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Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers

VSL-03R3800-1, Rev. 0, 9/15/03

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

Office of River Protection

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Richland, Washington 99352

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Final Report

Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers

prepared by

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for

Duratek, Inc.

and

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For W. Tamosaitis

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Completeness of Testing:

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

I.L. Pegg: _____ **Date:** 10/14/03
VSL Program Director/Principal Investigator

I. Joseph: Innocent Joseph **Date:** 10-14-03
Duratek Sub-Contract Manager

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List of Abbreviations

AA	Atomic Absorption Spectroscopy
ADS	Air Displacement Slurry
CFR	Code of Federal Regulation
DCP	Direct Current Plasma Emission Spectroscopy
DF	Decontamination Factor
DM	DuraMelter®
DOE	Department of Energy
DRE	Destruction & Removal Efficiency
EPA	Environmental Protection Agency
FTIR	Fourier Transform Infrared Spectroscopy
GC	Gas Chromatography
HEME	High-Efficiency Mist Eliminator
HEPA	High-Efficiency Particulate Air Filter
HLW	High Level Waste
ISE	Ion Selective Electrode
LAW	Low Activity Waste
PBS	Packed-bed Scrubber
PCB	Polychlorinated Biphenyls
QA	Quality Assurance
QAPjP	Quality Assurance Project Plan for Testing Programs Generating Environmental Regulatory Data
QAPP	Quality Assurance Project Plan
QC	Quality Control
RPP	River Protection Project
RPP-WTP	River Protection Project-Waste Treatment Plant
SBS	Submerged Bed Scrubber
SCR	Selective Catalytic Reduction
TCO	Thermal Catalytic Oxidizer
TDS	Total Dissolved Solids
TF COUP	Tank Farm Contractor Operation and Utilization Plan
THC	Total Hydrocarbon
TSS	Total Suspended Solids
VOC	Volatile Organic Compound
VSL	Vitreous State Laboratory
W.C.	Water Column
WESP	Wet Electrostatic Precipitator
WTP	Waste Treatment and Immobilization Plant
XRF	X-Ray Fluorescence

SUMMARY OF TESTING

A) Objectives

This report documents melter and off-gas performance results obtained on the DM1200 HLW Pilot Melter during processing of simulated HLW C-106/AY-102 feed.

The principal objectives of the DM1200 melter testing were to determine the achievable glass production rates for simulated HLW C-106/AY-102 feed; determine the effect of bubbling rate on production rate; 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 to perform pre- and post test inspections of system components.

B) Conduct of Testing

Testing was performed using a flow-sheet based C-106/AY-102 composition provided by the WTP project, from which a suitable simulant was developed for this work. Supporting glass formulation work was performed to develop a compliant glass formulation. Based on these results, melter feed simulant for these tests was prepared by a chemical vendor. The suspended solids in the *simulant* was assumed to be 20 wt%, which is equivalent to 21.49 wt% total solids, based on the data from AZ-102 testing. The theoretical glass yield of the resulting feed is 372 g of glass/kg of feed (about (485-550) g/l of feed, dependent on feed density. Screening tests were performed on the DM100-BL melter system as a prerequisite to proceeding to the larger-scale DM1200 tests. DM1200 testing was then performed in three contiguous 3-day segments, each at a progressively higher bubbling rate.

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. with an 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 m^2, as compared to 0.108 m^2 for the DM100-BL, 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. 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. A silver mordenite column is also installed to obtain engineering data on iodine capture efficiency on a 10% slip stream of the SCR/TCO exhaust.

C) Results and Performance Against Objectives

Tests were conducted at three bubbling rates over a nine-day period using feed yielding 557.5 g glass per liter. Over sixteen and a half metric tons of feed were processed to produce about 6.3 metric tons of glass. Cold-cap-limited, steady-state production rates of 330, 550 and 970 kg/m^2/day were maintained for test segments with bubbling rates of 8, 40, and 65 lpm, respectively. Some foaming occurred at the lower bubbling rates but did not prevent the attainment of steady-state conditions. The presently required glass output of each of the WTP HLW melters of 3 MT/d corresponds to a specific glass production rate of 800 kg/m^2/d. The highest bubbling rate test on the DM1200 melter exceeded this requirement. However, it should be noted that this test used a high solids content feed (20 wt% undissolved solids) from pretreatment; as shown in previous tests with AZ-101 simulants, lower concentrations will lead to progressively lower rates. It should also be noted that the full-scale WTP melter has slightly fewer bubblers per unit melt surface area than does the DM1200 (five bubblers in 3.75 m^2 vs. two bubblers in 1.2 m^2), which may lead to lower large-scale glass production rates on a per unit melt surface area basis.

With the exception of the ADS pump valve actuator failure described in Section 4.0, the general performance of the melter and off-gas treatment system was good. The DM1200 test was preceded by a 100-hour DM100 test to ensure that the new glass formulation and melter feed were acceptable for processing in the HLW pilot melter. Extensive sets of process engineering data were collected during both tests.

Isokinetic particulate samples were taken at the outlets of the melter, SBS, and WESP during the last test segment (65 lpm bubbling) to determine the efficiency of off-gas system components. Elemental DF values were determined across the melter, SBS, and WESP. Particle size distributions were determined for the melter emissions. The total solids carryover from the melter (0.67% of feed) was comparable to that observed for tests with other HLW compositions. Calculated DFs across the SBS were the lowest of any of the four HLW compositions, due in part to the much greater amounts of selenium and chlorine in the C-106/AY-102 simulant. Both of these elements exist in the exhaust as fine particles, whereas the SBS is most effective at removing coarse particulate. The WESP, which is effective in collecting finer particles, removed much of the additional particulate material exiting the SBS. As a result, the cumulative DF (Melter+SBS+WESP) was about 105,000 and comparable to other HLW tests conducted while using the Project-directed deluge cleaning procedure of the WESP. Observations during emissions sampling suggest that the majority of the measured particulate exiting the WESP occur while the power is off after the deluge process, rather than as a result of carryover during the

deluge.

The volumes of processing solutions generated in the SBS, WESP, HEME, and PBS were documented during testing and representative samples were subjected to complete 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 selenium, halogens, boron, and alkali metals, while the suspended species closely resembled the feed composition. The SBS TSS concentrations were between 200 and 2000 mg/l, whereas measured TDS values were 2 to 4 times higher. The WESP sump fluid was also in the neutral pH region but had negligible suspended solids. The WESP solutions contained significant concentrations of selenium, sulfate, chloride, and sodium. The WESP was sprayed continuously during this test and was deluged with 40 gallons of water once daily, resulting in a total blow-down volume of about 875 gallons. The 1641 gallons of liquid that accumulated in the SBS during the test originated from the condensation of water from the melter feed.

The glass product was close to the intended composition with little variation during testing. No macroscopic secondary phases were evident in the discharged product. No iodine and about 20% of the selenium in the feed were retained in the glass product.

A good mass balance was achieved for iodine around the melter, SBS, and WESP. A silver mordenite system for iodine removal was installed to treat a 10% slip stream of post SCR/TCO emissions. Samples were taken at the inlet, one third down, two thirds down, and outlet of the column. No iodine was measured at the column outlet resulting in DF values of over 1000.

Table 8.1 provides an evaluation of testing results compared to the specific test objectives.

D) Quality Requirements

This work was conducted under an NQA-1 (1989) and NQA-2a (1990) Part 2.7 based quality assurance program that is in place at the VSL. This program is supplemented by a Quality Assurance Project Plan for RPP-WTP work that is conducted at VSL. 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 did not generate data to support waste form quality 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 QAPjP for environmental and regulatory data.

E) Issues

The presently required glass output of each of the WTP HLW melters of 3 MT/d corresponds to a specific glass production rate of 800 kg/m^2/d. The highest bubbling rate test on the DM1200 melter exceeded this requirement. However, it should be noted that this test used a high solids content feed (about 20 wt% undissolved solids) from pretreatment; lower concentrations, which the WTP now expects, will lead to progressively lower rates. It should also be noted that the full-scale WTP melter has slightly fewer bubblers per unit melt surface area than does the DM1200 (five bubblers in 3.75 m^2 vs. two bubblers in 1.2 m^2), which may lead to lower large-scale glass production rates on a per unit melt surface area basis.

Feeding began using the installed, prototypical ADS pump but was switched to the air operated diaphragm (AOD) backup system after 93.5 hours into the test due to problems with the ADS pump's three-way actuator valve sticking midway during the purge cycle. The valve, which it was later determined suffered from a manufacturing defect, was replaced and the ADS system was returned to service at 145 hours into the test. The ADS pump was used for the remainder of the test as well as for the subsequent HLW C-104/AY-101 test without incident. However, a similar actuator failure was later observed on the LAW Pilot Melter ADS pump system.

Towards the end of the test it was noticed that the discharge vent air temperature had dropped from about 60°C to about 30°C. The discharge vent line connects the discharge chamber to the melter plenum and provides a flow path for balancing discharge chamber and plenum pressures. Cooling of the line is therefore suggestive of restricted gas flow. An inspection at the end of the test showed large amounts of solids deposited on the discharge chamber vent orifice plate. This is an area that has not been inspected or cleaned during earlier tests.

Video inspection of the inside of the SBS down-comer was conducted at the end of the test which showed rings of solids deposited near the down-comer bottom. About 70% of the cross sectional area of the pipe was occluded by solids. During previous tests with the down-comer in place, solids build-up was observed inside the down-comer close to the vertical location of the diffuser plate. Results from the present test indicate that removal of the down-comer extension does not alleviate this problem but the location of the accumulation appears to be somewhat higher.

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 m^2 installed at VSL have been used for this purpose, which, in combination with the 3.3 m^2 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 m^2) 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, 4] indicated that while processing rates considerably above the project baseline (400 $kg/m^2/d$) were possible with bubbling, the baseline rate was not achieved in tests performed without bubblers. None of the variables investigated, which included feed concentration, feed acidification, frit as the glass former additive, variable additions of reductant (sugar), continuous feeding (as opposed to pulsed) and increased glass temperature resulted in production rates approaching the project baseline. As a result of this testing it was concluded and recommended 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 [5]. Testing has shown that the use of bubblers could also provide ORP the performance enhancement necessary to achieve the expanded capacity per melter of 3.0 Mt/d (800 $kg/m^2/d$) required under the revised WTP baseline. Based on these results and Project guidance to include bubblers in the reference design, testing was designed to determine the processing rates for each of the Phase 1 HLW feed compositions in the DM1200 melter with bubbling. The testing is detailed in a Test Specification [6] and a corresponding series of Test Plans issued to address DM1200 testing at a variety of bubbling rates and feed concentrations using AZ-101, AZ-102, C-106/AY-102, and C-104/AY-101 simulants [7-9]. The tests were conducted between 07/02 and 03/03 with summary reports for each test series submitted shortly after the completion of each test [10-13]. This final report addresses DM1200 tests over a range of bubbling rates (8, 40, and 65 lpm) using the HLW C-106/AY-102 simulant and corresponding melter feed. Separate final reports will be issued to cover the other three Phase 1 HLW feed compositions described in the Test Specification and Test Plans [6-9].

