to dissolve an observed feed mound on the melter west side, and between 161.1 and 162.3 hours to

clear film cooler and transition line blockages. The system was switched to the emergency off-gas system and 0.254 kg of solid material was removed from the transition line bellows. During Test 8, between 34.9 and 35.7 hours the feed was stopped due to malfunctioning of the ADS poppet valve. The ammonia system was secured at 91.5 hours in Test 8 due to failure of the TCO/SCR heater. (Before the next test, on 8/18/03, the TCO/SCR heater main control board was replaced.) Again during Test 8, between 121.2 and 122.8 hours the feed was stopped to rod out the film cooler, as well as to dissolve excessive cold cap. During Test 10 between 55.0 and 56.4 hours, the feed was stopped due to mounding of the cold cap on the west side of the melter. Between 73.0 and 73.7 hours, feed was stopped to add sodium sulfate solution to the feed tank, and between 115.7 and 117.1 hours to reduce the cold cap ridge in the middle of the melter. During Test 9, at 36.2 hours, a booster pump was installed on the SBS cooling coil water line. At 101.2 hours, the SBS recirculation pump was replaced. At 140.2 hours, feeding was secured for 9 minutes to take still pictures of the SBS down-comer.

5.1.1 Melter Pressure

Test 2

The computer-logged melter pressures measured at the instrument port and calculated control air flow rates are plotted in Figure 5.7. The average melter pressure was -4.1 in. W.C. and melter pressure ranged from -7.3 in. W.C. to 0.2 in. W.C. The test ended at 219.9 hours. The control air system, to control melter pressure, was operational and effective during this test and its flow rate averaged 51.7 scfm. A review of the data files showed that only one positive pressure value was recorded; this occurred at 190 hours due to off-gas sampling.

The differential pressures across the transition line and film cooler are given in Figure 5.8. The film cooler was rinsed every 12 hours with 5 liters of water; however, the resultant short-term temperature decreases are not apparent in Figure 5.8 because of the time-averaging.

For reference, the connection pieces between the melter and SBS are shown in Figures 5.9 and 5.10. Figure 5.9 shows the sequence of transition line pieces connecting to the melter side. The transition line bellows shown on Figure 5.9 connects to the SBS side Y-piece shown in Figure 5.10; this piece then connects to the lid of the SBS. The Y-piece allows access to the SBS down-comer for inspections and cleaning and was used for post-test inspections, as described in the following sections.

The masses of the solid deposits removed from the film cooler and transition pipe sections are given in Table 5.4. Photographs of the solid deposits at the inlet and outlet of the film cooler are shown in Figures 5.11 and 5.12. Photographs of the solid deposits at the inlet and outlet of transition line section #1 are given in Figures 5.13 and 5.14. The largest mass of solids (2.28 kg) was collected from transition line section #2. The photographs of the solids deposits at the inlet and outlet of transition line section #2 are given in Figures 5.15 and 5.16. Photographs of the solid deposits at the inlet and outlet of transition line section #3 are given in Figures 5.17 and 5.18. Photographs of the solid deposits at the inlet and outlet of the transition line bellows

are given in Figures 5.19 and 5.20. Photographs of the solid deposits at the inlet and outlet of the transition line on SBS side are given in Figures 5.21 and 5.22. The film cooler and all sections of the transition line were cleaned before reassembly.

The solid deposits in the film cooler, transition line sections #1, #2, #3, transition line bellows, and transition line section #4 are the result of accumulations since 3/5/03, right after C-104/AY-101 HLW simulant test [12]. The maximum solids deposition was in transition line section #2 in both cases. The mass of solids collected from this section were 3.11 kg on 3/5/03 and 2.28 kg on 6/11/03. The tests conducted between the two dates were Tests 5, 6, and 2 of the HLW Reductant/Configuration series during which approximately 26,000 kg of glass was poured. The transition line differential pressure increased during the latter half of Test 6 [17] and was fairly steady during Test 2 (Figure 5.8), suggesting that the bulk of the transition line deposits may have occurred during Test 6.

Test 1

The computer-logged melter pressures measured at the instrument port and calculated control air flow rates are plotted in Figure 5.23. The average melter pressure was -3.8 in. W.C. and melter pressure ranged from -7.0 in. W.C. to 2.0 in. W.C. The test ended at 170.7 hours. The control air system, to control melter pressure, was operational and effective during this test and its flow rate averaged 53.8 scfm. A review of the data files showed that seven positive pressure values were recorded. The minor pressurizations within the first 4 hours of testing were associated with startup and cold cap development. Two positive pressure spikes, occurring at around 3 hours, appear to have resulted from foaming. Evidence of foaming at about three hours run time can be observed as a 0.2 g/ml decrease in melt density and an increase in melt level of 1.5" in Figure 3.6.b.

The differential pressures across the transition line and film cooler are provided in Figure 5.24. The film cooler was rodded out at 20 hours and 112 hours due to blockage. Two upward film cooler differential pressure peaks correspond to these times. Additionally, the film cooler was rodded out at 38, 45, 49, 61, 98, 120, 125, and 129 hours of operations due to increasing differential pressures. The transition line and its differential pressure sensor line were cleaned by gently tapping at 113 hours. The film cooler differential pressure sensor experienced occasional sensitivity problems and showed erratic readings, particularly around 60 hours and between 125 and 163 hours of runtime. The instrument and wiring were checked when the erratic readings occurred around 60 hours, but no specific cause of the problem could be determined.

After the test, the film cooler, transition pipe sections #2, #3, and transition line bellows were inspected. A photograph of the solid deposits at the inlet transition line section #2 is given in Figure 5.25 and shows a slight solids build-up. A photograph of the transition line section #3 is given in Figure 5.26 and shows very little particulate. A photograph of the solid deposits at the transition line bellows inlet is given in Figure 5.27. About 10 grams of solid deposits was removed from the transition bellows. The film cooler and above mentioned sections of the transition line were cleaned before reassembly.

Test 3

The computer-logged melter pressures measured at the instrument port and calculated control air flow rates are plotted in Figure 5.28. The average melter pressure was -3.5 in. W.C. and melter pressure ranged from -6.4 in. W.C. to 3.2 in. W.C. The test ended at 177.2 hours. The control air system, to control melter pressure, was operational and effective during this test and its flow rate averaged 67.0 scfm. A review of the data files showed that twelve positive pressure values were recorded. Two pressure spikes (at 102 and 154 hours) resulted when stalactites on the feed tube were removed (by tapping the feed tube with a rubber mallet). The remaining positive pressures occurred while rodding the film cooler (8 occurrences) or when the transition line was blocked and the off-gas system was switched over to the emergency off-gas system (2 occurrences).

The differential pressures across the transition line and film cooler are given in Figure 5.29. The film cooler required frequent rodding out; these rod-outs occurred at 17, 33, 56, 68, 75, 81, 88, 96, 100, 107, 121, 137, 150, 157, 161, 169 and 174 hours. The film cooler differential pressure increased due to increased clogging leading up to each rod-out. The transition line also clogged and was rodded out at 33, 53, 107, 161 and 174 hours because of increasing differential pressure. The upward peaks for the transition line differential pressures (see Figure 5.29) correspond to these times. At around 162.3 hours, the transition line bellows was removed due to clogging and a 4" diameter chunk of solid, which is shown in Figure 5.30.a, plus a small amount of debris totaling 0.254 kg were taken out of the bellows. An SEM macro image of particles in sample 1D2-O-25A, which is shown in Figure 5.30.b, indicates a reddish glassy admixture inundated with pores and periodically encrusted with a whitish substance. An SEM/EDS spectrum of this sample is presented in Figure 5.30.c. Observations about this sample can be summarized as follows:

- A general spectrum taken in a region that showed a somewhat eroded appearance in SEM BSE revealed that the mixture primarily contained Na, Al, Si, Fe, Zn, S, and Cl.
- In regions where whitish material was evident, high Na, S, and Cl peaks were observed.
- Sodium sulfate was readily observed across the sample.
- In areas where the surface had been cleaved, various undissolved feed components were observed in the cross section. Most notable was a sodium zirconium silicate.
- The material contains the major feed components indicating entrainment of feed components into the exhaust stream as well as higher than feed concentrations of volatile components such as sulfur indicating volatilization from the glass surface or cold cap.

At the end of the test, the film cooler was removed and inspected. Figures 5.31 shows some glazed build up of solids on air vent holes at the very bottom of the film cooler. Figure 5.31 also shows moderate particulate buildup on its louvers. The film cooler was replaced on 7/23/03, before Test 8. The transition line segments were not inspected after the test.

To cool and protect the film cooler during periods of extended idling, air from the discharge dam cooling air flow, which goes to the bypass off-gas piping during testing, is routed to the film cooler inlet where it mixes with and lowers the temperature of the air flowing from

the melter plenum into the film cooler. The cooling air flow rate is about 23 scfm at a temperature of about 135 °C at the outlet of the dam. This mixes with the plenum air, which is typically around 1020 °C during idling. As a result of this cooling system, the film cooler internal temperature is about 540 °C during idling.

Test 8

The computer-logged melter pressures measured at the instrument port and calculated control air flow rates are plotted in Figure 5.32. The average melter pressure was -3.2 in. W.C. and melter pressure ranged from -6.5 in. W.C. to 1.9 in. W.C. The test ended at 197.0 hours. The control air system, to control melter pressure, was operational and effective during this test and its flow rate averaged 49.5 scfm. Positive melter pressure values (approximately 20) occurred when the film cooler clogged and was rodded out.

The differential pressures across the transition line and film cooler are given in Figure 5.33. The film cooler was rodded out 34 times, including more concentrated periods of rodouts of: 15 times between 50 and 85 hours, 4 times between 107 and 128 hours, and 6 times between 169 and 188 hours. The film cooler differential pressure increased during the clogging. Since the plotted differential pressure values are hourly average values, the effect of film cooler clogging is not evident in every case in Figure 5.33. Film cooler and transition line sections were not inspected after this test.

Test 10

The computer-logged melter pressures measured at the instrument port and calculated control air flow rates are plotted in Figure 5.34. The average melter pressure was -3.2 in. W.C. and melter pressure ranged from -7.0 in. W.C. to 0.8 in. W.C. The test ended at 173.4 hours. The control air system, to control melter pressure, was operational and effective during this test and its flow rate averaged 58.3 scfm. The control air set-point was adjusted from -4.0 in. to -3 in. W.C. at 56 hours and it was readjusted from -3 in. W.C. to -3.75 in. W.C. at 66 hours of operations. Adjustments to the control air set-point are made based on melter plenum pressure behavior. A higher set-point (e.g., -4.0 in. W.C.) means a higher target melter vacuum, and typically the set-point is at a higher value at the beginning of a test when the injection of feed into the hot plenum and onto the hot melt surface produces larger spikes of steam. This higher set-point value results in more of the total flow being drawn from the plenum and less from the control air injection stream. As the cold cap develops and the plenum temperature stabilizes at a lower temperature, the control air set-point is typically lowered (e.g., to -3.0 in. W.C.) in order to reduce the amount of total air being drawn from the plenum and increase the amount of control air. This in turn tends to reduce the amount of material carryover from the plenum. However, if plenum pressure spikes are observed, due to poor cold cap behavior, rapid incorporation of cold cap pieces into the melt, or foaming, operators adjust the control air set-point upward to provide a greater vacuum margin to handle the off-gas flow surges.

The differential pressures across the transition line and film cooler are given in Figure 5.35. At 17 hours the film cooler clogged, with the differential pressure rising to 7.7 in. W.C., and the film cooler was therefore rodded out. At around 27 hours, partial film cooler clogging was noticed. At 20 and 161 hours, the transition line clogged; the clog was dislodged by tapping on the pipe with a rubber mallet.

The mass of solids removed from the film cooler was 0.57 kg. The mass of solids removed from the transition lines and bellows was 1.5 kg. Photographs of the solids deposits at the inlet and outlet of the film cooler are shown in Figures 5.36 through 5.38. Photographs of the solids deposits at the inlet and outlet of transition line section #1 are given in Figures 5.39 and 5.40. Photographs of the solids deposits at the inlet and outlet of transition line section #2 are given in Figures 5.41 and 5.42. Photographs of the solids deposits at the inlet and outlet of transition line section #3 are given in Figures 5.43 and 5.44. Photographs of the solids deposits at the inlet and outlet of the transition line bellows are given in Figures 5.45 and 5.46. A photograph of the solids deposits at inlet of the transition line on SBS side is given in Figure 5.47. The white deposits seen in the figures are presumed to be alkali metal oxides. The film cooler and all sections of the transition line were cleaned before reassembly. The cleaned film cooler inlet and outlet are shown in Figures 5.48 and 5.49.

Test 9

The computer-logged melter pressures measured at the instrument port and calculated control air flow rates are plotted in Figure 5.50. The average melter pressure was -3.0 in. W.C. and melter pressure ranged from -5.5 in. W.C. to 0.1 in. W.C. The test ended at 222.8 hours. The control air system, to control melter pressure, was operational and effective during this test and its flow rate averaged 40.6 scfm. A positive pressure value of 0.1 in. W.C. was recorded by LabVIEW during cold cap sampling and an additional two positive pressure values were recorded in the operations logbook during off-gas sampling.

The differential pressures across the film cooler and transition line are given in Figures 5.51 and 5.52, respectively. At 166.2, 183.9, 205.8, 210.3, and 213.5 hours of operation, the film cooler clogged at about 80%, 60%, 75%, 80%, and 80% occlusion, respectively, and was rodded out each time. In Figure 5.53, a view of the film cooler clogging at 166.2 hours is provided; this was taken with a camera mounted on the view-port on top of the film cooler. The differential pressure across the film cooler rose to 8.4 in. W.C. at this time. During this test, the film cooler was rinsed only once, at 15.4 hours. The change in rinse protocol was made in order to facilitate photography of film cooler blockages [41]. For these tests, the film cooler was rinsed by injecting the rinse water at the approximate location where the film cooler air is injected. The air and water then mixed and flowed down the film cooler annulus to the bottom of the film cooler.

Figure 5.54 shows some glazed buildup of solids on air vent holes at the very bottom of the film cooler. A photograph of the solids deposits at the outlet of the film cooler is shown in Figure 5.55. Photographs of the slight solids deposits at the inlet and outlet of transition line

section #1 are given in Figures 5.56 and 5.57. Photographs of the slight solids deposits at the inlet and outlet of transition line section #2 are given in Figures 5.58 and 5.59. Photographs of the slight solids deposits at the inlet and outlet of transition line section #3 are given in Figures 5.60 and 5.61. Photographs of the solids deposits at the inlet and outlet of the transition line bellows are given in Figures 5.62 and 5.63. Photographs of the solids deposits at inlet of the transition line section #4 are given in Figures 5.64, 5.65, and 5.66. The film cooler was partially cleaned, as shown in Figure 5.67, before the next test. The transition line sections were deliberately not cleaned before reassembly; however, some rough solids at transition line section #4 inlet and the bellows inlet fell away.

Film cooler rod-outs and transition line blockages appear to present significant operational issues at higher glass production and corresponding bubbling flow rates. Earlier tests with AZ-101 feed did not result in blockage problems [6, 9]. None of the AZ-101 HLW tests performed between 6/25/01-11/10/01 (Test 1 through Test 9) [6] experienced transition line or film cooler blockages requiring cleanout. For these tests, the average bubbling rates ranged from no bubbling (<4 lpm) to the maximum of 60 lpm. Similarly, the AZ-101 HLW tests performed between 7/23/02-10/24/02 (Test 1 through Test 6) [9] experienced no blockages of the transition line requiring cleanout. Blockage of the film cooler was also not a particular problem, although the film cooler had to be tapped with a rubber mallet once during the first test of the series. For these tests, the instantaneous bubbling rates ranged from <1 to 109 lpm, with test-average values ranging up to 73 lpm.

A summary of the solids deposition in the film cooler, transition line, and SBS for the HLW Reductant and Configuration Tests is presented in Table 5.5. Significant numbers of rod-outs were required in Tests 1, 3, 8, and 9. Most of these rod-outs occurred at bubbling rates above 65 lpm, suggesting that the higher bubbling flow rates may promote solids carryover. For Test 3, 15 of the rod-outs were at bubbling rates greater than 65 lpm; for Tests 8 and 9, all of the rod-outs were at these increased bubbling rates above 65 lpm.

5.1.2 SBS Performance

SBS inlet and outlet gas temperatures, pressures and flow rates, pressure drop across the SBS, SBS water temperature, heat exchanger inlet and outlet water temperatures, and flow rates were recorded during the test. The amounts of heat removed by the SBS jacket cooling water, and the plate heat exchanger/SBS inner cooling coil were calculated from the measured data. Before the last test, Test 9, the internal design of the SBS and cooling patterns were changed as discussed in Section 1.4.5.

Data on the performance of the SBS regarding solids removal from the off-gas stream are presented and discussed in Section 7.0. Results from the analysis of fluids accumulated in the SBS are presented and discussed in Section 5.2.

Test 2

The SBS inlet and outlet gas temperatures are plotted in Figure 5.68. The inlet gas temperature averaged 266°C, and the outlet gas temperature averaged 40.0°C. The maximum SBS inlet temperature (417°C) and outlet temperature (50.8°C) occurred during the initial feeding stages when the plenum temperature was still high and decreasing. The downward spikes in SBS inlet gas temperatures are due to periodic cleaning of the film cooler with water. At around 148 hours, the SBS outlet gas temperature increased due to reduced jacket water flow rate and high SBS inner coil water temperature. The inlet, outlet, and differential pressures are shown in Figure 5.69. The inlet gas pressure averaged -9.7 in. W.C., the outlet pressure averaged -49.6 in. W.C., and the pressure drop across the SBS averaged about 39.9 in. W.C. The pressure drop across the SBS increased by about 2.0 in. W.C. over 219.9 hours of testing with HLW AZ-101 feed during Test 2.

Water temperatures in the SBS, SBS chilled cooling water supply temperature, water cooling jacket outlet temperature, and water outlet temperature from the plate heat exchanger, are shown in Figure 5.70. There was an average of about 2.8°C difference in water temperatures measured at four depths (48, 60, 72 and 78 inches) within the SBS. The liquid in the SBS was heated to a maximum temperature of 61.9°C while the average SBS sump temperature was 43.5°C. Since the flow rate of the plate heat exchanger and jacket water decreased at 22 and 147 hours, respectively, outlet water temperatures of both increased at the corresponding times.

The SBS jacket, inner coil, and heat exchanger water flow rates are plotted in Figure 5.71. Average SBS jacket, inner coil, and heat exchanger water flow rates were 8.8, 24.4 and 6.8 gpm, respectively. The amounts of heat removed by the SBS cooling jacket and the plate heat exchanger are shown in Figure 5.72. The heat load data for SBS cooling jacket and plate heat exchanger are calculated based on hourly averaged cooling water temperature increases (outlet temperature minus supply temperature) across the cooling jacket and plate heat exchanger multiplied by the time-averaged flow rate through each. For this test, heat removal averaged 34.7 kW by the plate heat exchanger and 18.6 kW by the cooling jacket. About 65% of the heat load to the SBS was removed by the plate heat exchanger and about 35% by the cooling jacket. The SBS inner coil and plate exchanger water temperatures are plotted in Figure 5.73. The heat load data for the SBS inner coil was also calculated based on hourly averaged cooling coil water temperature increases (coil water outlet minus its inlet temperature) multiplied by the hourly averaged flow rate of the inner cooling coil water. The average SBS inner coil heat load was 37.3 kW.

At the end of Test 2, the SBS was blown down; 366.2 gallons were drained from the SBS itself and 22.5 gallons from the SBS overflow tank. A total of 26.22 kg of solids (dry weight) was removed from the SBS overflow tank, 8.63 kg of solids was removed from the SBS bowl, and 0.83 kg of solids was removed from the SBS down-comer. An infra-red video inspection was made of the SBS down-comer.

Unlike the two previous runs, the top of the Y-inlet (from the transition line) to the SBS down-comer had minimal solids, but the deposits on the top section of the down-comer were

significantly heavier. Figure 5.74 shows the relatively thick, heavy (about 1/8" thick), probably friable flakes, found in Test 2 instead of the small nodules seen in the previous runs. Figure 5.75 shows a ridge of deposits, about 1/16" to 1/8" thick, at about 5'6" below the top view-port. This ridge marks the boundary of the flake-like deposits, and below this ridge, surface deposits were much lighter and nodular in nature. Figure 5.76 shows the ring of deposits, which blocked 80% of the down-comer at a few inches above the bottom of the down-comer. Wire-brush cleaning/rod-out removed essentially all of the deposits from the down-comer.

Figure 5.77 shows the SBS bowl, which was dropped as part of a post-run inspection. About 12.19 kg of wet solids, much of it ceramic saddles, was collected from the SBS bowl. Some of the saddles are clearly visible in Figure 5.77 as the white specks in the debris pile. The saddles themselves, which would require at least a 3/8" opening to pass, could not be blown-down through the blow-down wand, which has 1/8" slots. Most of the saddles appeared intact, not broken. The higher amount of solids than usual trapped in the SBS bowl was due in part to two out of the four SBS bowl circulating lances being skewed. Normally, the four lances are arranged in a spiral (tangential) pattern to encourage circulation in the bowl during operation, thus preventing solids from settling on the bottom. Two of the lances (diametrically opposed) had been mis-installed after the previous SBS bowl inspection, preventing the optimum swirling flow, and allowing a higher than usual solids accumulation. The saddles and SBS solids accumulated in the southwest quadrant of the SBS bowl, the apparent dead spot in SBS bowl circulation. The bowl was cleaned of debris prior to the following run.

The presence of saddles in the SBS bowl after DM1200 testing has been documented previously [6, 10, 11, 12, 17, 30]. The original failure of the saddles, and their removal and replacement with ceramic balls is described in Reference [38]. When the original saddles were replaced with ceramic balls, some were lodged between the weir tubes at the bottom of the bed and could not be removed. The route taken by these saddles and pieces in getting to the SBS bowl bottom during DM1200 tests is not known. Note that the screen openings are 0.218" square, and the weir tube hole diameters are 3/8". No broken screen openings have been observed.

Test 1

The SBS inlet and outlet gas temperatures are plotted in Figure 5.78. The inlet gas temperature peaked at 411.2°C and averaged 284.3°C, and the outlet gas temperature peaked at 51.9°C and averaged 40.7°C. Both maximum temperatures, inlet and outlet, occurred at the beginning of the test when the plenum was still hot. The downward spikes in SBS inlet gas temperatures are due to periodic cleaning of the film cooler with water. The outlet gas temperature shows a minimum between 44.2 and 44.8 hours of operations because the feed was stopped due to failure of a solenoid valve associated with feed system, and the feed tube was rodded out at this time. The inlet, outlet, and differential pressures are shown in Figure 5.79. The inlet gas pressure averaged -7.5 in. W.C., the outlet pressure averaged -45.5 in. W.C., and the pressure drop across the SBS averaged about 37.9 in. W.C. The inlet and outlet SBS gas pressure decreased at 11.2 hours when the transition line was rodded out. The pressure drop across the

SBS increased by about 2.2 in. W.C. over 170.7 hours of testing with HLW AZ-101 feed.

Water temperatures in the SBS, SBS chilled cooling water supply temperature, water cooling jacket outlet temperature, and water outlet temperature from the plate heat exchanger, are shown in Figure 5.80. There was an average of about 3.2°C difference in water temperatures measured at four depths (48, 60, 72 and 78 inches) within the SBS. The liquid in the SBS was heated to a maximum temperature of 64.2°C during the initial period of water feeding, while the average SBS sump temperature was 47.4°C. Whenever the building cold water supply temperature increased, the water temperature in the SBS plate and jacket water outlet temperature followed that trend.

The SBS jacket, inner coil, and heat exchanger water flow rates are plotted in Figure 5.81. Average SBS jacket, inner coil, and heat exchanger water flow rates were 22.9, 24.1, and 19.6 gpm, respectively. The amounts of heat removed by the SBS cooling jacket and the plate heat exchanger are shown in Figure 5.82. The heat load data for SBS cooling jacket and plate heat exchanger are calculated based on hourly averaged cooling water temperature increases (outlet temperature minus supply temperature) across the cooling jacket and plate heat exchanger multiplied by the time-averaged flow rate through each. For this test, heat removal averaged 57.6 kW by the plate heat exchanger and 23.4 kW by the cooling jacket. About 71% of the heat load to the SBS was removed by the plate heat exchanger and about 29% by the cooling jacket. The SBS inner coil and plate exchanger water temperatures are plotted in Figure 5.83. The heat load data for SBS inner coil was also calculated based on hourly averaged cooling coil water temperature increases (coil water outlet minus its inlet temperature) multiplied by the hourly averaged flow rate of inner cooling coil water. The average SBS inner coil heat load was 62.0 kW.

At the conclusion of Test 2, diagnostic tests indicated that a weld sealing a sleeve to the outside of the lower portion of the down-comer (through the packed bed) was cracked, essentially allowing this sleeve to fill with the SBS fluid. This weld was repaired, and a pressure tap was permanently installed to provide an indication of any future leaks. Also, a new insulating sleeve was installed on the down-comer, insulating the down-comer from the top of the packed bed to the top lid of the SBS shell. Figure 5.84(a) is a photograph of the outside of the SBS down-comer above the packed bed, prior to the installation of the upper sleeve; Figure 5.84(b) shows the upper sleeve and pressure tap. At the time of the installation of the upper sleeve, 15.1 kg of packing was added to the top of the SBS bed.

At the end of Test 1, the SBS was blown down and 40.0 gallons of liquid was removed from the SBS overflow tank. The volume blown down from the SBS itself was not recorded. (The final SBS and SBS tank blow-down volumes are not part of the water mass balance around the SBS, since each run arbitrarily starts and finishes with both the SBS and the SBS overflow tank at the same levels for all runs.) The only solids recovered from around the SBS at the end of this run were 10 grams of material recovered from the transition line bellows.

An infra-red video inspection was made of the SBS down-comer. The upper half of the SBS down-comer had a heavier layer of large smooth, apparently friable “flakes” on the internal

surface than was the case in previous runs. Figure 5.85, an IR-image taken from about 5'6" down, shows these flakes. Below 6' down within the down-comer, the internal surface was clean. Figure 5.86 shows a ring of deposits a few inches above the base of the down-comer, blocking approximately 25% of the flow area. The average height of this ridge of deposits is estimated to be about ½". No solids were visible around the blow-down lance in the SBS sump, although it is possible there were solids submerged below the liquid level.

Test 3

Prior to Test 3, the SBS recirculation pump SBS-PW-501 was found to have a leaking seal and was replaced. The SBS inlet and outlet gas temperatures are plotted in Figure 5.87. During Test 3, between 72.8 and 73.3 hours, the feed was stopped to recover melter pool temperature, which had dropped slightly. Again, between 116.8 and 117.8 hours, feeding was secured to adjust the bubbler flow between bubblers in order to reduce an observed feed mound on the melter West side. Between 161.1 and 162.3 hours, the system was switched to the emergency off-gas system due to a transition line blockage, the effects of which can be seen in decreased inlet and outlet gas temperatures. The inlet gas temperature peaked at 457°C and averaged 296°C, and the outlet gas temperature peaked at 67.4°C and averaged 46.2°C. The downward spikes in SBS inlet gas temperatures are due to periodic cleaning of the film cooler with water. The inlet, outlet, and differential pressures are shown in Figure 5.88. The inlet gas pressure averaged -7.9 in. W.C., the outlet pressure averaged -45.8 in. W.C., and the pressure drop across the SBS averaged about 37.7 in. W.C. The pressure drop across the SBS increased by about 1.7 in. W.C. over 177.2 hours of testing with HLW AZ-101 feed.

Water temperatures in the SBS, SBS chilled cooling water supply temperature, water cooling jacket outlet temperature, and water outlet temperature from the plate heat exchanger, are shown in Figure 5.89. As shown in the figure, there were occasional periods with increased temperature of the chilled water supplied to the SBS. There was about 3.0°C difference in average water temperatures measured at four depths (48, 60, 72 and 78 inches) within the SBS. The liquid in the SBS was heated to a maximum temperature of 73.0°C during the initial period of water feeding, while the average SBS sump temperature was 54.1°C. Whenever the building cold water supply temperature increased, the water temperature in the SBS plate and jacket water outlet temperature followed that trend. When the feed was stopped at 72.8, 116.8, and 161.1 hours, the temperatures of the water in the SBS decreased sharply.

The SBS jacket, inner coil, and heat exchanger water flow rates are plotted in Figure 5.90. The average SBS jacket, inner coil and heat exchanger water flow rates were 27.7, 24.2, and 21.9 gpm, respectively. The amounts of heat removed by the SBS cooling jacket and the plate heat exchanger are shown in Figure 5.91. The heat load data for the SBS cooling jacket and the plate heat exchanger are calculated based on hourly averaged cooling water temperature increases (outlet temperature minus supply temperature) across the cooling jacket and plate heat exchanger multiplied by the time-averaged flow rate through each. For this test, heat removal averaged 70.7 kW by the plate heat exchanger and 29.6 kW by the cooling jacket. About 70% of the heat load to the SBS was removed by the plate heat exchanger and about 30% by the cooling

jacket. The SBS inner coil and plate heat exchanger water temperatures are plotted in Figure 5.92. The heat load data for the SBS inner coil were also calculated based on hourly averaged cooling coil water temperature increases (coil water outlet minus its inlet temperature) multiplied by the hourly averaged flow rate of inner cooling coil water. The average SBS inner coil heat load was 75.6 kW.

At the end of Test 3, the SBS was blown down; 361.3 gallons of fluid was drained from the SBS itself and 26 gallons from the SBS overflow tank. The only SBS-related solid sample recovered at the end of this run was 46.11 kg of dry solids from the SBS overflow tank. An infrared video inspection was made of the SBS down-comer. Figure 5.93 illustrates fairly smooth deposits at the top of the SBS down-comer at about 2'6" down from the top of the view-port (at the bottom of the Y-inlet from the transition line). Moving down in the top half of the down-comer, the deposits became thinner, becoming apparently large friable flakes; Figure 5.94 shows the flakes ending about 5'6" down from the view-port. At the bottom, there was essentially no ring of deposits at the base of the down-comer. Figure 5.95 shows that the blow-down wand in the SBS bowl was partially buried in solids. Burial of the wand likely indicates insufficient circulation within the SBS bowl in comparison to the solids load and settling tendency [17].

Test 8

The SBS inlet and outlet gas temperatures are plotted in Figure 5.96. Between 34.9 and 35.7 hours, and 121.2 and 122.8 hours of operation, the feed was turned off, the effect of which can be seen in decreased inlet and outlet gas temperatures. The inlet gas temperature peaked at 389°C and averaged 305°C, and the outlet gas temperature peaked at 55.9°C and averaged 47.7°C. The downward spikes in SBS inlet gas temperatures are due to periodic cleaning of the film cooler with water. The inlet, outlet, and differential pressures are shown in Figure 5.97. The inlet gas pressure averaged -7.7 in. W.C., the outlet pressure averaged -46.2 in. W.C., and the pressure drop across the SBS averaged about 38.1 in. W.C. At 165.5 hours, the SBS differential pressure sensor lines were checked, possibly eliminating some blocking, and the measured differential pressure came down. The pressure drop across the SBS increased by about 2.2 in. W.C. over 197.0 hours of testing with HLW AZ-101 feed. Water temperatures in the SBS, SBS chilled cooling water supply temperature, water cooling jacket outlet temperature, and water outlet temperature from the plate heat exchanger, are shown in Figure 5.98. There was about 3.3°C difference in average water temperatures measured at four depths (48, 60, 72 and 78 inches) within the SBS. The liquid in the SBS was heated to a maximum temperature of 72.2°C during the initial period of water feeding, while the average SBS sump temperature was 56.8°C. The SBS water temperature decreased sharply during the times when the feed was stopped at 34.9 and 121.2 hours for 0.8 and 1.6 hours, respectively.

The SBS jacket, inner coil, and heat exchanger water flow rates are plotted in Figure 5.99. The average SBS jacket, inner coil and heat exchanger water flow rates were 23.2, 24.2, and 24.3 gpm, respectively. The amounts of heat removed by the SBS cooling jacket and the plate heat exchanger are shown in Figure 5.100. The heat load data for the SBS cooling jacket and plate heat exchanger are calculated based on hourly averaged cooling water

temperature increases (outlet temperature minus supply temperature) across the cooling jacket and plate heat exchanger multiplied by the time-averaged flow rate through each. For this test, heat removal averaged 84.9 kW by the plate heat exchanger and 31.0 kW by the cooling jacket. About 73% of the heat load to the SBS was removed by the plate heat exchanger and about 27% by the cooling jacket. The SBS inner coil and plate exchanger water temperatures are plotted in Figure 5.101. The heat load data for SBS inner coil was also calculated based on hourly averaged cooling coil water temperature increases (coil water outlet minus its inlet temperature) multiplied by the hourly averaged flow rate of inner cooling coil water. The average SBS inner coil heat load was 89.8 kW.

At the end of Test 8, the volumes of fluid blown down from the SBS and the SBS overflow tank were not recorded. Post-run dry solids removed from the SBS overflow tank totaled 51.6 kg. An infra-red video inspection was made of the SBS down-comer. Traversing down the down-comer in the IR video inspection, at just below the Y-inlet from the transition line (2'-6" down), large, generally smooth, heavy flakes could be seen, along with debris that had rolled along the bottom of the transition line. Figure 5.102 shows this debris track to the lower left. Figure 5.103 shows that the heavy flakes ended fairly sharply at about 5'6" below the top of the down-comer. Between 5'6" to 6' down was a very thin (translucent to IR) layer of deposits, which ended abruptly at 6' down. Below 6' down, the down-comer was clean. The base of the down-comer had less than 1% obstruction (> 99% open). The blow-down wand was half-buried in solids, with one ceramic packing ring visible.

Test 10

The SBS inlet and outlet gas temperatures are plotted in Figure 5.104. During Test 10 between 55.0 and 56.4 hours, the feed was stopped due to cold cap mounding on the west side. Between 73.0 and 73.7 hours, feed was stopped to add sodium sulfate solution to the feed tank, and at 115.7 and 117.1 hours to reduce the cold cap ridge in the middle of the melter. The effect of turning off feed can be observed in decreased inlet and outlet gas temperatures. The inlet gas temperature peaked at 367°C and averaged 268°C, and the outlet gas temperature peaked at 54.3°C and averaged 41.2°C. The downward spikes in SBS inlet gas temperatures are due to periodic cleaning of the film cooler with water. The inlet, outlet, and differential pressures are shown in Figure 5.105. The inlet gas pressure averaged -5.4 in. W.C., the outlet pressure averaged -45.6 in. W.C., and the pressure drop across the SBS averaged about 39.4 in. W.C. The pressure drop across the SBS increased by about 1.6 in. W.C. over 173.4 hours of testing with HLW AZ-101 feed. Water temperatures in the SBS, SBS chilled cooling water supply temperature, water cooling jacket outlet temperature, and water outlet temperature from the plate heat exchanger, are shown in Figure 5.106. There was about 3.7°C difference in average water temperatures measured at four depths (48, 60, 72 and 78 inches) within the SBS. The liquid in the SBS was heated to a maximum temperature of 50.7°C during the initial period of water feeding, while the average SBS sump temperature was 48.1°C. The SBS water temperature decreased sharply during the times when the feed was stopped at 55.0, 73.0, and 115.7 hours for 1.4, 0.7, and 1.4 hours, respectively.

The SBS jacket, inner coil, and heat exchanger water flow rates are plotted in Figure 5.107. The average SBS jacket, inner coil, and heat exchanger water flow rates were 18.7, 24.1, and 20.3 gpm, respectively. The amounts of heat removed by the SBS cooling jacket and the plate heat exchanger are shown in Figure 5.108. The heat load data for the SBS cooling jacket and plate heat exchanger are calculated based on hourly averaged cooling water temperature increases (outlet temperature minus supply temperature) across the cooling jacket and plate heat exchanger multiplied by the time-averaged flow rate through each. For this test, heat removal averaged 61.9 kW by the plate heat exchanger and 22.8 kW by the cooling jacket. About 73% of the heat load to the SBS was removed by the plate heat exchanger and about 27% by the cooling jacket. The SBS inner coil and plate exchanger water temperatures are plotted in Figure 5.109. The heat load data for the SBS inner coil were also calculated based on hourly averaged cooling coil water temperature increases (coil water outlet minus its inlet temperature) multiplied by the hourly averaged flow rate of inner cooling coil water. The average SBS inner coil heat load was 66.8 kW.

At the end of Test 10, a combined total of 412.1 gallons was blown down from the SBS shell and the SBS overflow tank; separate volumes were not recorded. Post-run dry solids included 29.5 kg from the SBS overflow tank, which is shown in Figure 5.110 before drying, 15.3 kg from the SBS bowl, and 0.6 kg from the SBS down-comer. An infra-red video inspection was made of the SBS down-comer.

Near the top of the down-comer, just below the Y-inlet from the transition line, was a more or less smooth layer of thin ($\sim 1/16''$) flakes. These flakes ended fairly sharply at about 6' below the top view-port, and Figure 5.111 shows a series of 3-4 irregular, very thin rings of deposits between 6' and 7' down. Below 7', the down-comer was clean except for a ring of deposits near the base. Figure 5.112 shows this ring, which blocked approximately 25% of the flow area. The estimated average ridge height of this ring of deposits was about $1/2''$.

Figure 5.113, a view of the SBS sump from the base of the down-comer, shows that the blow-down wand was somewhat more than half buried in solids. A few packing saddles can be seen in this pile of solids. This figure shows conditions essentially the same as in the SBS bowl at the end of the previous test; there might have been a very small increase in the amount of solids, but there is certainly not a decrease in the amount.

A problem had been noted with the SBS recirculation pump during the immediately previous test (Test 4, see Table 5.1); in essence, the SBS internal circulation had been greatly reduced. It would be expected that reduction of circulation would cause an increase in the accumulation of solids in the SBS bowl. Figure 5.95 indicates that the accumulation of solids had already started during Test 3 in mid-July, prior to Test 4 when the pump problems were first noticed. It is, however, plausible that the recirculation pump problem started during the time of Test 3, but was only noticed later during Test 4. The persistence of the solids in the SBS bowl through multiple test campaigns can be seen by comparing Figures 5.95 and 5.113. The recirculation pump was functional for the last of these campaigns. This suggests that once particulates settle out in the SBS bowl for a significant time, they will not be re-suspended by the pump. Operators removing these SBS bowl solids after Test 10 noted that the deposits were very hard to remove from the SBS bowl. Figure 5.114 is a visible-light image of the solids pile in the

SBS bowl following Test 10. Several of the ceramic saddles can be recognized in Figure 5.114.

Test 9

Before Test 9, the internal structure of the SBS was modified as described in Section 1.4.5. The changes included design changes to the SBS itself and rerouting of the SBS cooling water to connect the coil and jacket in series instead of parallel. Figures 1.13 through 1.17 display the modified SBS. Thermocouples were installed at various levels (measured from the SBS lid) on the outside of the SBS down-comer inner sleeve, which is shown in Figure 1.17. A new SBS overflow tank shown in Figure 5.115, was installed. The bottom of the overflow tank has a conical shape to avoid solids build-up and improve solids transfer to the collection tanks.

The SBS inlet and outlet gas temperatures are plotted in Figure 5.116. At 140.2 hours the feed was secured for 9 minutes to take still pictures of the SBS, and at 15.8 hours the film cooler was rinsed. The effects can be seen in decreased inlet gas temperatures. The film cooler was rinsed only once during this test. The inlet gas temperature peaked at 431°C and averaged 275°C, and the outlet gas temperature peaked at 54.4°C and averaged 47.5°C. The inlet, outlet, and differential pressures are shown in Figure 5.117. The inlet gas pressure averaged -7.3 in. W.C., the outlet pressure averaged -39.3 in. W.C., and the pressure drop across the SBS averaged about 31.9 in. W.C. This value is less than the pressure differences during the previous tests; the difference is largely due to the modification of the SBS. The pressure drop across the SBS increased by about 3.0 in. W.C. over 222.8 hours of testing with HLW AZ 101 feed. The SBS down-comer annulus pressure is given in Figure 5.118. A slight pressure decrease occurred over the latter portion of the test, possibly due to barometric changes. Near the end of the test, at 216 hours, a small amount of air was flowed into the annulus, which resulted in a small pressure recovery. Air flow through the SBS annulus was 30 scfh up to 22.9 hours. After 215.8 hours the flow was 10 scfh. SBS off-gas down-comer temperatures measured at 12 depths (from 3 to 58 inches at 5-inch intervals) and SBS sump water temperature are given in Figure 5.119. The indirectly measured off-gas temperatures decrease as the depth from the SBS lid increases, except for the measurements at 3 and 8 inches. This is due to the fact that the 3-inch and 8-inch locations are close to the SBS lid, which serves as a heat sink for these two locations. (The decrease in annulus temperature with increasing depth is the result of cooling of the hot off-gas by the SBS liquid.) After about 75 hours, temperatures at 53, 48, 43, and 38 inches decreased. The temperatures at 58 inches ranged from 51.9°C to 76.2°C and averaged 64.7°C. The average SBS sump temperature was 41.9°C, which is 5.6°C less than the SBS outlet gas temperature.

Water temperatures at the SBS inner cooling coil inlet, inner cooling coil outlet/jacket inlet, and jacket outlet are given in Figure 5.120. The average water temperature difference was 23.7°C and 1.5°C across the SBS inner cooling coil and jacket, respectively. The SBS cooling coil/SBS jacket water flow rate is plotted in Figure 5.121. At 36.2 hours, a booster pump was installed on the SBS cooling coil water line. Between 136.2 and 160.6 hours, control of the SBS cooling coil/jacket water flow rate was switched from “automatic SBS gas outlet temperature control” to manual control. The average SBS cooling coil/SBS jacket water flow rate was 19.7 gpm. The amounts of heat removed by the SBS inner coil and jacket are shown in

Figure 5.122. The heat load data for the SBS inner cooling coil and jacket are calculated based on hourly averaged cooling water temperature increases (outlet temperature minus supply temperature) across the SBS inner cooling coil and cooling jacket multiplied by the same time-averaged water flow rate through each. For this test, heat removal averaged 99.8 kW by the SBS inner cooling coil and 6.6 kW by the cooling jacket. About 93% of the heat load to the SBS was removed by the inner cooling coil and about 7% by the cooling jacket.

At 217.2 hours, the SBS down-comer was inspected from the top of the SBS down-comer. Figures 5.123 and 5.124 show views of the solids deposits as seen from the top of the down-comer. Percent occlusion of the open area seen in Figure 5.123 is ~36%, but since there is a ~1/4" solids layer behind the solids ring seen at the bottom of down-comer, the percent total occlusion is higher than 36%. The height of the bottom ring was 1" and the height of the ~1/4" thick solids layer was 1' from the bottom of the down-comer. After the test, a view of black solids deposits located at the splash zone right above that 1' high solids layer is shown in Figure 5.125. At the end of Test 9, the SBS was blown down, and 488.7 gallons of liquid were removed from the SBS and SBS overflow tank. Figure 5.126 shows the photograph of the SBS overflow tank drain area with a thin residue. There were almost no solids deposits left in the SBS overflow tank. After the inspection, the SBS bottom was filled with enough water to cover the SBS down-comer. The next day the SBS was totally blown down again, and the SBS bowl was lowered for inspection. Figures 5.127 and 5.128 show two views of the wet solids at the bottom of the SBS bowl. The weight of the wet solids was estimated to be about 8 kg; these solids were not removed from the bowl. A view of the bottom of the SBS diffuser plate and cooling coil is provided in Figure 5.129. Very slight solids residues can be seen on the SBS cooling coil. After city water addition and blow-down, the bottom part of the SBS down-comer, which was observed from the top of the SBS down-comer, is shown in Figure 5.130. The bottom solids ring had dissolved and disappeared, but there were solids deposits remaining from the previous 1' high and 1/4" thick solids deposit layer. As shown in Figure 5.131, there were black solids deposits covering the SBS packing. After the installation of the SBS bowl without removing the deposits, city water was added up to a level high enough to cover the bottom of the SBS down-comer.

5.1.3 WESP Performance

The inlet and outlet gas temperatures and differential pressure across the WESP were measured and recorded by the computer data acquisition system during the tests, while the WESP current and voltage were recorded manually.

Data on the performance of the WESP regarding solids removal from the off-gas stream are presented and discussed in Section 7.0. Results of the analysis of fluids that accumulated in the WESP are presented and discussed in Section 5.2.

Immediately prior to Test 2, an acid wash was conducted utilizing 20 gallons of 5% HNO₃, 2% HCl, and 0.7% Na₃PO₄ in a two-hour period. Figures 5.132 and 5.133 indicate the grid condition after this wash. These figures indicate what is occasionally apparent from

conventional deluges, that the central hex-cells are washed more thoroughly than the peripheral hex-cells. Figure 5.132 indicates that the central hex-cell walls are clean and shiny, whereas tenacious thin deposits remain on the outer hex-cell walls. Similarly, Figure 5.133 shows that the central rods have fewer surface deposits than the rods in the corner cells or the far-right cell.

Test 2

The WESP inlet and outlet gas temperatures are plotted in Figure 5.134. The WESP inlet gas temperature averaged 40.5°C and the outlet temperature averaged 42.1°C, indicating a 1.6°C temperature increase across the WESP during this test. The downward spikes in the WESP outlet temperature are a result of the daily deluge of the WESP. At around 148 hours, the WESP gas inlet and outlet temperatures increased suddenly due to increased SBS bed temperature, as explained in the SBS performance section for Test 2. The WESP differential pressure and outlet gas flow rate are plotted in Figure 5.135. The pressure drop across the WESP averaged 2.7 in. W.C. The average WESP wet gas flow rate was 214.3 scfm.

The amount of liquid accumulated in the WESP is plotted as a function of run time in Figure 5.136, where it is compared with the amount of fresh water sprayed into the WESP. The inlet spray water was set to 2.0 ± 0.2 gph, as specified by the Test Plan. The actual spray water flow rate was ≈ 2.02 gph. As evident from Figure 5.136, spray water accounts for the majority of the liquid accumulation in the WESP. The difference between accumulated liquid and fresh water sprayed is equal to the amount of liquid removed from the off-gas, which is also plotted in Figure 5.136. The WESP electrodes were deluged daily, as planned, with water at a nominal rate of 12 gpm for 3.33 minutes.

The WESP voltage and current are plotted as a function of run time in Figure 5.137. For Test 2, the average operating voltage and current were about 23.4 kV and 17.0 mA, respectively. The voltage and current remained steady throughout the test. The time required to manually stabilize power to operating values after deluges of the WESP ranged from 5 to 16 minutes and averaged about 9 minutes, as shown in Table 5.6. Starting with this test, the spraying procedure of the WESP was changed. The WESP spray was turned off for 5 minutes before the deluge and was restored 5 minutes after power stability was restored. This procedure drastically reduced the time required to stabilize WESP power after the deluge.

Figure 5.138 illustrates the deterioration which had occurred in the glass-filled PTFE grid support rods by the end of Test 2. These supports were replaced with Ultra-High Molecular Weight PolyEthylene (UHMWPE) at the conclusion of the test. Figure 5.139 was taken from a digital video of the post-deluge WESP grid. While no nodules are visible on the rods, a thin tenacious white film is visible on the hex walls; in this figure, the deposits are light (white) in color, and the bare metal is dark.

About 6.4 grams of solids (X12-O-154A) were removed from the WESP blow-down flow-indicating transmitter at 95.7 hours of operations during Test 2. A SEM micrograph of this yellowish-orange-red colored sample is given in Figure 5.140. EDS spectra of regions #1 through #4, indicated in Figure 5.140, are given in Figure 5.141 and revealed the material to be

primarily iron, selenium, and lead. Iron appeared to be distributed uniformly. A small phase containing Ag was observed occasionally at higher magnifications. X-ray maps seemed to indicate the presence of a calcium carbonate phase as well.

About 25.5 grams of solids (Z12-O-37H) was collected by tapping on the WESP support grid, electrodes and rods. A SEM micrograph of that sample is shown in Figure 5.142. An EDS spectrum of this sample is given in Figure 5.143, which revealed the material to be primarily iron oxide deposits; chlorine, phosphorus, selenium, sulfur, sodium, and calcium were observed as well, based on both EDS and X-ray mapping.

At the end of the test, 73.0 gallons of liquid was initially blown down. After a deluge, an additional 46.5 gallons of liquid was removed.

Test 1

The WESP inlet and outlet gas temperatures are plotted in Figure 5.144. The WESP inlet gas temperature averaged 40.0°C and the outlet temperature averaged 41.7°C, indicating a 1.7°C temperature increase across the WESP during this test. The downward spikes in the WESP outlet temperature are a result of the daily deluge of the WESP; however, a few of the minimum temperatures measured are unreasonably low. The WESP differential pressure and outlet gas flow rate are plotted in Figure 5.145. The pressure drop across the WESP averaged 2.5 in. W.C. The average WESP wet gas flow rate was 210.5 scfm. In Figure 5.145, downward spikes in both the gas flow rate and differential pressure at 20.0, 38.0, 61.0, and 112.0 hours correspond to feed interruptions to rod out the film cooler. The WESP wet gas flow rate increased around 166 hours as a result of an increase in blower speed.

The amount of liquid accumulated in the WESP is plotted as a function of run time in Figure 5.146, where it is compared with the amount of fresh water sprayed into the WESP. The inlet spray water was set to 2.0 ± 0.2 gph, as specified by the Test Plan. The actual spray water flow rate was ≈ 2.04 gph. As evident from Figure 5.146, spray water accounts for the majority of the liquid accumulation in the WESP. The difference between accumulated liquid and fresh water sprayed is equal to the amount of liquid removed from the off-gas, which is also plotted in Figure 5.146. The WESP electrodes were deluged daily, as planned, with water at a nominal rate of 12 gpm for 3.33 minutes.

The WESP voltage and current are plotted as a function of run time in Figure 5.147. For Test 1, the average operating voltage and current were about 28.6 kV and 16.9 mA, respectively. The voltage and current remained steady throughout the test. The time required to stabilize power to operating values after deluge of the WESP ranged from 4 to 7 minutes and averaged 5.5 minutes, as shown in Table 5.7.

At the end of the test, 66.3 gallons of liquid was initially blown down. After a deluge, an additional 45.6 gallons of liquid was removed. While pre- and post-deluge inspections were made by IR video after Test 1, resolution was poor. In both the pre- and post-deluge inspections,

a smooth, light-colored tenacious, very thin layer was observed on the hex walls. The observation of nodular deposits on either the hex walls or rods was beyond the resolution of the IR camera.

Test 3

The WESP inlet and outlet gas temperatures are plotted in Figure 5.148. The WESP inlet gas temperature averaged 45.4°C and the outlet temperature averaged 46.9°C, indicating a 1.5°C temperature increase across the WESP during this test. The downward spikes in the WESP outlet temperature are a result of the daily deluge of the WESP. The WESP differential pressure and outlet gas flow rate are plotted in Figure 5.149. The pressure drop across the WESP averaged 2.6 in. W.C. The average WESP wet gas flow rate was 210.9 scfm. In Figure 5.149, downward spikes in both the gas flow rate and differential pressure around 33, 56, and 68 hours correspond to feed interruptions to rod out film cooler, and at 161 hours to rod out the film cooler and clean the transition line.

The amount of liquid accumulated in the WESP is plotted as a function of run time in Figure 5.150, where it is compared with the amount of fresh water sprayed into the WESP. The inlet spray water was set to 2.0 ± 0.2 gph, as specified by the Test Plan. The actual spray water flow rate was ≈ 2.06 gph. As evident from Figure 5.150, spray water accounts for the majority of the liquid accumulation in the WESP. The difference between accumulated liquid and fresh water sprayed is equal to the amount of liquid removed from the off-gas, which is also plotted in Figure 5.150. The WESP electrodes were deluged daily, as planned, with water at a nominal rate of 12 gpm for 3.33 minutes.

The WESP voltage and current are plotted as a function of run time in Figure 5.151. The average operating voltage and current were about 29.1 kV and 17.0 mA, respectively. The voltage and current remained steady throughout the test. The time required to stabilize power to operating values after deluge of the WESP ranged from 3 to 6 minutes and averaged 4.2 minutes, as shown in Table 5.8.

At the end of the test, 77.5 gallons of liquid was initially blown down. After a deluge, an additional 47.4 gallons of liquid was removed. A visual digital camera was used in these inspections, which generally gave superior clarity and resolution than the IR camera. Figure 5.152 indicates light surface deposits (discoloration) on the rod stars and light flaking on one hex cell wall, pre-deluge. Figure 5.153 indicates that both the light deposits on the rod and the flakes on the wall remained, post-deluge. Visually, the stars and the rods appeared somewhat cleaner after the deluge, but the difference was minor.

Test 8

The WESP inlet and outlet gas temperatures are plotted in Figure 5.154. The WESP inlet gas temperature averaged 46.9°C and the outlet temperature averaged 47.8°C, indicating a 0.9°C

temperature increase across the WESP during this test. The downward spikes in the WESP outlet temperature are a result of the daily deluge of the WESP. The WESP differential pressure and outlet gas flow rate are plotted in Figure 5.155. The pressure drop across the WESP averaged 2.8 in. W.C. The average WESP wet gas flow rate was 219.1 scfm. In Figure 5.155, upward spikes in both the gas flow rate and differential pressure around 122 hours correspond to an increase of blower speed. The downward spike in gas flow rate at around 167 hours corresponds to a pause in feeding while the film cooler was rodded out.

The amount of liquid accumulated in the WESP is plotted as a function of run time in Figure 5.156, where it is compared with the amount of fresh water sprayed into the WESP. The inlet spray water was set to 2.0 ± 0.2 gph, as specified by the Test Plan. The actual spray water flow rate was ≈ 2.05 gph. As is evident from Figure 5.156, spray water accounts for the majority of the liquid accumulation in the WESP. The difference between accumulated liquid and fresh water sprayed is equal to the amount of liquid removed from the off-gas, which is also plotted in Figure 5.156. The WESP electrodes were deluged daily, as planned, with water at a nominal rate of 12 gpm for 3.33 minutes.

The WESP voltage and current are plotted as a function of run time in Figure 5.157. The average operating voltage and current were about 29.7 kV and 17.0 mA, respectively. The voltage and current remained steady throughout the test. The time required to stabilize power to operating values after deluge of the WESP ranged from 2 to 5 minutes and averaged 3 minutes, as shown in Table 5.9.

At the end of the test, 93.7 gallons of liquid was initially blown down. After a deluge, an additional 38.2 gallons of liquid was removed. Overall, WESP inspection results were identical to the inspection at the end of Test 3; Figure 5.158 illustrates the light flaking on one of the hex cell walls, pre-deluge. Figure 5.159 shows that the rod deposits and flakes remain, post-deluge. Figure 5.159 is typical of most of the hex cell walls, post-deluge, with only very smooth, thin, tenacious deposits.

Test 10

The WESP inlet and outlet gas temperatures are plotted in Figure 5.160. The WESP inlet gas temperature averaged 40.5°C and the outlet temperature averaged 42.1°C, indicating a 1.6°C temperature increase across the WESP during this test. The downward spikes in the WESP outlet temperature are a result of the daily deluge of the WESP. The WESP differential pressure and outlet gas flow rate are plotted in Figure 5.161. The pressure drop across the WESP averaged 3.3 in. W.C. The average WESP wet gas flow rate was 214.3 scfm. The decrease of WESP flow rate at 16 hours is the result of a film cooler restriction of about 75% of the flow area.

The amount of liquid accumulated in the WESP is plotted as a function of run time in Figure 5.162, where it is compared with the amount of fresh water sprayed into the WESP. The inlet spray water was set to 2.0 ± 0.2 gph, as specified by the Test Plan. The actual spray water flow rate was ≈ 2.05 gph. As evident from Figure 5.162, spray water accounts for the majority of

the liquid accumulation in the WESP. The difference between accumulated liquid and fresh water sprayed is equal to the amount of liquid removed from the off-gas, which is also plotted in Figure 5.162. The WESP electrodes were deluged daily, as planned, with water at a nominal rate of 12 gpm for 3.33 minutes.

The WESP voltage and current are plotted as a function of run time in Figure 5.163. The average operating voltage and current were about 29.6 kV and 17.0 mA, respectively. The voltage and current remained steady throughout the test. The time required to stabilize power to operating values after deluge of the WESP ranged from 5 to 9 minutes and averaged 7.7 minutes, as shown in Table 5.10.

At the end of the test, first 14.0 gallons and then 80.1 gallons of liquid was initially blown down. After a deluge, an additional 40.4 gallons of liquid was removed. Figure 5.164 indicates that the hex walls of the grid, as well as the grid rods, had a light coating of very small nodules, pre-deluge. Subsequent to most tests, a smooth, very thin tenacious coating was observed on the hex cell walls. The unusual characteristics seen after this test include the observation that the coating on the hex cell walls is nodular and that the coating on the rods is light-colored. Presumably, the light colored nodules are from the salt in the feed; this is supported by Figure 5.165, taken post-deluge, which shows that at least some of the material has been washed off the hex cell walls and that the light-colored deposits on the rods have been washed off.

Test 9

The WESP inlet and outlet gas temperatures are plotted in Figure 5.166. The WESP inlet gas temperature averaged 46.7°C and the outlet temperature averaged 47.9°C, indicating a 1.2°C temperature increase across the WESP during this test. The WESP inlet and outlet gas temperatures increased with run time, in parallel with the SBS outlet gas temperatures. The downward spikes in the WESP outlet temperature are a result of the daily deluge of the WESP. The WESP differential pressure and outlet gas flow rate are plotted in Figure 5.167. The pressure drop across the WESP averaged 2.7 in. W.C. The average WESP wet gas flow rate was 225.8 scfm.

The amount of liquid accumulated in the WESP is plotted as a function of run time in Figure 5.168, where it is compared with the amount of fresh water sprayed into the WESP. The inlet spray water was set to 2.0 ± 0.2 gph as specified by the Test Plan. The actual spray water flow rate was ≈ 2.09 gph. As evident in Figure 5.168, spray water accounts for the majority of the liquid accumulation in the WESP. The difference between accumulated liquid and fresh water sprayed is equal to the amount of liquid removed from the off-gas, which is also plotted in Figure 5.168. The WESP electrodes were deluged daily, as planned, with water at a nominal rate of 12 gpm for 3.33 minutes.

The WESP voltage and current are plotted as a function of run time in Figure 5.169. At around 15 hours LabVIEW malfunctioned in recording current and voltage readings; therefore only current and voltage values reported in the logbooks are plotted. Up to about 17 hours, the

current fluctuated due to a calibration check on WESP current. The average operating voltage and current were about 29.9 kV and 16.9 mA, respectively. Except for the initial current fluctuations, the voltage and current remained steady throughout the test. After 34 hours the WESP current was constant at 17.1 mA. The time required to stabilize power to operating values after deluge of the WESP ranged from 2 to 3 minutes and averaged 2.1 minutes, as shown in Table 5.11.

At the end of the test, 81.1 gallons of liquid was initially blown down. After a deluge, an additional 41.1 gallons of liquid was removed. The most salient feature of the pre-deluge inspection was that almost all of the hex cell walls were covered with a thin black layer, as illustrated in Figure 5.170. Based on appearance, the black deposits were probably ruthenium oxide [39]. (Data and discussion of ruthenium in both the SBS and WESP solutions are provided in Section 8.4.3.) Pre-deluge, the black deposits extended the entire length of most of the tubes. The deluge removed most of the black deposits from 80% of the hex cells, as illustrated by Figure 5.171, although some of the cells had the black deposits starting further up the interior of the grid, as indicated by Figure 5.172. Two of the cells, located near the periphery of the grid, remained coated with black deposits for most to all of the length of the grid, as shown in Figure 5.173.

5.1.4 HEME #1

A HEME (HEME #1) that follows the WESP in the off-gas system removes any water droplets that may be present in water-saturated gas exiting the WESP.

For Test 2, the outlet gas temperature and differential pressure are plotted in Figure 5.174. The average HEME #1 gas outlet temperature was 39.4 °C. The average pressure drop across HEME #1 was 2.1 in. W.C. At the end of the test, 34.5 gallons of liquid was blown-down from HEME #1. The interior of the HEME #1 outlet, where 0.15 grams of solids was collected at the end of Test 2, can be seen in Figure 5.175. There was a very light dry coating of white powder which showed some crystalline structure.

For Test 1, the outlet gas temperature and differential pressure are plotted in Figure 5.176. The average HEME #1 gas outlet temperature was 40.5°C. The average pressure drop across HEME #1 was 2.1 in. W.C. At the end of the test, 25.1 gallons of liquid was blown-down from HEME #1. The downward peak of differential pressure at 20 hours corresponds to a film cooler blockage.

For Test 3, the outlet gas temperature and differential pressure are plotted in Figure 5.177. The average HEME #1 gas outlet temperature was 45.0°C. The average pressure drop across HEME #1 was 2.2 in. W.C. At the end of the test, 34.1 gallons of liquid was blown-down from HEME #1.

For Test 8, the outlet gas temperature and differential pressure are plotted in Figure 5.178. The average HEME #1 gas outlet temperature was 46.0°C. The average pressure

drop across HEME #1 was 2.3 in. W.C. At the end of the test, 41.1 gallons of liquid was blown-down from HEME #1. The maximum differential pressure at 182 hours occurred when the film cooler blocked and was rodded out.

For Test 10, the outlet gas temperature and differential pressure are plotted in Figure 5.179. The average HEME #1 gas outlet temperature was 40.8°C. The average pressure drop across HEME #1 was 2.3 in. W.C. At the end of the test, 30.8 gallons of liquid was blown-down from HEME #1. At the end of Test 10, the interior of HEME #1 inlet and outlet piping was examined and found to be clean.

For Test 9, the outlet gas temperature and differential pressure are plotted in Figure 5.180. The average HEME #1 gas outlet temperature was 45.6 °C. The average pressure drop across HEME #1 was 1.2 in. W.C. At the end of the test, 39.3 gallons of liquid was blown down from HEME #1. The HEME #1 differential pressure went to 0 in. W.C. at 116.3 hours during a LabVIEW shutdown and activation of the emergency off-gas system. The pressure drop across HEME #1 for Test 9 is lower than measured for the previous configurations tests. Prior to Test 9, the HEME #1 was used in the LAW Production Rate Test [30], which was run between Tests 10 and 9 of the HLW configuration test series. The HEME #1 was pressure-washed at the end of the LAW Production Rate Test, and this may have contributed to its reduced pressure drop observed in Test 9.

5.1.5 HEPA Filter

HEME #1 is followed in the off-gas system by a heater, a HEPA filter (HEPA #1), and a Paxton blower (Blower #1). The purpose of the heater is to ensure that water-saturated gas exiting HEME #1 is heated above its dew point before passing through the HEPA filter in order to prevent moisture condensation in the HEPA filter. The outlet gas temperature and the pressure differential across HEPA #1 are the only two parameters that were monitored by the off-gas data acquisition system, and these are provided in Figure 5.181 and Figures 5.185 through 5.188 for Tests 2, 1, 3, 8, and 10, respectively. For the five tests, the average HEPA #1 outlet temperature was between 61.2°C and 63.6°C. The average differential pressure across HEPA #1 was between 0.1 and 0.2 in. W.C. These data indicate that no significant particulate loading or moisture blinding of the HEPA #1 filter occurred during these five tests.

After Test 2, HEPA #1 and its housing were inspected. Figure 5.182 shows the solids deposits in the area between the HEPA #1 pre-filter and filter. The mass of solids was 65.9 grams, the majority of which were from on or near the bottom of the housing. Significant corrosion on the metal parts was observed. Figure 5.183 provides a view of the HEPA #1 pre-filter looking from the downstream side. Between the HEPA #1 pre-filter and the process air heater, 4.8 grams of solids were collected, as shown in Figure 5.184. As can be seen in Figure 5.189, the bottom of the HEPA housing was clean after Test 10.

For Test 9, the outlet gas temperature and the pressure differential across HEPA #1 are given in Figure 5.190. For this test, the average HEPA #1 outlet temperature was 67.0°C and the

average differential pressure was 0.4 in. WC. At 112.6 and 132.5 hours, the heater 701 set-point was raised from 67°C to 70°C and 70°C to 72°C, respectively. The set-point was raised to try to maintain a 20°C temperature difference between the WESP outlet off-gas and the HEPA outlet off-gas.

5.1.6 Paxton Blowers (Blower 701 and Blower 702)

After Test 2, blowers 701 and 702 were inspected. About 30% of the blower 701 impeller surface was covered with a green crystalline powder and the rest of the surface was covered with a moist, grayish-white powder (about 1 gram). From the inlet pipe of blower 701, shown in Figure 5.191, a small amount of greenish crystalline solids (about 1.5 grams) was observed.

In blower 702, the same observations were obtained except that all the solids were dry. From the blower bellows and inlet pipe, 0.33 grams, and from the impeller surface (shown in Figure 5.192), 1.1 grams of solids were collected.

5.1.7 TCO/SCR Unit

The TCO/SCR unit consists of a heater, a Thermal Catalytic Oxidizer (TCO), and a Selective Catalytic Reduction (SCR) unit with an ammonia injection system. After the off-gas is heated in the TCO/SCR heater, organics are catalytically oxidized in the TCO. The off-gas is then mixed with ammonia before entering the SCR unit where NO_x is reduced to nitrogen. The TCO inlet thermocouple is located in the gas stream before the catalytic bed, 34" from the TCO/SCR heater vertical exit plane.

Test 2

The TCO/SCR heater gas inlet temperature is plotted in Figure 5.193 and averaged 82.0°C. The TCO inlet, SCR inlet and outlet, and post SCR temperatures during the test are plotted in Figure 5.194. The average TCO inlet gas temperature was 477°C, while the average SCR inlet gas temperature was 402°C. The average SCR outlet gas temperatures were 397°C and 378°C at two locations, one foot apart, at the outlet of the SCR. The average temperature after the SCR was 367°C. A sharp decrease in the temperatures at about 93 hours into the test can be seen in Figure 5.194. The transition line was opened for off-gas testing at that time.

The differential pressures across the TCO, SCR, and TCO/SCR are plotted in Figure 5.195. Average differential pressures were 3.1 in. W.C., 6.3 in. W.C., and 9.7 in. W.C., respectively.

Information on NO_x and CO removal in the TCO/SCR is provided in Table 5.12. During test segments B, C, and D, nitrogen oxide removals were >97.4%, >97.3%, and >97.9%, respectively. During test segments B, C, and D, carbon monoxide removals were >6.1%,

>97.0%, and >42.8%, respectively. Gas residence times in the TCO during Test 2 are given in Table 5.18 and averaged 0.20 seconds. Average ammonia injections into the SCR during test segments A, B, C, and D were 0.05, 0.14, 0.15 and 0.15 lbs/hr, respectively. Ammonia slippages during the test segments B, C, and D were 0.4%, ~0.4% and ~0.5%, respectively. Average ammonia concentration after the SCR unit, during test segments A, B, C, and D were <1.0 ppm, <1.0 ppm, <1.0 ppm, and 1.4 ppm, respectively.

Test 1

The TCO/SCR heater gas inlet temperature is plotted in Figure 5.196 and averaged 80.3°C. At 23 hours the feed was interrupted in order to work on the ADS pump, and at 113 hours, the transition line was tapped and opened to remove a blockage. The effect of these events can be observed in the TCO/SCR heater inlet gas temperature. The TCO inlet, SCR inlet and outlet, and post SCR temperatures during the test are plotted in Figure 5.197. The average TCO inlet gas temperature was 476°C, while the average SCR inlet gas temperature was 402°C. The average SCR outlet gas temperatures were 398°C and 380°C at two locations, one foot apart, at the outlet of the SCR. The average temperature after the SCR was 367°C. At 20 and 112 hours, the feed was interrupted to allow rod-out of the film cooler. The downward peaks in TCO and SCR temperatures correspond to these times.

The differential pressures across the TCO, SCR, and TCO/SCR are plotted in Figure 5.198. Average differential pressures were 3.1 in. W.C., 6.3 in. W.C., and 9.7 in. W.C., respectively.

Information on NO_x and CO removal in the TCO/SCR is provided in Table 5.13. During test segments B, C, and D, nitrogen oxide removals were 83.4%, >87.3%, and 86.8%, respectively. During test segments C, and D, carbon monoxide removals were >60.2% and >72.1%, respectively. Gas residence times in the TCO during Test 2 are given in Table 5.18 and averaged 0.20 seconds. Average ammonia injections into the SCR during test segments A, B, C, and D were 0.08, 0.17, 0.17, and 0.17 lbs/hr, respectively. Ammonia slippages during test segments B, C, and D were 2.4%, 1.9%, and 1.5%, respectively. Average ammonia concentration after the SCR unit, during test segments A, B, C, and D were 1.3 ppm, 6.9 ppm, 5.5 ppm, and 4.5 ppm, respectively.

Test 3

The TCO/SCR heater gas inlet temperature is plotted in Figure 5.199 and averaged 81.1°C. The downward spike of heater gas inlet temperature was due to a feed interruption to clean the transition line and film cooler at around 161 hours of operations. The TCO inlet, SCR inlet and outlet, and post SCR temperatures during the test are plotted in Figure 5.200. The average TCO inlet gas temperature was 475°C, while the average SCR inlet gas temperature was 404°C. The average SCR outlet gas temperatures were 399°C and 383°C at two locations, one foot apart, at the outlet of the SCR. The average temperature after the SCR was 349°C. The

downward temperature peaks at 100 and 169 hours corresponds to film cooler cleaning, and at 107 and 164 hours correspond to cleaning both the transition line and film cooler. At 115 hours the TCO/SCR heater controller began to malfunction by sending alternate signals to cool down and heat up. Therefore, at 117 hours, the TCO/SCR heater controller was replaced due to the inability to maintain stable output temperatures.

The differential pressures across the TCO, SCR, and TCO/SCR are plotted in Figure 5.201. Average differential pressures were 2.8 in. W.C., 5.7 in. W.C., and 8.8 in. W.C., respectively. The effect of a long feed stoppage at 161 hours can be observed in decreased differential pressure values in Figure 5.201.

Information on NO_x and CO removal in the TCO/SCR is provided in Table 5.14. During test segments B and C, nitrogen oxide removals were 86.8% and 81.9%, respectively. During test segments B and C, carbon monoxide removals were 72.2% and 70.6%, respectively. Gas residence times in the TCO during Test 3 are given in Table 5.18 and averaged 0.20 seconds. Average ammonia injections into the SCR during test segments A, B, and C were 0.11, 0.18, and 0.15 lbs/hr, respectively. Ammonia slippages during test segments A, B, and C were 2%, ~3.2% and ~4.4%, respectively. Average ammonia concentration after the SCR unit, during test segments A, B, and C were 3.9 ppm, 9.8 ppm, and 12 ppm, respectively.

Test 8

The TCO/SCR heater gas inlet temperature is plotted in Figure 5.202 and averaged 81.3°C. Downward temperature spikes at 121 hours and 182 hours in Figure 5.202 correspond to times when the feed was secured due to film cooler cleaning. The TCO/SCR heater failed and the TCO/SCR unit was bypassed after 90.7 hours. The TCO inlet, SCR inlet and outlet, and post SCR temperatures during the test are plotted in Figure 5.203. Up to 90.7 hours of operations, the average TCO inlet gas temperature was 465°C, while the average SCR inlet gas temperature was 393°C. The average SCR outlet gas temperatures were 387°C and 368°C at two locations, one foot apart, at the outlet of the SCR. The average temperature after the SCR was 358°C. The downward temperature spikes at 51, 54, 75, and 86 hours in Figure 5.203 correspond to film cooler cleaning. At 48 hours the TCO/SCR heater malfunctioned and returned to normal after resetting.