1.1 Test Objectives

As listed in the Test Specification for this work [6], the principal objectives of these tests are identified below. DM1200 testing covered in this final report addresses only C-106/AY-102. Any deviations from the Test Specification are noted below. For traceability to the Test Specification, test objectives are sequential and correspond to the objectives in the referenced Test Specification:

The objectives to be achieved under the Test Specification [6] are:

1. Perform analyses, laboratory and small-melter testing, as required, to assess and specify "working glass" compositions, glass forming chemicals, and additives utilizing the estimated C-106/AY-102 feed composition in this specification.
2. Utilizing the DM1200 melter and associated feed handling and off-gas treatment equipment, design and conduct testing in which representative C-106/AY-102 simulant is processed. The duration of tests shall be sufficient to achieve at least four melter glass inventory turnovers (8 MT) for each composition.
3. Determine the effect of bubbling rate on melter production rate and operating stability for C-106/AY-102 melter feed.
4. Determine the effect of feed concentration on melter production rate and operating stability for *AZ-101* melter feed. [Note: This objective was completed under another Test Plan [7].]
5. Fabricate, install and evaluate the performance of the HLW bubbler design and placement recommended by the Duratek design staff.
6. Characterize the melter emissions (particulate, aerosol, and gaseous) under nominal steady-state operating conditions for inorganic and organic compounds including the effect of air displacement slurry (ADS) pump operation on feed entrainment. Measurement of organic compounds will be satisfied through the use of Fourier Transform Infrared (FTIR) spectrometry and gas chromatography (including H_2).
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 (submerged bed scrubber (SBS), wet electrostatic precipitator (WESP) and high-efficiency mist eliminator (HEME)) to remove particulate, aerosol and gas phase emissions under steady-state melter conditions.
9. Characterize the chemical and physical characteristics of the aqueous streams (feed, SBS, WESP, and caustic scrubber).
10. Characterize the performance of the secondary off-gas treatment equipment (selective catalytic reduction (SCR) and thermal catalytic oxidizer (TCO) and small-scale silver mordenite column) to treat NO_x, organics, and iodine under steady-state melter conditions.
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, especially ammonium nitrate downstream of the SCR.
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.
15. Operate and evaluate the performance of the air-displacement slurry (ADS) pump under operating conditions that are applicable to expected WTP plant operations. The ADS pump has been installed and will be used during these tests; in addition, a separate Test Plan has been issued to address the detailed pump testing outlined in Section 6.0 of the Test Specification [6].
16. Conduct one of the melter tests with the SBS water circulation tubes (located at the bottom distribution plate) plugged to prevent their use. This test configuration has been requested by Process Engineering to assess the need for these tubes when combined with the perforations in the distribution plate. [Note: This objective was completed under an earlier Test Plan [7].]

1.2 Test Overview

Previous melter testing with HLW simulants was conducted with recipes based on TFCOUP Rev. 1 [14]. The current Test Specification [6] stipulates the use of TFCOUP Rev. 3A [15] and that Sr/TRU precipitation products be included with the C-106/AY-102 simulant. This change in simulated waste composition required a revised glass formulation and testing at both the crucible and DM100 melter scales prior to use in the DM1200. A 100-hour DM100 melter test was completed prior to the DM1200 melter tests in order to provide the required confidence in the new formulation. Testing parameters such as plenum and glass temperatures mimicked those used in the DM1200 tests.

After successful completion of the DM100 test, a nine day test was conducted on the DM1200. The effects of bubbling rate on glass production rates and the viable range of bubbling rates were addressed in an earlier Test Plan [7]. The results from these tests were used to define the "Low," "Medium," and "High" bubbling rates used for the present tests; these rates were 8, 40, and 65 lpm. During each test segment, the bubbling rate was fixed and the feed rate adjusted to attain the desired near-complete cold cap. The solids content of the feed was fixed at 20 wt% undissolved solids based on the present WTP baseline value for the solids content of the feeds from pretreatment since the effect of feed solids content was addressed in an earlier Test Plan [7]. Each test segment had a nominal duration of three days. Variables that were held constant during each test to the extent possible included melt temperature, plenum temperature, cold cap coverage, the waste simulant composition, glass-forming additives, 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. A variety of processing data was taken throughout the test to document the performance of the feed, melter, and off-gas systems.

1.3 Quality Assurance

This work was conducted under an NQA-1 (1989) and NQA-2a (1990) Part 2.7 based quality assurance program that is in place at the VSL. This program is supplemented by a Quality Assurance Project Plan for RPP-WTP work [16] 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 [17].

This work did not generate data to support waste form quality 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 QAPjP [18] 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. Any required feed additive can be added to the mix tank either manually or through a dry-chemical handling system. 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 to 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 RPP-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 un-cooled 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 RPP-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. The reservoir is then 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.

A backup system is used when necessary to introduce feed into the melter using 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. The DM1200 is shown schematically 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 [19]. The DuraMelter™ 1200 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 ft^3. Cross-sectional diagrams of the melter illustrating the discharge chamber and electrode configuration are provided in Figures 1.1 and 1.2.

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 DuraMelter™ 1200 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 were used, located in diagonally opposite corners.

1.4.3 Off-Gas System

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, shown schematically in Figure 1.3, 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. Note that the PBS and the second HEME are not part of the WTP off-gas train, which effectively ends at the SCR. A silver mordenite column of sufficient size is also installed to obtain engineering data on iodine capture efficiency on a 10% slip stream of the SCR/TCO exhaust. This column was placed downstream of the SCR during the present test; however the current location envisioned in the full-scale system is before the TCO/SCR unit. Therefore, this DM1200 unit has been relocated for future tests. A sulfur-impregnated carbon bed unit for removal of mercury is being considered for use in the HLW off-gas system downstream from the particulate removal subsystem; however it was not included in the present DM1200 test. The system can be functionally divided into four subsystems:

Particulate Removal: Components from the submerged bed scrubber (SBS) to the HEPA serve to remove essentially all of the particulate from the gas stream with an estimated removal efficiency of greater than 99.9999% for particles greater than 0.3 μm in size. 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 (TCO) 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 (PBS) to remove remaining acid gases.

Stack System: The emergency/bypass exhaust system, which includes a second HEPA, and the primary off-gas system both feed into the building stack system for exhausting to the atmosphere.

Liquid Processing: Components including the 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.

Information on individual off-gas component design features can be found in Reference [2]. With minor exceptions, noted above, the DM1200 off-gas system processing sequence follows the proposed design for the full-scale RPP-WTP HLW melter system.

Initial quenching of the melter exhaust gas stream is effected by the film cooler. Immediately downstream of the film cooler is the injection point for control air, which is used to regulate melter pressure. The gas entering the balance of the off-gas system is at a temperature of about 250 to 350°C and a flow rate of about 100-250 scfm, of which about 10-80 scfm is water vapor. The off-gas is then rapidly quenched by direct liquid water contact in the Submerged Bed Scrubber (SBS), which also effects removal of most of the larger particulates. The piping between the film cooler and SBS has a high superficial gas velocity to minimize particulate deposition. The gas stream leaving the SBS is at a low temperature (typically between 40-50°C). Further mist and particulate removal is effected in the WESP, HEME, and 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 are located in the WESP, PBS, and facility HEMEs to wash down deposits and dissolved species into their respective collection sumps from which they can be sampled. The system components are fabricated from corrosion resistant materials including AL6XN in the SBS and 316L stainless steel and various plastics in less demanding locations. There are extensive provisions for sampling both the gas and liquid streams throughout the system in order to collect mass balance information and removal efficiency data for each treatment stage.

The off-gas system maintains the melter plenum under slight negative pressure, typically about -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 after the film cooler. The air is supplied by a blower through a diverter valve. The setting of the diverter valve, and therefore the air flow rate, is controlled by a process controller that responds to the signal from a melter pressure transducer. When the plenum pressure becomes more positive, the air injection flow rate is decreased, which tends to restore the pressure to the set-point. Conversely, the flow rate is increased when the plenum pressure becomes more negative.

A silver mordenite system was added to the DM1200 system to obtain engineering data on iodine capture efficiency. This system treats a slip-stream of up to about 10% of the off-gas stream exiting the SCR, which is then returned to the PBS[1]. A schematic diagram of the silver mordenite system is shown in Figure 1.4. The slip-stream gas is first cooled in a non-condensing

[1] Note that after the completion of these tests, the WTP design was revised to place the silver mordenite column *before* the TCO/SCR; the results of DM1200 tests performed with that configuration will be presented in later test reports.

heat exchanger before entering the top of a glass column that is loaded with 1/16" diameter x 0.12" length pellets of C-Chem Ag-900 silver-impregnated zeolite. The active part of the column is a cylinder, 32" long and 6" in diameter containing about 30 lb of the zeolite packing (57.4 lb/ft^3 bulk density). C-Chem claims 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 were monitored continuously. The gas exiting at the bottom of the column is further cooled to protect the down-stream blower. Design ranges of flow conditions at specific points along the system are indicated in Figure 1.4. There are four analytical sampling ports provided: 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.

SECTION 2.0
WASTE SIMULANT AND GLASS FORMULATIONS

The composition of the C-106/AY-102 HLW simulant used for these tests were derived and specified in the BNI Test Specification [6]. The C-106/AY-102 waste data and blending assumptions stipulated in the Test Specification are different than those used in previous melter testing with C-106/AY-102 simulant [20] such that there was a need to develop and test new glass formulations. This Section summarizes the composition of the simulant provided in the Test Specification and describes the corresponding glass formulations selected for melter testing.

2.1 C-106/AY-102 Waste Simulant

Formulation of the C-106/AY-102 waste simulant makes use of inventory data from the TFCOUP [15], calculated data from ACM modeling, and analytical data on Cs- and Tc-removal eluates from LAW pretreatment [21]. In addition, products from Sr/TRU removal for pretreatment of LAW are also included in the waste blend.

The composition of the C-106/AY-102 Envelope D solids is based on the inventory data found in Revision 3A of the TFCOUP [15]. 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 TFCOUP revisions [14] and the Best Basis Inventory (BBI) database (e.g., cadmium). The use of other data sources (e.g., HLW Feed Staging Plan [22]) to supplement the TFCOUP, as was done in previous tests, is therefore no longer necessary. The WTP ACM model calculates the composition of the recycle stream, which is then blended with the Envelope D solids based on the expected daily processing rates (i.e., 3.79E+04 lb/day for Envelope D solids and 1.31E+03 lb/day for the recycle stream on a dry solid basis). The resulting material is concentrated and pretreated through caustic leaching/water washing and ultra-filtration to produce the pretreated HLW solids. The separation factors due to caustic leaching and ultra-filtration are given in Table 2.1. Note that some of the separation factors are larger than unity (many of which were ignored in derivation of the waste composition, but which was used as-provided [6] in the present work) and that the ACM model predicts mass increases for Fe and Zr after ultra-filtration (75 lb/day and 68 lb/day, respectively) [6].

To complete the simulant formulation, the pretreated HLW solids are blended with wastes from LAW pretreatment. Similar to the blending scenario used in Part B1 tests [20], Sr/TRU removal products from pretreatment of Envelope C wastes were added for these tests, although the amounts of Sr and Mn (449 lb/day and 499 lb/day, respectively) blended were considerably less than those used in earlier tests, which results in lower concentrations of SrO and MnO in the current test glass (e.g., 0.92 wt% vs. 7.35 wt% for SrO) [20]. Analytical data on eluates from Cs- and Tc-removal on an Envelope C sample (AN-102) [21] provide the compositional bases for the respective ACM-model feed streams CNP12 and TEP12, although that was not the case for the Sr/TRU stream. The blending proportions are determined by the projected daily processing rate of sodium in the eluates (i.e., 2.02E+01 lb/day for Cs-removal

and 9.14E-01 lb/day for Tc-removal). It can be seen in Table 2.1 that waste blending primarily leads to increases of manganese, strontium, sodium, chloride, and nitrate in the HLW simulant.

The calculated composition of the blended HLW solids (HLP09b), which is shown in Table 2.1, lists a total of 55 components. A few of the components, however, were left out of the blended solids in Test Specification [6] because of missing separation factors, low concentrations, and other unspecified reasons (e.g., Be, Co, and Mo). In addition, similar to the approach taken in previous melter tests, radionuclides, noble metals (including silver), and minor components (< 0.02 wt% in glass on an oxide basis) were omitted from the simulant formulations. Cesium and iodine were spiked for analytical purposes, at an amount equivalent to 0.05 wt% and 0.10 wt%, respectively, in glass. The resulting HLW simulant formulation, which is given in Table 2.2, consists of 30 components, 26 of which are non-volatile (compared with 33 and 29, respectively, for the previous C-106/AY-102 simulant [20]).

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

With updated compositions for the C-106/AY-102 Envelope D solids and a different waste blending scenario, new glass formulations were developed and tested at VSL to support these tests. The glass composition selected as the basis for these tests, HLW98-86, is presented in Table 2.2. On an oxide basis, this glass has a total waste loading of 27.75 wt%, of which 25.13 wt% is Envelope D waste. These can be compared with the respective values of 51.00 wt% and 39.42 wt% for HLW98-34, the reference glass used in Part B1 [20]. The difference is primarily due to the presence of much more Na_2O in the Part B1 simulant (20.61 wt% vs. 2.11 wt% for the current simulant). The current target glass (HLW98-86) is also different from HLW98-34 in that it meets the contract minimum component limit by incorporating 12.56 wt% of Fe_2O_3 [20], instead of > 21 wt% of (Al_2O_3+Fe_2O_3+ZrO_2).

Crucible melts of HLW98-86 and related formulations have been prepared and tests performed to determine that the target glass meets the necessary processing requirements. Heat treatment at 950°C for over 70 hours of HLW98-86 results in a homogeneous dark brown glass that is free of secondary phases. The viscosity and electrical conductivity measured for HLW98-86AG (at 1150°C), which has the same composition as HLW98-86 except with Ag_2O excluded, are 44 P and 0.36 S/cm, respectively. Finally, the normalized PCT leach rates of HLW98-86 are (in g/(m^2-day)) 0.058, 0.047, 0.046 and 0.028, respectively, for B, Li, Na, and Si; these values can be compared with those for the reference glass (DWPF-EA) of 1.17, 0.71, 0.80 and 0.27, respectively. The target glass formulation for these tests, which is also given in Table 2.2, differs slightly from HLW98-86, with the removal of silver and the addition of small amounts of cesium and iodine.

The additional constituents required to form the target test glass from the C-106/AY-102 HLW simulant are aluminum, boron, lithium, sodium, silicon, and zinc. The chemical additives that are the sources for the glass-forming additives are selected based on previous testing and direction from the RPP-WTP Project. Table 2.3 lists the starting materials and amounts required to produce the target C-106/AY-102 simulant and melter feed. Note that all of the TOC is assumed to be oxalate and that only 1.23 (g/100 g oxide) of carbonate is present in the simulant,

instead of the required 1.29 (g/100 g oxide). The small discrepancy in carbonate does not impact the tests since much greater amounts are present in the glass forming additives. The suspended solids in the *simulant* is assumed to be 20 wt%, which is equivalent to 21.49 wt% total solids, based on the data from AZ-102 testing [8]. The theoretical glass yield of the resulting feed is 372 g of glass/kg of feed (about (485-550) g/l of feed, dependent on feed density).

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.

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 chemical composition and physical properties. Sample names, sampling dates, and measured properties are provided for DM100 and DM1200 feed samples in Table 2.4. All samples were taken from the feed line immediately upstream of the entrance point to the melter. The measured glass yields were slightly higher than the target glass yield of 372 g of glass per kg of feed but were within 5% of that value; consequently, the target value was used for calculating glass production rates. The average measured glass yield on mass per volume basis, 557.5 g glass per liter of feed, was slightly higher than the 485 – 550 expected range given in the Test Plan [9]. This range was intended as an estimate since the feed density was not known at that time. All measured parameters including glass conversion ratio, water content, density, and pH fall within narrow ranges, confirming the relative consistency of the melter feed. The measured values for the DM1200 and DM100 feed samples were very similar, as expected in light of the shared source and recipe. On average, the DM100 samples had a slightly higher glass conversion ratio and slightly lower water content, perhaps due to the use of less water during feed transfer.

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 [23]. 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 step wise 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 [23], which examined a range of temperatures, showed a relatively weak effect of temperature.

Rheograms which show the feed viscosity versus shear rate for the DM1200 and DM100 feeds are presented in Figure 2.1; measured values for viscosity at selected shear rates and the yield stress values are shown in Table 2.4. The yield stress and viscosity values for the DM1200 and DM100 feed samples are very similar, as expected given their shared origin and composition. The values are within or slightly below the range measured for melter feeds with HLW AZ-101 simulants used in a previous study [4].

2.3.3 Chemical Composition

Feed samples collected during this test were subjected to chemical analysis using x-ray fluorescence (XRF). The chemical compositions of the feed samples from the test 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 Tables 2.5 – 2.7 and are compared to the target composition.

The compositional analysis results can be discussed by dividing the 26 elements into three categories: major elements with measured oxide concentrations greater than 3%, intermediate elements with measured oxide concentrations between 0.5 and 3%, the remainder being minor elements. The major elements constitute the bulk of the glass and, therefore, largely determine its properties. XRF results for the major elements (Al, Fe, Mn, Na, and Si,) are consistently within 10 percent of the target composition for the DM1200 feed samples. Deviations were slightly greater than this for aluminum and manganese on the DM100 samples. The only element to significantly vary from target in the intermediate concentration range (Mg, Sr, and Zn) was strontium, which was on average about 14% below target. This deficiency has been observed in past studies with feed procured from NOAH [1, 3, 4]. The noted deviations in major and intermediate elements would not be expected to have a consequential effect on the processing properties of the feed or glass. The large number of minor elements (As, Ca, Cl, Cr, Cs, Cu, I, La, Nd, Ni, P, Pb, Sb, Se, Ti, and Zr) are all inherited from 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. As expected, highly volatile elements such as selenium and halogens are under-represented in the glasses. Conversely, common elements, which are typical impurities in bulk chemicals, such as calcium are over-represented when the constituent is a minor component. The excess in titanium oxide in the feed samples has also been observed in previous studies [19, 24, 25], suggesting that titanium is a common contaminant in the source chemicals. Potassium and sulfur, which are not included in glass formulation, were detected at low levels in the feed as impurities.

SECTION 3.0
DM100 OPERATIONS

The DM100-BL vitrification system has served extensively as a screening tool for subsequent tests on the DM1200 HLW pilot melter [10, 13, 27]. Factors such as new HLW glass formulations, different glass forming additive sources, and feed nitration were successfully tested on the smaller melter prior to use on the DM1200. A similar tiered approach has also been employed with the combination of the DM100-WV and the LAW Pilot Melter in Columbia for LAW testing. The C-106/AY-102 simulant and glass composition had not been tested previously in a melter and, therefore, a DM100 test was conducted to identify any issues with the feed or glass prior to embarking on the DM1200 tests. This section presents a description of the DM100-BL system, glass product analysis, and screening level process data from the DM100 test.

3.1 Melter System Description

3.1.1 Feed System

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

3.1.2 Melter System

The DM100-BL unit is a ceramic refractory-lined melter fitted with a total of five electrodes: two pairs of opposing Inconel 690 plate electrodes as well as a bottom electrode. Power can be supplied in either three-phase or single-phase configurations. All of the tests in the present work were performed with the upper and lower electrodes on each side connected together and powered by a single-phase supply; the bottom electrode was not powered. Melt pool agitation is achieved by either a removable lance entering from the top of the melter or a permanent bubbler installed through the bottom electrode; only the lance bubbler was used for the present tests. The glass product is removed from the melter by means of an airlift discharge system. The melter has a melt surface area of 0.108 m^2 and a variable glass inventory of about 120 kg, when only the bottom pair of electrodes is used and between 180 and 200 kg when both pairs of electrodes are used. In these tests both pairs of electrodes were used.

3.1.3 Off-Gas System

For operational simplicity, the DM 100s are equipped with dry off-gas treatment systems involving gas filtration operations only. Exhaust gases leave the melter plenum through a film cooler device that minimizes the formation of solid deposits. The film-cooler air has constant flow rate and its temperature is thermostatically controlled. Consequently, the exhaust gases passing through the transition line (between the melter and the first filtration device) can be sampled at constant temperature and airflow rate. The geometry of the transition line conforms to the requirements of the 40-CFR-60 air sampling techniques. Immediately downstream of the transition line are cyclonic filters equipped with internal coarse filter elements followed by conventional pre-filters and HEPA filters. The temperature of the cyclonic filters and the HEPAs are held above 100°C to prevent moisture condensation. For each melter, the entire train of gas filtration operations is duplicated and each train is used alternately. An induced draft fan completes the system.

3.2 Melter Testing

The DM100 test was conducted between 12/16/02 and 12/20/02, producing over 518 kg of glass. A summary of the test conditions and results is provided in Table 3.1. The total test duration, including the time for water feeding was 100.4 hours. The measured glass production rate is depicted in Figure 3.1 as cumulative and one-hour moving averages. After twenty hours of slurry feeding, the lance bubbler was replaced resulting in a seventeen minute gap in feeding. Subsequently, the glass production rate gradually increased to about 1150 kg/m^2/day during last three days of the test. No processing problems such as foaming were encountered during the test other than occasional dried feed bridging from the walls across melt pool. This is much more of an issue in smaller melters and, therefore, was not projected to be a problem with the larger DM1200.

A variety of operational measurements are recorded during these tests, the most important of which are glass temperature (Figure 3.2), electrode power (Figure 3.2), plenum temperature (Figure 3.3), and glass bubbling rate (Figure 3.4). The target glass temperature of 1150°C was successfully maintained for most of the glass pool during the test. Plenum temperatures were higher than the 400 - 500°C target range for the DM1200 as a result of intentional openings in the cold-cap required to prevent excessive bridging across the melt pool. The exposed thermocouple often read significantly higher than the thermocouple in the thermowell due to its proximity to an opening in the cold cap. After changing the bubbler at 20 hours run time, electrode power varied only 2.5 kW from an average of about 22.5 kW. Bubbling was increased at the beginning of the test to 25 lpm as the cold cap developed. After the bubbler was replaced, the bubbling rate was relatively consistent at about 18 lpm. The gap in bubbling data between 20 and 23 hours run time shown in Figure 3.4 is the result of monitoring equipment being calibrated after installation of the new bubbler, during which time bubbling was manually set at 14 lpm. Consequently, bubbling was interrupted only during the actual change-out of the lances.

3.3 Glass Product Analysis

Over 500 kg of glass product was discharged from the melter through an airlift system into 5-gallon pails. The discharged product glass was sampled from each pail by removing sufficient glass from the top for total inorganic analysis. Product glass masses, discharge date, and the analyses performed are listed in Table 3.2.

Glass samples were crushed and analyzed directly by XRF. The target value 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 3.3. 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 2.4, even though the melter had not experienced three complete turnovers (540 - 600 kg of glass produced) at the end of the test. Aluminum was closer to target in the discharged glass than in the feed samples, whereas magnesium was farther from the target. Sulfur and potassium were again observed in the glass at very low levels, even though they are not included in the feed recipe. Less than 20% of feed selenium and no iodine were retained in the glass product, consistent with their known volatility.