The differential pressures across the TCO, SCR, and TCO/SCR are plotted in Figure 5.204. Average differential pressures were 3.1 in. W.C., 6.4 in. W.C., and 9.8 in. W.C., respectively.

Information on NO_x and CO removal in the TCO/SCR is provided in Table 5.15. During test segments A and B, nitrogen oxide removals were ~57.8% and 31.6%, respectively. During test segment B, carbon monoxide removal was >48.6%. Gas residence times in the TCO during Test 8 are given in Table 5.18 and averaged 0.19 seconds before the TCO/SCR heater malfunction. Average ammonia injections into the SCR during test segments A, B, and C were 0.11, 0.16, and 0.00 lbs/hr, respectively. Ammonia slippages during the test segments A and B

were ~1.5%, and ~2.2%, respectively. Average ammonia concentration after the SCR unit, during test segments A, B, and C were 2.6 ppm, 6.1 ppm, and <1.0 ppm, respectively.

Test 10

The TCO/SCR heater gas inlet temperature is plotted in Figure 5.205 and averaged 78.9°C. During Test 10, between 55.0 and 56.4 hours, the feed was stopped due to cold cap mounding on the west side. Between 73.0 and 73.7 hours, feed was stopped to add sodium sulfate solution to the feed tank, and between 115.7 and 117.1 hours to reduce the cold cap ridge in the middle of the melter. The effect of these interruptions can be seen as downward peaks in Figure 5.205. The TCO inlet, SCR inlet and outlet, and post SCR temperatures during the test are plotted in Figure 5.206. The dip in post SCR temperature between 23 and 28 hours is due to experimental checks of ammonia delivery and air inleakage. The dips around 115 and 139 hours are due to tests of the silver mordenite and sulfur impregnated activated carbon beds, which occurred during these times. The average TCO inlet gas temperature was 475°C, while the average SCR inlet gas temperature was 399°C. The average SCR outlet gas temperatures were 390°C and 370°C at two locations, one foot apart, at the outlet of the SCR. The average temperature after the SCR was 357°C.

The differential pressures across the TCO, SCR, and TCO/SCR are plotted in Figure 5.207. Average differential pressures were 3.0 in. W.C., 6.1 in. W.C., and 9.4 in. W.C., respectively.

Information on NO_x and CO removal in the TCO/SCR is provided in Table 5.16. During test segments A, B, C, and D, nitrogen oxide removals were >66.6%, 60.0%, 85.7%, and >92.0%, respectively. During test segments A, B, C, and D, carbon monoxide removals were >95.3%, >84.7%, >77.6%, and >81.6%, respectively. Gas residence times in the TCO during Test 10 are given in Table 5.18 and averaged 0.20 seconds. Average ammonia injections into the SCR during test segments A, B, C, and D were 0.04, 0.05, 0.11, and 0.14 lbs/hr, respectively. Ammonia slippages during test segments A, B, C, and D were 13.6%, <1.2%, ~1.8%, and 2.9%, respectively. Average ammonia concentration after the SCR unit, during test segments A, B, C, and D were 10.0 ppm, <1.0 ppm, 3.2 ppm, and 7.3 ppm, respectively.

Test 9

The TCO/SCR heater gas inlet temperature is plotted in Figure 5.208 and averaged 81.2°C. Upward temperature spikes at 116.3 and 132.5 hours are due to raising the heater 701 set-point. The TCO inlet, SCR inlet and outlet, and post SCR temperatures during the test are plotted in Figure 5.209. The average TCO inlet gas temperature was 475.3°C, while the average SCR inlet gas temperature was 410.6°C. The average SCR outlet gas temperatures were 399°C and 380°C at two locations, one foot apart, at the outlet of the SCR. The average temperature after the SCR was 366°C.

The differential pressures across the TCO, SCR, and TCO/SCR are plotted in Figure 5.210. Average differential pressures were 3.3 in. W.C., 6.7 in. W.C., and 10.3 in. W.C., respectively.

Information on NO_x and CO removal in the TCO/SCR is provided in Table 5.17. During test segments A and B, nitrogen oxide removals were 62.5% and 58.1%, respectively. During test segments A and B, carbon monoxide removals were >94.7% and >96.8%, respectively. Gas residence times in the TCO during Test 9 are given in Table 5.18 and averaged 0.19 seconds. Ammonia was not used during this test.

A slipstream of the off-gas exiting the SCR was directed to the sulfur-impregnated activated carbon column, followed by a silver mordenite column. The slipstream was combined with the main stream prior to the PBS. Data on the column temperatures, pressure drops, and performance are presented in Section 7.5.

5.1.8 Packed Bed Scrubber (PBS)

The TCO/SCR is followed in the off-gas train by a packed bed caustic scrubber (PBS) to remove iodine and acid gases from the off-gas stream. The effluent solution can be pumped out of the PBS sump and process water and caustic solution (25% NaOH) added to control the solid content and pH of the scrubber liquid.

The inlet gas temperature and the pressure drop across the PBS for Test 2 are shown in Figure 5.211. The average PBS differential pressure was 3.3 in. W.C. The average PBS inlet gas temperature for this test was 343°C. The PBS sump temperature and pH are plotted in Figure 5.212 and averaged 24.8°C and 9.0, respectively. At the end of the test, 42.8 gallons of liquid was blown down from the PBS.

The inlet gas temperature and the pressure drop across the PBS for Test 1 are shown in Figure 5.213. The average PBS differential pressure was 3.3 in. W.C. The average PBS inlet gas temperature for this test was 344.0°C. The PBS sump temperature and pH are plotted in Figure 5.214 and averaged 31.4°C and 8.3, respectively. At the end of the test, 31.0 gallons of liquid was blown down from PBS. At the end of Test 1, a large amount of settled solids (1B2-O-29A) was removed from the PBS recirculation pump (P-702) head. XRD analysis of this sample showed good matches for quartz (silicon oxide), aragonite (calcium carbonate), and another polymorph of calcium carbonate.

The inlet gas temperature and the pressure drop across the PBS for Test 3 are shown in Figure 5.215. The average PBS differential pressure was 3.3 in. W.C. The average PBS inlet temperature for this test was 326.0°C. The PBS sump temperature and pH are plotted in Figure 5.216 and averaged 34.8°C and 9.1, respectively. At the end of the test, 26.0 gallons of liquid was blown down from PBS.

The inlet gas temperature and the pressure drop across the PBS for Test 8 are shown in

Figure 5.217. Up to 90.7 hours of operation, the average PBS differential pressure was 3.4 in. W.C. and the average PBS inlet temperature was 337°C. The PBS sump temperature and pH are plotted in Figure 5.218 and averaged 34.5°C and 9.0, respectively. At the end of the test, no liquids were blown-down from PBS.

The inlet gas temperature and the pressure drop across the PBS during Test 10 are shown in Figure 5.219. The average PBS differential pressure was 3.5 in. W.C. The average PBS inlet temperature was 334°C. The PBS sump temperature and pH are plotted in Figure 5.220 and averaged 31.3°C and 9.2, respectively. At the end of the test, 24.8 gallons of liquid was blown down from PBS.

The inlet gas temperature and the pressure drop across the PBS for Test 9 are shown in Figure 5.221. The average PBS differential pressure was 4.3 in. W.C. and the average PBS inlet temperature was 344°C. The PBS sump temperature and pH are plotted in Figure 5.222 and averaged 37.1°C and 9.2, respectively. At the end of the test, no liquids were blown down from PBS.

5.1.9 HEME #2

A HEME (HEME # 2) that follows the PBS in the off-gas system removes any water droplets that may be present in water-saturated gas exiting the PBS.

For Test 2, inlet and outlet gas temperatures and differential pressure are plotted in Figure 5.223. The average HEME # 2 inlet gas temperature was 27.4°C, and the average outlet gas temperature was 28.8°C. The average pressure drop across HEME # 2 was 5.0 in. W.C. At the end of the test, 44.3 gallons of liquid was blown down from HEME #2.

For Test 1, inlet and outlet gas temperatures and differential pressure are plotted in Figure 5.224. The average HEME # 2 inlet gas temperature was 33.3°C and the average outlet gas temperature was 34.6°C. The average pressure drop across HEME #2 was 5.9 in. W.C. At the end of the test, 40.9 gallons of liquid was blown down from HEME #2. At the end of Test 1, pre-washing and post-washing views of HEME #2 filter media, looking upstream, were taken and are provided in Figure 5.225 and 5.226, respectively. A slight grayish color of the filter media was observed before the washing.

Inlet and outlet gas temperatures and differential pressure for Test 3 are plotted in Figure 5.227. The average HEME #2 gas inlet temperature was 36.5°C and the average outlet temperature was 37.4°C. The average pressure drop across HEME #2 was 5.4 in. W.C. At the end of the test, 48.1 gallons of liquid were blown down from HEME #2.

Inlet and outlet gas temperatures and differential pressure for Test 8 are plotted in Figure 5.228. The average HEME #2 gas inlet temperature was 35.8°C and the average outlet temperature was 36.6°C. The average pressure drop across HEME #2 was 6.2 in. W.C. At the end of the test, 39.7 gallons of liquid was blown down from HEME #2.

Inlet and outlet gas temperatures and differential pressure for Test 10 are plotted in Figure 5.229. The average HEME #2 gas inlet temperature was 33.0°C and the average outlet temperature was 33.9°C. The average pressure drop across HEME #2 was 5.0 in. W.C. At the end of the test, 24.8 gallons of liquid was blown-down from HEME #2.

Inlet and outlet gas temperatures and differential pressure for Test 9 are plotted in Figure 5.230. The average HEME #2 gas inlet temperature was 38.5°C and the average outlet temperature was 38.7°C. The average pressure drop across HEME #2 was 6.3 in. W.C. At the end of the test, 21.4 gallons of liquid was blown down from HEME #2.

5.1.10 Final Paxton Blower (Blower 801)

At the end of Test 10, the head of the final Paxton blower, Blower 801, was removed and 0.26 kg of wet solids was removed from the outlet liquid collector shown in Figure 5.231. Approximately 0.07 kg of solids was removed from the Blower 801 exterior housing shown in Figure 5.232.

5.1.11 Effluent Liquid Treatment System

Effluent liquids from the SBS, WESP, PBS, HEME #1, and HEME #2 are all piped to a series of sampling tanks that discharge to three 500-gallon storage tanks for neutralization, mixing, and storage. The largest effluent volume is overflow (blow-down) from the SBS, which is pumped to one of two SBS sampling tanks. Caustic solution (25% NaOH) from the same caustic tank that supplies the PBS can also be added to the 500-gallon storage tank that receives acidic effluents from SBS sampling tanks; this storage tank is therefore referred to as the neutralization tank.

5.2 SBS, WESP, HEME, and PBS Process Fluids

5.2.1 SBS Fluids

One-liter samples were collected from the SBS sump each time liquids were blown down and at the end of each test. Selected samples were subjected to total dissolved solids (TDS) and total suspended solids (TSS) determinations by gravimetric analysis of filtered material and the evaporated filtrate. An additional sample was filtered to generate solids and filtrate for complete chemical analysis, which included pH determination, direct current plasma emission spectroscopy (DCP) analysis for metals, ion selective electrode (ISE) for ammonium, and ion chromatography for all other anions; the dried filtered solids underwent microwave-assisted acid dissolution prior to chemical analysis.

All of the SBS sump samples that were taken throughout the DM1200 tests are listed in Table 5.19; the middle letter in the sample name is "S" for the SBS samples. The table provides

pH values for each sample, as well as the blow-down volume from which each SBS sample was taken and the cumulative SBS blow-down volume. The analyzed chemical compositions for samples taken at or near the end of each test are provided in Table 5.20. Additional anion analysis for samples from the end of each test segment from Test 10 (chloride and sulfate spiked into feed) is provided in Table 5.21. The pH values for the SBS liquids for each test are plotted in Figure 5.233 as a function of the amount of glass produced. The sump solution pH varied within a narrow range of 8.0 to 8.5 for the majority of testing due to the consistency of the feed; this is consistent with previous experience using the same feed [9]. The pH drops in response to the spiking with sodium chloride and sulfate during Test 10. Samples with high pH values were generated near the beginning of Test 9 and are the first from the newly modified SBS. A small amount of residual material from the manufacturing process could easily affect the pH of weakly buffered tap water present in the unit at the beginning of the test. The pH of solutions from Test 9 quickly dropped to values similar to other tests, even though the feed contained low concentrations of sugar and was spiked with ruthenium nitrate solution.

Figures 5.234 – 5.239 compare the amount of water fed to the total volumetric accumulations in the SBS over the course of each test. Included is the water fed to cool the melter plenum at the start of each test to create a cold cap and thereby minimize subsequent off-gas surges due to pulsed feeding onto bare glass (this is the same feed start-up protocol as that used at West Valley). The amount of water fed into the melter is proportional to the amount of water in the feed and the feed rate; hence Tests 8 and 9, which had the highest feed rates and feed water contents had the highest water input to the SBS. The difference between the amounts of SBS water coming from the feed and the amounts blown down represents the amount of water carried out in the off-gas stream as a result of it being saturated at the SBS sump temperature, as well as a small amount of entrained droplets. This amount is largely determined by the SBS sump water temperature, which was targeted at 40°C in Tests 2, 1, 3, 8 and 10; however, demand on the system and difficulties in obtaining appropriately chilled water during Tests 3 and 8 resulted in test segment average temperatures of 43°C to 48°C and 42°C to 50°C, for each test, respectively. Based on this experience and the Project's desire to test the system at the higher SBS sump temperatures, the sump temperature was intentionally increased from 45°C to 50°C over the duration of Test 9. The higher test average sump temperature in Test 9 resulted in about 330 more gallons of water exiting the SBS than in Test 8, even though the amount of water feed into the melter (6443 vs. 6402 gallons) was about the same.

Figures 5.240 - 5.242 compare the feed composition to the SBS dissolved and suspended fractions determined from samples taken at or near the end of Test 3. These samples are indicative of samples from the other tests as a result of the same feed being used throughout the tests, except for the low concentration spikes added to portions of Tests 9 and 10. As might be expected, the dissolved solids consist mainly of soluble species such as halogens, boron, alkali metals, and sulfate. These species are readily volatilized from the glass and cold cap in the melter as soluble salts. Similar results were obtained from analysis of SBS solutions in tests with other HLW simulants [3, 6, 9-12, 17]. Dissolved chlorine was observed in significant proportions in all the tests, even though it was only targeted in the feed during portions of Test 10, indicating that chlorine was present in the feed as a contaminant. Iodine was observed as a dissolved species in significant concentrations in the initial test, and at trace levels in many of the samples from other

tests. A portion of the feed used in the first test was residual feed from previous AZ-101 tests that contained iodine corresponding to 0.1 wt% in the product glass [9]. Nitrite and nitrate constitute a large fraction of the dissolved SBS solids in LAW melter tests [21-23] but are present only in small quantities in these samples due to their much lower concentrations in the melter feeds. The sugar added to the feed in Test 9 further served to decrease the concentration of nitrates and nitrites in the SBS solution by reducing nitrogen oxides to molecular nitrogen in the melter (see Section 7). A byproduct of sugar additions to the feed, ammonia, is also observed at the highest concentration in solutions from Test 9. The sample with the highest TDS concentration was from Test 10, where the volatile and soluble species chloride and sulfate were spiked into the feed. Anion analysis of samples from the end of each segment of Test 10 shows the expected increases in concentration in response to the spiked feed concentrations. The suspended solids more closely resemble the feed and consist primarily of iron, silicon, zinc, and aluminum, as well as high concentrations (relative to those in the feed) of the more volatile constituent cadmium. Chromium, although not included in the feed formulation, was observed in both the dissolved and suspended fraction, due presumably to release from melter components and carry-over from previous tests. The dissolved and suspended fractions were within 50% of each other in each test. Total concentrations were higher as the sump temperature increased, and lower as the feed solids content and rate decreased, thus diluting the solids in the sump solutions.

5.2.2 WESP, PBS, and HEME Fluids

One-liter samples were collected from the WESP, PBS, and HEME sumps each time liquids were blown down and at the end of the tests. All of the WESP and PBS sump samples that were taken throughout the test are listed in Tables 5.22 - 5.24; the middle letter in the sample name is “W”, “P”, and “H” for the WESP, PBS, and HEME samples, respectively. The tables provide pH values for each sample, as well as the blow-down volume from which each sample was taken and the cumulative blow-down volumes. Between 80 and 120 gallons of liquid was blown down from the WESP daily: the first 40 to 80 gallons from the previous day’s accumulation of water from spraying and condensation (typically, the sample with suffix “A” in the name) and the second from the 40-gallon deluge (typically, the sample with suffix “B” in the name). The PBS was blown down as required to maintain constant volume. The first HEME (immediately downstream of the WESP) was continuously sprayed at 0.2 gal/hr, resulting in the addition of up to 42 gallons of water, depending on the duration of the test. The liquid accumulated during each of the tests either approximated this volume or was less than the total sprayed volume, indicating that essentially no water carried over from the WESP accumulated in the first HEME.

Results from the analysis of sump samples from the WESP taken at the end of each test, before and after the deluge, are given in Table 5.25. The composite (pre- and post-deluge) chemical composition of these samples is illustrated in Figure 5.243. The WESP solution pH values were higher (7 to 9 vs. 2 to 7) than for the previous HLW tests [3, 6] due to dilution from the added deluge, higher than for the previous LAW Sub-Envelope B1 tests [22] (7 to 9 vs. 2 to 4) due to the lower concentrations of nitrates/nitrites in the feed, and comparable to more recent HLW tests that also employed a daily deluge for cleaning the WESP electrodes [9-12, 17]. A near total absence of suspended material was measured in both the pre-deluge blow-down

solutions. Higher, but still low, concentrations of suspended material were found in post-deluge solutions; this material was presumably material that was dislodged from the electrodes. Volatile salts (alkali halides, borates, sulfates) carried over from the SBS and constituents from previous tests or impurities in feed and tap water are major constituents in the WESP solutions. The observed solution chemistry supports the expectation that the majority of the coarser, less-soluble species were removed by the SBS, leaving predominantly highly soluble species for accumulation in the WESP. The concentrations of most elements are higher in the solutions prior to the deluge, although the relative proportion of elements is very similar.

Anion analysis of the PBS and HEME #1 blow-down solutions taken at the end of each test is given in Table 5.26. The pH of the PBS sump is maintained between 9 and 10 during testing by the addition of 25% sodium hydroxide solution. Conversely, the pH of HEME solutions is a result of constituents removed from the exhaust stream. It is important to note that while various anions were present at measurable concentrations in the PBS solutions, they certainly are not removed quantitatively from the exhaust stream by the PBS in the 9 to 10 pH range. Also, the scrubber sump is not changed after each test, resulting in carry-over from previous tests. Significant concentrations of several anions, including ammonium, sulfate, and nitrate were measured in HEME solutions; however, the HEME plays only a small role in the mass balance as a result of the small volumes of liquids collected.

5.2.3 Estimates of Accumulations in SBS, WESP, HEME and PBS and Fluids

Estimates of elemental accumulations in the SBS, WESP, and PBS blow-down solutions for Test 3 are provided in Table 5.27. This test was selected for these calculations since the chemistry and relative proportions of constituents in samples is very similar for all the tests and emissions data for the melter, SBS, and WESP were available. The accumulation totals are the product of the analyses given in Tables 5.20, 5.25, and 5.26 and the total accumulated liquids given in Tables 5.19, 5.22-5.24. Single sample analysis from the end of each test was used for the estimates. The accumulations given, therefore, are mostly upper estimates, since the concentration values were taken near the end of tests and the concentrations certainly increased over the course of the test. They do not include the solids in the SBS bowl or in the down-comer. The accumulations estimated from blow-down data are also compared to estimates calculated from test average emissions data as percent of feed (see Section 7.0). The equivalent of nine to thirteen kilograms of boron, iron, sodium, and silica accumulated in the SBS during the test. One to two kilograms of aluminum, lithium, zinc, zirconium, fluorine, chlorine, nitrate, and sulfur are estimated to have accumulated in the SBS liquids during the test with varying amounts of all other feed components in proportion to their abundance in the feed and their volatility. Despite the significant accumulated masses, the SBS liquids constitute a significant proportion of the elemental mass balance only for sulfur, halogens, and to lesser extent, nitrate/nitrite, boron, and potassium. Several constituents have accumulations in the SBS fluids of about one to two percent of feed: Al, Ca, Cd, Fe, Li, Mg, Na, Pb, Sr, and Zn. Estimates of accumulations in WESP solutions are smaller than for the SBS solutions, although similar in that they are dominated by halogens, sulfur, alkali metals, and boron. Agreement between the two methods for estimating accumulations in the SBS and WESP (analyzed solution concentration x accumulated liquid

amounts vs. feed percent calculated from emissions data) was excellent for most elements. A difference between the two estimates is that the solids on the bottom of the SBS or in the down-comer were not included in the estimate based on blow-down solutions, but were certainly derived from melter emissions. Both estimation methods indicate little feed accumulation in the WESP. Some of the calcium, fluorine, and magnesium in the WESP solutions originated from city water used to constantly spray the WESP and conduct the deluge, which would not be reflected in the exhaust sampling estimates. Finally, as expected, the PBS and first HEME sump fluids account for only a modest percentage of feed anions.

SECTION 6.0 GLASS PRODUCT

Over fifty six metric tons of glass product was discharged from the melter through an airlift system into 55-gallon drums. The discharged product glass was sampled from each drum by removing sufficient glass from the top for total inorganic analysis. Product glass masses, discharge date, and the analyses performed are listed in Table 6.1.

6.1 Compositional Analysis

Glass samples were crushed and analyzed directly by XRF. The target values for the boron and lithium oxide concentrations were used for normalizing the XRF data, since boron and lithium were not determined by XRF. Analyzed compositions for discharged glass samples are provided in Table 6.2. There was good agreement with the target composition for the majority of oxides and, in particular, for the major oxides, as described for feed samples in Section 2.3. All major and intermediate oxides were within 10% of the target composition with the exception of zirconium and zinc. The zirconium deviation was very similar to that observed in the feed samples (about 25%); the zinc deviation was slightly below 10% in the feed samples, and is slightly above 10% in the discharged glass. The zirconium deviation in the feed and glass samples is likely due to contamination in the feed chemicals or higher than assumed zirconia content in the mineral (zircon) used as the glass former additive. Chlorine, chromium, phosphorous, and titanium were measured at low levels in the glasses from tests in which they were not included in the target composition. Chromium is generated by corrosion of melter components, and the others originate as contaminants in the glass forming additives. Common elements targeted at low concentrations, such as calcium and potassium, are over-represented in the glass product also, due to trace contamination in the glass forming additives. Ruthenium and yttrium were introduced as a spike in Test 9 to trace the behavior of these elements in melt pool and, therefore, they are observed in the results for that test. Note, however, that with respect to these elements, data of much higher sensitivity and precision were obtained from a separate set of analyses given in Section 8.0. Chlorine and sulfur were spiked into feed during portions of Test 10 at rates targeting 0.5 wt% Cl and 0.48 wt% SO₃ (0.4 wt% as spike, 0.08 wt.% in the nominal composition) on a glass basis; however, the test segments were not of sufficient duration to achieve these concentrations in the glass product.

Compositional trends from the XRF data are plotted for selected elements in Figures 6.1-6.5. The figures illustrate many of the points apparent in the tabular summaries of the data: good agreement with target for all major oxides except zirconium after the melt pool has experienced three turnovers (~5000 kg of glass produced), compositional consistency of major oxides over each test, an increase in chlorine and sulfur concentration in response to spiking during Test 10, and compositional changes at the beginning of testing as well as at the beginning of Test 9 resulting from turnover from the C-106/AY-102 composition present in the melt pool prior to these tests [17, 31]. The turnovers are best observed as decreases from intermediate to minor oxide concentration ranges of strontium, calcium, manganese, and magnesium in Figures 6.3 and 6.4. Aside from zirconium, which has a higher concentration in the AZ-101 composition,

concentrations of the major and intermediate range oxides such as silicon, sodium, iron, aluminum, and zinc change very little due to the similarity in concentration of these components in the two compositions. The change in concentration of chlorine and sulfur in response to spiking during Test 10 is easily observed in Figure 6.5. Sulfur concentrations reached nearly 0.3 wt% SO_3 or 62 percent of target, and chlorine 0.2 wt% or 40 percent of target. Sulfur was closer to target due to the higher volatility of chlorine and the fact that the two 2-day segments with sulfur spiking were contiguous, whereas the segments with chloride spiking were separated by two days. Chlorine and sulfur were introduced as solutions of sodium salts; however, the effect of the added sodium cannot be discerned due to the high concentration of sodium in the AZ-101 target glass composition (11.65 wt% Na_2O). Another observation of note is the relative uniformity of nickel concentrations once the melt was turned over, as shown in Figure 6.4. This is in contrast to previous tests with AZ-101 feed and higher sugar concentrations, which had decreased concentrations of nickel in the discharged glass due to deposition of nickel sulfide on the bottom of the melter [17].

6.2 Iron Redox State

The iron oxidation state for glasses sampled throughout Test 9 was measured using colorimetric methods to determine whether the amount of sugar added to the feed resulted in divalent iron fractions within the target range of 5–10 percent [15]. In addition to glass samples taken from the top of the drums listed in Table 6.1, grab samples from the discharge stream were taken to provide more rapid analysis of the iron oxidation state while the tests were ongoing. Although the redox analyses are time consuming, they were expedited to the extent possible and performed concurrently with the melter testing to provide feedback as rapidly as possible with respect to the redox state of the glass pool during the test in order to adjust the feed sugar content. Measured iron oxidation states and the associated sample names, sampling times, and amount of sugar added to the feed are given in Table 6.3 for both grab and discharge samples. All samples had measured divalent iron within the five to ten percent target range. As a result of these analyses conducted while the test was in progress, no changes were made to the feed sugar content during the test. The feed sugar concentration of 3.8 g/L selected for Test 9 was based on results from a previous test with the AZ-101 composition and various concentrations of sugar [17]. The measurements from both tests indicate that the iron oxidation state of glass produced from the AZ-101 composition is very sensitive to small additions of sugar to the feed.

SECTION 7.0 MONITORED OFF-GAS EMISSIONS

7.1 Particulate and Gaseous Emissions

Forty three exhaust samples were taken from the melter and various off-gas system components using 40-CFR-60 Methods 3, 5, and 29 to examine particulate and certain gaseous fluxes. Single samples were taken during the steady-state portion of each test segment except for Test 9, where triplicate samples were taken of the melter and SBS exhaust. Sampling durations were one to three hours for the melter and SBS exhaust, whereas sampling durations of up to 36 hours were required for the WESP exhaust due to the low particle concentration. Sampling of WESP exhaust was not conducted during the deluge cleaning process. Teflon filters were used to allow for analysis of all feed components. The majority of the off-gas analyte concentrations were derived from laboratory data on solutions extracted from air samples (filters and various solutions) together with measurements of the volume of air sampled. The volume of air sampled and the rate at which it can be sampled are defined in 40-CFR-60 and SW-846. 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), was used. Typically, a sample size of 30 dscf is taken at a rate of between 0.5 and 0.75 dscfm. Total particulate loading was determined by gravimetric analysis of the standard particle filter and of probe-rinse solutions. Downstream of the particulate filter in the sampling train are iced impingers with acidic (5% concentrated nitric acid plus 10% hydrogen peroxide) and basic (2 N sodium hydroxide) solutions. The analysis of these solutions permits the determination of total gaseous emissions of several elements, notably halides and sulfur. An additional procedure was required for particulate samples containing ruthenium (Test 9). Undissolved ruthenium particles were filtered from the nitric/hydrofluoric acid digestate, fused with sodium hydroxide, and dissolved with hydrochloric acid. A list of all inorganic isokinetic samples taken is provided in Table 7.1, including sampling location, air sample volume, air flow rates, particulate emission rates, and air moisture content. All samples were within 10% of isokinetic except for three samples from Test 9, which were within 17% of isokinetic. Results from the samples that were sampled outside of the 10% window were very similar to the other samples for the same melter condition, indicating a lack of sampling bias for these samples.

Elemental emission rates and DFs obtained during the tests are provided in Tables 7.2-7.18 for the melter, SBS, and WESP. 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 μ m heated filter. Since the same AZ-101 feed is used throughout the tests with little compositional changes, the data generated are a good opportunity to show the effect of changes in melter operation, particularly bubbler configuration and usage, on melter emissions and primary off-gas system performance. Figure 7.1 compares solids and sodium carry-over from the various tests. The percent solids carryover from the melter is indicative of most of the elemental particulate emissions: emissions were lower for tests conducted at the lower bubbling rate of

65 lpm. The previous tests with the same AZ-101 feed as well as the same bubbler configuration and bubbling rate had a solids carry-over from the melter of 0.55% and 0.78% for feeds at 530 and 400 g solids per liter, respectively [9]. These values are comparable to those obtained during Tests 1 and 2, suggesting that bubbler height within the melt pool and skewing does not have a discernable effect on particulate emissions. Values are also comparable to those from Test 9A, which was conducted at the same total bubbler flow rate but with the flow spread out over four outlets and with the more dilute feed, suggesting that spreading bubbler flow out over the surface not only enhances production rate, but also reduces solids carry-over from the melter. Other conditions tested that showed increased emissions were a higher melt temperature and the addition of chloride and sulfate to the feed. Solids carry-over from the melter in the test with the sulfate only spike was higher than expected, particularly considering that the test with the same amount of sulfate and chloride had about half the melter carry-over. The high value is probably due to the inherent variability in melter emissions as a result of continuing changes in the cold cap and the difficulty in establishing an even cold cap during portions of Test 10.

A comparison of melter system DF values from tests using AZ-101 simulants and various bubbling configurations is shown in Table 7.19. Melter DF values are uniformly higher at lower bubbling rates. The SBS performance was relatively uniform throughout most of the tests. Emissions high in fine sulfate and chloride particles are less effectively removed by the SBS resulting in lower DF values across the SBS. Modifications to the SBS prior to Test 9 (see Section 1.4.5) did not result in a discernable change in particle removal efficiency. The WESP daily deluge contributes a large fraction to the WESP emissions; sampling was not conducted during the deluge for these tests, in contrast to the previous AZ-101 tests [9]; WESP DF values for the current tests, therefore, were typically a factor of 2 to 3 higher. The cumulative DF values, which are calculated from feed fluxes into the melter and emissions from the WESP, were also affected by the exclusion of the WESP deluge in the sampling period, increasing by a factor of 2. Data from Test 10 show the difficulty of removing particulate sulfur in the primary off-gas system.

The average compositions of feed, melter emissions, SBS, and WESP emissions (excluding oxygen, carbon, nitrate, and nitrite) for samples taken during Test 3 are displayed in Figures 7.2-7.5. Notice that the relative percentages of volatiles, such as halides, increase downstream as the major constituents decrease. For example, silicon, which constitutes about 41% of the glass (Figure 7.2) comprises 21 percent of melter emissions (Figure 7.3), 3 percent of SBS emissions (Figure 7.4), and less than 0.01 percent of WESP emissions (Figure 7.5). Conversely, sulfur, which constitutes only 0.05 percent of the glass, constitutes about three percent of the melter emissions and a fifth of the SBS and WESP emissions. Exclusive of sulfur and chlorine, for portions of Test 10, the compositions of the particles and gases in the melter, SBS, and WESP exhaust are very similar for all the tests, indicating that changes in bubbler gas flow and configuration do not have an observable effect on the elemental content of the emissions. Impinger solutions from off-gas sampling were analyzed for all of the elements in the feed, but only halides, boron, and sulfur were detected. The presence of these elements in the gas fraction is consistent with observations from previous studies [3, 6, 9-12, 17, 20-22]. The amount of particulate collected on sampling filters was not sufficient to conduct both metals and total halide analysis and, therefore, some sample analyses (mainly SBS and WESP) only account for

gaseous chlorine and fluorine. Residual feed from previous AZ-101 tests contained iodine [9] and was used at the startup of testing resulting in the detection of iodine in diminishing concentrations over the course of the first test that was conducted.

7.2 Particle Size Distribution

Samples were taken using a University of Washington cascade impactor, which separates particles into particle size ranges, enabling the determination of particle size distributions. The melter exhaust stream was sampled during most test segments of each test. Data for the particle size distributions are provided in Tables 7.20 – 7.24. In each sample, the greatest amount of material was collected as the coarsest size fraction ($> 9.05 - 13.1 \mu\text{m}$). From 51.6 to 79.6 percent of the total particulate mass was observed in this size fraction, with the remainder being spread out over the remaining seven finer size fractions. The same observations have been made in melter emission samples from previous tests [9-12, 17] indicating that particles are typically greater than about 9 microns, or that sub-micron particles readily coalesce and the sampling method is incapable of making the distinction between the two. No obvious trend of changing particle size with test parameters was observed, although samples from Test 3 had a significantly higher proportion of material in the coarsest fraction.

7.3 FTIR Analysis

Off-gas analysis by Fourier Transform Infrared (FTIR) spectroscopy was performed using an On-Line Technologies Inc. Model 2010 Multi-Gas™ Analyzer. Data were recorded at 71 s intervals, corresponding to an average of 128 scans at 0.5 cm^{-1} spectral resolution. The melter off-gas supplied to the FTIR spectrometer was extracted using a heated sampling and transfer loop, which removed a gas sample stream from the off-gas system at 5 liters per minute. The sampling and transfer loop was maintained at 150°C throughout in order to prevent analyte loss due to condensation.

Off-gas emissions were monitored by FTIR spectroscopy throughout each test for a set of selected species over discrete time intervals at specified off-gas system locations. Tables 7.25 – 7.30 display summaries of the average and range of analyte concentrations measured over the course of the tests. The melter emissions data show the expected ratios of constituents for a feed low in nitrate, nitrite, and organic carbon: low concentrations of nitrogen oxides, with NO being the most abundant nitrogen oxide present, and few byproducts of organic combustion, such as carbon monoxide. Nitrogen oxides are unaffected by the primary off-gas system, but were reduced across the SCR catalyst, as intended. Ammonia is introduced into the SCR, and therefore it is detected downstream of the unit. The incorporation of sugar into feed during Test 9 served to decrease the concentration of nitrogen oxides and increase the concentration of byproducts from sugar decomposition, such as carbon monoxide and ammonia in the melter emissions. The sodium chloride and sulfate spike solution did not contribute to the gaseous HCl and SO_2 monitored by the FTIR, due primarily to emissions from the spike being mostly particulate. Water emissions downstream of the SBS are relatively constant due to SBS sump temperature being maintained within a narrow range. Another aspect of the emissions is the high

degree of variation during testing, as can discerned from the concentration ranges.

7.4 Hydrogen by Gas Chromatography

Monitoring for hydrogen was performed using Gas Chromatography (GC). The GC was equipped with a 3' × 1/8" stainless-steel column packed with molecular sieve 5A and a thermal conductivity detector operated with an argon carrier gas at 4 psi and a column temperature of 40°C. The unit was calibrated against a certified standard gas (1090 ppmv hydrogen in air) that was progressively diluted using mass-flow controllers to obtain six different hydrogen concentrations ranging between 1090 ppmv and 10 ppmv. The limit of detection of this system was below the 10-ppmv lower calibration point, but was not further quantified. Measurements were made only at the WESP outlet and are indicative of melter emissions, since no hydrogen is removed by the SBS or WESP. Hydrogen values are compared to data from previous tests [9, 17] with the same feed stream in Table 7.31. Low concentrations were measured in all tests, similar to previous tests with AZ-101 feed and no added sugar. Measured hydrogen concentrations in AZ-101 tests with sugar were considerably higher than those measured in these tests, in keeping with the expectation that hydrogen is a byproduct of organic matter decomposition. The small amount of sugar added to feed during Test 9 did not result in more hydrogen emitted than in comparable tests due perhaps to the ruthenium nitrate spike solution added to the feed. No trend was observed between hydrogen emissions and feed rate, contrary to expectations.

7.5 Sulfur-Impregnated Activated Carbon (S-AC) Bed Testing

A small-scale sulfur-impregnated activated carbon (S-AC) column has been added to the slipstream immediately upstream of the silver mordenite column. This material is typically intended to remove mercury from exhaust streams and therefore S-AC performance with respect to organic compounds is unknown. Vendors vouch only for performance of S-AC for mercury removal and loading, and not for performance with respect to VOCs. The mass of activated carbon in the column was 18 lb [30]. Testing of the column was specified in a Test Exception [40] for both LAW and HLW melter tests. During Test 10, the slipstream air upstream of the column was spiked with volatile organic compounds (VOCs: chlorobenzene and trichloroethylene) while monitoring the air at four locations on the column (inlet, two-thirds down, one-thirds down, and outlet) with a gas chromatograph. The VOC injection rate was 0.287 g/min into an average of 20 scfm slipstream air yielding a concentration of 0.0143 g/scf. Spiking was continued until 132 g of VOC was injected into the air stream. Decontamination factors (DFs) for VOCs were calculated by comparing peak areas at the column inlet with the other three locations. No peaks were detected at the column outlet and, therefore, a more sensitive method, such as SW-846-0030, is required to determine the DF for the entire, freshly-packed column. Peaks measured at the other three locations were used to calculate the DFs depicted in Figure 7.6. The gas chromatograph sensitivity for chlorobenzene is much higher than for trichloroethylene, which is reflected in the decontamination factors shown in Figure 7.6. After injecting 20 g of each VOC into the slipstream, column breakthrough was observed for trichloroethylene two-thirds into the column, and for chlorobenzene one-third into the column.

Subsequently, during Test 10, the slipstream air upstream of the column was spiked with hydrochloric acid while air was sampled simultaneously at the column inlet and outlet and scrubbed in impingers containing 2 M sodium hydroxide solution. Chlorine concentrations dropped from 3863 $\mu\text{g/dscf}$ to 400 $\mu\text{g/dscf}$ across the column. An FTIR was also used to monitor various gaseous species (e.g., CO, NO, and NO₂) at various column locations; however, concentrations entering the column were very low due to the low concentration of nitrogen and organic carbon species in the feed. Testing was continued in subsequent LAW melter tests on high nitrogen oxide exhaust streams [30] with disappointing results: virtually none of the spiked organics were removed by the carbon, organics were measured in the column exhaust after organic spiking was discontinued, and sulfur was observed bleeding off the column during testing.

The column inlet and outlet temperatures during Test 10 are plotted in Figure 7.7. The average column inlet and outlet temperatures were 81.2°C and 67.2°C, respectively. The gas inlet temperature falls within the range specified in the test plan of 75°C to 85°C. The inlet and differential pressures are shown in Figure 7.8, and averaged -6.7 in. W.C., and 12.6 in. W.C., respectively. The outlet pressure sensor was out of service. The average inlet gas flow rate was 19.0 scfm and falls within the range specified in the test plan of 5 to 35 scfm.

7.6 Thermal Catalytic Oxidizer (TCO) Testing

The performance of the thermal catalytic oxidizer (TCO) was evaluated by spiking the melter feed with a mixture of trichloroethylene, chlorobenzene, and naphthalene while monitoring the inlet and outlet exhaust streams. A gas chromatograph was used to monitor trichloroethylene and chlorobenzene; flame ionization (40 CFR 60, Method 25A) was used to monitor total gaseous hydrocarbons. Testing was conducted on June 2, 2003 during Test 2, hence the feed composition was AZ-101 with no carbon added in the form of sugar. The results obtained are compared to those obtained for an analogous test with LAW Sub Envelope B1 feed [22] in Table 7.32. The data from this study agree with previous data collected during LAW tests [22, 23]; destruction of total hydrocarbons and chlorobenzene is between 90 and 99 percent, whereas only about three-quarters of the trichloroethylene was destroyed. This suggests that high concentrations of nitrogen oxides and, to a lesser extent, carbon monoxide in the LAW exhaust streams, do not affect TCO performance. The data also indicate that the melter and off-gas configuration tested, including the installed catalyst, do not achieve 99.99% destruction for trichloroethylene and chlorobenzene in any of the tested melter feeds.

SECTION 8.0

DM1200 TESTS WITH NOBLE METALS

The overall strategy for noble metals testing to support the WTP HLW facility is based on a series of small- and intermediate-scale experiments and melter tests in combination with computer modeling [41, 42]. The results are intended to provide the basis for reducing the uncertainty in the estimate of the lifetime of the WTP HLW melter, as well as for identifying potential approaches for increasing that lifetime. Results from previous DM1200 melter tests were reported earlier [39, 17]. Per the Test Plan for the present DM1200 tests [13], ruthenium was included in the AZ-101 feed (Test 9) in order to assess the effects of redox on its volatility. This also provided the opportunity to investigate the effects on the retention of ruthenium in the melter. Information obtained from these tests with respect to these issues is presented in this section.

8.1 Introduction

AZ-101 feed was spiked with ruthenium, which is one of the three noble metals typically found in HLW. As in previous tests [39, 17], yttrium was used as a tracer. Sugar was added to the feed as a reducing agent at a concentration of 3.5 g/L. Compared with previous tests in DM1200 with ruthenium and sugar added to the feed, the concentration of sugar used in this test was lower than the lowest one (7.5 g/L) used before [17]. One of the objectives of these tests was to determine whether the volatility of ruthenium, which is high under oxidizing conditions [39], could be decreased by the addition of small amounts of sugar without converting a significant fraction of the ruthenium to the metallic state, which was observed in previous tests at higher sugar concentrations [17].

Samples of the feed, the melt pool, the melter off-gas emissions, and the SBS blow-down liquids were collected and analyzed to determine the behavior of ruthenium in the melter system. Following a description of testing, the results and a discussion are presented.

8.2 Ruthenium and Yttrium Spiking

This section describes the selection of the ruthenium target concentration in the glass, the make-up of the spike solution, the use of the yttrium tracer, and the spike delivery system.

8.2.1 Target Concentration of Ruthenium in the Glass

The concentrations of noble metals in Envelope D waste are not known exactly. A compilation of analytical data and other information on noble metals concentrations is given in reference [39]. The noble metals oxide concentration used for previous DM1200 melter testing [39] using Ru, Rh, and Pd totaled 0.17 wt% (0.09, 0.03, and 0.05 wt% for RuO₂, Rh₂O₃ and PdO,

respectively). For the current test, as in the preceding test [17, 39], Ru was the only noble metal added to the feed. Ruthenium is the most abundant and most volatile of the three noble metals. The RuO_2 concentration was maintained at the same value (0.09 wt%) as used in the preceding test for comparison purposes. In addition, our review of waste analyses and relative fission yields ($\text{RuO}_2:\text{Rh}_2\text{O}_3:\text{PdO} \approx 4:1:2$) indicated that a RuO_2 concentration of 0.09 wt% is a reasonable value for testing purposes.

8.2.2 Ruthenium Spike Solution

Ruthenium was added to the AZ-101 feed as $\text{RuNO}(\text{NO}_3)_3$ (ruthenium nitrosyl nitrate) in aqueous solution at room temperature. The choice of this particular compound has been discussed in a previous report [17]. The chemical was commercially available as a nitric acid solution. The concentration of the spike solution was adjusted such that the steady-state target concentration of RuO_2 in the product glass would be 0.09 wt% and that the necessary injection rate could be handled by the spike delivery system (Section 8.2.4). The yttrium spike was added by dissolving yttrium nitrate, also a commercial product, in the spike solution. The chemicals were added on a mass basis to a 120-liter plastic container. After adding both chemicals, the container was placed on a scale and water was added under stirring until the net mass reached about 108 kg. The decrease of net mass during spike solution injection is then proportional to the total mass of each element (Y, Ru) injected into the feed.

The concentration of yttrium in the spike solution was such that a steady-state concentration of $C_{\text{Y}_2\text{O}_3} = 0.075$ wt% was reached in the glass. The results of confirmatory DCP-AES analyses of the ruthenium and yttrium spike solution are given in Table 8.1. Agreement between target and measured concentrations was within $\pm 4\%$.

8.2.3 Yttrium Tracer

The yttrium tracer was added to the spike solution to track the spiking process from the point of feed entry into the melter to the point of discharge of melt from the melter into the 55-gallon drums. Unlike ruthenium, yttrium at this concentration dissolves quantitatively in the glass melt and is not volatile. It is neither retained in the melter nor selectively partitioned to the off-gas stream. Yttrium therefore provides a baseline against which to compare the behavior of ruthenium. There was no yttrium in the feed or in the melter before its injection together with ruthenium.

Previous tests have shown that the concentration increase of yttrium in the discharged glass followed very closely the mathematically predicted pattern of a well-mixed reactor [17, 39]. Any deviation of the measured relative ruthenium concentration, $C_{\text{Ru}}(m)/C_{\text{Ru},\infty}$, from the measured relative yttrium concentration, $C_{\text{Y}}(m)/C_{\text{Y},\infty}$, would indicate “non-ideal” behavior of ruthenium due to settling and/or volatilization. Here, $C_i(m)$ is the concentration of oxide ‘i’ ($i = \text{RuO}_2$ or Y_2O_3) in the melt after discharge of mass m (kg) of glass; and $C_{i,\infty}$ is the target steady-

state concentration of oxide i , if there are no losses from the glass melt due to volatilization or settling ($C_{Ru,\infty} = 0.09 \text{ wt\% RuO}_2$ and $C_{Y,\infty} = 0.075 \text{ wt\% Y}_2\text{O}_3$).

8.2.4 Spike Delivery System

Injection of the spike solution into the melter was effected by the arrangement (spike delivery system) shown in Figure 8.1 [17]. The spike solution is contained in a 120-liter plastic tank placed on an electronic scale and flows from this reservoir through a ball valve, which is located near the bottom of the tank. The flow rate is controlled by a calibrated ceramic piston pump, which transports solution continuously through a check valve into a 1-liter stainless steel bottle. This bottle also receives the HLW AZ-101 feed from the ADS pump. Mixing of feed and spike solution takes place in the bottle while a feed pulse of approximately 1 liter enters and leaves the bottle. The spiked feed then flows along the feed line into the DM1200 melter. Using the distance between the lower end of the exit pipe and the bottom of the bottle and its radius, a heel volume of about 10 ml was estimated.

The device was operated such that the flow rate of the spike solution (g/min) was controlled by adjusting the piston pump setting in proportion to the feed rate to the melter. The mass of spike solution injected into the melter was calculated from the recorded mass loss of the tank. Prior to operating the system, a blank test was conducted with water to verify proper operation of the system.

8.3 Sampling and Analyses

Samples were collected from the discharged glass, the melt pool, the cold cap, the feed, and the off-gas system. This section describes the sampling methods used and the samples collected that are relevant to analysis of noble metals behavior.

8.3.1 Discharged Glass

Sampling was done manually by introducing an all-thread metallic rod into the melt stream during discharge. The rod and the captured glass were placed in a ceramic crucible and cooled in the open air. The glass shattered upon cooling and was easily separated from the rod. In this way, 10 g to 20 g of glass was collected for each sample. The glass was powdered and analyzed for ruthenium and yttrium by XRF. Sample identification, date, time, total mass of glass discharged, and the measured concentrations of yttrium and ruthenium as oxides in the glass are given in Table 8.2.

8.3.2 Melt Pool

Suction samples were taken from the DM1200 melt pool during testing with ruthenium.

Suction samples were taken from different locations within the melt pool through one port in the lid of the melter. A ceramic pipe (4 feet long, 1/3 inch inner diameter), connected to a stainless steel pipe was lowered into the melt. A three-way valve allowed application of either suction or pressure to the ceramic pipe. During introduction into the melt, sufficient pressure was applied to yield an air flow rate of 1 scfh to prevent melt from entering the pipe. The distance of the lower end of the ceramic pipe from the bottom of the melter was estimated and, when the desired position was reached, suction was applied. Glass entered the ceramic pipe to a level above the cold cap inside the melter where it froze. The ceramic pipe was then withdrawn and cooled to room temperature.

The uppermost part of the ceramic pipe, i.e., the glass that was drawn in first, was sampled for further characterization. A section about 1/2-inch long was cut from the ceramic pipe, polished and prepared for SEM analysis. The glass matrix and secondary phases in the samples were analyzed by SEM/EDS.

8.3.3 Melter Feed

Melter feed samples were taken from the feed line. Samples were taken downstream of the point of spike introduction by disconnecting the feed pipe from the melter and diverting the feed into a vessel for collection. Each sample weighed about 1 kg. The sample names along with analyses of water content, density, glass yield, and pH are given in Table 2.4. The results from XRF composition analyses of the melter feeds after crucible-melt vitrification are presented in Table 2.6.

8.3.4 Off-Gas System

In the course of melter testing, off-gas samples were collected and analyzed for ruthenium. The melter gas emission samples and SBS blow-down samples are listed in Tables 8.3 and 8.4, respectively. Methods to analyze ruthenium quantitatively in gas emission samples and SBS blow-down liquids were the same as reported earlier [17, 39].

8.4 Results

The results from ruthenium and yttrium spike testing are presented in this section. A discussion of the results follows in Section 8.5.

8.4.1 Ruthenium and Yttrium in the Discharged Glass

Figure 8.2 shows the measured cumulative mass of Y_2O_3 injected into the melter and the corresponding mass found by XRD in the discharged glass as a function of time. In this plot, run time is the time during which the spike solution was injected into the feed.

Figure 8.3 shows the measured cumulative mass of RuO₂ injected into the melter and the corresponding mass found by XRD in the discharged glass as a function of time. In this plot, run time is the time during which the spike solution was injected into the feed.

Table 8.2 shows the concentrations of Y₂O₃ and RuO₂ in the discharged glass. Figure 8.4 shows the concentration C_i(m) of Y₂O₃ in the melt as a function of the mass of discharged glass. It was assumed that concentration of an element in the discharged glass represents its concentration in the melt. This assumption was confirmed in previous tests [17, 39] by the fact that the concentrations of tracers (Y, Ce) measured in the discharged glass could be reproduced using the model of a well-stirred reactor.

The solid line in Figure 8.4 shows the predicted concentration of yttrium based on the model of a well-stirred reactor; equation (1):

$$C_i(m) = C_{i,\infty} \times (1 - \exp(-(m - m_0)/M)) \quad (1)$$

where m₀ is the mass of glass (kg) discharged as part of the ruthenium test segment but prior to injection of ruthenium into the feed; m is the mass of glass (kg) discharged (m = m₀ at the beginning of ruthenium injection); M is the mass of glass melt (kg) in the melter; and ‘i’ is Y₂O₃ or RuO₂, respectively. The mass of glass melt in the melter is about 2,000 kg but varies a little with melter operating conditions. “M” was estimated in previous tests with noble metals [17] and ranged between 1942 kg and 1953 kg. For the current calculations, an “M” value of 1950 kg was used.

Figure 8.5 shows the concentration C_i(m) of RuO₂ in the melt as a function of the mass of discharged glass. The solid line shows the respective concentration calculated with the help of equation (1).

For the first 37.72 hours, during which conditions in the melter were allowed to approach their steady-state values, the spike solution was not injected into the feed. During this time, about 1,611.6 kg (= m₀) of glass was discharged. The total mass of glass produced during spiking was about 10,525 kg. This corresponds to a little more than 5 melt turnovers.

8.4.2 Ruthenium in the Melt Pool

Samples taken from the melt pool (Table 8.5) were characterized by SEM. Figure 8.6 shows an SEM micrograph of a glass sample taken from the bottom of the melt pool. This glass sample shows large clusters, 100 μm in size, of smaller RuO₂ particles (5 to 20 μm). At higher magnification (Figure 8.7) relatively small particles of Ru metal become visible inside some RuO₂ particles. Figure 8.8 shows EDS spectra taken at the two positions marked in Figure 8.7. The absence of an oxygen peak in spectrum EDS-2 is interpreted as evidence of ruthenium being present in the metallic state. Figure 8.9 shows clusters of RuO₂ in the melt. The clusters are less aggregated than on the bottom of the melter. Ru metal was not observed in these particles.

The glass sample from the middle of the melt pool (Figure 8.9) was taken about 6 hours after melter feeding ended. The finding that RuO_2 clusters were less aggregated than on the bottom cannot be explained by gravity settling during idling. In six hours, individual RuO_2 particles are not expected to sink more than 1 to 5 cm, assuming a Stoke's velocity on the order of 10^{-6} m/s. Ru metal particles could have settled faster because of their shape (closer to spherical than RuO_2 rods) and density that is double that of the oxide. This would explain the absence of metal particles in the middle of the melt pool. At the bottom of the melter, particles are more likely to fall on top of each other leading to aggregation.

The discharged glass was not analyzed in terms of noble metal particle morphology because the cooling histories of poured glass and a suction sample are different. A suction sample is small, has a large surface-to-volume ratio and cools very quickly in air, whereas the poured glass cools much more slowly. Spinel was observed in the poured glass, which may have altered or obscured the original morphology of noble metal particles in the melt. In contrast, a rapidly cooled suction sample from the middle of the melt pool is practically free of spinel.

8.4.3 Ruthenium in the Off-Gas System

The results of ruthenium measurements in off-gas samples are given in Tables 8.3 and 8.4. Table 8.3 shows ruthenium volatility data as determined by analysis of melter gas emission samples. Notice that the analytical data have been reported as masses of Ru, not RuO_2 . Nevertheless, Ru is expected to be present as RuO_2 , as was determined experimentally in previous tests [17]. The average emission rate of Ru from the melter was 40.28 mg/min. The ruthenium emission rate increased by a factor of up to about two as bubbling rate was increased from 64 lpm to 131 lpm. Using the data from gas emission samples, the average total loss of ruthenium from the melter was calculated as 5.64% of the amount fed into the melter (Table 8.3).

Most of the Ru coming from the melter was expected to be retained in the SBS and most of the remainder in the WESP. Gas emission data showed (Table 8.3) that the emission rate of Ru from the SBS was 12.07 mg/min. A small amount corresponding to a rate of 0.79 mg/min Ru, or about 2% of the melter emission rate, leaves the WESP to downstream components.

Table 8.4 shows the concentrations of Ru found in the SBS and WESP by analyzing blow-down liquids. As in Table 8.3, the results have been reported as masses of Ru, not RuO_2 , unless otherwise stated. Ru concentrations were fairly constant (last column of Table 8.4) and did not indicate changes with bubbling rate. The calculated average mass of Ru in the SBS amounts to 9.78% of the total amount of Ru injected into the melter. This value is more than twice that calculated with the melter gas emission data from Table 8.3. Analysis of WESP blow down samples from the end of Test 9 indicate that the majority of the ruthenium in the WESP samples was dislodged from the rods by deluging with 40 gallons of water. The ruthenium concentration of the sample taken after the deluge (1T2-W-99B) was over 140 times that of the pre-deluge sample (1T2-W-99A) showing the strong tendency of ruthenium to adhere to the WESP internals.

According to the SBS emission data in Table 8.3, about 30% of Ru entering the SBS is emitted to the WESP. Hence, this amount should be taken into account in calculating the total amount of Ru in the off-gas system based on SBS blow-down data. This correction increases the 9.78% value given above to 13.97%. This latter value is two and half times as high as that determined based on melter gas emission data.

8.5 Discussion

The results from DM1200 melter testing with ruthenium are discussed in this section. Overall, the behavior of ruthenium in this test can be characterized as ‘intermediate’ in the sense that the behavior lies between what was observed when no sugar was added to the feed [39] and when enough sugar was added to reduce ruthenium quantitatively to the metallic state [17].

8.5.1 Ruthenium in Discharged Glass

In previous tests [39], yttrium was used successfully as a tracer to predict Ru, Rh, and Pd concentrations that would be observed if the noble metals, Ru in particular, were soluble in the glass and not subject to partial volatilization and settling. In the test reported here, yttrium was used for the same purpose.

Figure 8.2 shows that the cumulative masses of Y_2O_3 injected into the melter compare favorably with those found in the discharged glass. The small deviation of the Y_2O_3 masses in the glass from the injected masses can be explained by the error of about $\pm 2\%$ of the estimated mass of the melt ‘M’ in equation (1). Increasing the melt mass brings the data (triangles in Figure 8.2) closer to the solid line.

Figure 8.3 shows that there is a large discrepancy between the cumulative masses of RuO_2 injected and found in the discharged glass. This can only be explained by loss of RuO_2 either due to volatilization of RuO_2 or retention in the melter or both. The total mass of RuO_2 injected was 9386.90 g. As defined in [17], the total mass loss (ML_{inj}) of a noble metal, in this case RuO_2 , was calculated as follows (equation 2):

$$ML_{inj} = M_{inj} - M_{dis} - M_i - \Delta m \quad (2)$$

where M_{inj} is the total injected mass of RuO_2 (measured); M_{dis} is the total mass of RuO_2 in the glass discharged during injection; M_i is the mass of a noble metal in the melter pool calculated using the experimentally determined mass of RuO_2 in a glass sample at the end of injection; and Δm is the change in mass of RuO_2 in the melt due to cold cap dissolution. The mass of glass resulting from the cold cap was estimated to be 103 kg [17], which contains 92.70 g RuO_2 . The total mass of RuO_2 found in the discharged glass, in the cold cap, and in the melt was 6401.60 g. Hence, the loss of RuO_2 was 2985.3 g, corresponding to 31.8% of the mass injected.

The materials balance cannot be closed based on measurements alone. The amount of

RuO_2 lost to the off-gas system can be measured by analyzing SBS blow-down and gas emission samples for Ru. However, the amount of RuO_2 settled and thus retained in the melter cannot be measured. The sampling difficulties and the likelihood of inhomogeneous distribution of settled RuO_2 prevents reliable estimation of the amount retained based on melt pool samples. The fraction of Ru retained in the melter therefore must be calculated as the difference between what was injected and what was found in the glass and in the off-gas (see below).

Figure 8.4 shows the increase in concentration of Y_2O_3 in the melt as a function of the mass of discharged glass. The figure shows that injection started after some 1600 kg of glass had already been produced in this segment of the overall test (Test 9). The solid curve was calculated using equation (1). As mentioned in the discussion of Figure 8.2, increasing ‘M’, the mass of the melt, would bring the measured values even closer to the target. In this case, the target curve would move towards the measured concentrations. Figure 8.4 shows that the steady state concentration (0.075 wt%) of Y_2O_3 was reached in the melt. Figure 8.5 compares the modeled target concentrations of RuO_2 with those measured in the glass. It appears that a steady state concentration of RuO_2 is approached in the melt. This would be expected under steady state melter operating conditions, i.e., the rate at which Ru is lost from the melter and the rate at which Ru settles to the bottom of the melter are expected to become constant. Figure 8.5 shows that there is still a slight increase in the RuO_2 concentration after 10,000 kg of glass was produced. Yet the steady state concentration of RuO_2 in the glass can be expected to be about 0.06 wt%. This would suggest that under the given melter operating conditions, 1/3 of RuO_2 injected into the melter is not present in the discharged glass.

8.5.2 Ruthenium in the Melt Pool

Figures 8.6 and 8.7 show that RuO_2 particles settled to the bottom of the melter. Figure 8.8 shows that Ru is present as metal and as an oxide. The presence of some metal is not surprising because the glass redox ratio $[\text{Fe}^{2+}/(\text{Fe}^{2+} + \text{Fe}^{3+})]$ (Section 6) was about 0.1, ranging from 0.06 to 0.1 (Table 6.5). It has been shown in tests [17] where the sugar concentration was varied that Ru was entirely reduced to the metallic state when the glass redox was > 0.1 , ranging from 0.1 to 0.5. The reason for Ru metal being seen only in RuO_2 particles at the bottom of the melter and not within the melt (Figure 8.9) cannot be determined without further investigation of this phenomenon.

It is interesting to note that the shape of the RuO_2 particles in this test is different from the shape of RuO_2 particles found in previous tests [39]. Typically, RuO_2 forms long, thin needles in glass, which were seen before under oxidizing conditions [39]. The shape seen in this test resembles, not needles, but rather, rods that are short and thick. Crystal shapes can be affected by variables such as temperature, concentration, crystal growth rates, nucleating agents, etc. Since the glass redox was considerably different between this test (≈ 0.1) and the test in which needles were seen (< 0.01), this variable may have affected the particle morphology. For example, the higher glass redox favors the trivalent state of Ru, whereas Ru is tetravalent in RuO_2 . Unfortunately, information on the Ru valence is not available to support this hypothesis.

Another aspect of the particle morphology is related to retention. Recent melter modeling and lifetime studies conducted by Glass Service, Inc., Czech Republic, use particle characteristics for long, thin needles. These particles can be expected to have a different, most likely smaller, settling velocity in the melter than short thick rods, which would settle faster for a given particle mass. Consequently, the particle characteristics for the current test should be measured and its effect on the sludge accumulation rate calculated by Glass Service Inc. as part of computer modeling and melter lifetime estimates.

8.5.3 Ruthenium in the Off-Gas System

Table 8.6 summarizes the results of ruthenium volatility from this and previous tests. Under oxidizing conditions (glass redox < 0.01), i.e., in the absence of sugar, the only species found in the glass and in the off-gas system was RuO_2 [39]. (In light of more recent results from gradient furnace testing, the Ru species occurring in the melter (not in the off-gas) must be complemented by a spinel that contains some Ru [42].)

Under oxidizing conditions, Ru volatility was found to increase strongly with the bubbling rate, i.e., from 3.9% loss of Ru at 0 lpm to 32.8% at 65 lpm (Table 8.6). In the current test, the loss of Ru determined by melter gas emission analyses was 5.64%. This value is very low and, if accurate, would compare with the small loss of Ru in a previous test without bubbling (Table 8.6).

The value of 5.64% appears to be too low for two reasons: (1) Based on previous experience, one would expect a relatively high loss if RuO_2 is the dominant Ru species found in the glass, which is the case in this test. (2) The Ru loss calculated with the help of SBS blow-down data is at least twice, if not three times, as high as the values based on melter emission data. In conclusion, we do not consider the gas emission data on ruthenium gathered in the current test as representative of the overall average ruthenium emission rate, perhaps as a result of variation over time and the relatively short sampling time. However, they do provide evidence that Ru is volatile and that its concentration decreased before and after the SBS, and even after the WESP (Table 8.4).

The loss of Ru from the melter was also calculated using data from SBS blow-down analyses (section 8.4.3). The value of 9.78% increases to 13.97 %, as shown section 8.4.3, if we assume that Ru emission rates before and after the SBS are accurate (Table 8.3). Table 8.6 shows that the value of 9.78%, which was obtained at high bubbling rates (64 and 131 lpm) at a glass redox of 0.1, compares favorably with the value of 11.2%, which was obtained at a medium bubbling rate (40 lpm) under oxidizing conditions (glass redox < 0.01). The corrected value of 13.97%, presumably the total loss of Ru from the melter in the present test, compares favorably with the respective value of 15.6% in the test with a bubbling rate of 40 lpm. If the melting condition were oxidizing (no sugar added) in the current test, one would expect the Ru volatility to be at least twice as high as measured (see ‘previous’ test at 65 lpm in Table 8.6). This indicates that the volatility of Ru is lower under mildly reducing than oxidizing conditions. This beneficial effect of slight reducing condition was not unexpected. The volatility of Ru is

enhanced, under oxidizing conditions, by the formation of gaseous oxides such as RuO_3 and RuO_4 , where Ru is hexa- and octavalent, respectively. Formation of these higher valence states of Ru is thermodynamically not favored when reducing conditions prevail.

Table 8.7 summarizes the results on ruthenium retention from this and previous tests. The results do not indicate a significant effect of mildly reducing conditions in the melter (glass redox < 0.1) on Ru retention. The mechanisms controlling settling, and thus retention and growth, of the sludge layer are not well understood. Under oxidizing conditions (glass redox < 0.01), RuO_2 crystallized in the melt as long, thin needles which settled as such or as clusters [39]. In a previous test, under oxidizing conditions (Table 8.7), Ru retention was found to be 20.9% when the melt was not bubbled, versus 13.3 to 17.7% at a bubbling rate of 40 lpm. Under mildly reducing conditions (the present test, Table 8.7), Ru retention (at the melter bottom) was calculated to be 17.83%. This value results from subtracting the volatile Ru (13.97 %, Table 8.6) from the total Ru loss of 31.8% (Section 8.5.1). Ru retention was a little higher than under oxidizing conditions. Considering that the bubbling rates (64 and 131 lpm) were much higher in this test than in the previous test (40 lpm, Table 8.6), we conclude that better mixing did not significantly enhance suspension of RuO_2 particles and their discharge with the melt. The reason for the fairly high retention of Ru of 17.83% could be that the RuO_2 particles form clusters in the melt, which are much larger (10 to 20 times, Figure 8.6) than the individual RuO_2 particles. These clusters can be expected to settle faster than individual particles. Faster settling would also increase the rate at which the sludge layer grows. This effect of faster settling could be evaluated by Glass Service, Inc. in their melter modeling studies for DM1200 and the WTP melter.

Finally, another test previously conducted showed that more reducing conditions (glass redox > 0.1 , e.g., 0.1-0.5) increased retention of Ru to about 90% (Table 8.7) because Ru was reduced to metal and formed large particles, which sank rapidly to the bottom of the melter [17]. The density of the metal is about twice that of the oxide and the particle shape is much more compact.

8.6 Summary and Conclusions

DM1200 melter tests were completed with ruthenium injection into an AZ-101 feed with a low (3.5 g/L feed) sugar concentration. The ruthenium concentration in the feed was such that the steady-state target concentration in the glass would be 0.09 wt% RuO_2 if there were no ruthenium losses by retention and volatilization. The major conclusions from the test are:

- About 1/3 of the ruthenium injected into the melter was not present in the glass based on quantitative XRF analysis of discharged glass samples. The fraction of ruthenium not found by glass analysis is the sum of what was lost to the off-gas and what was retained in the melter.
- The results of off-gas measurements to determine Ru loss from the melter vary by a factor of two between melter gas emission (5.64%) and SBS blow-down liquid analyses (9.8%). The cause is uncertain but may reflect variations of the emissions and the

relatively short off-gas sampling time. We therefore assume that the SBS data acquired in this test are more representative than the melter gas emission data.

- Retention of ruthenium in the melter was relatively high (1783 %) and in the same range as previously observed (13.3 to 20.9%).
- With the small sugar addition to the feed, a relatively small fraction of ruthenium was reduced to the metallic state. Metallic ruthenium was found at the bottom of the melter. Most of the ruthenium in the glass and at the bottom of the melter occurred as RuO₂. The glass redox ratio was about 0.1 (Section 6.2).
- RuO₂ particles suspended in the melt form clusters, several hundred micrometers in diameter. Individual particles are on the order of 5 to 10 µm long and have an estimated average thickness of about 5 µm. The particle morphology of RuO₂ is different from that observed under oxidizing conditions. Long, thin needles were observed before (oxidizing conditions) whereas short thick rods were observed in this test (mild reducing conditions). The reason for the different morphology seen in this test may be the higher glass redox ≈ 0.1 compared with < 0.01 previously.

In light of the results presented in this report, and by comparing them with results from previous tests, the following can be concluded:

- Addition of sugar to the melter feed, even at a concentration as low as 3.5 g/L, reduces the volatility of ruthenium, as compared to tests without sugar.
- Under mildly reducing conditions (e. g., 0.06 - 0.1 Fe²⁺/total iron) Ru volatility increased by a factor of up to about two as bubbling rate was increased from 64 lpm to 131 lpm. Previous melter testing also has shown increased Ru volatility under oxidizing conditions with increasing bubbling rate (Table 8.6). At glass redox > 0.1 , e.g., 0.1 - 0.5, dependence of Ru volatility on bubbling rates, though not measured, would be insignificant because Ru volatility is very low (about 1%).
- A comparison of Ru retention under mildly reducing (glass redox 0.06-0.1) and oxidizing conditions (glass redox < 0.01), as previously tested, suggests that there is no significant effect of the glass redox on retention of ruthenium under mildly reducing conditions (glass redox about 0.1). At strong reducing conditions (glass redox 0.1-0.5), retention increases rapidly to about 90%.

SECTION 9.0 SUMMARY AND CONCLUSIONS

Melter tests were conducted on the DM1200 to determine the effects of bubbler operation and configuration on glass production rate and off-gas system performance while processing the HLW AZ-101 feed composition. Six tests of durations between seven and nine days were conducted using a variety of bubbler configurations, operational strategies, and bubbling rates. An additional test was also conducted with sodium chloride and sulfate spikes to determine the effects of the addition of these salts on production rate. Ruthenium was added to the feed in the last test to investigate its behavior at low feed sugar concentrations. Each of the tests began with a day of feeding to establish the cold cap before determining the production rate during the two- to four-day test segments. Of the test variables investigated, the number of bubbler outlets and their locations had the greatest impact on processing rate. Tests using four outlets either as four lances simulating two double-outlet bubblers or two actual double-outlet bubblers resulted in production rates between 1200 and 1400 kg/m²/day for feed containing 400 g glass per liter. This result was obtained with four lances simulating two double-outlet bubblers with either 8" or 14" separation. Production rates dropped from 1300 to 1100 kg/m²/day when the number of bubbler outlets was reduced from four to two. A 25°C increase in glass temperature did not produce a large rate increase as a result of power supply limitations; however, a production rate of 1450 kg/m²/day was obtained in that test with 23% less bubbling than in the comparable test at 1150°C. Increasing bubbler depth increased production rate; however, the only test systematically evaluating that variable was complicated as a result of bubbler orientation (parallel to the electrode as opposed to diagonally pointing towards the melter center, which placed the bubbler flow closer to the wall), which had a larger effect than did the depth. A smaller but discernable production rate increase was observed as a result of varying the flow between the two bubblers while keeping the total flow constant (skewing). The effect of the chemical additives sodium chloride and sodium sulfate on production rate was unclear in these tests. Sodium chloride and sodium sulfate alone appeared to dramatically decrease production rate while the two combined appeared to increase production rate. However, it is believed that these decreases in production rate may be attributable to cold-cap ridges that built up in the first two test segments that were burned off prior to the last segment.

Since the WTP expectations for the solids content in the feed from pretreatment was revised from 20% to about 15% undissolved solids, the production rate demands on the HLW melter have increased accordingly. Previous tests with the same AZ-101 feed at 15% undissolved solids from pretreatment and the previous nominal bubbler configuration (two single-outlet bubblers, 6 in. from the melter floor, 65 lpm) produced glass at only 750 kg/m²/day [9], which is significantly below the WTP requirement. Consequently, an important result of this work is that the new bubbler configuration (two double-outlet bubblers on the melter floor) yielded significantly higher glass production rates that meet the WTP requirement, even with the more dilute feed.

The general performance of the DM1200 melter and off-gas treatment system was good. However, the results of post-test inspections showed that solids accumulation in the SBS down-

comer continued to be an issue for the first five of these tests. Design modifications to the internals of the SBS, directed by the Project to address this issue, were completed and installed prior to last of the present series of tests. Limited testing (one nine-day test) suggested that the build-up of deposits in the down-comer may be less extensive as a result of the modifications. Numerous film cooler blockages requiring mechanical clean-out occurred throughout several of the tests. Transition line clogs between the film cooler and SBS inlet also occurred and, on one occasion, required removal of part of the line to remove the occluding material. The ADS pump worked well throughout testing although the actuator solenoid valve had to be replaced twice during the tests. Extensive sets of process engineering data were collected during the six tests. Energy balances were conducted for select test segments around the melter and SBS with excellent closure. The glass product was close to the intended composition once the melt inventory was turned over for all elements except zirconium, which did not impact testing. The amount of divalent iron was within the 5 to 10 percent target range for the test evaluating ruthenium behavior in the cold cap and melt pool.