Compositional trends from the XRF data are plotted for selected elements in Figures 3.5-3.7. The graphs illustrate three trends: elements with oxide concentrations that either did not change as a result of the similarity to the previous AZ-101 composition [7, 10] (Figure 3.5), systematically decreased in concentration towards target (Figure 3.6), or systematically increased towards target (Figure 3.7). The oxides shown in Figure 3.3 and oxides of silicon, boron, and lithium, changed little over the test due to similarities between the two glass compositions. The principal compositional change was the increase in manganese and strontium oxides resulting from the incorporation of Sr/TRU removal products in the C-106/AY-102 simulant (Figure 3.7). Part of this increase was at the expense of zirconium, which has a low target composition.

3.4 DM100 Test Summary

The DM100 tests were conducted in order to screen for possible melter operational or feed processing issues prior to DM1200 testing since the C-106/AY-102 simulant and glass composition had not been tested previously in a melter. No processing problems such as foaming were encountered during the test other than occasional dried feed bridging from the walls across melt pool. This is much more of an issue in smaller melters and, therefore, was not projected to be a problem with the larger DM1200.

Results from glass analysis using XRF indicated good agreement with the target composition for the majority of oxides and, in particular, for the major oxides even though the melter had not experienced three complete turnovers (540 - 600 kg of glass produced) at the end of the test.

The successful DM100 test results supported subsequent DM1200 testing.

SECTION 4.0
DM1200 OPERATIONS

Melter tests were conducted on the DM1200 with the HLW C-106/AY-102 simulant between 1/22/03 and 1/31/03, producing over 6,300 kg of glass. A summary of the test conditions and results is provided in Table 4.1. The total test duration, including the time for water feeding and cold-cap burn-off, was 217.5 hours. The test consisted of three 3-day segments of successively higher bubbling rates of 8, 40, and 65 lpm respectively. The measured glass production rate is depicted in Figure 4.1 as cumulative and one-hour moving averages for each of the three segments. The three steady-state production rates (330, 550, and 970 kg/m^2/day) were obtained for at least half of each three-day segment and almost the entirety of the first segment. Minor foaming occurred on the surface of the glass but diminished as bubbling increased over the course of the test. The exhaust stream was sampled for particles during the last two days of testing after the final steady-state rate was reached.

Feeding began using the installed, prototypical ADS pump but was switched to the air operated diaphragm (AOD) backup system after 93.5 hours into the test. About four hours prior to the switch, problems were observed with ADS functions that control pump cavity filling and purging. Initially the LabView computer system was momentarily stopped and rebooted with the expectation that the problems were with the computer control system. This had no effect on the ADS system as it appeared the water flush cycle was being continuously repeated. Further inspection of the ADS pump showed that the three-way valve actuator was sticking midway during the purge cycle and that water was constantly leaking into the reservoir. Feeding was stopped for less than 15 minutes to change to the AOD system; however, the last hour of feeding with the ADS was erratic due to the mechanical problems. The valve, which it was later determined suffered from a manufacturing defect, was replaced and the ADS system was returned to service at 145 hours into the test. The ADS pump was used for the remainder of the test as well as for the subsequent HLW C-104/AY-101 test [13] without incident. The AOD system performed with no difficulties during its two days of operation with the ancillary benefit of the lack of stalactite formation on the water cooled feed tube. The prototypical feed tube used with the ADS pump is not cooled and has a much greater tendency for stalactite formation on the feed tube tip, which in turn results in feed being directed into the melter in unpredictable and often undesirable directions. As necessary in the case of extreme build ups, stalactites had to be mechanically removed, which was generally accomplished by tapping the external portion of the feed tube with a rubber mallet. Subsequent tests have employed a new feed tube design which lessened the extent of stalactite formation to the point that mechanical intervention has been unnecessary [13, 26].

A variety of operational measurements recorded during these tests, including temperatures throughout the melter system, are given in Table 4.2. The target glass temperature of 1150°C was successfully maintained for most of the glass pool during each test segment, as illustrated in Figure 4.2. 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. This temperature difference decreased in the last

three-day test segment as bubbling was increased. Plenum temperatures (Figure 4.3) were typically between 400 - 600°C, with higher temperatures at the beginning of the test during cold cap formation, about 90 hours into the test due to inconsistent feeding from the malfunctioning ADS pump, and while transitioning to the highest bubbling rate (the transition period also included a 25-minute feeding interruption while switching back to the ADS pump). Visual observations of the cold cap corroborated the plenum temperature indications that melt pool coverage was nearly complete for the vast majority of the test.

Electrode temperatures averaged well below 1150°C throughout testing. The temperature difference between the East and bottom electrodes was about 75°C, as shown in Figure 4.4 (note that the bottom electrode was not powered in these tests). During the first two test segments the East and West electrode temperatures were relatively close to each other but varied considerably presumably due to changes in electrode power made in response to glass foaming. As foaming lessened in response to increased bubbling rate and the associated power manipulations were not required, the electrode temperatures became more stable with the East electrode being about 25°C hotter than the West. This small temperature difference between the two sides of the melter has been observed over the lifetime of the DM1200 [3, 4, 19, 24, 25]. Differences between side and bottom electrode temperatures are greater in HLW tests, which do not use the bottom bubbler [4], than in the LAW tests which employ them [19, 24, 25]. The discharge chamber and riser temperatures were largely maintained above 950°C throughout the tests. Gas temperatures after film-cooler dilution typically ranged between 250°C and 350°C but were higher during periods of higher plenum temperatures, such as the beginning of the test as the cold cap was forming and during the replacement of the ADS pump.

Conditions in the glass pool are illustrated for electrical properties in Figure 4.5, level and density in Figure 4.6, and bubbling in Figure 4.7. Electrode power increased from about 75 to 160 kW over the course of testing as bubbling and production increased, as expected. The fluctuations of about 30 kW during the first two test segments were responses to foaming on the glass surface. Glass resistance increased during this same period but decreased during the latter portions of the test as foaming subsided. The glass level increased over the course of the test from 27.5 to 30 inches from the floor due to a slight unintended mismatch between feed and glass pour rates. The glass density remained between 2.225 and 2.245 g/cc except during the middle test segment where the density spiked down 0.01 to 0.02 g/cc about every seven hours. These drops in density coincided with instances of foaming in the melter and stopped occurring as bubbling was increased to a total of 65 lpm. The target total bubbling rates of 8, 40 and 65 lpm were held for each three-day segment, as shown in Figure 4.7. The average values for total bubbling during each segment given in Table 4.2 are slightly below the target because the time for transitioning up in bubbling rate is included. Lance bubbler flow rates were skewed slightly to prevent buildup of feed on the West side of the melter for portions of the last two test segments. As usual, power per unit glass production decreased with increasing production rate and was similar to previous tests with HLW AZ-101 feeds that had comparable water contents [4]; it was, however, much higher than for the previous LAW tests (3.5-5.1 vs. 1.6-2.0 kW/kg glass) [19, 25] due to the higher feed water content and much lower glass production rates.

SECTION 5.0
OFF-GAS SYSTEM PERFORMANCE

The off-gas treatment system, shown schematically in Figure 1.3 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 silver mordenite system for iodine capture, a packed-bed caustic scrubber (PBS); a high-efficiency mist eliminator (HEME 2); and a second HEPA on the bypass off-gas system. A silver mordenite system was installed in January 2003 before the HLW C-106/AY-102 test, which treats a slip-stream of up to 10% of the off-gas stream exiting the SCR before returning it prior to the PBS. A schematic diagram of the silver mordenite system is shown in Figure 2.4. Data on the off-gas system performance collected during the test with HLW C-106/AY-102 feed are presented and discussed in this section.

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 the first test segment; the two remaining test segments were appended in chronological order. 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 Table 5.1. A plot of the typical sequence of gas temperatures through the DM 1200 off-gas system at various locations is given in Figure 5.1.

5.1.1 Melter Pressure

The time-averaged (hourly average values) computer logged melter pressures measured at the level detector and instrument ports at two-minute interval are shown in Figure 5.2. The average melter pressure was -3.7 in W.C and melter pressure ranged from -6.8 in W.C. to 0.7 in. W.C.

A control-air system that was installed in the DM1200 to control melter pressure in the manner planned for the WTP was operational during this test. The computer logged melter pressures measured at the instrument port and calculated control air flow rates are plotted in Figure 5.3. The control air flow rate averaged 49.9 scfm during the test. Excursions in melter pressure shown in Figure 5.3 typically occurred during feed introduction into the melter, and during installation and removal of off-gas sampling equipment.

The differential pressures across the transition line and film cooler are given in Figure 5.2. The sudden decreases in the film cooler differential pressures are due to cleaning of the film cooler. Film cooler and transition line sections were not inspected during or after this test.

Towards the end of the test it was noticed that the discharge vent air temperature had dropped from about 60°C to about 30°C. The discharge vent line connects the discharge chamber to the melter plenum and provides a flow path for balancing discharge chamber and plenum pressures. Cooling of the line is therefore suggestive of restricted gas flow. An inspection at the end of the test showed large amounts of solids deposited on the discharge chamber vent orifice plate. This is an area that has not been inspected or cleaned during earlier tests. Photographs of the deposits are shown in Figures 5.4 and 5.5. A photograph of the discharge chamber vent orifice plate after cleaning is shown in Figure 5.6.

5.1.2 SBS Performance

It should be noted that, per WTP direction, the SBS was operated without the down-comer extension in place for the C-106/AY-102 test in order to investigate the effects on operation and solids build up in the down-comer.

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.

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.

The SBS inlet and outlet gas temperatures are plotted in Figure 5.7. The inlet gas temperature peaked at 440°C and the outlet gas temperatures peaked at 45.9°C. The initial spike in temperature shown in Figure 5.7 results from the high release of superheated steam into the off-gas during establishment of the cold cap. The average inlet gas temperature was 248°C. The average outlet gas temperature was 39.5°C. During the early part of the test (up to about 92 hours) the SBS inlet gas temperature was relatively low as result of lower melter plenum temperatures and slightly high control air flow rates. The inlet, outlet, and differential pressures are shown in Figure 5.8. The inlet gas pressure averaged -7.2 in. W.C., the outlet pressure averaged –44.2 in. W.C., and the pressure drop across the SBS averaged about 38.8 in. W.C. This differential pressure is about 6 to 7 inches lower than in previous tests and is consistent with the fact that the down-comer extension, which was in place for previous tests, was removed for this test. The pressure drop across the SBS increased by about 4.2 in. W.C. over nine days of testing with HLW C-106/AY-102 feed because of solids build-up in the lower down-comer section.

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 5.9. There was an average of about 4°C temperature difference in water temperatures measured at four depths (48, 60, 72 and 78 inches) within the SBS. The maximum temperature difference was 11.7°C. The liquid in the SBS was heated to a maximum temperature of 72.7°C during the initial period of water feeding, while the average SBS sump temperature was 48.2°C. The average outlet gas temperature was 39.5°C. It is noteworthy that all of the installed thermocouples showed SBS sump temperatures higher than the SBS outlet gas temperature, which is different than observations in all previous tests with the down-comer extension in place. Since this is contrary to expectations, the temperature measurements were checked and verified. Since the installed thermocouples in the SBS sump are inside the packed column, it was surmised that the apparent higher sump fluid temperature was the result of an increased temperature gradient because it is not thermodynamically possible for the temperature of *all* of the sump fluid to be higher than that of the gas outlet temperature. In agreement with this, an additional temporary thermocouple inserted into the sump fluid in the outer annulus of the SBS showed lower temperatures that were consistent with the outlet gas temperature. This result is also consistent with the temperatures at the recirculation pump discharge, which are close to the outlet gas temperature and very close to the values observed in previous tests.

SBS jacket, inner coil and heat exchanger water flow rates are plotted in Figure 5.10. Average SBS jacket, inner coil, and heat exchanger water flow rates were 11.0, 24.6 and 5.5 gpm respectively. The amounts of heat removed by the SBS cooling jacket and the plate heat exchanger are shown in Figure 5.11. 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 27.8 kW by the plate heat exchanger and 20.3 kW by the cooling jacket. About 57.8% of the heat load to the SBS was removed by the plate heat exchanger and about 42.2% by the cooling jacket. The SBS inner coil and plate exchanger water temperatures are plotted in Figure 5.12. The heat load data for the SBS inner coil is 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 28.1 kW. The heat load difference between SBS inner coil and plate heat exchanger is plotted in Figure 5.13 and averages about 0.3 kW; independently calculated SBS inner coil heat load and plate heat exchanger heat load values were thus in good agreement.

At the end of the HLW C-106/AY-102 tests, the SBS was blown down and 355 gallons of liquid was removed from the SBS and overflow tank. However, the SBS bottom was not opened and inspected at the end of this test. Instead, video inspection of the inside of the SBS down-comer was conducted at the end of the test. Views looking downward from inside the SBS inlet pipe showing rings of solids deposited near the bottom are given in Figures 5.14 and 5.15; about 70% of the cross sectional area of the pipe was occluded by solids. During previous tests with the down-comer in place, solids build-up was observed inside the down-comer close to the vertical location of the diffuser plate. Results from the present test indicate that removal of the down-comer extension does not alleviate this problem but the location of the accumulation appears to be somewhat higher. The WTP is currently in the process of modifying and testing

alternative down-comer extension designs to address this problem.

5.1.3 WESP Performance

The inlet and outlet gas temperatures and differential pressure across the WESP were measured and recorded by the computerized data acquisition system during the test, 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.

The WESP inlet and outlet gas temperatures are plotted in Figure 5.16. The WESP inlet gas temperature averaged 39.2°C and the outlet temperature averaged 40.4°C, indicating a 1.2°C temperature increase across the WESP during this test. The average WESP inlet temperature is 0.3°C lower than the average SBS outlet gas temperature during this time. WESP differential pressure and gas flow rate out of the WESP are plotted in Figure 5.17. The pressure drop across the WESP averaged 2.6 in. W.C and the average WESP gas flow rate was 227.2 scfm.

The amount of liquid accumulated in the WESP is plotted as a function of run time in Figure 5.18 where it is compared with the amount of fresh water sprayed into the WESP. The inlet spray water flow rate was set at 2.0±0.2 gph, as specified in the Test Plan [9]. As shown in Figure 5.18, the spray water accounts for the majority of the liquid accumulation in the WESP. The difference between accumulated liquid and fresh water sprayed is the condensed liquid, which is also plotted in Figure 5.18. Up to 95 hours of operations, there was more fresh water sprayed than accumulated liquid, which is due to evaporation of water from the WESP. As planned, the WESP electrodes were deluged daily with water at a nominal rate of 20 gpm for 2 minutes.

The WESP voltage and current are plotted as a function of run time in Figure 5.19. The voltage and current interruptions at regular intervals seen in the figure are due to the time delay in restoring operating voltage and current after deluges to clean the WESP electrodes. The average operating voltage and current were about 29.5 kV and 17.0 mA, respectively. The voltage and current remained steady throughout the test. The time required for power to return to operating values after deluge of the WESP ranged from 5 to 65 minutes and averaged 24.5 minutes, as shown in Table 5.2.

At the end of the test, a total of 78.9 gallons of liquid was blown down. Video inspections of the WESP were conducted at the end of the test before and after a deluge. Very minor build-up of particulate was found on ionizing rods and collector plates before the deluge; the deluge was observed to be effective in cleaning this material from the rods and collector plates. Very small amount of solids were observed at the bottom of WESP before the deluge and slightly more solids after the deluge.

5.1.4 HEME #1

HEME #1 follows the WESP in the off-gas system and removes any water droplets that may be present in water saturated gas exiting the WESP. The outlet gas temperature and differential pressure are plotted in Figure 5.20. The average HEME #1 gas outlet temperature was 38.7°C and the average pressure drop was 2.8 in. W.C. At the end of the test, 57.2 gallons of liquid was blown-down from HEME #1.

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 the WESP is heated above its dew point before passing through the HEPA filter in order to prevent moisture condensation in the HEPA filter. The outlet temperature and the pressure differential across HEPA #1 are the only two parameters that are monitored by the off-gas data acquisition system, both of which are given in Figure 5.21. The outlet temperature averaged 61.2°C and the differential pressure averaged 0.2 in. W.C., indicating that no significant particulate loading or moisture blinding of the filter occurred during this test.

5.1.6 First Paxton Blower (Blower-701)

Blower-701 gas outlet and TCO/SCR heater gas inlet temperatures are plotted in Figure 5.22. The blower outlet gas temperature averaged 80.4°C and the TCO/SCR heater gas inlet temperature averaged 80.1°C.

5.1.7 TCO/SCR Unit

The TCO/SCR unit consists of a heater, a Thermal Catalytic Oxidizer (TCO), and a Selective Catalytic Reduction system (SCR) 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. TCO inlet, SCR inlet and outlet and post-SCR temperatures during the test are plotted in Figure 5.23. The average TCO inlet gas temperature was 476°C, while the average SCR inlet gas temperature was 383°C. The average SCR outlet gas temperatures were 346°C and 340°C at two locations 1 foot apart at the outlet of the SCR.

The differential pressures across the TCO, SCR and TCO/SCR are plotted in Figure 5.24 and averaged 3.2 in. W.C., 6.7 in. W.C., and 10.2 in. W.C., respectively.

Percent NO_x and CO destruction efficiencies are provided in Table 5.3. Note that due to their very low concentrations, a number of the measured values were near or below the detection limit of the measuring instrument and, therefore, the DRE values have large uncertainties.

During the test segments A, B, and C percent nitrogen oxide removals were about 61.4, 91.2 and 95.2, respectively. Gas residence times in the TCO during the test segments A, B, and C were 0.19, 0.18 and 0.19 seconds, respectively. Average ammonia injections into the SCR during test segments A, B, and C were 0.034, 0.054, and 0.037 lbs/hr, respectively. Ammonia slippages during the test segments A, B and C were 6.1%, 3.3%, and less than 1.5%, respectively, as shown in Table 5.4. The average ammonia concentrations after the SCR unit during test segments A, B, and C were 3.4 ppm, 2.8 ppm, and less than 1 ppm, respectively.

As mentioned above, a number of measured values were near or below detection limits of the measuring instrument. This largely results from the small amounts of NOx and CO in the off-gas stream at the TCO/SCR, and the lack of organic spiking in this test. The small amounts of NOx and CO are due to small amounts of generating sources (primarily nitrates and sugar) in the feed. The TCO/SCR units were seeing small duty in this test and. therefore, conclusions about trends are not made from these data. Other testing with high nitrate feeds and organic spiking [19, 24] provide a better quantitative basis from which to evaluate TCO/SCR performance.

5.1.8 Silver Mordenite System

A silver mordenite system was used to determine iodine removal from a slip-stream of up to 10% of the off-gas stream exiting the SCR, which was then returned to the PBS. The silver mordenite system consists of a packed-bed of silver mordenite pellets in a column. The column inlet, and outlet temperatures during the test are plotted in Figure 5.25. The average column inlet and outlet gas temperatures were 173°C and 124°C, respectively. The inlet gas temperature falls within the range specified in the Test Plan of 130°C to 230°C. The inlet, outlet, and differential pressures are shown in Figure 5.26 and averaged 21.8 in. W.C., 70.9 in. W.C., and 49.2 in. W.C., respectively.

As the silver mordenite pellets react with iodine in the off-gas stream, discoloration takes place and the original gray color of the silver mordenite pellets turns to a light yellow. A view of the column after 27.2 hours of operations is shown in Figure 5.27. Discoloration of the column can therefore be used as a rough indication of the amount of unreacted material remaining in the column. The height of the column that has changed color as a function of run time is plotted in Figure 5.28.

5.1.9 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% to 30% NaOH) can be added to control the solid content and pH of the scrubber liquid. The inlet gas temperature and the pressure drop across the PBS during the test are shown in Figure 5.29. The average PBS differential pressure was 3.4 in W.C. The average PBS inlet temperature for this test was 284°C. The PBS sump temperature and pH are plotted in Figure 5.30 and averaged 24.1°C and about

9.2, respectively. When the sump pH falls below about 9, caustic solution is added to raise the pH. After about 99 hours of operation, pH values were not electronically recorded due to a sensor error; during this time, pH values were measured and recorded manually.

5.1.10 HEME #2

HEME #2 follows the PBS in the off-gas system and removes any water droplets that may be present in water-saturated gas exiting the PBS. Inlet and outlet gas temperature and differential pressure are plotted in Figure 5.31. The average gas inlet and outlet temperatures were 25.6°C and 27.5°C, respectively, and the average pressure drop was 5.8 in. W.C. At the end of the test, 41.9 gallons of liquid was blown-down from HEME #2.

5.1.11 Effluent Liquid Treatment System

Effluent liquids from the SBS, WESP, PBS 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. Effluents collected in the storage tanks can be pumped to the Landa Evaporator for concentration and recycle, as needed; however, that was not used during this test. The various effluent liquid sampling and storage tanks are visually monitored during periodic rounds and effluent liquid transfers made as needed.

5.2 SBS and WESP 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, atomic absorption (AA) for cesium, 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. The only anions determined in the filtered solids were sulfate and iodide due to interference from the acids required to dissolve the filtered solids.

All of the SBS sump samples that were taken throughout the DM1200 tests are listed in Table 5.5; 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 the end of each of the three test segments are provided in Table 5.6. The pH values for the SBS liquids are plotted in Figure 5.32. Notice that the solution pH varies between

about 6 and 8 during testing and, for the large majority of the test, was within a quarter of a pH unit of pH 7. The neutral pH is partly due to the low feed concentrations of nitrates, nitrites, and sulfates, which form acid gases in the melter and decrease the SBS sump pH when scrubbed [8, 9]. In previous HLW tests conducted with AZ-101 simulant and glass pool bubbling [2, 6], SBS sump pH values were also in the neutral region [5-7].

Figure 5.33 compares the amount of water fed to the total volumetric accumulations in the SBS over the course of the test. There is close agreement between these quantities at the beginning of the test, followed by slight divergence as the testing progressed. Also notice that the change in water feed rate as a result of increased bubbling is paired with an increase in the water accumulation rate in the SBS. By the end of the test, about 732 gallons more water was fed than was condensed in the SBS. This difference is dependent on the SBS sump temperature set-point of 40°C (lower temperatures would decrease this difference) and the feed rate of water into the SBS. Previous testing with HLW AZ-101 feed [3, 4] showed that a near-room-temperature SBS sump condensed virtually all of the feed water, whereas a sump temperature of 40°C resulted in a portion of feed water being emitted. SBS water condensation plots from LAW tests (C1, A1, and B1) and HLW tests that used a sump temperature of 40°C are very similar. Figure 5.33 could be further refined by taking into account the water feeding used to cool the melter plenum at the start of the test and by employing the instantaneous feed rate as opposed to the test average feed rate. Water was fed to the melter at the beginning of each test segment 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 last solution, identified as O12-S-37A in Table 5.5, was taken from the draining of the SBS after the test was over and therefore was not included in calculation of condensed water.