Isokinetic particulate samples were taken at the outlets of the melter and SBS for each bubbler operational setting and once during most of the tests at the WESP outlet. The purpose of these samples was to determine the effects of changes in bubbler operation on emissions, as well as to determine the efficiency of off-gas system components. Particulate carryover from the melter increased with increasing bubbling rate but was unaffected by bubbler configuration. The composition of the melter emissions was unchanged by differences in bubbling rate and operation. Elemental DF values were determined across the melter, SBS, and WESP. Calculated DFs across the primary off-gas system components were higher for most of these tests as compared to previous tests that included the WESP deluges during the exhaust sampling interval. Modifications of the SBS made prior to the last test did not result in discernable changes in particle removal efficiency. Additional emissions data collected during the tests were particle size distributions of the melter emissions, concentrations of various gaseous species throughout the off-gas system by FTIR, and hydrogen concentrations by gas chromatography at the WESP outlet.

The volumes of processing solutions generated in the SBS, WESP, HEME, and PBS were documented during testing and representative samples were subjected to chemical analysis. The SBS solutions were close to neutral pH, due in large part to the lack of acid gases in the exhaust stream. The major dissolved species were halogens, boron, and alkali metals, while the suspended species closely resembled the feed composition. The measured SBS TSS and TDS concentrations each ranged between 2 to 5 g/L. The WESP sump fluid was also in the neutral pH region but had negligible suspended solids. The WESP solutions contained significant concentrations of boron, sulfate, and alkali halides. The WESP was sprayed continuously during these tests and was deluged with 40 gallons of water once daily, resulting in a daily blow-down volume of between 80 and 120 gallons. The 23,330 gallons of liquid that accumulated in the SBS during testing originated from the condensation of water from the melter feed.

The TCO and a slip stream carbon column were evaluated for removal of trichloroethylene and chlorobenzene during one of the tests; the former by spiking these compounds into the melter feed and the latter by injecting the slip stream air with the organic

compounds. Measured TCO destruction efficiencies of 93% for chlorobenzene, 77% for trichloroethylene, and 97% for total hydrocarbons were very similar to those measured during tests with LAW feeds. The carbon column installed on a 10% slip stream taken upstream of the catalyst was evaluated for removal of HCl, trichloroethylene, and chlorobenzene. Column breakthrough at points one-third and two-thirds into the carbon was demonstrated. Removal of chlorine by the column was about 90%.

One of the tests used feed spiked with ruthenium and an yttrium tracer to determine the retention and volatilization of ruthenium under mildly reducing conditions (iron redox ratio around 0.06 - 0.1). The fraction of ruthenium lost to the off-gas stream under mildly reducing conditions was between 2.5 and 10%, which is less than was found under oxidizing conditions. Retention of ruthenium in the melter was relatively high (17.83%) and in the same range as previously observed (13.3 to 20.9%) under oxidizing conditions, and significantly less than observed under more reducing conditions (90%). Under mildly reducing conditions (e. g., 0.06-0.1 Fe^{2+} /total iron) Ru volatility increased by a factor of up to about two as bubbling rate was increased from 64 lpm to 131 lpm. With the small sugar addition to the feed, a relatively small fraction of ruthenium was reduced to the metallic state. Metallic ruthenium was found at the bottom of the melter, but most of the ruthenium in the glass and at the bottom of the melter occurred as RuO_2 . The particle morphology of RuO_2 was different from that observed under oxidizing conditions. Long, thin needles were observed before (oxidizing conditions), whereas short thick rods were observed in this test (mild reducing conditions). This shape difference is likely to affect settling rates.

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- [40] “Test Exception to Define Testing for a Small Scale S-AC Bed in the Secondary Off-Gas Treatment Equipment Train,” 24590-WTP-TEF-RT-03-046, 8/14/03.
- [41] “Noble Metals Testing to Support RPP-WTP HLW Vitrification: Gradient Furnace, Crucible, and Melter Testing”, W. Lutze, W. Gong, I. L. Pegg, Test Plan, Rev. 0, VSL-02T7400-1, July 2002.
- [42] “Modeling the Behavior of Noble Metals During HLW Vitrification”, W. Lutze, W. Gong, P. Schill, C. C. Chapman, I. L. Pegg, Test Plan, VSL-03T33740-1, Rev. 1, August 6, 2003.
- [43] “Noble Metals Testing to Support WTP HLW Vitrification: Interim Report on Gradient Furnace Testing”, W. Lutze, W. Gong, I. L. Pegg, VSL-04S4740-1, February 13, 2004, Rev. 0.

Table 2.1. Compositional Summary of Different Waste Streams and Blended Solids.

Chemical Species	AZ-101 Solids	Recycle Stream	Separation Factor*	Cs-Eluate	Tc-Eluate	Blended Solids
	FRP02	PWD01	-	CNP12	TEP12	HLP09b
	(lb/day)	(lb/day)	(fraction remained)	(lb/day)	(lb/day)	(lb/day)
Ag	4.66E+00	4.17E-21	1.00E+00	-	-	4.66E+00
Al	1.49E+03	1.77E+00	4.20E-01	5.27E-01	2.11E-02	6.26E+02
As	1.43E+00	1.21E-01	1.00E+00	-	-	1.56E+00
B	6.44E+00	3.11E+00	1.00E+00	6.60E-01	6.80E-02	1.03E+01
Ba	1.58E+01	1.64E-04	2.42E-01	1.71E-03	1.33E-04	3.82E+00
Be	2.24E-01	0.00E+00	1.00E+00	-	-	2.24E-01
Bi	1.49E+00	2.34E-04	1.00E+00	-	-	1.49E+00
Ca	4.60E+01	8.14E-02	9.88E-01	3.75E-02	2.29E-03	4.56E+01
Cd	1.54E+02	6.19E-04	8.27E-02	5.12E-03	-	1.27E+01
Ce	1.88E+01	5.88E+00	7.72E-02	-	-	1.90E+00
Cl	1.15E+00	9.42E-02	7.95E-02	-	1.28E-02	1.12E-01
Co	1.00E+00	0.00E+00	1.00E+00	-	-	1.00E+00
Carbonate	4.46E+01	2.24E+00	1.31E-01	-	-	6.12E+00
Cr	7.33E+00	2.15E-01	1.52E-01	6.31E-02	3.18E-03	1.21E+00
Cs	7.06E-01	0.00E+00	1.15E-01	2.80E-01	-	3.61E-01
Cu	5.20E+00	2.37E-44	1.00E+00	2.94E-01	-	5.50E+00
F	1.01E+02	1.27E+00	8.25E-02	-	-	8.42E+00
Fe	1.96E+03	1.41E+00	9.94E-01	1.28E-01	2.22E-02	1.95E+03
Hg	4.55E-02	1.90E-05	1.00E+00	-	-	4.55E-02
K	4.64E+01	6.82E-01	9.29E-02	1.86E+00	4.16E-02	6.28E+00
La	8.02E+01	1.80E-02	9.85E-01	-	-	7.90E+01
Li	1.45E+00	8.15E-01	1.00E+00	-	-	2.26E+00
Mg	1.46E+01	7.28E-06	1.00E+00	-	2.98E-04	1.46E+01
Mn	2.44E+01	8.20E-02	9.99E-01	1.71E-03	2.98E-04	2.45E+01
Mo	1.25E+00	0.00E+00	1.00E+00	-	-	1.25E+00
Na	1.18E+03	3.59E+02	1.15E-01	1.71E+01	3.32E-01	1.94E+02
Nd	4.88E+01	0.00E+00	1.00E+00	-	-	4.88E+01
Ni	1.11E+02	1.07E-01	9.83E-01	2.61E-01	2.65E-03	1.10E+02
Nitrite	3.04E+02	2.56E-01	7.84E-02	-	-	2.38E+01
Nitrate	2.03E+02	8.21E+02	7.77E-02	4.92E+01	-	1.29E+02
Hydroxide	1.85E+03	3.16E+01	5.97E-01	-	-	1.12E+03
Hydroxide(Bound)	4.15E+03	0.00E+00	7.68E-02	-	-	3.19E+02
Pb	7.00E+00	2.00E-02	1.00E+00	1.14E-01	-	7.14E+00
Pd	0.00E+00	1.95E-09	1.00E+00	-	-	1.95E-09
Phosphate	5.10E+00	5.01E-03	2.20E-01	-	-	1.16E+00
Pr	1.16E+01	0.00E+00	1.00E+00	-	-	1.16E+01
Rb	3.18E-01	0.00E+00	1.00E+00	-	-	3.18E-01
Rh	3.85E+00	0.00E+00	1.00E+00	-	-	3.85E+00
Sb	1.76E-01	0.00E+00	-	-	-	0.00E+00
Se	6.48E-01	0.00E+00	-	-	-	0.00E+00
Si	3.60E+01	6.46E+00	9.97E-01	4.57E-01	9.29E-02	4.29E+01
Sulfate	2.36E+02	2.46E+01	7.86E-02	-	-	2.05E+01
Sr	6.46E+00	0.00E+00	9.58E-01	-	-	6.18E+00
Ta	1.76E-01	0.00E+00	-	-	-	0.00E+00
Te	1.93E+00	0.00E+00	-	-	-	0.00E+00
Th	6.35E+00	0.00E+00	-	-	-	0.00E+00
Ti	7.84E-01	1.39E-03	1.00E+00	-	-	7.85E-01
Tl	1.76E-01	0.00E+00	-	-	-	0.00E+00
TOC	7.02E+01	0.00E+00	7.67E-02	-	-	5.39E+00
U	1.34E+02	0.00E+00	-	6.13E-01	-	6.13E-01
V	7.13E-01	0.00E+00	-	-	-	0.00E+00
Zn	2.09E+00	4.71E-01	1.00E+00	5.29E-02	2.32E-04	2.61E+00
Zr	6.42E+02	3.13E-01	9.99E-01	-	-	6.41E+02
TOTAL	1.30E+04	1.26E+03 [#]	-	7.16E+01	5.99E-01	5.50E+03

* Analytes with undetermined separation factors are omitted.

[#] 1.28E+03 of H⁺ is included.

"-" Empty data field.

Table 2.2. Compositional Summary (Oxide Basis) of the AZ-101 HLW Simulant, Glass Additives, Target Test Glass, and the Corresponding Crucible-Melt Glass (HLW98-77).

Constituent	HLW Simulant	Glass Former (as wt% of glass)	Melter Test Target Glass	HLW98-77
Ag ₂ O	-	-	-	0.02%
Al ₂ O ₃	20.64%	-	5.21%	5.20%
B ₂ O ₃	0.58%	11.75%	11.91%	11.91%
BaO	0.07%	-	0.02%	-
CaO	1.11%	-	0.28%	0.28%
CdO	0.25%	-	0.06%	0.06%
Cs ₂ O	0.01%	-	0.00%	-
CuO	0.12%	-	0.03%	0.03%
F	0.15%	-	0.04%	0.04%
Fe ₂ O ₃	48.56%	-	12.26%	12.22%
K ₂ O	0.13%	-	0.03%	0.03%
La ₂ O ₃	1.62%	-	0.41%	0.41%
Li ₂ O	0.08%	3.50%	3.52%	3.53%
MgO	0.42%	-	0.11%	0.11%
MnO	0.67%	-	0.17%	0.17%
Na ₂ O	4.56%	10.50%	11.65%	11.66%
Nd ₂ O ₃	1.22%	-	0.31%	0.31%
NiO	2.44%	-	0.62%	0.61%
PbO	0.13%	-	0.03%	0.03%
SiO ₂	1.61%	47.00%	47.40%	47.45%
SO ₃	0.30%	-	0.08%	0.08%
SrO	0.13%	-	0.03%	0.03%
ZnO	0.06%	2.00%	2.02%	2.02%
ZrO ₂	15.12%	-	3.82%	3.81%
TOTAL	100.00%	74.75%	100.00%	100.00%
Volatiles (g/100 g oxide)	-	-	-	-
Carbonate	0.106	-	-	-
Nitrite	0.414	-	-	-
Nitrate	2.237	-	-	-
TOC	0.093	-	-	-

"-" Empty data field.

Table 2.3. Composition of Melter Feed to Produce 1 Metric Ton of Target Glass from AZ-101 HLW Simulant (22.6 wt% total solids).

AZ-101 HLW Simulant		Glass-Forming Additives	
Starting Materials	Target Weight (kg)	Starting Materials	Target Weight (kg)
Al(OH) ₃	83.61	-	-
H ₃ BO ₃	2.63	Na ₂ B ₄ O ₇ ·10H ₂ O	325.08
Ba(OH) ₂ ·8H ₂ O	0.37	-	-
Ca(OH) ₂	3.78	-	-
CdO	0.64	-	-
CsOH (solution)	0.05	-	-
CuO	0.31	-	-
NaF	0.84	-	-
Fe(OH) ₃ (13% slurry)	1257.25	-	-
KNO ₃	0.71	-	-
La(OH) ₃ ·3H ₂ O	6.15	-	-
Li ₂ CO ₃	0.51	Li ₂ CO ₃	88.78
Mg(OH) ₂	1.55	-	-
MnO ₂	2.09	-	-
NaOH	9.24	Na ₂ CO ₃	91.03
Nd ₂ O ₃	3.11	-	-
Ni(OH) ₂	7.89	-	-
PbO	0.33	-	-
SiO ₂	4.08	SiO ₂	474.75
Na ₂ SO ₄	1.36	-	-
Sr(OH) ₂ ·8H ₂ O	0.86	-	-
ZnO	0.15	ZnO	20.20
Zr(OH) ₄ ·xH ₂ O	98.27	-	-
NaNO ₂	1.61	-	-
NaNO ₃	7.19	-	-
H ₂ C ₂ O ₄ ·2H ₂ O	1.24	-	-
Water	60.00	-	-
TOTAL	1555.84	TOTAL	999.84
-	-	FEED TOTAL	2555.67

"-" Empty data field.

Table 2.4. Properties of DM1200 Melter Feed Samples.

Test	Date	Name	% Water	Density	Glass Yield		pH
				(g/ml)	(kg/kg)	(g/l)	
2 (Bubbler Depth)	5/28/03	X12-F-21A	55.24	1.39	0.392	544	10.51
	5/29/03	X12-F-58A	55.42	1.37	0.364	498	10.72
	5/30/03	X12-F-92A	55.56	1.36	0.373	508	10.67
	5/31/03	X12-F-125A	56.96	1.37	0.365	500	10.56
	6/1/03	Y12-F-10A	56.15	1.37	0.371	508	10.58
	6/2/03	Y12-F-44A	56.03	1.35	0.381	514	10.55
	6/3/03	Y12-F-78A	55.73	1.36	0.374	508	10.54
	6/4/03	Y12-F-115A	56.06	1.36	0.377	513	10.59
	6/5/03	Y12-F-148A	55.52	1.36	0.377	512	10.56
1 (Bubbler Skewing)	6/25/03	Z12-F-65A	55.15	1.39	0.384	533	10.61
	6/26/03	Z12-F-101A	55.35	1.39	0.386	537	10.58
	6/27/03	Z12-F-140A	55.10	1.37	0.384	526	10.58
	6/28/03	1A2-F-27A	55.20	1.37	0.382	523	10.68
	6/29/03	1A2-F-65A	55.41	1.36	0.374	508	10.71
	6/30/03	1A2-F-102A	55.75	1.39	0.376	523	10.60
	7/1/03	1A2-F-140A	55.77	1.36	0.378	514	10.60
Average (Tests 1 and 2)			55.65	1.37	0.377	517	10.60
Average for previous DM1200 tests at same target [9]			55.3	1.39	0.383	534	10.63
3 (Bubbler Placement)	7/15/03	1B2-F-56A	63.81	1.32	0.309	407	10.36
	7/16/03	1B2-F-96A	64.58	1.32	0.294	388	10.37
	7/17/03	1B2-F-135A	62.99	1.33	0.311	413	10.31
	7/18/03	1C2-F-27A	63.00	1.33	0.313	416	10.33
	7/19/03	1C2-F-69A	62.85	1.33	0.316	420	10.35
	7/20/03	1C2-F-114A	62.95	1.33	0.311	413	10.32
	7/21/03	1D2-F-8A	63.02	1.33	0.314	418	10.31
	7/22/03	1D2-F-47A	62.97	1.34	0.310	415	10.30
8 (Bubbler in Corners)	8/5/03	1D2-F-90A	64.27	1.32	0.303	400	10.31
	8/6/03	1D2-F-129A	62.86	1.32	0.314	414	10.34
	8/7/03	1D2-F-151A	63.11	1.32	0.312	412	10.28
		1E2-F-24A	62.68	1.33	0.318	423	10.37
	8/8/03	1E2-F-60A	63.11	1.33	0.311	414	10.37
	8/9/03	1E2-F-72A	63.09	1.33	0.315	419	10.37
		1E2-F-87A	64.05	1.32	0.308	406	10.38
		1E2-F-104A	63.08	1.33	0.313	416	10.41
	8/10/03	1E2-F-124A	62.73	1.33	0.318	423	10.44
		1E2-F-144A	62.75	1.33	0.314	418	10.44
	8/11/03	1F2-F-5A	62.59	1.34	0.318	426	10.43
		1F2-F-16A	62.85	1.34	0.313	419	10.42
		1F2-F-42A	63.03	1.34	0.311	416	10.39
	8/12/03	1F2-F-58A	62.81	1.33	0.317	421	10.41
		1F2-F-72A	63.13	1.33	0.314	418	10.43
	8/13/03	1F2-F-90A	62.99	1.32	0.318	420	10.45
		1F2-F-106A	63.60	1.32	0.311	410	10.41

Table 2.4. Properties of DM1200 Melter Feed Samples (continued).

Test	Date	Name	% Water	Density	Glass Yield		pH
				g/ml	kg/kg	g/l	
10 (Salt Chemistry)	9/3/03	1I2-F-77A	62.96	1.32	0.310	410	10.47
	9/4/03	1I2-F-97A	62.85	1.33	0.310	412	10.49
	9/5/03	1I2-F-118A	63.94	1.32	0.305	402	10.50
	9/6/03	1J2-F-17A	62.38	1.32	0.313	413	10.52
	9/7/03	1J2-F-68A	62.54	1.33	0.310	413	10.54
	9/8/03	1J2-F-90A	62.01	1.32	0.312	412	10.46
		1J2-F-97A	62.51	1.33	0.317	421	10.52
	9/9/03	1J2-F-125A	63.00	1.33	0.317	421	10.51
		1J2-F-141A	65.74	1.32	0.290	383	10.56
		1J2-F-144A	63.45	1.32	0.312	412	10.52
	9/10/03	1J2-F-155A	62.33	1.34	0.321	429	10.52
9 (Best Configuration)	3/24/04	1R2-F-21A	61.40	1.34	0.317	425	10.59
	3/25/04	1R2-F-58A	62.20	1.32	0.314	414	10.53
		1R2-F-72A	63.56	1.32	0.304	401	10.50
	3/26/04	1R2-F-123A	63.20	1.31	0.308	403	10.63
	3/27/04	1R2-F-144A	63.12	1.33	0.311	413	10.59
	3/28/04	1S2-F-47A	62.70	1.33	0.315	419	10.62
	3/29/04	1S2-F-84A	62.90	1.33	0.308	410	10.56
	3/30/04	1S2-F-128A	63.05	1.33	0.310	412	10.55
	3/31/04	1T2-F-24A	63.05	1.33	0.309	411	10.60
	4/1/04	1T2-F-68A	63.30	1.34	0.310	415	10.58
Average (Tests 3, 8, 10, 11)			63.07	1.33	0.311	413	10.45
Average from AZ-101 Reductant test [17]			62.62	1.33	0.307	408	10.37
Average for previous DM1200 tests at same target [9]			63.70	1.33	0.304	405	10.45

Table 2.5. Feed Properties and Rheological Characteristics of Melter Feed Samples.

Test	Date	Name	% Water	Density	Glass Yield		pH	Yield Stress (Pa)	Viscosity (Poise)		
				(g/ml)	(kg/kg)	(g/l)			@1/s	@10/s	@100/s
8	08/13/03	1F2-F-106A	63.60	1.32	0.311	410	10.41	3.7	16.06	2.07	0.33
9	03/25/04	1R2-F-58A	62.20	1.32	0.314	414	10.53	3.0	18.02	2.30	0.37
	03/28/04	1S2-F-47A	62.70	1.33	0.315	419	10.62	2.4	16.27	2.09	0.35
	04/01/04	1T2-F-68A	63.30	1.34	0.310	415	10.58	2.2	16.27	1.95	0.33
Average from Previous DM1200 Tests [9]			63.70	1.33	0.304	405	10.45	1.9	12.53	1.60	0.26
Average from Reductant Tests [17]			62.62	1.33	0.307	408	10.37	1.9	9.83	1.34	0.23

Table 2.6. XRF Analyzed Compositions for Melter feed Samples (wt%).

Test		2										1
-	Target	X12-F-21A	X12-F-58A	X12-F-92A	X12-F125A	Y12-F-10A	Y12-F-44A	Y12-F-78A	Y12-F-115A	Y12-F-148A	Z12-F-65A	
Al ₂ O ₃	5.21	5.47	5.43	5.46	5.30	5.31	5.32	5.29	5.30	5.35	5.28	
B ₂ O ₃ *	11.90	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	
BaO	0.02	0.06	0.06	0.05	0.06	0.05	0.05	0.05	0.06	0.05	0.05	
CaO	0.28	0.42	0.41	0.40	0.40	0.40	0.39	0.40	0.40	0.40	0.40	
CdO	0.06	0.09	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.08	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	0.10	0.18	0.19	0.20	0.20	0.20	0.21	0.22	0.19	
CuO	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Fe ₂ O ₃	12.26	13.08	12.26	12.45	12.69	12.53	12.19	12.39	12.36	12.33	12.40	
K ₂ O	0.03	0.11	0.11	0.11	0.11	0.12	0.11	0.11	0.11	0.11	0.11	
La ₂ O ₃	0.41	0.45	0.42	0.44	0.43	0.45	0.41	0.43	0.43	0.42	0.44	
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	
MgO	0.11	0.11	0.12	0.12	0.11	0.04	0.04	0.09	0.11	0.08	0.08	
MnO	0.17	0.38	0.28	0.28	0.24	0.22	0.20	0.20	0.20	0.20	0.27	
Na ₂ O	11.65	10.90	11.45	11.11	10.53	10.69	11.31	11.03	10.91	10.77	10.54	
Nd ₂ O ₃	0.31	0.32	0.31	0.31	0.32	0.31	0.31	0.31	0.31	0.31	0.30	
NiO	0.62	0.64	0.69	0.62	0.64	0.64	0.63	0.63	0.63	0.63	0.64	
P ₂ O ₅	¶	<0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	
PbO	0.03	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.04	
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
SiO ₂	47.41	45.23	46.06	46.03	46.35	46.48	46.51	46.44	46.52	46.66	46.66	
SO ₃	0.08	0.05	0.06	0.06	0.07	0.07	0.07	0.06	0.07	0.07	0.06	
SrO	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	
TiO ₂	¶	0.10	0.09	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.10	
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	2.02	1.98	1.83	1.87	1.90	1.88	1.82	1.83	1.84	1.83	1.87	
ZrO ₂	3.82	4.82	4.68	4.76	4.92	4.87	4.73	4.81	4.82	4.84	4.94	
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

“-“ sign for blank field

NA – Not analyzed

Table 2.6. XRF Analyzed Compositions for Melter feed Samples (wt%) (continued).

Test		1						3			
-	Target	Z12-F-101A	Z12-F-140A	1A2-F-27A	1A2-F-65A	1A2-F-102A	1A2-F-140A	1B2-F-21A	1B2-F-56A	1B2-F-96A	1B2-F-135A
Al ₂ O ₃	5.21	5.31	5.11	5.18	5.20	5.24	5.22	6.07	5.87	6.33	5.73
B ₂ O ₃ *	11.90	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.06	0.05	0.06	0.05	0.06	0.06	0.06	0.06	0.05	0.06
CaO	0.28	0.40	0.41	0.40	0.41	0.42	0.41	0.40	0.41	0.38	0.39
CdO	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.05	0.06
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	¶	0.20	0.19	0.23	0.22	0.20	0.18	<0.01	<0.01	<0.01	<0.01
CuO	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	12.44	12.55	12.61	12.83	12.82	12.41	11.81	11.67	10.99	11.15
K ₂ O	0.03	0.12	0.12	0.12	0.12	0.12	0.11	0.14	0.14	0.15	0.15
La ₂ O ₃	0.41	0.42	0.42	0.44	0.43	0.43	0.40	0.39	0.39	0.40	0.41
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.07	0.07	0.06	0.06	0.05	0.08	0.06	0.12	0.06	0.07
MnO	0.17	0.22	0.21	0.20	0.20	0.19	0.19	0.16	0.19	0.18	0.17
Na ₂ O	11.65	10.78	11.01	10.90	10.45	10.27	11.27	10.26	10.76	11.33	11.18
Nd ₂ O ₃	0.31	0.30	0.31	0.32	0.33	0.33	0.33	0.30	0.30	0.30	0.29
NiO	0.62	0.65	0.69	0.70	0.69	0.68	0.65	0.57	0.56	0.52	0.52
P ₂ O ₅	¶	0.02	0.02	0.02	0.02	0.01	0.02	<0.01	0.02	0.02	0.02
PbO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	<0.01	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	46.43	46.07	46.00	46.11	46.30	46.05	47.48	47.27	47.71	47.90
SO ₃	0.08	0.07	0.06	0.06	0.07	0.07	0.07	0.08	0.07	0.08	0.08
SrO	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.03
TiO ₂	¶	0.09	0.09	0.09	0.10	0.09	0.09	0.10	0.10	0.09	0.09
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	2.02	1.85	1.92	1.88	1.93	1.93	1.88	1.79	1.79	1.65	1.70
ZrO ₂	3.82	4.94	5.10	5.13	5.19	5.20	4.96	4.73	4.72	4.19	4.49
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

"-" sign for blank field

NA – Not analyzed

Table 2.6. XRF Analyzed Compositions for Melter feed Samples (wt%) (continued).

Test		3					8				
-	Target	1C2-F-27A	1C2-F-69A	1C2-F-114A	1D2-F-8A	1D2-F-47A	1D2-F-90A	1D2-F-129A	1D2-F-151A	1E2-F-24A	1E2-F-60A
Al ₂ O ₃	5.21	5.19	5.20	5.74	6.02	6.17	5.25	5.24	6.08	5.85	5.34
B ₂ O ₃ *	11.90	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.06	0.05	0.06	0.05	0.05	0.06	0.06	0.06	0.06	0.06
CaO	0.28	0.40	0.39	0.39	0.38	0.40	0.42	0.41	0.40	0.42	0.42
CdO	0.06	0.08	0.07	0.05	0.06	0.05	0.07	0.07	0.06	0.06	0.06
Cl	§	<0.01	<0.01	0.01	<0.01	<0.01	0.02	0.01	0.01	0.01	0.01
Cr ₂ O ₃	¶	0.21	0.22	<0.01	<0.01	<0.01	0.21	0.21	<0.01	<0.01	0.20
CuO	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	12.62	12.55	11.25	11.29	11.55	12.64	12.33	11.29	11.47	12.14
K ₂ O	0.03	0.11	0.11	0.15	0.14	0.15	0.11	0.11	0.17	0.16	0.11
La ₂ O ₃	0.41	0.42	0.42	0.40	0.41	0.41	0.43	0.43	0.42	0.43	0.43
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.07	0.08	0.09	0.08	0.10	0.09	0.09	0.09	0.07	0.07
MnO	0.17	0.20	0.20	0.17	0.16	0.16	0.18	0.19	0.16	0.18	0.19
Na ₂ O	11.65	10.83	10.72	10.94	11.10	10.49	10.79	11.31	10.98	10.81	11.30
Nd ₂ O ₃	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.31	0.31	0.30	0.32
NiO	0.62	0.67	0.66	0.54	0.55	0.56	0.64	0.63	0.54	0.57	0.63
P ₂ O ₅	¶	0.02	0.03	0.02	0.02	0.02	0.02	<0.01	0.02	0.02	0.02
PbO	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	46.19	46.42	47.91	47.37	47.35	46.14	46.18	47.31	47.47	46.40
SO ₃	0.08	0.07	0.08	0.07	0.07	0.08	0.09	0.07	0.08	0.08	0.08
SrO	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
TiO ₂	¶	0.09	0.09	0.09	0.10	0.11	0.10	0.09	0.09	0.09	0.09
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	2.02	1.89	1.86	1.71	1.74	1.79	1.89	1.84	1.76	1.83	1.82
ZrO ₂	3.82	5.03	4.99	4.59	4.64	4.72	5.02	4.89	4.65	4.60	4.80
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

“-“ sign for blank field

NA – Not analyzed

Table 2.6. XRF Analyzed Compositions for Melter feed Samples (wt%) (continued).

Test		8									
-	Target	1E2-F-72A	1E2-F-87A	1E2-F-104A	1E2-F-124A	1E2-F-144A	1F2-F-5A	1F2-F-16A	1F2-F-42A	1F2-F-58A	1F2-F-72A
Al ₂ O ₃	5.21	5.59	5.27	5.59	5.61	5.48	5.61	5.27	5.47	5.29	5.27
B ₂ O ₃ *	11.90	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.05	0.06	0.06	0.06	0.05	0.06	0.06	0.05	0.06	0.05
CaO	0.28	0.41	0.41	0.41	0.41	0.41	0.40	0.41	0.42	0.41	0.40
CdO	0.06	0.07	0.06	0.07	0.06	0.07	0.06	0.07	0.07	0.06	0.07
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	¶	<0.01	0.20	<0.01	<0.01	<0.01	<0.01	0.20	<0.01	0.21	0.22
CuO	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	11.64	12.41	11.59	11.68	11.87	11.55	12.34	12.15	12.13	12.42
K ₂ O	0.03	0.12	0.12	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11
La ₂ O ₃	0.41	0.42	0.43	0.43	0.43	0.44	0.42	0.45	0.44	0.43	0.44
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.10	0.08	0.08	0.07	0.08	0.09	0.03	0.09	0.12	0.09
MnO	0.17	0.18	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.18	0.19
Na ₂ O	11.65	11.27	11.08	11.41	11.03	10.90	11.45	11.08	10.51	11.55	10.91
Nd ₂ O ₃	0.31	0.31	0.30	0.31	0.31	0.30	0.31	0.30	0.31	0.30	0.31
NiO	0.62	0.56	0.63	0.56	0.56	0.58	0.56	0.63	0.58	0.61	0.63
P ₂ O ₅	¶	0.02	<0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	<0.01
PbO	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	46.94	46.34	46.98	47.22	47.06	46.99	46.40	47.02	46.21	46.43
SO ₃	0.08	0.08	0.07	0.08	0.07	0.08	0.06	0.08	0.08	0.07	0.08
SrO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03
TiO ₂	¶	0.09	0.09	0.10	0.10	0.10	0.09	0.09	0.10	0.09	0.09
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	2.02	1.83	1.86	1.82	1.82	1.87	1.79	1.86	1.89	1.79	1.84
ZrO ₂	3.82	4.77	4.89	4.67	4.71	4.86	4.70	4.89	4.96	4.78	4.91
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

“-“ sign for blank field

NA – Not analyzed

Table 2.6. XRF Analyzed Compositions for Melter feed Samples (wt%) (continued).

Test		8		10							
-	Target	1F2-F-90A	1F2-F-106A	1I2-F-77A	1I2-F-97A	1I2-F-118A	1J2-F-97A	1J2-F-17A	1J2-F-68A	1J2-F-90A	1J2-F-125A
Al ₂ O ₃	5.21	6.01	5.81	6.07	6.43	6.56	5.56	6.02	5.60	6.03	6.02
B ₂ O ₃ *	11.90	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.05	0.07
CaO	0.28	0.40	0.42	0.42	0.41	0.40	0.39	0.42	0.42	0.41	0.39
CdO	0.06	0.06	0.07	0.08	0.06	0.06	0.07	0.06	0.07	0.05	0.06
Cl	§	<0.01	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	0.01	0.18
Cr ₂ O ₃	¶	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CuO	0.03	0.03	0.03	0.02	0.02	0.03	0.04	0.04	0.03	0.04	0.03
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	11.38	11.64	11.73	11.28	11.55	11.38	11.80	11.61	11.63	11.25
K ₂ O	0.03	0.14	0.13	0.14	0.16	0.17	0.12	0.14	0.12	0.15	0.15
La ₂ O ₃	0.41	0.42	0.42	0.41	0.40	0.43	0.43	0.44	0.43	0.43	0.40
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.10	0.10	0.07	0.07	0.08	0.06	0.11	0.07	0.11	0.06
MnO	0.17	0.17	0.17	0.18	0.18	0.16	0.18	0.19	0.19	0.18	0.17
Na ₂ O	11.65	10.95	11.08	10.55	10.54	10.42	11.29	10.21	10.99	10.34	11.05
Nd ₂ O ₃	0.31	0.31	0.31	0.31	0.30	0.31	0.30	0.30	0.30	0.30	0.29
NiO	0.62	0.55	0.56	0.50	0.47	0.57	0.58	0.59	0.57	0.57	0.54
P ₂ O ₅	¶	0.02	0.03	0.02	0.02	0.03	0.02	0.03	<0.01	0.02	<0.01
PbO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	47.46	46.96	47.23	47.71	47.16	47.25	47.20	47.21	47.32	47.13
SO ₃	0.08	0.05	0.06	0.03	0.05	0.08	0.23	0.04	0.12	0.13	0.26
SrO	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03
TiO ₂	¶	0.10	0.10	0.10	0.11	0.12	0.09	0.10	0.09	0.10	0.10
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	2.02	1.74	1.79	1.76	1.67	1.71	1.76	1.82	1.80	1.81	1.72
ZrO ₂	3.82	4.56	4.75	4.80	4.55	4.61	4.68	4.94	4.81	4.83	4.62
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.01	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

“-“ sign for blank field

NA – Not analyzed

Table 2.6. XRF Analyzed Compositions for Melter feed Samples (wt%) (continued).

Test		10			9				
-	Target	1J2-F-125A	1J2-F-141A	1J2-F-155A	1R2-F-21A	1R2-F-58A	1R2-F-72A	1R2-F-123A	1R2-F-144A
Al ₂ O ₃	5.21	6.02	5.81	5.79	5.12	5.23	5.20	5.21	5.55
B ₂ O ₃ *	11.90	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.07	0.05	0.05	0.05	0.06	0.05	0.06	0.13
CaO	0.28	0.39	0.40	0.40	0.34	0.33	0.32	0.33	0.33
CdO	0.06	0.06	0.05	0.07	0.06	0.06	0.06	0.07	0.07
Cl	§	0.18	0.15	0.14	<0.01	<0.01	<0.01	<0.01	<0.01
Cr ₂ O ₃	¶	<0.01	<0.01	<0.01	<0.01	<0.01	0.00	0.01	0.01
CuO	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.03	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	11.25	10.94	11.46	12.54	12.32	11.98	12.04	12.30
K ₂ O	0.03	0.15	0.14	0.13	0.15	0.16	0.15	0.14	0.16
La ₂ O ₃	0.41	0.40	0.40	0.43	0.43	0.44	0.43	0.42	0.43
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.06	0.13	0.10	0.12	0.05	0.13	0.13	0.11
MnO	0.17	0.17	0.16	0.18	0.20	0.18	0.18	0.18	0.19
Na ₂ O	11.65	11.05	12.74	11.20	11.14	10.97	11.59	11.82	10.65
Nd ₂ O ₃	0.31	0.29	0.30	0.30	0.33	0.33	0.33	0.33	0.35
NiO	0.62	0.54	0.53	0.57	0.63	0.61	0.59	0.60	0.61
P ₂ O ₅	¶	<0.01	0.02	0.02	<0.01	<0.01	<0.01	0.01	<0.01
PbO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	0.02	0.03
SiO ₂	47.41	47.13	46.12	46.82	46.38	47.08	46.49	46.11	46.16
SO ₃	0.08	0.26	0.24	0.22	0.07	0.06	0.07	0.06	0.07
SrO	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.04
TiO ₂	¶	0.10	0.10	0.10	0.07	0.07	0.07	0.07	0.09
Y ₂ O ₃	§	<0.01	<0.01	<0.01	<0.01	<0.01	0.17	0.04	0.06
ZnO	2.02	1.72	1.67	1.77	1.99	1.91	1.88	1.92	1.97
ZrO ₂	3.82	4.62	4.51	4.71	4.84	4.62	4.66	4.89	5.19
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

“-“ sign for blank field

NA – Not analyzed

Table 2.6 XRF Analyzed Compositions for Melter feed Samples (wt%) (continued).

Test		9					All Samples	
-	Target	1S2-F-47A	1S2-F-84A	1S2-F-128A	1T2-F-24A	1T2-F-68A	Average	% Dev.
Al ₂ O ₃	5.21	6.06	5.16	5.44	5.22	5.14	5.55	6.60
B ₂ O ₃ *	11.90	11.91	11.91	11.91	11.91	11.91	11.91	NC
BaO	0.02	0.07	0.06	0.08	0.06	0.06	0.06	NC
CaO	0.28	0.34	0.34	0.33	0.33	0.33	0.39	NC
CdO	0.06	0.06	0.07	0.07	0.07	0.08	0.07	NC
Cl	§	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	NC
Cr ₂ O ₃	¶	<0.01	0.01	<0.01	<0.01	0.02	0.08	NC
CuO	0.03	0.03	0.03	0.04	0.03	0.03	0.03	NC
F	0.04	NA	NA	NA	NA	NA	NC	NC
Fe ₂ O ₃	12.26	11.68	12.07	12.18	11.95	12.45	12.00	-2.11
K ₂ O	0.03	0.18	0.15	0.14	0.15	0.15	0.13	NC
La ₂ O ₃	0.41	0.42	0.43	0.44	0.44	0.44	0.43	3.76
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	NC
MgO	0.11	0.13	0.10	0.08	0.10	0.12	0.09	NC
MnO	0.17	0.18	0.18	0.19	0.19	0.19	0.19	NC
Na ₂ O	11.65	11.67	11.29	10.98	11.33	10.85	10.99	-5.64
Nd ₂ O ₃	0.31	0.32	0.33	0.33	0.33	0.35	0.31	NC
NiO	0.62	0.58	0.60	0.61	0.59	0.63	0.60	-3.37
P ₂ O ₅	¶	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	NC
PbO	0.03	0.03	0.03	0.03	0.03	0.05	0.03	NC
RuO ₂	§	0.01	0.05	0.04	0.03	0.02	0.00	NC
SiO ₂	47.41	45.84	46.40	46.37	46.65	46.33	46.71	-1.48
SO ₃	0.08	0.06	0.06	0.07	0.06	0.06	0.08	NC
SrO	0.03	0.03	0.04	0.03	0.03	0.04	0.04	NC
TiO ₂	¶	0.09	0.07	0.08	0.07	0.08	0.09	NC
Y ₂ O ₃	§	0.04	0.09	0.08	0.07	0.05	0.01	NC
ZnO	2.02	1.84	1.91	1.94	1.89	1.99	1.84	-9.10
ZrO ₂	3.82	4.90	5.09	5.03	4.92	5.11	4.82	26.05
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

* Target values

§ - Spiked constituents

¶ - Not a target constituent; Ru and Y in Test 9, Cl and S in Test 10.

-- sign for blank field

NA - Not analyzed

NC- Not calculated

Table 3.1. Summary of Test Conditions and Results for Test 2.

AZ-101 (Target Glass Yield = 0.375 kg/kg or 530 g/l), Bubbling = 65 lpm with Two J Bubblers Oriented Parallel to Electrodes					
-		A	B	C	D
Time	Feed Start	5/28/03 13:42	5/29/03 14:29	6/01/03 14:31	6/03/03 14:33
	Feed End	5/29/03 14:29	6/01/03 14:31	6/03/03 14:33	6/06/03 14:40
	Interval	24.8 hr	72 hr	48 hr	72.1 hr
Water Feeding for Cold Cap		0.8 hr	NA	NA	NA
Slurry Feeding		24 hr	72 hr	48 hr	72.1 hr
Cold cap burn		NA	NA	NA	2.9 hr
Bubbler Depth		Shallow: 12" from floor	Shallow: 12" from floor	Nominal: 6" from floor	Deep: on melter floor
Feed	Used	2067 kg	5328 kg	3922 kg	6131 kg
	Average Rate	86.1 kg/hr	74 kg/hr	81.7 kg/hr	85 kg/hr
Glass Produced	Poured	827 kg	1999 kg	1486 kg	2468 kg
	Average Rate ^{\$}	689 kg/m ² /day	555 kg/m ² /day	619 kg/m ² /day	686 kg/m ² /day
	Average Rate [*]	645 kg/m ² /day	551 kg/m ² /day	610 kg/m ² /day	638 kg/m ² /day
	Steady State Rate [*]	Not Attained	550 kg/m ² /day	640 kg/m ² /day	680 kg/m ² /day

\$ - Rates calculated from glass poured.

*- Rates calculated from feed data.

Note: Rates do not take into account the time for water feeding and cold cap burn-off.

NA: Not applicable.

Table 3.2. Summary of Test Conditions and Results for Test 1.

AZ-101 (Target Glass Yield = 0.375 kg/kg or 530 g/l), Bubbling = 65 lpm with Two J Bubblers 6" from floor pointed towards the melt pool center					
-		A	B	C	D
Time	Feed Start	6/25/03 12:00	6/26/03 13:00	6/28/03 13:02	6/30/03 13:02
	Feed End	6/26/03 13:00	6/28/03 13:02	6/30/03 13:02	7/02/03 13:01
	Interval	25 hr	48 hr	48 hr	48 hr
Water Feeding for Cold Cap		1 hr	NA	NA	NA
Slurry Feeding		24 hr	48 hr	48 hr	48 hr
Cold cap burn		NA	NA	NA	1.7 hr
Bubbler Skewing		None	None	16 lpm, step	16 lpm, gradual
Feed	Used	2344 kg	6643 kg	6907 kg	7034 g
	Average Rate	97.7 kg/hr	138.4 kg/hr	143.9 kg/hr	146.5 kg/hr
Glass Produced	Poured	795 kg	2484 kg	2619 kg	2757 kg
	Average Rate ^{\$}	663 kg/m ² /day	1035 kg/m ² /day	1091 kg/m ² /day	1148 kg/m ² /day
	Average Rate [*]	733 kg/m ² /day	1038 kg/m ² /day	1079 kg/m ² /day	1099 kg/m ² /day
	Steady State Rate [*]	Not Attained	1050 kg/m ² /day	1100 kg/m ² /day	1100 kg/m ² /day

\$ - Rates calculated from glass poured.

*- Rates calculated from feed data.

Note: Rates do not take into account the time for water feeding and cold cap burn-off.

NA: Not applicable.

Table 3.3. Summary of Test Conditions and Results for Test 3.

AZ-101 (Target Glass Yield = 0.315 kg/kg or 400 g/l), Bubblers on floor, 8" apart on East and West side, one bubbler outlet 11.3" from feed tube. Refer to Figure 1.6 for Segments 3A & 3B bubbler placement. Segment 3C used only the L bubblers in Figure 1.6.				
-		A	B	C
Time	Feed Start	7/15/03 12:15	7/16/03 12:53	7/20/03 10:02
	Feed End	7/16/03 12:53	7/20/03 10:02	7/22/03 20:20
	Interval	24.6 hr	93.2 hr	58.3 hr
Water Feeding for Cold Cap		0.6 hr	NA	NA
Slurry Feeding		24 hr	93.2 hr	58.3 hr
Cold cap burn		NA	NA	1.1 hr
Bubblers	Outlets	4	4	2
	Steady State Bubbling Rate	NA	135 lpm	80 lpm
Feed	Used	2289 kg	17252 kg	9532 kg
	Average Rate	95.4 kg/hr	185.1 kg/hr	163.5 kg/hr
Glass Produced	Poured	658 kg	5358 kg	3173 kg
	Average Rate ^{\$}	548 kg/m ² /day	1150 kg/m ² /day	1089 kg/m ² /day
	Average Rate [*]	600 kg/m ² /day	1164 kg/m ² /day	1028 kg/m ² /day
	Steady State Rate [*]	Not Attained	1300 kg/m ² /day	1100 kg/m ² /day

\$ - Rates calculated from glass poured.

*- Rates calculated from feed data.

Note: Rates do not take into account the time for water feeding and cold cap burn-off.

NA: Not applicable.

Table 3.4. Summary of Test Conditions and Results for Test 8.

AZ-101 (Target Glass Yield = 0.315 kg/kg or 400 g/l), four bubblers on floor, one in each corner, 14" apart on East and West side. Refer to Figure 1.7 for bubbler placement.				
-		A	B	C
Time	Feed Start	8/05/03 12:16	8/06/03 12:00	8/10/03 15:00
	Feed End	8/06/03 12:00	8/10/03 15:00	8/13/03 15:01
	Interval	23.7 hr	99 hr	72 hr
Water Feeding for Cold Cap		1.7 hr	NA	NA
Slurry Feeding		22 hr	99 hr	72 hr
Cold cap burn		NA	NA	1.1 hr
Glass Temperature		1150°C	1150°C	1175°C
Steady State Bubbling Rate		NA	117 lpm	90 lpm
Steady State Power Use		NA	238 kW	243 kW
Feed	Used	2596 kg	19079 kg	16515 kg
	Average Rate	118.0 kg/hr	192.7 kg/hr	229.4 kg/hr
Glass Produced	Poured	780 kg	5931 kg	5351 kg
	Average Rate ^{\$}	709 kg/m ² /day	1198 kg/m ² /day	1486 kg/m ² /day
	Average Rate [*]	742 kg/m ² /day	1212 kg/m ² /day	1443 kg/m ² /day
	Steady State Rate [*]	Not Attained	1400 kg/m ² /day	1450 kg/m ² /day

\$ - Rates calculated from glass poured.

*- Rates calculated from feed data.

Note: Rates do not take into account the time for water feeding and cold cap burn-off.

NA: Not applicable.

Table 3.5. Summary of Test Conditions and Results for Test 10.

AZ-101 (Target Glass Yield = 0.315 kg/kg or 400 g/l), Two L Bubblers on floor, Bubbler on East side 11.3" from feed tube as shown for the two L bubblers in Figure 1.6, Bubbling rate = 80 lpm.					
-		A	B	C	D
Time	Feed Start	9/03/03 12:46	9/04/03 13:51	9/06/03 14:30	9/08/03 15:29
	Feed End	9/04/03 13:51	9/06/03 14:30	9/08/03 15:29	9/10/03 15:30
	Interval	25.1 hr	48.7 hr	49 hr	48 hr
Water Feeding for Cold Cap		1 hr	NA	NA	NA
Slurry Feeding		24.1 hr	48.7 hr	49 hr	48 hr
Cold cap burn		NA	NA	1.1 hr	2.7 hr
Spike Solution Used		None	NaCl	Na ₂ SO ₄	NaCl + Na ₂ SO ₄
Feed	Used	2789 kg	6604 kg	5804 kg	7029 kg
	Average Rate	115.7 kg/hr	135.6 kg/hr	118.4 kg/hr	146.4 kg/hr
Glass Produced	Poured	770 kg	1958 kg	1920 kg	2516 kg
	Average Rate ^{\$}	639 kg/m ² /day	804 kg/m ² /day	784 kg/m ² /day	1048 kg/m ² /day
	Average Rate [*]	730 kg/m ² /day	853 kg/m ² /day	745 kg/m ² /day	921 kg/m ² /day
	Steady State Rate [*]	Not Attained	Not Attained	Not Attained	930 kg/m ² /day

\$ - Rates calculated from glass poured.

*- Rates calculated from feed data.

Note: Rates do not take into account the time for water feeding and cold cap burn-off.

NA: Not applicable.

Table 3.6. Summary of Test Conditions and Results for Test 9.

AZ-101 (Target Glass Yield = 0.315 kg/kg or 400 g/l), Two bubblers, each with two outlets 8 inches apart, placed on the floor, one bubbler outlet 11.3” from feed tube. Refer to Figure 1.9 for bubbler placement.			
-		A	B
Time	Feed Start	3/23/04 19:21	3/29/04 20:35
	Feed End	3/29/04 20:35	4/1/04 20:35
	Interval	145.2 hr	72.0 hr
Water Feeding for Cold Cap		1.2 hr	NA
Slurry Feeding		144.0 hr	72.0 hr
Cold cap burn		NA	5.7 hr
Sugar concentration		3.8 g/l	3.8 g/l
Bubblers	Outlets	4	4
	Steady State Bubbling Rate	64 lpm	134 lpm
Feed	Used	23248 kg	15206 kg
	Average Rate	161 kg/hr	211 kg/hr
Glass Produced	Poured	7240 kg	4920 kg
	Average Rate ^{\$}	1006 kg/m ² /day	1366 kg/m ² /day
	Average Rate [*]	1017 kg/m ² /day	1330 kg/m ² /day
	Steady State Rate [*]	1050 kg/m ² /day	1400 kg/m ² /day

\$ - Rates calculated from glass poured.

*- Rates calculated from feed data.

Note: Rates do not take into account the time for water feeding and cold cap burn-off.

NA: Not applicable.

Table 3.7. DM1200 Melter System Measured Parameters for Test 2.

-			2A			2B			2C			2D		
			avg	min	max	avg	min	max	avg	min	max	avg	min	max
TEMPERATURE (°C)	Glass	13" from floor E	1153	1092	1193	1155	1135	1169	1152	1135	1165	1150	1128	1163
		15.5" from floor E	1150	1095	1185	1153	1132	1166	1150	1132	1163	1148	1126	1161
		18" from floor E	1152	1099	1185	1154	1135	1167	1151	1133	1164	1149	1128	1162
		27" from floor E	1136	977	1177	1141	960	1160	1142	1111	1156	1140	1120	1153
		13" from floor W	1150	1130	1197	1151	1124	1165	1152	1125	1161	1156	1125	1170
		15.5" from floor W	1148	1125	1184	1150	1122	1165	1152	1124	1161	1156	1125	1170
		18" from floor W	1145	1123	1182	1147	1119	1162	1150	1123	1159	1153	1124	1168
		27" from floor W	1121	1018	1176	1121	887	1151	1138	1112	1149	1144	1117	1157
	Plenum	8" below ceiling	539	469	714	495	442	547	525	482	583	587	474	661
		17" below ceiling	574	533	696	527	457	594	579	523	625	617	491	676
		Exposed	517	430	687	484	399	550	511	455	572	564	431	659
	Discharge	TC 1	1006	951	1044	1013	995	1044	1014	984	1046	1014	985	1052
		TC 2	1069	1018	1099	1076	1059	1099	1077	1063	1100	1079	1054	1104
		Air Flow	92	84	108	92	84	109	97	90	112	99	89	113
		Riser	884	794	1166	1013	961	1114	1055	996	1131	1056	1026	1125
	Electrode	East	1069	1050	1090	1078	1054	1100	1094	1066	1109	1092	1074	1108
		West	1077	1028	1091	1091	1083	1109	1091	1073	1102	1086	1070	1099
		Bottom	664	629	728	813	728	854	931	849	946	947	928	962
	Film Cooler	Added Air	80	71	81	80	77	83	81	64	88	82	80	86
		Outlet	380	70	513	333	70	409	364	72	425	382	71	469
Glass	Density (g/cc)		2.39	2.29	2.44	2.36	2.26	2.43	2.32	2.24	2.40	2.30	2.22	2.38
	Level (" from floor)		28.93	27.79	29.95	28.93	27.56	29.91	29.53	28.30	30.65	32.05	28.70	33.93
	Resistance (ohms)		0.1307	0.1126	0.1400	0.1271	0.1195	0.1359	0.1185	0.1141	0.1326	0.1115	0.1065	0.1267
Electrodes	Current (A)		922	782	995	940	903	976	1027	916	1068	1095	790	1137
	Voltage (V)		120	94	130	119	116	123	122	119	128	122	100	127
	Power (kW)		111	76	123	112	110	114	125	111	130	134	79	138
Lance Bubbles	1	Rate (lpm)	26.9	1.6	37.2	33.8	26.9	37.2	35.2	26.7	37.1	34.6	26.7	37.1
		Temp. (°C)	1107	1074	1173	1095	1075	1120	1095	1072	1124	1104	1032	1127
	2	Rate (lpm)	25.9	1.4	37.0	30.0	26.6	37.3	28.8	26.7	37.2	29.2	26.6	37.2
		Temp. (°C)	1153	1092	1193	1155	1135	1169	1152	1135	1165	1150	1128	1163
Total Bubbling (lpm)			54.0	4.2	65.8	65.1	62.8	65.6	65.1	58.5	68.3	65.0	54.9	65.6

"-" Empty data field

Table 3.8. DM1200 Melter System Measured Parameters for Test 1.

			1A			1B			1C			1D		
			avg	min	max	avg	min	max	avg	min	max	avg	min	max
TEMPERATURE (°C)	Glass	13" from floor E	1144	1066	1221	1156	1131	1193	1158	1105	1191	1157	1123	1186
		15.5" from floor E	1142	1061	1223	1152	1122	1189	1157	1106	1187	1154	1116	1184
		18" from floor E	1144	1062	1227	1152	1123	1189	1161	1109	1189	1155	1116	1189
		27" from floor E	1057	511	1198	1088	965	1175	1081	717	1180	1072	896	1170
		13" from floor W	1134	1067	1193	1137	1100	1186	1133	1070	1173	1125	1088	1160
		15.5" from floor W	1135	1061	1196	1137	1100	1187	1135	1074	1173	1126	1086	1162
		18" from floor W	1131	1048	1198	1131	1091	1183	1130	1062	1176	1118	1076	1159
		27" from floor W	1093	713	1192	1102	965	1185	1095	771	1179	1078	861	1173
	Plenum	8" below ceiling	607	499	730	584	528	764	567	439	650	558	519	634
		17" below ceiling	625	483	728	598	530	787	571	507	662	570	527	629
		Exposed	615	434	736	603	101	813	600	440	703	608	534	708
	Discharge	TC 1	1014	942	1077	987	891	1031	960	923	1008	964	863	1015
		TC 2	1079	1016	1134	1052	1011	1088	1024	1003	1059	1028	984	1062
		Air Flow	102	72	117	101	84	116	95	77	108	94	80	105
		Riser	1047	921	1161	1130	1097	1178	1136	1112	1179	1143	1120	1186
	Electrode	East	1116	1056	1144	1149	1141	1155	1151	1143	1160	1155	1152	1160
		West	1099	1024	1145	1128	1105	1145	1128	1107	1149	1135	1112	1150
		Bottom	971	917	1016	1031	1016	1042	1041	1029	1054	1043	1036	1052
	Film Cooler	Added Air	77	75	80	79	76	85	85	82	93	92	90	96
		Outlet	400	73	528	400	76	504	386	76	461	387	76	439
Glass	Density (g/cc)		2.32	2.17	2.43	2.30	2.23	2.36	2.31	2.24	2.38	2.31	2.24	2.39
	Level (" from floor)		29.35	27.57	30.32	29.96	29.14	30.81	29.77	28.72	30.71	29.67	28.77	30.48
	Resistance (ohms)		0.1060	0.0959	0.1285	0.0974	0.0925	0.1037	0.0957	0.0924	0.1005	0.0951	0.0930	0.0976
Electrodes	Current (A)		1128	818	1309	1333	1284	1395	1356	1305	1414	1362	1326	1399
	Voltage (V)		119	81	133	130	124	134	130	125	134	130	127	132
	Power (kW)		136	67	172	173	165	181	176	168	186	176	170	183
Lance Bubbles	1	Rate (lpm)	21.7	1.6	34.2	32.2	32.0	48.2	32.1	12.1	48.5	32.2	16.1	48.2
		Temp. (°C)	1146	1093	1188	1156	1138	1174	1155	1128	1188	1160	1138	1182
	2	Rate (lpm)	21.0	1.3	36.3	32.1	15.9	32.3	32.2	11.2	52.4	32.1	15.9	48.5
		Temp. (°C)	1130	1085	1197	1117	1092	1166	1144	1085	1189	1165	1140	1182
Total Bubbling (lpm)			43.8	4.1	65.6	65.3	65.0	65.6	65.3	54.3	66.0	65.3	64.7	65.9

"-" Empty data field

Table 3.9. DM1200 Melter System Measured Parameters for Test 3.

-			3A			3B			3C		
			avg	min	max	avg	min	max	avg	min	max
TEMPERATURE (°C)	Glass	13" from floor E	1152	1107	1203	1165	1100	1195	1152	1111	1202
		15.5" from floor E	1150	1106	1200	1162	1097	1193	1149	1109	1202
		18" from floor E	1152	1108	1201	1163	1099	1197	1150	1111	1207
		27" from floor E	1126	970	1188	1151	1013	1193	1109	1030	1202
		13" from floor W	1116	1010	1188	1124	1050	1185	1117	1050	1189
		15.5" from floor W	1117	1008	1193	1124	1046	1184	1117	1053	1189
		18" from floor W	1110	985	1195	1118	1028	1183	1110	1042	1187
		27" from floor W	1068	536	1201	1120	977	1192	1111	1017	1200
	Plenum	8" below ceiling	638	474	803	616	491	908	642	536	910
		17" below ceiling	606	435	736	576	341	711	588	426	903
		Exposed	623	422	775	584	50	975	638	460	941
	Discharge	TC 1	1001	877	1048	1016	966	1078	982	868	1044
		TC 2	1068	992	1104	1081	1044	1123	1048	993	1099
		Air Flow	95	88	107	94	79	108	92	67	117
		Riser	1006	912	1124	1115	1061	1168	1106	1073	1162
	Electrode	East	1109	1025	1146	1148	1104	1164	1154	1120	1163
		West	1096	1057	1146	1140	1085	1165	1140	1093	1162
		Bottom	1005	943	1048	1075	1044	1091	1079	1054	1090
	Film Cooler	Added Air	90	85	98	97	88	104	93	75	99
		Outlet	407	76	635	434	81	518	411	76	534
Glass	Density (g/cc)		2.38	2.14	2.54	2.31	2.14	2.40	2.36	2.20	2.47
	Level (" from floor)		28.94	27.14	30.98	29.80	28.06	32.52	30.25	28.98	31.62
	Resistance (ohms)		0.1092	0.0996	0.1281	0.1055	0.0966	0.1321	0.0973	0.0877	0.1061
Electrodes	Current (A)		1089	791	1376	1418	1027	1534	1409	979	1508
	Voltage (V)		119	82	141	150	128	162	137	89	148
	Power (kW)		131	65	190	212	132	243	194	88	219
Lance Bubbler	1	Rate (lpm)	21.8	3.1	34.2	49.5	0.0	100.6	39.4	9.8	55.3
		Temp. (°C)	1146	1066	1185	1153	1092	1178	1154	1137	1180
	2	Rate (lpm)	21.9	2.8	34.6	49.8	0.0	100.2	39.0	8.3	55.1
		Temp. (°C)	1168	1108	1202	1173	1115	1203	1176	1156	1204
Total Bubbling (lpm)			44.7	6.9	69.7	100.3	1.0	181.6	79.4	20.6	111.4

"-" Empty data field

Table 3.10. DM1200 Melter System Measured Parameters for Test 8.

			8A			8B			8C		
			avg	min	max	avg	min	max	avg	min	max
TEMPERATURE (°C)	Glass	13" from floor E	1119	1021	1167	1154	1117	1207	1172	1116	1201
		15.5" from floor E	1116	1015	1167	1152	1110	1205	1169	1116	1198
		18" from floor E	1119	1021	1168	1155	1109	1205	1171	1114	1199
		27" from floor E	1053	605	1167	1146	1018	1194	1165	1034	1199
		13" from floor W	1125	1027	1158	1146	1078	1197	1167	1085	1196
		15.5" from floor W	1126	1033	1159	1146	1078	1197	1167	1088	1195
		18" from floor W	1122	1021	1156	1142	1064	1196	1164	1082	1194
		27" from floor W	1138	724	1173	1139	895	1851	1179	959	1203
	Plenum	8" below ceiling	593	516	668	592	454	941	586	465	942
		17" below ceiling	626	523	705	629	233	911	625	418	917
		Exposed	585	480	683	473	234	962	435	228	963
	Discharge	TC 1	1012	968	1058	1024	934	1080	1001	925	1050
		TC 2	1079	1041	1112	1085	1015	1127	1060	1020	1093
		Air Flow	93	86	102	91	67	137	82	62	138
		Riser	937	934	945	1039	815	1175	1038	794	1095
	Electrode	East	1099	1044	1131	1134	1105	1171	1154	1141	1173
		West	1085	1024	1116	1130	1100	1168	1150	1132	1175
		Bottom	1036	995	1064	1084	1060	1101	1102	1085	1114
	Film Cooler	Added Air	95	92	97	95	92	99	95	93	99
		Outlet	439	79	503	430	82	538	419	80	547
Glass	Density (g/cc)		2.35	2.21	2.54	2.30	2.12	2.43	2.32	2.18	2.42
	Level (" from floor)		29.62	27.36	31.20	30.56	29.30	32.97	31.17	29.55	32.77
	Resistance (ohms)		0.1088	0.1000	0.1259	0.1019	0.0794	0.1129	0.0941	0.0893	0.1002
Electrodes	Current (A)		1189	891	1338	1468	689	1620	1606	342	1745
	Voltage (V)		128	106	140	150	55	162	151	34	161
	Power (kW)		154	95	188	220	38	261	243	12	279
Lance Bubblers	1	Rate (lpm)	23.2	2.9	36.3	50.9	10.0	100.2	44.7	38.1	84.3
		Temp. (°C)	1129	1077	1158	1138	1101	1168	1158	1103	1179
	2	Rate (lpm)	22.3	3.0	36.3	50.6	9.9	100.0	44.4	37.8	84.1
		Temp. (°C)	1148	1078	1174	1170	1147	1192	1186	1154	1203
Total Bubbling (lpm)			46.4	7.0	73.5	102.4	20.9	201.2	90.0	76.9	169.4

"-" Empty data field

Table 3.11. DM1200 Melter System Measured Parameters for Test 10.

			10A			10B			10C			10D		
			avg	min	max	avg	min	max	avg	min	max	avg	min	max
TEMPERATURE (°C)	Glass	13" from floor E	1142	1064	1184	1150	1117	1190	1155	1133	1182	1156	1128	1171
		15.5" from floor E	1140	1057	1195	1146	1116	1189	1154	1131	1182	1154	1125	1172
		18" from floor E	1140	1053	1202	1145	1115	1184	1157	1132	1184	1155	1122	1176
		27" from floor E	1009	137	1111	1047	950	1140	1123	1008	1175	1127	1064	1169
		13" from floor W	1153	1115	1181	1161	1127	1182	1151	1126	1177	1154	1133	1182
		15.5" from floor W	1148	1105	1177	1159	1130	1185	1149	1124	1176	1151	1128	1180
		18" from floor W	1144	1084	1175	1157	1130	1186	1148	1121	1177	1149	1119	1179
		27" from floor W	971	451	1134	1061	938	1162	1101	1012	1165	1111	1058	1167
	Plenum	8" below ceiling	607	551	677	520	422	732	608	469	848	501	429	589
		17" below ceiling	625	506	718	469	314	685	551	446	850	528	430	621
		Exposed	623	538	729	536	318	858	625	247	910	480	372	627
	Discharge	TC 1	991	890	1053	1006	969	1052	1015	970	1055	1043	1012	1069
		TC 2	1057	967	1108	1070	1048	1101	1078	1056	1102	1101	1074	1114
		Air Flow	77	68	90	76	68	91	75	69	93	78	73	82
		Riser	975	840	1140	985	934	1106	1017	937	1139	970	914	1073
	Electrode	East	1101	1033	1140	1138	1111	1163	1146	1133	1162	1144	1136	1153
		West	1056	1025	1093	1107	1089	1130	1117	1099	1133	1113	1077	1133
		Bottom	1004	916	1045	1056	1044	1067	1054	1039	1073	1054	1044	1066
	Film Cooler	Added Air	88	86	89	87	85	90	88	64	90	88	86	91
		Outlet	416	80	499	325	77	384	358	74	476	369	81	418
Glass	Density (g/cc)		2.40	2.31	2.48	2.36	2.26	2.45	2.34	2.18	2.43	2.32	2.22	2.40
	Level (" from floor)		29.53	27.93	30.39	29.68	28.56	31.13	30.93	28.89	32.58	31.59	30.51	32.90
	Resistance (ohms)		0.1069	0.0972	0.1213	0.1022	0.0960	0.1080	0.1033	0.0972	0.1095	0.1022	0.0954	0.1081
Electrodes	Current (A)		1182	916	1346	1269	1179	1344	1246	1182	1308	1318	1274	1364
	Voltage (V)		126	106	141	130	120	137	129	122	137	135	127	138
	Power (kW)		150	102	181	165	146	179	160	152	177	177	167	179
Lance Bubbler	1	Rate (lpm)	27.9	1.6	49.9	39.2	35.3	43.7	37.4	34.3	44.8	37.4	36.6	42.2
		Temp. (°C)	1127	1068	1147	1135	1117	1153	1129	1115	1146	1128	1111	1143
	2	Rate (lpm)	28.7	1.3	49.8	40.0	35.6	43.8	41.8	34.6	44.8	41.8	37.1	42.3
		Temp. (°C)	1141	1108	1159	1143	865	1168	1141	1118	1162	1138	534	1162
Total Bubbling (lpm)			57.7	3.9	80.7	80.2	79.9	80.6	80.2	79.7	80.5	80.2	77.9	80.6

"-" Empty data field

Table 3.12. DM1200 Melter System Measured Parameters for Test 9.

			9A			9B		
			avg	min	max	avg	min	max
TEMPERATURE (°C)	Glass	13" from floor E	1155	1096	1174	1137	1115	1167
		15.5" from floor E	1151	1095	1173	1133	1113	1163
		18" from floor E	1151	1095	1177	1133	1113	1162
		27" from floor E	1129	955	1158	1127	602	2694
		13" from floor W	1152	1113	1173	1136	1117	1164
		15.5" from floor W	1150	1111	1171	1134	1116	1162
		18" from floor W	1147	1113	1170	1132	1113	1161
		27" from floor W	1122	1034	1158	1119	1084	1149
	Plenum	8" below ceiling	501	432	761	544	424	733
		17" below ceiling	506	409	738	557	285	844
		Exposed	563	234	747	ND	ND	ND
	Discharge	TC 1	1030	815	1095	1071	1024	1095
		TC 2	1054	891	1119	1101	1055	1117
		Air Flow	63	56	73	65	60	68
		Riser	1110	947	1163	1106	1083	1151
	Electrode	East	1118	1014	1134	1094	1080	1123
		West	1151	1033	1182	1106	1084	1157
		Bottom	1081	1012	1100	1073	1058	1094
	Film Cooler	Added Air	82	80	84	83	80	85
		Outlet	356	83	560	387	305	470
Glass	Density (g/cc)		2.41	2.33	2.55	2.33	2.23	2.43
	Level (" from floor)		32.97	30.34	34.16	33.21	31.65	34.60
	Resistance (ohms)		0.0856	0.0774	0.1214	0.0917	0.0811	0.1002
Electrodes	Current (A)		1455	868	1550	1554	1492	1587
	Voltage (V)		124	105	138	143	123	156
	Power (kW)		181	91	199	222	186	243
Lance Bubblers	1	Rate (lpm)	30.5	1.6	44.0	57.8	32.7	94.6
		Temp. (°C)	ND	ND	ND	ND	ND	ND
	2	Rate (lpm)	30.9	1.5	44.3	56.9	34.2	105.0
		Temp. (°C)	ND	ND	ND	ND	ND	ND
Total Bubbling (lpm)			62.4	4.1	88.4	115.7	67.9	190.5

"-" Empty data field

ND: No data due to failed thermocouple

Table 4.1. Calculated Values and Basis for the DM1200 Melter Energy Balance.

Calculated Value	Other Calculated or Recorded Information	Test Data Files		
SBS/Melter Exhaust Dry Air Flow (dscfm or lb/hr)	Water Vapor Pressure (psia)	WESP Exhaust Wet Air Flow (wscfm)	WESP Exhaust Air Temperature (°C)	WESP Exhaust Air Pressure (in. W.C.)
SBS Exhaust Water Flow (lb/hr)	Water Vapor Pressure (psia)	SBS Exhaust Air Temperature (°C)	SBS Exhaust Air Pressure (in. W.C.)	--
Melter Exhaust Water Flow (lb/hr)	SBS Blowdown (lb/hr) SBS Exhaust Water Flow (lb/hr)	--	--	--
SBS Dry Air Sensible Heat (BTU/hr)	SBS Exhaust Dry Air Flow (lb/hr)	SBS Inlet Air Temperature (°C)	SBS Exhaust Air Temperature (°C)	--
SBS Total Water Vapor Sensible Heat (BTU/hr)	Melter Exhaust Water Flow (lb/hr)	SBS Inlet Air Temperature (°C)	SBS Exhaust Air Temperature (°C)	--
SBS Condensed Water Latent Heat (BTU/hr)	SBS Blowdown (lb/hr)	SBS Recirculation Pump Temperature (°C)	--	--
Total SBS Gas Side Duty (BTU/hr)	SBS Air Sensible Heat SBS Water Sensible & Latent Heats (BTU/hr)	--	--	--
SBS Coil Duty (BTU/hr)	--	SBS Coil Flow Rate (gal/min)	Coil Inlet Temperature (°C)	Coil Exit Temperature (°C)
SBS Jacket Duty (BTU/hr)	Cooling Water Ethylene Glycol Concentration	SBS Jacket Cooling Water Flow Rate (gal/min)	Jacket Inlet Temperature (°C)	Jacket Exit Temperature (°C)
Total SBS Water Side Duty (BTU/hr)	SBS Coil and Jacket Duties (BTU/hr)	--	--	--
SBS Plate/Frame Heat Exchanger CW duty (BTU/hr)	Cooling Water Ethylene Glycol Concentration	Cooling Water to SBS Plate/Frame Flow (gal/min)	Cooling Water to SBS Plate Frame Inlet Temperature (°C)	Cooling Water from SBS Plate Frame Exit Temperature (°C)
Transition Line Temperature (°F)	Melter Exhaust Air Flow lb/hr; Melter Exhaust Water Vapor Flow, lb/hr; Adiabatic Mixture Temperature Calculation	Control Air Temperature (°F); and Flow (scfm)	Control Air flow (scfm)	Film Cooler Discharge Temperature (°C)

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**Table 4.1. Calculated Values and Basis for the DM1200 Melter Energy Balance
(continued).**

Calculated Value	Other Calculated or Recorded Information	Test Data Files		
Transition Line Actual Convection Heat Loss (BTU/hr)	Melter Exhaust Air Flow lb/hr; Melter Exhaust Water Vapor Flow, lb/hr; Transition Line Inlet Temperature (°F)	SBS Inlet Air Temperature (°C)	--	--
Transition Line Calculated Convection Heat Loss (BTU/hr)	Transition Line Inlet Temperature (°C)	SBS Inlet Air Temperature (°C)	--	--
Melter Skin Convection Heat Loss (BTU/hr)	Melter Skin Temperature Measurements; Actual and Calculated Transition Line Heat Losses	--	--	--
Melter Electrode Power (BTU/hr)	--	Melter Electrode Power (kW)	--	--
Combustion in Melter (BTU/hr)	Reductant (Sugar) in Feed (kg/hr)	Average Plenum Temperature (°F)	--	--
Salt Decomposition Chemical Reaction Heats in Melter (BTU/hr)	Melter Glass Discharge Rate (kg/hr)	--	--	--
Glass Phase Transition Heats in Melter (BTU/hr)	Melter Glass Discharge Rate (kg/hr)	--	--	--
Molten Glass Sensible Heat (BTU/hr)	Melter Glass Discharge Rate (kg/hr) Melter Slurry Feed Temperature (°F)	Average Melt Pool Bottom Temperature (°C)	--	--
Melter Cooling Panel Duty (BTU/hr)	--	Melter Cooling Panel Total CW Flow (gal/min)	Melter Cooling Panel CW Inlet Temperature (°C)	Melter Cooling Panel CW Exit Temperature (°C)
Feed/Product Minor Control Air Thermal Heat Difference (BTU/hr)	--	Control Air Inlet Temperature (°C)	Control Air Flow Rate (SCFM)	SBS Exhaust Temperature (°C)

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**Table 4.1. Calculated Values and Basis for the DM1200 Melter Energy Balance
(continued).**

Calculated Value	Other Calculated or Recorded Information	Test Data Files		
Feed/Product Minor Film Cooler Air Thermal Heat Difference (BTU/hr)	--	Film Cooler Air Inlet Temperature (°F)	Film Cooler Air Flow Rate (SCFM or lb/hr)	SBS Exhaust Temperature (°F)
Inleakage Air Flow Rate (scfm)	SBS Dry Air Rate (dscfm)	Control Air Rate (scfm)	Film Cooler Air Rate (scfm)	Bubbling Air Rate (lpm)
Feed/Product Minor Inleakage Air Thermal Heat Difference (BTU/hr)	Melter Ambient Air Temperature (°F) Inleakage Air Flow Rate (scfm)	SBS Exhaust Temperature (°C)	--	--
Feed/Product Minor Bubbling Air Thermal Heat Difference (BTU/hr)	Melter Ambient Air Temperature (°F)	SBS Exhaust Temperature (°C)	Bubbling Air Rate (lpm)	--
Feed/Product Minor Water Thermal Heat Difference (BTU/hr)	Slurry Feed Temperature (°F)	SBS Recirculation. Pump Temperature (°C)	--	--
Water in Control Air, Film Cooler Air, and Inleakage Air (kg/hr)	Melter Ambient Air Temperature (°F) and Relative Humidity Inleakage Air Rate (scfm)	Film Cooler Air Rate (scfm)	Control Air Rate (scfm)	--
Water Balance	Water in Melter Feed Slurry Water in SBS Blowdown Water in SBS Exhaust Water in Control, Film Cooler and Inleakage Air (kg/hr)	--	--	--

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Table 4.2. Closure on Overall Melter + SBS Energy Balances.

Test	Energy Balance Closure, % ²	Range of energy balance closures for test segments, %
3	107.9%	106.6% - 113.3%
8	110.6%	110.2% - 114.0%
9 ¹	112.3%	--

¹ During the last 24 hours of feeding.

²Closure values less than 100% imply that there are more energy losses from the system than have been accounted for. Closure values of greater than 100% imply that there are fewer energy losses than have been accounted for. 100% closure implies that all energy flows have been identified, understood, and measured accurately.

- Empty data cell.

Table 4.3. Energy Balance within SBS for each Test.

Test	Cooling- Water-side Heat Transfer (kW)	Process- side Heat Transfer (kW)	Difference Between Process and Water Side	Range of differences between process and water sides
3	104.7	103.1	-1.5%	-2.5% to +0.0%
8	119.6	120.7	1.0%	-0.5% to + 8.0%
9	128.4	125.7	-2.1%	--

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Table 4.4. Water Balance Closure for Tests 3, 8, and 9.

--	Water Source	Test 3	Test 8	Test 9 (last 24 hours)
Kg of water	Melter Slurry	18,981	21,714	3,323
	Control and Inleakage Air Moisture	426	486	49
	Film Cooler	287	363	0
	Purge Water	148	168	17
	Start-up Water	<u>101</u>	<u>179</u>	<u>0</u>
	Melter Subtotal	19,943	22,910	3,389
	SBS Blowdown	15,172	20,075	2,762
	SBS Exhaust	5,180	6,430	895
Overall Balance		102.0%	115.7%	107.9%

Table 4.5. Test 3 Melter-Only Energy Balance, and Melter + SBS Energy Balance.

--	Melter Only	Melter + SBS
Melter Electrode Power, kW	195.0	195.0
Film Cooler Air Sensible Heat, Kw	13.1	NC
Bubbling and Inleakage Air Sensible Heat, kW	11.9	NC
Water Latent Heat, kW	78.5	NC
Water Sensible Heat, kW	25.5	NC
Transition Line Heat Loss, kW	--	7.6
Total SBS Duties, kW	--	104.7
Exhaust vs. Feed Energies*, kW	--	19.7
Melter Cooling Panels, kW	34.1	34.1
Glass Sensible Heat, kW	22.4	22.4
Sugar Combustion, kW	0.0	0.0
Melter Skin Convection, kW	4.9	4.9
Reaction & Transition Heats, kW	16.9	16.9
Total "Melter-Only" Energy, kW (excluding electrode power)	207.3	--
% Difference between "Melter-Only" & Electrode Power	6.3%	--
Total "Melter + SBS" Energy, kW (excluding electrode power)	--	208.7
% Difference between "Melter + SBS" & Electrode Power	--	7.9%

* Energy associated with the SBS exhaust streams being slightly warmer (40°C) than the feed slurry (27°C), and with ca. 98% of the water fed to the melter in liquid state, but 25-30% of the water leaving the SBS as water vapor. All material streams, e.g. film cooler, control, bubbling, and inleakage air, are included in this calculation.

-- Empty cell. Value is not part of the specific energy balance.

NC Not calculated. Because of the different envelope borders for the "Melter-Only" vs. "Melter + SBS" energy balances, a meaningful comparison is not possible. These heat flows are lumped into the SBS and Transition Line values.

Table 4.6. Test 8 Melter-Only Energy Balance, and Melter + SBS Energy Balance.

--	Melter Only	Melter + SBS
Melter Electrode Power, kW	221.2	221.2
Film Cooler Air Sensible Heat, kW	14.0	NC
Bubbling and Inleakage Air Sensible Heat, kW	16.9	NC
Water Latent Heat, kW	92.8	NC
Water Sensible Heat, kW	30.5	NC
Transition Line Heat Loss, kW	--	12.3
Total SBS Duties, kW	--	119.6
Exhaust vs. Feed Energies*, kW	--	23.1
Melter Cooling Panels, kW	36.4	36.4
Glass Sensible Heat, kW	27.1	27.1
Sugar Combustion, kW	0.0	0.0
Melter Skin Convection, kW	5.8	5.8
Reaction & Transition Heats, kW	20.4	20.4
Total "Melter-Only" Energy, kW (excluding electrode power)	243.8	--
% Difference between "Melter-Only" & Electrode Power	10.2%	--
Total "Melter + SBS" Energy, kW (excluding electrode power)	--	245.8
% Difference between "Melter + SBS" & Electrode Power	--	10.6%

* Energy associated with the SBS exhaust streams being slightly warmer (40°C) than the feed slurry (27°C), and with ca. 98% of the water fed to the melter in liquid state, but 25-30% of the water leaving the SBS as water vapor. All material streams, e.g. film cooler, control, bubbling, and inleakage air, are included in this calculation.

-- Empty cell. Value is not part of the specific energy balance.

NC Not calculated. Because of the different envelope borders for the "Melter-Only" vs. "Melter + SBS" energy balances, a meaningful comparison is not possible. These heat flows are lumped into the SBS and Transition Line values.

**Table 4.7. Test 9 Melter-Only Energy Balance, and Melter + SBS Energy Balance
(for last 24 hours of feeding).**

--	Melter Only	Melter + SBS
Melter Electrode Power, kW	226.8	226.8
Film Cooler Air Sensible Heat, kW	12.4	NC
Bubbling and Inleakage Air Sensible Heat, kW	16.1	NC
Water Latent Heat, kW	102.1	NC
Water Sensible Heat, kW	29.4	NC
Transition Line Heat Loss, kW	--	9.0
Total SBS Duties, kW	--	128.3
Exhaust vs. Feed Energies*, kW	--	30.9
Melter Cooling Panels, kW	40.6	40.6
Glass Sensible Heat, kW	27.1	27.1
Sugar Combustion, kW	-2.3	-2.3
Melter Skin Convection, kW	3.4	3.4
Reaction & Transition Heats, kW	20.5	20.5
Total "Melter-Only" Energy, kW (excluding electrode power)	249.1	--
% Difference between "Melter- Only" & Electrode Power	9.8%	--
Total "Melter + SBS" Energy, kW (excluding electrode power)	--	254.8
% Difference between "Melter + SBS" & Electrode Power	--	12.3%

* Energy associated with the SBS exhaust streams being slightly warmer (40°C) than the feed slurry (27°C), and with ca. 98% of the water fed to the melter in liquid state, but 25-30% of the water leaving the SBS as water vapor. All material streams, e.g. film cooler, control, bubbling, and inleakage air, are included in this calculation.

-- Empty cell. Value is not part of the specific energy balance.

NC Not calculated. Because of the different envelope borders for the "Melter-Only" vs. "Melter + SBS" energy balances, a meaningful comparison is not possible. These heat flows are lumped into the SBS and Transition Line values.

Table 4.8. Melter and SBS Duties for Test 3.

--		A	B	C	Average
Glass, kg/hr		27.4	58.1	55.6	53.1
Melter (kW)	Heat Transferred in SBS (water side)	70.6	114.9	102.8	104.7
	Heat Transferred in SBS (gas-side)	68.8	112.2	103.2	103.1
	Cooling Panels Heat	32.5	34.3	34.5	34.1
	Heat Carried Away by Discharge Glass	11.5	24.6	23.3	22.4
	Salt/Organics Decomposition and Transition Heat	8.7	18.5	17.7	16.9
	Transition Line Heat Loss	5.4	8.6	7.0	7.6
	Melter Skin Heat Loss	4.9	4.9	4.9	4.9
	Minor Heat Loss/Gain from Feed/Product Temperatures	15.2	22.8	17.2	19.7
	Sugar Combustion Heat	0.0	0.0	0.0	0.0
	Total of Melter Energy Streams Other than Electrodes	147.0	225.9	207.9	208.7
	Average Melter Electrode Power	131.3	211.9	194.7	195.0
SBS (kW)	Water Side: Coil Heat	51.7	82.3	73.8	75.2
	Water Side: Jacket Heat	18.9	32.7	28.9	29.5
	Water Side: Total Heat	70.6	114.9	102.8	104.7
	Gas-Side Water Latent Heat	32.8	65.2	58.6	58.6
	Gas Side: Water Vapor Sensible Heat	9.9	19.4	16.8	17.1
	Gas Side: Sensible Air Heat	26.1	27.7	27.9	27.5
	Gas Side: Total Heat	68.8	112.2	103.2	103.1
SBS (°C)	Coil Approach Temperature	6.0	7.6	7.2	7.2
	Jacket Approach Temperature	15.4	22.8	21.2	21.3

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Table 4.9. Melter and SBS Duties for Test 8.

--		A	B	C	Average
Glass, kg/hr		35.5	61.4	74.3	63.3
Melter (kW)	Heat Transferred in SBS (water side)	83.3	119.8	131.3	119.6
	Heat Transferred in SBS (gas-side)	89.7	119.2	132.4	120.7
	Cooling Panels Heat	34.0	36.3	37.2	36.4
	Heat Carried Away by Discharge Glass	14.7	26.1	32.3	27.1
	Salt/Organics Decomposition and Transition Heat	11.4	19.7	23.9	20.4
	Transition Line Heat Loss	10.9	12.3	13.0	12.3
	Melter Skin Heat Loss	5.8	5.8	5.8	5.8
	Feed Vs. Exhaust	15.3	23.1	26.3	23.1
	Sugar Combustion Heat	0.0	0.0	0.0	0.0
	Total of Melter Energy Streams Other than Electrodes	181.8	242.6	270.9	245.8
	Average Melter Electrode Power	153.9	220.9	242.3	221.2
SBS (kW)	Water Side: Coil Heat	61.4	87.9	98.8	88.7
	Water Side: Jacket Heat	21.8	32.0	32.5	30.9
	Water Side: Total Heat	83.3	119.8	131.3	119.6
	Gas-Side Water Latent Heat	44.9	68.9	80.2	70.4
	Gas Side: Water Vapor Sensible Heat	13.8	20.6	23.5	20.9
	Gas Side: Sensible Air Heat	31.0	29.7	28.7	29.5
	Gas Side: Total Heat	89.7	119.2	132.4	120.7
SBS (°C)	Coil Approach Temperature	5.7	8.2	9.4	8.3
	Jacket Approach Temperature	17.9	23.7	25.2	23.6

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Table 4.10. Melter and SBS Duties for Test 9 (during the last 24 hours of feeding) and Comparison to Overall Average Values for Tests 3 and 8.

--		Test 9 last 24 hours	Test 3 all segments	Test 8 all segments
Glass, kg/hr		64.5	53.1	63.3
Melter (kW)	Heat Transferred in SBS (water side)	128.3	104.7	119.6
	Heat Transferred in SBS (gas-side)	125.7	103.1	120.7
	Cooling Panels Heat	40.6	34.1	36.4
	Heat Carried Away by Discharge Glass	27.1	22.4	27.1
	Salt/Organics Decomposition and Transition Heat	20.5	16.9	20.4
	Transition Line Heat Loss	9.0	7.6	12.3
	Melter Skin Heat Loss	3.4	4.9	5.8
	Minor Heat Loss/Gain from Feed/Product Temperatures	30.9	19.7	23.1
	Sugar Combustion Heat	-2.3	0.0	0.0
	Total of Melter Energy Streams Other than Electrodes	254.8	208.7	245.8
	Average Melter Electrode Power	226.8	195.0	221.2
SBS (kW)	Water Side: Coil Heat	116.8	75.2	88.7
	Water Side: Jacket Heat	11.5	29.5	30.9
	Water Side: Total Heat	128.3	104.7	119.6
	Gas-Side Water Latent Heat	76.2	58.6	70.4
	Gas Side: Water Vapor Sensible Heat	22.1	17.1	20.9
	Gas Side: Sensible Air Heat	27.4	27.5	29.5
	Gas Side: Total Heat	125.7	103.1	120.7
SBS (°C)	Coil Approach Temperature	7.0	7.2	8.3
	Jacket Approach Temperature	6.0	21.3	23.6

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Table 5.1. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications During the HLW Bubbler Configuration and Reductant Test Series.

Test	Operational notes		Post-test inspections and cleanings	Post-test equipment modifications
	Run time (hours)	Run time note		
Prior to Test 5	-	-	-	Before test: flared extension piece added to bottom of SBS downcomer.
5	Feed started: 4/30/03 11:32 (Silver mordenite column used. Carbon column not yet installed.)		1. Infrared inspection of SBS downcomer.	1. WESP heat shrink sleeve on top south grid support removed due to degradation, and post greased with silicone grease as a temporary measure.
	26.6 – 27.1	Feed interrupted due to repair of emergency off-gas vent valve.		
	45.0	Two (out of four) SBS isolation pinch valves replaced.		
	52.5 – 53.8	Feed interrupted due to cold cap ridges.		
	141.1 - 145.7	Feed interrupted due to cold cap ridges.		
	Feed ended: 5/9/03 15:45			
6	Feed started 5/14/03 12:05 (Silver mordenite column used. Carbon column not yet installed.)		1. Infrared inspection of SBS downcomer. 2. SBS downcomer solid sample analyzed by SEM. 3. WESP solid sample analyzed by SEM. 4. SBS downcomer cleaned from top with wire brush. 5. Acid wash of WESP grid.	1. WESP top south grid support post replaced with a UHMW polyethylene post. 2. WESP spray nozzle replaced. Spraying procedure changed – WESP spray turned off right before and after deluges.
	27.7 - 30.8	Feed turned off for seal replacement on the melter cooling pump, MCL-CW-P-402A.		
	120 - 122	Problems with chilled water supply which affected cooling within the SBS.		
	140.6 – 142.1	Feed turned off to replace the SBS recirculation pump, SBS-PW-P-501, which had a seal failure.		
	Feed ended 5/23/03 16:30			

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Table 5.1. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications During the HLW Bubbler Configuration and Reductant Test Series (continued).

Test	Operational notes		Post-test inspections and cleanings	Post-test equipment modifications
	Run time (hours)	Run time note		
2	Feed started 5/28/03 13:42 (Silver mordenite column NOT used. Carbon column not yet installed.)		1. Infrared inspection of SBS downcomer. 2. SBS bowl dropped and solids cleaned. 3. Film cooler and transition line cleaned, and solids sampled. 4. WESP solid sample removed and analyzed. 5. Blowers 701 and 702 (Paxton) examined. Solids sample collected. 6. HEPA filter and housing inspected.	1. Sleeve welded to SBS down-comer due to cracked down-comer pipe being noticed. 2. 15.1 kg of packing added to the top of the SBS bed.
	Feed ended 6/06/03 14:40			
1	Feed started 6/25/03 12:00 (Silver mordenite column NOT used. Carbon column not yet installed.)		1. Infrared inspection of SBS downcomer. 2. Film cooler and transition line inspected and small amount of solids removed. 3. Solids sample removed for analysis from PBS recirculation pump head.	1. Additional pressure measurement added to transition line inlet to allow calculation of transition line differential pressure by difference, as an alternate method. 2. Sulfur-impregnated carbon bed installed for use. (Used in Tests 3 and 10.) 3. SBS recirculation pump SBS-PW-501 replaced due to leaking seal.
	44.2 – 44.8	Failure of ADS poppet valve in feed system. Feed system rodded.		
	Feed ended 7/2/03 13:01			

Table 5.1. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications During the HLW Bubbler Configuration and Reductant Test Series (continued).

Test	Operational notes		Post-test inspections and cleanings	Post-test equipment modifications
	Run time (hours)	Run time note		
3	Feed started 7/15/03 12:15 (Carbon and silver mordenite columns used.)		1. Infrared inspection of SBS downcomer. 2. Film cooler inspected.	1. Film cooler replaced.
	17 - 174	Frequent clogging of film cooler and transition line. Cleanouts by rodding.		
	72.8 – 73.3	Stopped feed to reduce cold cap.		
	115 - 117	Problems with TCO/SCR heater controller. Controller replaced at 117 hours.		
	116.8 – 117.8	Stopped feed to adjust bubbling rate.		
	161.1 – 162.3	Blockage in transition line. Bellows removed to clear blockage.		
	Feed ended 7/22/03 20:20			
8	Feed started 8/5/03 12:16 (Carbon and silver mordenite columns NOT used.)		1. Infrared inspection of SBS downcomer.	1. Replaced TCO/SCR heater main control board.
	34.9 – 35.7	Stuck poppet on ADS pump, feed stopped.		
	50 - 188	Frequent clogging of film cooler. Cleanouts by rodding.		
	91.5	Ammonia system secured, due to TCO/SCR heater failure.		
	121.2 – 122.8	Stopped feed to rod out the film cooler.		
	Feed ended 8/13/03 15:01			

Table 5.1. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications During the HLW Bubbler Configuration and Reductant Test Series (continued).

Test	Operational notes		Post-test inspections and cleanings	Post-test equipment modifications
	Run time (hours)	Run time note		
4	Feed started 8/19/03 11:15 (Carbon and silver mordenite columns NOT used.)		1. Infrared inspection of SBS downcomer.	1. Recalibrated the SBS recirculation pump pressure gauge.
	Throughout test.	Problems experienced with the SBS recirculation pump pressure reading. Reduction of SBS recirculation flow. (Problem diagnosed after test completion.)		
	Feed ended 8/28/03 13:31			
10	Feed started 9/3/03 12:46 (Carbon and silver mordenite columns used.)		1. Infrared inspection of SBS downcomer. 2. SBS bowl dropped and solids cleaned. 3. Film cooler and transition line cleaned and solid samples removed and photographed. 4. HEME #1 interior and connecting piping examined. 5. HEPA housing examined. 6. Final blower examined and solids removed.	1. Blower 801 head, belt, and tensioner replaced (after 2243 hours of operation since last replacement). 2. SBS major modification. SBS cooling system layout changed.
	55.0 – 56.4	Feed stopped due to cold cap imbalance.		
	73.0 – 73.7	Feed stopped to add sodium sulfate solution to feed tank.		
	115.7 – 117.1	Feed stopped to burn off cold cap ridge in the melter.		
	Feed ended 9/10/03 15:30			

Note: Tests with LAW Simulants [30] and turnover feeds [31] were run between Tests 10 and 9 of this HLW Configuration series.

Table 5.1. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications During the HLW Bubbler Configuration and Reductant Test Series (continued).

Test	Operational notes		Post-test inspections and cleanings	Post-test equipment modifications
	Run time (hours)	Run time note		
9	Feed started 3/19/04 19:21 (Carbon and silver mordenite columns NOT used.)		<ol style="list-style-type: none">1. Infrared inspection of SBS downcomer.2. Visible light inspection of SBS downcomer.3. Inspection of SBS bowl, solids were not removed.4. Inspection of SBS internals.5. Inspection of SBS overflow tank.6. Film cooler and transition line inspected.7. WESP solid sample removed and analyzed.8. Film cooler bottom holes were cleaned.	-
	~15.0	LabVIEW and current voltage readings malfunctioned.		
	22.9	Isolated air flow through SBS annulus.		
	36.2	SBS booster pump was installed and put online.		
	101.2	Feed turned off to replace the SBS recirculation pump, SBS-PW-P-501, which was leaking at its inlet head.		
	136.2 – 160.6	SBS coil/jacket water flow rate placed on manual control.		
	140.2	Feed was secured for 9 minutes to take still picture of SBS downcomer.		
	166.2, 183.9, 205.8, 210.3 and 213.5	Film cooler was clogged and rodded out.		
	Feed ended at 4/1/2004 20:35			

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Note: Tests with LAW Simulants [29] and turnover feeds [30] were run between tests 10 and 9 of this HLW Configuration series.

Table 5.2. DM1200 AZ-101 Bubbler Configuration Tests Off Gas System Measured Parameters.

Test		2A			2B			2C		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Melter	Pressure at Level Detector Port ("water)	-3.9	-5.4	-1.2	-4.0	-5.6	-2.1	-4.0	-5.7	-2.3
	Pressure at Instrument Port ("water)	-4.1	-5.5	-1.3	-4.1	-5.7	-2.1	-4.1	-5.8	-2.4
	Control Air Flow Rate (scfm)	49.3	25.4	71.3	52.3	18.9	72.6	53.9	16.0	69.4
SBS	Differential Pressure ("water)	39.3	35.1	42.3	39.4	34.9	43.6	39.9	36.1	42.9
	Inlet gas pressure ("water)	-9.9	-15.5	-6.7	-9.4	-15.7	-6.0	-9.8	-14.0	-7.0
	Outlet gas pressure ("water)	-49.2	-54.7	-46.5	-48.7	-59.2	-45.6	-49.7	-54.7	-47.2
	Inlet gas Temp. (°C)	278	169	417	244	125	292	266	150	318
	Outlet gas Temp. (°C)	39.8	34.7	50.8	40.0	37.2	43.2	39.7	36.7	42.6
	Chilled Water Inlet Temp (°C)	14.4	11.1	19.7	14.1	10.6	19.3	14.6	10.5	19.2
	Chilled Water Outlet Temp (°C)	23.5	18.8	39.6	21.9	17.9	26.5	23.4	20.6	27.4
	Submerged 48" Temp (°C)	43.8	37.6	58.2	43.2	38.9	50.2	42.5	39.4	46.9
	Submerged 60" Temp (°C)	43.5	36.6	58.1	42.9	38.9	51.1	42.2	38.6	46.9
	Submerged 72" Temp (°C)	46.8	40.0	61.9	45.8	41.3	55.8	45.1	41.5	52.1
	Submerged 78" Temp (°C)	43.7	37.5	58.4	43.2	39.2	51.3	42.5	38.7	47.2
	Recirc. pump discharge Temp (°C)	39.3	33.4	46.4	39.7	37.1	42.1	39.2	36.6	41.9
	Heat Exchanger Outlet Temp (°C)	32.6	23.5	41.5	35.8	32.1	38.5	35.2	31.5	39.1
	Chilled Water Flow (gal/min)	4.1	2.4	27.6	5.7	2.4	20.5	10.3	6.8	36.1
	Heat Exchanger Flow (gal/min)	11.0	2.5	30.5	5.9	2.5	12.3	6.2	2.9	17.9
	Recirc. pump discharge Pressure	38.6	32.7	40.7	38.1	31.7	40.5	37.8	31.4	40.1
	Inner C. Coil W. Inlet Temp (°C)	26.3	18.2	40.7	31.0	26.0	35.7	30.4	25.3	36.3
	Inner C. Coil W. Outlet Temp(°C)	34.2	28.0	42.3	36.4	32.9	39.3	35.8	32.3	39.4
	Inner C. Coil W. Flow (gal/min)	24.4	23.8	25.0	24.5	23.8	25.0	24.5	23.9	24.9
	WESP	Differential Pressure ("water)	2.6	2.1	3.1	2.7	1.6	3.2	2.7	2.1
Inlet gas Temp. (°C)		39.4	35.0	50.5	39.3	36.5	42.4	39.1	36.5	41.6
Outlet gas Temp. (°C)		40.6	24.9	47.1	40.6	22.1	42.6	40.3	19.6	42.4
Gas Flow Rate (scfm)		210.9	186.3	224.3	211.4	180.4	223.7	214.0	191.5	262.4
HEPA 1	HEME #1, Outlet Gas Temp. (°C)	39.8	31.7	45.5	39.4	31.8	41.5	39.0	31.5	40.8
	Differential Pressure ("water)	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2
	Outlet Gas Temp. (°C)	62.5	60.6	63.9	62.5	60.8	63.0	62.3	60.4	63.0
TCO	TCO/SCR Heater Inlet Gas Temp. (°C)	82.0	81.2	85.3	81.9	81.4	82.6	81.9	81.1	82.8
	Inlet Gas Temp. (°C)	477	473	482	477	422	481	477	473	482
	Differential Pressure ("water)	3.2	2.8	3.4	3.1	2.5	3.3	3.1	2.8	3.3
SCR	Inlet Gas Temp. (°C)	401	396	406	401	377	405	402	399	409
	Outlet Gas Temp. Right (°C)	395	387	400	396	374	400	397	394	403
	Outlet Gas Temp. Left (°C)	376	369	381	377	356	381	379	376	384
	Differential Pressure ("water)	6.5	5.7	7.0	6.4	4.8	6.8	6.4	5.7	6.7
	Post Outlet Gas Temp. (°C)	366	358	370	367	351	369	368	365	373
PBS	Inlet Gas Temp. (°C)	342	332	344	342	334	345	343	341	348
	PBS Sump Temp. (°C)	25.1	22.0	28.1	24.1	22.0	26.5	25.2	23.3	27.7
	Differential Pressure ("water)	3.8	2.8	4.4	3.3	1.9	3.8	3.3	2.7	3.7
HEME #2	Inlet Gas Temp. (°C)	27.2	25.0	30.3	26.8	24.7	28.9	27.7	25.7	30.1
	Outlet Gas Temp. (°C)	29.2	27.2	32.0	28.2	26.1	30.2	29.0	27.7	31.5
Exhaust Stack Absolute Pressure ("water)		-8.4	-8.5	-8.3	-8.1	-8.5	-7.9	-8.5	-8.6	-8.3

Table 5.2. DM1200 AZ-101 Bubbler Configuration Tests Off Gas System Measured Parameters (continued).

Test		2D			1A			1B		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Melter	Pressure at Level Detector Port (“water)	-4.0	-7.3	0.2	-3.9	-7.0	2.0	-3.9	-5.9	0.4
	Pressure at Instrument Port (“water)	-4.1	-7.5	0.1	-4.0	-7.0	1.8	-4.0	-6.0	0.3
	Control Air Flow Rate (scfm)	50.3	22.3	71.6	53.3	1.9	85.9	49.4	15.3	73.6
SBS	Differential Pressure (“water)	40.7	36.4	43.8	37.1	28.4	40.7	37.9	33.8	41.2
	Inlet gas pressure (“water)	-10.0	-13.7	-2.3	-7.5	-19.1	1.2	-7.7	-13.8	-1.0
	Outlet gas pressure (“water)	-50.6	-55.8	-41.3	-44.8	-56.2	-26.3	-45.7	-52.4	-38.7
	Inlet gas Temp. (°C)	283	168	335	288	172	411	294	180	349
	Outlet gas Temp. (°C)	40.1	37.0	49.9	41.4	36.4	51.9	40.3	33.2	44.1
	Chilled Water Inlet Temp (°C)	14.7	10.6	20.0	16.8	14.8	24.9	17.5	14.9	24.7
	Chilled Water Outlet Temp (°C)	22.9	19.7	35.3	24.6	21.6	30.1	21.7	18.5	28.1
	Submerged 48" Temp (°C)	42.5	38.2	52.9	46.9	39.3	63.0	47.1	40.2	54.6
	Submerged 60" Temp (°C)	42.3	38.2	52.9	46.5	38.7	61.8	46.9	40.3	53.9
	Submerged 72" Temp (°C)	44.8	40.3	55.3	49.2	40.4	64.2	49.9	40.6	57.1
	Submerged 78" Temp (°C)	42.7	38.8	52.8	46.6	38.6	61.8	46.8	40.2	54.6
	Recirc. pump discharge Temp (°C)	39.6	36.9	48.5	41.0	36.2	48.2	40.0	34.3	43.3
	Heat Exchanger Outlet Temp (°C)	35.1	32.0	48.4	34.6	29.9	44.5	29.7	23.9	34.2
	Chilled Water Flow (gal/min)	12.4	4.3	42.4	12.6	2.5	37.4	24.8	2.4	42.6
	Heat Exchanger Flow (gal/min)	6.7	2.5	15.0	11.5	3.1	22.0	21.1	2.6	35.0
	Recirc. pump discharge Pressure	37.1	30.9	39.6	38.5	31.2	40.8	38.2	31.2	40.4
	Inner C. Coil W. Inlet Temp (°C)	30.0	24.4	48.9	29.0	23.6	41.8	23.8	20.6	29.3
	Inner C. Coil W. Outlet Temp(°C)	35.8	32.8	49.3	36.5	32.5	45.3	33.9	26.6	38.6
	Inner C. Coil W. Flow (gal/min)	24.4	23.9	25.2	24.1	23.6	24.9	24.0	23.5	24.5
	WESP	Differential Pressure (“water)	2.6	2.0	3.5	2.6	1.5	3.3	2.5	1.6
Inlet gas Temp. (°C)		39.8	31.3	49.3	40.6	35.7	51.4	39.6	32.6	43.4
Outlet gas Temp. (°C)		40.8	13.5	48.2	42.4	27.8	49.7	41.7	5.7	44.9
Gas Flow Rate (scfm)		209.9	176.2	225.3	211.3	5.2	227.8	209.9	186.2	235.3
HEME #1, Outlet Gas Temp. (°C)		39.5	32.1	45.8	41.5	36.1	47.6	40.2	33.6	42.9
HEPA 1	Differential Pressure (“water)	0.2	0.1	0.2	0.1	0.0	0.8	0.1	0.1	0.2
	Outlet Gas Temp. (°C)	62.6	61.0	63.5	62.8	53.6	64.2	62.9	61.8	63.6
TCO/SCR Heater Inlet Gas Temp. (°C)		82.2	81.3	83.0	80.3	66.6	99.7	80.4	79.7	81.3
TCO	Inlet Gas Temp. (°C)	477	472	489	475	313	527	476	470	483
	Differential Pressure (“water)	3.1	2.7	3.6	3.1	0.4	3.4	3.1	2.7	3.4
SCR	Inlet Gas Temp. (°C)	403	398	405	401	312	407	402	396	406
	Outlet Gas Temp. Right (°C)	397	394	399	395	316	400	398	390	402
	Outlet Gas Temp. Left (°C)	379	376	381	377	300	382	381	375	384
	Differential Pressure (“water)	6.2	5.5	7.7	6.3	0.3	6.9	6.2	5.5	7.0
	Post Outlet Gas Temp. (°C)	368	365	369	365	305	370	368	363	371
PBS	Inlet Gas Temp. (°C)	343	341	345	341	305	345	344	339	346
	PBS Sump Temp. (°C)	25.3	23.1	28.1	29.2	26.5	35.8	31.3	29.7	36.3
	Differential Pressure (“water)	3.0	2.3	4.2	3.3	0.5	4.3	3.4	2.5	4.4
HEME #2	Inlet Gas Temp. (°C)	27.9	26.0	30.2	31.0	28.9	37.2	33.5	32.1	38.6
	Outlet Gas Temp. (°C)	29.2	27.7	31.1	33.1	31.1	38.4	34.9	33.8	39.3
Exhaust Stack Absolute Pressure (“water)		-8.5	-8.7	-8.3	-8.3	-8.8	-7.6	-8.4	-8.6	-7.6

Table 5.2. DM1200 AZ-101 Bubbler Configuration Tests Off Gas System Measured Parameters (continued).

Test		1C			1D			3A		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Melter	Pressure at Level Detector Port ("water)	-3.5	-5.9	0.4	-3.5	-5.3	-0.1	-3.9	-6.4	0.4
	Pressure at Instrument Port ("water)	-3.6	-6.0	0.3	-3.6	-5.5	-0.2	-3.9	-6.4	0.3
	Control Air Flow Rate (scfm)	56.9	14.1	79.1	55.3	14.3	84.0	70.8	14.9	124.1
SBS	Differential Pressure ("water)	38.2	33.9	53.0	38.1	30.1	41.5	37.1	30.8	40.7
	Inlet gas pressure ("water)	-7.8	-19.4	-1.0	-7.1	-11.7	-4.4	-7.4	-14.2	0.2
	Outlet gas pressure ("water)	-46.0	-58.0	-39.1	-45.2	-49.0	-38.7	-44.6	-51.0	-39.2
	Inlet gas Temp. (°C)	278	138	331	279	164	318	273	155	457
	Outlet gas Temp. (°C)	40.8	38.1	47.1	40.6	38.1	44.3	42.6	36.0	67.4
	Chilled Water Inlet Temp (°C)	17.6	15.2	24.7	17.8	13.9	24.3	23.8	21.7	26.7
	Chilled Water Outlet Temp (°C)	22.1	19.5	29.1	21.7	18.3	27.7	27.9	23.8	38.5
	Submerged 48" Temp (°C)	46.8	39.1	58.2	46.4	43.3	52.6	48.4	39.3	73.0
	Submerged 60" Temp (°C)	46.9	39.7	57.0	46.6	42.7	53.7	47.9	39.2	72.9
	Submerged 72" Temp (°C)	49.8	40.9	60.5	49.6	43.9	58.2	50.4	41.6	74.1
	Submerged 78" Temp (°C)	46.6	39.0	57.5	45.9	42.1	51.6	47.9	39.2	72.9
	Recirc. pump discharge Temp (°C)	40.5	37.9	46.1	40.2	37.1	43.5	43.3	38.6	55.2
	Heat Exchanger Outlet Temp (°C)	30.1	27.8	37.3	30.1	27.0	34.4	34.2	29.1	49.8
	Chilled Water Flow (gal/min)	23.0	4.9	42.9	26.2	2.7	42.7	22.9	2.8	29.9
	Heat Exchanger Flow (gal/min)	20.8	18.8	39.2	21.1	2.8	39.3	20.2	2.8	29.5
	Recirc. pump discharge Pressure	37.5	31.2	39.8	37.8	30.0	40.5	35.3	28.0	38.3
	Inner C. Coil W. Inlet Temp (°C)	24.1	21.6	31.0	24.1	21.3	29.0	29.1	26.1	36.5
	Inner C. Coil W. Outlet Temp (°C)	34.3	31.6	40.6	34.2	31.6	38.2	37.3	32.1	55.7
	Inner C. Coil W. Flow (gal/min)	24.1	23.5	24.6	24.1	23.5	24.6	24.2	23.5	24.8
WESP	Differential Pressure ("water)	2.5	1.3	3.4	2.4	1.9	3.3	2.6	1.9	3.6
	Inlet gas Temp. (°C)	40.0	37.3	45.9	39.9	33.7	43.3	42.1	35.7	65.9
	Outlet gas Temp. (°C)	41.5	28.8	45.4	41.6	22.4	43.8	43.9	27.5	61.1
	Gas Flow Rate (scfm)	213.1	157.6	242.2	208.0	192.8	239.3	212.4	169.9	251.4
HEPA 1	HEME #1, Outlet Gas Temp. (°C)	40.3	34.0	44.2	40.5	35.0	42.6	43.0	38.1	62.3
	Differential Pressure ("water)	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2
	Outlet Gas Temp. (°C)	62.9	61.5	63.8	62.9	62.1	63.6	63.1	60.7	70.6
TCO/SCR Heater Inlet Gas Temp. (°C)		80.5	79.8	84.6	79.9	79.0	81.0	80.0	78.6	82.4
TCO	Inlet Gas Temp. (°C)	476	462	495	476	470	481	476	470	485
	Differential Pressure ("water)	3.1	2.3	3.5	3.0	2.7	3.5	3.1	2.5	3.7
SCR	Inlet Gas Temp. (°C)	402	394	407	402	398	406	402	392	408
	Outlet Gas Temp. Right (°C)	398	389	402	398	393	402	397	380	403
	Outlet Gas Temp. Left (°C)	381	373	383	380	377	384	379	364	385
	Differential Pressure ("water)	6.3	4.4	7.1	6.1	5.5	7.1	6.2	5.0	7.4
	Post Outlet Gas Temp. (°C)	368	361	371	368	365	371	364	331	372
PBS	Inlet Gas Temp. (°C)	345	336	347	344	341	347	341.1	313.3	348.0
	PBS Sump Temp. (°C)	32.0	30.3	37.2	32.0	30.1	37.4	36.9	32.1	43.0
	Differential Pressure ("water)	3.4	1.9	4.4	3.2	1.3	4.3	3.7	2.2	5.8
HEME #2	Inlet Gas Temp. (°C)	33.7	32.5	38.4	33.9	26.1	101.0	38.1	33.3	44.2
	Outlet Gas Temp. (°C)	34.8	33.6	39.6	34.8	31.2	64.6	39.4	35.7	45.9
Exhaust Stack Absolute Pressure ("water)		-8.4	-8.7	-7.3	-8.4	-8.8	-0.1	-8.4	-8.6	-7.5

Table 5.2. DM1200 AZ-101 Bubbler Configuration Tests Off Gas System Measured Parameters (continued).

Test		3B			3C			8A		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Melter	Pressure at Level Detector Port ("water)	-3.3	-5.9	0.8	-3.5	-6.2	3.2	-4.0	-5.8	-1.5
	Pressure at Instrument Port ("water)	-3.4	-5.9	0.8	-3.5	-6.1	3.2	-4.0	-5.8	-1.7
	Control Air Flow Rate (scfm)	68.2	13.6	100.4	63.6	13.4	94.7	57.5	40.4	77.5
SBS	Differential Pressure ("water)	37.8	32.9	42.3	37.7	33.7	43.3	37.4	33.2	41.0
	Inlet gas pressure ("water)	-8.2	-22.3	-0.9	-7.8	-22.3	-0.5	-7.8	-11.9	-4.0
	Outlet gas pressure ("water)	-46.1	-63.9	-39.6	-45.8	-64.8	-38.9	-45.6	-48.4	-42.6
	Inlet gas Temp. (°C)	302	166	367	296	107	372	295	202	358
	Outlet gas Temp. (°C)	48.3	31.4	57.4	44.3	22.8	51.4	42.2	37.3	50.4
	Chilled Water Inlet Temp (°C)	20.2	15.1	31.1	18.3	14.1	27.6	17.1	12.3	20.6
	Chilled Water Outlet Temp (°C)	25.2	18.1	35.8	22.7	15.2	32.0	23.6	20.0	26.7
	Submerged 48" Temp (°C)	56.4	33.1	70.1	51.6	21.8	61.2	49.5	42.2	58.8
	Submerged 60" Temp (°C)	56.1	33.1	70.3	51.3	21.6	61.8	49.0	42.2	59.6
	Submerged 72" Temp (°C)	58.8	35.5	73.6	54.5	22.0	67.1	52.3	44.8	63.4
	Submerged 78" Temp (°C)	55.8	33.1	70.1	51.1	21.8	61.2	49.0	41.2	58.8
	Recirc. pump discharge Temp (°C)	48.0	34.9	55.0	44.0	22.6	51.1	41.8	37.7	47.6
	Heat Exchanger Outlet Temp (°C)	35.3	23.9	45.3	32.0	17.6	40.3	32.7	27.2	37.3
	Chilled Water Flow (gal/min)	28.6	6.0	29.6	28.4	3.0	29.4	16.7	6.6	28.6
	Heat Exchanger Flow (gal/min)	22.2	2.9	23.0	22.2	21.7	22.8	16.9	10.1	25.0
	Recirc. pump discharge Pressure	35.6	27.2	38.5	33.9	26.1	37.4	33.8	27.0	36.0
	Inner C. Coil W. Inlet Temp (°C)	27.4	19.8	37.3	25.0	15.9	33.8	26.2	21.9	29.9
	Inner C. Coil W. Outlet Temp (°C)	40.4	27.0	49.7	36.7	18.8	44.6	36.0	31.5	41.6
	Inner C. Coil W. Flow (gal/min)	24.2	23.5	24.8	24.1	23.4	24.9	24.1	23.6	24.7
	Differential Pressure ("water)	2.6	1.1	3.8	2.6	0.6	3.7	2.8	2.3	3.3
WESP	Inlet gas Temp. (°C)	47.5	33.1	56.6	43.5	24.3	50.6	41.6	37.6	49.7
	Outlet gas Temp. (°C)	48.8	32.3	56.7	45.3	31.9	51.1	42.1	12.3	46.8
	Gas Flow Rate (scfm)	211.2	128.5	242.6	209.9	116.7	236.5	224.6	212.3	244.3
HEME #1, Outlet Gas Temp. (°C)		46.7	36.5	54.0	43.0	29.2	49.0	42.5	37.1	48.2
HEPA 1	Differential Pressure ("water)	0.1	0.0	0.2	0.1	0.0	0.2	0.1	0.1	0.2
	Outlet Gas Temp. (°C)	63.8	61.6	66.1	63.3	61.1	64.5	62.9	62.0	63.9
TCO/SCR Heater Inlet Gas Temp. (°C)		81.4	79.8	83.0	81.2	79.0	82.1	81.5	80.8	81.8
TCO	Inlet Gas Temp. (°C)	474	326	546	476	325	627	472	430	489
	Differential Pressure ("water)	2.8	1.8	3.3	2.8	1.4	3.2	3.2	3.0	3.4
SCR	Inlet Gas Temp. (°C)	404	313	440	404	332	445	397	376	409
	Outlet Gas Temp. Right (°C)	399	317	430	399	335	431	391	372	403
	Outlet Gas Temp. Left (°C)	384	306	414	384	319	416	371	352	382
	Differential Pressure ("water)	5.7	3.2	7.2	5.6	2.2	6.6	6.5	6.0	6.9
	Post Outlet Gas Temp. (°C)	346	290	367	346	302	370	361	344	371
PBS	Inlet Gas Temp. (°C)	324.2	282.6	337.6	323.1	300.7	343.0	340	325	349
	PBS Sump Temp. (°C)	35.6	30.7	45.1	32.7	25.6	41.0	30.9	28.4	34.9
	Differential Pressure ("water)	3.4	1.3	4.6	3.2	0.8	4.0	3.4	2.8	4.2
HEME #2	Inlet Gas Temp. (°C)	37.2	33.1	46.3	34.8	28.8	42.2	32.5	29.9	36.3
	Outlet Gas Temp. (°C)	38.0	34.2	46.3	35.7	30.2	42.9	34.2	32.1	37.4
Exhaust Stack Absolute Pressure ("water)		-8.4	-8.6	-2.3	-8.3	-8.8	-7.3	-8.5	-8.6	-8.3

Table 5.2. DM1200 AZ-101 Bubbler Configuration Tests Off Gas System Measured Parameters (continued).

Test		8B			8C			10A		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Melter	Pressure at Level Detector Port ("water)	-3.3	-6.5	0.8	-2.7	-4.9	1.9	-3.6	-7.0	-0.4
	Pressure at Instrument Port ("water)	-3.3	-6.5	0.7	-2.7	-4.8	1.8	-3.6	-6.9	-0.7
	Control Air Flow Rate (scfm)	50.2	12.2	87.9	44.0	12.0	85.2	44.9	1.7	66.1
SBS	Differential Pressure ("water)	37.9	33.5	41.9	39.0	35.0	42.7	38.6	34.8	41.8
	Inlet gas pressure ("water)	-8.1	-22.2	-0.3	-7.1	-17.3	0.9	-6.2	-16.1	-2.1
	Outlet gas pressure ("water)	-46.4	-59.7	-38.5	-46.2	-59.4	-39.0	-45.6	-54.3	-42.1
	Inlet gas Temp. (°C)	307	179	389	306	182	373	303	205	367
	Outlet gas Temp. (°C)	47.5	33.1	55.9	49.6	26.3	55.3	41.5	36.2	54.3
	Chilled Water Inlet Temp (°C)	18.1	14.4	22.7	17.5	13.9	20.8	16.8	13.4	20.3
	Chilled Water Outlet Temp (°C)	23.5	18.3	29.5	24.0	16.2	27.8	24.1	21.5	30.0
	Submerged 48" Temp (°C)	56.6	43.1	69.9	58.1	29.0	68.9	47.3	41.0	62.6
	Submerged 60" Temp (°C)	55.9	40.8	67.8	57.8	28.0	68.2	47.0	40.3	62.2
	Submerged 72" Temp (°C)	59.3	45.4	72.2	61.1	31.4	71.9	50.0	42.8	65.2
	Submerged 78" Temp (°C)	56.0	40.8	68.7	57.7	28.0	68.8	46.8	40.3	62.6
	Recirc. pump discharge Temp (°C)	47.2	31.8	53.8	49.2	27.3	53.9	41.2	37.1	51.7
	Heat Exchanger Outlet Temp (°C)	33.2	24.4	40.4	32.7	18.7	37.1	30.6	26.4	36.0
	Chilled Water Flow (gal/min)	25.9	2.4	40.0	21.6	2.7	23.8	13.3	3.0	36.9
	Heat Exchanger Flow (gal/min)	23.8	3.5	29.1	27.4	4.8	28.0	19.9	10.2	26.2
	Recirc. pump discharge Pressure	32.4	-1.4	35.5	31.2	23.1	34.6	38.1	31.2	40.5
	Inner C. Coil W. Inlet Temp (°C)	25.1	20.3	30.8	24.2	16.5	27.6	24.4	21.2	29.1
	Inner C. Coil W. Outlet Temp (°C)	39.0	27.6	46.8	39.8	21.8	45.1	34.6	30.7	44.0
	Inner C. Coil W. Flow (gal/min)	24.2	23.5	24.8	24.2	23.4	24.7	24.1	23.5	24.6
	Differential Pressure ("water)	2.8	1.0	4.4	2.7	0.9	4.1	2.8	1.8	3.5
WESP	Inlet gas Temp. (°C)	46.8	32.4	55.1	48.7	27.7	54.4	40.9	36.9	54.5
	Outlet gas Temp. (°C)	47.6	14.6	55.0	49.7	32.7	54.3	41.6	32.6	49.8
	Gas Flow Rate (scfm)	220.2	118.4	266.3	214.2	105.2	276.0	209.1	7.2	225.9
HEPA 1	HEME #1, Outlet Gas Temp. (°C)	45.9	33.6	52.6	47.1	31.4	51.0	42.0	37.3	52.1
	Differential Pressure ("water)	0.1	0.0	0.2	0.1	-0.2	0.3	0.2	0.1	0.2
	Outlet Gas Temp. (°C)	63.5	50.7	65.6	63.4	53.8	64.7	61.4	59.9	63.0
TCO	TCO/SCR Heater Inlet Gas Temp. (°C)	81.6	69.1	83.7	80.9	72.5	82.0	78.9	77.6	80.0
	Inlet Gas Temp. (°C)	462	323	522	34	33	38	476	468	484
	Differential Pressure ("water)	3.1	2.1	3.6	-	-	-	3.0	2.4	3.2
SCR	Inlet Gas Temp. (°C)	391	304	422	35	33	42	398	390	403
	Outlet Gas Temp. Right (°C)	386	304	413	36	34	44	388	379	393
	Outlet Gas Temp. Left (°C)	367	284	393	36	34	44	368	361	372
	Differential Pressure ("water)	6.3	4.3	7.2	-	-	-	6.0	4.7	6.5
	Post Outlet Gas Temp. (°C)	356	286	381	79	71	80	357	341	363
PBS	Inlet Gas Temp. (°C)	335	280	357	75	69	76	334	321	339
	PBS Sump Temp. (°C)	34.5	30.2	41.4	35.6	26.9	38.8	29.7	27.2	33.3
	Differential Pressure ("water)	3.4	1.6	4.2	2.0	0.9	3.2	3.7	2.4	4.5
HEME #2	Inlet Gas Temp. (°C)	36.0	32.4	42.8	36.6	28.9	40.0	31.6	29.4	34.6
	Outlet Gas Temp. (°C)	36.9	33.6	42.9	37.0	29.4	40.0	33.0	30.8	36.2
Exhaust Stack Absolute Pressure ("water)		-8.5	-8.7	-7.4	-8.7	-9.0	-7.8	-8.7	-8.9	-8.2

"-" Empty data field

Table 5.2. DM1200 AZ-101 Bubbler Configuration Tests Off Gas System Measured Parameters (continued).

Test		10B			10C			10D		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Melter	Pressure at Level Detector Port (“water)	-3.2	-6.1	0.0	-3.0	-6.2	0.8	-3.0	-5.1	-1.1
	Pressure at Instrument Port (“water)	-3.2	-6.0	0.0	-3.1	-6.1	0.6	-3.0	-5.0	-1.2
SBS	Control Air Flow Rate (scfm)	61.7	2.3	76.5	59.4	13.1	77.5	46.2	16.6	63.0
	Differential Pressure (“water)	39.1	34.2	42.6	39.7	35.0	42.9	39.9	36.0	43.2
	Inlet gas pressure (“water)	-5.6	-12.8	-0.2	-4.9	-9.9	0.8	-5.1	-12.4	-2.3
	Outlet gas pressure (“water)	-45.6	-54.5	-40.6	-45.4	-51.7	-38.7	-45.7	-55.4	-42.5
	Inlet gas Temp. (°C)	251	148	307	266	149	353	270	166	328
	Outlet gas Temp. (°C)	41.0	27.7	46.3	40.0	28.4	43.4	42.6	39.7	46.3
	Chilled Water Inlet Temp (°C)	17.1	12.6	19.9	16.8	14.3	19.0	17.3	13.6	20.1
	Chilled Water Outlet Temp (°C)	22.1	18.0	24.6	22.3	17.6	24.5	22.2	19.6	24.4
	Submerged 48" Temp (°C)	48.6	30.6	60.8	45.6	29.8	53.8	48.5	43.4	58.5
	Submerged 60" Temp (°C)	47.8	30.3	59.1	45.4	29.6	54.2	48.5	43.6	56.7
	Submerged 72" Temp (°C)	51.7	32.3	64.3	48.7	31.8	59.0	52.0	46.0	62.8
	Submerged 78" Temp (°C)	48.0	30.0	60.4	45.2	29.6	53.7	48.1	42.5	57.6
	Recirc. pump discharge Temp (°C)	40.9	29.2	45.0	39.8	28.9	43.1	42.4	40.2	45.0
	Heat Exchanger Outlet Temp (°C)	30.0	22.6	34.9	30.1	21.4	32.5	30.7	28.1	32.9
	Chilled Water Flow (gal/min)	20.2	2.5	37.8	16.8	2.5	37.7	21.9	2.5	43.0
	Heat Exchanger Flow (gal/min)	21.0	17.6	25.6	18.9	16.7	39.4	21.1	3.3	40.2
	Recirc. pump discharge Pressure	38.3	31.1	40.7	38.3	31.0	40.6	38.3	30.8	40.8
	Inner C. Coil W. Inlet Temp (°C)	23.7	19.7	26.4	24.0	18.7	26.1	24.0	21.0	26.4
	Inner C. Coil W. Outlet Temp(°C)	34.3	24.6	38.5	33.7	23.6	36.0	35.2	32.6	38.4
Inner C. Coil W. Flow (gal/min)	24.1	23.5	24.6	24.1	23.5	24.6	24.1	23.5	24.6	
WESP	Differential Pressure (“water)	3.2	2.0	3.7	3.4	2.4	4.6	3.7	2.6	4.2
	Inlet gas Temp. (°C)	40.3	28.2	45.6	39.3	28.4	42.7	41.9	39.3	45.0
	Outlet gas Temp. (°C)	41.9	30.6	45.9	41.4	30.8	43.8	43.2	30.5	45.7
	Gas Flow Rate (scfm)	221.6	7.5	238.6	216.1	193.3	232.1	207.8	133.8	227.4
HEME #1, Outlet Gas Temp. (°C)		40.7	31.8	44.5	39.6	31.9	42.5	41.6	36.5	43.4
HEPA 1	Differential Pressure (“water)	0.2	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.2
	Outlet Gas Temp. (°C)	61.1	59.6	62.2	61.3	60.3	61.9	61.3	60.2	62.1
TCO/SCR Heater Inlet Gas Temp. (°C)		79.4	78.2	80.1	78.7	77.9	79.5	78.8	78.3	79.3
TCO	Inlet Gas Temp. (°C)	475	444	483	475	466	486	475	464	501
	Differential Pressure (“water)	3.2	2.7	3.4	3.1	2.6	3.3	2.9	2.3	3.1
SCR	Inlet Gas Temp. (°C)	399	389	404	398	394	402	399	393	402
	Outlet Gas Temp. Right (°C)	391	384	395	390	386	394	391	385	395
	Outlet Gas Temp. Left (°C)	371	361	373	370	368	374	371	367	375
	Differential Pressure (“water)	6.4	5.3	7.0	6.2	5.1	6.8	5.8	4.3	6.3
	Post Outlet Gas Temp. (°C)	359	337	364	357	335	362	355	336	364
PBS	Inlet Gas Temp. (°C)	337	317	341	335	314	340	331	315	339
	PBS Sump Temp. (°C)	32.5	28.7	41.1	30.2	28.0	31.2	31.9	30.2	33.0
	Differential Pressure (“water)	4.0	3.0	5.0	3.3	2.3	3.9	2.9	1.4	3.4
HEME #2	Inlet Gas Temp. (°C)	34.1	30.6	42.3	32.1	29.7	33.3	33.6	31.8	34.8
	Outlet Gas Temp. (°C)	34.9	31.8	42.0	32.9	30.7	33.8	34.3	32.6	35.4
Exhaust Stack Absolute Pressure (“water)		-8.7	-8.9	-8.6	-8.8	-8.9	-8.3	-8.9	-9.2	-8.7

**Table 5.3. DM1200 AZ-101 Best Configuration Test (Test 9)
Off Gas System Measured Parameters.**

Test		9A			9B		
		Avg.	Min.	Max.	Avg.	Min.	Max.
Melter	Pressure at Level Detector Port ("water)	-3.0	-5.5	0.1	-2.7	-4.7	-0.1
	Pressure at Instrument Port ("water)	-3.1	-5.5	0.0	-2.7	-4.6	-0.2
	Control Air Flow Rate (scfm)	41.6	11.4	71.6	38.8	7.1	63.8
Film Cooler Differential Pressure ("water)		1.4	0.4	3.5	1.7	0.2	10.1
Transition Line Differential Pressure ("water)		2.8	1.1	6.1	3.2	1.7	9.0
SBS	Differential Pressure ("water)	31.4	24.4	34.2	32.8	29.2	41.0
	Inlet gas pressure ("water)	-7.2	-11.6	-1.7	-7.7	-19.0	-3.1
	Outlet gas pressure ("water)	-38.6	-43.3	-33.6	-40.6	-52.7	-34.3
	Downcomer Annulus Pressure (psia)	14.5	14.3	14.7	14.2	13.6	14.6
	Inlet gas Temp. (°C)	265	170	432	296	189	368
	Outlet gas Temp. (°C)	46.5	42.3	51.7	49.6	45.4	54.4
	C. Coil W. Inlet Temp (°C)	16.4	10.0	43.7	17.3	11.5	25.6
	C. Coil W. Outlet Temp (°C)	39.8	34.7	46.7	41.7	36.2	46.9
	Jacket W. Outlet Temp (°C)	41.0	27.2	47.4	43.7	38.5	48.7
	Sump Temp. (°C)	41.1	37.0	46.9	43.6	39.0	48.3
	Offgas Downcomer Temp @3" (°C)	230	156	353	258	201	310
	Offgas Downcomer Temp @8" (°C)	237	175	375	265	207	317
	Offgas Downcomer Temp @13" (°C)	238	182	384	265	208	317
	Offgas Downcomer Temp @18" (°C)	237	182	383	262	207	312
	Offgas Downcomer Temp @23" (°C)	234	182	380	258	204	308
	Offgas Downcomer Temp @28" (°C)	231	182	374	256	203	305
	Offgas Downcomer Temp @33" (°C)	229	180	367	248	199	292
	Offgas Downcomer Temp @38" (°C)	221	173	361	198	145	236
	Offgas Downcomer Temp @43" (°C)	214	160	350	151	104	204
	Offgas Downcomer Temp @48" (°C)	190	89	337	92	82	147
	Offgas Downcomer Temp @53" (°C)	144	72	252	76	65	82
	Offgas Downcomer Temp @58" (°C)	67	57	76	60	52	67
	C. Coil/Jacket W. Flow Rate (gal/min)	18.4	0.8	30.7	22.2	7.3	30.7
	Recirc. pump discharge Temp (°C)	46.4	42.6	50.6	49.5	46.2	52.5
	Recirc. pump discharge Pressure (psi)	38.8	31.7	40.6	38.3	33.5	39.7
WESP	Differential Pressure ("water)	2.8	1.8	4.0	2.7	1.5	4.0
	Inlet gas Temp. (°C)	45.6	41.7	50.8	48.7	44.8	53.5
	Outlet gas Temp. (°C)	47.0	19.9	50.9	49.9	24.0	53.5
	Wet Gas Flow Rate (scfm)	229	188	270	219	175	255
HEME #1	Differential Pressure ("water)	1.3	0.9	1.7	1.2	0.8	1.7
	Outlet Gas Temp. (°C)	44.8	32.0	47.9	47.1	35.8	49.8
HEPA 1	Differential Pressure ("water)	0.4	0.3	0.5	0.4	0.4	0.5
	Outlet Gas Temp. (°C)	65.9	57.5	70.9	69.3	61.2	71.5
TCO/SCR Heater Inlet Gas Temp. (°C)		80.0	75.9	83.6	83.7	80.0	86.1
TCO	Inlet Gas Temp. (°C)	475	467	484	475	460	483
	Differential Pressure ("water)	3.3	2.8	4.0	3.2	2.7	3.7
SCR	Inlet Gas Temp. (°C)	410	404	414	412	409	415
	Outlet Gas Temp. Right (°C)	398	390	403	400	397	404
	Outlet Gas Temp. Left (°C)	379	373	382	382	379	385
	Differential Pressure ("water)	6.8	5.5	8.2	6.6	5.4	7.6
	Post Outlet Gas Temp. (°C)	365	355	370	367	364	370
PBS	Inlet Gas Temp. (°C)	344	333	350	345	342	348
	PBS Sump Temp. (°C)	37.4	33.4	43.5	36.4	34.0	41.4
	Differential Pressure ("water)	4.5	2.3	12.6	3.9	2.1	5.2
HEME #2	Differential Pressure ("water)	6.0	3.5	7.2	6.8	5.7	7.7
	Inlet Gas Temp. (°C)	38.9	35.4	45.0	37.6	35.2	42.5
	Outlet Gas Temp. (°C)	39.2	36.7	45.0	37.8	36.0	41.5
Exhaust Stack Absolute Pressure ("water)		-8.7	-9.0	-7.7	-8.7	-9.0	-8.0

Table 5.4. Mass of Solid Deposits Removed from the Film Cooler and Transition Line Sections after Test 2.

Section Name	Mass (kg)	Pre-cleaning Figures
Film Cooler	0.08	5.11, 5.12
Transition line section #1	0.74	5.13, 5.14
Transition line section #2	2.28	5.15, 5.16
Transition line section #3	0.41	5.17, 5.18
Transition line bellows	0.27	5.19, 5.20
Transition line Section #4	0.26	5.21, 5.22
Total	4.04	--

Table 5.5. Blockages and Solids Removed from Film Cooler, Transition Line, and SBS.

Test	Increase in Differential Pressure Across the SBS During Test ("water)	% Occlusion Estimated in SBS Down-comer	Mass of Dried Solids Removed from SBS Overflow Tank and Bowl* (kg)	Number of Film Cooler Rod-Outs	Number of Transition Line Blockages
5	6.1	10%	0	0	0
6	6.8	32%	Overflow Tank: 42.7	1	0
2	2.4	80%	Bowl: 8.6 Overflow Tank: 26.2	0	4
1	1.7	23%	0	10	1
3	1.8	0%	Overflow Tank: 46.1	17	5
8	2.5	1%	Overflow Tank 51.6	34	0
4	0.5	7%	Overflow Tank: 25.4	0	0
10	1.6	25%	Bowl: 15.3 Overflow Tank: 29.5	1	2
9	3.0	>36% [#]	Bowl: 8 (wet) ⁺ Overflow Tank: 0	5	0

* - The SBS bowl was dropped only after Tests 2, 10, and 9. Solids removed from Tests 2 and 10 should be attributed to all previous tests following last bowl cleaning. The bowl was dropped for inspection after Test 9, but the solids were not removed.

- The estimated occlusion is somewhat greater than 36% as described in the text.

+ - Bowl solids mass for Test 9 is an estimated amount. These were not removed at the end of the test.

Table 5.6. Time Needed to Restore Power after Deluge of WESP and Duration of Spray Water Flow Interruptions during Test 2.

DATE	TIME	Time Required to Restore Power (Minutes)
5/29/2003	13:46	6
5/30/2003	13:04	6
5/31/2003	13:33	7
6/1/2002	12:25	10
6/2/2003	12:59	16
6/3/2003	12:47	11
6/4/2003	12:41	5
6/5/2003	12:38	13
Avg.		~9

Note: Duration of spray water flow interruptions was not recorded during Test 2.

Table 5.7 Time Needed to Restore Power after Deluge of WESP and Duration of Spray Water Flow Interruptions during Test 1.

DATE	TIME	Time Required to Restore Power (Minutes)	Duration of Spray Water Flow Interruption (Minutes)
6/26/2003	11:09	6	-
6/27/2003	11:04	6	-
6/28/2003	11:10	6	-
6/29/2003	11:16	4	14
6/30/2003	11:00	6	17
7/1/2003	11:11	3	13
Avg.		~5	~15

"-" Empty data field

Table 5.8. Time Needed to Restore Power after Deluge of WESP and Duration of Spray Water Flow Interruptions During Test 3.

DATE	TIME	Time Required to Restore Power (Minutes)	Duration of Spray Water Flow Interruption (Minutes)
7/16/2003	11:09	3	13
7/17/2003	11:03	3	12
7/18/2003	11:02	3	13
7/19/2003	9:57	6	14
7/20/2003	11:37	5	15
7/21/2003	10:59	5	15
Avg.		~4	~14

Table 5.9. Time Needed to Restore Power after Deluge of WESP and Duration of Spray Water Flow Interruptions During Test 8.

DATE	TIME	Time Required to Restore Power (Minutes)	Duration of Spray Water Flow Interruption (Minutes)
8/6/2003	11:10	3	13
8/7/2003	11:19	3	13
8/8/2003	11:18	3	12
8/9/2003	11:22	2	13
8/10/2003	11:30	2	11
8/11/2003	11:28	5	14
Avg.		3	~13

Table 5.10. Time Needed to Restore Power after Deluge of WESP and Duration of Spray Water Flow Interruptions During Test 10.

DATE	TIME	Time Required to Restore Power (Minutes)	Duration of Spray Water Flow Interruption (Minutes)
9/4/2003	12:05	7	16
9/5/2003	10:51	9	15
9/6/2003	11:38	8	15
9/7/2003	11:35	9	17
9/8/2003	11:30	8	14
9/9/2003	11:13	5	12
Avg.		~8	~15

Table 5.11. Time Needed to Restore Power after Deluge of WESP and Duration of Spray Water Flow Interruptions During Test 9.

DATE	TIME	Time Required to Restore Power (Minutes)	Duration of Spray Water Flow Interruption (Minutes)
3/24/2004	12:25	2	14
3/25/2004	10:15	2	10
3/26/2004	10:24	2	12
3/27/2004	10:34	2	18
3/28/2004	10:12	2	10
3/29/2004	08:06	2	9
3/30/2004	11:24	3	12
3/31/2004	08:32	2	12
Avg.		~2	~12

Table 5.12. Nitrogen Oxides and Carbon Monoxide Destruction across TCO-SCR Catalytic Unit During Test 2.

Test	Gaseous Species	Conc. at Melter Outlet (ppmv)	Conc. at SBS Outlet (ppmv)	Flux at WESP outlet (mol/hr)	Flux at TCO-SCR outlet (mol/hr)	NO _x , CO, NH ₃ removal (%)	DF
2A	N ₂ O	2.1	2.1	-	0.025	-	-
	NO	110	110	-	0.430	-	-
	NO ₂	3.6	3.7	-	0.430	-	-
	Total NO _x	-	-	-	0.885	-	-
	CO	<1.0	<1.0	-	<0.015	-	-
	CO ₂	3300	2900	-	29.2	-	-
	NH ₃	exhaust	<1.0	1.0	<0.015	-	-
		injected	-	-	1.394	-	-
		Total	-	-	-	-	-
2B	N ₂ O	1.6	1.6	0.028	<0.015	-	-
	NO	110	100	1.637	<0.015	-	-
	NO ₂	3.3	3.8	0.101	<0.015	-	-
	Total NO _x	-	-	1.766	<0.046	>97.4	>38.3
	CO	1.0	<1.0	0.016	<0.015	>6.1	>1.1
	CO ₂	3100	2700	43.1	6.6	-	-
	NH ₃	exhaust	<1.0	3.3	0.015	-	-
		injected	-	-	3.599	-	-
		Total	-	-	3.614	0.015	99.6
2C	N ₂ O	1.6	1.6	0.024	<0.016	-	-
	NO	110	120	1.506	<0.016	-	-
	NO ₂	8.4	6.0	0.196	<0.016	-	-
	Total NO _x	-	-	1.726	<0.047	>97.3	>37.1
	CO	7.3	1.6	0.512	<0.016	>97.0	>33.0
	CO ₂	3900	3000	46.7	6.5	-	-
	NH ₃	exhaust	<1.0	<1.0	<0.051	-	-
		injected	-	-	3.999	-	-
		Total	-	-	<4.050	<0.016	~99.6
2D	N ₂ O	1.4	1.6	0.025	<0.015	-	-
	NO	120	130	1.920	<0.015	-	-
	NO ₂	9.7	8.5	0.192	<0.015	-	-
	Total NO _x	-	-	2.138	<0.046	>97.9	>46.9
	CO	1.3	1.5	0.027	<0.015	>42.8	>1.7
	CO ₂	3600	3200	47.3	7.3	-	-
	NH ₃	exhaust	<1.0	<1.0	<0.015	-	-
		injected	-	-	3.999	-	-
		Total	-	-	<4.014	0.021	~99.5

"-" Empty data field

**Table 5.13. Nitrogen Oxides and Carbon Monoxide Destruction across
TCO-SCR Catalytic Unit During Test 1.**

Test	Gaseous Species	Conc. at Melter Outlet (ppmv)	Conc. at SBS Outlet (ppmv)	Flux at WESP outlet (mol/hr)	Flux at TCO-SCR outlet (mol/hr)	NO _x , CO, NH ₃ removal (%)	DF
1A	N ₂ O	-	-	-	0.041	-	-
	NO	-	-	-	0.414	-	-
	NO ₂	-	-	-	1.105	-	-
	Total NO _x	-	-	-	1.559	-	-
	CO	-	-	-	<0.015	-	-
	CO ₂	-	-	-	67.4	-	-
	NH ₃	exhaust	-	-	0.020	-	-
		injected	-	2.133	-	-	-
		Total	-	-	-	-	-
1B	N ₂ O	2.0	3.1	0.043	0.113	-	-
	NO	200	280	3.841	0.134	-	-
	NO ₂	20	22	0.443	0.473	-	-
	Total NO _x	-	-	4.327	0.720	83.4	6.0
	CO	2.3	3.9	<0.015	<0.015	-	~1.0
	CO ₂	5400	7000	100.5	88.5	-	-
	NH ₃	exhaust	14	0.061	-	-	-
		injected	-	4.399	-	-	-
		Total	-	4.459	0.105	97.6	42.4
1C	N ₂ O	2.3	3.3	0.042	0.113	-	-
	NO	220	300	3.748	<0.016	-	-
	NO ₂	20	20	0.405	0.403	-	-
	Total NO _x	-	-	4.195	<0.532	>87.3	>7.9
	CO	1.7	4.2	0.039	<0.016	>60.2	>2.5
	CO ₂	5500	7500	96.0	86.9	-	-
	NH ₃	exhaust	3.9	<0.015	-	-	-
		injected	-	4.532	-	-	-
		Total	-	<4.547	0.085	<98.1	<53.3
1D	N ₂ O	2.5	3.6	0.051	0.129	-	-
	NO	220	320	4.390	0.067	-	-
	NO ₂	21	23	0.468	0.454	-	-
	Total NO _x	-	-	4.910	0.649	86.8	7.6
	CO	1.3	3.3	0.054	<0.015	>72.1	>3.6
	CO ₂	5500	7900	111.2	98.3	-	-
	NH ₃	exhaust	2.7	<1.0	<0.015	-	-
		injected	-	4.532	-	-	-
		Total	-	<4.547	0.068	<98.5	<66.8

"-" Empty data field

Table 5.14. Nitrogen Oxides and Carbon Monoxide Destruction Across TCO-SCR Catalytic Unit During Test 3.