Figures 5.34 - 5.36 compare the feed composition to the SBS dissolved and suspended fractions from a sample taken near the end of the test (O12-S-33A). As might be expected, the dissolved solids consist mainly of species such as halogens, boron, selenium, and alkali metals. These species are readily volatilized from the glass surface and cold cap in the melter as soluble salts. Nitrite and ammonium, which constitute greater than half the dissolved SBS solids in the LAW melter tests [19, 24, 25], are present only in very small quantities due to very low feed concentrations of nitrate/nitrite and the lack of sugar additions. The suspended solids more closely resemble the feed and consist primarily of iron and silicon, with significant amounts of titanium, aluminum, sodium, and zinc. Iodide was present only in the dissolved fraction. The sulfate present in SBS solutions originated from residual material from previous high-sulfur LAW Sub-Envelope B1 tests and feed contaminants (see Section 2.3.3).

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 test. All of the WESP, PBS, and HEME sump samples that were taken throughout the test are listed in Table 5.7; the middle letter in the sample name is "W", "P", and "H" for the WESP, PBS, and HEME samples, respectively. The table provides pH values for each sample, as well as the blow-down volume from which each sample

was taken and the cumulative blow-down volumes. About 80 gallons were blown down from the WESP daily: the first 40 gallons from the previous day's accumulation of water from spraying and condensation (sample with suffix "A" in name) and the second from the 40-gallon deluge (sample with suffix "B" in name). The PBS was blown down as required to maintain constant volume. Since no liquids accumulated in the HEME immediately downstream of the WESP (HEME #1) during testing, a sample was taken only at the end of the test.

Results from the analysis of sump samples from the WESP taken before and after the deluge are compared to SBS results in Table 5.6 and illustrated in Figure 5.37. The WESP solution pH values were higher (6.5 to 8 vs. 2 to 7) than the previous HLW tests [6] due to dilution from the added deluge and higher than the previous LAW Sub-Envelope B1 tests [25] (6.5 to 8 vs. 2 to 4) due to the lower concentrations of nitrates/nitrites in the feed. A near total absence of suspended material was measured in both the pre- and post-deluge blow-down solutions. The principal constituent in the WESP solutions was selenium, with lesser concentrations of volatile salts (alkali halides, boron) carried over from the SBS and residual sulfate from previous tests. The concentrations of all elements are significantly higher in the solutions prior to the deluge, indicating that large amounts of material are not being washed from the electrodes by the deluge. The results confirm 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.

Anion analysis of the PBS blow-down solution taken at the end of the test is given in Table 5.8. The pH of the PBS sump is maintained between 9 and 10 during testing by the addition of 25% sodium hydroxide solution. It is important to note that while iodide is the most abundant anion present in these solutions, it is certainly not removed quantitatively in the PBS in this pH range.

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

Estimates of elemental accumulations in the SBS, WESP, and PBS blow-down solutions are provided in Table 5.9. The accumulation totals are the product of the average analysis given in Tables 5.6 and 5.8 and the total accumulated liquids given in Tables 5.5 and 5.7. These values are upper estimates of accumulations since the concentration values were taken from the end of test segments and the concentrations increased from near zero at the beginning of the test when the sumps were filled with water. The accumulations estimated from blow-down data are also compared to estimates calculated from emissions data as percent of feed. The equivalent of over seven and a half kilograms of selenium and sodium chloride, two kilograms of boron and iron, one and half kilograms of silicon, as well as hundreds of grams of calcium, lithium, magnesium, manganese, strontium, zinc, and iodine are estimated to have accumulated in the SBS during testing. However, the SBS liquids could constitute a significant proportion of the elemental mass balance only for selenium and halogens with between 14 to 52 percent of these feed constituents reporting to the SBS fluids. Although a significant percentage of feed iodine accumulated in the SBS, much less accumulated than in previous LAW tests [19, 25] (15 vs. > 50%) due presumably to the difference in solution composition or the speciation of iodine in the melter

emissions. Estimates of accumulations in WESP solutions are the equivalent of almost four kilograms of selenium as well as hundreds of grams of boron, calcium, sodium, and chlorine over the course of the test. The WESP liquids constitute a significant proportion of the elemental mass balance only for selenium and chlorine. Agreement between the two methods for estimating accumulations was excellent, particularly considering the limited SBS and WESP samples analyzed and that emission samples were taken only during the latter portion of the third steady-state period. Estimates of accumulations are within a factor of two to three for most elements. Some of the calcium, sodium, and chlorine 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. Cesium was retained in SBS and WESP solutions at 0.6 to 2.0 percent of feed. Finally, as expected, the PBS accounts for only a modest percentage of feed anions.

SECTION 6.0
GLASS PRODUCT FROM THE DM1200

Over 6,300 kg 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 value 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. Aluminum was closer to target in the discharged glass than in the feed samples, whereas magnesium was farther from the target. Sulfur and potassium were again observed in the glass at very low levels, even though they are not included in the feed recipe. Less than 20% of feed selenium was retained in the glass product in agreement with its known volatility, results from previous melter tests [4, 24], the high concentrations measured in off-gas system process fluids (see Section 5.2), and the high measured melter emission rates (see Section 7.1). Consistent with previous melter tests using lower alkali glass [4, 19, 25], no measurable feed iodine was retained in the glass product.

Compositional trends from the XRF data are plotted for selected elements in Figures 6.1-6.3. The figures illustrate many of the points apparent in the tabular summaries of the data: good agreement with target for all oxides after the melt pool has experienced three turnovers (~6000 kg of glass produced), the total loss of iodine, and about 80% loss of selenium. The figures also illustrate the three compositional trends that occurred: elements with oxide concentrations that either did not change as a result of the similarity to the previous AZ-102 composition [8, 11] (Figure 6.1), systematically decreased in concentration towards target (Figure 6.2), or systematically increased towards target (Figure 6.3). The oxides shown in Figure 6.1 combined with oxides of silicon, boron, and lithium, which also changed little over the test due to similarities with the AZ-102 glass composition, constitute over 90% of the total. The principal compositional change was the increase in manganese and strontium oxides resulting from the incorporation of Sr/TRU removal products in the C-106/AY-102 simulant (Figure 6.3). Part of this increase was at the expense of zirconium, which has a low target composition. All of these trends closely parallel those observed in the DM100 test, described in Section 3.

6.2 Bulk Density Determination

Measurements were made on the last four drums of glass that were poured to permit the calculation of glass bulk density. The method used was the same as that applied previously to drums of AZ-101 glass [28]. The bulk density of glass that was poured into each of four 55-gallon drums was calculated from the measured glass mass and the estimated bulk volume of the glass in the drum, as shown in Table 6.3. A perfect cylinder was assumed for the bulk volume calculations. This assumption neglects the small volume contribution from the two externally protruding strengthening rings located one-third and two-thirds from the base of the drum and the slightly internally protruding drum bottom. The glass volume was calculated as:

$$\text{Glass volume } (cm^3) = (D/2)^2 \times 3.1416 \times (H - d) \times 16.3872\ cm^3/inch^3.$$

where D = Drum diameter in inches
H = Height of drum in inches
d = Depth from top of drum to glass surface in inches

The bulk glass density was then calculated using this volume and the glass mass. The average values calculated for the C-106/AY-102 and AZ-101 glass compositions are remarkably similar (2.573 vs. 2.578 g/cc), particularly considering the simplifying assumptions that were made, the lack of uniformity in purchased drums, and that measurements were made to within about an eighth of an inch.

SECTION 7.0
MONITORED OFF-GAS EMISSIONS

7.1 Particulate and Gaseous Emissions

Seven 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. All samples were taken during the steady-state portion of the third test segment. Sampling durations were one to three hours for the melter and SBS exhaust, whereas 24-hour samples were required for the WESP exhaust due to the low particle concentration. The WESP was not deluged during the first exhaust sample but was deluged during the second sample. 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. 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. All samples were within 10% of isokinetic.

Elemental emission rates and DFs are provided in Tables 7.2-7.4 for the melter, SBS, and WESP, respectively. Notice the distinction that is made between constituents sampled as particles and as "gas". The "gaseous" constituents are operationally defined as those species that are scrubbed in the impinger solutions after the air stream has passed through a 0.45 μm heated filter. Solids carry-over from the melter averaged only 0.67% of feed solids and was comparable to carry-over from tests with the other three HLW simulants [10, 11, 13]. The SBS averaged 90% removal of the particulates emitted from the melter, which is comparable to performance in the LAW Sub-Envelope C1 and A1 [19, 24] tests but less than for other HLW tests [4, 10, 11, 13]. This difference is believed to be due to the much greater content of selenium and chlorine in the C-106/AY-102 simulant, both of which tend to form fine particulate that is not efficiently captured by the SBS. More than 98 percent of the particles exiting the SBS were removed by the WESP. Most of the particulate matter on the sampling filter was deposited after the deluge cleaning process while power to the unit was off. Seventeen hours of sampling occurred prior to the WESP deluge with only a modest pressure differential developing across the sampling filter indicating that particle loading was minimal. After the deluge, power to the WESP was off for 65 minutes (see Table 5.2) as stable electrical characteristics were reestablished. Thirty seven minutes into this period, the pressure differential across the sampling filter increased to the

extent that sampling had to be terminated. Particle loading appeared to occur after the deluge as a result of gas being untreated while the power is off, not during the deluge from carry-over of the deluge spray itself. The cumulative DF value, which is calculated from feed fluxes into the melter and emissions from the WESP, was 104,797 and on the low end of those measured for the four HLW compositions.

The composition of the particles in the melter exhaust is similar to that observed in previous studies [3, 4, 24, 25]: high in volatile species such as halides, boron, selenium, and alkali, with lower concentrations of all other feed constituents. SBS, and to a greater extent WESP particle emissions, are even higher in halides, sulfur, and alkali metals and even lower in other major feed constituents, such as silicon, aluminum, and iron. Impinger solutions from off-gas sampling were analyzed for all of the elements in the feed but only the halides, selenium, and boron were detected. The presence of these elements in the gas fraction is consistent with observations from previous studies [3, 4, 24, 25]. The average composition of feed, melter emissions, SBS and WESP emissions (excluding oxygen, carbon, nitrate, and nitrite) are displayed in Figures 6.1-6.4, respectively. Notice that the relative percentages of volatiles, such as halides and selenium, increase downstream as the major constituents decrease. Iodine constitutes the majority of WESP emissions as the result of no retention in the glass and poor iodine removal in the SBS and WESP. These results are consistent with previously observed trends: melter emissions are the result of both volatile constituents and feed entrainment and the SBS removes all but some of the more volatile feed constituents, which form the majority of the finer particulate matter and gaseous compounds.

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 in triplicate during the second steady-state test segment. Data for the particle size distributions are provided in Table 7.5. Between 56 to 62% of the total particulate mass was observed in the coarsest size fraction (> 12.6-13.0 μm) with the remainder being spread out over the remaining seven finer size fractions.

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 during each test segment for a

set of selected species over discrete time intervals at specified off-gas system locations. Table 7.6 displays a summary of the average analyte concentrations measured over the course of the test. Real-time concentrations of NO, NH_3, CO_2, and water are presented in Figures 7.5-7.8. Only NO, CO_2, and water had average concentrations greater than 10 ppmv as a result of the lack of carbon and nitrogen compounds in the feed. As expected, concentrations increased as feed rates increased over the course of the test. The low nitrogen monoxide concentrations were reduced to barely detectable levels downstream of the TCO/SCR. Another aspect of the emissions is the high degree of variation during testing, as can be observed in Figures 7.5 and 7.7. Notice that, even over short periods of time, NO_x emissions can vary by factors of 2 to 5. Moisture percentages for the last test segment at the melter, SBS, WESP, and the TCO/SCR outlet were comparable to those measured using the stack sampling methods shown in Table 7.1. The moisture data also indicate that measurable condensation occurs only in the SBS, as intended.