Test	Gaseous Species	Conc. at Melter Outlet (ppmv)	Conc. at SBS Outlet (ppmv)	Flux at WESP outlet (mol/hr)	Flux at TCO-SCR outlet (mol/hr)	NO _x , CO, NH ₃ removal (%)	DF
3A	N ₂ O	1.8	2.4	<0.015	0.048	-	-
	NO	180	180	0.179	<0.015	-	-
	NO ₂	14	10	0.027	0.215	-	-
	Total NO _x	-	-	0.221	0.278	-	0.8
	CO	2.0	-	<0.015	<0.015	-	1.0
	CO ₂	6000	4500	14.9	43.0	-	-
	NH ₃	exhaust	<1.0	0.025	-	-	-
		injected	-	3.012	-	-	-
		Total	-	3.038	0.060	98.0	50.7
3B	N ₂ O	1.4	2.9	0.042	0.070	-	-
	NO	120	320	4.459	0.276	-	-
	NO ₂	12	21	0.431	0.306	-	-
	Total NO _x	-	-	4.931	0.652	86.8	7.6
	CO	1.2	3.4	0.055	0.015	72.2	3.6
	CO ₂	4200	8000	108.5	72.0	-	-
	NH ₃	exhaust	4.6	<0.015	-	-	-
		injected	-	4.671	-	-	-
		Total	-	<4.686	0.150	~96.8	~31.3
3C	N ₂ O	1.8	2.9	0.040	0.078	-	-
	NO	170	270	3.841	0.381	-	-
	NO ₂	20	19	0.325	0.305	-	-
	Total NO _x	-	-	4.206	0.763	81.9	5.5
	CO	1.6	3.2	0.052	0.015	70.6	3.4
	CO ₂	5400	6700	96.0	77.6	-	-
	NH ₃	exhaust	3.8	<0.015	-	-	-
		injected	-	4.105	-	-	-
		Total	-	<4.120	0.183	~95.6	~22.6

"-" Empty data field

**Table 5.15. Nitrogen Oxides and Carbon Monoxide Destruction Across
TCO-SCR Catalytic Unit During Test 8.**

Test	Gaseous Species	Conc. at Melter Outlet (ppmv)	Conc. at SBS Outlet (ppmv)	Flux at WESP outlet (mol/hr)	Flux at TCO-SCR outlet (mol/hr)	NO _x , CO, NH ₃ removal (%)	DF
8A	N ₂ O	1.2	1.7	<0.016	0.049	-	-
	NO	130	170	0.948	0.065	-	-
	NO ₂	4.7	5.6	0.074	0.325	-	-
	Total NO _x	-	-	<1.039	0.438	~57.8	~2.4
	CO	<1.0	1.1	<0.016	<0.016	-	~1.0
	CO ₂	6700	4200	26.9	45.4	-	-
	NH ₃	exhaust	<1.0	0.016	-	-	-
		injected	-	2.814	-	-	-
		Total	-	<2.830	0.042	~98.5	~67.1
8B	N ₂ O	<1.0	1.8	0.026	0.061	-	-
	NO	85.6	200	2.634	1.594	-	-
	NO ₂	3.5	8.0	0.201	0.303	-	-
	Total NO _x	-	-	2.862	1.958	31.6	1.5
	CO	<1.0	2.0	0.031	<0.016	>48.6	>1.9
	CO ₂	3800	4900	68.2	68.6	-	-
	NH ₃	exhaust	<1.0	<0.015	-	-	-
		injected	-	4.320	-	-	-
		Total	-	<4.336	0.097	~97.8	~44.6
8C	N ₂ O	1.3	2.2	-	0.027	-	-
	NO	150	240	-	2.864	-	-
	NO ₂	8.1	8.8	-	0.211	-	-
	Total NO _x	-	-	-	3.102	-	-
	CO	1.2	3.6	-	0.044	-	-
	CO ₂	3700	5900	-	75.4	-	-
	NH ₃	exhaust	<1.0	<1.0	-	-	-
		injected	-	0.000	-	-	-
		Total	-	-	<0.0015	-	-

"-" Empty data field

Table 5.16. Nitrogen Oxides and Carbon Monoxide Destruction Across TCO-SCR Catalytic Unit During Test 10.

Test	Gaseous Species		Conc. at Melter Outlet (ppmv)	Conc. at SBS Outlet (ppmv)	Flux at WESP outlet (mol/hr)	Flux at TCO-SCR outlet (mol/hr)	NOx, CO, NH ₃ removal (%)	DF
10A	N2O		1.8	4.8	0.049	0.049	-	-
	NO		6.2	11	0.141	<0.015	-	-
	NO2		1.3	5.3	0.047	<0.015	-	-
	Total NOx		-	-	0.237	<0.079	>66.6	>3.0
	CO		14	26	0.324	<0.015	>95.3	>21.3
	CO2		6000	4700	63.3	31.9	-	-
	NH3	exhaust	30	10	0.138	-	-	-
		injected	-	-	0.977	-	-	-
		Total	-	-	1.116	0.152	86.4	7.3
10B	N2O		1.5	2.5	0.041	0.032	-	-
	NO		55	77	0.826	0.099	-	-
	NO2		1.5	1.0	0.022	0.224	-	-
	Total NOx		-	-	0.889	0.356	60.0	2.5
	CO		4.4	6.0	0.104	<0.016	>84.7	>6.5
	CO2		5200	4000	57.7	40.1	-	-
	NH3	exhaust	<1.0	5.6	0.076	-	-	-
		injected	-	-	1.233	-	-	-
		Total	-	-	1.310	<0.016	>98.8	>81.7
10C	N2O		1.4	2.3	0.026	0.041		
	NO		110	130	1.673	0.067		
	NO2		6.1	4.2	0.070	0.145		
	Total NOx		-	-	1.768	0.253	85.7	7.0
	CO		3.4	5.8	0.070	<0.016	>77.6	>4.5
	CO2		6700	4300	57.8	37.5	-	-
	NH3	exhaust	<1.0	1.7	<0.015	-	-	-
		injected	-	-	2.810	-	-	-
		Total	-	-	<2.825	0.050	~98.2	~56.4
10D	N2O		<1.0	1.9	0.028	<0.056	-	-
	NO		65	160	2.340	0.015	-	-
	NO2		1.9	3.8	0.146	0.131	-	-
	Total NOx				2.514	<0.202	>92.0	>12.5
	CO		1.7	4.9	0.082	<0.015	>81.6	>5.4
	CO2		2700	4600	67.3	43.6	-	-
	NH3	exhaust	3.4	<1.0	<0.015	-	-	-
		injected	-	-	3.796	-	-	-
		Total	-	-	<3.811	0.110	~97.1	~34.7

"-" Empty data field

**Table 5.17. Nitrogen Oxides and Carbon Monoxide Destruction Across
TCO-SCR Catalytic Unit During Test 9.**

Test	Gaseous Species	Conc. at Melter Outlet (ppmv)	Conc. at SBS Outlet (ppmv)	Flux at WESP outlet (mol/hr)	Flux at TCO-SCR outlet (mol/hr)	NO _x , CO, NH ₃ removal (%)	DF
9A	N ₂ O	4.2	5.4	0.086	0.032	-	-
	NO	<1.0	29	0.387	0.040	-	-
	NO ₂	3.3	1.1	0.039	0.119	-	-
	Total NO _x	-	-	0.512	0.192	62.5	2.7
	CO	13.0	19.0	0.307	<0.016	>94.7	>19.0
	CO ₂	1800	6500	101.7	40.3	-	-
	NH ₃	exhaust	11.0	12.0	0.178	-	-
		injected	-	-	0.000	-	-
		Total	-	-	0.178	<0.016	>90.9
9B	N ₂ O	4.8	7.9	0.115	0.045	-	-
	NO	9.6	35	0.477	0.059	-	-
	NO ₂	3.0	2.7	0.057	0.169	-	-
	Total NO _x	-	-	0.650	0.272	58.1	2.4
	CO	18	29	0.477	<0.015	>96.8	>31.0
	CO ₂	4200	8000	121.6	50.8	-	-
	NH ₃	exhaust	6.8	6.4	0.091	-	-
		injected	-	-	0.000	-	-
		Total	-	-	0.091	<0.015	>83.1

"-" Empty data field

Table 5.18. Gas Residence Times in TCO.

Test Number	Residence Time (seconds)
2A	0.20
2B	0.20
2C	0.20
2D	0.20
1A	0.20
1B	0.20
1C	0.20
1D	0.20
3A	0.20
3B	0.20
3C	0.20
8A	0.19
8B	0.19
8C	0.46
10A	0.20
10B	0.19
10C	0.20
10D	0.20
9A	0.18
9B	0.19

Table 5.19. Listing of Samples from SBS Blow-Downs.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
2	05/28/03	X12-S-12A	8.10	40.00	40.00
		X12-S-20A	7.80	40.00	80.00
	05/29/03	X12-S-24A	7.97	40.20	120.20
		X12-S-35A	7.98	40.10	160.30
		X12-S-38A	8.04	40.00	200.30
		X12-S-51A	8.05	40.00	240.30
		X12-S-55A	8.06	39.70	280.00
		X12-S-59A	8.06	40.00	320.00
		X12-S-70A	8.23	40.00	360.00
		X12-S-75A	8.10	40.00	400.00
	05/30/03	X12-S-87A	8.15	40.00	440.00
		X12-S-90A	8.26	40.00	480.00
	05/31/03	X12-S-94A	8.25	40.10	520.10
		X12-S-105A	8.28	40.20	560.30
		X12-S-109A	8.10	40.00	600.30
		X12-S-121A	8.10	39.80	640.10
		X12-S-126A	8.02	40.00	680.10
	06/01/03	X12-S-139A	8.02	40.10	720.20
		X12-S-144A	8.03	40.00	760.20
		Y12-S-8A	8.24	40.00	800.20
		Y12-S-12A	7.96	39.80	840.00
	06/02/03	Y12-S-24A	8.09	40.00	880.00
		Y12-S-27A	8.11	40.00	920.00
		Y12-S-40A	8.09	40.00	960.00
		Y12-S-42A	8.01	40.00	1000.00
		Y12-S-46A	8.04	40.10	1040.10
	06/03/03	Y12-S-58A	8.10	40.00	1080.10
		Y12-S-60A	8.07	40.00	1120.10
		Y12-S-65A	8.12	40.00	1160.10
		Y12-S-75A	8.17	39.90	1200.00
		Y12-S-80A	8.08	40.00	1240.00
	06/04/03	Y12-S-84A	8.05	40.00	1280.00
		Y12-S-96A	8.09	40.20	1320.20
		Y12-S-99A	8.10	40.00	1360.20
		Y12-S-110A	8.16	40.00	1400.20
		Y12-S-114A	8.13	40.00	1440.20
	06/05/03	Y12-S-117A	8.15	40.00	1480.20
		Y12-S-128A	7.97	40.10	1520.30
		Y12-S-132A	8.17	40.00	1560.30
		Y12-S-136A	8.10	40.00	1600.30
		Y12-S-146A	8.18	40.00	1640.30
		Y12-S-150A	8.11	40.00	1680.30
	06/06/03	Y12-S-152A	8.16	40.20	1720.50
		Y12-S-154A	8.02	40.10	1760.60

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test#	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
2	06/06/03	Z12-S-16A	8.16	40.00	1800.60
		Z12-S-18A	8.23	40.00	1840.60
	06/09/03	Z12-S-29A	8.51	366.2	2206.80
		No Sample	NA	22.50	2229.30
1	06/25/03	Z12-S-59A	7.84	41.60	2270.90
		Z12-S-65A	8.03	40.00	2310.90
	06/26/03	Z12-S-77A	8.14	40.10	2351.00
		Z12-S-79A	8.18	40.10	2391.10
		Z12-S-82A	8.06	40.00	2431.10
		Z12-S-85A	8.16	50.30	2481.40
		Z12-S-95A	8.12	40.00	2521.40
		Z12-S-96A	8.17	39.60	2561.00
		Z12-S-100A	8.14	40.00	2601.00
		Z12-S-101A	8.18	39.90	2640.90
		Z12-S-102A	8.19	40.00	2680.90
	06/27/03	Z12-S-113A	8.22	40.00	2720.90
		Z12-S-115A	8.15	38.70	2759.60
		Z12-S-117A	8.25	40.00	2799.60
		Z12-S-120A	8.24	40.00	2839.60
		Z12-S-122A	8.36	40.00	2879.60
		Z12-S-131A	8.32	40.00	2919.60
		Z12-S-135A	8.33	40.00	2959.60
		Z12-S-137A	8.34	39.90	2999.50
		Z12-S-139A	8.37	40.00	3039.50
		Z12-S-140A	8.40	40.00	3079.50
		Z12-S-149A	8.40	40.00	3119.50
	06/28/03	Z12-S-152A	8.38	40.10	3159.60
		1A2-S-5A	8.37	40.00	3199.60
		1A2-S-9A	8.34	39.80	3239.40
		1A2-S-19A	8.37	40.00	3279.40
		1A2-S-23A	8.39	40.10	3319.50
		1A2-S-24A	8.37	40.00	3359.50
		1A2-S-27A	8.33	40.00	3399.50
		1A2-S-28A	8.37	40.00	3439.50
	06/29/03	1A2-S-38A	8.38	40.00	3479.50
		1A2-S-39A	8.37	40.00	3519.50
		1A2-S-40A	8.37	40.00	3559.50
		1A2-S-43A	8.35	40.00	3599.50
		1A2-S-45A	8.34	40.00	3639.50
		1A2-S-54A	8.33	40.00	3679.50
		1A2-S-57A	8.33	40.00	3719.50
		1A2-S-60A	8.32	40.00	3759.50
		1A2-S-62A	8.31	40.10	3799.60

NA – Not analyzed

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
1	06/29/03	1A2-S-64A	8.32	40.00	3839.60
		1A2-S-66A	8.31	40.00	3879.60
	06/30/03	1A2-S-74A	8.33	39.90	3919.50
		1A2-S-75A	8.29	40.00	3959.50
		1A2-S-78A	8.32	40.00	3999.50
		1A2-S-81A	8.32	40.00	4039.50
		1A2-S-83A	8.31	40.00	4079.50
		1A2-S-85A	8.32	40.00	4119.50
		1A2-S-94A	8.29	40.00	4159.50
		1A2-S-98A	8.33	40.00	4199.50
		1A2-S-100A	8.32	40.10	4239.60
		1A2-S-102A	8.31	40.00	4279.60
		1A2-S-103A	8.35	40.00	4319.60
		1A2-S-106A	8.34	39.90	4359.50
	07/01/03	1A2-S-108A	8.32	40.40	4399.90
		1A2-S-111A	8.30	40.00	4439.90
		1A2-S-113A	8.32	40.00	4479.90
		1A2-S-114A	8.33	40.00	4519.90
		1A2-S-117A	8.36	39.90	4559.80
		1A2-S-133A	8.38	40.00	4599.80
		1A2-S-136A	8.34	40.10	4639.90
		1A2-S-137A	8.37	40.00	4679.90
		1A2-S-139A	8.35	40.00	4719.90
		1A2-S-141A	8.36	40.00	4759.90
		1A2-S-149A	8.38	40.00	4799.90
	07/02/03	1A2-S-151A	8.39	40.20	4840.10
		1A2-S-154A	8.37	40.00	4880.10
		1A2-S-155A	8.34	39.40	4919.50
		1B2-S-8A	8.39	40.00	4959.50
		1B2-S-9A	8.41	40.00	4999.50
		1B2-S-19A	8.37	40.00	5039.50
		1B2-S-26A	8.39	40.00	5079.50
3	07/15/03	1B2-S-50A	8.27	40.00	5119.50
		1B2-S-56A	8.16	40.00	5159.50
	07/16/03	1B2-S-62A	8.37	40.14	5199.64
		1B2-S-72A	8.42	40.00	5239.64
		1B2-S-75A	8.44	40.00	5279.64
		1B2-S-78A	8.41	40.00	5319.64
		1B2-S-80A	8.47	40.00	5359.64
		1B2-S-88A	8.46	39.90	5399.54
		1B2-S-89A	8.41	40.00	5439.54
		1B2-S-94A	8.42	40.00	5479.54
		1B2-S-96A	8.34	40.00	5519.54

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
3	07/16/03	1B2-S-97A	8.39	40.00	5559.54
		1B2-S-98A	8.40	40.00	5599.54
		1B2-S-101A	8.34	40.00	5639.54
	01/17/03	1B2-S-102A	8.42	40.10	5679.64
		1B2-S-103A	8.28	31.70	5711.34
		1B2-S-106A	8.31	40.20	5751.54
		1B2-S-108A	8.35	40.00	5791.54
		1B2-S-109A	8.41	40.00	5831.54
		1B2-S-111A	8.36	40.00	5871.54
		1B2-S-112A	8.31	40.00	5911.54
		1B2-S-127A	8.39	40.00	5951.54
		1B2-S-131A	8.30	39.90	5991.44
		1B2-S-132A	8.42	40.10	6031.54
		1B2-S-134A	8.47	40.00	6071.54
		1B2-S-135A	8.45	40.10	6111.64
		1B2-S-136A	8.49	40.10	6151.74
		1B2-S-137A	8.51	40.00	6191.74
		1B2-S-146A	8.53	39.60	6231.34
	01/18/03	1B2-S-148A	8.57	40.00	6271.34
		1B2-S-149A	8.55	40.00	6311.34
		1B2-S-150A	8.45	40.00	6351.34
		1B2-S-151A	8.49	40.00	6391.34
		1B2-S-154A	8.52	40.00	6431.34
		1B2-S-155A	8.58	40.00	6471.34
		1C2-S-10A	8.61	40.00	6511.34
		1C2-S-12A	8.34	39.90	6551.24
		1C2-S-20A	8.28	40.00	6591.24
		1C2-S-22A	8.35	40.00	6631.24
		1C2-S-25A	8.43	40.00	6671.24
		1C2-S-26A	8.40	40.00	6711.24
		1C2-S-27A	8.41	40.00	6751.24
		1C2-S-29A	8.41	40.00	6791.24
		1C2-S-31A	8.40	40.00	6831.24
	07/19/03	1C2-S-32A	8.40	40.00	6871.24
		1C2-S-33A	8.37	40.10	6911.34
		1C2-S-44A	8.34	40.40	6951.74
		1C2-S-45A	8.43	39.50	6991.24
		1C2-S-48A	8.46	40.20	7031.44
		1C2-S-49A	8.45	39.90	7071.34
		1C2-S-50A	8.39	40.00	7111.34
		1C2-S-52A	8.35	40.00	7151.34
		1C2-S-53A	8.42	40.00	7191.34
		1C2-S-55A	8.39	40.00	7231.34

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
3	07/19/03	1C2-S-59A	8.39	40.00	7271.34
		1C2-S-59B	8.39	40.00	7311.34
		1C2-S-67A	8.43	40.00	7351.34
		1C2-S-69A	8.43	40.00	7391.34
		1C2-S-71A	8.42	40.00	7431.34
		1C2-S-73A	8.40	40.00	7471.34
		1C2-S-81A	8.41	40.10	7511.44
	07/20/03	1C2-S-83A	8.42	39.90	7551.34
		1C2-S-84A	8.45	40.00	7591.34
		1C2-S-85A	8.43	40.10	7631.44
		1C2-S-87A	8.46	40.00	7671.44
		1C2-S-89A	8.34	40.00	7711.44
		1C2-S-91A	8.41	40.00	7751.44
		1C2-S-93A	8.31	40.00	7791.44
		1C2-S-98A	8.42	40.00	7831.44
		1C2-S-106A	8.44	40.00	7871.44
		1C2-S-108A	8.47	39.80	7911.24
		1C2-S-110A	8.41	40.00	7951.24
		1C2-S-111A	8.42	40.00	7991.24
		1C2-S-114A	8.35	40.00	8031.24
		1C2-S-117A	8.37	40.00	8071.24
		1C2-S-125A	8.42	40.20	8111.44
	07/21/03	1C2-S-126A	8.50	40.00	8151.44
		1C2-S-127A	8.51	40.00	8191.44
		1C2-S-129A	8.49	40.00	8231.44
		1C2-S-133A	8.53	40.00	8271.44
		1C2-S-136A	8.48	40.00	8311.44
		1C2-S-137A	8.49	40.00	8351.44
		1C2-S-147A	8.38	40.00	8391.44
		1C2-S-150A	8.35	40.00	8431.44
		1C2-S-153A	8.37	40.00	8471.44
		1C2-S-155A	8.41	40.00	8511.44
		1C2-S-155B	8.43	40.00	8551.44
		1D2-S-8A	8.39	40.00	8591.44
		1D2-S-17A	8.45	40.00	8631.44
	07/22/03	1D2-S-18A	8.40	40.00	8671.44
		1D2-S-19A	8.46	40.00	8711.44
		1D2-S-21A	8.39	40.30	8751.74
		1D2-S-26A	8.42	40.00	8791.74
		1D2-S-29A	8.47	40.00	8831.74
		1D2-S-30A	8.43	40.10	8871.84
		1D2-S-40A	8.48	40.00	8911.84
		1D2-S-41A	8.45	40.00	8951.84

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
3	07/22/03	1D2-S-42A	8.49	39.70	8991.54
		1D2-S-43A	8.44	40.00	9031.54
		1D2-S-44A	8.51	40.00	9071.54
		1D2-S-47A	8.49	40.00	9111.54
	07/23/03	1D2-S-55A	8.47	361.30	9472.84
8	08/05/03	1D2-S-78A	8.52	40.00	9512.84
		1D2-S-81A	8.26	40.00	9552.84
		1D2-S-92A	8.21	40.00	9592.84
	08/06/03	1D2-S-95A	8.21	40.00	9632.84
		1D2-S-98A	8.22	40.00	9672.84
		1D2-S-100A	8.22	40.00	9712.84
		1D2-S-108A	8.21	40.00	9752.84
		1D2-S-111A	8.21	40.00	9792.84
		1D2-S-112A	8.16	41.40	9834.24
		1D2-S-114A	8.27	40.00	9874.24
		1D2-S-117A	8.22	38.70	9912.94
		1D2-S-118A	8.21	40.00	9952.94
		1D2-S-120A	8.19	40.00	9992.94
		1D2-S-129A	8.17	39.90	10032.84
		1D2-S-131A	8.23	40.00	10072.84
	08/07/03	1D2-S-133A	8.21	40.03	10112.87
		1D2-S-135A	8.22	40.00	10152.87
		1D2-S-137A	8.25	40.00	10192.87
		1D2-S-148A	8.23	40.00	10232.87
		1D2-S-149A	8.23	40.00	10272.87
		1D2-S-151A	8.25	40.00	10312.87
		1D2-S-152A	8.26	40.00	10352.87
		1D2-S-154A	8.25	40.00	10392.87
		1D2-S-155A	8.25	40.00	10432.87
		1E2-S-8A	8.30	40.00	10472.87
		1E2-S-11A	8.29	40.00	10512.87
		1E2-S-22A	8.27	40.00	10552.87
		1E2-S-23A	8.28	40.00	10592.87
		1E2-S-24A	8.24	40.00	10632.87
		1E2-S-25A	8.29	40.00	10672.87
	08/08/03	1E2-S-27A	8.27	40.00	10712.87
		1E2-S-27B	8.26	40.00	10752.87
		1E2-S-28A	8.24	40.00	10792.87
		1E2-S-29A	8.27	39.90	10832.77
		1E2-S-40A	8.27	40.00	10872.77
		1E2-S-41A	8.24	40.00	10912.77
		1E2-S-42A	8.23	40.00	10952.77
		1E2-S-43A	8.25	40.00	10992.77

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
8	08/08/03	1E2-S-46A	8.27	40.00	11032.77
		1E2-S-47A	8.21	40.00	11072.77
		1E2-S-49A	8.25	40.00	11112.77
		1E2-S-51A	8.27	40.00	11152.77
		1E2-S-60A	8.28	40.00	11192.77
		1E2-S-61A	8.27	40.00	11232.77
		1E2-S-63A	8.25	40.00	11272.77
		1E2-S-63B	8.26	40.00	11312.77
		1E2-S-68A	8.24	40.00	11352.77
	08/09/03	1E2-S-70A	8.22	40.00	11392.77
		1E2-S-71A	8.35	32.00	11424.77
		1E2-S-72A	8.42	42.30	11467.07
		1E2-S-73A	8.32	40.00	11507.07
		1E2-S-82A	8.34	39.80	11546.87
		1E2-S-84A	8.36	40.00	11586.87
		1E2-S-85A	8.35	40.00	11626.87
		1E2-S-86A	8.35	40.00	11666.87
		1E2-S-87A	8.37	40.00	11706.87
		1E2-S-89A	8.43	39.10	11745.97
		1E2-S-90A	8.41	40.00	11785.97
		1E2-S-92A	8.41	40.00	11825.97
		1E2-S-93A	8.40	40.00	11865.97
		1E2-S-93B	8.37	40.00	11905.97
		1E2-S-103A	8.39	40.00	11945.97
		1E2-S-104A	8.34	40.00	11985.97
		1E2-S-106A	8.34	40.30	12026.27
	08/10/03	1E2-S-107A	8.32	40.10	12066.37
		1E2-S-109A	8.31	40.00	12106.37
		1E2-S-110A	8.33	39.60	12145.97
		1E2-S-110B	8.31	40.00	12185.97
		1E2-S-112A	8.22	40.10	12226.07
		1E2-S-121A	8.33	40.00	12266.07
		1E2-S-122A	8.34	40.60	12306.67
		1E2-S-125A	8.37	39.30	12345.97
		1E2-S-126A	8.33	50.20	12396.17
		1E2-S-128A	8.26	44.80	12440.97
		1E2-S-129A	8.26	40.00	12480.97
		1E2-S-133A	8.25	40.00	12520.97
		1E2-S-134A	8.24	40.00	12560.97
		1E2-S-143A	8.30	40.20	12601.17
		1E2-S-144A	8.26	40.00	12641.17
		1E2-S-145A	8.30	40.00	12681.17
		1E2-S-147A	8.30	40.00	12721.17

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test#	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
8	08/10/03	1E2-S-149A	8.29	40.00	12761.17
	08/11/03	1E2-S-150A	8.25	40.00	12801.17
		1E2-S-152A	8.29	39.70	12840.87
		1E2-S-154A	8.24	40.70	12881.57
		1E2-S-155A	8.27	39.40	12920.97
		1F2-S-5A	8.30	40.00	12960.97
		1F2-S-9A	8.26	40.00	13000.97
		1F2-S-10A	8.30	39.90	13040.87
		1F2-S-11A	8.20	40.00	13080.87
		1F2-S-13A	8.20	40.00	13120.87
		1F2-S-14A	8.22	40.00	13160.87
		1F2-S-16A	8.24	40.00	13200.87
		1F2-S-17A	8.24	40.10	13240.97
		1F2-S-27A	8.25	40.00	13280.97
		1F2-S-28A	8.25	40.00	13320.97
		1F2-S-38A	8.28	40.00	13360.97
		1F2-S-40A	8.29	40.00	13400.97
		1F2-S-41A	8.30	40.00	13440.97
		1F2-S-42A	8.31	39.90	13480.87
		1F2-S-43A	8.32	39.90	13520.77
	08/12/03	1F2-S-44A	8.30	40.10	13560.87
		1F2-S-47A	8.31	40.10	13600.97
		1F2-S-48A	8.28	40.00	13640.97
		1F2-S-48B	8.35	40.10	13681.07
		1F2-S-49A	8.33	40.00	13721.07
		1F2-S-58A	8.36	40.00	13761.07
		1F2-S-60A	8.38	40.00	13801.07
		1F2-S-62A	8.33	40.00	13841.07
		1F2-S-64A	8.32	40.00	13881.07
		1F2-S-66A	8.35	40.80	13921.87
		1F2-S-67A	8.35	40.00	13961.87
		1F2-S-69A	8.32	40.00	14001.87
		1F2-S-70A	8.36	40.00	14041.87
		1F2-S-73A	8.38	40.00	14081.87
		1F2-S-81A	8.39	40.00	14121.87
		1F2-S-82A	8.34	40.00	14161.87
		1F2-S-83A	8.34	40.00	14201.87
		1F2-S-86A	8.32	40.00	14241.87
		1F2-S-87A	8.29	40.00	14281.87
	08/13/03	1F2-S-89A	8.22	40.00	14321.87
		1F2-S-90A	8.20	40.20	14362.07
		1F2-S-91A	8.24	39.70	14401.77
		1F2-S-93A	8.26	40.00	14441.77

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
8	08/13/03	1F2-S-94A	8.28	40.10	14481.87
		1F2-S-102A	8.26	40.00	14521.87
		1F2-S-105A	8.26	40.00	14561.87
		1F2-S-105B	8.26	39.90	14601.77
		1F2-S-106A	8.27	40.00	14641.77
		1F2-S-108A	8.27	40.00	14681.77
		1F2-S-110A	8.27	40.10	14721.87
		1F2-S-112A	8.26	40.00	14761.87
		1F2-S-114A	8.37	39.90	14801.77
10	09/03/03	1I2-S-73A	8.14	40.00	14841.77
		1I2-S-76A	8.03	40.10	14881.87
		1I2-S-79A	8.18	40.00	14921.87
	09/04/03	1I2-S-89A	8.29	40.00	14961.87
		1I2-S-91A	8.32	40.00	15001.87
		1I2-S-93A	8.29	40.00	15041.87
		1I2-S-94A	8.25	39.90	15081.77
		1I2-S-98A	8.22	40.00	15121.77
		1I2-S-98B	8.36	40.00	15161.77
		1I2-S-100A	8.31	40.00	15201.77
		1I2-S-102A	8.38	40.00	15241.77
		1I2-S-106A	8.39	40.00	15281.77
		1I2-S-108A	8.49	40.00	15321.77
		1I2-S-116A	8.53	40.00	15361.77
		1I2-S-117A	8.54	40.10	15401.87
	09/05/03	1I2-S-126A	8.55	40.00	15441.87
		1I2-S-126B	8.55	39.90	15481.77
		1I2-S-127A	8.48	40.10	15521.87
		1I2-S-131A	8.45	40.00	15561.87
		1I2-S-133A	8.46	40.00	15601.87
		1I2-S-134A	8.09	40.00	15641.87
		1I2-S-143A	8.13	40.00	15681.87
		1I2-S-144A	8.14	40.00	15721.87
		1I2-S-148A	8.11	40.00	15761.87
		1I2-S-150A	8.15	40.00	15801.87
		1I2-S-153A	8.19	40.00	15841.87
	09/06/03	1I2-S-154A	8.21	40.00	15881.87
		1I2-S-155A	8.24	40.00	15921.87
		1J2-S-17A	8.20	40.00	15961.87
		1J2-S-18A	8.27	40.00	16001.87
		1J2-S-20A	8.19	40.00	16041.87
		1J2-S-30A	8.17	40.00	16081.87
		1J2-S-31A	8.22	40.00	16121.87
		1J2-S-34A	8.25	40.40	16162.27

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
10	09/06/03	1J2-S-36A	8.27	40.00	16202.27
		1J2-S-40A	8.24	40.00	16242.27
	09/07/03	1J2-S-49A	8.29	40.00	16282.27
		1J2-S-50A	8.21	40.00	16322.27
		1J2-S-52A	8.25	40.00	16362.27
		1J2-S-55A	8.11	40.00	16402.27
		1J2-S-58A	8.09	40.00	16442.27
		1J2-S-67A	8.13	40.00	16482.27
		1J2-S-69A	8.10	40.10	16522.37
		1J2-S-71A	8.13	40.00	16562.37
		1J2-S-74A	8.07	40.00	16602.37
		1J2-S-75A	8.15	40.00	16642.37
	09/08/03	1J2-S-78A	8.17	40.00	16682.37
		1J2-S-85A	8.12	40.00	16722.37
		1J2-S-90A	8.16	40.10	16762.47
		1J2-S-92A	8.15	40.00	16802.47
		1J2-S-95A	8.18	40.10	16842.57
		1J2-S-96A	8.14	40.00	16882.57
		1J2-S-101A	8.17	40.10	16922.67
		1J2-S-103A	8.12	40.00	16962.67
		1J2-S-111A	8.13	40.00	17002.67
		1J2-S-112A	8.12	40.00	17042.67
	09/09/03	1J2-S-114A	8.15	40.00	17082.67
		1J2-S-123A	7.89	40.00	17122.67
		1J2-S-124A	7.71	40.00	17162.67
		1J2-S-125A	7.67	40.00	17202.67
		1J2-S-126A	7.60	40.00	17242.67
		1J2-S-127A	7.58	40.00	17282.67
		1J2-S-138A	7.56	40.00	17322.67
		1J2-S-139A	7.42	40.10	17362.77
		1J2-S-141A	7.37	40.00	17402.77
		1J2-S-143A	7.54	40.00	17442.77
	09/10/03	1J2-S-151A	7.23	40.00	17482.77
		1J2-S-152A	7.05	40.00	17522.77
		1J2-S-153A	6.94	40.00	17562.77
		1J2-S-155A	6.88	40.00	17602.77
		1K2-S-16A	7.03	40.00	17642.77
		1K2-S-17A	7.17	40.00	17682.77
		1K2-S-18A	7.21	40.00	17722.77
		1K2-S-26A	7.30	39.90	17762.67
		1K2-S-27A	7.22	40.00	17802.67
		1R2-S-16A	10.40	40.00	17842.67
		1R2-S-19A	9.10	40.00	17882.67

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test#	Ru Spike	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
9	No	03/24/04	R2-S-22A	9.02	40.00	17922.67
			1R2-S-24A	8.53	40.00	17962.67
			1R2-S-26A	8.38	40.00	18002.67
			1R2-S-27A	8.50	40.00	18042.67
			1R2-S-28A	8.54	40.00	18082.67
			1R2-S-31A	8.59	40.00	18122.67
			1R2-S-33A	8.60	40.00	18162.67
			1R2-S-52A	8.65	40.00	18202.67
			1R2-S-53A	8.82	40.00	18242.67
		03/25/04	1R2-S-54A	8.67	40.00	18282.67
			1R2-S-57A	8.69	40.00	18322.67
			1R2-S-59A	8.70	40.00	18362.67
			1R2-S-60A	8.80	40.00	18402.67
			1R2-S-60B	8.84	40.00	18442.67
			1R2-S-63A	8.83	40.00	18482.67
			1R2-S-69A	8.90	40.00	18522.67
			1R2-S-69B	8.87	40.00	18562.67
			1R2-S-70A	8.80	40.10	18602.77
			1R2-S-72A	8.90	40.00	18642.77
			1R2-S-82A	9.00	40.00	18682.77
			1R2-S-82B	8.90	40.00	18722.77
			1R2-S-87A	8.90	40.10	18762.87
			1R2-S-96A	8.90	39.90	18802.77
			1R2-S-96B	8.90	40.10	18842.87
	Yes	03/26/04	1R2-S-97A	8.80	39.80	18882.67
			1R2-S-100A	8.90	40.00	18922.67
			1R2-S-110A	7.95	40.08	18962.75
			1R2-S-111A	7.75	40.00	19002.75
			1R2-S-113A	7.71	40.00	19042.75
			1R2-S-115A	7.79	40.00	19082.75
			1R2-S-116A	7.81	40.00	19122.75
			1R2-S-117A	7.90	40.00	19162.75
			1R2-S-121A	7.90	40.00	19202.75
			1R2-S-123A	7.80	42.70	19245.45
			1R2-S-124A	7.80	40.00	19285.45
			1R2-S-134A	7.90	40.10	19325.55
		03/27/04	1R2-S-136A	7.80	40.00	19365.55
			1R2-S-138A	7.90	37.20	19402.75
			1R2-S-139A	7.80	40.00	19442.75
			1R2-S-139B	7.90	40.00	19482.75
			1R2-S-141A	7.86	40.00	19522.75
			1R2-S-143A	7.86	40.00	19562.75
			1R2-S-148A	7.94	40.00	19602.75

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test	Ru Spike	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol.(gal)
9	Yes	03/27/04	1R2-S-149A	7.65	40.04	19642.79
			1R2-S-151A	7.70	40.00	19682.79
			1R2-S-152A	7.70	40.10	19722.89
			1R2-S-153A	7.70	40.00	19762.89
			1S2-S-14A	8.39	40.00	19802.89
			1S2-S-15A	8.32	40.00	19842.89
		03/28/04	1S2-S-16A	8.36	40.00	19882.89
			1S2-S-17A	8.34	39.50	19922.39
			1S2-S-31A	8.31	40.00	19962.39
			1S2-S-32A	8.41	40.00	20002.39
			1S2-S-33A	8.35	40.00	20042.39
			1S2-S-34A	8.38	40.00	20082.39
			1S2-S-47A	8.39	40.00	20122.39
			1S2-S-47B	8.32	40.00	20162.39
			1S2-S-48A	8.36	40.00	20202.39
			1S2-S-50A	8.38	40.00	20242.39
			1S2-S-54A	8.31	40.00	20282.39
			1S2-S-55A	8.33	40.00	20322.39
			1S2-S-66A	8.34	40.00	20362.39
		03/29/04	1S2-S-67A	8.37	40.00	20402.39
			1S2-S-69A	8.36	39.90	20442.29
			1S2-S-69B	8.35	40.00	20482.29
			1S2-S-72A	8.36	40.00	20522.29
			1S2-S-74A	8.37	40.50	20562.79
			1S2-S-77A	8.39	39.50	20602.29
			1S2-S-78A	8.40	40.00	20642.29
			1S2-S-80A	8.43	40.00	20682.29
			1S2-S-84A	8.39	40.10	20722.39
			1S2-S-85A	8.41	40.00	20762.39
			1S2-S-86A	8.38	40.00	20802.39
			1S2-S-88A	8.40	40.00	20842.39
			1S2-S-99A	8.38	40.20	20882.59
		03/30/04	1S2-S-101A	8.36	39.70	20922.29
			1S2-S-103A	8.37	40.00	20962.29
			1S2-S-104A	8.39	40.00	21002.29
			1S2-S-105A	8.42	40.10	21042.39
			1S2-S-106A	8.42	40.60	21082.99
			1S2-S-117A	8.35	40.00	21122.99
			1S2-S-118A	8.33	40.00	21162.99
			1S2-S-123A	8.34	40.00	21202.99
			1S2-S-128A	8.31	40.00	21242.99
			1S2-S-126A	8.40	40.00	21282.99
			1S2-S-130A	8.34	40.00	21322.99

Table 5.19. Listing of Samples from SBS Blow-Downs, continued.

Test	Ru Spike	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
9	Yes	03/30/04	1S2-S-131A	8.57	40.00	21362.99
			1S2-S-132A	8.32	40.00	21402.99
			1S2-S-133A	8.35	40.00	21442.99
			1S2-S-134A	7.90	40.00	21482.99
			1T2-S-5A	8.31	40.70	21523.69
		03/31/04	1T2-S-9A	8.36	40.00	21563.69
			1T2-S-10A	8.61	40.70	21604.39
			1T2-S-11A	8.34	40.10	21644.49
			1T2-S-11B	8.30	40.10	21684.59
			1T2-S-13A	8.37	40.10	21724.69
			1T2-S-15A	8.33	37.30	21761.99
			1T2-S-17A	8.29	40.00	21801.99
			1T2-S-18A	8.27	40.00	21841.99
			1T2-S-21A	8.33	40.00	21881.99
			1T2-S-24A	8.45	40.00	21921.99
			1T2-S-24B	8.40	40.00	21961.99
			1T2-S-26A	8.47	40.00	22001.99
			1T2-S-28A	8.35	40.00	22041.99
			1T2-S-29A	8.34	40.00	22081.99
			1T2-S-39A	8.29	40.00	22121.99
			1T2-S-42A	8.27	40.00	22161.99
			1T2-S-43A	8.31	40.00	22201.99
			1T2-S-45A	8.33	40.00	22241.99
		04/01/04	1T2-S-46A	8.35	40.00	22281.99
			1T2-S-48A	8.39	40.20	22322.19
			1T2-S-49A	8.32	40.00	22362.19
			1T2-S-52A	8.46	39.80	22401.99
			1T2-S-52B	8.34	40.30	22442.29
			1T2-S-64A	8.42	39.70	22481.99
			1T2-S-65A	8.37	40.00	22521.99
			1T2-S-68A	8.11	40.90	22562.89
			1T2-S-69A	8.12	39.10	22601.99
			1T2-S-70A	8.21	40.00	22641.99
			1T2-S-72A	8.25	40.00	22681.99
			1T2-S-74A	8.22	40.00	22721.99
			1T2-S-75A	8.24	40.00	22761.99
			1T2-S-76A	8.23	40.00	22801.99
			1T2-S-76B	8.24	40.00	22841.99
		04/02/04	1T2-S-99A	8.44	488.70	23330.69

Table 5.20. Analytical Results for Selected SBS Blow-down Fluids (mg/l).

Test	2			1			3		
Sample	Z12-S-18A			1B2-S-26A			1D2-S-47A		
Glass (kg)	6492			15387			24450		
pH	8.23			8.39			8.49		
-	Sus*	Dis.#	Total	Sus*	Dis.#	Total	Sus*	Dis.#	Total
Total	1980	3260	5240	3280	4528	7808	3352	4508	7860
Al	52.66	0.30	52.96	100.79	0.41	101.20	103.44	0.39	103.83
B	16.20	463.03	479.23	43.75	624.09	667.84	41.31	573.33	614.64
Ba	0.33	0.01	0.34	0.60	0.02	0.62	0.58	<0.01	0.58
Ca	6.72	2.96	9.68	13.25	2.26	15.51	12.39	2.26	14.65
Cd	1.45	<0.03	1.45	3.47	<0.03	3.47	3.01	<0.03	3.01
Cr	0.40	0.61	1.01	0.59	0.39	0.98	0.60	0.39	0.99
Cu	0.50	<0.02	0.50	0.85	<0.02	0.85	0.87	<0.02	0.87
Fe	393.45	0.24	393.69	621.26	0.30	621.56	634.90	0.24	635.14
K	1.36	3.91	5.27	1.96	6.07	8.03	2.00	4.44	6.44
Li	3.95	54.41	58.36	8.33	87.51	95.84	9.16	82.85	92.01
Mg	3.46	3.60	7.06	5.73	2.76	8.49	5.70	2.70	8.40
Mn	2.28	<0.04	2.28	2.06	<0.04	2.06	2.19	<0.04	2.19
Na	32.27	515.50	547.77	81.04	783.57	864.61	87.47	672.27	759.74
Ni	12.26	0.10	12.36	21.35	0.09	21.44	21.82	0.08	21.90
P	0.56	<0.60	0.56	0.81	<0.60	0.81	0.83	<0.60	0.83
Pb	1.57	0.74	2.31	2.11	1.08	3.19	2.15	0.98	3.13
Si	311.85	10.47	322.32	514.40	6.90	521.30	538.31	8.06	546.37
Sr	1.55	0.34	1.89	1.42	0.10	1.52	1.33	0.08	1.41
Ti	2.71	<0.02	2.71	4.08	0.02	4.10	4.06	<0.02	4.06
Zn	64.37	0.33	64.70	8.93	0.11	9.04	108.00	0.09	108.09
Zr	33.74	0.06	33.80	66.32	0.22	66.54	66.08	0.09	66.17
F	NA	144.28	144.28	NA	121.64	121.64	NA	130.47	130.47
Cl	NA	143.76	143.76	NA	113.91	113.91	NA	104.77	104.77
I	NA	38.22	38.22	NA	1.33	1.33	NA	<0.1	<0.1
NH ₄ ⁺	NA	<6.0	<6.0	NA	6.00	6.00	NA	<6.0	<6.0
Nitrate	NA	89.99	89.99	NA	97.84	97.84	NA	70.85	70.85
Nitrite	NA	21.92	21.92	NA	68.15	68.15	NA	59.43	59.43
Sulfate	NA	292.55	292.55	NA	351.19	351.19	NA	315.63	315.63

"-" Empty data field

* Suspended Solids; # Dissolved Solids

Table 5.20. Analytical Results for Selected SBS Blow-Down Fluids (mg/l), continued.

Test	8			10			9		
Sample	1F2-S-114A			1K2-S-27A			1T2-S-76B		
Glass (kg)	36585			43517			55738		
pH	8.37			7.22			8.24		
-	Sus*	Dis.#	Total	Sus*	Dis.#	Total	Sus*	Dis.#	Total
Total	4060	3776	7836	4832	4992	9824	3082	4654	7736
Al	110.42	0.29	110.71	141.25	1.26	142.51	120.8	0.93	121.73
B	50.89	535.69	586.58	50.76	538.83	589.59	31.8	742.45	774.25
Ba	0.70	<0.01	0.70	0.88	0.03	0.91	1.20	0.01	1.21
Ca	15.33	2.50	17.83	14.83	9.21	24.04	34.20	2.12	36.32
Cd	4.15	<0.03	4.15	8.24	0.16	8.40	7.50	<0.03	7.5
Cr	0.70	0.27	0.97	0.93	0.08	1.01	6.0	0.07	6.07
Cu	1.12	<0.02	1.12	1.99	<0.02	1.99	<0.02	0.03	0.03
Fe	642.14	0.23	642.37	772.39	<0.05	772.39	980.6	0.11	980.71
K	2.04	4.41	6.45	2.31	8.87	11.18	1.00	8.08	9.08
Li	8.19	63.41	71.60	10.74	84.06	94.80	5.00	87.70	92.7
Mg	6.41	2.90	9.31	5.87	8.19	14.06	17.4	4.67	22.07
Mn	3.18	<0.04	3.18	4.78	0.09	4.87	3.1	<0.04	3.1
Na	97.92	652.35	750.27	88.36	1106.20	1194.56	90.3	935.72	1026.02
Ni	24.83	0.10	24.93	31.87	0.18	32.05	15.6	0.19	15.79
P	0.91	<0.60	0.91	0.85	<0.60	0.85	0.60	<0.60	0.6
Pb	2.41	0.99	3.40	3.33	0.93	4.26	0.10	0.87	0.97
Si	728.23	8.42	736.65	869.30	12.37	881.67	398.5	8.55	407.05
Sr	1.49	0.08	1.57	1.67	0.68	2.35	3.7	0.11	3.81
Ti	4.37	<0.02	4.37	5.30	<0.02	5.30	3.7	<0.02	3.7
Zn	115.63	0.14	115.77	138.24	1.36	139.60	149.4	0.16	149.56
Zr	104.32	0.11	104.43	132.45	0.02	132.47	14.9	0.20	15.1
F	NA	98.51	98.51	NA	95.75	95.75	NA	303.13	303.13
Cl	NA	122.42	122.42	NA	1047.91	1047.91	NA	128.99	128.99
I	NA	0.82	0.82	NA	<0.1	<0.1	NA	2.67	2.67
NH ₄ ⁺	NA	<6.0	<6.0	NA	<6.0	<6.0	NA	18.00	18.00
Nitrate	NA	58.19	58.19	NA	39.26	39.26	NA	9.95	9.95
Nitrite	NA	54.02	54.02	NA	54.10	54.10	NA	9.61	9.61
Sulfate	NA	265.74	265.74	NA	1004.37	1004.37	NA	308.65	308.65

"-" Empty data field

* Suspended Solids; # Dissolved Solids

Table 5.21. Anion Concentrations in SBS Blow-Down Liquids from Select Test 10 Samples (mg/l).

Test	Spiked with	Sample Name	pH	F	Cl	I	NH ₄ ⁺	Nitrate	Nitrite	Sulfate
10B	NaCl	1J2-S-31A	8.22	93.07	1070.05	<0.1	8.70	26.06	21.58	388.11
10C	Na ₂ SO ₄	1J2-S-96A	8.14	107.13	729.47	<0.1	<4.9	57.28	58.63	633.88
10D	NaCl+Na ₂ SO ₄	1K2-S-27A	7.22	95.75	1047.91	<0.1	<6.0	54.10	39.26	1004.37

Table 5.22. Listing of Samples from WESP Blow-Downs.

Test#	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
2	05/29/03	X12-W-51A	6.80	44.40	44.40
		X12-W-51B	7.40	43.20	87.60
	05/30/03	X12-W-87A	7.46	56.20	143.80
		X12-W-87B	7.52	40.10	183.90
	05/31/03	X12-W-119A	7.57	57.90	241.80
		X12-W-119B	7.64	39.30	281.10
	06/01/03	X12-W-145A	7.54	53.90	335.00
		X12-W-145B	7.52	40.00	375.00
	06/02/03	Y12-W-40A	7.50	58.80	433.80
		Y712-W-40B	7.55	40.00	473.80
	06/03/03	Y12-W-66A	7.57	62.50	536.30
		Y12-W-66B	7.74	49.60	585.90
	06/04/03	Y12-W-101A	7.73	63.00	648.90
		Y12-W-101B	7.66	49.30	698.20
	06/05/03	Y12-W-136A	7.66	53.90	752.10
		Y12-W-136B	7.37	41.00	793.10
1	06/06/03	Z12-W-29A	8.51	73.00	866.10
		Z12-W-29B	7.95	46.50	912.60
	06/26/03	Z12-W-85A	7.62	50.30	962.90
		Z12-W-85B	7.33	41.50	1004.40
	06/27/03	Z12-W-131A	7.44	55.62	1060.02
		Z12-W-131B	7.48	41.32	1101.34
	06/28/03	1A2-W-18A	7.72	57.00	1158.34
		1A2-W-18B	7.45	40.40	1198.74
	06/29/03	1A2-W-54A	7.67	57.90	1256.64
		1A2-W-54B	7.48	40.10	1296.74
	06/30/03	1A2-W-93A	7.59	55.70	1352.44
		1A2-W-93B	7.42	40.30	1392.74
	07/01/03	1A2-W-133A	7.68	42.40	1435.14
		1A2-W-133B	7.65	40.00	1475.14
	07/02/03	1B2-W-26A	7.58	66.30	1541.44
		1B2-W-26B	7.61	45.60	1587.04
3	07/16/03	1B2-W-80A	8.10	52.00	1639.04
		1B2-W-80B	7.78	39.80	1678.84
	07/17/03	1B2-W-112A	7.54	60.20	1739.04
		1B2-W-112B	7.67	39.50	1778.54
	07/18/03	1C2-W-11A	7.76	60.70	1839.24
		1C2-W-11B	8.04	36.00	1875.24
	07/19/03	1C2-W-50A	7.65	61.30	1936.54
		1C2-W-50B	7.50	39.60	1976.14
	07/20/03	1C2-W-97A	7.69	66.50	2042.64
		1C2-W-97B	7.75	41.20	2083.84
	07/21/03	1C2-W-137A	7.85	54.70	2138.54
		1C2-W-137B	7.72	40.00	2178.54

Table 5.22. Listing of Samples from WESP Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
3	07/22/03	1D2-W-43A	7.96	11.90	2190.44
	07/23/03	1D2-W-54A	8.01	77.50	2267.94
		1D2-W-55A	8.03	47.40	2315.34
8	08/06/03	1D2-W-112A	8.51	65.40	2380.74
		1D2-W-112B	8.54	39.20	2419.94
	08/07/03	1D2-W-153A	7.96	59.80	2479.74
		1D2-W-153B	7.76	39.70	2519.44
	08/08/03	1E2-W-43A	7.63	63.00	2582.44
		1E2-W-43B	7.70	40.30	2622.74
	08/09/03	1E2-W-84A	7.64	29.60	2652.34
		1E2-W-86A	7.65	43.70	2696.04
	08/10/03	1E2-W-127A	7.62	63.50	2759.54
		1E2-W-127B	7.68	40.30	2799.84
	08/11/03	1F2-W-14A	7.63	63.00	2862.84
		1F2-W-14B	7.58	40.40	2903.24
	08/12/03	1F2-W-69A	7.71	64.40	2967.64
		1F2-W-69B	7.62	40.40	3008.04
	08/13/03	1F2-W-119A	7.75	93.70	3101.74
		1F2-W-119B	7.90	38.20	3139.94
10	09/04/03	1I2-W-99A	7.75	49.70	3189.64
		1I2-W-99B	7.67	43.10	3232.74
	09/05/03	1I2-W-134A	7.71	55.80	3288.54
		1I2-W-134B	7.67	40.20	3328.74
	09/06/03	1J2-W-20A	7.78	67.90	3396.64
		1J2-W-20B	7.73	41.70	3438.34
	09/07/03	1J2-W-66A	7.78	59.00	3497.34
		1J2-W-66B	7.69	42.00	3539.34
	09/08/03	1J2-W-93A	7.81	56.90	3596.24
		1J2-W-93B	7.65	41.10	3637.34
	09/09/03	1J2-W-127A	7.17	64.80	3702.14
		1J2-W-127B	7.13	40.40	3742.54
	09/10/03	1K2-W-33A	7.07	14.00	3756.54
		1K2-W-33B	7.13	80.10	3836.64
	09/11/03	1K2-W-34A	7.73	40.40	3877.04
9	03/24/04	1R2-W-27A	8.02	41.65	3918.69
		1R2-W-27B	7.90	37.96	3956.65
	03/25/04	1R2-W-63A	8.70	55.30	4011.95
		1R2-W-63B	8.02	39.20	4051.15
	03/26/04	1R2-W-113A	7.29	60.60	4111.75
		1R2-W-113B	6.67	40.10	4151.85
	03/27/04	1R2-W-143A	7.29	62.20	4214.05
		1R2-W-143B	7.04	38.70	4252.75

Table 5.22. Listing of Samples from WESP Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol.(gal)
9	03/28/04	1S2-W-36A	7.66	61.60	4314.35
		1S2-W-36B	7.68	34.90	4349.25
	03/29/04	1S2-W-74A	7.71	58.90	4408.15
		1S2-W-74B	7.69	39.40	4447.55
	03/30/04	1S2-W-123A	7.67	73.90	4521.45
		1S2-W-123B	8.34	39.90	4561.35
	03/31/04	1T2-W-15A	7.75	60.30	4621.65
		1T2-W-15B	7.79	35.90	4657.55
	04/01/04	1T2-W-70A	7.43	17.50	4675.05
		1T2-W-76A	7.41	17.70	4692.75
	04/02/04	1T2-W-99A	7.65	81.10	4773.85
		1T2-W-99B	7.25	41.10	4814.95

Table 5.23. Listing of Samples from PBS Blow-Downs.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
2	05/29/03	X12-P-33A	9.34	29.50	29.50
		X12-P-54A	9.24	33.30	62.80
	05/30/03	X12-P-68A	9.23	29.60	92.40
		X12-P-87A	9.07	31.60	124.00
	05/31/03	X12-P-104A	9.16	40.20	164.20
		X12-P-121A	9.22	26.80	191.00
	06/01/03	X12-P-138A	9.27	33.19	224.19
		Y12-P-9A	9.09	31.10	255.29
	06/02/03	Y12-P-24A	9.11	29.30	284.59
		Y12-P-42A	9.59	32.80	317.39
	06/03/03	Y12-P-59A	9.18	34.70	352.09
		Y12-P-77A	9.19	26.30	378.39
	06/04/03	Y12-P-95A	9.04	29.30	407.69
		Y12-P-110A	9.18	23.10	430.79
	06/05/03	Y12-P-128A	10.00	36.00	466.79
1	06/06/03	Y12-P-147A	9.24	33.20	499.99
		Y12-P-155A	9.04	29.60	529.59
	06/26/03	Z12-P-29A	9.50	42.80	572.39
		Z12-P-77A	9.68	28.10	600.49
	06/27/03	Z12-P-96A	9.50	34.90	635.39
		Z12-P-135A	9.11	28.60	663.99
	06/28/03	1A2-P-20A	9.04	28.20	692.19
	06/29/03	1A2-P-55A	8.91	34.10	726.29
		1A2-P-78A	8.89	24.60	750.89
	06/30/03	1A2-P-103A	9.22	24.50	775.39
		1A2-P-114A	9.25	34.10	809.49
	07/01/03	1A2-P-114B	9.25	49.80	859.29
		1A2-P-141A	9.30	21.20	880.49
	07/02/03	1B2-P-27A	9.26	31.00	911.49
3	07/16/03	1B2-P-88A	9.11	30.00	941.49
	07/17/03	1B2-P-103A	8.89	31.70	973.19
		1B2-P-110A	9.02	15.70	988.89
	07/18/03	1B2-P-133A	9.01	39.30	1028.19
		1B2-P-149A	8.99	29.70	1057.89
	07/19/03	1C2-P-20A	9.25	32.60	1090.49
		1C2-P-30A	9.16	24.70	1115.19
	07/20/03	1C2-P-45A	9.43	27.10	1142.29
		1C2-P-56A	9.05	33.00	1175.29
	07/21/03	1C2-P-71A	9.05	24.90	1200.19
		1C2-P-87A	9.09	29.40	1229.59
	07/22/03	1C2-P-107A	9.12	27.00	1256.59
		1C2-P-127A	9.10	33.80	1290.39
	07/23/03	1C2-P-154A	8.88	24.20	1314.59
		1D2-P-21A	8.97	40.30	1354.89
		1D2-P-44A	9.01	29.40	1384.29
		1D2-P-55A	9.01	26.00	1410.29

NA: Not measured

Table 5.23. Listing of Samples from PBS Blow-Downs, continued.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
8	08/06/03	1D2-P-98A	9.08	35.67	1445.96
		1D2-P-131A	9.02	30.10	1476.06
	08/07/03	1D2-P-155A	9.05	30.40	1506.46
		1E2-P-25A	9.02	31.60	1538.06
	08/08/03	1E2-P-43A	8.96	36.10	1574.16
		1E2-P-60A	9.57	28.40	1602.56
	08/09/03	1E2-P-70A	9.16	40.00	1642.56
		1E2-P-85A	9.67	36.20	1678.76
		1E2-P-103A	9.10	34.70	1713.46
	08/10/03	1E2-P-112A	9.34	25.80	1739.26
		1E2-P-127A	9.28	32.80	1772.06
		1E2-P-145A	9.07	30.00	1802.06
	08/11/03	1F2-P-5A	9.59	30.90	1832.96
		1F2-P-18A	9.01	34.70	1867.66
		1F2-P-41A	8.86	25.00	1892.66
	08/12/03	1F2-P-49A	9.49	30.20	1922.86
		1F2-P-86A	9.09	27.80	1950.66
	08/13/03	1F2-P-94A	8.89	29.00	1979.66
		1F2-P-112A	9.26	32.50	2012.16
10	09/03/03	1I2-P-79A	9.17	30.40	2042.56
	09/04/03	1I2-P-98A	9.06	25.20	2067.76
	09/05/03	1I2-P-130A	9.13	29.20	2096.96
	09/06/03	1I2-P-154A	9.08	30.30	2127.26
	09/06/03	1J2-P-36A	8.27	30.60	2157.86
	09/07/03	1J2-P-71A	9.15	35.60	2193.46
		1J2-P-89A	9.21	21.20	2214.66
	09/08/03	1J2-P-111A	9.10	31.00	2245.66
		1J2-P-127A	9.08	27.10	2272.76
		1J2-P-151A	8.95	21.30	2294.06
	09/10/03	1K2-P-26A	8.98	26.30	2320.36
	09/11/03	1K2-P-34A	9.58	24.80	2345.16
9	03/24/04	1R2-P-21A	10.40	23.10	2368.26
	03/25/04	1R2-P-59A	9.90	29.10	2397.36
	03/26/04	1R2-P-116A	8.76	27.90	2425.26
	03/27/04	1R2-P-139A	8.80	27.80	2453.06
		1S2-P-14A	8.73	23.90	2476.96
	03/28/04	1S2-P-33A	8.92	24.40	2501.36
		1S2-P-48A	8.81	21.40	2522.76
	03/29/04	1S2-P-67A	8.74	33.50	2556.26
		1S2-P-80A	8.75	30.70	2586.96
	03/30/04	1S2-P-105A	8.81	40.60	2627.56
		1S2-P-131A	8.57	22.30	2649.86
	03/31/04	1T2-P-10A	8.61	38.00	2687.86
		1T2-P-25A	8.37	26.70	2714.56
		1T2-P-43A	8.41	17.30	2731.86
	04/01/04	1T2-P-52A	8.46	34.00	2765.86
		1T2-P-70A	9.04	23.30	2789.16

Table 5.24. Listing of Samples from HEME 1 Blow-Downs.

Test	Date	Sample Name	pH	Blow-down Vol. (gal)	Cumulative Vol. (gal)
2	06/07/03	Z12-H1-29A	6.24	34.50	34.50
1	07/02/03	1B2-H1-27A	6.78	25.10	59.60
3	07/22/03	1D2-H1-55A	7.87	34.10	93.70
8	08/13/03	1F2-H1-119A	3.51	41.10	134.80
10	09/11/03	1K2-H1-33A	6.81	30.80	165.60
9	04/01/04	1T2-H1-78A	7.54	15.84	181.44
	04/02/04	1T2-H1-97A	7.53	39.30	220.74

Table 5.25. Analytical Results for Dissolved Solids in Select WESP Blow-Down Fluids (mg/l).

Test	2		1		3	
Sample I.D.	Z12-W-29A	Z12-W-29B	1B2-W-26A	1B2-W-26B	1C2-W-137A	1C2-W-137B
Glass (kg)	6780		15435		22746	
TSS (mg/l)	<1	20	<1	<1	6	34
TDS (mg/l)	512	172	762	354	894	348
pH	8.51	7.95	7.58	7.61	7.85	7.72
Al	<0.03	0.08	<0.03	0.12	0.16	0.07
B	22.53	3.80	53.83	16.44	60.01	14.83
Ba	0.04	0.02	<0.00	0.04	0.04	0.04
Ca	39.84	34.72	41.90	42.81	43.88	45.61
Cd	0.11	<0.03	0.13	0.26	0.20	0.55
Cr	0.72	0.05	0.15	0.12	0.51	0.18
Cu	0.06	<0.02	<0.02	0.03	<0.02	<0.02
Fe	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
K	4.49	2.80	2.66	3.55	4.90	3.41
Li	6.90	2.12	14.82	6.08	15.40	5.00
Mg	7.47	6.56	7.44	7.93	8.74	8.84
Mn	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Na	98.39	30.70	137.88	55.11	139.35	47.57
Ni	<0.04	<0.04	<0.04	0.09	0.08	0.14
P	<0.60	<0.60	3.69	<0.60	<0.60	<0.60
Pb	<10	<0.10	0.14	<0.10	0.17	<0.10
Si	5.13	3.90	6.00	3.97	5.17	4.60
Sr	0.19	0.14	<0.00	0.19	0.26	0.22
Ti	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zn	0.44	0.32	0.21	0.57	0.39	0.90
Zr	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
F	10.77	4.37	28.62	16.60	26.06	12.54
Cl	72.75	38.47	80.22	52.62	86.44	46.33
I	0.95	<0.1	0.20	<0.1	0.20	<0.1
NH ₄ ⁺	11.30	3.70	13.40	4.20	<5.1	2.90
Nitrate	16.14	0.33	53.32	6.94	50.04	11.36
Nitrite	23.83	28.56	19.14	37.74	16.90	29.83
Sulfate	159.66	64.95	217.47	108.43	239.59	111.30

Table 5.25. Analytical Results for Dissolved Solids in Select WESP Blow-down Fluids, continued (mg/l).

Test	8		10		9	
Sample I.D.	1F2-W-119A	1F2-W-119B	1K2-W-33B	1K2-W-34A	1T2-W-99A	1T2-W-99B
Glass (kg)	36686		43849		56009	
TSS (mg/l)	16	44	10	38	8	280
TDS (mg/l)	974	342	2230	396	1182	636
pH	7.75	7.90	7.07	7.13	7.65	7.25
Al	0.16	0.07	0.07	<0.03	0.26	0.05
B	59.34	7.27	54.76	4.19	70.57	28.11
Ba	0.05	0.04	0.09	0.04	0.03	0.01
Ca	45.27	19.63	48.41	43.55	31.48	36.64
Cd	0.61	0.71	35.40	2.31	1.65	0.74
Cr	0.46	0.05	0.16	<0.01	0.11	0.14
Cu	<0.02	<0.02	0.02	<0.02	<0.02	<0.02
Fe	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
K	6.38	4.06	14.72	5.73	8.18	4.81
Li	17.61	3.90	27.29	3.04	16.00	7.75
Mg	10.37	10.97	9.66	8.74	7.16	8.34
Mn	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Na	190.46	57.67	562.57	71.51	320.15	121.26
Ni	0.13	<0.04	0.29	<0.04	0.07	<0.04
P	<0.60	<0.60	<0.60	<0.60	<0.60	<0.60
Pb	0.17	<0.10	<0.10	<0.10	<0.1	<0.1
Si	5.65	2.84	5.78	3.70	7.83	5.81
Sr	0.31	0.26	0.52	0.21	0.18	0.22
Ti	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zn	0.62	0.36	11.61	0.71	0.87	0.29
Zr	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
F	23.17	9.01	4.87	2.66	66.23	33.33
Cl	158.57	74.02	547.72	118.46	112.79	76.46
I	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
NH ₄ ⁺	6.60	4.40	16.40	4.10	47.40	27.40
Nitrate	54.65	1.35	21.21	24.12	27.33	37.45
Nitrite	30.07	33.78	18.69	1.32	24.24	1.48
Sulfate	244.32	97.53	472.92	67.07	517.75	163.37

Table 5.26. Anion Concentrations for Select PBS and HEME Blow-Down Liquid Samples (mg/l).

-	Test#	Sample Name	pH	F	Cl	I	NH ₄ ⁺	Nitrate	Nitrite	Sulfate
PBS	2	Z12-P-29A	9.50	0.37	92.83	10.03	229.00	9.95	24.12	0.29
	1	1B2-P-27A	9.26	0.48	71.53	1.51	119.60	40.37	74.33	11.62
	3	1D2-P-55A	9.01	0.22	59.12	<0.1	148.50	116.91	153.60	4.12
	8	1F2-P-112A	9.26	0.08	78.83	<0.1	23.10	154.43	753.01	4.02
	10	1K2-P-34A	9.58	0.37	53.83	<0.1	169.10	46.40	69.27	4.17
	9	1T2-P-70A	9.04	0.65	62.27	8.68	3.30	36.86	209.23	2.86
HEME	2	Z12-H1-29A	6.24	2.72	35.06	0.29	111.60	316.69	189.32	57.28
	1	1B2-H1-27A	6.78	3.40	26.52	<0.1	27.30	69.13	86.87	45.26
	3	1D2-H1-55A	7.87	3.96	31.35	<0.1	72.80	309.98	16.26	53.80
	8	1F2-H1-119A	3.51	4.97	49.04	<0.1	132.40	642.30	0.65	72.59
	10	1K2-H1-33A	6.81	1.92	55.79	<0.1	47.50	119.60	135.69	21.21
	9	1T2-H1-97A	7.53	6.87	20.75	<0.1	101.20	182.36	201.60	42.79

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Table 5.27. Upper Estimates of Accumulations in Off-Gas Liquids from Test 3.

Analyte	Feed (kg)	SBS			WESP			HEME 1		PBS	
		Mass (g)	Percent Feed	Percent Feed Calculated From Emissions Data	Mass (g)	Percent Feed	Percent Feed Calculated From Emissions Data	Mass (g)	Percent Feed	Mass (g)	Percent Feed
Al	252	1727	0.68	1.11	0.32	< 0.01	< 0.01	-			
B	339	10221	3.02	2.45	103.12	0.03	0.02				
Ba	1.64	10	0.61	1.06	0.11	0.01	< 0.01				
Ca	18.3	244	1.33	1.68	123.31	0.67	0.02				
Cd	4.92	50	1.02	1.31	1.03	0.02	0.04				
Cr	0	16	NC	NA	0.95	NC	NA				
Cu	2.20	14	0.64	1.34	< 0.06	< 0.01	< 0.01				
Fe	785	10562	1.35	1.31	< 0.14	< 0.01	< 0.01				
K	2.28	107	4.69	4.33	11.45	0.50	0.37				
Li	150	1530	1.02	0.80	28.11	0.02	0.02				
Mg	6.07	140	2.30	2.55	24.22	0.40	< 0.01				
Mn	12.1	36	0.30	0.89	< 0.11	< 0.01	0.01				
Na	792	12634	1.60	1.22	257.56	0.03	0.04				
Ni	44.6	364	0.82	1.16	0.30	< 0.01	< 0.01				
P	0	14	NC	NA	< 1.65	NA	NA				
Pb	2.55	52	2.04	2.39	0.47	0.02	0.09				
Si	2030	9086	0.45	0.64	13.46	< 0.01	< 0.01				
Sr	2.32	23	0.99	1.31	0.66	0.03	< 0.01				
Ti	0	68	NC	NA	< 0.06	NA	NA				
Zn	149	1797	1.21	1.34	1.78	< 0.01	0.01				
Zr	259	1100	0.42	1.27	< 0.06	< 0.01	< 0.01				
F	3.66	2170	59.24	133*	53.19	1.45	< 0.01*	0.5	0.01	0.4	0.01
Cl	0	1742	NC	NA	182.94	NC	NA	4.0	NC	111.7	NC
I	0	< 0.1	NC	NA	0.55	NC	NA	0.0	NC	0.0	NC
Ammonium	0	< 0.1	NC	NA	7.99	NC	NA	9.4	NC	280.5	NC
Nitrate	51.7	1178	2.28	NA	84.60	0.16	NA	40.0	0.08	220.8	0.43
Nitrite	9.57	988	10.32	NA	64.39	0.67	NA	2.1	0.02	290.1	3.03
S	2.94	1752	59.67	53.8	483.49	16.47	4.64	6.9	0.23	7.8	0.27

* - Gaseous F only, no water dissolution available for F analysis of SBS and WESP Emissions.

NA – Data Not Available.

NC – Not Calculated

"-" Empty data field

Table 6.1. Listing of Glass Discharged, Masses, and Analysis Performed.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
2	05/28/03	X12-G-12A	-	-	-
		X12-G-17A	-	-	-
		X12-G-18A	-	-	-
		X12-G-20A	-	-	-
		X12-G-21A	-	-	-
		X12-G-22A	-	-	-
		X12-G-23A	-	-	-
		X12-G-23B	-	-	-
	05/29/03	X12-G-24A	-	-	-
		X12-G-34A	-	-	-
		X12-G-34B	XRF	514.0	514.0
		X12-G-35A	-	-	-
		X12-G-36A	-	-	-
		X12-G-38A	-	-	-
		X12-G-39A	-	-	-
		X12-G-41A	-	-	-
		X12-G-42A	-	-	-
		X12-G-42B	-	-	-
		X12-G-53A	-	-	-
		X12-G-54A	-	-	-
		X12-G-56A	-	-	-
		X12-G-56B	XRF	492.5	1006.5
		X12-G-59A	-	-	-
		X12-G-59B	-	-	-
	05/30/03	X12-G-60A	-	-	-
		X12-G-69A	-	-	-
		X12-G-70A	-	-	-
		X12-G-70B	-	-	-
		X12-G-71A	-	-	-
		X12-G-73A	-	-	-
		X12-G-76A	-	-	-
		X12-G-86A	XRF	496.5	1503.0
		X12-G-87A	-	-	-
		X12-G-88A	-	-	-
		X12-G-89A	-	-	-
		X12-G-90A	-	-	-
		X12-G-93A	-	-	-
		X12-G-93B	-	-	-
	05/31/03	X12-G-102A	-	-	-
		X12-G-104A	-	-	-
		X12-G-105A	-	-	-
		X12-G-107A	XRF	518.5	2021.5
		X12-G-108A	-	-	-

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
2	05/31/03	X12-G-109A	-	-	-
		X12-G-110A	-	-	-
		X12-G-119A	-	-	-
		X12-G-121A	-	-	-
		X12-G-122A	-	-	-
		X12-G-123A	-	-	-
		X12-G-125A	-	-	-
		X12-G-129A	-	-	-
	06/01/03	X12-G-136A	XRF	499.0	2520.5
		X12-G-138A	-	-	-
		X12-G-139A	-	-	-
		X12-G-140A	-	-	-
		X12-G-143A	-	-	-
		X12-G-144A	-	-	-
		X12-G-154A	-	-	-
		X12-G-155A	-	-	-
		Y12-G-8A	-	-	-
		Y12-G-10A	-	-	-
		Y12-G-12A	XRF	509.5	3030.0
		Y12-G-13A	-	-	-
		Y12-G-14A	-	-	-
	06/02/03	Y12-G-15A	-	-	-
		Y12-G-24A	-	-	-
		Y12-G-25A	-	-	-
		Y12-G-26A	-	-	-
		Y12-G-26B	-	-	-
		Y12-G-28A	-	-	-
		Y12-G-29A	-	-	-
		Y12-G-30A	XRF	504.0	3534.0
		Y12-G-41A	-	-	-
		Y12-G-42A	-	-	-
		Y12-G-42B	-	-	-
		Y12-G-44A	-	-	-
		Y12-G-46A	-	-	-
		Y12-G-46B	-	-	-
	06/03/03	Y12-G-48A	-	-	-
		Y12-G-57A	-	-	-
		Y12-G-58A	-	-	-
		Y12-G-59A	XRF	517.5	4051.5
		Y12-G-60A	-	-	-
		Y12-G-63A	-	-	-
		Y12-G-64A	-	-	-
		Y12-G-65A	-	-	-
		Y12-Y-66A	-	-	-

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
2	06/03/03	Y12-G-76A	-	-	-
		Y12-G-77A	-	-	-
		Y12-G-80A	-	-	-
		Y12-G-81A	-	-	-
		Y12-G-81B	XRF	521.0	4572.5
	06/04/03	Y12-G-83A	-	-	-
		Y12-G-85A	-	-	-
		Y12-G-94A	-	-	-
		Y12-G-96A	-	-	-
		Y12-G-99A	-	-	-
		Y12-G-101A	-	-	-
		Y12-G-110A	-	-	-
		Y12-G-113A	-	-	-
		Y12-G-114A	-	-	-
		Y12-G-115A	XRF	524.0	5096.5
		Y12-G-116A	-	-	-
	06/05/03	Y12-G-117A	-	-	-
		Y12-G-126A	-	-	-
		Y12-G-127A	-	-	-
		Y12-G-128A	-	-	-
		Y12-G-130A	-	-	-
		Y12-G-132A	-	-	-
		Y12-G-135A	-	-	-
		Y12-G-136A	XRF	513.0	5609.5
		Y12-G-137A	-	-	-
		Y12-G-146A	-	-	-
		Y12-G-147A	-	-	-
		Y12-G-148A	-	-	-
		Y12-G-150A	-	-	-
		Y12-G-151A	-	-	-
		Y12-G-151B	-	-	-
	06/06/03	Y12-G-152A	-	-	-
		Y12-G-153A	-	-	-
		Y12-G-154A	XRF	517.0	6126.5
		Y12-G-154B	-	-	-
		Y12-G-155A	-	-	-
		Z12-G-15A	-	-	-
		Z12-G-16A	-	-	-
		Z12-G-17A	-	-	-
		Z12-G-26A	-	-	-
		Z12-G-26B	XRF	511.0	6637.5
		Z12-G-28A	XRF	142.5	6780.0

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1	06/25/03	Z12-G-61A	-	-	-
		Z12-G-63A	-	-	-
		Z12-G-64A	-	-	-
		Z12-G-65A	-	-	-
		Z12-G-66A	-	-	-
		Z12-G-67A	-	-	-
	06/26/03	Z12-G-69A	-	-	-
		Z12-G-78A	-	-	-
		Z12-G-79A	-	-	-
		Z12-G-79B	-	-	-
		Z12-G-80A	XRF	492.5	7272.5
		Z12-G-81A	-	-	-
		Z12-G-82A	-	-	-
		Z12-G-82B	-	-	-
		Z12-G-83A	-	-	-
		Z12-G-93A	-	-	-
		Z12-G-93B	-	-	-
		Z12-G-95A	-	-	-
		Z12-G-95B	-	-	-
		Z12-G-96A	-	-	-
		Z12-G-98A	XRF	503.5	7776.0
		Z12-G-98B	-	-	-
		Z12-G-100A	-	-	-
		Z12-G-101A	-	-	-
		Z12-G-101B	-	-	-
		Z12-G-101C	-	-	-
		Z12-G-102A	-	-	-
		Z12-G-112A	-	-	-
		Z12-G-112B	-	-	-
	06/27/03	Z12-G-114A	-	-	-
		Z12-G-114B	XRF	501.5	8277.5
		Z12-G-115A	-	-	-
		Z12-G-117A	-	-	-
		Z12-G-117B	-	-	-
		Z12-G-118A	-	-	-
		Z12-G-120A	-	-	-
		Z12-G-120B	-	-	-
		Z12-G-121A	-	-	-
		Z12-G-122A	-	-	-
		Z12-G-130A	-	-	-
		Z12-G-131A	XRF	508.0	8785.5
		Z12-G-133A	-	-	-
		Z12-G-135A	-	-	-

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1	06/27/03	Z12-G-135B	-	-	-
		Z12-G-136A	-	-	-
		Z12-G-137A	-	-	-
		Z12-G-137B	-	-	-
		Z12-G-139A	-	-	-
		Z12-G-139B	-	-	-
		Z12-G-140A	-	-	-
		Z12-G-148A	XRF	508.0	9293.5
		Z12-G-148B	-	-	-
		Z12-G-149A	-	-	-
		Z12-G-150A	-	-	-
		Z12-G-150B	-	-	-
		Z12-G-152A	-	-	-
		Z12-G-154A	-	-	-
		Z12-G-154B	-	-	-
		Z12-G-154C	-	-	-
		Z12-G-155A	-	-	-
		Z12-G-155B	XRF	465.5	9759.0
		1A2-G-5A	-	-	-
		1A2-G-9A	-	-	-
	06/28/03	1A2-G-9B	-	-	-
		1A2-G-10A	-	-	-
		1A2-G-18A	-	-	-
		1A2-G-19A	-	-	-
		1A2-G-20A	-	-	-
		1A2-G-22A	-	-	-
		1A2-G-22B	-	-	-
		1A2-G-23A	XRF	499.0	10258.0
		1A2-G-23B	-	-	-
		1A2-G-24A	-	-	-
		1A2-G-25A	-	-	-
		1A2-G-25B	-	-	-
		1A2-G-27A	-	-	-
		1A2-G-28A	-	-	-
		1A2-G-29A	-	-	-
		1A2-G-29B	-	-	-
		1A2-G-38A	-	-	-
		1A2-G-39A	XRF	508.0	10766.0
		1A2-G-39B	-	-	-
		1A2-S-40A	-	-	-
		1A2-G-40B	-	-	-
		1A2-G-41A	-	-	-
		1A2-G-41B	-	-	-

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1	06/28/03	1A2-G-43A	-	-	-
		1A2-G-43B	-	-	-
		1A2-G-45A	-	-	-
		1A2-G-53A	XRF	455.5	11221.5
		1A2-G-54A	-	-	-
		1A2-G-54B	-	-	-
		1A2-G-55A	-	-	-
		1A2-G-57A	-	-	-
		1A2-G-57B	-	-	-
	06/29/03	1A2-G-60A	-	-	-
		1A2-G-61	-	-	-
		1A2-G-61B	-	-	-
		1A2-G-62A	-	-	-
		1A2-G-62B	XRF	529.0	11750.5
		1A2-G-64A	-	-	-
		1A2-G-65A	-	-	-
		1A2-G-66A	-	-	-
		1A2-G-66B	-	-	-
		1A2-G-74A	-	-	-
	06/30/03	1A2-G-74B	-	-	-
		1A2-G-75A	-	-	-
		1A2-G-76A	-	-	-
		1A2-G-76B	-	-	-
		1A2-G-78A	XRF	486.5	12237.0
		1A2-G-80A	-	-	-
		1A2-G-80B	-	-	-
		1A2-G-80C	-	-	-
		1A2-G-81A	-	-	-
		1A2-G-83A	-	-	-
		1A2-G-84A	-	-	-
		1A2-G-84B	-	-	-
		1A2-G-85A	-	-	-
		1A2-G-94A	-	-	-
		1A2-G-95A	XRF	489.5	12726.5
		1A2-G-95B	-	-	-
		1A2-G-98A	-	-	-
		1A2-G-99A	-	-	-
		1A2-G-100A	-	-	-
		1A2-G-101A	-	-	-
		1A2-G-102A	-	-	-
		1A2-G-102B	-	-	-
		1A2-G-103A	-	-	-
		1A2-G-105A	-	-	-
		1A2-G-105B	XRF	524.0	13250.5

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
1	07/30/03	1A2-G-106A	-	-	-
	07/01/03	1A2-G-108A	-	-	-
		1A2-G-108B	-	-	-
		1A2-G-110A	-	-	-
		1A2-G-111A	-	-	-
		1A2-G-111B	-	-	-
		1A2-G-113A	-	-	-
		1A2-G-113B	-	-	-
		1A2-G-114A	-	-	-
		1A2-G-116A	XRF	503.0	13753.5
		1A2-G-117A	-	-	-
		1A2-G-117B	-	-	-
		1A2-G-132A	-	-	-
	07/01/03	1A2-G-132B	-	-	-
		1A2-G-133A	-	-	-
		1A2-G-134A	-	-	-
		1A2-G-134B	-	-	-
		1A2-G-136A	-	-	-
		1A2-G-137A	-	-	-
		1A2-G-137B	XRF	510.0	14263.5
		1A2-G-140A	-	-	-
		1A2-G-139A	-	-	-
		1A2-G-140B	-	-	-
		1A2-G-141A	-	-	-
		1A2-G-141B	-	-	-
		1A2-G-149A	-	-	-
		1A2-G-149B	-	-	-
	07/02/03	1A2-G-151A	-	-	-
		1A2-G-152A	-	-	-
		1A2-G-152B	XRF	477.0	14740.5
		1A2-G-154A	-	-	-
		1A2-G-154B	-	-	-
		1A2-G-155A	-	-	-
		1A2-G-155B	-	-	-
		1B2-G-8A	-	-	-
		1B2-G-8B	-	-	-
		1B2-G-9A	-	-	-
		1B2-G-10A	-	-	-
		1B2-G-10B	XRF	501.5	15242.0
		1B2-G-19A	-	-	-
		1B2-G-21A	-	-	-
		1B2-G-26A	-	-	-
	07/02/03	1B2-G-26B	XRF	193.0	15435.0

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
3	07/15/03	1B2-G-50A	-	-	-
		1B2-G-54A	-	-	-
		1B2-G-57A	-	-	-
		1B2-G-60A	-	-	-
	07/16/03	1B2-G-63A	-	-	-
		1B2-G-63B	-	-	-
		1B2-G-72A	-	-	-
		1B2-G-74A	-	-	-
		1B2-G-75A	-	-	-
		1B2-G-75B	XRF	504.0	15939.0
		1B2-G-78A	-	-	-
		1B2-G-79A	-	-	-
		1B2-G-80A	-	-	-
		1B2-G-88A	-	-	-
		1B2-G-89A	-	-	-
		1B2-G-89B	-	-	-
		1B2-G-90A	-	-	-
		1B2-G-94A	-	-	-
		1B2-G-95A	-	-	-
		1B2-G-96A	XRF	512.5	16451.5
		1B2-G-97A	-	-	-
		1B2-G-98A	-	-	-
		1B2-G-100A	-	-	-
		1B2-G-100B	-	-	-
	07/17/03	1B2-G-101A	-	-	-
		1B2-G-101B	-	-	-
		1B2-G-103A	-	-	-
		1B2-G-103B	-	-	-
		1B2-G-106A	-	-	-
		1B2-G-106B	XRF	493.0	16944.5
		1B2-G-107A	-	-	-
		1B2-G-109A	-	-	-
		1B2-G-109B	-	-	-
		1B2-G-110A	-	-	-
		1B2-G-111A	-	-	-
		1B2-G-111B	-	-	-
		1B2-G-112A	-	-	-
		1B2-G-127A	-	-	-
		1B2-G-131A	-	-	-
		1B2-G-131B	XRF	518.5	17463.0
		1B2-G-132A	-	-	-
		1B2-G-132B	-	-	-
		1B2-G-133A	-	-	-

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
3	07/17/03	1B2-G-134A	-	-	-
		1B2-G-135A	-	-	-
		1B2-G-136A	-	-	-
		1B2-G-136A	-	-	-
		1B2-G-136B	-	-	-
		1B2-G-137A	-	-	-
		1B2-G-146A	XRF	512.0	17975.0
	7/18//03	1B2-G-148A	-	-	-
		1B2-G-148B	-	-	-
		1B2-G-149A	-	-	-
		1B2-G-150A	-	-	-
		1B2-G-150B	-	-	-
		1B2-G-150C	-	-	-
		1B2-G-151A	-	-	-
		1B2-G-152A	-	-	-
		1B2-G-154A	XRF	492.5	18467.5
		1B2-G-155A	-	-	-
		1B2-G-155B	-	-	-
		1C2-G-12A	-	-	-
		1C2-G-20A	-	-	-
		1C2-G-22A	-	-	-
		1C2-G-23A	-	-	-
		1C2-G-23B	-	-	-
		1C2-G-24A	XRF	508.5	18976.0
		1C2-G-25A	-	-	-
		1C2-G-26A	-	-	-
		1C2-G-26B	-	-	-
		1C2-G-27A	-	-	-
		1C2-G-29A	-	-	-
		1C2-G-30A	-	-	-
		1C2-G-30B	-	-	-
		1C2-G-31A	-	-	-
	07/19/03	1C2-G-32A	-	-	-
		1C2-G-33A	XRF	506.5	19482.5
		1C2-G-43A	-	-	-
		1C2-G-44A	-	-	-
		1C2-G-47A	-	-	-
		1C2-G-47B	-	-	-
		1C2-G-48A	-	-	-
		1C2-G-48B	-	-	-
		1C2-G-49A	-	-	-
		1C2-G-50A	-	-	-
		1C2-G-50B	-	-	-
		1C2-G-51A	XRF	500.0	19982.5

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
3	07/19/03	1C2-G-51B	-	-	-
		1C2-G-52A	-	-	-
		1C2-G-53A	-	-	-
		1C2-G-55A	-	-	-
		1C2-G-55B	-	-	-
		1C2-G-55C	-	-	-
		1C2-G-56A	-	-	-
		1C2-G-56B	-	-	-
		1C2-G-59A	-	-	-
		1C2-G-67A	XRF	493.0	20475.5
		1C2-G-67B	-	-	-
		1C2-G-68A	-	-	-
		1C2-G-69A	-	-	-
		1C2-G-69B	-	-	-
		1C2-G-71A	-	-	-
		1C2-G-73A	-	-	-
		1C2-G-73B	-	-	-
		1C2-G-81A	-	-	-
	07/20/03	1C2-G-83A	-	-	-
		1C2-G-84A	XRF	492.5	20968.0
		1C2-G-84B	-	-	-
		1C2-G-85A	-	-	-
		1C2-G-85B	-	-	-
		1C2-G-89A	-	-	-
		1C2-G-90A	-	-	-
		1C2-G-91A	-	-	-
		1C2-G-91B	-	-	-
		1C2-G-92A	-	-	-
		1C2-G-92B	XRF	483.0	21451.0
		1C2-G-93A	-	-	-
		1C2-G-98A	-	-	-
		1C2-G-107A	-	-	-
		1C2-G-107B	-	-	-
		1C2-G-108A	-	-	-
		1C2-G-110A	-	-	-
		1C2-G-111A	-	-	-
		1C2-G-112A	-	-	-
		1C2-G-114A	-	-	-
		1C2-G-115A	XRF	510.0	21961.0
		1C2-G-115B	-	-	-
		1C2-G-117A	-	-	-
		1C2-G-125A	-	-	-
		1C2-G-125B	-	-	-

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
3	07/21/03	1C2-G-126A	-	-	-
		1C2-G-126B	-	-	-
		1C2-G-127A	-	-	-
		1C2-G-128A	-	-	-
		1C2-G-129A	-	-	-
		1C2-G-132A	XRF	507.0	22468.0
		1C2-G-133A	-	-	-
		1C2-G-135A	-	-	-
		1C2-G-135B	-	-	-
		1C2-G-136A	-	-	-
		1C2-G-137A	-	-	-
		1C2-G-138A	-	-	-
		1C2-G-147A	-	-	-
		1C2-G-148A	-	-	-
		1C2-G-148B	XRF	499.5	22967.5
		1C2-G-150A	-	-	-
		1C2-G-153A	-	-	-
		1C2-G-154A	-	-	-
		1C2-G-155A	-	-	-
		1D2-G-8A	-	-	-
		1D2-G-8B	-	-	-
		1D2-G-9A	-	-	-
		1D2-G-9B	-	-	-
		1D2-G-18A	-	-	-
	07/22/03	1D2-G-18B	XRF	504.0	23471.5
		1D2-G-19A	-	-	-
		1D2-G-20A	-	-	-
		1D2-G-20B	-	-	-
		1D2-G-21A	-	-	-
		1D2-G-22A	-	-	-
		1D2-G-28A	-	-	-
		1D2-G-28B	-	-	-
		1D2-G-29A	-	-	-
		1D2-G-30A	XRF	483.0	23954.5
		1D2-G-31A	-	-	-
		1D2-G-31B	-	-	-
		1D2-G-40A	-	-	-
		1D2-G-41A	-	-	-
		1D2-G-41B	-	-	-
		1D2-G-42A	-	-	-
		1D2-G-43A	-	-	-
		1D2-G-43B	-	-	-
		1D2-G-44A	-	-	-
		1D2-G-47A	XRF	495.0	24449.5

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
3	07/22/03	1D2-G-49A			
		1D2-G-54A	XRF	174.5	24624.0
8	08/05/03	1D2-G-81A	-	-	-
		1D2-G-90A	-	-	-
		1D2-G-91A	-	-	-
		1D2-G-93A	-	-	-
		1D2-G-93B	-	-	-
		1D2-G-96A	-	-	-
	08/06/03	1D2-G-98A	-	-	-
		1D2-G-99A	-	-	-
		1D2-G-99B	-	-	-
		1D2-G-100A	XRF	501.0	25125.0
		1D2-G-108A	-	-	-
		1D2-G-109A	-	-	-
		1D2-G-111A	-	-	-
		1D2-G-112A	-	-	-
		1D2-G-114A	-	-	-
		1D2-G-116A	-	-	-
		1D2-G-117A	-	-	-
		1D2-G-117B	-	-	-
		1D2-G-118A	XRF	501.5	25626.5
		1D2-G-120A	-	-	-
		1D2-G-128A	-	-	-
		1D2-G-128B	-	-	-
		1D2-G-131A	-	-	-
		1D2-G-132A	-	-	-
	08/07/03	1D2-G-134A	-	-	-
		1D2-G-135A	-	-	-
		1D2-G-137A	-	-	-
		1D2-G-137B	-	-	-
		1D2-G-138A	XRF	507.0	26133.5
		1D2-G-148A	-	-	-
		1D2-G-148B	-	-	-
		1D2-G-149A	-	-	-
		1D2-G-150A	-	-	-
		1D2-G-150B	-	-	-
		1D2-G-152A	-	-	-
		1D2-G-152B	-	-	-
		1D2-G-153A	-	-	-
		1D2-G-154A	-	-	-
		1D2-G-154B	XRF	502.5	26636.0
		1D2-G-155A	-	-	-
		1E2-G-6A	-	-	-

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
8	08/08/03	1E2-G-8A	-	-	-
		1E2-G-11A	-	-	-
		1E2-G-11B	-	-	-
		1E2-G-14A	-	-	-
		1E2-G-23A	-	-	-
		1E2-G-23B	-	-	-
		1E2-G-24A	-	-	-
		1E2-G-24B	XRF	506.0	27142.0
		1E2-G-25A	-	-	-
		1E2-G-26A	-	-	-
	08/08/03	1E2-G-26B	-	-	-
		1E2-G-27A	-	-	-
		1E2-G-27B	-	-	-
		1E2-G-28A	-	-	-
		1E2-G-29A	-	-	-
		1E2-G-29B	-	-	-
		1E2-G-39A	-	-	-
		1E2-G-39B	XRF	496.5	27638.5
		1E2-G-40A	-	-	-
		1E2-G-41A	-	-	-
		1E2-G-41B	-	-	-
		1E2-G-42A	-	-	-
		1E2-G-43A	-	-	-
		1E2-G-44A	-	-	-
		1E2-G-46A	-	-	-
		1E2-G-46B	-	-	-
		1E2-G-47A	XRF	500.0	28138.5
		1E2-G-48A	-	-	-
		1E2-G-49A	-	-	-
		1E2-G-51A	-	-	-
		1E2-G-51B	-	-	-
		1E2-G-60A	-	-	-
		1E2-G-61A	-	-	-
		1E2-G-62A	-	-	-
		1E2-G-63A	-	-	-
		1E2-G-66A	XRF	501.0	28639.5
		1E2-G-66B	-	-	-
	08/09/03	1E2-G-68A	-	-	-
		1E2-G-69A	-	-	-
		1E2-G-70A	-	-	-
		1E2-G-70B	-	-	-
		1E2-G-71A	-	-	-
		1E2-G-72A	-	-	-

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
8	08/09/03	1E2-G-72B	-	-	-
		1E2-G-73A	-	-	-
		1E2-G-73B	XRF	499.0	29138.5
		1E2-G-82A	-	-	-
		1E2-G-82B	-	-	-
		1E2-G-82C	-	-	-
		1E2-G-84A	-	-	-
		1E2-G-85A	-	-	-
		1E2-G-85B	-	-	-
		1E2-G-86A	-	-	-
		1E2-G-87A	-	-	-
		1E2-G-87B	-	-	-
		1E2-G-89A	XRF	503.5	29642.0
		1E2-G-89B	-	-	-
		1E2-G-90A	-	-	-
		1E2-G-92A	-	-	-
		1E2-G-92B	-	-	-
		1E2-G-93A	-	-	-
		1E2-G-103A	-	-	-
		1E2-G-103B	-	-	-
		1E2-G-104A	-	-	-
		1E2-G-104B	-	-	-
		1E2-G-106A	XRF	509.0	30151.0
		1E2-G-106B	-	-	-
		1E2-G-107A	-	-	-
	08/10/03	1E2-G-107B	-	-	-
		1E2-G-109A	-	-	-
		1E2-G-109B	-	-	-
		1E2-G-110A	-	-	-
		1E2-G-110B	-	-	-
		1E2-G-112A	-	-	-
		1E2-G-112B	-	-	-
		1E2-G-121A	XRF	508.5	30659.5
		1E2-G-121B	-	-	-
		1E2-G-122A	-	-	-
		1E2-G-122B	-	-	-
		1E2-G-124A	-	-	-
		1E2-G-125A	-	-	-
		1E2-G-126A	-	-	-
		1E2-G-127A	-	-	-
		1E2-G-128A	XRF	485.0	31144.5
		1E2-G-129A	-	-	-
		1E2-G-131A	-	-	-
		1E2-G-132A	-	-	-

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
8	08/11/03	1E2-G-134A	-	-	-
		1E2-G-143A	-	-	-
		1E2-G-143B	-	-	-
		1E2-G-144A	-	-	-
		1E2-G-144B	XRF	506.0	31650.5
		1E2-G-145A	-	-	-
		1E2-G-145B	-	-	-
		1E2-G-147A	-	-	-
		1E2-G-149A	-	-	-
		1E2-G-150A	-	-	-
	08/11/03	1E2-G-150B	-	-	-
		1E2-G-152A	-	-	-
		1E2-G-152B	-	-	-
		1E2-G-154A	XRF	510.5	32161.0
		1E2-G-154B	-	-	-
		1E2-G-155A	-	-	-
		1E2-G-155B	-	-	-
		1F2-G-5A	-	-	-
		1F2-G-5B	-	-	-
		1F2-G-9A	-	-	-
		1F2-G-10A	-	-	-
		1F2-G-11A	-	-	-
		1F2-G-11B	XRF	501.5	32662.5
		1F2-G-12A	-	-	-
		1F2-G-13A	-	-	-
		1F2-G-14A	-	-	-
		1F2-G-16A	-	-	-
		1F2-G-17A	-	-	-
		1F2-G-17B	-	-	-
		1F2-G-18A	-	-	-
		1F2-G-27A	-	-	-
		1F2-G-27B	-	-	-
		1F2-G-28A	XRF	510.5	33173.0
		1F2-G-28B	-	-	-
		1F2-G-38A	-	-	-
		1F2-G-38B	-	-	-
		1F2-G-40A	-	-	-
		1F2-G-40B	-	-	-
		1F2-G-41A	-	-	-
		1F2-G-41B	-	-	-
		1F2-G-41C	-	-	-
		1F2-G-42A	-	-	-
		1F2-G-43A	XRF	511.0	33684.0

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Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
8	08/12/03	1F2-G-43B	-	-	-
		1F2-G-44A	-	-	-
		1F2-G-44B	-	-	-
		1F2-G-47A	-	-	-
		1F2-G-47B	-	-	-
		1F2-G-48A	-	-	-
		1F2-G-48B	-	-	-
		1F2-G-49A	-	-	-
		1F2-G-49B	-	-	-
		1F2-G-49C	XRF	498.0	34182.0
		1F2-G-59A	-	-	-
		1F2-G-59B	-	-	-
		1F2-G-60A	-	-	-
		1F2-G-62A	-	-	-
		1F2-G-63A	-	-	-
		1F2-G-63B	-	-	-
		1F2-G-64A	-	-	-
		1F2-G-66A	-	-	-
		1F2-G-67A	-	-	-
		1F2-G-67B	XRF	481.5	34663.5
		1F2-G-69A	-	-	-
		1F2-G-70A	-	-	-
		1F2-G-72A	-	-	-
		1F2-G-73A	-	-	-
		1F2-G-81A	-	-	-
		1F2-G-81B	-	-	-
		1F2-G-82A	-	-	-
		1F2-G-83A	-	-	-
		1F2-G-83B	-	-	-
		1F2-G-84A	XRF	492.5	35156.0
		1F2-G-86A	-	-	-
		1F2-G-86B	-	-	-
		1F2-G-87A	-	-	-
		1F2-G-89A	-	-	-
	08/13/03	1F2-G-89B	-	-	-
		1F2-G-89C	-	-	-
		1F2-G-90A	-	-	-
		1F2-G-91A	-	-	-
		1F2-G-93A	-	-	-
		1F2-G-93B	XRF	519.5	35675.5
		1F2-G-94A	-	-	-
		1F2-G-94B	-	-	-
		1F2-G-102A	-	-	-
		1F2-G-104A	-	-	-

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
8	08/13/03	1F2-G-104B	-	-	-
		1F2-G-105A	-	-	-
		1F2-G-106A	-	-	-
		1F2-G-106B	-	-	-
		1F2-G-108A	-	-	-
		1F2-G-109A	XRF	508.0	36183.5
		1F2-G-109B	-	-	-
		1F2-G-110A	-	-	-
		1F2-G-112A	-	-	-
		1F2-G-114A	-	-	-
		1F2-G-119A	XRF	502.0	36685.5
10	09/03/03	1I2-G-74A	-	-	-
		1I2-G-76A	-	-	-
		1I2-G-77A	-	-	-
		1I2-G-79A	-	-	-
		1I2-G-80A	-	-	-
	09/04/03	1I2-G-89A	-	-	-
		1I2-G-91A	-	-	-
		1I2-G-92A	-	-	-
		1I2-G-94A	-	-	-
		1I2-G-95A	XRF	512.5	37198.0
		1I2-G-97A	-	-	-
		1I2-G-97B	-	-	-
		1I2-G-98A	-	-	-
		1I2-G-99A	-	-	-
		1I2-G-99B	-	-	-
		1I2-G-100A	-	-	-
		1I2-G-102A	-	-	-
		1I2-G-105A	-	-	-
		1I2-G-106A	-	-	-
		1I2-G-108A	XRF	514.5	37712.5
		1I2-G-116A	-	-	-
		1I2-G-117A	-	-	-
		1I2-G-118A	-	-	-
	09/05/03	1I2-G-118B	-	-	-
		1I2-G-126A	-	-	-
		1I2-G-127A	-	-	-
		1I2-G-130A	-	-	-
		1I2-G-130B	-	-	-
		1I2-G-131A	-	-	-
		1I2-G-131B	XRF	496.5	38209.0
		1I2-G-133A	-	-	-
		1I2-G-134A	-	-	-
		1I2-G-134B	-	-	-

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
10	09/05/03	1I2-G-143A	-	-	-
		1I2-G-147A	-	-	-
		1I2-G-150A	-	-	-
		1I2-G-151A	-	-	-
		1I2-G-151B	XRF	499.0	38708.0
		1I2-G-152A	-	-	-
		1I2-G-152B	-	-	-
		1I2-G-153A	-	-	-
	09/06/03	1I2-G-155A	-	-	-
		1I2-G-155B	-	-	-
		1J2-G-17A	-	-	-
		1J2-G-17B	-	-	-
		1J2-G-18A	-	-	-
		1J2-G-19A	XRF	503.5	39211.5
		1J2-G-20A	-	-	-
		1J2-G-20B	-	-	-
		1J2-G-30A	-	-	-
		1J2-G-31A	-	-	-
		1J2-G-33A	-	-	-
		1J2-G-34A	-	-	-
		1J2-G-34B	-	-	-
		1J2-G-35A	-	-	-
		1J2-G-36A	-	-	-
		1J2-G-36B	XRF	503.5	39715.0
		1J2-G-40A	-	-	-
		1J2-G-40B	-	-	-
	09/07/03	1J2-G-49A	-	-	-
		1J2-G-50A	-	-	-
		1J2-G-51A	-	-	-
		1J2-G-52A	-	-	-
		1J2-G-52B	-	-	-
		1J2-G-56A	-	-	-
		1J2-G-58A	-	-	-
		1J2-G-66A	XRF	499.0	40214.0
		1J2-G-67A	-	-	-
		1J2-G-69A	-	-	-
		1J2-G-71A	-	-	-
		1J2-G-71B	-	-	-
		1J2-G-72A	-	-	-
		1J2-G-74A	-	-	-
		1J2-G-75A	-	-	-
		1J2-G-76A	-	-	-
	09/08/03	1J2-G-76B	XRF	511.0	40725.0

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
10	09/08/03	1J2-G-78A	-	-	-
		1J2-G-85A	-	-	-
		1J2-G-89A	-	-	-
		1J2-G-90A	-	-	-
		1J2-G-91A	-	-	-
		1J2-G-92A	-	-	-
		1J2-G-93A	-	-	-
		1J2-G-95A	-	-	-
		1J2-G-95B	XRF	501.5	41226.5
		1J2-G-96A	-	-	-
		1J2-G-97A	-	-	-
		1J2-G-99A	-	-	-
		1J2-G-101A	-	-	-
		1J2-G-101B	-	-	-
		1J2-G-103A	-	-	-
		1J2-G-103B	-	-	-
		1J2-G-111A	-	-	-
		1J2-G-112A	XRF	481.0	41707.5
		1J2-G-112B	-	-	-
	09/09/03	1J2-G-114A	-	-	-
		1J2-G-123A	-	-	-
		1J2-G-124A	-	-	-
		1J2-G-125A	-	-	-
		1J2-G-125B	-	-	-
		1J2-G-124A	-	-	-
		1J2-G-124B	-	-	-
		1J2-G-125A	-	-	-
		1J2-G-125B	-	-	-
		1J2-G-126A	-	-	-
		1J2-G-126B	-	-	-
		1J2-G-127A	XRF	506.5	42214.0
		1J2-G-138A	-	-	-
		1J2-G-138B	-	-	-
		1J2-G-139A	-	-	-
		1J2-G-139B	-	-	-
		1J2-G-142A	-	-	-
		1J2-G-142B	-	-	-
		1J2-G-143A	-	-	-
		1J2-G-143B	-	-	-
		1J2-G-149A	-	-	-
		1J2-G-149B	XRF	500.5	42714.5
		1J2-G-150A	-	-	-
		1J2-G-151A	-	-	-

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
10	09/09/03	1J2-G-151B	-	-	-
	9/10/03	1J2-G-152A	-	-	-
		1J2-G-152B	-	-	-
		1J2-G-153A	-	-	-
		1J2-G-155A	-	-	-
		1K2-G-16A	-	-	-
		1K2-G-17A	XRF	517.5	43232.0
		1K2-G-18A	-	-	-
		1K2-G-18B	-	-	-
		1K2-G-26A	-	-	-
		1K2-G-27A	-	-	-
		1K2-G-27B	-	-	-
		1K2-G-28A	-	-	-
		1K2-G-33A	XRF	498.0	43730.0
		1K2-G-33B	XRF	119.0	43849.0
9	03/23/04	1Q2-G-155A	-	-	-
	03/24/04	1R2-G-16A	-	-	-
		1R2-G-17A	-	-	-
		1R2-G-17B	-	-	-
		1R2-G-19A	-	-	-
		1R2-G-21A	-	-	-
		1R2-G-23A	-	-	-
		1R2-G-24A	-	-	-
		1R2-G-25A	-	-	-
		1R2-G-25B	XRF, Fe ²⁺	517.0	44366.0
		1R2-G-27A	-	-	-
		1R2-G-27B	-	-	-
		1R2-G-28A	-	-	-
		1R2-G-28B	-	-	-
		1R2-G-31A	-	-	-
		1R2-G-32A	-	-	-
		1R2-G-32B	-	-	-
		1R2-G-33A	-	-	-
		1R2-G-52A	-	-	-
		1R2-G-52B	XRF, Fe ²⁺	526.5	44892.5
		1R2-G-53A	-	-	-
		1R2-G-53B	-	-	-
	03/25/04	1R2-G-54A	-	-	-
		1R2-G-57A	-	-	-
		1R2-G-57B	-	-	-
		1R2-G-58A	-	-	-
		1R2-G-58B	-	-	-
		1R2-G-59A	-	-	-

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Ru Spike	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
9	No	03/25/04	1R2-G-60A	-	-	-
	Yes		1R2-G-60B	XRF	517.5	45410.0
			1R2-G-62A	-	-	-
			1R2-G-63A	-	-	-
			1R2-G-68A	-	-	-
			1R2-G-68B	-	-	-
			1R2-G-69A	-	-	-
			1R2-G-69B	-	-	-
			1R2-G-70A	-	-	-
			1R2-G-70B	-	-	-
			1R2-G-71A	XRF	455.0	45865.0
			1R2-G-73A	-	-	-
			1R2-G-73B	-	-	-
			1R2-G-82A	-	-	-
			1R2-G-83A	-	-	-
			1R2-G-83B	-	-	-
			1R2-G-87A	-	-	-
			1R2-G-96A	-	-	-
		03/26/04	1R2-G-96B	-	-	-
			1R2-G-96C	XRF	448.5	46313.5
			1R2-G-97A	-	-	-
			1R2-G-99A	-	-	-
			1R2-G-99B	-	-	-
			1R2-G-100A	-	-	-
			1R2-G-100B	-	-	-
			1R2-G-110A	-	-	-
			1R2-G-111A	-	-	-
			1R2-G-111B	-	-	-
			1R2-G-113A	XRF	469.5	46783.0
	1R2-G-114A		-	-	-	
	1R2-G-115A		-	-	-	
	1R2-G-116A		-	-	-	
	1R2-G-117A		-	-	-	
	1R2-G-117B		-	-	-	
	1R2-G-120A		-	-	-	
	1R2-G-121A		-	-	-	
1R2-G-121B	-	-	-			
1R2-G-123A	-	-	-			
1R2-G-124A	XRF	516.5	47299.5			
1R2-G-124B	-	-	-			
1R2-G-134A	-	-	-			
03/27/04	1R2-G-134B	-	-	-		
	1R2-G-136A	-	-	-		

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Ru Spike	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
9	Yes	03/27/04	1R2-G-138A	-	-	-
			1R2-G-138B	-	-	-
			1R2-G-138C	-	-	-
			1R2-G-139A	-	-	-
			1R2-G-139B	XRF	509.5	47809.0
			1R2-G-141A	-	-	-
			1R2-G-141B	-	-	-
			1R2-G-143A	-	-	-
			1R2-G-143B	-	-	-
			1R2-G-144A	-	-	-
			1R2-G-148A	-	-	-
			1R2-G-148B	-	-	-
			1R2-G-149A	-	-	-
			1R2-G-149B	-	-	-
			1R2-G-151A	XRF, Fe ⁺²	518.0	48327.0
			1R2-G-152A	-	-	-
			1R2-G-152B	-	-	-
			1R2-G-153A	-	-	-
			1R2-G-154A	-	-	-
			1R2-G-154B	-	-	-
			1S2-G-14A	-	-	-
			1S2-G-15A	-	-	-
			1S2-G-15B	-	-	-
		03/28/04	1S2-G-16A	-	-	-
			1S2-G-17A	XRF	507.0	48834.0
			1S2-G-17B	-	-	-
			1S2-G-31A	-	-	-
			1S2-G-31B	-	-	-
			1S2-G-32A	-	-	-
			1S2-G-32B	-	-	-
			1S2-G-33A	-	-	-
			1S2-G-33B	-	-	-
			1S2-G-34A	-	-	-
			1S2-G-36A	-	-	-
			1S2-G-46A	XRF	491.5	49325.5
			1S2-G-46B	-	-	-
			1S2-G-47A	-	-	-
			1S2-G-47B	-	-	-
			1S2-G-48A	-	-	-
			1S2-G-50A	-	-	-
			1S2-G-50B	-	-	-
			1S2-G-52A	-	-	-
			1S2-G-54A	-	-	-

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Ru Spike	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
9	Yes	03/29/04	1S2-G-54B	-	-	-
			1S2-G-55A	XRF -	506.0	49831.5
			1S2-G-55B	-	-	-
			1S2-G-66A	-	-	-
			1S2-G-66B	-	-	-
		03/29/04	1S2-G-67A	-	-	-
			1S2-G-67B	-	-	-
			1S2-G-69A	-	-	-
			1S2-G-69B	-	-	-
			1S2-G-69C	-	-	-
			1S2-G-72A	-	-	-
			1S2-G-72B	XRF -	496.0	50327.5
			1S2-G-73A	-	-	-
			1S2-G-74A	-	-	-
			1S2-G-74B	-	-	-
			1S2-G-77A	-	-	-
			1S2-G-78A	-	-	-
			1S2-G-79A	-	-	-
			1S2-G-79B	-	-	-
			1S2-G-80A	-	-	-
			1S2-G-80B	-	-	-
			1S2-G-82A	XRF	493.0	50820.5
			1S2-G-84A	-	-	-
			1S2-G-85A	-	-	-
			1S2-G-85B	-	-	-
			1S2-G-86A	-	-	-
			1S2-G-87A	-	-	-
			1S2-G-88A	-	-	-
			1S2-G-99A	-	-	-
			1S2-G-99B	-	-	-
		03/30/04	1S2-G-101A	-	-	-
			1S2-G-101B	XRF	536.5	51357.0
			1S2-G-103A	-	-	-
			1S2-G-103B	-	-	-
			1S2-G-104A	-	-	-
			1S2-G-105A	-	-	-
			1S2-G-105B	-	-	-
			1S2-G-106A	-	-	-
			1S2-G-106B	-	-	-
			1S2-G-116A	-	-	-
			1S2-G-116B	-	-	-
			1S2-G-117A	XRF	483.5	51840.5
			1S2-G-118A	-	-	-

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Ru Spike	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
9	Yes	03/31/04	1S2-G-122A	-		
			1S2-G-122B	-		
			1S2-G-123A	-		
			1S2-G-124A	-		
			1S2-G-125A	-		
			1S2-G-125B	-		
			1S2-G-126A	-		
			1S2-G-128A	-		
			1S2-G-130A	XRF	530.0	52370.5
			1S2-G-132A	-		
			1S2-G-132B	-		
			1S2-G-133A	-		
			1S2-G-133B	-		
			1S2-G-134A	-		
			1S2-G-134B	-		
			1S2-G-146A	-		
		03/31/04	1T2-G-5A	-		
			1T2-G-5B	-		
			1T2-G-9A	XRF	509.5	52880.0
			1T2-G-10A	-		
			1T2-G-10B	-		
			1T2-G-10C	-		
			1T2-G-11A	-		
			1T2-G-11B	-		
			1T2-G-13A	-		
			1T2-G-13B	-		
			1T2-G-14A	-		
			1T2-G-15A	-		
			1T2-G-15B	XRF	511.0	53391.0
			1T2-G-18A	-		
			1T2-G-18B	-		
			1T2-G-20A	-		
			1T2-G-21A	-		
			1T2-G-22A	-		
			1T2-G-22B	-		
			1T2-G-24A	-		
			1T2-G-25A	-		
			1T2-G-26A	-		
			1T2-G-28A	XRF	511.5	53902.5
			1T2-G-29A	-		
			1T2-G-29B	-		
			1T2-G-38A	-		
			1T2-G-39A	-		

"-" Empty data field

Table 6.1. List of Glass Discharged, Masses, and Analysis Performed, continued.

Test	Ru Spike	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
9	Yes	03/31/04	1T2-G-39B	-	-	-
			1T2-G-42A	-	-	-
			1T2-G-43A	-	-	-
			1T2-G-45A	-	-	-
		04/01/04	1T2-G-45B	-	-	-
			1T2-G-46A	XRF	487.5	54390.0
			1T2-G-48A	-	-	-
			1T2-G-48B	-	-	-
			1T2-G-49A	-	-	-
			1T2-G-49B	-	-	-
			1T2-G-50A	-	-	-
			1T2-G-52A	-	-	-
			1T2-G-62A	-	-	-
			1T2-G-62B	-	-	-
			1T2-G-64A	XRF	500.0	54890.0
			1T2-G-64B	-	-	-
			1T2-G-65A	-	-	-
			1T2-G-66A	-	-	-
			1T2-G-66B	-	-	-
			1T2-G-68A	-	-	-
			1T2-G-69A	-	-	-
			1T2-G-70A	-	-	-
			1T2-G-72A	SEM	-	-
			1T2-G-72B	-	-	-
			1T2-G-74A	XRF	504.5	55394.5
			1T2-G-74B	-	-	-
			1T2-G-75A	-	-	-
			1T2-G-75B	-	-	-
			1T2-G-76A	-	-	-
			1T2-G-76B	-	-	-
	No	04/02/04	1T2-G-97A	XRF	516.0	55910.5
			1T2-G-97B	XRF	98.5	56009.0

"-" Empty data field

**Table 6.2. XRF Analyzed Compositions of Discharged Glasses.
(wt%)**

Test		2									
Glass (kg)		514	1007	1503	2022	2521	3030	3534	4052	4573	5097
Constituent	Target	X12-G-34B	X12-G-56B	X12-G-86A	X12-G-107A	X12-G-136A	Y12-G-12A	Y12-G-30A	Y12-G-59A	Y12-G-81B	Y12-G-115A
Al ₂ O ₃	5.21	5.58	5.79	5.22	5.29	5.28	5.60	5.52	5.55	5.53	5.26
As ₂ O ₃	¶	0.13	0.10	0.10	0.07	0.05	0.04	0.02	0.03	0.02	0.01
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.05	0.05	0.05	0.06
CaO	0.28	0.44	0.50	0.44	0.43	0.43	0.40	0.41	0.40	0.40	0.43
CdO	0.06	0.01	0.03	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.07
Cl	§	0.04	0.03	0.02	0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01
Cr ₂ O ₃	¶	0.07	0.05	0.21	0.17	0.16	0.03	0.02	0.02	0.02	0.17
Cs ₂ O	<0.01	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	<0.01	<0.01
CuO	0.03	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	11.50	11.45	12.87	12.73	12.67	11.52	11.78	11.60	11.53	12.09
K ₂ O	0.03	0.11	0.15	0.10	0.11	0.11	0.13	0.14	0.13	0.14	0.11
La ₂ O ₃	0.41	0.27	0.31	0.35	0.38	0.39	0.39	0.41	0.40	0.41	0.41
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	1.02	0.83	0.62	0.45	0.40	0.33	0.29	0.24	0.22	0.17
MnO	0.17	3.16	2.48	2.16	1.67	1.31	1.03	0.85	0.71	0.58	0.48
Na ₂ O	11.65	11.27	10.70	10.67	10.49	10.64	11.12	10.61	11.17	10.84	11.39
Nd ₂ O ₃	0.31	0.17	0.20	0.23	0.26	0.27	0.27	0.28	0.28	0.29	0.28
NiO	0.62	0.19	0.28	0.42	0.47	0.51	0.45	0.50	0.50	0.52	0.59
P ₂ O ₅	¶	0.09	0.07	0.06	0.06	0.05	0.04	0.03	0.03	0.03	0.03
PbO	0.03	0.10	0.09	0.08	0.07	0.06	0.05	0.05	0.05	0.04	0.04
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sb ₂ O ₃	¶	0.22	0.19	0.15	0.12	0.09	0.06	0.05	0.04	0.03	0.02
SeO ₂	¶	0.03	0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01
SiO ₂	47.41	46.35	46.82	45.35	45.88	45.90	47.12	47.23	47.11	47.19	45.88
SO ₃	0.08; §	0.05	0.05	0.06	0.07	0.06	0.06	0.06	0.06	0.07	0.07
SrO	0.03	0.67	0.52	0.47	0.35	0.28	0.21	0.17	0.14	0.11	0.09
TiO ₂	¶	0.18	0.17	0.15	0.14	0.13	0.11	0.11	0.10	0.10	0.10
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	2.02	1.81	1.84	2.02	2.00	1.97	1.82	1.87	1.82	1.83	1.87
ZrO ₂	3.82	1.02	1.85	2.71	3.24	3.67	3.60	4.00	4.04	4.52	4.90
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA – Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (wt%), continued.

Test		2				1					
Glass (kg)		5610	6127	6638	6780	7273	7776	8278	8786	9294	9759
Constituent	Target	Y12-G-136A	Y12-G-154A	Z12-G-26B	Z12-G-28A	Z12-G-80A	Z12-G-98A	Z12-G-114B	Z12-G-131A	Z12-G-148A	Z12-G-155B
Al ₂ O ₃	5.21	5.29	5.28	5.55	5.51	5.94	5.92	5.86	5.93	5.90	5.23
As ₂ O ₃	¶	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.05
CaO	0.28	0.41	0.42	0.41	0.40	0.40	0.40	0.40	0.38	0.40	0.40
CdO	0.06	0.07	0.07	0.07	0.06	0.08	0.08	0.07	0.07	0.07	0.07
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	¶	0.17	0.15	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.19
Cs ₂ O	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CuO	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	12.36	12.43	11.66	11.64	11.41	11.21	11.43	11.09	11.22	12.08
K ₂ O	0.03	0.12	0.12	0.14	0.14	0.14	0.14	0.13	0.14	0.14	0.11
La ₂ O ₃	0.41	0.43	0.43	0.43	0.42	0.42	0.40	0.42	0.41	0.41	0.42
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.12	0.10	0.12	0.16	0.07	0.09	0.13	0.08	0.09	0.09
MnO	0.17	0.43	0.38	0.34	0.33	0.32	0.30	0.28	0.26	0.25	0.26
Na ₂ O	11.65	10.77	10.69	10.91	10.81	10.85	11.04	11.12	11.63	11.46	11.45
Nd ₂ O ₃	0.31	0.31	0.31	0.30	0.30	0.29	0.29	0.30	0.30	0.31	0.31
NiO	0.62	0.62	0.63	0.56	0.55	0.54	0.52	0.54	0.53	0.55	0.63
P ₂ O ₅	¶	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	<0.01	0.02
PbO	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sb ₂ O ₃	¶	0.02	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01
SeO ₂	¶	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	46.05	46.07	46.97	47.02	47.14	47.40	46.97	47.05	47.01	46.24
SO ₃	0.08; §	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.07	0.07
SrO	0.03	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.05
TiO ₂	¶	0.10	0.10	0.10	0.09	0.11	0.10	0.10	0.10	0.10	0.09
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	2.02	1.92	1.94	1.84	1.86	1.77	1.72	1.75	1.71	1.74	1.81
ZrO ₂	3.82	5.06	5.13	4.87	4.92	4.77	4.65	4.78	4.59	4.67	4.91
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA - Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (wt%), continued.

Test		1									
Glass (kg)		10258	10766	11222	11751	12237	12727	13251	13754	14264	14741
Constituent	Target	1A2-G-23A	1A2-G-39A	1A2-G-53A	1A2-G-62B	1A2-G-78A	1A2-G-95A	1A2-G-105B	1A2-G-116A	1A2-G-137B	1A2-G-152B
Al ₂ O ₃	5.21	5.27	5.26	5.24	5.32	5.28	5.27	5.81	5.28	5.18	5.75
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
CaO	0.28	0.41	0.40	0.41	0.41	0.40	0.42	0.40	0.41	0.41	0.43
CdO	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
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	¶	0.18	0.19	0.18	0.18	0.17	0.14	0.02	0.21	0.24	0.02
Cs ₂ O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CuO	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.04	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	12.39	11.96	12.28	12.33	12.22	12.38	11.52	12.35	12.49	11.77
K ₂ O	0.03	0.11	0.12	0.12	0.12	0.11	0.12	0.13	0.12	0.12	0.14
La ₂ O ₃	0.41	0.44	0.42	0.43	0.43	0.42	0.44	0.41	0.42	0.41	0.40
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.08	0.07	0.08	0.07	0.10	0.02	0.11	0.04	0.06	0.11
MnO	0.17	0.24	0.22	0.23	0.22	0.21	0.21	0.19	0.20	0.20	0.19
Na ₂ O	11.65	10.92	11.65	11.09	10.96	11.05	11.00	11.20	11.17	11.13	10.61
Nd ₂ O ₃	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.31	0.32	0.32	0.32
NiO	0.62	0.66	0.65	0.65	0.67	0.65	0.65	0.58	0.65	0.67	0.59
P ₂ O ₅	¶	<0.01	0.02	0.02	0.02	<0.01	0.02	0.02	<0.01	0.03	0.02
PbO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO ₂	¶	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	46.17	46.23	46.26	46.21	46.39	46.16	46.82	46.18	45.98	47.04
SO ₃	0.08; §	0.07	0.07	0.08	0.08	0.08	0.08	0.07	0.08	0.07	0.07
SrO	0.03	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
TiO ₂	¶	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10
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	2.02	1.87	1.79	1.85	1.86	1.83	1.88	1.78	1.84	1.87	1.83
ZrO ₂	3.82	5.11	4.87	5.03	5.07	5.02	5.14	4.85	5.00	5.09	4.94
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA – Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (wt%), continued.

Test		1		3							
Glass (kg)		15242	15435	15939	16452	16945	17463	17975	18468	18976	19483
Constituent	Target	1B2-G-10B	1B2-G-26B	1B2-G-75B	1B2-G-96A	1B2-G-106B	1B2-G-131B	1B2-G-146A	1B2-G-154A	1C2-G-24A	1C2-G-33A
Al ₂ O ₃	5.21	5.95	5.24	5.28	5.36	6.05	5.38	6.01	5.38	6.09	5.29
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.06	0.06	0.05	0.06	0.06	0.06	0.05	0.05	0.05	0.06
CaO	0.28	0.40	0.39	0.41	0.40	0.39	0.41	0.40	0.40	0.40	0.41
CdO	0.06	0.07	0.08	0.07	0.07	0.06	0.07	0.07	0.08	0.07	0.07
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	¶	0.02	0.21	0.24	0.22	0.02	0.17	0.02	0.17	0.02	0.24
Cs ₂ O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CuO	0.03	0.03	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	11.44	12.10	12.69	12.36	11.09	12.33	11.23	12.27	11.33	12.39
K ₂ O	0.03	0.15	0.11	0.11	0.11	0.18	0.12	0.17	0.12	0.18	0.11
La ₂ O ₃	0.41	0.40	0.41	0.41	0.40	0.39	0.42	0.41	0.41	0.40	0.42
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.10	0.07	0.12	0.09	0.10	0.06	0.06	0.06	0.06	0.13
MnO	0.17	0.19	0.19	0.24	0.22	0.19	0.21	0.18	0.20	0.19	0.21
Na ₂ O	11.65	10.93	11.75	10.71	11.40	11.59	10.99	11.00	11.16	10.48	10.86
Nd ₂ O ₃	0.31	0.31	0.31	0.32	0.31	0.29	0.32	0.31	0.31	0.31	0.32
NiO	0.62	0.57	0.64	0.67	0.65	0.54	0.63	0.55	0.64	0.56	0.66
P ₂ O ₅	¶	0.02	0.02	0.03	0.02	<0.01	<0.01	0.02	0.02	0.02	0.02
PbO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	47.21	46.03	45.97	45.82	47.23	46.24	47.44	46.16	47.70	46.24
SO ₃	0.08; §	0.08	0.08	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.07
SrO	0.03	0.04	0.04	0.05	0.04	0.03	0.04	0.04	0.04	0.03	0.04
TiO ₂	¶	0.10	0.09	0.09	0.09	0.08	0.10	0.09	0.09	0.09	0.09
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	2.02	1.75	1.79	1.88	1.83	1.69	1.86	1.74	1.87	1.76	1.85
ZrO ₂	3.82	4.73	4.88	5.08	4.97	4.49	5.01	4.68	5.00	4.70	5.02
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA - Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (wt%), continued.

Test		3									
Glass (kg)		19983	20476	20968	21451	21961	22468	22968	23472	23955	24450
Constituent	Target	1C2-G-51A	1C2-G-67A	1C2-G-84A	1C2-G-92B	1C2-G-115A	1C2-G-132A	1C2-G-148B	1D2-G-18B	1D2-G-30A	1D2-G-47A
Al ₂ O ₃	5.21	5.31	5.98	5.92	5.85	5.84	5.79	5.90	5.79	5.88	5.89
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.06	0.06	0.05
CaO	0.28	0.41	0.39	0.39	0.39	0.40	0.39	0.39	0.39	0.38	0.39
CdO	0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.06	0.06	0.07	0.07
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	¶	0.20	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01
Cs ₂ O	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CuO	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	12.31	11.08	11.39	10.95	11.13	11.05	10.87	10.96	10.96	11.07
K ₂ O	0.03	0.11	0.18	0.18	0.17	0.15	0.16	0.16	0.16	0.16	0.17
La ₂ O ₃	0.41	0.42	0.40	0.41	0.41	0.41	0.41	0.41	0.40	0.40	0.42
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.11	0.07	0.06	0.10	0.06	0.06	0.09	0.05	0.08	0.06
MnO	0.17	0.20	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.17
Na ₂ O	11.65	11.07	10.98	10.50	11.34	11.06	11.35	11.26	11.36	11.35	11.02
Nd ₂ O ₃	0.31	0.32	0.29	0.31	0.30	0.31	0.29	0.29	0.30	0.30	0.30
NiO	0.62	0.65	0.54	0.55	0.52	0.54	0.54	0.52	0.54	0.54	0.54
P ₂ O ₅	¶	0.02	0.03	0.02	<0.01	0.02	0.02	0.03	0.02	0.03	0.02
PbO	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	46.11	47.73	47.78	47.74	47.70	47.65	47.95	47.85	47.67	47.81
SO ₃	0.08; §	0.07	0.06	0.06	0.06	0.06	0.06	0.07	0.06	0.07	0.07
SrO	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03
TiO ₂	¶	0.09	0.09	0.09	0.08	0.09	0.08	0.09	0.08	0.09	0.09
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	2.02	1.87	1.71	1.77	1.67	1.71	1.70	1.66	1.68	1.68	1.70
ZrO ₂	3.82	5.07	4.61	4.74	4.59	4.68	4.60	4.48	4.54	4.56	4.60
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA - Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (wt%), continued.

Test		3	8								
Glass (kg)		24624	25125	25627	26134	26636	27142	27639	28139	28640	29139
Constituent	Target	1D2-G-54A	1D2-G-100A	1D2-G-118A	1D2-G-138A	1D2-G-154B	1E2-G-24B	1E2-G-39B	1E2-G-47A	1E2-G-66A	1E2-G-73B
Al ₂ O ₃	5.21	5.90	5.53	5.58	6.46	6.37	6.31	5.29	5.28	5.28	5.25
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.05	0.05	0.06
CaO	0.28	0.39	0.41	0.40	0.39	0.40	0.40	0.41	0.41	0.41	0.43
CdO	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07
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	¶	0.02	0.02	0.02	0.02	0.01	0.01	0.18	0.20	0.21	0.20
Cs ₂ O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
CuO	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	11.14	12.10	11.55	10.82	11.09	11.13	12.29	12.08	12.22	12.36
K ₂ O	0.03	0.17	0.12	0.13	0.16	0.17	0.15	0.12	0.12	0.11	0.11
La ₂ O ₃	0.41	0.41	0.43	0.42	0.40	0.41	0.41	0.44	0.42	0.44	0.43
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.07	0.07	0.05	0.09	0.09	0.10	0.06	0.07	0.08	0.10
MnO	0.17	0.18	0.19	0.18	0.17	0.18	0.18	0.20	0.19	0.19	0.20
Na ₂ O	11.65	11.08	10.52	11.65	10.97	10.93	11.31	11.07	11.52	11.24	11.05
Nd ₂ O ₃	0.31	0.29	0.31	0.31	0.28	0.29	0.31	0.32	0.31	0.31	0.31
NiO	0.62	0.54	0.60	0.57	0.51	0.54	0.54	0.63	0.64	0.65	0.65
P ₂ O ₅	¶	0.02	<0.01	0.02	<0.01	0.02	0.02	0.02	<0.01	<0.01	0.02
PbO	0.03	0.03	0.03	0.03	0.03	<0.01	0.02	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SeO ₂	¶	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	47.70	46.68	46.53	47.76	47.35	47.00	46.13	46.16	46.24	46.03
SO ₃	0.08; §	0.07	0.07	0.06	0.07	0.07	0.06	0.06	0.06	0.06	0.07
SrO	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.04
TiO ₂	¶	0.09	0.10	0.10	0.11	0.11	0.11	0.09	0.09	0.09	0.09
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	2.02	1.73	1.91	1.80	1.65	1.71	1.72	1.88	1.83	1.86	1.89
ZrO ₂	3.82	4.57	5.27	4.97	4.49	4.67	4.61	5.13	4.96	4.94	5.11
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA - Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (wt%), continued.

Test		8									
Glass (kg)		29642	30151	30660	31145	31651	32161	32663	33173	33684	34182
Constituent	Target	1E2-G-89A	1E2-G-106A	1E2-G-121A	1E2-G-128A	1E2-G-144B	1E2-G-154A	1F2-G-11B	1F2-G-28A	1F2-G-43A	1F2-G-49C
Al ₂ O ₃	5.21	5.23	5.44	5.21	5.29	5.90	6.20	6.20	5.77	5.85	5.77
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.06	0.05	0.06
CaO	0.28	0.42	0.41	0.42	0.41	0.40	0.40	0.41	0.41	0.42	0.41
CdO	0.06	0.08	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.06
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	¶	0.21	0.16	0.23	0.21	0.01	0.02	0.02	0.01	0.01	0.01
Cs ₂ O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
CuO	0.03	0.04	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.03
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	12.48	12.00	12.58	12.17	11.14	11.40	11.49	11.37	11.28	11.41
K ₂ O	0.03	0.11	0.12	0.12	0.11	0.14	0.16	0.16	0.14	0.13	0.13
La ₂ O ₃	0.41	0.45	0.43	0.44	0.43	0.42	0.42	0.42	0.41	0.42	0.42
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.05	0.11	0.05	0.06	0.11	0.05	0.09	0.08	0.10	0.08
MnO	0.17	0.20	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.18
Na ₂ O	11.65	10.88	11.18	10.81	11.38	11.58	10.91	10.58	11.58	11.45	11.31
Nd ₂ O ₃	0.31	0.32	0.30	0.32	0.32	0.29	0.30	0.31	0.30	0.31	0.29
NiO	0.62	0.67	0.63	0.68	0.64	0.54	0.56	0.57	0.55	0.55	0.56
P ₂ O ₅	¶	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03
PbO	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	46.08	46.38	45.97	46.12	47.10	47.05	47.13	46.90	47.08	47.17
SO ₃	0.08; §	0.06	0.07	0.07	0.06	0.07	0.07	0.06	0.07	0.06	0.07
SrO	0.03	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.04
TiO ₂	¶	0.10	0.09	0.09	0.09	0.10	0.11	0.11	0.10	0.10	0.10
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	2.02	1.91	1.82	1.92	1.85	1.72	1.77	1.78	1.75	1.75	1.76
ZrO ₂	3.82	5.16	4.99	5.20	4.97	4.63	4.72	4.82	4.69	4.63	4.64
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA - Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (wt%), continued.

Test		8					10				
Glass (kg)		34664	35156	35676	36184	36686	37198	37713	38209	38708	39212
Constituent	Target	1F2-G-67B	1F2-G-84A	1F2-G-93B	1F2-G-109A	1F2-G-119A	1I2-G-95A	1I2-G-108A	1I2-G-131B	1I2-G-151B	1J2-G-19A
Al ₂ O ₃	5.21	6.31	6.01	6.03	6.01	5.91	5.79	5.85	5.69	5.75	5.62
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05
CaO	0.28	0.39	0.40	0.39	0.39	0.40	0.41	0.40	0.41	0.41	0.41
CdO	0.06	0.07	0.07	0.06	0.06	0.07	0.06	0.07	0.06	0.08	0.07
Cl	§	0.01	0.01	0.01	0.01	0.02	0.01	0.05	0.11	0.16	0.17
Cr ₂ O ₃	¶	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01
Cs ₂ O	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01
CuO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.05
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	10.84	11.15	10.85	10.95	11.07	11.56	11.41	11.51	11.55	11.46
K ₂ O	0.03	0.22	0.16	0.19	0.18	0.18	0.14	0.14	0.13	0.14	0.12
La ₂ O ₃	0.41	0.41	0.41	0.40	0.40	0.41	0.42	0.43	0.42	0.42	0.43
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.11	0.10	0.13	0.10	0.08	0.08	0.06	0.07	0.04	0.09
MnO	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.18	0.19	0.18
Na ₂ O	11.65	10.41	11.34	11.73	11.51	11.34	11.16	10.89	11.50	11.37	11.28
Nd ₂ O ₃	0.31	0.29	0.30	0.29	0.29	0.30	0.30	0.30	0.31	0.31	0.30
NiO	0.62	0.52	0.55	0.52	0.52	0.54	0.54	0.56	0.59	0.62	0.63
P ₂ O ₅	¶	<0.01	<0.01	0.02	<0.01	0.03	<0.01	<0.01	0.01	0.01	0.01
PbO	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	48.44	47.27	47.43	47.52	47.51	47.02	47.46	46.83	46.52	46.95
SO ₃	0.08; §	0.07	0.07	0.06	0.08	0.10	0.07	0.07	0.07	0.08	0.08
SrO	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
TiO ₂	¶	0.09	0.10	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.09
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	2.02	1.66	1.73	1.65	1.67	1.70	1.77	1.73	1.76	1.75	1.76
ZrO ₂	3.82	4.39	4.58	4.39	4.46	4.50	4.81	4.71	4.66	4.88	4.73
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA - Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (in wt%), continued.

Test		10									
Glass (kg)		39715	40214	40725	41227	41708	42214	42715	43232	43730	43849
Constituent	Target	1J2-G-36B	1J2-G-66A	1J2-G-76B	1J2-G-95B	1J2-G-112A	1J2-G-127A	1J2-G-149B	1K2-G-17A	1K2-G-33A	1K2-G-33B
Al ₂ O ₃	5.21	5.73	6.35	5.75	5.18	5.33	5.42	5.26	5.82	6.31	5.72
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.05	0.07	0.06	0.06	0.05	0.05	0.06	0.05	0.06	0.06
CaO	0.28	0.41	0.40	0.40	0.41	0.40	0.39	0.40	0.40	0.39	0.40
CdO	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Cl	§	0.16	0.10	0.07	0.06	0.09	0.13	0.17	0.17	0.18	0.20
Cr ₂ O ₃	¶	0.01	0.01	0.01	0.21	0.19	0.17	0.21	0.01	0.01	0.01
Cs ₂ O	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
CuO	0.03	0.04	0.03	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	11.52	10.85	11.29	12.14	11.82	11.63	11.69	10.95	10.59	11.21
K ₂ O	0.03	0.14	0.15	0.14	0.12	0.12	0.12	0.12	0.13	0.15	0.13
La ₂ O ₃	0.41	0.42	0.41	0.42	0.44	0.43	0.42	0.42	0.41	0.39	0.41
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.10	0.10	0.09	0.09	0.06	0.14	0.10	0.07	0.13	0.08
MnO	0.17	0.18	0.17	0.18	0.19	0.19	0.18	0.19	0.18	0.17	0.18
Na ₂ O	11.65	11.17	11.03	11.52	11.24	11.43	11.63	11.66	11.75	11.66	11.30
Nd ₂ O ₃	0.31	0.30	0.29	0.30	0.31	0.30	0.30	0.30	0.30	0.28	0.30
NiO	0.62	0.63	0.58	0.60	0.69	0.67	0.65	0.65	0.56	0.53	0.57
P ₂ O ₅	¶	0.01	0.02	<0.01	0.02	0.02	0.02	0.01	0.02	0.02	<0.01
PbO	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	46.71	47.49	46.82	46.25	46.51	46.37	46.42	46.92	47.22	47.01
SO ₃	0.08; §	0.12	0.18	0.22	0.24	0.25	0.27	0.28	0.30	0.28	0.28
SrO	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.04
TiO ₂	¶	0.10	0.11	0.10	0.09	0.09	0.09	0.09	0.09	0.10	0.09
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	2.02	1.78	1.65	1.74	1.80	1.77	1.73	1.73	1.69	1.61	1.73
ZrO ₂	3.82	4.84	4.44	4.72	4.84	4.68	4.67	4.63	4.58	4.33	4.70
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA - Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (wt%), continued.

Test		9									
Glass (kg)		44366	44893	45410	45865	46314	46783	47300	47809	48327	48834
Constituent	Target	1R2-G-25B	1R2-G-52B	1R2-G-60B	1R2-G-71A	1R2-G-96C	1R2-G-113A	1R2-G-124A	1R2-G-139B	1R2-G-151A	1S2-G-17A
Al ₂ O ₃	5.21	5.81	5.93	5.48	5.81	5.36	5.31	5.30	5.42	5.22	5.27
As ₂ O ₃	¶	0.11	0.08	0.07	0.06	0.05	0.03	0.03	0.02	0.02	0.01
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	<0.01	<0.01	<0.01	0.05	<0.01	0.05	0.06	0.04	0.05	0.05
CaO	0.28	0.56	0.50	0.48	0.44	0.43	0.40	0.39	0.38	0.37	0.36
CdO	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	<0.01	0.05	0.06	0.05
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	¶	0.07	0.06	0.05	0.05	0.04	0.03	0.03	0.02	0.02	0.02
Cs ₂ O	<0.01	0.04	0.02	0.02	0.02	0.01	0.01	0.01	<0.01	0.01	<0.01
CuO	0.03	0.07	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	10.86	10.98	11.41	11.46	11.51	11.55	11.14	11.28	11.92	11.74
K ₂ O	0.03	0.16	0.15	0.14	0.15	0.15	0.15	0.15	0.15	0.16	0.15
La ₂ O ₃	0.41	0.27	0.31	0.34	0.36	0.36	0.37	0.37	0.38	0.41	0.41
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.89	0.68	0.61	0.50	0.45	0.36	0.31	0.25	0.24	0.21
MnO	0.17	0.87	1.97	1.66	1.38	1.20	0.98	0.79	0.68	0.60	0.52
Na ₂ O	11.65	12.11	11.49	11.67	11.73	11.14	11.53	12.17	11.49	10.88	12.30
Nd ₂ O ₃	0.31	0.17	0.20	0.23	0.25	0.25	0.27	0.27	0.29	0.31	0.30
NiO	0.62	0.24	0.32	0.38	0.42	0.42	0.46	0.46	0.48	0.54	0.52
P ₂ O ₅	¶	0.10	0.08	0.05	0.05	0.05	0.03	0.03	<0.01	<0.01	0.02
PbO	0.03	0.09	0.07	0.07	0.06	0.06	0.08	0.04	0.04	0.04	0.04
RuO ₂	§	<0.01	<0.01	<0.01	0.01	0.02	0.03	0.04	0.04	0.05	0.05
Sb ₂ O ₃	¶	0.20	0.13	0.12	0.09	0.07	0.06	0.04	0.03	0.03	0.02
SiO ₂	47.41	47.49	46.64	46.23	45.83	47.08	46.69	47.05	47.56	46.84	45.98
SO ₃	0.08; §	0.03	0.03	0.05	0.06	0.06	0.06	0.07	0.07	0.06	0.06
SrO	0.03	0.55	0.43	0.38	0.31	0.26	0.21	0.16	0.13	0.13	0.11
TiO ₂	¶	0.20	0.18	0.15	0.15	0.12	0.11	0.10	0.09	0.09	0.08
Y ₂ O ₃	§	<0.01	<0.01	0.00	0.01	0.03	0.04	0.05	0.05	0.06	0.06
ZnO	2.02	1.80	1.79	1.88	1.87	1.84	1.85	1.75	1.77	1.90	1.87
ZrO ₂	3.82	1.89	2.49	3.06	3.41	3.58	3.79	3.71	3.82	4.50	4.32
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA - Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (wt%), continued.

Test		9									
Glass (kg)		49326	49832	50328	50821	51357	51841	52371	53391	53903	54890
Constituent	Target	1S2-G-46A	1S2-G-55A	1S2-G-72B	1S2-G-82A	1S2-G-101B	1S2-G-117A	1S2-G-130A	1T2-G-15B	1T2-G-28A	1T2-G-64A
Al ₂ O ₃	5.21	5.27	5.24	5.20	5.26	5.29	5.24	5.11	5.24	5.33	5.29
As ₂ O ₃	¶	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91
BaO	0.02	0.05	0.06	0.05	0.06	0.05	0.06	0.05	0.04	0.05	0.06
CaO	0.28	0.36	0.36	0.34	0.34	0.36	0.33	0.35	0.34	0.34	0.33
CdO	0.06	0.05	0.06	0.06	0.07	0.06	0.06	0.07	0.05	0.06	0.07
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	¶	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Cs ₂ O	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CuO	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04
F	0.04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe ₂ O ₃	12.26	11.73	11.95	11.69	11.95	11.91	11.81	12.39	11.74	11.55	11.65
K ₂ O	0.03	0.15	0.15	0.15	0.15	0.16	0.15	0.13	0.16	0.16	0.16
La ₂ O ₃	0.41	0.40	0.41	0.41	0.43	0.41	0.40	0.45	0.41	0.41	0.42
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
MgO	0.11	0.20	0.15	0.17	0.15	0.15	0.13	0.08	0.15	0.08	0.08
MnO	0.17	0.45	0.40	0.36	0.33	0.30	0.28	0.28	0.23	0.23	0.22
Na ₂ O	11.65	12.22	11.60	11.98	11.21	11.63	11.64	11.04	11.51	11.41	11.41
Nd ₂ O ₃	0.31	0.31	0.32	0.32	0.31	0.32	0.32	0.33	0.33	0.32	0.32
NiO	0.62	0.53	0.55	0.50	0.56	0.56	0.57	0.57	0.54	0.51	0.52
P ₂ O ₅	¶	0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
PbO	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
RuO ₂	§	0.05	0.05	0.06	0.07	0.05	0.06	0.07	0.06	0.07	0.07
Sb ₂ O ₃	¶	0.02	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SiO ₂	47.41	46.17	46.48	46.39	46.58	46.36	46.51	46.20	46.85	47.10	46.90
SO ₃	0.08; §	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07
SrO	0.03	0.09	0.08	0.08	0.06	0.06	0.05	0.05	0.04	0.04	0.04
TiO ₂	¶	0.08	0.08	0.07	0.08	0.08	0.07	0.07	0.07	0.07	0.07
Y ₂ O ₃	§	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.08	0.08	0.08
ZnO	2.02	1.85	1.88	1.85	1.91	1.90	1.85	1.99	1.88	1.84	1.87
ZrO ₂	3.82	4.36	4.52	4.63	4.82	4.68	4.79	5.09	4.67	4.73	4.83
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA - Not analyzed

Table 6.2. XRF Analyzed Compositions for Discharged Glass (in wt%), continued.