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 provided in Table 7.6. As expected, hydrogen concentrations were low and increased with increasing feed rate over the course of the test. The average concentration for the last test segment was about half that measured in LAW Sub-Envelope B1 tests [25] and an eighth of what was measured in LAW Sub-Envelope A1 tests [24], presumably due to feed carbon being considerably lower.

7.5 Iodine Mass Balance and Silver Mordenite Column Performance

Iodine mass balance closure has been an objective of a large number of melter runs. Deficits of iodine occurred in many tests (e.g., [19, 24]) due to the neutralization of basic impinger solutions and inability of off-gas system components to quantitatively remove iodine from the exhaust stream. This test provided a good opportunity to measure iodine emission rates due to the low concentrations of acid gases in the exhaust stream, which tend to neutralize basic impinger solutions. A summary of the iodine mass balance is presented in Table 7.7 in terms of percent feed iodine. Notice that despite the lack of iodine in the glass, reasonable mass closure around the melter was achieved as either melter emissions (85%) or the sum of SBS blow-down solutions and SBS emissions (15 + 77 = 92%). The amount of iodine detected in the WESP emissions is higher than in any previous study due to the lack of acid gases in the exhaust; the presence of these acid gasses neutralizes the impingers solutions that are in place for up to 12 hours during WESP sampling. The data validate the long held assumption that the WESP

removes little or no iodine and, therefore, the amount of iodine entering and exiting the WESP are equivalent. Less iodine was detected at the entrance of silver mordenite system (taken as a slipstream from the TCO/SCR catalyst unit outlet) than at the WESP outlet. The only obvious sink for iodine between the two sampling points is the HEME; however, only 57 gallons of liquid collected in the unit during the test, which would require high iodine concentrations (about 3 g/l) in the HEME solutions to account for the difference. Also, the HEME solution pH was less than 9, which is too low to effectively remove iodine. Further downstream, 18% of feed iodine was detected in the PBS blow-down solutions. Again, the pH was too low (about 9) to remove iodine quantitatively. Consequently, sampling downstream of the PBS would be required to give a mass balance across the entire off-gas system. No iodine was detected in the particulate fraction and no more than 20% of the impinger catch was in the acidic impinger solutions, indicating that the iodine is emitted predominantly as a molecular gas (I_2) as opposed to HI or particles.

The silver mordenite column for the removal of iodine installed downstream of TCO/SCR catalyst units was operated for the first time during these tests. An off-gas slip-stream of about 25 scfm was passed through the column, which was maintained at 150°C. Air was sampled simultaneously at four locations on the column (inlet, one-third down, two-thirds down, and outlet) and scrubbed in impingers containing 2 M sodium hydroxide solution. These solutions were analyzed for iodide, which with the known solution and air volumes, allowed calculation of the iodine concentrations that are given in Table 7.8. No iodine was measured at the column outlet resulting in DF values of over 1000, based on present detection limits. During testing, a color change of the media from grey to yellow was apparent and the band gradually spread from near the inlet towards the bottom of the column. The decreasing efficiency at the sampling point located one-third into the column is consistent with this coloration reflecting loading of the media.

SECTION 8.0
CONCLUSIONS

Melter tests were conducted on the DM1200 to determine the effects of bubbling rate on glass production rate and off-gas system performance while processing a HLW C-106/AY-102 feed composition. Tests were conducted at three bubbling rates over a nine-day period using feed yielding 557.5 g glass per liter. Over sixteen and a half metric tons of feed were processed to produce about 6.3 metric tons of glass. Cold-cap-limited, steady-state production rates of 330, 550 and 970 kg/m^2/day were maintained for test segments with bubbling rates of 8, 40, and 65 lpm, respectively. Some foaming occurred at the lower bubbling rates but did not prevent the attainment of steady-state conditions. The presently required glass output of each of the WTP HLW melters of 3 MT/d corresponds to a specific glass production rate of 800 kg/m^2/d. The highest bubbling rate test on the DM1200 melter exceeded this requirement. However, it should be noted that this test used a high solids content feed (20 wt% undissolved solids) from pretreatment; lower concentrations will lead to progressively lower rates [10]. It should also be noted that the full-scale WTP melter has slightly fewer bubblers per unit melt surface area than does the DM1200 (five bubblers in 3.75 m^2 vs. two bubblers in 1.2 m^2), which may lead to lower large-scale glass production rates on a per unit melt surface area basis.

With the exception of the ADS pump valve actuator failure described in Section 4.0, the general performance of the melter and off-gas treatment system was good. The DM1200 test was preceded by a 100-hour DM100 test to ensure that the new glass formulation and melter feed were acceptable for processing in the HLW pilot melter. Extensive sets of process engineering data were collected during both tests.

Isokinetic particulate samples were taken at the outlets of the melter, SBS, and WESP during the last test segment (65 lpm bubbling) to determine the efficiency of off-gas system components. Elemental DF values were determined across the melter, SBS, and WESP. Particle size distributions were determined for the melter emissions. The total solids carryover from the melter (0.67% of feed) was comparable to that observed for tests with other HLW compositions. Calculated DFs across the SBS were the lowest of any of the four HLW compositions, due in part to the much greater amounts of selenium and chlorine in the C-106/AY-102 simulant. Both of these elements exist in the exhaust as fine particles, whereas the SBS is most effective at removing coarse particulate. The WESP, which is effective in collecting finer particles, removed much of the additional particulate material exiting the SBS. As a result, the cumulative DF (Melter+SBS+WESP) was about 105,000 and comparable to other HLW tests conducted while using the Project-directed deluge cleaning procedure of the WESP. Observations during emissions sampling suggest that the majority of the measured particulate exiting the WESP occur while the power is off after the deluge process, rather than as a result of carryover during the deluge.

The volumes of processing solutions generated in the SBS, WESP, HEME, and PBS were documented during testing and representative samples were subjected to complete 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 selenium, halogens, boron, and alkali metals, while the suspended species closely resembled the feed composition. The SBS TSS concentrations were between 200 and 2000 mg/l, whereas measured TDS values were 2 to 4 times higher. The WESP sump fluid was also in the neutral pH region but had negligible suspended solids. The WESP solutions contained significant concentrations of selenium, sulfate, chloride, and sodium. The WESP was sprayed continuously during this test and was deluged with 40 gallons of water once daily, resulting in a total blow-down volume of about 875 gallons. The 1641 gallons of liquid that accumulated in the SBS during the test originated from the condensation of water from the melter feed.

The glass product was close to the intended composition with little variation during testing. No macroscopic secondary phases were evident in the discharged product. No iodine and about 20% of the selenium in the feed were retained in the glass product.

A good mass balance was achieved for iodine around the melter, SBS, and WESP. A silver mordenite system for iodine removal was installed to treat a 10% slip stream of post SCR/TCO emissions. Samples were taken at the inlet, one third down, two thirds down, and outlet of the column. No iodine was measured at the column outlet resulting in DF values of over 1000.

Table 8.1 provides an evaluation of testing results compared to the Test Objectives presented in Section 1.1 above.

SECTION 9.0
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Table 2.1. Compositional Summary of Different Waste Streams and Blended Solids for the C-106/AY-102 HLW Simulant [6].

Waste Component	C-106/AY-102 Solids	Recycle Stream	Separation Factor	Sr/TRU Product	Cs-Eluate	Tc-Eluate	Blended Solids
Stream Number	FRP02	PWD01	—	—	CNP12	TEP12	HLP09b
—	(lb/day)	(lb/day)	fraction remained)	(lb/day)	(lb/day)	(lb/day)	(lb/day)
Ag	9.20E+01	5.49E-21	4.885*	—	—	—	9.20E+01
Al	3.19E+03	2.17E+00	0.395	—	5.13E+00	7.54E-02	1.27E+03
As	9.77E+01	1.32E-01	1.825*	—	—	—	9.78E+01
B	1.83E+01	2.88E+00	2.759*	—	7.27E+00	—	2.84E+01
Ba	6.59E+01	2.69E-04	0.054	—	6.24E-03	2.10E-03	3.55E+00
Be	4.89E+00	0.00E+00	1.000	—	—	—	4.89E+00
Bi	1.71E+00	2.58E-04	5.303*	—	—	—	1.71E+00
Ca	4.01E+02	9.03E-02	0.360	—	9.31E-01	2.22E-02	1.45E+02
Cd	1.07E+01	1.57E-04	0.028	—	1.19E-02	2.05E-03	3.10E-01
Ce	5.08E+01	5.90E+00	0.041	—	—	—	2.33E+00
Cl	3.83E+01	2.13E+00	0.064	—	5.94E+01	1.14E+01	7.34E+01
Co	2.05E+01	0.00E+00	1.000	—	—	5.59E-03	2.05E+01
Carbonate	4.73E+03	2.41E+00	0.185	—	—	—	8.74E+02
Cr	1.27E+02	2.01E-01	0.281	—	1.38E-01	5.45E-03	3.58E+01
Cs	7.84E-01	0.00E+00	0.186	—	6.33E-02	3.35E-07	2.09E-01
Cu	2.34E+01	6.86E-33	200.513*	—	3.75E-01	3.89E-03	2.38E+01
F	1.30E+01	7.49E-01	0.037	—	—	—	5.07E-01
Fe	5.87E+03	1.49E+00	1.897*	—	9.57E-02	5.63E-03	5.95E+03
Hg	2.56E+01	2.09E-05	4.438*	—	—	—	2.56E+01
K	2.09E+01	9.11E-01	0.134	—	9.77E-01	2.03E-02	3.91E+00
La	1.39E+02	1.98E-02	2.753*	—	—	2.00E-02	1.39E+02
Li	0.00E+00	7.57E-01	2.848	—	—	5.65E-03	2.16E+00
Mg	2.21E+02	4.89E-06	2.154	—	1.50E-01	4.17E-03	4.76E+02
Mn	1.26E+03	9.01E-02	1.000	4.49E+02	8.20E-03	7.73E-04	1.71E+03
Mo	3.94E+00	0.00E+00	1.000	—	—	2.07E-03	3.94E+00
Na	4.28E+03	3.65E+02	0.059	—	**2.02E+01**	**9.14E-01**	2.93E+02
Nd	8.71E+01	0.00E+00	1.000	—	—	—	8.71E+01
Ni	2.20E+02	1.10E-01	0.411	—	5.85E-01	6.68E-03	9.13E+01
Nitrite	4.47E+01	5.06E-01	0.050	—	—	—	2.28E+00
Nitrate	2.93E+01	8.67E+02	0.037	—	1.14E+02	—	1.47E+02
Hydroxide	8.33E+03	3.16E+01	0.114	—	—	—	9.56E+02
Hydroxide(Bound)	5.34E+03	0.00E+00	0.076	—	—	—	4.06E+02
Pb	2.56E+02	2.27E-02	0.353	—	0.00E+00	2.11E-02	9.04E+01
Pd	0.00E+00	2.15E-09	5.392	—	—	—	1.16E-08
Phosphate	1.15E+03	1.66E-02	0.074	—	—	—	8.53E+01
Pr	0.00E+00	0.00E+00	1.000	—	—	—	0.00E+00
Rb	0.00E+00	0.00E+00	1.000	—	—	—	0.00E+00
Rh	0.00E+00	0.00E+00	1.000	—	—	—	0.00E+00
Ru	0.00E+00	0.00E+00	1.000	—	—	—	0.00E+00
Sb	5.91E+01	0.00E+00	2.434	—	—	—	1.44E+02
Se	9.77E+01	0.00E+00	1.825	—	—	—	1.78E+02
Si	6.36E+02	6.02E+00	4.398*	—	2.13E+00	5.69E-02	6.44E+02
Sulfate	3.48E+01	5.45E-01	0.034	—	—	—	1.20E+00
Sr	2.52E+01	0.00E+00	0.985	4.99E+02	—	1.05E-03	5.24E+02
Ta	0.00E+00	0.00E+00	—	—	—	—	0.00E+00
Tc	5.83E+00	0.00E+00	—	—	—	—	0.00E+00
Th	0.00E+00	0.00E+00	—	—	—	—	0.00E+00
Ti	1.07E+01	1.53E-03	5.306	—	—	5.02E-03	5.69E+01
Tl	1.97E+02	0.00E+00	—	—	—	—	0.00E+00
TOC	2.96E+02	0.00E+00	0.017	—	—	—	4.92E+00
U	2.18E+02	0.00E+00	—	—	2.01E-01	—	2.01E-01
V	4.89E+01	0.00E+00	—	—	—	9.14E-03	9.14E-03
Y	0.00E+00	0.00E+00	—	—	—	—	0.00E+00
Zn	1.30E+01	4.36E-01	2.843	—	4.66E-02	2.87E-03	3.81E+01
Zr	6.14E+01	3.44E-01	4.576*	—	—	6.94E-03	1.30E+02
TOTAL	**3.79E+04**	**1.31E+03****	—	**9.48E+02**	**2.12E+02**	**1.26E+01**	**1.49E+04**