Test		9			All Tests	
Glass (kg)		55395	55911	56009	5610-43849; 49326-56009	
Constituent	Target	1T2-G-74A	1T2-G-97A	1T2-G-97B	Average	%Dev
Al ₂ O ₃	5.21	5.18	5.18	5.08	5.61	7.75
As ₂ O ₃	¶	<0.01	<0.01	<0.01	<0.01	NC
B ₂ O ₃ *	11.9	11.91	11.91	11.91	11.91	NC
BaO	0.02	0.06	0.06	0.05	0.06	NC
CaO	0.28	0.33	0.33	0.35	0.39	NC
CdO	0.06	0.07	0.07	0.08	0.07	NC
Cl	§	<0.01	0.01	0.01	0.02	NC
Cr ₂ O ₃	¶	0.02	0.02	0.02	0.07	NC
Cs ₂ O	<0.01	<0.01	<0.01	<0.01	<0.01	NC
CuO	0.03	0.04	0.03	0.03	0.03	NC
F	0.04	NA	NA	NA	NC	NC
Fe ₂ O ₃	12.26	12.14	11.77	11.93	11.65	-4.97
K ₂ O	0.03	0.15	0.15	0.15	0.14	NC
La ₂ O ₃	0.41	0.43	0.42	0.45	0.42	1.72
Li ₂ O*	3.52	3.52	3.52	3.52	3.52	NC
MgO	0.11	0.07	0.11	0.15	0.09	NC
MnO	0.17	0.22	0.21	0.21	0.22	NC
Na ₂ O	11.65	11.13	11.84	11.80	11.23	-3.64
Nd ₂ O ₃	0.31	0.32	0.32	0.33	0.31	NC
NiO	0.62	0.58	0.57	0.61	0.58	-5.65
P ₂ O ₅	¶	<0.01	<0.01	0.01	0.02	NC
PbO	0.03	0.04	0.04	0.04	0.03	NC
RuO ₂	§	0.07	0.07	0.07	0.01	NC
Sb ₂ O ₃	¶	<0.01	<0.01	<0.01	<0.01	NC
SiO ₂	47.41	46.45	46.33	46.03	46.81	-1.27
SO ₃	0.08	0.07	0.09	0.08	0.09	NC
SrO	0.03	0.04	0.04	0.04	0.04	NC
TiO ₂	¶	0.08	0.08	0.08	0.09	NC
Y ₂ O ₃	§	0.09	0.09	0.08	0.01	NC
ZnO	2.02	1.96	1.87	1.92	1.79	-11.32
ZrO ₂	3.82	5.03	4.86	4.96	4.79	25.31
Sum	100.00	100.00	100.00	100.00	100.00	NC

* Target values

§ - Spiked constituents; Ru and Y in Test 9, Cl and S in Test 10.

¶ - Not a target constituent

NA – Not analyzed

NC – Not calculated

Table 6.3. Measured Iron Oxidation State from Test 9.

Ru Spiking	Date	Time	Sample I.D.	Glass (kg)	% Fe²⁺/ Total Fe
No	03/24/04	10:50	1R2-G-25B	44366.3	5.8
		21:13	1R2-G-52B	44892.8	8.2
Yes	03/25/04	09:52	1R2-N-63A	45511.4	9.5
		11:39	1R2-N-68A	45567.0	9.9
		13:27	1R2-N-69A	45663.1	8.3
	03/26/04	03:52	1R2-N-99A	46418.1	6.7
		05:45	1R2-N-100A	46522.5	6.6
		11:15	1R2-N-114A	46835.0	8.2
	03/27/04	16:14	1R2-G-151A	48327.0	8.4
		17:15	1R2-N-152A	48378.0	8.4
	03/29/04	07:04	1S2-N-73A	50377.1	9.1
		16:40	1S2-N-84A	50874.5	7.8
	03/30/04	10:44	1S2-N-122A	51999.8	9.1
		12:04	1S2-N-124A	52105.8	7.3
		20:51	1S2-N-134A	52625.6	8.3

Table 7.1. Summary of Method 29 Particulate Matter Results.

-	Outlet Location	Sampling Interval	Total wt. gain (mg)	Meter Volume (dscf)	Conc. (mg/dscf)	Flow Rate (dscfm)	Emission Rate (mg/min)	Moisture (% Vol.)	% Isokinetic
Test 2	Melter	06/01/03 10:24 – 11:24	334.9	23.886	14.0	203	2848	15.9	91.5
	Melter	06/03/03 11:10 – 12:10	379.4	24.302	15.6	210	3271	19.7	92.7
	Melter	06/05/03 12:01 – 13:01	576.4	26.178	22.0	197	4336	20.8	103.5
	SBS	06/01/03 10:10 – 12:10	30.6	65.590	0.467	227	106	8.08	105.5
	SBS	06/03/03 10:35 – 12:35	24.8	61.309	0.405	213	86.3	7.60	105.0
	SBS	06/05/03 10:58 – 12:58	20.2	61.277	0.330	212	70.0	7.89	105.5
	WESP	06/04/03 07:55 – 20:27, 06/04/03 20:32 – 06/05/03 08:32, 06/05/03 08:55 – 21:52	15.2	1553.428	0.0098	214	2.10	7.17	100.0, 99.6, 99.6
Test 1	Melter	06/28/03 10:02 – 10:27	577.4	19.432	29.7	187	5568	26.72	104.5
	Melter	06/30/03 09:15 – 10:15	2225.8	46.956	47.4	189	8935	24.84	104.6
	Melter	07/02/03 08:43 – 09:13	973.4	24.095	40.4	176	7128	28.00	114.6
	SBS	06/28/03 09:55 – 12:15	336.0	125.819	2.67	220	588	7.54	103.6
	SBS	06/30/03 09:18 – 11:32	98.0	99.887	0.981	210	206	9.69	99.9
	SBS	07/02/03 07:30-08:50	51.6	61.757	0.836	202	169	7.57	96.3
	WESP	06/29/03 07:25 – 20:00, 07/01/03 06:45 – 19:30	0.02	1076.110	0.019	214	4.06	7.47	103.8, 103.7
Test 3	Melter	07/19/03 16:55 – 17:15	1174.2	13.515	86.9	194	16838	37.01	103.7
	Melter	07/22/03 10:30 – 11:30	2785.8	38.810	71.8	164	11776	33.78	117.2
	SBS	07/19/03 16:20 – 18:20	56.6	58.242	0.972	214	208	15.46	97.4
	SBS	07/22/03 09:40 – 11:40	45.6	63.061	0.723	225	163	10.45	100.3
	WESP	07/20/03 07:50 – 21:00, 07/21/03 07:10 – 19:30	15.6	791.973	0.0197	198	3.89	9.33	102.4, 102.9
Test 8	Melter	08/10/03 11:30 – 12:30	1798	33.925	53.0	155	8215	39.66	109.4
	Melter	08/12/03 14:46 – 15:46	4030	33.951	118.7	172	20444	40.91	98.5
	SBS	08/10/03 10:50 – 12:50	NA	60.989	NA	206	NA	12.0	104.2
	SBS	08/12/03 14:03 – 16:03	60.4	62.532	0.966	212	204.7	12.9	103.5
	WESP	08/10 – 08/11/03 16:10 – 15:40 08/11 – 08/12/03 16:00 – 13:47	10.8	734.196	0.0147	208	3.06	11.7, 12.1	105.8, 104.5

Table 7.1. Summary of Method 29 Particulate Matter Results, continued

-	Outlet Location	Sampling Interval	Total wt. gain (mg)	Meter Volume (dscf)	Conc. (mg/dscf)	Flow Rate (dscfm)	Emission Rate (mg/min)	Moisture (% Vol.)	% Isokinetic
Test 10	Melter	09/06/03 11:12 – 12:12	2228.2	49.898	44.7	179	7987	26.8	110.9
	Melter	09/08/03 12:57 – 13:57	3552.8	40.930	86.8	168	14588	30.1	97.6
	Melter	09/09/03 19:48 – 20:38	1639.3	35.581	46.1	176	8111	28.0	97.2
	SBS	09/06/03 10:49 – 12:49	80.5	61.952	1.30	234	303	7.4	100.1
	SBS	09/08/03 12:15 – 14:15	65.9	58.864	1.12	217	242	8.8	102.5
	SBS	09/09/03 18:40 – 20:40	100.4	57.958	1.70	217	376	8.6	100.6
	WESP	09/06 - 09/07/03 16:20 – 16:20, 09/08 - 09/09/03 16:20 – 17:15	34.5	770.284	0.04	225	10	7.0, 8.3	99.6, 102.5
Test 9	Melter	03/29/04 10:57 – 11:14	541.9	11.838	45.8	184	8427	32.7	94
	Melter	03/29/04 12:55 – 14:55	2686	61.525	43.7	184	8041	32.4	115
	Melter	03/29/04 16:46 – 18:46	1134	64.367	17.6	188	3309	32.2	117
	Melter	03/31/04 09:08 – 10:08	2601	31.601	82.3	169	13909	37.6	104
	Melter	03/31/04 11:28 – 12:28	3068	37.160	82.5	185	15263	37.2	103
	Melter	03/31/04 14:44-15:44	2730	36.949	73.9	204	15076	36.7	101
	SBS	03/29/04 10:20 – 11:19	34.9	37.186	0.9	217	195	12.5	87
	SBS	03/29/04 12:34 – 15:05	136.9	104.585	1.3	218	283	11.5	102
	SBS	03/29/04 16:35 – 18:50	141.7	99.648	1.4	214	300	12.0	102
	SBS	03/31/04 08:57 – 10:17	81.2	60.637	1.3	217	282	12.0	104
	SBS	03/31/04 11:20 – 12:40	73.6	61.079	1.2	221	265	11.2	103
	SBS	03/31/04 14:29-15:49	59.8	61.117	1.0	219	219	12.4	104

Table 7.2. Results from Test 2B Emissions Sampling.

		Feed Rate (mg/min)	Melter			SBS		
			Emissions Rate (mg/min)	% Feed	DF	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS
Particulate	Total ^s	505800	2848	0.56	177.6	106	3.72	26.9
	Al	11852	54.19	0.46	218.7	0.14	0.26	387.1
	B	15894	151.88	0.96	104.6	0.71	0.47	213.9
	Ba	77	0.35	0.46	218.4	< 0.10	< 28.5	> 3.5
	Ca	861	8.59	1.00	100.2	0.31	3.61	27.7
	Cd	231	1.05	0.45	220.8	< 0.10	< 9.52	> 10.5
	Cu	103	0.48	0.46	215.2	< 0.10	< 20.83	> 4.8
	F*	172	7.03	4.09	24.5	NA	NA	NA
	Fe	36863	285.66	0.77	129.0	0.54	0.19	529.0
	K	107	4.15	3.88	25.8	0.58	13.98	7.2
	Li	7031	28.73	0.41	244.7	1.88	6.54	15.3
	Mg	285	5.18	1.82	55.0	< 0.10	< 1.93	> 51.8
	Mn	566	7.44	1.31	76.1	0.17	2.28	43.8
	Na	37167	274.33	0.74	135.5	21.86	7.97	12.5
	Ni	2095	12.58	0.60	166.5	< 0.10	< 0.79	> 125.8
	Pb	120	0.88	0.73	136.3	0.44	50.00	2.0
	S	138	21.27	15.43	6.5	13.02	61.21	1.6
	Si	95279	356.56	0.37	267.2	0.40	0.11	891.4
	Sr	109	1.70	1.56	64.1	< 0.10	< 5.88	> 17.0
	Zn	6978	81.95	1.17	85.1	0.45	0.55	182.1
	Zr	12160	62.29	0.51	195.2	< 0.10	< 0.16	> 622.9
Gas	B	15894	92.23	0.58	172.3	3.87	4.20	23.8
	F	172	< 0.10	< 0.01	> 1720	< 0.10	NC	NC
	I	< 430 [#]	95.74	NC	NC	0.49	0.51	195.4
	S	138	< 0.10	< 0.01	> 1380	10.59	NC	NC

^s - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

- Amount of iodine in residual feed not rigorously known.

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.3. Results from Test 2C Emissions Sampling.

		Feed Rate (mg/min)	Melter			SBS		
			Emissions Rate (mg/min)	% Feed	DF	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS
Particulate	Total ^{\$}	645100	3271	0.51	197.2	86.3	2.64	37.9
	Al	15113	60.10	0.40	251.5	< 0.10	< 0.01	> 601
	B	20268	165.42	0.82	122.5	0.92	0.56	179.8
	Ba	98	0.46	0.47	212.3	< 0.10	< 0.22	> 4.6
	Ca	1097	9.89	0.90	111.0	0.17	1.72	58.2
	Cd	295	1.07	0.36	276.4	< 0.10	< 0.09	> 10.7
	Cu	131	0.53	0.40	247.1	< 0.10	< 0.19	> 5.3
	F*	219	12.38	5.65	17.7	NA	NA	NA
	Fe	47007	336.02	0.71	139.9	0.37	0.11	908.2
	K	137	3.58	2.62	38.1	0.26	7.26	13.8
	Li	8966	31.19	0.35	287.5	1.60	5.13	19.5
	Mg	364	5.68	1.56	64.0	< 0.10	< 0.02	> 56.8
	Mn	722	3.04	0.42	237.8	< 0.10	< 0.03	> 30.4
	Na	47395	306.61	0.65	154.6	17.10	5.58	17.9
	Ni	2671	14.43	0.54	185.1	< 0.10	< 0.01	> 144.3
	Pb	153	1.62	1.06	94.3	0.24	14.81	6.8
	S	176	18.56	10.56	9.5	8.36	45.04	2.2
	Si	121499	370.81	0.31	327.7	0.25	0.07	1483.2
	Sr	139	1.90	1.37	73.2	< 0.10	< 0.05	> 19
	Zn	8899	70.42	0.79	126.4	0.32	0.45	220.1
	Zr	15507	57.19	0.37	271.1	< 0.10	< 0.01	> 571.9
Gas	B	20268	110.10	0.54	184.1	3.10	2.82	35.5
	F	219	< 0.10	< 0.01	> 2190	< 0.10	NC	NC
	I	< 548 [#]	26.89	NC	NC	0.45	1.67	59.8
	S	176	0.69	0.40	253.1	13.55	NC	0.1

^{\$} - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

- Amount of iodine in residual feed not rigorously known.

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.4. Results from Test 2D Emissions Sampling.

-		Feed Rate (mg/min)	Melter			SBS			Wesp			
			Emissions Rate (mg/min)	Percent Feed	DF Across Melter	Emissions Rate (mg/min)	Percent of Melter Emissions	DF Across SBS	Emissions Rate (mg/min)	Percent of SBS Emissions	DF Across Wesp	Cumulative DF
Particulate	Total ^{\$}	658800	4336	0.66	151.9	70.0	1.61	61.9	2.1	3.00	33.4	313714
	Al	15435	86.54	0.56	178.4	0.12	0.14	721.2	< 0.10	< 83.33	> 1.2	> 154350
	B	20699	219.32	1.06	94.4	0.78	0.36	281.2	< 0.10	< 12.82	> 7.8	> 206990
	Ba	100	0.60	0.59	168.3	< 0.10	16.67	6.0	< 0.10	NC	NC	1000
	Ca	1121	10.92	0.97	102.6	0.22	2.01	49.6	< 0.10	< 45.45	> 2.2	> 11210
	Cd	301	1.64	0.55	183.2	< 0.10	6.10	16.4	< 0.10	NC	NC	3010
	Cu	134	0.81	0.60	166.1	< 0.10	12.35	8.1	< 0.10	NC	NC	1340
	F*	224	16.77	7.49	13.4	NA	NA	NA	NA	NA	NA	NA
	Fe	48008	442.80	0.92	108.4	0.43	0.10	1029.8	< 0.10	< 23.26	> 4.3	> 480080
	K	139	3.12	2.24	44.7	0.25	8.01	12.5	< 0.10	< 40.00	> 2.5	> 1390
	Li	9157	36.26	0.40	252.5	1.37	3.78	26.5	< 0.10	< 7.30	> 13.7	> 91570
	Mg	371	5.88	1.58	63.2	< 0.10	1.70	58.8	< 0.10	NC	NC	3710
	Mn	737	3.93	0.53	187.8	< 0.10	2.54	39.3	< 0.10	NC	NC	7370
	Na	48404	406.59	0.84	119.0	17.72	4.36	22.9	0.48	2.71	36.9	100840
	Ni	2728	19.18	0.70	142.2	< 0.10	0.52	191.8	< 0.10	NC	NC	27280
	Pb	156	0.83	0.53	187.6	0.26	31.33	3.2	< 0.10	< 38.46	> 2.6	> 1560
	S	180	28.36	15.80	6.3	9.24	32.58	3.1	0.13	1.41	71.1	1385
	Si	124084	546.56	0.44	227.0	0.26	0.05	2102.2	< 0.10	< 38.46	> 2.6	> 1240840
	Sr	142	1.27	0.90	111.7	< 0.10	7.87	12.7	< 0.10	NC	NC	> 1420
	Zn	9088	82.31	0.91	110.4	0.35	0.43	235.2	< 0.10	< 28.57	> 3.5	> 90880
	Zr	15837	97.23	0.61	162.9	< 0.10	0.10	972.3	< 0.10	NC	NC	> 158370
Gas	B	20699	118.68	0.57	174.4	2.99	2.52	39.7	0.66	22.07	4.5	31360
	F	224	< 0.10	< 0.01	> 2240	< 0.10	NC	NC	< 0.10	NC	NC	2240
	I	< 560 [#]	6.40	NC	NC	< 0.10	1.56	64.0	0.23	NC	NC	NC
	S	180	44.43	24.75	4.0	< 0.10	0.23	444.3	< 0.10	NC	NC	1800

^{\$} - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

- Amount of iodine in residual feed not rigorously known.

NC - Not calculated

NA - Not available due to insufficient particulate loading for separate anion analysis

Table 7.5. Results from Test 1B Emissions Sampling.

-		Feed Rate (mg/min)	Melter			SBS		
			Emissions Rate (mg/min)	% Feed	DF	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS
Particulate	Total ^s	1060700	5568	0.52	190.5	588	10.56	9.5
	Al	24852	90.01	0.36	276.1	8.74	9.71	10.3
	B	33327	328.96	0.99	101.3	29.97	9.11	11.0
	Ba	162	0.72	0.45	224.3	< 0.10	< 13.89	> 7.2
	Ca	1805	16.56	0.92	109.0	1.24	7.49	13.4
	Cd	484	4.02	0.83	120.6	0.63	15.67	6.4
	Cu	216	0.71	0.33	303.1	< 0.10	< 14.08	> 7.1
	F	361	NA	NA	NA	NA	NA	NA
	Fe	77298	603.81	0.78	128.0	30.27	5.01	19.9
	K	225	7.99	3.56	28.1	1.35	16.90	5.9
	Li	14743	59.47	0.40	247.9	7.26	12.21	8.2
	Mg	598	8.39	1.40	71.3	0.65	7.75	12.9
	Mn	1187	4.11	0.35	288.9	0.28	6.81	14.7
	Na	77936	583.60	0.75	133.5	69.81	11.96	8.4
	Ni	4393	20.76	0.47	211.6	1.90	9.15	10.9
	Pb	251	2.57	1.02	97.6	0.52	20.23	4.9
	S	289	43.07	14.90	6.7	15.04	34.92	2.9
	Si	199790	525.48	0.26	380.2	44.02	8.38	11.9
	Sr	229	1.54	0.67	148.3	< 0.10	< 6.49	> 15.4
	Zn	14633	100.83	0.69	145.1	7.38	7.32	13.7
Zr	25499	48.33	0.19	527.6	6.73	13.93	7.2	
Gas	B	33327	208.33	0.63	160.0	4.70	2.26	44.3
	F	361	< 0.10	< 0.01	> 3610	< 0.10	NC	NC
	S	289	97.00	33.56	3.0	0.25	0.26	388.0

^s - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.6. Results from Emissions Sampling Test 1C.

-		Feed Rate (mg/min)	Melter			SBS		
			Emissions Rate (mg/min)	% Feed	DF	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS
Particulate	Total ^s	1121500	8935	0.80	125.5	206	2.31	43.37
	Al	26276	115.90	0.44	226.7	0.78	0.67	148.6
	B	35237	497.40	1.41	70.8	9.40	1.89	52.9
	Ba	171	1.31	0.76	130.8	< 0.10	< 7.63	> 13.1
	Ca	1908	24.91	1.31	76.6	0.32	1.28	77.8
	Cd	512	5.86	1.14	87.5	0.36	6.14	16.3
	Cu	228	1.40	0.61	163.8	< 0.10	< 7.14	> 14.0
	F*	381	357.17	93.75	1.1	NA	NA	NA
	Fe	81727	790.61	0.97	103.4	3.43	0.43	230.5
	K	237	9.84	4.14	24.1	1.13	11.48	8.7
	Li	15588	68.47	0.44	227.7	3.78	5.52	18.1
	Mg	632	12.15	1.92	52.0	< 0.10	< 0.82	> 121.5
	Mn	1255	5.89	0.47	213.2	0.41	6.96	14.4
	Na	82402	849.29	1.03	97.0	42.19	4.97	20.1
	Ni	4645	33.71	0.73	137.8	0.21	0.62	160.5
	Pb	265	4.64	1.75	57.2	0.52	11.21	8.9
	S	306	57.46	18.80	5.3	14.00	24.36	4.1
	Si	211238	675.56	0.32	312.7	5.93	0.88	113.9
	Sr	242	2.71	1.12	89.2	< 0.10	< 3.69	> 27.1
	Zn	15471	157.50	1.02	98.2	1.25	0.79	126.0
	Zr	26960	65.50	0.24	411.6	0.31	0.47	211.3
Gas	B	35237	242.83	0.69	145.1	5.73	2.36	42.4
	F	381	< 0.10	< 0.01	> 3810	< 0.10	NC	NC
	S	306	95.37	31.20	3.2	0.19	0.20	501.9

^{\$} - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.7. Results from Test 1D Emissions Sampling.

-		Feed Rate (mg/min)	Melter			SBS			WESP			
			Emissions Rate (mg/min)	%of Feed	DF Across Melter	Emissions Rate (mg/min)	Percent of Melter Emissions	DF Across SBS	Emissions Rate (mg/min)	Percent of SBS Emissions	DF Across Wesp	Cumulative DF
Particulate	Total ^s	1081300	7128	0.66	151.7	169	2.37	42.2	4.06	2.4	41.6	266300
	Al	25334	141.14	0.56	179.5	0.49	0.35	288.0	< 0.10	< 20.41	> 4.9	> 253340
	B	33974	438.46	1.29	77.5	6.75	1.54	65.0	0.13	1.93	51.9	261338
	Ba	165	1.13	0.69	145.5	<0.10	< 8.85	> 11.3	<0.10	NC	NC	> 1650
	Ca	1840	24.61	1.34	74.8	0.27	1.10	91.1	<0.10	< 37.04	> 2.7	> 18400
	Cd	494	5.31	1.08	93.0	0.18	3.39	29.5	<0.10	< 55.56	> 1.8	> 4940
	Cu	220	1.16	0.53	189.4	<0.10	< 8.62	> 11.6	<0.10	NC	NC	> 2200
	F*	368	208.68	56.7	1.8	NA	NA	NA	NA	NA	NA	NA
	Fe	78798	742.77	0.94	106.1	3.06	0.41	242.7	<0.10	< 3.27	> 30.6	> 787980
	K	229	9.38	4.10	24.4	1.21	12.90	7.8	<0.10	< 8.26	> 12.1	> 2290
	Li	15030	81.67	0.54	184.0	3.29	4.03	24.8	<0.10	< 3.04	> 32.9	> 150300
	Mg	610	12.16	1.99	50.1	<0.10	< 0.82	> 121.6	<0.10	NC	NC	> 6100
	Mn	1210	7.65	0.63	158.3	0.11	1.44	69.5	<0.10	< 90.91	> 1.1	> 12100
	Na	79449	761.44	0.96	104.3	33.85	4.45	22.5	0.89	2.63	38.0	89269
	Ni	4478	28.36	0.63	157.9	0.22	0.78	128.9	<0.10	< 45.45	> 2.2	> 44780
	Pb	256	3.85	1.50	66.5	0.65	16.88	5.9	<0.10	< 15.38	> 6.5	> 2560
	S	295	39.21	13.30	7.5	13.53	34.51	2.9	0.15	1.11	90.2	1967
	Si	203668	657.20	0.32	309.9	3.09	0.47	212.7	0.23	7.44	13.4	885513
	Sr	233	2.10	0.90	111.2	<0.10	< 4.76	> 21.0	<0.10	NC	NC	> 2330
	Zn	14917	140.75	0.94	106.0	1.08	0.77	130.3	<0.10	< 9.26	> 10.8	> 149170
Zr	25994	85.99	0.33	302.3	<0.10	< 0.12	> 859.9	<0.10	NC	NC	> 259940	
Gas	B	33974	205.22	0.60	165.6	6.14	2.99	33.4	0.89	14.50	6.9	38173
	F	368	< 0.10	< 0.01	> 3680	<0.10	NC	NC	< 0.10	NC	NC	> 3680
	S	295	91.80	31.15	3.2	0.48	0.52	191.3	0.2	41.67	2.4	1475

^{\$} - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.8. Results from Test 3B Emissions Sampling.

	-	Feed Rate (mg/min)	Melter			SBS		
			Emissions Rate (mg/min)	% Feed	DF	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS
Particulate	Total ^{\$}	1344400	16838	1.25	79.8	208.1	1.24	80.9
	Al	31205	349.50	1.12	89.3	0.52	0.15	672.1
	B	41847	855.80	2.05	48.9	7.24	0.85	118.2
	Ba	203	2.18	1.08	92.9	< 0.10	< 4.59	> 21.8
	Ca	2266	40.03	1.77	56.6	0.84	2.10	47.7
	Cd	608	8.87	1.46	68.6	0.48	5.41	18.5
	Cu	271	3.70	1.36	73.4	< 0.10	< 2.70	> 37.0
	F*	453	244.29	53.93	1.9	NA	NA	NA
	Fe	97058	1565.19	1.61	62.0	3.58	0.23	437.2
	K	282	15.46	5.48	18.2	1.48	9.57	10.4
	Li	18512	172.17	0.93	107.5	3.66	2.13	47.0
	Mg	751	20.64	2.75	36.4	0.11	0.53	187.6
	Mn	1491	12.80	0.86	116.4	< 0.10	< 0.78	> 128.0
	Na	97859	1519.70	1.55	64.4	44.65	2.94	34.0
	Ni	5516	69.42	1.26	79.5	0.53	0.76	131.0
	Pb	315	7.81	2.48	40.4	0.33	4.23	23.7
	S	363	83.82	23.09	4.3	16.23	19.36	5.2
	Si	250864	1977.69	0.79	126.8	3.17	0.16	623.9
	Sr	287	3.92	1.37	73.2	< 0.10	< 2.55	> 39.2
	Zn	18373	268.69	1.46	68.4	1.50	0.56	179.1
	Zr	32017	371.53	1.16	86.2	< 0.10	< 0.03	> 3715.3
Gas	B	41847	390.30	0.93	107.2	7.72	1.98	50.6
	F	453	< 0.10	< 0.01	> 4530	< 0.10	NC	NC
	S	363	147.91	40.75	2.5	0.56	0.38	264.1

^{\$} - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.9. Results from Test 3C Emissions Sampling.

-		Feed Rate (mg/min)	Melter			SBS			WESP			
			Emissions Rate (mg/min)	% of Feed	DF Across Melter	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS	Emissions Rate (mg/min)	% of SBS Emissions	DF Across WESP	Cumulative DF
Particulate	Total ^s	1085500	11776	1.08	92.2	162.8	1.38	72.3	3.89	2.39	41.9	279050
	Al	25196	278.71	1.11	90.4	0.44	0.16	633.4	0.1	22.73	4.4	251960
	B	33789	604.33	1.79	55.9	3.17	0.52	190.6	< 0.10	< 3.15	> 31.7	> 337890
	Ba	164	1.73	1.06	94.6	< 0.10	< 0.06	> 1730.0	< 0.10	NC	NC	> 1640
	Ca	1830	31.11	1.70	58.8	0.44	1.41	70.7	< 0.10	< 22.73	> 4.4	> 18300
	Cd	491	6.71	1.37	73.2	0.30	4.47	22.4	< 0.10	< 33.33	> 3.0	> 4910
	Cu	219	2.93	1.34	74.9	< 0.10	< 0.03	> 2930.0	< 0.10	NC	NC	> 2190
	F*	366	486.75	1.33	0.8	NA	NA	NA	NA	NA	NA	NA
	Fe	78370	1024.18	1.31	76.5	2.60	0.25	393.9	< 0.10	< 3.85	> 26.0	> 783700
	K	228	10.80	4.74	21.1	0.94	8.70	11.5	< 0.10	< 10.64	> 9.4	> 2280
	Li	14948	122.28	0.82	122.2	3.33	2.72	36.7	< 0.10	< 3.00	> 33.3	> 149480
	Mg	606	15.47	2.55	39.2	< 0.10	< 0.01	> 15470	< 0.10	NC	NC	> 6060
	Mn	1204	10.93	0.91	110.1	0.24	2.20	45.5	< 0.10	< 41.67	> 2.4	> 12040
	Na	79016	999.11	1.26	79.1	32.12	3.21	31.1	0.58	1.81	321.2	790160
	Ni	4454	52.18	1.17	85.3	0.26	0.50	200.7	< 0.10	< 38.46	> 2.6	> 44540
	Pb	255	6.42	2.52	39.6	0.34	5.30	18.9	< 0.10	< 29.41	> 3.4	> 2550
	S	293	54.21	18.50	5.4	13.58	25.05	4.0	0.14	1.03	135.8	2930
	Si	202560	1301.11	0.64	155.7	2.14	0.16	608.0	< 0.10	< 4.67	> 21.4	> 2025600
	Sr	232	3.03	1.31	76.6	< 0.10	< 3.30	> 30.3	< 0.10	NC	NC	> 2320
	Zn	14836	199.87	1.35	74.2	1.00	0.50	199.9	< 0.10	< 10.00	> 10.0	> 148360
Zr	25852	328.48	1.27	78.7	< 0.10	< 0.01	> 328480	< 0.10	NC	NC	> 258520	
Gas	B	33789	232.33	0.69	145.4	6.93	2.98	33.5	0.79	11.40	69.3	337890
	F	366	< 0.10	< 0.01	> 3660	< 0.10	NC	NC	< 0.10	NC	NC	> 3660
	S	293	117.44	40.07	2.5	0.42	0.36	279.6	0.26	61.90	4.2	2930

^s - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC - Not calculated

NA - Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.10. Results from Test 8B Emissions Sampling.

		Feed Rate (mg/min)	Melter			SBS		
			Emissions Rate (mg/min)	% Feed	DF	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS
Particulate	Total ^s	1412700	8215	0.58	172.0	NA	NA	NA
	Al	32789	134.46	0.41	243.9	0.67	0.50	200.7
	B	43973	365.00	0.83	120.5	4.03	1.10	90.6
	Ba	213	1.28	0.60	167.1	< 0.10	< 7.81	> 12.8
	Ca	2381	22.54	0.95	105.6	1.08	4.79	20.9
	Cd	639	5.69	0.89	112.4	0.43	7.56	13.2
	Cu	285	1.40	0.49	203.9	< 0.10	< 7.14	> 14.0
	F*	476	425.77	89.45	1.1	NA	NA	NA
	Fe	101988	759.44	0.74	134.3	4.41	0.58	172.2
	K	296	9.47	3.20	31.3	1.14	12.04	8.3
	Li	19453	71.61	0.37	271.7	3.21	4.48	22.3
	Mg	789	10.36	1.31	76.1	0.19	1.83	54.5
	Mn	1566	6.14	0.39	255.1	0.16	2.61	38.4
	Na	102829	739.32	0.72	139.1	45.97	6.22	16.1
	Ni	5796	26.90	0.46	215.5	0.18	0.67	149.4
	Pb	331	4.15	1.25	79.8	0.40	9.64	10.4
	S	381	50.29	13.19	7.6	13.46	26.76	3.7
	Si	263605	831.56	0.32	317.0	2.94	0.35	282.8
	Sr	302	2.61	0.86	115.7	< 0.10	< 3.83	> 26.1
	Zn	19307	130.82	0.68	147.6	1.45	1.11	90.2
	Zr	33643	112.98	0.34	297.8	0.12	0.11	941.5
Gas	B	43973	488.65	1.11	90.0	8.02	1.64	60.9
	F	476	3.27	0.69	145.5	< 0.10	< 3.06	> 32.7
	S	381	115.63	30.32	3.3	0.57	0.49	202.9

^s - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.11. Results from Test 8C Emissions Sampling.

-		Feed Rate (mg/min)	Melter			SBS			WESP			
			Emissions Rate (mg/min)	% of Feed	DF Across Melter	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS	Emissions Rate (mg/min)	% of SBS Emissions	DF Across WESP	Cumulative DF
Particulate	Total ^{\$}	1439800	20444	1.42	70.4	204.7	1.00	99.9	3.06	1.49	66.9	470523
	Al	33419	424.61	1.27	78.7	0.52	0.12	816.6	< 0.10	< 0.19	> 520.0	> 334190
	B	44817	1123.25	2.51	39.9	6.81	0.61	164.9	< 0.10	< 0.01	> 6810.0	> 448170
	Ba	217	3.56	1.64	61.0	< 0.10	2.81	35.6	< 0.10	NC	NC	> 2170
	Ca	2427	59.84	2.47	40.6	0.88	1.47	68.0	< 0.10	< 0.11	> 880.0	> 24270
	Cd	651	14.18	2.18	45.9	0.53	3.74	26.8	< 0.10	< 0.19	> 530.0	> 6510
	Cu	291	4.39	1.51	66.2	< 0.10	2.28	43.9	< 0.10	NC	NC	> 2910
	F	485	708.36	> 100	< 1	NA	NA	NA	NA	NA	NA	NA
	Fe	103945	1857.40	1.79	56.0	4.27	0.23	435.0	< 0.10	< 0.02	> 4270.0	> 1039450
	K	302	15.40	5.10	19.6	0.65	4.22	23.7	< 0.10	< 0.15	> 650.0	> 3020
	Li	19826	168.25	0.85	117.8	4.14	2.46	40.6	< 0.10	< 0.02	> 4140.0	> 198260
	Mg	804	27.34	3.40	29.4	0.14	0.51	195.3	< 0.10	< 0.71	> 140.0	> 8040
	Mn	1596	16.37	1.03	97.5	0.10	0.61	163.7	< 0.10	< 1.00	> 100.0	> 15960
	Na	104803	1897.88	1.81	55.2	47.25	2.49	40.2	0.69	0.01	6847.8	151888
	Ni	5907	84.41	1.43	70.0	0.23	0.27	367.0	< 0.10	< 0.43	> 230.0	> 59070
	Pb	338	11.90	3.53	28.4	0.32	2.69	37.2	< 0.10	< 0.31	> 320.0	> 3380
	S	389	72.61	18.68	5.4	15.23	20.98	4.8	< 0.10	< 0.01	> 15230.0	> 3890
	Si	268664	2543.73	0.95	105.6	2.39	0.09	1064.3	< 0.10	< 0.04	> 2390.0	> 2686640
	Sr	308	6.81	2.21	45.2	< 0.10	1.47	68.1	< 0.10	NC	NC	3080
	Zn	19677	337.47	1.72	58.3	1.62	0.48	208.3	< 0.10	< 0.06	> 1620.0	> 196770
Zr	34289	508.36	1.48	67.5	0.17	0.03	2990.4	< 0.10	< 0.59	> 170.0	> 342890	
Gas	B	44817	413.98	0.92	108.3	8.64	2.09	47.9	1.10	0.13	785.5	40743
	F	485	1.44	0.30	337.1	< 0.10	6.94	14.4	< 0.10	NC	NC	> 4850
	S	389	155.72	40.06	2.5	0.27	0.17	576.7	0.15	0.56	180.0	2593

^{\$} - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.12. Results from Test 10B Emissions Sampling.

		Feed Rate (mg/min)	Melter			SBS		
			Emissions Rate (mg/min)	% Feed	DF	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS
Particulate	Total ^s	861900	7987	0.93	107.9	303	3.79	26.4
	Al	20005	120.66	0.60	165.8	0.53	0.44	227.7
	B	26828	291.18	1.09	92.1	0.50	0.17	582.4
	Ba	130	1.22	0.94	106.7	< 0.10	< 8.20	> 12.2
	Ca	1453	24.05	1.66	60.4	1.22	5.07	19.7
	Cd	390	6.16	1.58	63.4	0.20	3.25	30.8
	Cl*	3629	608.36	16.76	6.0	NA	NA	NA
	Cu	174	2.17	1.24	80.3	< 0.10	< 4.61	> 21.7
	F*	290	192.81	66.49	1.5	NA	NA	NA
	Fe	62224	752.00	1.21	82.7	2.32	0.31	324.1
	K	181	10.12	5.60	17.9	1.22	12.06	8.3
	Li	11868	74.98	0.63	158.3	2.92	3.89	25.7
	Mg	481	12.00	2.49	40.1	0.16	1.33	75.0
	Mn	956	5.17	0.54	184.8	0.16	3.09	32.3
	Na	65107	966.75	1.48	67.3	88.11	9.11	11.0
	Ni	3536	26.96	0.76	131.2	0.14	0.52	192.6
	Pb	202	4.82	2.39	41.9	0.53	11.00	9.1
	S	233	50.27	21.60	4.6	10.52	20.93	4.8
	Si	160829	546.15	0.34	294.5	1.71	0.31	319.4
	Sr	184	2.81	1.53	65.5	< 0.10	< 3.56	> 28.1
	Zn	11779	133.64	1.13	88.1	0.73	0.55	183.1
	Zr	20526	53.97	0.26	380.3	0.19	0.35	284.1
G a s	B	26828	259.34	0.97	103.4	10.39	4.01	25.0
	Cl	3629	569.05	15.68	6.4	33.08	5.81	17.2
	F	290	85.09	29.31	3.4	< 0.10	< 0.12	> 850.9
	S	233	66.43	28.55	3.5	1.45	2.18	45.8

^{\$} - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.13. Results from Test 10C Emissions Sampling.

-		Feed Rate (mg/min)	Melter			SBS			WESP			
			Emissions Rate (mg/min)	% Feed	DF	Emissions Rate (mg/min)	% of Melter Emissions	DF Across SBS	Emissions (mg/min)	% of SBS Emissions	DF Across WESP	Cumulative DF
Particulate	Total ^s	734200	14588	1.99	50.3	242	1.66	60.3	10	4.13	24.2	73420
	Al	17042	314.91	1.85	54.1	0.43	0.14	732.3	<0.10	23.26	4.3	170420
	B	22855	607.82	2.66	37.6	1.56	0.26	389.6	<0.10	6.41	15.6	228550
	Ba	111	2.49	2.25	44.5	<0.10	<4.02	>24.9	<0.10	NC	NC	1110
	Ca	1238	44.79	3.62	27.6	1.51	3.37	29.7	<0.10	6.62	15.1	12380
	Cd	332	7.33	2.21	45.3	0.11	1.50	66.6	<0.10	90.91	1.1	3320
	Cl*	0	274.57	NC	NC	NA	NA	NA	NA	NA	NA	NA
	Cu	148	3.66	2.47	40.5	<0.10	<2.73	>36.6	<0.10	NC	NC	1480
	F*	247	139.74	56.57	1.77	NA	NA	NA	NA	NA	NA	NA
	Fe	53008	1320.97	2.49	40.1	1.77	0.13	746.3	<0.10	5.65	17.7	530080
	K	154	10.86	7.05	14.2	2.04	18.78	5.3	<0.10	4.90	20.4	1540
	Li	10111	118.57	1.17	85.3	3.62	3.05	32.8	<0.10	2.76	36.2	101110
	Mg	410	21.23	5.18	19.3	0.14	0.66	151.6	<0.10	71.43	1.4	4100
	Mn	814	13.35	1.64	61.0	<0.10	<0.75	>133.5	<0.10	NC	NC	8140
	Na	54868	1365.96	2.49	40.2	59.58	4.36	22.9	0.83	1.39	71.8	66106
	Ni	3013	65.09	2.16	46.3	0.16	0.25	406.8	<0.10	62.50	1.6	30130
	Pb	172	7.48	4.35	23.0	0.48	6.42	15.6	<0.10	20.83	4.8	1720
	S	1023	134.21	13.11	7.6	33.10	24.66	4.1	0.47	1.42	70.4	2177
	Si	137009	1704.91	1.24	80.4	3.76	0.22	453.4	0.15	3.99	25.1	913393
	Sr	157	4.93	3.14	31.8	<0.10	<2.03	>49.3	<0.10	NC	NC	1570
	Zn	10035	245.10	2.44	40.9	0.98	0.40	250.1	<0.10	10.20	9.8	100350
	Zr	17486	348.23	1.99	50.2	0.18	0.05	1934.6	<0.10	55.56	1.8	174860
G a s	B	22855	195.44	0.86	116.9	7.07	3.62	27.6	0.51	7.21	13.9	44814
	Cl	0	27.48	NC	NC	3.32	12.08	8.3	0.55	16.57	6.0	0
	F	247	68.15	27.55	3.6	<0.10	<0.15	>681.5	<0.10	NC	NC	2470
	S	1023	213.89	20.90	4.8	0.52	0.24	411.3	0.18	34.62	2.9	5683

^s - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC - Not calculated

NA - Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.14. Results from Test 10D Emissions Sampling.

	-	Feed Rate (mg/min)	Melter			SBS			WESP			
			Emissions (mg/min)	% of Feed	DF Across Melter	Emissions (mg/min)	% of Melter Emissions	DF Across SBS	Emissions (mg/min)	% of SBS Emissions	DF Across WESP	Cumulative DF
Particulate	Total ^s	910400	8111	0.89	112.2	376	4.64	21.6	10	2.66	37.6	91040
	Al	21131	145.02	0.69	145.7	0.30	0.21	483.4	< 0.10	< 33.33	> 3.0	> 211310
	B	28338	288.68	1.02	98.2	0.79	0.27	365.4	< 0.10	< 12.66	> 7.9	> 283380
	Ba	137	1.24	0.91	110.4	< 0.10	< 8.06	> 12.4	< 0.10	NC	NC	1370
	Ca	1534	21.18	1.38	72.4	0.67	3.16	31.6	< 0.10	< 14.93	> 6.7	> 15340
	Cd	412	4.92	1.19	83.8	0.20	4.07	24.6	< 0.10	< 50.00	> 2.0	> 4120
	Cl*	3833	694.96	18.13	5.5	NA	NA	NA	NA	NA	NA	NA
	Cu	184	2.24	1.22	82.0	< 0.10	< 4.46	> 22.4	< 0.10	NC	NC	1840
	F*	307	83.90	27.33	3.6	NA	NA	NA	NA	NA	NA	NA
	Fe	65725	754.25	1.15	87.1	1.29	0.17	584.7	< 0.10	< 7.75	> 12.9	> 657250
	K	191	8.51	4.46	22.4	1.68	19.74	5.1	< 0.10	< 5.95	> 16.8	> 1910
	Li	12536	77.69	0.62	161.4	4.48	5.77	17.3	< 0.10	< 2.23	> 44.8	> 125360
	Mg	509	10.48	2.06	48.5	< 0.10	< 0.95	> 104.8	< 0.10	NC	NC	5090
	Mn	1009	7.08	0.70	142.5	< 0.10	< 1.41	> 70.8	< 0.10	NC	NC	10090
	Na	70533	988.44	1.40	71.4	101.18	10.24	9.8	0.83	< 0.01	> 10118.0	> 84980
	Ni	3735	29.27	0.78	127.6	0.12	0.41	243.9	< 0.10	< 83.33	> 1.2	> 37350
	Pb	214	5.27	2.47	40.5	0.47	8.92	11.2	< 0.10	< 21.28	> 4.7	> 2140
	S	1269	114.00	8.98	11.1	28.44	24.95	4.0	0.47	0.02	2844.0	2700
	Si	169877	1140.41	0.67	149.0	1.87	0.16	609.8	0.15	0.08	187.0	1132513
	Sr	194	2.56	1.32	76.0	< 0.10	< 3.91	> 25.6	< 0.10	NC	NC	1940
	Zn	12442	136.76	1.10	91.0	0.83	0.61	164.8	< 0.10	< 12.05	> 8.3	> 124420
	Zr	21681	117.23	0.54	184.9	0.11	0.09	1065.7	< 0.10	< 90.91	> 110.0	> 216810
G a s	B	28338	234.53	0.83	120.8	9.71	4.14	24.2	0.51	0.05	971.0	55565
	Cl	3833	479.77	12.52	8.0	13.01	2.71	36.9	0.55	0.04	1301.0	6969
	F	307	89.83	29.29	3.4	< 0.10	< 0.11	> 898.3	< 0.10	NC	NC	3070
	S	1269	238.44	18.79	5.3	0.64	0.27	372.6	0.18	0.16	640.0	12690

^s - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.15. Results from Test 9A Melter Emissions Sampling.

		Feed Rate (mg/min)	Melter					DF
			Emissions Rate (mg/min)	Emissions Rate (mg/min)	Emissions Rate (mg/min)	Average Emissions Rate (mg/min)	% Feed	
Particulate	Total ^s	1059610	8417	8050	3317	6595	0.62	160.7
	Al	24594	147.94	132.44	43.57	107.98	0.44	227.8
	B	32982	431.42	371.61	84.85	295.96	0.90	111.4
	Ba	160	1.24	1.32	0.51	1.02	0.64	156.4
	Ca	1786	32.71	18.14	7.17	19.34	1.08	92.3
	Cd	479	12.94	11.37	9.09	11.13	2.32	43.0
	Cu	214	1.73	1.57	0.56	1.29	0.60	166.3
	F*	357	96.54	466.28	310.90	291.24	81.58	1.2
	Fe	76498	941.46	851.23	338.72	710.47	0.93	107.7
	K	222	18.41	10.64	5.65	11.57	5.21	19.2
	Li	14591	84.19	74.55	36.00	64.91	0.44	224.8
	Mg	592	15.94	11.75	5.70	11.13	1.88	53.2
	Mn	1175	4.71	5.34	1.39	3.81	0.32	308.1
	Na	77129	1028.58	910.57	413.71	784.29	1.02	98.3
	Ni	4347	34.41	30.63	10.40	25.15	0.58	172.9
	Pb	249	3.04	3.52	1.63	2.73	1.10	91.2
	Ru	610	41.11	18.58	14.88	24.86	4.08	24.5
	S	286	116.98	123.31	106.23	115.51	40.39	2.5
	Si	197722	1080.64	757.08	231.37	689.70	0.35	286.7
	Sr	226	2.83	2.93	1.24	2.33	1.03	96.9
	Y	527	0.54	0.54	< 0.10	< 0.39	< 0.06	> 1351.9
	Zn	14481	181.43	159.12	63.53	134.69	0.93	107.5
	Zr	25235	129.45	119.29	24.27	91.00	0.36	277.3
Gas	B	32982	379.95	348.52	393.25	373.91	1.13	88.2
	F	357	3.81	5.54	< 0.10	< 3.15	< 0.88	> 113.3
	S	286	79.15	79.21	73.98	77.45	27.08	3.7

^s - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.16. Results from Test 9A SBS Emissions Sampling.

	-	Average Melter Emissions Rate (mg/min)	SBS					DF
			Emissions Rate (mg/min)	Emissions Rate (mg/min)	Emissions Rate (mg/min)	Average Emissions Rate (mg/min)	% of Melter Emissions	
Particulate	Total ^{\$}	6594.67	203	285	305	264	4.01	24.9
	Al	107.98	0.84	0.57	0.34	0.58	0.54	185.1
	B	295.96	1.78	2.29	1.7	1.92	0.65	153.9
	Ba	1.02	< 0.10	< 0.10	< 0.10	< 0.10	< 9.80	> 10.2
	Ca	19.34	1.96	0.7	0.57	1.08	5.57	18.0
	Cd	11.13	0.76	1	1.41	1.06	9.49	10.5
	Cu	1.29	< 0.10	< 0.10	< 0.10	< 0.10	< 7.75	> 12.9
	F*	291.24	NA	NA	NA	NA	NA	NA
	Fe	710.47	3.28	3.59	2.65	3.17	0.45	223.9
	K	11.57	2.12	1.75	1.77	1.88	16.25	6.2
	Li	64.91	4.79	5.23	3.76	4.59	7.08	14.1
	Mg	11.13	0.19	0.12	< 0.10	< 0.14	< 1.23	> 81.4
	Mn	3.81	< 0.10	< 0.10	< 0.10	< 0.10	< 2.62	> 38.2
	Na	784.29	53.97	62.53	61.2	59.23	7.55	13.2
	Ni	25.15	0.32	0.2	0.22	0.25	0.98	101.9
	Pb	2.73	0.28	0.34	0.7	0.44	16.12	6.2
	Ru	24.86	12.78	3.36	23.13	13.09	52.65	1.9
	S	115.51	34.38	40.64	42.4	39.14	33.89	3.0
	Si	689.70	4.73	2.9	2.34	3.32	0.48	207.5
	Sr	2.33	< 0.10	< 0.10	< 0.10	< 0.10	< 4.29	> 23.3
	Y	< 0.39	< 0.10	< 0.10	< 0.10	< 0.10	NC	NC
	Zn	134.69	11.2	6.73	10.08	9.34	6.93	14.4
	Zr	91.00	0.13	< 0.10	< 0.10	< 0.11	< 0.12	> 8273
Gas	B	373.91	10.12	10.65	11.74	10.84	2.90	34.5
	F	< 3.15	0.13	0.10	0.18	0.14	> 4.44	< 22.5
	S	77.45	1.56	< 0.10	< 0.10	< 0.59	< 0.76	> 131.3

^{\$} - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.17. Results from Test 9B Melter Emissions Sampling.

		Feed Rate (mg/min)	Melter					DF
			Emissions Rate (mg/min)	Emissions Rate (mg/min)	Emissions Rate (mg/min)	Average Emissions Rate (mg/min)	% Feed	
Particulate	Total ^s	1324800	13917	15283	15083	14761	1.11	89.8
	Al	30750	219.61	265.15	259.45	248.07	0.81	124.0
	B	41237	856.68	910.16	745.25	837.36	2.03	49.2
	Ba	200	2.63	3.01	2.64	2.76	1.38	72.5
	Ca	2233	33.22	37.46	35.78	35.49	1.59	62.9
	Cd	599	15.69	16.28	16.17	16.05	2.68	37.3
	Cu	267	2.48	3.02	2.82	2.77	1.04	96.3
	F*	446	169.25	22.11	283.62	158.33	35.50	2.8
	Fe	95644	1819.76	1926.38	1722.09	1822.74	1.91	52.5
	K	278	15.05	15.79	16.54	15.79	5.68	17.6
	Li	18243	129.98	147.28	133.92	137.06	0.75	133.1
	Mg	740	22.55	24.43	24.72	23.90	3.23	31.0
	Mn	1469	8.12	10.35	10.62	9.70	0.66	151.5
	Na	96433	1837.30	1922.33	1675.79	1811.81	1.88	53.2
	Ni	5436	52.63	61.25	62.82	58.90	1.08	92.3
	Pb	311	5.78	6.08	6.82	6.23	2.00	49.9
	Ru	763	57.73	48.90	34.73	47.12	6.18	16.2
	S	358	157.87	160.29	179.41	165.86	46.33	2.2
	Si	247208	1090.47	1378.56	1394.16	1287.73	0.52	192.0
	Sr	283	6.24	6.89	6.31	6.48	2.29	43.7
	Y	659	0.70	2.12	1.13	1.32	0.15	498.9
	Zn	18106	282.63	295.58	301.47	293.23	1.62	61.7
	Zr	31551	162.40	230.27	215.77	202.81	0.64	155.6
Gas	B	41237	441.78	441.63	544.00	475.80	1.15	86.7
	F	446	4.44	7.08	8.38	6.63	1.49	67.2
	S	358	86.28	90.30	87.97	88.18	24.63	4.1

^s - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.18 Results from Test 9B SBS Emissions Sampling

-		Average Melter Emissions Rate (mg/min)	SBS					DF
			Emissions Rate (mg/min)	Emissions Rate (mg/min)	Emissions Rate (mg/min)	Average Emissions Rate (mg/min)	% Melter Emissions	
Particulate	Total ^{\$}	14761.00	290	267	213	257	1.74	57.5
	Al	248.07	0.91	0.82	0.65	0.79	0.32	312.7
	B	837.36	3.17	2.33	2.08	2.53	0.30	331.4
	Ba	2.76	< 0.10	< 0.10	< 0.10	< 0.10	< 3.62	> 27.6
	Ca	35.49	0.98	0.72	0.47	0.72	2.04	49.1
	Cd	16.05	0.4	0.36	0.26	0.34	2.12	47.2
	Cu	2.77	< 0.10	< 0.10	< 0.10	< 0.10	< 3.61	> 27.7
	F*	158.33	NA	NA	NA	NA	NA	NA
	Fe	1822.74	7.12	4.99	5.88	6.00	0.33	304.0
	K	15.79	1.89	1.55	1.34	1.59	10.09	9.9
	Li	137.06	4.35	3.89	3.96	4.07	2.97	33.7
	Mg	23.90	0.22	0.16	0.15	0.18	0.74	135.3
	Mn	9.70	< 0.10	< 0.10	< 0.10	< 0.10	< 1.03	> 97.0
	Na	1811.81	75.03	65.88	69.03	69.98	3.86	25.9
	Ni	58.90	0.2	0.18	0.1	0.16	0.27	368.1
	Pb	6.23	0.34	0.43	0.34	0.37	5.94	16.8
	Ru	47.12	17.00	12.91	14.32	14.74	31.29	3.2
	S	165.86	46.74	42.36	46.1	45.07	27.17	3.7
	Si	1287.73	4.89	4.36	3.57	4.27	0.33	301.3
	Sr	6.48	< 0.10	< 0.10	< 0.10	< 0.10	< 1.54	> 64.8
	Y	1.32	< 0.10	< 0.10	< 0.10	< 0.10	< 7.58	> 13.2
	Zn	293.23	5.85	5.48	3.97	5.10	1.74	57.5
	Zr	202.81	0.13	< 0.10	< 0.10	< 0.11	< 0.05	> 1843.7
Gas	B	475.80	12.33	10.69	11.03	11.35	2.39	41.9
	F	6.63	< 0.10	0.11	< 0.10	0.11	1.66	60.3
	S	88.18	< 0.10	< 0.10	< 0.10	< 0.10	< 0.11	> 881.8

^{\$} - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

NA – Not available due to insufficient particulate loading for separate anion analysis

"-" Empty data field

Table 7.19. Particulate DFs for AZ-101 Tests.

Test	Previous [9]		2D	1D	3C	8C	10D	9C
Feed Solids Content (g/l)	400	530	530	530	400	400	400	400
Bubbling Rate (lpm)	65	65	65	65	80	90	80	134
Melter DF	129	181	152	152	92	70	112	90
SBS DF	40	48	62	42	72	100	22	58
WESP DF	26	15	33	42	42	67	38	ND
Cumulative DF	132,755	132,838	313,714	266,300	279,050	470,523	91,040	ND

ND – Not Determined.

Table 7.20. Particle Size Distribution Results for Test 2 Melter Emissions.

-	Cutpoint (μm)	Net Weight (mg)	Concentration (mg/dscf)	Mass Fraction
Test 2B 06/01/03 11:58 – 12:02	> 12.9	21.4	10.84	54.8
	9.73 – 12.9	4.65	2.36	11.9
	3.76 – 9.73	5.39	2.73	13.8
	1.89 – 3.76	2.79	1.41	7.1
	1.09 – 1.89	1.67	0.85	4.3
	0.61 – 1.09	1.37	0.69	3.5
	0.37 – 0.61	0.39	0.20	1.0
	< 0.37	1.39	0.71	3.6
Test 2C 06/03/03 13:00 – 13:03	> 11.0	29.8	18.52	67.8
	8.29 – 11.0	7.88	4.90	18.0
	3.20 – 8.29	1.85	1.15	4.2
	1.61 – 3.20	1.80	1.12	4.1
	0.93 – 1.61	0.68	0.42	1.5
	0.53 – 0.93	0.87	0.54	2.0
	0.32 – 0.53	0.16	0.10	0.4
	< 0.32	0.88	0.55	2.0
Test 2D 06/05/03 14:00 – 14:03	> 10.9	15.27	9.37	69.8
	8.19 – 10.9	2.11	1.30	9.6
	3.16 – 8.19	1.36	0.84	6.2
	1.60 – 3.16	0.59	0.36	2.7
	0.92 – 1.60	0.44	0.27	2.0
	0.52 – 0.92	0.92	0.59	4.2
	0.32 – 0.52	0.13	0.08	0.6
	< 0.32	1.07	0.66	4.9

"-" Empty data field

Table 7.21. Particle Size Distribution Results for Test 1 Melter Emissions.

-	Cutpoint (µm)	Net Weight (mg)	Concentration (mg/dscf)	Mass Fraction
Test 1B 06/28/03 12:36 – 12:38	> 13.1	38.56	44.89	64.8
	9.89 – 13.1	3.84	4.47	6.5
	3.82 – 9.89	5.09	5.93	8.6
	1.92 – 3.82	4.86	5.66	8.2
	1.10 – 1.92	3.08	3.59	5.2
	0.62 – 1.10	2.05	2.39	3.4
	0.37 – 0.62	0.59	0.69	1.0
	< 0.37	1.47	1.71	2.5
Test 1C 06/30/03 12:03 – 12:05	> 12.8	18.25	19.79	53.7
	9.69 – 12.8	2.44	2.65	7.2
	3.75 – 9.69	4.36	4.73	12.8
	1.88 – 3.75	3.75	4.07	11.0
	1.08 – 1.88	2.21	2.40	6.5
	0.61 – 1.08	1.95	2.12	5.7
	0.36 – 0.61	0.01	0.01	< 0.1
	< 0.36	0.99	1.08	2.9
Test 1D 07/02/03 10:00 – 10:02	> 12.8	18.70	21.64	60.8
	9.67 – 12.8	2.73	3.16	8.9
	3.74 – 9.67	2.15	2.49	7.0
	1.88 – 3.74	2.81	3.25	9.1
	1.08 – 1.88	1.90	2.20	6.2
	0.61 – 1.08	0.42	0.49	1.4
	0.36 – 0.61	0.53	0.61	1.7
	< 0.36	1.51	1.75	4.9

"-" Empty data field

Table 7.22. Particle Size Distribution Results for Test 3 Melter Emissions.

-	Cutpoint (µm)	Net Weight (mg)	Concentration (mg/dscf)	Mass Fraction (%)
Test 3B 07/19/03 17:35 – 17:36	> 12.5	29.33	49.3	76.2
	9.46 – 12.5	1.96	3.29	5.1
	3.66 – 9.46	2.18	3.66	5.7
	1.84 – 3.66	1.22	2.05	3.2
	1.06 – 1.84	0.65	1.09	1.7
	0.59 – 1.06	0.57	0.96	1.5
	0.36 – 0.59	0.33	0.56	0.9
	< 0.36	2.27	3.82	5.9
Test 3C 07/22/03 11:50 – 11:51	> 11.1	66.74	113	79.6
	8.4 – 11.1	3.30	5.57	3.9
	3.25 – 8.4	3.32	5.61	4.0
	1.64 – 3.25	3.86	6.52	4.6
	0.94 – 1.64	2.04	3.45	2.4
	0.53 – 0.94	1.72	2.91	2.1
	0.32 – 0.53	1.08	1.82	1.3
	< 0.32	1.74	2.94	2.1

"-" Empty data field

Table 7.23. Particle Size Distribution Results for Test 8 Melter Emissions.

-	Cutpoint (µm)	Net Weight (mg)	Concentration (mg/dscf)	Mass Fraction (%)
Test 8B 08/10/03 11:50 – 11:52	> 10.6	32.4	26.51	65.8
	8.01 – 10.6	3.25	2.66	6.6
	3.1 – 8.01	4.28	3.50	8.7
	1.56 – 3.1	3.16	2.59	6.4
	0.90 – 1.56	1.36	1.11	2.8
	0.51 – 0.90	0.99	0.81	2.0
	0.31 – 0.51	1.30	1.06	2.6
	< 0.31	2.48	2.08	5.0
Test 8C 08/12/03 10:24 – 10:25	> 10.1	47.6	17.0	55.8
	7.6 – 10.1	3.07	11.0	3.6
	2.9 – 7.6	3.07	11.0	3.6
	1.5 – 2.9	3.37	12.0	3.9
	0.86 – 1.5	1.63	5.82	1.9
	0.48 – 0.86	0.45	1.61	0.5
	0.30 – 0.48	0.75	2.68	0.9
	< 0.30	25.4	9.06	29.7

"-" Empty data field

Table 7.24. Particle Size Distribution Results for Test 10 Melter Emissions.

-	Cutpoint (µm)	Net Weight (mg)	Concentration (mg/dscf)	Mass Fraction
Test 10B 09/06/03 13:03 – 13:04	> 9.05	10.65	26.962	57.1
	6.28 – 9.05	1.38	3.494	7.4
	2.64 – 6.28	1.27	3.215	6.8
	1.33 – 2.64	2.0	5.063	10.7
	0.77 – 1.33	0.58	1.468	3.1
	0.44 – 0.77	1.13	2.86	6.0
	0.27 – 0.44	0.33	0.835	1.8
	< 0.27	1.30	3.291	7.0
Test 10C 09/08/03 12:40 – 12:42	> 11.7	16.91	23.356	51.6
	8.83 – 11.7	5.67	7.831	17.3
	3.41 – 8.83	3.48	4.807	10.6
	1.72 – 3.41	2.59	3.577	7.9
	0.99 – 1.72	1.33	1.837	4.0
	0.55 – 0.99	1.29	1.782	3.9
	0.33 – 0.55	0.27	0.373	0.8
	< 0.33	1.26	1.740	3.8
Test 10D 09/09/03 19:29 – 19:30	> 11.5	17.02	31.754	55.4
	8.65 – 11.5	3.25	6.063	10.6
	3.35 – 8.65	3.25	6.063	10.6
	1.68 – 3.35	2.51	4.683	8.2
	0.97 – 1.68	0.95	1.772	3.1
	0.55 – 0.97	1.91	3.563	6.2
	0.33 – 0.55	0.61	1.138	1.9
	< 0.33	1.24	2.313	4.0

"-" Empty data field

**Table 7.25.a. Test 2 Average Concentrations [ppmv] of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet				SBS Outlet				WESP Outlet			TCO Outlet			
Test	A	B	C	D	A	B	C	D	B	C	D	A	B	C	D
N ₂ O	2.1	1.6	1.6	1.4	2.1	1.6	1.6	1.6	1.9	1.6	1.7	1.6	<1.0	<1.0	<1.0
NO	110	110	110	120	110	100	120	130	110	100	130	28	<1.0	<1.0	<1.0
NO ₂	3.6	3.3	8.4	9.7	3.7	3.8	6.0	8.5	6.8	13	13	28	<1.0	<1.0	<1.0
NH ₃	<1.0	<1.0	<1.0	<1.0	1.0	3.3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0
H ₂ O [%]	13	11	13	14	4.7	5.0	4.8	4.9	4.6	4.7	4.8	3.3	1.0	0.8	1.0
CO ₂	3300	3100	3900	3600	2900	2700	3000	3200	2900	3100	3200	1900	430	420	420
HCN	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
SO ₂	1.3	1.5	1.6	2.1	<1.0	1.1	<1.0	1.1	1.2	<1.0	1.4	<1.0	<1.0	<1.0	<1.0
Acetonitrile	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<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	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
CO	<1.0	1.0	7.3	1.3	<1.0	<1.0	1.6	1.5	1.1	34	1.8	<1.0	<1.0	<1.0	<1.0
HCl	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<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	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

**Table 7.25.b. Test 2 Concentration [ppmv] Ranges of Selected Species in Off-Gas
 Measured by FTIR Spectroscopy.**

Port	Melter Outlet				SBS Outlet				WESP Outlet			TCO Outlet			
Test	A	B	C	D	A	B	C	D	B	C	D	A	B	C	D
N₂O	1.6 – 2.6	1.2 – 2.3	1.3 – 1.9	1.1 – 1.9	1.4 – 3.5	1.0 – 2.5	1.2 – 2.2	1.1 – 2.2	1.0 – 3.4	<1.0 – 2.2	1.2 – 2.4	<1.0 – 2.5	<1.0	<1.0	<1.0 – 1.0
NO	78 – 148	66 – 160	25 – 180	83 – 180	71 – 180	64 – 150	76 – 180	82 – 200	48 – 180	28 – 160	72 – 200	<1.0 – 63	<1.0	<1.0	<1.0
NO₂	1.4 – 5.4	1.2 – 6.7	3.8 – 48	2.9 – 16	1.7 – 6.8	1.6 – 6.5	3.0 – 12	3.9 – 19	1.4 – 17	<1.0 – 27	3.4 – 25	<1.0 – 58	<1.0 – 1.3	<1.0	<1.0
NH₃	<1.0	<1.0	<1.0	<1.0	<1.0 – 1.3	<1.0 – 13	<1.0	<1.0	<1.0 – 3.6	<1.0	<1.0 – 1.6	<1.0 – 1.3	<1.0	<1.0	<1.0 – 5.3
H₂O [%]	11 – 15	6.1 – 16	11 – 18	10 – 20	4.1 – 5.9	4.5 – 6.7	4.3 – 5.5	4.5 – 5.7	2.9 – 6.0	2.8 – 5.7	3.1 – 6.8	2.0 – 4.3	0.8 – 1.2	0.2 – 1.0	0.7 – 1.3
CO₂	2500 – 4100	2200 – 4600	2700 – 5600	2400 – 5300	2000 – 4300	2100 – 3600	2200 – 4200	2100 – 4600	30 – 4500	1100 – 4900	1900 – 4900	200 – 3200	300 – 600	300 – 600	2 – 800
HCN	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
SO₂	<1.0 – 3.1	<1.0 – 3.2	<1.0 – 3.9	<1.0 – 4.6	<1.0	<1.0 – 3.1	<1.0	<1.0 – 2.9	<1.0 – 28	<1.0	<1.0 – 4.1	<1.0	<1.0 – 1.8	<1.0	<1.0
Acetonitrile	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<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	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
CO	<1.0	<1.0 – 1.7	<1.0 – 95	<1.0 – 2.9	<1.0 – 1.9	<1.0 – 2.4	<1.0 – 19	<1.0 – 2.9	<1.0 – 3.3	<1.0 – 99	<1.0 – 3.8	<1.0 – 1.4	<1.0	<1.0	<1.0
HCl	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0 – 3.5	<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	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

**Table 7.26.a. Test 1 Average Concentrations [ppmv] of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet			SBS Outlet			WESP Outlet			TCO Outlet			
Test	B	C	D	B	C	D	B	C	D	A	B	C	D
N ₂ O	2.0	2.3	2.5	3.1	3.3	3.6	2.9	2.8	3.5	2.7	7.4	7.3	8.5
NO	200	220	220	280	300	320	260	250	300	27	8.8	< 1.0	4.4
NO ₂	20	20	21	22	20	23	30	27	32	72	31	26	30
NH ₃	14	3.9	2.7	4.7	1.3	< 1.0	4.1	< 1.0	< 1.0	1.3	6.9	5.5	4.5
H ₂ O [%]	24	25	24	6.8	7.6	7.2	6.4	6.1	6.7	6.3	5.7	5.6	6.1
CO ₂	5400	5500	5500	7000	7500	7900	6800	6400	7600	4400	5800	5600	6500
HCN	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
SO ₂	1.5	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
CO	2.3	1.7	1.3	3.9	4.2	3.3	4.4	2.6	3.7	< 1.0	< 1.0	< 1.0	< 1.0
HCl	3.9	< 1.0	< 1.0	2.7	1.2	< 1.0	2.1	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HF	2.1	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.2	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0

**Table 7.26.b. Test 1 Concentration [ppmv] Ranges of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet			SBS Outlet			WESP Outlet			TCO Outlet			
Test	B	C	D	B	C	D	B	C	D	A	B	C	D
N ₂ O	<1.0 – 3.2	1.5 – 2.9	2.0 – 3.0	<1.0 – 4.3	2.0 – 5.0	2.7 – 4.5	2.4 – 3.8	<1.0 – 4.3	2.6 – 4.5	<1.0 – 5.4	<1.0 – 11	1.7 – 10	2.0 – 11
NO	<1.0 – 340	150 – 310	160 – 320	61 – 400	200 – 450	230 – 390	210 – 350	26 – 350	220 – 410	<1.0 – 84	<1.0 – 40	<1.0	<1.0 – 22
NO ₂	3.0 – 31	11 – 33	13 – 27	3.0 – 35	11 – 37	14 – 32	23 – 44	2.4 – 44	20 – 48	1.5 – 170	<1.0 – 96	<1.0 – 99	<1.0 – 72
NH ₃	3.2 – 24	<1.0 – 6.9	<1.0 – 3.9	<1.0 – 10	<1.0 – 3.3	<1.0	2.6 – 6.9	<1.0 – 4.3	<1.0 – 3.4	<1.0 – 6.2	1.4 – 25	<1.0 – 19	<1.0 – 14
H ₂ O [%]	6.9 – 38	16 – 37	7.5 – 32	6.0 – 7.5	6.7 – 9.5	6.6 – 8.4	5.4 – 7.5	5.1 – 7.1	5.6 – 7.6	3.1 – 7.9	0.1 – 6.9	3.7 – 6.8	4.6 – 6.8
CO ₂	300 – 9500	10 – 11000	300 – 7700	2700 – 9400	5300 – 11000	6200 – 9700	5600 – 8700	2100 – 8900	5800 – 10000	1200 – 8300	10 – 8300	2000 – 8900	2500 – 8700
HCN	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
SO ₂	<1.0 – 4.3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
CO	<1.0 – 5.4	<1.0 – 3.8	<1.0 – 2.8	<1.0 – 7.7	1.0 – 9.0	<1.0 – 6.1	2.8 – 7.4	<1.0 – 6.9	1.8 – 6.8	<1.0	<1.0 – 1.3	<1.0	<1.0
HCl	<1.0 – 12	<1.0 – 3.7	<1.0 – 1.2	<1.0 – 7.0	<1.0 – 1.7	<1.0	1.5 – 2.8	<1.0 – 3.2	<1.0 – 1.5	<1.0 – 1.6	<1.0 – 2.4	<1.0 – 8.8	<1.0
HF	<1.0 – 5.2	<1.0 – 1.1	<1.0	<1.0 – 1.9	<1.0	<1.0	<1.0 – 1.9	<1.0	<1.0	<1.0 – 1.2	<1.0 – 1.3	<1.0	<1.0

Table 7.27.a. Test 3 Average Concentrations [ppmv] of Selected Species in Off-Gas Measured by FTIR Spectroscopy.

Port	Melter Outlet			SBS Outlet			WESP Outlet			TCO Outlet		
Test	A	B	C	A	B	C	A	B	C	A	B	C
N ₂ O	1.8	1.4	1.8	2.4	2.9	2.9	< 1.0	2.8	2.7	3.1	4.6	5.1
NO	180	120	170	180	320	270	12	300	260	< 1.0	18	25
NO ₂	14	12	20	10	21	19	1.8	29	22	14	20	20
NH ₃	< 1.0	4.6	3.8	< 1.0	2.0	1.1	1.7	< 1.0	< 1.0	3.9	9.78	12
H ₂ O [%]	28	21	25	8.1	11	9.0	5.5	9.5	5.8	5.4	6.4	6.1
CO ₂	6000	4200	5400	4500	8000	6700	1000	7300	6500	2800	4700	5100
HCN	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
SO ₂	< 1.0	2.0	1.8	< 1.0	1.8	1.6	1.1	< 1.0	< 1.0	1.0	1.9	1.4
CO	1.1	1.2	1.6	1.7	3.4	3.2	< 1.0	3.7	3.5	< 1.0	< 1.0	< 1.0
HCl	< 1.0	< 1.0	< 1.0	< 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	< 1.0	< 1.0	< 1.0

**Table 7.27.b. Test 3 Concentration [ppmv] Ranges of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet			SBS Outlet			WESP Outlet			TCO Outlet		
Test	A	B	C	A	B	C	A	B	C	A	B	C
N ₂ O	1.6 – 2.1	< 1.0 – 2.7	< 1.0 – 3.2	< 1.0 – 4.0	1.8 – 4.9	< 1.0 – 4.6	< 1.0	1.6 – 4.4	1.3 – 4.3	< 1.0 – 5.0	< 1.0 – 9.7	< 1.0 – 11
NO	150 – 210	9.3 – 240	56 – 260	14 – 310	210 – 580	67 – 360	4.1 – 30	170 – 470	170 – 430	< 1.0 – 24	2.5 – 56	< 1.0 – 87
NO ₂	12 – 17	< 1.0 – 21	1.5 – 34	< 1.0 – 20	8.6 – 50	1.1 – 30	< 1.0 – 4.6	9.7 – 52	10 – 40	< 1.0 – 55	< 1.0 – 78	< 1.0 – 83
NH ₃	< 1.0 – 20	1.8 – 12	< 1.0 – 6.7	< 1.0 – 2.6	< 1.0 – 4.0	< 1.0 – 3.4	< 1.0 – 13	< 1.0	< 1.0	< 1.0 – 23	< 1.0 – 35	< 1.0 – 120
H ₂ O [%]	25 – 31	3.3 – 33	7.8 – 40	5.2 – 13	8.2 – 14	7.6 – 12	5.1 – 5.8	5.8 – 14	5.0 – 6.5	3.4 – 7.5	4.3 – 8.6	2.7 – 8.2
CO ₂	2000 – 7300	10 – 8000	800 – 8400	900 – 7300	5200 – 14000	1900 – 9300	900 – 1300	4300 – 11300	4900 – 9700	1200 – 4500	2100 – 7300	500 – 9600
HCN	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0 – 1.1	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
SO ₂	< 1.0	< 1.0 – 2.8	< 1.0 – 5.4	< 1.0	< 1.0 – 5.3	< 1.0 – 4.9	< 1.0 – 3.4	< 1.0	< 1.0	< 1.0 – 2.6	< 1.0 – 6.1	< 1.0 – 4.0
CO	< 1.0 – 1.0	< 1.0 – 3.3	< 1.0 – 3.8	< 1.0 – 4.6	< 1.0 – 10	1.1 – 6.1	< 1.0 – 1.1	1.4 – 6.8	< 1.0 – 9.5	< 1.0	< 1.0	< 1.0
HCl	< 1.0 – 1.2	< 1.0 – 1.8	< 1.0	< 1.0 – 1.7	< 1.0 – 1.2	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HF	< 1.0 – 1.3	< 1.0 – 1.5	< 1.0 – 1.0	< 1.0 – 1.6	< 1.0 – 1.3	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0

**Table 7.28.a. Test 8 Average Concentrations [ppmv] of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet			SBS Outlet			WESP Outlet		TCO Outlet		
Test	A	B	C	A	B	C	A	B	A	B	C
N ₂ O	1.2	<1.0	1.3	1.7	1.8	2.2	<1.0	1.7	3.0	3.8	1.8
NO	130	86	150	170	200	240	60	170	4.0	100	190
NO ₂	4.7	3.5	8.1	5.6	8.0	8.8	4.7	13	20	19	14
NH ₃	5.9	<1.0	<1.0	<1.0	1.4	<1.0	<1.0	<1.0	2.6	6.1	<1.0
H ₂ O [%]	21	16	26	6.3	6.6	7.9	5.1	6.3	4.8	6.2	6.4
CO ₂	6700	3800	3700	4200	4900	5900	1700	4400	2800	4300	5000
HCN	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
SO ₂	2.6	2.1	1.6	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Acetonitrile	<1.0	<1.0	<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	<1.0	<1.0
CO	<1.0	<1.0	1.2	1.1	2.0	3.6	<1.0	2.0	<1.0	<1.0	2.9
HCl	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
HF	1.1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

**Table 7.28.b. Test 8 Concentration [ppmv] Ranges of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet			SBS Outlet			WESP Outlet		TCO Outlet		
Test	A	B	C	A	B	C	A	B	A	B	C
N ₂ O	<1.0 – 2.0	<1.0 – 1.3	<1.0 – 2.2	1.5 – 2.1	<1.0 – 3.4	<1.0 – 4.2	<1.0 – 1.3	<1.0 – 2.6	1.6 – 6.4	<1.0 – 9.0	<1.0 – 3.2
NO	93 – 170	28 – 140	1.8 – 280	150 – 190	38 – 380	47 – 450	1.9 – 81	23 – 280	<1.0 – 16	<1.0 – 380	70 – 320
NO ₂	3.0 – 8.3	<1.0 – 7.1	<1.0 – 20	3.7 – 6.8	<1.0 – 24	<1.0 – 25	<1.0 – 7.8	<1.0 – 25	2.3 – 51	<1.0 – 61	<1.0 – 32
NH ₃	<1.0 – 35	<1.0 – 2.5	<1.0	<1.0	<1.0 – 9.2	<1.0	<1.0	<1.0	<1.0 – 10	<1.0 – 64	<1.0
H ₂ O [%]	20 – 25	10 – 24	5.0 – 54	6.2 – 6.6	2.4 – 10	2.4 – 13	4.2 – 7.8	4.0 – 8.4	3.6 – 5.2	3.2 – 9.0	3.9 – 7.9
CO ₂	3100 – 8100	1000 – 7300	10 – 8000	3800 – 4600	1800 – 8000	2100 – 11000	200 – 2300	1400 – 6200	1100 – 4900	300 – 7200	2600 – 8000
HCN	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
SO ₂	<1.0 – 4.9	<1.0 – 4.8	<1.0 – 4.9	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0 – 2.0
Acetonitrile	<1.0	<1.0	<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	<1.0	<1.0
CO	<1.0 – 1.7	<1.0 – 2.1	<1.0 – 3.1	<1.0 – 1.5	<1.0 – 5.9	<1.0 – 8.5	<1.0 – 1.9	<1.0 – 5.0	<1.0	<1.0 – 12	<1.0 – 6.9
HCl	<1.0 – 1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0 – 1.5	<1.0
HF	<1.0 – 1.6	<1.0 – 1.3	<1.0 – 1.4	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0 – 14	<1.0

**Table 7.29.a. Test 10 Average Concentrations [ppmv] of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet				SBS Outlet				WESP Outlet				TCO Outlet			
Test	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
N ₂ O	1.8	1.5	1.4	<1.0	4.8	2.5	2.3	1.9	3.3	2.6	1.7	1.9	3.2	2.0	2.6	3.7
NO	6.2	55	110	65	11	77	130	160	9.6	53	110	160	<1.0	6.2	4.3	<1.0
NO ₂	1.3	1.5	6.1	1.9	5.3	1.0	4.2	3.8	3.2	1.4	4.6	10	<1.0	14	9.3	8.7
NH ₃	30	<1.0	<1.0	3.4	10	5.6	1.7	<1.0	9.4	4.9	<1.0	<1.0	10	<1.0	3.2	7.3
H ₂ O [%]	21	18	22	14	5.7	5.3	6.1	6.2	5.3	5.0	5.3	5.5	2.9	3.5	3.9	4.1
CO ₂	6000	5200	6700	2700	4700	4000	4300	4600	4300	3700	3800	4600	2100	2500	2400	2900
HCN	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
SO ₂	3.0	1.2	2.1	1.4	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Acetonitrile	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<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	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
CO	14	4.4	3.4	1.7	26	6.0	5.8	4.9	22	6.7	4.6	5.6	<1.0	<1.0	<1.0	<1.0
HCl	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<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	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

**Table 7.29.b. Test 10 Concentration [ppmv] Ranges of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet				SBS Outlet				WESP Outlet				TCO Outlet			
Test	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
N ₂ O	1.6 – 1.9	<1.0 – 2.7	1.0 – 1.8	<1.0 – 1.4	3.7 – 6.2	1.6 – 3.7	1.8 – 2.9	1.0 – 2.7	2.6 – 4.4	1.8 – 3.4	1.2 – 2.7	1.3 – 2.4	<1.0 – 6.5	1.1 – 3.3	1.4 – 3.8	<1.0 – 5.1
NO	2.0 – 9.3	1.4 – 130	63 – 140	50 – 89	7.4 – 15	23 – 164	91 – 170	64 – 230	4.0 – 17	20 – 100	68 – 160	120 – 200	<1.0 – 2.0	<1.0 – 19	<1.0 – 13	<1.0 – 90
NO ₂	<1.0 – 2.6	<1.0 – 4.8	2.5 – 8.3	<1.0 – 3.4	3.7 – 7.4	<1.0 – 3.5	1.3 – 7.4	1.7 – 7.5	1.5 – 5.0	<1.0 – 3.0	1.4 – 9.5	5.0 – 17	<1.0 – 3.3	<1.0 – 46	<1.0 – 34	<1.0 – 40
NH ₃	13 – 52	<1.0	<1.0	<1.0 – 10	4.2 – 11	<1.0 – 10	<1.0 – 4.7	<1.0	4.4 – 12	4.0 – 6.3	<1.0 – 1.3	<1.0	<1.0 – 16	<1.0	<1.0 – 14	<1.0 – 23
H ₂ O [%]	19 – 22	6.0 – 26	18 – 31	11 – 17	5.2 – 6.4	3.8 – 6.1	3.8 – 8.0	4.6 – 7.1	3.2 – 6.4	3.9 – 5.5	4.3 – 6.9	4.3 – 6.9	2.4 – 3.9	2.4 – 4.0	2.9 – 4.6	3.2 – 4.5
CO ₂	5300 – 6800	200 – 8300	3100 – 8300	2300 – 4600	4000 – 5600	3100 – 5200	3400 – 5100	2100 – 6100	3500 – 5300	2100 – 4800	3000 – 5300	3700 – 5700	30 – 4000	1500 – 3800	1200 – 3400	400 – 4400
HCN	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
SO ₂	1.2 – 4.1	<1.0 – 3.4	<1.0 – 3.7	<1.0 – 3.3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Acetonitrile	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<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	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
CO	9.8 – 16	1.4 – 15	<1.0 – 4.8	<1.0 – 3.2	20 – 37	1.1 – 10	1.1 – 6.9	1.9 – 7.8	17 – 29	3.7 – 10	20 – 7.3	3.0 – 7.8	<1.0	<1.0	<1.0	<1.0
HCl	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<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	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

**Table 7.30.a. Test 9 Average Concentrations [ppmv] of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet		SBS Outlet		WESP Outlet		TCO Outlet	
Test	A	B	A	B	A	B	A	B
N ₂ O	4.2	4.8	5.4	7.9	5.3	7.5	2.0	3.1
NO	< 1.0	9.6	29	35	24	31	2.5	4.1
NO ₂	3.3	3.0	1.1	2.7	2.4	3.7	7.4	11
NH ₃	11	6.8	12	6.4	11	5.9	< 1.0	< 1.0
H ₂ O [%]	26	30	8.4	9.7	7.8	8.9	3.4	4.0
CO ₂	1800	4200	6500	8000	6300	7900	2500	3400
HNO ₂	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HNO ₃	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HCN	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
SO ₂	1.3	1.5	1.4	< 1.0	1.4	< 1.0	< 1.0	< 1.0
Acetonitrile	< 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
CO	13	18	19	29	19	31	< 1.0	< 1.0
HCl	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HF	1.8	< 1.0	1.2	< 1.0	1.0	< 1.0	< 1.0	< 1.0

**Table 7.30.b. Test 9 Concentration [ppmv] Ranges of Selected Species in Off-Gas
Measured by FTIR Spectroscopy.**

Port	Melter Outlet		SBS Outlet		WESP Outlet		TCO Outlet	
Test	1	2	1	2	1	2	1	2
N ₂ O	2.1 – 6.1	2.5 – 6.6	2.7 – 8.8	4.2 – 13	2.8 – 8.7	2.9 – 12	< 1.0 – 3.7	1.1 – 4.9
NO	< 1.0	< 1.0 – 26	11 – 45	7.2 – 110	< 1.0 – 48	2.6 – 63	< 1.0 – 7.4	< 1.0 – 8.9
NO ₂	< 1.0 – 5.0	< 1.0 – 5.3	< 1.0 – 2.9	< 1.0 – 6.3	< 1.0 – 5.1	< 1.0 – 6.6	< 1.0 – 22	2.4 – 21
NH ₃	2.0 – 46	< 1.0 – 40	< 1.0 – 25	< 1.0 – 8.7	3.4 – 28	3.2 – 8.2	< 1.0 – 2.5	< 1.0 – 1.3
H ₂ O [%]	18 – 32	19 – 39	7.0 – 11	8.1 – 12	4.6 – 10	5.0 – 12	2.1 – 4.9	2.6 – 4.6
CO ₂	< 1.0 – 8200	30 – 9500	4800 – 8300	5400 – 11000	3700 – 8500	5000 – 11000	300 – 4300	1800 – 4500
HNO ₂	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HNO ₃	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HCN	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
SO ₂	< 1.0 – 4.1	< 1.0 – 3.5	< 1.0 – 2.3	< 1.0 – 2.3	< 1.0 – 3.7	< 1.0 – 2.4	< 1.0	< 1.0
Acetonitrile	< 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
CO	4.9 – 20	4.9 – 28	11 – 27	7.6 – 48	6.3 – 29	6.9 – 51	< 1.0	< 1.0
HCl	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
HF	< 1.0 – 5.1	< 1.0 – 1.6	< 1.0 – 2.7	< 1.0	< 1.0 – 2.0	< 1.0	< 1.0 – 1.6	< 1.0

Table 7.31. Average Hydrogen Concentrations from AZ-101 Tests Measured by Gas Chromatography.

Test		H ₂ Concentration (ppmv) at the WESP Outlet
Previous Tests [9]		6 - 13
Previous Tests with Sugar [17]		7 - 430
2	B	< 5
	C	7
	D	9
1	B	11
	C	12
	D	12
3	B	22
	C	26
8	B	< 5
	C	13
9	A	16
	B	19

Table 7.32 Measured TCO Performance (% DRE).

-	Method	Number of Measurements per Location	LAW B1 [22]	HLW AZ-101
Chlorobenzene	Online GC	9-13	99.4 %	92.8 %
Trichloroethylene	Online GC	9-13	79.0 %	76.5 %
Total Hydrocarbons (as propane)	40CFR 60 Method 25A	> 250	97.7 %	96.5 %

"-" Empty data field

Table 8.1. Analysis of Ruthenium-Yttrium Spike Solutions by DCP-AES.

Element	Target Concentration (wt%)	Sample I.D: RuCL1		Sample I.D: 1T2-O-78B	
		Concentration (wt%)	Deviation (%)	Concentration (wt%)	Deviation (%)
Ru	1.43	1.37	-4.00	1.37	-3.77
Y	1.23	1.20	-2.70	1.22	-1.16

Table 8.2. Concentrations of Y₂O₃ and RuO₂ in Discharge Stream Glass Samples (wt%).

Date	Time	Sample Name	Glass (kg)*	Y ₂ O ₃	RuO ₂
03/25/04	9:52	IR2-N-63A	1662.1	0.0015	0.0005
	11:04	IR2-N-68A	1712.7	0.0048	0.0022
	12:25	IR2-N-69A	1813.8	0.0067	0.0056
	15:08	IR2-N-70A	1965.4	0.0096	0.0080
	17:41	IR2-N-73A	2065.8	0.0137	0.0108
	19:43	IR2-N-82A	2165.5	0.0161	0.0169
	21:47	IR2-N-83A	2265.2	0.0185	0.0153
	23:54	IR2-N-96A	2364.8	0.0223	0.0189
03/26/04	1:06	IR2-N-96C	2414.7	0.0240	0.0213
	3:52	IR2-N-99A	2568.8	0.0277	0.0240
	5:45	IR2-N-100A	2673.2	0.0301	0.0249
	7:38	IR2-N-110A	2777.5	0.0321	0.0273
	9:04	IR2-N-111A	2881.8	0.0338	0.0297
	11:15	IR2-N-114A	2985.7	0.0359	0.0300
	13:25	IR2-N-116A	3089.0	0.0380	0.0339
	15:46	IR2-N-117A	3192.3	0.0394	0.0354
	17:36	IR2-N-121A	3295.6	0.0408	0.0350
	19:13	IR2-N-123A	3398.9	0.0415	0.0357
	20:24	IR2-N-124A	3450.5	0.0429	0.0359
	22:35	IR2-N-134A	3563.7	0.0437	0.0349
03/27/04	1:27	IR2-N-136A	3705.3	0.0445	0.0373
	3:33	IR2-N-138A	3807.2	0.0449	0.0374
	4:55	IR2-N-139A	3903.4	0.0461	0.0385
	7:15	IR2-N-141A	4011.8	0.0453	0.0370
	9:18	IR2-N-143A	4115.4	0.0494	0.0420
	17:15	IR2-N-152A	4528.7	0.0542	0.0450
	18:52	IR2-N-153A	4630.1	0.0549	0.0440
	20:47	IR2-N-154A	4680.8	0.0560	0.0437
	22:52	1S2-N-15A	4832.9	0.0558	0.0438
03/28/04	0:49	1S2-N-16A	4934.3	0.0566	0.0437
	6:08	1S2-N-32A	5230.8	0.0590	0.0464
	8:13	1S2-N-33A	5329.1	0.0612	0.0501
	10:27	1S2-N-36A	5427.4	0.0618	0.0555
	12:21	1S2-N-46A	5527.1	0.0618	0.0501
	13:48	1S2-N-47A	5628.3	0.0628	0.0517
	16:01	1S2-N-50A	5729.5	0.0629	0.0523
	17:55	1S2-N-52A	5830.7	0.0634	0.0497
	19:34	1S2-N-54A	5931.9	0.0642	0.0515
	21:43	1S2-N-55A	6032.1	0.0636	0.0495
	23:34	1S2-N-66A	6131.3	0.0635	0.0486

* Cumulative mass from Test# 9 (Best Configuration Test)

Table 8.2. Concentrations of Y₂O₃ and RuO₂ in Discharge Stream Glass Samples, continued.

Date	Time	Sample Name	Glass (kg)*	Y2O3	RuO2
03/29/04	1:37	1S2-N-67A	6230.5	0.0648	0.0521
	3:32	1S2-N-69A	6329.7	0.0555	0.0439
	5:15	1S2-N-72A	6428.9	0.0666	0.0536
	7:04	1S2-N-73A	6527.8	0.0654	0.0505
	8:41	1S2-N-74A	6626.4	0.0668	0.0505
	10:55	1S2-N-78A	6725.0	0.0678	0.0558
	12:50	1S2-N-79A	6823.6	0.0680	0.0530
	14:37	1S2-N-80A	6922.2	0.0683	0.0532
	16:40	1S2-N-84A	7025.2	0.0689	0.0546
	18:40	1S2-N-85A	7132.5	0.0690	0.0554
	20:44	1S2-N-87A	7239.8	0.0680	0.0538
	22:30	1S2-N-99A	7347.1	0.0689	0.0520
03/30/04	0:18	1S2-N-101A	7454.4	0.0695	0.0532
	2:26	1S2-N-103A	7556.4	0.0693	0.0536
	4:14	1S2-N-104A	7653.1	0.0692	0.0533
	5:47	1S2-N-105A	7749.8	0.0707	0.0567
	7:09	1S2-N-106A	7846.5	0.0712	0.0568
	8:07	1S2-N-116A	7943.2	0.0712	0.0572
	9:34	1S2-N-118A	8044.5	0.0712	0.0570
	10:44	1S2-N-122A	8150.5	0.0697	0.0553
	12:04	1S2-N-124A	8256.5	0.0715	0.0579
	13:50	1S2-N-125A	8362.5	0.0709	0.0571
	15:12	1S2-N-128A	8468.5	0.0710	0.0557
	17:58	1S2-N-132A	8572.5	0.0712	0.0562
	19:12	1S2-N-133A	8674.4	0.0705	0.0577
	20:51	1S2-N-134A	8776.3	0.0719	0.0592
	22:50	1S2-N-146A	8878.2	0.0707	0.0577
03/31/04	0:48	1T2-N-5A	8980.1	0.0718	0.0601
	1:58	1T2-N-10A	9082.1	0.0717	0.0578
	3:19	1T2-N-10B	9184.3	0.0702	0.0547
	4:37	1T2-N-11A	9286.5	0.0706	0.0555
	5:54	1T2-N-13A	9388.7	0.0718	0.0570
	8:05	1T2-N-15A	9490.9	0.0727	0.0604
	9:42	1T2-N-18A	9593.2	0.0702	0.0551
	11:04	1T2-N-20A	9695.5	0.0725	0.0602
	12:43	1T2-N-22A	9756.6	0.0723	0.0609
	14:03	1T2-N-24A	9900.1	0.0712	0.0568
	17:38	1T2-N-29A	10102.3	0.0723	0.0603
	19:14	1T2-N-38A	10199.8	0.0723	0.0612

* Cumulative mass from Test# 9 (Best Configuration Test)

Table 8.2. Concentrations of Y₂O₃ and RuO₂ in Discharge Stream Glass Samples, continued.

Date	Time	Sample Name	Glass (kg)*	Y ₂ O ₃	RuO ₂
03/31/04	20:48	1T2-N-39A	10297.3	0.0726	0.0604
	22:44	1T2-N-43A	10394.8	0.0731	0.0599
04/01/04	0:23	1T2-N-45A	10492.3	0.0731	0.0595
	1:52	1T2-N-48A	10596.6	0.0732	0.0594
	3:10	1T2-N-49A	10707.7	0.0738	0.0614
	4:41	1T2-N-50A	10818.8	0.0725	0.0604
	5:15	1T2-N-52A	10874.3	0.0731	0.0602
	7:17	1T2-N-62A	10985.4	0.0739	0.0636
	8:34	1T2-N-64A	11091.5	0.0701	0.0554
	9:53	1T2-N-66A	11192.4	0.0726	0.0596
	11:23	1T2-N-68A	11203.3	0.0707	0.0566
	13:42	1T2-N-70A	11394.2	0.0739	0.0621
	15:17	1T2-N-72A	11495.1	0.0726	0.0623
	16:57	1T2-N-74A	11631.5	0.0742	0.0637
	18:32	1T2-N-75A	11803.5	0.0745	0.0662
	20:16	1T2-N-76A	11975.5	0.0743	0.0608
04/02/04	0:37	1T2-N-97A	12061.5	0.0744	0.0642
	1:04	1T2-N-97B	12160.0	0.0743	0.0658

* Cumulative mass from Test# 9 (Best Configuration Test)

Table 8.3. Results of Gas Emission Sample Analyses for Ruthenium (EPA Method 5/29).

Sampling Location	Bubbling Rate (lpm)	Sampling Interval	Ru Feed Rate (mg/min)*	Ru Emission Rate (mg/min)	% of Ru Fed into Melter
Melter	64	3/29/04 10:57 - 11:14	577.14	41.44	7.18
		3/29/04 12:55 - 14:55	748.36	18.58	2.48
		3/29/04 16:46 - 18:46#	605.64	14.88	2.45
		Average	643.71	24.97	4.04
	131	3/31/04 09:08 - 10:08	740.23	57.73	7.81
		3/31/04 11:28 - 12:28	761.60	48.90	6.42
		3/31/04 14:44 - 15:44	804.35	34.73	4.32
		Average	768.73	47.12	6.18
	-	Overall Melter Average	706.22	40.28	5.64
SBS	64	3/29/04 10:20 - 11:19	N/A	12.78	NC
		3/29/04 12:34 - 15:05	N/A	3.36	NC
		3/29/04 16:35 - 18:50#	N/A	23.13	NC
		Average	N/A	13.09	NC
	131	3/31/04 08:57 - 10:17	N/A	17.00	NC
		3/31/04 11:20 - 12:40	N/A	12.91	NC
		3/31/04 14:29 - 15:49	N/A	14.32	NC
		Average	N/A	14.74	NC
	-	Overall SBS Average	N/A	12.07	NC
WESP	131	3/30/04 15:18 - 17:18	N/A	0.79	NC

* From actual injection data of the spike solution

The emission data were not used for overall average calculations due to a larger SBS emission rate than the melter emission rate

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N/A – Not applicable

NC – Not calculated

Table 8.4. Results of SBS and WESP Liquids Analyses for Ruthenium.

-	Bubbling Rate (lpm)	Date	Time	Sample I.D.	Ru Concentration (mg/l)	Corrected Ru Concentration (mg/l)
S B S	64	03/25/04	7:40	1R2-S-60B [#]	0.85	0.00
		03/26/04	19:29	1R2-S-123A	34.50	33.65
		03/28/04	0:37	1S2-S-16A	40.35	39.50
		03/29/04	13:45	1S2-S-80A	44.80	43.95
	131	03/31/04	15:48	1T2-S-26A	32.45	31.60
		04/01/04	20:29	1T2-S-76B	43.75	42.90
	Average for the Corrected Ru Concentration					38.32
WESP		04/02/04	3:13	1T2-W-99A	1.30	-
		04/02/04	5:00	1T2-W-99B	184.35	-
Total RuO ₂ Injected (g)		Total SBS Liquid (l)*		Total RuO ₂ in SBS:		
9386.9		18200.3		918.24 g (= 9.78% of total injected into the melter)		

* Blow-down volumes from Test# 9 after spike solution fed plus 1849.9 liters leftover in the SBS

[#] Ruthenium not yet spiked into feed when sample 1R2-S-60B was taken hence for calculative purposes viewed as a blank.

Table 8.5. Information on Samples from the Melt Pool.

Sampling Date	Sample I.D.	Location in the Melter	Analysis Performed
04/01/04	1T2-O-78A	Cold Cap	NA
04/02/04	1T2-O-97A	Bottom	SEM/EDS
	1T2-O-97B	Bottom	NA
	1T2-O-97C	Middle	SEM/EDS
	1T2-O-97D	Top	NA

NA – Not analyzed

Table 8.6. Summary of Ruthenium Volatility Data from This and Previous Tests.

Test	Glass Redox	Bubbling Rate	Ru Species		RuO ₂ in Off-gas (%)		Ref.
	Fe ²⁺ /All Fe	lpm	In the melt	On the Bottom	In SBS Blow-down	In Total Off-gas	
Previous	<0.01	0	RuO ₂	RuO ₂	NA	3.9	[39]
		40			11.2	15.6	
		65			23.8	32.8	
This	≈0.1	64, 131	RuO ₂	RuO ₂ , Ru	9.8	5.64 13.97*	-
Previous	≥0.15	65	#	Ru, Ru-alloys	ND	< 1	[17]

NA – Not analyzed

* calculated in section 8.4.3

very few, too small to identify

“-“ sign for blank field

Table 8.7. Summary of Ruthenium Retention Data from this and Previous Tests.

Test	Glass Redox	Bubbling Rate	Ru Species			Retention	Ref.
	Fe ²⁺ /All Fe	lpm	In Melt	On the Bottom		%	
			Species		Shape		
Previous	<0.01	0	RuO ₂	RuO ₂	No data	20.9	[39]
		40			Long thin needles	13.3~17.7	
		65				No Data	
This	≈0.1	64, 131	RuO ₂	RuO ₂ , Ru	Short thick needles	17.83	-
Previous	≥0.15	65	#	Ru, Ru-alloys	Large clusters	90.0	[17]

very few, too small to identify

NA – Not analyzed

“-“ sign for blank field

Figure 1.1. Cross-section of the DM1200 melter through the discharge chamber.

Figure 1.2. Cross-section through the DM1200 melter showing electrodes.

Figure 1.3. Single Outlet “J” Bubbler.

Figure 1.4. Single Outlet "L" Bubbler.

Figure 1.5. Double Outlet “J” Bubbler.

L's in C2 and B3
J's in C1 and A3

Figure 1.6. Placement of 4 single outlet bubblers simulating 2 double outlet bubblers; 8" separation between outlets on each side of the melter. Note: solid circles represent location of bubbler outlet.

L's in A1 and D3
J's in D1 and A3

Figure 1.7. Placement of 4 single outlet bubblers simulating 2 double outlet bubblers; 14" separation between outlets on each side of the melter. Note: solid circles represent location of bubbler outlet.

Figure 1.8. Specifications of Double Outlet “J” Bubbler.

Figure 1.9. Placement of double outlet bubblers. Note: solid circles represent location of bubbler outlet.

Figure 1.10. Schematic diagram of DM1200 off-gas system. “Sx” indicates sampling point.

Figure 1.11. Sulfur activated carbon and silver mordenite slipstream off-gas treatment system.

Figure 1.12. Overall schematic view of the new SBS internals.

Figure 1.13. Photograph of the new SBS internals.

Figure 1.14. SBS view from top of packing area and top of weir tubes.

Figure 1.15. SBS view of bottom of diffuser plate, bottom of weir tubes, coils and blow-down wand pipe interfacing.

Figure 1.16. View of SBS packing top grating interface.

Figure 1.17. View of SBS downcomer inner sleeve with installed thermocouples.

Figure 2.1. Viscosity vs. shear rate of AZ-101 (400 g glass / l) melter feed samples.

Figure 3.1.a. Production rates for Test 2 (530 g glass/l, various bubbler depths).

Figure 3.1.b. Production rates for Test 1 (530 g glass/l, bubbler skewing).

Figure 3.1.c. Production rates for Test 3 (400 g glass/l, 2 and 4 bubblers in prototypical locations).

Figure 3.1.d. Production rates for Test 8 (400 g glass/l, bubblers in corner).

Figure 3.1.e. Production rates for Test 10 (400 g glass/l with halide and sulfate spikes).

Figure 3.1.f. Production rates for Test 9 (400 g glass/l, 2 double outlet bubblers).

Figure 3.2.a. Glass temperatures (hourly averages) for Test 2 (530 g glass/l, various bubbler depths).

**Figure 3.2.b. Glass temperatures (hourly averages) for Test 1
(530 g glass/l, bubbler skewing).**

**Figure 3.2.c. Glass temperatures (hourly averages) for Test 3
(400 g glass/l, 2 and 4 bubblers in prototypical locations).**

**Figure 3.2.d. Glass temperatures (hourly averages) for Test 8
(400 g glass/l, bubblers in each corner).**

**Figure 3.2.e. Glass temperatures (hourly averages) for Test 10
(400 g glass/l with halide and sulfate).**

**Figure 3.2.f. Glass temperatures (hourly averages) for Test 9
(400 g glass/l, 2 double outlet bubblers).**

Figure 3.3.a. Plenum temperatures and electrode power (hourly averages) for Test 2 (530 g glass/l, various bubbler depths).

Figure 3.3.b. Plenum temperatures and electrode power (hourly averages) for Test 1 (530 g glass/l, bubbler skewing).

Figure 3.3.c. Plenum temperatures and electrode power (hourly averages) for Test 3 (400 g glass/l, 2 and 4 bubblers in prototypical locations).

Figure 3.3.d. Plenum temperatures and electrode power (hourly averages) for Test 8 (400 g glass/l, bubblers in each corner).

Figure 3.3.e. Plenum temperatures and electrode power (hourly averages) for Test 10 (400 g glass/l with halide and sulfate spikes).

Figure 3.3.f. Plenum temperatures and electrode power (hourly averages) for Test 9 (400 g glass/l, 2 double outlet bubblers).

Figure 3.4.a. Electrode temperatures and power (hourly averages) for Test 2 (530 g glass/l, various bubbler depths).

Figure 3.4.b. Electrode temperatures and power (hourly averages) for Test 1 (530 g glass/l. bubbler skewing).

Figure 3.4.c. Electrode temperatures and power (hourly averages) for Test 3 (400 g glass/l, 2 and 4 bubblers in prototypical locations).

Figure 3.4.d. Electrode temperatures and power (hourly averages) for Test 8 (400 g glass/l, bubblers in each corner).

Figure 3.4.e. Electrode temperatures and power (hourly averages) for Test 10 (400 g glass/l with halide and sulfate spikes).

Figure 3.4.f. Electrode temperatures and power (hourly averages) for Test 9 (400 g glass/l, 2 double outlet bubblers).

**Figure 3.5.a. Electrode power and glass resistance for Test 2
(530 g glass/l, various bubbler depths).**

**Figure 3.5.b. Electrode power and glass resistance for Test 1
(530 g glass/l, bubbler skewing).**

**Figure 3.5.c. Electrode power and glass resistance for Test 3
(400 g glass/l, 2 and 4 bubblers in prototypical locations).**

**Figure 3.5.d. Electrode power and glass resistance for Test 8
(400 g glass/l, bubblers in each corner).**

**Figure 3.5.e. Electrode power and glass resistance for Test 10
(400 g glass/l with halide and sulfate spikes).**

**Figure 3.5.f. Electrode power and glass resistance for Test 9
(400 g glass/l, 2 double outlet bubblers).**

**Figure 3.6.a. Glass density and level for Test 2
(530 g glass/l, various bubbler depths).**

Figure 3.6.b. Glass density and level for Test 1 (530 g glass/l, bubbler skewing)

**Figure 3.6.c. Glass density and level for Test 3
(400 g glass/l, 2 and 4 bubblers in prototypical locations).**

Figure 3.6.d. Glass density and level for Test 8 (400 g glass/l, bubblers in corners).

**Figure 3.6.e. Glass density and level for Test 10
(400 g glass/l with halide and sulfate spikes).**

Figure 3.6.f. Glass density and level for Test 9 (400 g glass/l, 2 double outlet bubblers).

Figure 3.7.a. Glass pool bubbling for Test 2 (530 g glass/l, various bubbler depths).

Figure 3.7.b. Glass pool bubbling for Test 1 (530 g glass/l, bubbler skewing).

Figure 3.7.c. Glass pool bubbling for Test 3 (400 g glass/l, 2 and 4 bubblers in prototypical locations).

Figure 3.7.d. Glass pool bubbling for Test 8 (400 g glass/l, bubblers in each corner).

Figure 3.7.e. Glass pool bubbling for Test 10 (400 g glass/l, bubblers in each corner).

Figure 3.7.f. Glass pool bubbling for Test 9 (400 g glass/l, 2 double outlet bubblers).

Figure 4.1. Schematic diagram of DM1200 energy balance concept for Tests 3 and 8.

Figure 4.2. Schematic diagram of DM1200 energy balance concept for Test 9.

Figure 4.3. View of west side of DM1200 melter

Figure 4.4. View of top of DM1200 melter

Figure 4.5. SBS energy balance process schematic for Tests 3 and 8.

Figure 4.6. SBS energy balance during Test 3.

Figure 4.7. SBS energy balance during Test 8.

Figure 4.8. SBS energy balance process schematic for Test 9.

Figure 4.9. Component energies during Test 3.

Figure 4.10. Melt pool and SBS temperature histories during Test 3.

Figure 4.11. Component energies during Test 8.

Figure 4.12. Melt pool and SBS temperature histories during Test 8.

Figure 5.1. Average gas temperatures along the DM1200 off-gas train during Test 2.

Figure 5.2. Average gas temperatures along the DM1200 off-gas train during Test 1.

Figure 5.3. Average gas temperatures along the DM1200 off-gas train during Test 3.

Figure 5.4. Average gas temperatures along the DM1200 off-gas train during Test 8.

Figure 5.5. Average gas temperatures along the DM1200 off-gas train during Test 10.

Figure 5.6. Average gas temperatures along the DM1200 off-gas train during Test 9.

Figure 5.7. Melter pressure at instrument port and control air flow rate during Test 2.

Figure 5.8. Transition line and film cooler differential pressures (hourly average values) during Test 2.

Figure 5.9. Layout of film cooler and transition line sections.

Figure 5.10. SBS Y-piece (Transition Line #4) connecting transition line bellows to the SBS inlet.

Figure 5.11. Film cooler inlet after Test 2.

Figure 5.12. Film cooler outlet after Test 2.

Figure 5.13. Transition line section #1 inlet after Test 2.

Figure 5.14. Transition line section #1 outlet after Test 2.

Figure 5.15. Transition line section #2 inlet after Test 2.

Figure 5.16. Transition line section #2 outlet after Test 2.

Figure 5.17. Transition line section #3 inlet after Test 2.

Figure 5.18. Transition line section #3 outlet after Test 2.

Figure 5.19. Transition line bellows inlet after Test 2.

Figure 5.20. Transition line bellows outlet after Test 2.

Figure 5.21. Transition line section #4 inlet after Test 2.

Figure 5.22. Transition line section #4 outlet after Test 2.

Figure 5.23. Melter pressure at instrument port and control air flow rate during Test 1.

Figure 5.24. Transition line and film cooler differential pressures (hourly average values) during Test 1.

Figure 5.25. Transition line section #2 inlet after Test 1.

Figure 5.26. Transition line section #3 after Test 1.

Figure 5.27. Transition line bellows inlet after Test 1.

Figure 5.28. Melter pressure at instrument port and control air flow rate during Test 3.

Figure 5.29. Transition line and film cooler differential pressures (hourly average values) during Test 3.

Figure 5.30.a. View of large debris removed from transition line bellows inlet during Test 3.

Figure 5.30.b. Macro image of sample removed from the transition line during Test #3 (Sample # 1D2-O-25A).

Figure 5.30.c. General EDS spectrum of the transition line sample (Sample # 1D2-O-25A).

Figure 5.31. Close-up of clogged perforation of film cooler inlet after Test 3.

Figure 5.32. Melter pressure at instrument port and control air flow rate during Test 8.

Figure 5.33. Transition line and film cooler differential pressures (hourly average values) during Test 8.

Figure 5.34. Melter pressure at instrument port and control air flow rate during Test 10.

Figure 5.35. Transition line and film cooler differential pressure (hourly average values) during Test 10.

Figure 5.36. Film cooler inlet after Test 10.

Figure 5.37. Close-up of film cooler inlet after Test 10.

Figure 5.38. Film cooler outlet after Test 10.

Figure 5.39. Transition line section #1 inlet after Test 10.

Figure 5.40. Transition line section #1 outlet after Test 10.

Figure 5.41. Transition line section #2 inlet after Test 10.

Figure 5.42. Transition line section #2 outlet after Test 10.

Figure 5.43. Transition line section #3 inlet after Test 10.

Figure 5.44. Transition line section #3 outlet after Test 10.

Figure 5.45. Transition line bellows inlet after Test 10.

Figure 5.46. Transition line bellows outlet after Test 10.

Figure 5.47. Transition line section #4 inlet after Test 10.

Figure 5.48. Film cooler inlet (post-cleaning) after Test 10.

Figure 5.49. Film cooler outlet (post-cleaning) after Test 10.

Figure 5.50. Melter pressure at instrument port and control air flow rate during Test 9.

Figure 5.51. Film cooler differential pressure during Test 9.

Figure 5.52. Transition line differential pressure during Test 9.

Figure 5.53. View of film cooler clogging at 166.2 hours during Test 9.

Figure 5.54. Film cooler inlet and internals after Test 9.

Figure 5.55. Film cooler outlet after Test 9.

Figure 5.56. Transition line section # 1 inlet after Test 9.

Figure 5.57. Transition line section #1 outlet after Test 9.

Figure 5.58. Transition line section #2 inlet after Test 9.

Figure 5.59. Transition line section #2 outlet piping after Test 9.

Figure 5.60. Transition line section #3 inlet piping after Test 9.

Figure 5.61. Transition line section #3 outlet piping after Test 9.

Figure 5.62. Transition line bellows inlet flange and inlet piping after Test 9.

Figure 5.63. Transition line bellows outlet flange and piping after Test 9.

Figure 5.64. Transition line section #4 inlet flange (on bellows side) after Test 9.

Figure 5.65. Transition line section #4 piping after inlet flange after Test 9.

Figure 5.66. Transition line section #4 inlet flange after placing on the floor.

Figure 5.67. View of film cooler inlet and internals (partial post-cleaning) after Test 9.

Figure 5.68. SBS inlet and outlet gas temperatures during Test 2.

Figure 5.69. SBS inlet, outlet, and differential pressures (hourly average values) during Test 2.

Figure 5.70. SBS cooling water and bed temperatures (hourly average values) during Test 2.

Figure 5.71. SBS jacket, inner coil, and heat exchanger water flow rates (hourly average values) during Test 2.

Figure 5.72. Calculated heat loads on the cooling jacket and plate heat exchanger (hourly average values) during Test 2.

Figure 5.73. SBS inner coil and plate heat exchanger water temperatures (hourly average values) during Test 2.

**Figure 5.74. IR image looking down SBS downcomer from just below Y-inlet,
before cleaning after Test 2.**

Figure 5.75. IR image looking down SBS downcomer from location at about 5'6" below top, before cleaning after Test 2.

**Figure 5.76. Visual image looking up SBS downcomer from below,
before cleaning after Test 2.**

Figure 5.77. Visual image SBS bowl after liquid removal, before cleaning after Test 2.

Figure 5.78. SBS inlet and outlet gas temperatures during Tests 1.

Figure 5.79. SBS inlet, outlet, and differential pressures (hourly average values) during Test 1.

Figure 5.80. SBS cooling water and bed temperatures (hourly average values) during Test 1.

Figure 5.81. SBS jacket, inner coil, and heat exchanger water flow rates (hourly average values) during Test 1.

Figure 5.82. Calculated heat loads on the cooling jacket and plate heat exchanger (hourly average values) during Test 1.

Figure 5.83. SBS inner coil and plate heat exchanger water temperatures (hourly average values) during Test 1.

(a)

(b)

**Figures 5.84. SBS shell above packed bed (a) before installation of SBS downcomer upper sleeve.
(b) after sleeve installation.**

Figure 5.85. IR image looking down SBS downcomer from the location 5'6" below top viewport after Test 1.

Figure 5.86. IR image looking down SBS downcomer from the location ~ 6" above bottom of downcomer after Test 1.

Figure 5.87. SBS inlet and outlet gas temperatures during Test 3.

Figure 5.88. SBS inlet, outlet, and differential pressures (hourly average values) during Test 3.

Figure 5.89. SBS cooling water and bed temperatures (hourly average values) during Test 3.

Figure 5.90. SBS jacket, inner coil, and heat exchanger water flow rates (hourly average values) during Test 3.

Figure 5.91. Calculated heat loads on the cooling jacket and plate heat exchanger (hourly average values) during Test 3.

Figure 5.92. SBS inner coil and plate heat exchanger water temperatures (hourly average values) during Test 3.

Figure 5.93. IR image looking down SBS downcomer, immediately below Y-inlet from transition line after Test 3.

Figure 5.94. IR image looking down SBS downcomer, from location ~ 5'6" down from top viewport after Test 3.

Figure 5.95. IR image looking down from bottom of SBS downcomer after Test 3.

Figure 5.96. SBS inlet and outlet gas temperatures during Test 8.

Figure 5.97. SBS inlet, outlet, and differential pressures (hourly average values) during Test 8.

Figure 5.98. SBS cooling water and bed temperatures (hourly average values) during Test 8.

Figure 5.99. SBS jacket, inner coil, and heat exchanger water flow rates (hourly average values) during Test 8.

Figure 5.100. Calculated heat loads on the cooling jacket and plate heat exchanger (hourly average values) during Test 8.

Figure 5.101. SBS inner coil and plate heat exchanger water temperatures (hourly average values) during Test 8.

**Figure 5.102. IR image looking down downcomer from the transition line
Y-inlet after Test 8.**

**Figure 5.103. IR Image looking down SBS downcomer from the location
~5"6" below viewport after Test 8.**

Figure 5.104. SBS inlet and outlet gas temperatures during Test 10.

Figure 5.105. SBS inlet, outlet, and differential pressures (hourly average values) during Test 10.

Figure 5.106. SBS cooling water and bed temperatures (hourly average values) during Test 10.

Figure 5.107. SBS jacket, inner coil, and heat exchanger water flow rates (hourly average values) during Test 10.

Figure 5.108. Calculated heat loads on the cooling jacket and plate heat exchanger (hourly average values) during Test 10.

Figure 5.109. SBS inner coil and plate heat exchanger water temperatures (hourly average values) during Test 10.

Figure 5.110. View of the SBS overflow tank residual solids After Test 10.

Figure 5.111. IR image, looking down into SBS Bowl from downcomer, near 6' down after Test 10.

Figure 5.112. Visual image looking up SBS downcomer from below, before cleaning after Test 10.

Figure 5.113. IR image, looking down into SBS Bowl from downcomer after Test 10

Figure 5.114. Visual image of SBS Bowl, close-up of debris pile after Test 10.

Figure 5.115. Overall view of the new SBS overflow tank.

Figure 5.116. SBS inlet and outlet gas temperatures during Test 9.

Figure 5.117. SBS inlet, outlet, and differential pressures (hourly average values) during Test 9.

Figure 5.118. SBS downcomer annulus pressure (hourly average values) during Test 9.

Figure 5.119. SBS off-gas downcomer and sump water temperatures (hourly average values) during Test 9.

Figure 5.120. SBS cooling coil inlet, cooling coil outlet/jacket inlet and jacket outlet water temperatures (hourly average values) during Test 9.

Figure 5.121. SBS cooling coil/jacket water flow rate (hourly average values) during Test 9.

Figure 5.122. Calculated heat loads on the inner coil and jacket (hourly average values) during Test 9.

Figure 5.123. View of SBS down-comer (with visible light) at 217.2 hours.

Figure 5.124. View of SBS down-comer (with infrared light) at 217.2 hours.

Figure 5.125. View of top splash zone of SBS down-comer (with visible light) after Test 9.

Figure 5.126. View of bottom of SBS overflow tank after Test 9.

Figure 5.127. SBS bowl solids after Test 9.

Figure 5.128. Close-up view of SBS bowl solids after Test 9.

Figure 5.129. View from the bottom of SBS diffuser plate after Test 9.

Figure 5.130. Bottom view of SBS down-comer (with visible light) after filling SBS with water and draining.

Figure 5.131. View of SBS packing top grating interface after Test 9.

Figure 5.132. WESP bottom of grid, post-acid-wash, pre-Test 2.

Figure 5.133. WESP bottom of grid, post-acid-wash, pre-Test 2.

Figure 5.134. WESP inlet and outlet temperatures during Test 2. (Note: downward outlet temperature spikes are the result of WESP deluges).

Figure 5.135. WESP differential pressure and outlet gas flow rate (hourly average values) during Test 2.

Figure 5.136. Accumulated WESP blow-down volume, accumulated fresh spray water, water removed from off-gas during Test 2.

Figure 5.137. Voltage and current across the WESP during Test 2.

Figure 5.138. WESP top grid support before removal after Test 2.

Figure 5.139. Post deluge view of WESP after Test 2.

Figure 5.140. SEM micrograph of a sample removed from WESP blowdown flow indicating transmitter at 95.7 hours of operations during Test #2 (sample # X12-O-154A).

Figure 5.141. EDS spectra of regions #1 through region #4 indicated in Figure 5.153. (Sample # X12-O-154A).

Figure 5.142. SEM micrograph of a sample removed from WESP collector rods and plates (sample # Z12-O-37H).

**Figure 5.143. EDS spectra of unmounted/uncoated material indicated in Figure 5.155
(Sample # Z12-O-37H).**

Figure 5.144. WESP inlet and outlet temperatures during Test 1. (Note: downward outlet temperature spikes are the result of WESP deluges).

Figure 5.145. WESP differential pressure and outlet gas flow rate (hourly average values) during Test 1.

Figure 5.146. Accumulated WESP blow-down volume, accumulated fresh spray water and water removed from off-gas during Test 1.

Figure 5.147. Voltage and current across the WESP during Test 1.

Figure 5.148. WESP inlet and outlet temperatures during Test 3. (Note: downward outlet temperature spikes are the result of WESP deluges).

Figure 5.149. WESP differential pressure and gas flow rate (hourly average values) during Test 3.

Figure 5.150. Accumulated WESP blow down volume, accumulated fresh spray water, water removed from off-gas during Test 3.

Figure 5.151. Voltage and current across the WESP during Test 3. (Note: during the deluges WESP was turned off).

Figure 5.152. Pre-deluge view of WESP rod and collector plate after Test 3.

Figure 5.153. Post-deluge view of WESP after Test 3.

Figure 5.154. WESP inlet and outlet temperatures during Test 8. (Note: downward outlet temperature spikes are the result of WESP deluges).

Figure 5.155. WESP differential pressure and gas flow rate (hourly average values) during Test 8.

Figure 5.156. Accumulated WESP blow down volume, accumulated fresh spray water, and water removed from off-gas during Test 8.

Figure 5.157. Voltage and current across the WESP during Test 8.
(Note: during the deluges WESP was turned off).

Figure 5.158. Pre-deluge view of WESP grid after Test

Figure 5.159. Post-deluge view of WESP grid after Test 8.

Figure 5.160. WESP inlet and outlet temperatures during Test 10. (Note: downward outlet temperature spikes are the result of WESP deluges).

Figure 5.161. WESP differential pressure and gas flow rate (hourly average values) during Test 10.

Figure 5.162. Accumulated WESP blow down volume, accumulated fresh spray water, and water removed from off-gas during Test 10.

Figure 5.163. Voltage and current across the WESP during Test 10. (Note: during the deluges WESP was turned off).

Figures 5.164. Pre-deluge WESP, view from bottom of grid after Test 10.

Figure 5.165. Post-deluge WESP, view from bottom of grid after Test 10.

Figure 5.166. WESP inlet and outlet temperatures during Test 9. (Note: downward outlet temperature spikes are the result of WESP deluges).

Figure 5.167. WESP differential pressure and gas flow rate (hourly average values) during Test 9.

Figure 5.168. Accumulated WESP blow down volume, accumulated fresh spray water, and water removed from off-gas during Test 9.

Figure 5.169. Voltage and current across the WESP during Test 9.
(Note: during the deluges WESP was turned off).

Figure 5.170. View looking at grid and collectors from bottom, pre-deluge after Test 9.

Figure 5.171. Post-deluge view of WESP grid after Test 9.

Figure 5.172. Post-deluge view of WESP grid after Test 9.

Figure 5.173. Post-deluge view of WESP grid after Test 9.

Figure 5.174. Outlet temperature and differential pressure for HEME #1 during Test 2.

Figure 5.175. Interior view of HEME #1 outlet after Test 2.

Figure 5.176. Outlet temperature and differential pressure for HEME #1 during Test 1.

Figure 5.177. Outlet temperature and differential pressure for HEME #1 during Test 3.

Figure 5.178. Outlet temperature and differential pressure for HEME #1 during Test 8.

Figure 5.179. Outlet temperature and differential pressure for HEME #1 during Test 10.

Figure 5.180. Outlet temperature and differential pressure for HEME #1 during Test 9.

**Figure 5.181. Outlet temperature and differential pressure for HEPA #1
(hourly average values) during Test 2.**

Figure 5.182. View of bottom of HEPA housing after Test 2.

Figure 5.183. View of HEPA #1 pre-filter (downstream side) after Test 2.

Figure 5.184. View of area from HEPA #1 pre-filter towards the process air heater after Test 2.

**Figure 5.185. Outlet temperature and differential pressure for HEPA #1
(hourly average values) during Test 1.**

Figure 5.186. Outlet temperature and differential pressure for HEPA #1 (hourly average values) during Test 3.

Figure 5.187. Outlet temperature and differential pressure for HEPA #1 (hourly average values) during Test 8.

**Figure 5.188. Outlet temperature and differential pressure for HEPA #1
(hourly average values) during Test 10.**

Figure 5.189. View of bottom of HEPA housing after Test 10.

Figure 5.190. Outlet temperature and differential pressure for HEPA #1 (hourly average values) during Test 9.

Figure 5.191. View of blower 701 inlet pipe after Test 2.

Figure 5.192. View of blower 702 impeller after Test 2.

Figure 5.193. TCO/SCR heater gas inlet temperature during Test 2.

Figure 5.194. TCO/SCR temperatures (hourly average values) during Test 2.

Figure 5.195. TCO/SCR differential pressures (hourly average values) during Test 2.

Figure 5.196. TCO/SCR heater gas inlet temperature during Test 1.

Figure 5.197. TCO/SCR temperatures (hourly average values) during Test 1.

Figure 5.198. TCO/SCR differential pressures (hourly average values) during Test 1.

Figure 5.199. TCO/SCR heater gas inlet temperature during Test 3.

Figure 5.200. TCO/SCR temperatures (hourly average values) during Test 3.

Figure 5.201. TCO/SCR differential pressures (hourly average values) during Test 3.

Figure 5.202. TCO/SCR heater gas inlet temperature during Test 8.

Figure 5.203. TCO/SCR temperatures (hourly average values) during Test 8.

Figure 5.204. TCO/SCR differential pressures (hourly average values) during Test 8.

Figure 5.205. TCO/SCR heater gas inlet temperature during Test 10.

Figure 5.206. TCO/SCR temperatures (hourly average values) during Test 10.

Figure 5.207. TCO/SCR differential pressures (hourly average values) during Test 10.

Figure 5.208. TCO/SCR heater gas inlet temperature during Test 9.

Figure 5.209. TCO/SCR temperatures (hourly average values) during Test 9.

Figure 5.210. TCO/SCR differential pressures (hourly average values) during Test 9.

Figure 5.211. Inlet temperature and differential pressure for PBS (hourly average values) during Test 2.

Figure 5.212. Sump temperature and pH for PBS during Tests 2.

Figure 5.213. Inlet temperature and differential pressure for PBS (hourly average values) during Test 1.

Figure 5.214. Sump temperature and pH for PBS during Tests 1.

Figure 5.215. Inlet temperature and differential pressure for PBS (hourly average values) during Test 3.

Figure 5.216. Sump temperature and pH for PBS during Test 3.

**Figure 5.217. Inlet temperature and differential pressure for PBS
(hourly average values) during Test 8.**

Figure 5.218. Sump temperature and pH for PBS during Test 8.

**Figure 5.219. Inlet temperature and differential pressure for PBS
(hourly average values) during Test 10.**

Figure 5.220. Sump temperature and pH for PBS during Test 10.

Figure 5.221. Inlet temperature and differential pressure for PBS (hourly average values) during Test 9.

Figure 5.222. Sump temperature and pH for PBS during Tests 9.

Figure 5.223. Inlet and outlet temperatures and differential pressure for HEME #2 during Test 2.

Figure 5.224. Inlet and outlet temperatures and differential pressure for HEME #2 during Test 1.

Figure 5.225. View of HEME #2 filter media looking upstream after Test 1, before washing.

Figure 5.226. View of HEME #2 filter media looking upstream after Test 1, after washing.

Figure 5.227. Inlet and outlet temperatures and differential pressure for HEME #2 during Test 3.

Figure 5.228. Inlet and outlet temperatures and differential pressure for HEME #2 during Test 8.

Figure 5.229. Inlet and outlet temperatures and differential pressure for HEME #2 during Test 10.

Figure 5.230. Inlet and outlet temperatures and differential pressure for HEME #2 during Test 9.

Figure 5.231. View of Blower 801 impeller outlet funnel liquid collector after Test 10.

Figure 5.232. View of Blower-801 exterior housing after Test 10.

Figure 5.233. pH of SBS blow-down solutions.

Figure 5.234. Accumulated SBS blow-down volume and accumulated feed water during Test 2.

Figure 5.235. Accumulated SBS blow-down volume and accumulated feed water during Test 1.

Figure 5.236. Accumulated SBS blow-down volume and accumulated feed water during Test 3.

Figure 5.237. Accumulated SBS blow-down volume, and accumulated feed water during Test 8.

Figure 5.238. Accumulated SBS blow-down volume, and accumulated feed water during Test 10.

Figure 5.239. Accumulated SBS blow-down volume, and accumulated feed water during Test 9.

Figure 5.240. AZ-101 feed composition (excludes oxygen and carbon).

Figure 5.241. Suspended solids composition from Test 3, SBS sample (1D2-S-47A).

Figure 5.242. Dissolved solids composition from Test 3, SBS sample (1D2-S-47A).

Figure 5.243. Dissolved solids composition from Test 3 WESP samples (1C2-W-137A and B).

Figure 6.1. XRF analysis of sodium and silicon oxides in discharged glasses.

Figure 6.2. XRF analysis of selected major oxides in discharged glasses.

Figure 6.3. XRF analysis of select minor oxides in discharged glasses.

Figure 6.4. XRF analysis of select oxides in discharged glasses.

Figure 6.5. XRF analysis of chloride and sulfur oxide in discharged glasses.

Figure 7.1. Solids and sodium carry-over from the melter.

Figure 7.2. Feed composition (excludes oxygen, nitrogen and carbon compounds) from Test 3.

Figure 7.3. Melter exhaust composition (excludes oxygen, nitrogen, and carbon compounds) from Test Segment 3C.

Figure 7.4. SBS exhaust composition from Test Segment 3C (excludes oxygen, nitrogen, fluoride, and carbon compounds).

Figure 7.5. WESP exhaust composition from Test Segment 3C (excludes oxygen, nitrogen, fluoride, and carbon compounds).

Figure 7.6 Decontamination factors for trichloroethylene and chlorobenzene across the carbon column.

Figure 7.7. Sulfur impregnated activated carbon bed temperature during Test 10.

Figure 7.8. Sulfur impregnated activated carbon bed pressure during Test 10.

Figure 8.1. Schematic of ruthenium injection system.

Figure 8.2. Cumulative mass of yttrium injected into the melter and measured in the glass discharged.

Figure 8.3. Cumulative mass of ruthenium injected into the melter and measured in the glass discharged.

Figure 8.4. Measured and modeled concentrations of yttrium in the glass discharged.

Figure 8.5. Measured and modeled concentrations of ruthenium in the glass discharged.

Figure 8.6. RuO₂ clusters at the bottom of the melter.

Figure 8.7. RuO₂ and Ru metal particles at the bottom of the melter.

Figure 8.8. EDS spectra of RuO_2 (EDS-1) and Ru metal (EDS-2).

Figure 8.9. RuO₂ clusters in the middle of the melt pool.

RECEIVED
AUG 17 2004
By le403 Page 1 of 1

3) To be Completed by Reviewer*

My significant comments have been addressed.

Acceptance: _____

Print/Type Name Signature Date

* An e-mail to the R&T contact stating that significant comments are addressed can substitute for this acceptance.

Petkus, Lawrence

From: Hyman, Marve
Sent: Monday, September 27, 2004 4:31 PM
To: Petkus, Lawrence
Cc: Ongpin, Maria; Rouse, James; Lee, Ernest D (WTP); Carl, Daniel
Subject: FW: Comment Responses - VSL-04R4800-4, "Integrated DM1200 Melter Testing of Bubbler Configurations Using HLW AZ-101 Simulants"

Larry: Rod Gimpel has accepted responses; Dan Carl has accepted responses to his Mandatory comments; and on behalf of Engineering we concur with Document VSL-04R4800-4 Rev 0.

I assume that you will eventually conclude with Dan Carl his reply to the response to non-Mandatory comment No. 09.
Marve

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

From: Petkus, Lawrence
Sent: Friday, September 17, 2004 7:47 AM
To: Hyman, Marve; Carl, Daniel; Gimpel, Rod
Subject: Comment Responses - VSL-04R4800-4, "Integrated DM1200 Melter Testing of Bubbler Configurations Using HLW AZ-101 Simulants"

Attached are the responses to your comments on VSL-04R4800-4. Please let me know if these responses are acceptable. Thank you.

Larry Petkus

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

ComResp DM1200
config RG.doc

Petkus, Lawrence

From: Carl, Daniel
Sent: Thursday, October 14, 2004 6:02 AM
To: Petkus, Lawrence
Subject: RE: Responses to Comments on DM1200 Configuration Report

Larry,

This seems ok to me.

Dan

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

From: Petkus, Lawrence
Sent: Wednesday, October 13, 2004 3:40 PM
To: Carl, Daniel
Subject: RE: Responses to Comments on DM1200 Configuration Report

Dan,
I now have the final version of VSL-04R4800-4. It is large, 13 Meg, located on the R&T drive. See link below:

<\\Wtpps0166\R&T\Vitrification\HLW Mltr Tstg\DM1200\Redox & Bubbler Testing\Bubble Config Final Report\VSL-04R4800-4, Rev. 0 - DM1200 Bubbler Config Report.pdf>

You had one unresolved comment, 09, which I also wanted clarified. If you look at pages 50 and 51 of the report, not much has been clarified. After rereading this section - again - I have a new view. I have been hung up on the "however" in the last sentence in the paragraph, middle of page 51. The "however" leads me to expect an explaining by exception in the rest of the sentence. It's not there. Our comments (a least mine) were made in order to lift the explanation out of the rest of the sentence.

It's just a misplaced "however" there is no explanation. Ridges, or stiff cold cap, formed during the chloride addition and the sulfate addition. Production was slow and not very stable. Several attempts were made to get rid off these ridges by shutting off the feed, but to no avail. There was a last feed shut down just before the start of combined chloride and sulfate portion. Production was more stable during this last part of the run.

I can't explain the result, but that's the data. I'm planning to let this die. I hope you agree. Marve has already sent concurrence since this is an "I" issue.

Larry

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

From: Petkus, Lawrence
Sent: Friday, September 17, 2004 4:17 PM
To: 'ianp@vsl.cua.edu'
Cc: Perez, Joseph; ioseph@duratekinc.com; brad Bowan; Carl, Daniel
Subject: RE: Responses to Comments on DM1200 Configuration Report

Ian,
I don't have all of the Enginnering responses back yet, I am sending what I have. Responses for me and E&NS are acceptable.

Joe Perez had some additional comments included on his CRF, attached.

Dan has one follow-on question to his comment #9:
"Responses were acceptable except for my comment 09, which was significance "I," which may mean it doesn't matter. However, the response implies there was a significant observation not mentioned in the report (unless I missed it). Namely, the implication is that the formation of mounds and ridges increased as the run segments progressed. This would imply

that for a given test segment there were significantly more of these formations on day two than there were on day one, even more on day three, and even more yet again on day four (see figures 3.1a and 3.1e). I'd like to know if this is true."

To add to Dan's question - It seems that in Test 10 several actions were taken to improve the production rate. It appears that feed was stopped twice (fig 3.1.e) and the glass level was increased (fig 3.6.e) Further explanation of this test would be helpful. Maybe we just don't know what happened.

Larry

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

From: ianp@vsl.cua.edu [mailto:ianp@vsl.cua.edu]

Sent: Thursday, September 16, 2004 4:43 PM

To: Petkus, Lawrence

Cc: Perez, Joseph; ioseph@duratekinc.com; brad Bowan

Subject: Responses to Comments on DM1200 Configuration Report

Larry:

Please find the subject comment responses attached.

Regards,

Ian.

COMMENT RESOLUTION FORM

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JEP
10/13/04

Return to: Lawrence Petkus

Comments Due: August 31, 2004

Document Title: Integrated DM1200 Melter Testing of Bubbler Configurations Using HLW AZ-101 Simulants		Document No. VSL-04R4800-4		Revision: A	Date: August 17, 2004
Reviewer: Joe Perez	Date: 8/30/04	Response by:	Date:	Comments Resolved:	Date: 10/13/04

Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^b	Response	Resolution
1	Pg. 22, Summary of Testing, a) Objectives, first para.	Second sentence states, "...subset of three tests". Later sentences describe up to six tests. Clarify description please. Third sentence states, total solids. Based on 20% to 15% discussion this should be undissolved solids. Clarify please.	M		Three will be corrected to six . Total will be changed to undissolved .	OK
2	Pg. 23, Objectives table	Objective 4.(b) defers providing any details on bubbler testing exposure times until, "...when it is available". This information will be expected to be provided in the next DM1200 test report (ID 1139 in Duratek schedule) and again in the MACT testing report.	I		Reporting on bubbler exposure will be done at the conclusion of MACT testing in order to provide maximum exposure duration. R&T: In lieu of the weekly Duratek report that provided this information weekly (days of feeding and days of idling) this can be provided separately to R&T by Duratek
3	Pg. 24, Objective 5; effect of bubblers placed deep. AND Pg. 31, last sentence AND	Data extracted from Duratek analyses of VSL data and presented at the April 2004 R&T Peer Review stated the following: 1. Bubbler placement near floor increased production rate at the same bubbling rate by 33% 2. Bubbler placement near floor allows for a 38% higher bubbling rate resulting in higher production rates 3. The combined effect is a 46% increase in production rate	M		Presumably, you are referring to the March 2004 Peer Review and the presentation entitled "Scale-up of HLW Throughput Attainment with Bubblers," March 17, 2004. Page 21 of that presentation indeed includes, verbatim, these declarative statements (your #1, 2, and 3). However, the presentation does not provide any information on how these conclusions were obtained. Consequently, we have reviewed the test results in an effort to determine how one might have reached these conclusions. Each point is discussed below.

ORP-51442, Rev. 0

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COMMENT RESOLUTION FORM

Page 1 of 3 ^{1 of 1} _{10/8/04}

Return to: Lawrence Petkus

Comments Due: August 31, 2004

Document Title: Integrated DM1200 Melter Testing of Bubbler Configurations Using HLW AZ-101 Simulants		Document No. VSL-04R4800-4		Revision: A	Date: August 17, 2004
Reviewer: Lawrence Petkus	Date:	Response by:	Date:	Comments Resolved: <i>Lawrence Petkus</i>	Date: <i>10/13/04</i>

Item No.	Section/ Paragraph	Comment	Significance ^a	"M" Comment Justification ^b	Response	Resolution
1	1.4.3	The distances from bubbler to feed port are really the distance in the "XY plane" and not in space. This should be clarified.	I		Will clarify that the distance specified is in the plane of the melt surface.	
2	1.4.4	First blower is upstream not downstream of the TCO	M		Will correct.	
3	1.4.4 Particulate Removal	"Components <u>from</u> the SBS <u>through</u> the HEPA ..." rather than "between"	I		Will reword as suggested.	
4	Table 4.4	Water balance: Since the two components or "SBS Blowdown + exhaust" are different one measured and the other calculated, It would be helpful if they were listed separately	M		Will add a row to provide separate values for each of these.	
5	5.1 / 1	report mentions "failure" of poppet valve. The ADS pump report VSL-04-R4800-2 describes pump failure due to dried feed on actuator rod. Clear up inconsistency	M	Confusing , could lead to incorrect conclusions	The ADS report is describing a problem on 4/26/03 whereas this problem occurred on 6/27/03 @ ~8:13. The problem on 6/27/03 (Test 1, this series) resulted in replacement of the poppet air solenoid valve (FS-CA-V-064). We will add text to compare observations in these tests with those in the ADS report.	
6	5.1.1 test 2 / 5 (last)	The transition line DP measurements for test s 5, 6, and 2 show that the DP increased during the last part of test 6. This is the probable time of solids accumulation	M		We will add text to make the connection to the observed dP in the Reductant Test 6.	

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R&T Technology Issues Summary

Page 1 of 2

Test Report Title: Integrated DM1200 Melter Testing of Bubbler Configuration Using HLW AZ-101 Simulants

Test Report Number: VSL-04R4800-4

Prepared By: Lawrence Petkus

Date: October 13, 2004

Signature:

Lawrence Petkus 10/14/04

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.

1) These tests showed that significant improvements in glass production rates could be achieved by employing modified bubbler configurations. These improvements appear to be sufficient to more than make up for the production rate short-fall brought about by the reduction in the solids content in the feed from pretreatment from 20 wt% to 15 wt% undissolved solids. However, further reduction in solids content or increases in waste loading (which increases the water content in the melter feed) could again challenge rate attainment.

2) The modified SBS design appeared to show less tendency for clogging than did the previous design, but longer test durations are needed to confirm this.

3) Film cooler and transition line clogging continued to be a significant operational problem; their frequency appeared to increase with bubbling rate and glass production rate.

4) Maintaining a cold cap limited feed rate during DM1200 tests is dependent on frequent visual monitoring of conditions in the melter plenum. Planned operation of the WTP melter based on only non-visual data, such as plenum temperature, could lead to either under feeding of the melter resulting in lower than attainable production rates or over feeding of the melter resulting in excessive cold-cap buildup as well as other operational difficulties. Testing under such conditions is therefore recommended.

If appropriate, is a Request for Technology Development attached.

Yes

No

Additional comments (include researcher recommendations):

R&T Technology Issues Summary

Page 2 of 2

Test Report Title: Integrated DM1200 Melter Testing of Bubbler Configuration Using HLW AZ-101 Simulants

Test Report Number: VSL-04R4800-4

1) This work shows sufficient production rate capability with the limit that increasing air flow increases off gas film cooler plugging. The HLW melter design includes a film cooler cleanout device for use as necessary to remove solids accumulation. Test data indicate that at bubbler air rates required to meet the equivalent 3 MT/d goal, solids accumulations in the film cooler may require the cleanout device to be used on a daily or weekly maintenance basis. Testing has demonstrated that the WTP HLW melter production rates will be met across the design basis feed concentration range.

2. SBS testing has demonstrated that solids accumulations experienced previously under similar test durations and feed chemistry conditions do not occur with the prototypic design. While more extended testing would of course be useful, the risk is judged to have been sufficiently addressed.

3. See #1 above. In addition, the majority of plugging occurred during testing periods when maximum air bubbler rates and feed rates are tested. These rates are over 30% above rates required to meet the 3 MT/d equivalent target. Off-gas jumper plugging occurred in testing when water additions to the film cooler air were tested as a means of washing the film cooler. The carryover of water into the jumper is believed to initiate solids accumulations in this pipe.

4. It is acknowledged that during testing to demonstrate maximum rates, frequent visual observations are required. This is different than the previous Duratek engineer's experience operating the LAW DM3300 melter. During HLW DM1200 operation at the target rate of 3 MT/d equivalent VSL staff had indicated steady state conditions over the specified testing periods. Nevertheless, R&T staff believe periodic visual monitoring capability in the WTP HLW melter is important in the long-term to optimize and maximize throughput. Visual observation of the melter and cold cap via a in-melter camera assembly had been part of the baseline design until very recently. R&T has recommended to C&T that temporary viewing be used during cold commissioning to permit direct viewing and comparison of operations to the pilot-plant and to be able to relate instrumentation readings to the physical conditions in the melter. Meeting hot commissioning throughput goals are considered achievable without viewing capability. However, R&T recommends that ORP incorporate remote viewing for the long-term mission of the facility so that differences in melting characteristics can be observed and the proper response actions taken.