*Separation Factors not Used in Calculation (see text). **Includes negligible components that are omitted. – Indicates empty data field.

Table 2.2. Compositional Summary (Oxide Basis) of the C-106/AY-102 HLW Simulant, Glass Additives, Target Test Glass, and the Reference Glass (HLW98-86).

Oxide	C-106/AY-102 HLW Simulant	Glass Former (as wt% of glass)	C-106/AY-102 Melter Target Glass	HLW98-86
Ag_2O	—	—	—	0.15%
Al_2O_3	12.77%	1.75%	5.29%	5.29%
As_2O_3	0.69%	—	0.19%	0.19%
B_2O_3	0.49%	9.25%	9.39%	9.39%
CaO	1.09%	—	0.30%	0.30%
Cl	0.39%	—	0.11%	0.11%
Cr_2O_3	0.28%	—	0.08%	0.08%
Cs_2O	0.18%	—	0.05%	—
CuO	0.16%	—	0.04%	0.04%
Fe_2O_3	45.35%	—	12.58%	12.56%
I	0.36%	—	0.10%	—
La_2O_3	0.87%	—	0.24%	0.24%
Li_2O	0.02%	3.00%	3.01%	3.01%
MgO	4.21%	—	1.17%	1.17%
MnO**	14.41%	—	4.00%	3.99%
Na_2O	2.11%	11.25%	11.83%	11.84%
Nd_2O_3	0.54%	—	0.15%	0.15%
NiO	0.62%	—	0.17%	0.17%
P_2O_5	0.34%	—	0.09%	0.09%
PbO	0.52%	—	0.14%	0.14%
Sb_2O_3	0.92%	—	0.25%	0.26%
SeO_2	1.34%	—	0.37%	0.37%
SiO_2	7.35%	45.00%	47.04%	47.07%
SrO	3.31%	—	0.92%	0.92%
TiO_2	0.51%	—	0.14%	0.14%
ZnO	0.25%	2.00%	2.07%	2.07%
ZrO_2	0.93%	—	0.26%	0.26%
TOTAL	100.0%	72.25%	100.00%	100.00%
Volatiles (g/100 g oxide)	—	—	—	—
Carbonate	4.650	—	—	—
Nitrite	0.034	—	—	—
Nitrate	2.174	—	—	—
TOC	0.073	—	—	—

**MnO_2 in Reference [6]. — Indicates empty data field.

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

C-106/AY-102 HLW Simulant		Glass-Forming Additives	
Starting Materials	**Target Weight (kg)***	**Starting Materials**	**Target Weight (kg)**
$Al(OH)_3$	57.08	Al_2O_3	17.68
As_2O_3	1.93	--	--
H_3BO_3	2.43	$Na_2B_4O_7 \cdot 10H_2O$	255.91
$CaCO_3$	5.49	--	--
NaCl	1.81	--	--
Cr_2O_3	0.78	--	--
CsOH (50% solution)	1.06	--	--
CuO	0.45	--	--
$Fe(OH)_3$ (13% slurry)	1287.78	--	--
NaI	1.19	--	--
$La(OH)_3 \cdot 3H_2O$	3.66	--	--
Li_2CO_3	0.18	Li_2CO_3	76.10
$Mg(OH)_2$	17.25	--	--
MnO_2	49.49	--	--
Na_2CO_3	6.12	Na_2CO_3	123.20
Nd_2O_3	1.52	--	--
$Ni(OH)_2$	2.21	--	--
$FePO_4 \cdot xH_2O$ (80%)	2.51	--	--
PbO	1.46	--	--
Sb_2O_3	2.57	--	--
SeO_2	3.75	--	--
SiO_2	20.61	SiO_2	454.55
$SrCO_3$	13.41	--	--
TiO_2	1.42	--	--
ZnO	0.71	ZnO	20.20
$Zr(OH)_4 \cdot xH_2O$ (50%)	6.70	--	--
$NaNO_2$	0.05	--	--
$NaNO_3$	3.00	--	--
$H_2C_2O_4 \cdot 2H_2O$	0.38	--	--
Water	233.50	--	--
TOTAL	1727.24	TOTAL	947.64
--	--	FEED TOTAL	2674.88

*Target weights adjusted for assay information of starting materials.
-- Indicates empty data field.

Table 2.4. Properties of C-106/AY-102 Melter Feed Samples.

-	Date	Name	Wt. % Water	Density (g/ml)	Glass Yield		pH	Yield Stress (Pa)	Viscosity (Poise)		
					kg/kg	g/l			@1/s	@10/s	@100/s
DM1200	1/22/03	L12-F-136A	53.9	1.43	0.393	563.2	10.23	NA	NA	NA	NA
	1/23/03	M12-F-15A	53.9	1.42	0.396	562.3	10.23	NA	NA	NA	NA
	1/24/03	M12-F-61A	53.9	1.42	0.391	554.5	10.22	NA	NA	NA	NA
	1/24/03	M12-F-84A	54.4	1.42	0.388	550.8	10.21	NA	NA	NA	NA
	1/25/03	M12-F-103A	53.9	1.42	0.393	558.3	10.23	5.5	23.28	2.62	0.42
	1/26/03	M12-F-144A	53.9	1.43	0.390	558.1	10.26	NA	NA	NA	NA
	1/27/03	N12-F-34A	54.0	1.41	0.392	552.7	10.23	NA	NA	NA	NA
	1/28/03	N12-F-56A	54.0	1.44	0.380	545.3	10.28	NA	NA	NA	NA
	1/29/03	N12-F-99A	54.2	1.43	0.395	564.7	10.21	NA	NA	NA	NA
	1/30/03	N12-F-138A	56.0	1.42	0.369	524.4	10.21	NA	NA	NA	NA
	1/31/03	O12-F-28A	54.2	1.41	0.390	549.2	10.24	NA	NA	NA	NA
	Average		54.2	1.42	0.389	553.1	10.23	5.5	23.28	2.62	0.42
DM100BL	12/16/02	BLE-F-88A	53.7	1.46	0.393	574.2	10.28	5.5	25.89	3.13	0.49
	12/18/02	BLE-F-107A	53.7	1.45	0.394	570.9	10.23	NA	NA	NA	NA
	12/18/02	BLE-F-122A	54.0	1.45	0.396	574.1	10.24	NA	NA	NA	NA
	12/19/02	BLE-F-135A	54.3	1.44	0.385	554.1	10.32	NA	NA	NA	NA
	12/19/02	BLE-F-141A	54.2	1.45	0.388	562.5	10.25	5.3	26.09	3.16	0.49
	Average		54.0	1.45	0.391	567.1	10.26	5.4	25.99	3.15	0.49

NA – Not analyzed

Table 2.5. XRF Analyzed Compositions for Vitrified DM100 Melter Feed Samples (wt%).

-	Target	BLE-F-88A	BLE-F-107A	BLE-F-122A	BLE-F-135A	BLE-F-141A
Al_2O_3	5.29	6.34	6.09	5.83	5.92	5.96
As_2O_3	0.19	0.18	0.18	0.17	0.18	0.17
B_2O_3*	9.39	9.39	9.39	9.39	9.39	9.39
CaO	0.30	0.48	0.45	0.45	0.43	0.44
Cl	0.11	0.08	0.05	0.04	0.05	0.04
Cr_2O_3	0.08	0.08	0.08	0.08	0.08	0.08
Cs_2O	0.05	0.05	0.06	0.05	0.05	0.05
CuO	0.04	0.04	0.04	0.05	0.04	0.04
Fe_2O_3	12.58	11.32	11.35	11.68	11.29	11.30
I	0.10	<0.01	<0.01	<0.01	<0.01	<0.01
K_2O	<0.01	0.13	0.11	0.10	0.10	0.11
La_2O_3	0.24	0.24	0.24	0.26	0.25	0.26
Li_2O*	3.01	3.01	3.01	3.01	3.01	3.01
MgO	1.17	1.08	1.04	1.04	1.05	1.11
MnO	4.00	3.51	3.50	3.64	3.50	3.50
Na_2O	11.83	11.28	12.01	11.46	12.30	11.76
Nd_2O_3	0.15	0.14	0.15	0.15	0.14	0.14
NiO	0.17	0.14	0.14	0.15	0.14	0.14
P_2O_5	0.09	0.10	0.11	0.10	0.10	0.10
PbO	0.14	0.11	0.11	0.12	0.11	0.11
Sb_2O_3	0.25	0.29	0.29	0.28	0.29	0.29
SeO_2	0.37	0.09	0.08	0.09	0.10	0.07
SiO_2	47.05	48.60	48.31	48.49	48.29	48.76
SO_3	<0.01	0.09	0.06	0.05	0.05	0.04
SrO	0.92	0.75	0.75	0.78	0.75	0.75
TiO_2	0.14	0.22	0.21	0.21	0.21	0.21
ZnO	2.07	1.82	1.80	1.87	1.78	1.78
ZrO_2	0.26	0.44	0.43	0.43	0.41	0.41
Sum	100.00	100.00	100.00	100.00	100.00	100.00

* Target values
< = less than

Table 2.6. XRF Analyzed Compositions for Vitrified DM1200 Melter Feed Samples (wt%).

Sample I.D.	Target	L12-F-136A	M12-F-15A	M12-F-61A	M12-F-84A	M12-F-103A	M12-F-144A	N12-F-34A	N12-F-56A	N12-F-99A	N12-F-138A	O12-F-28A
Al_2O_3	5.29	5.70	5.67	5.63	6.01	5.71	5.92	5.66	5.77	5.74	5.76	5.67
As_2O_3	0.19	0.18	0.19	0.19	0.19	0.18	0.19	0.18	0.18	0.19	0.20	0.20
B_2O_3*	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39
CaO	0.30	0.48	0.50	0.48	0.47	0.47	0.49	0.47	0.49	0.46	0.46	0.47
Cl	0.11	0.05	0.05	0.06	0.05	0.04	0.06	0.05	0.05	0.05	0.06	0.07
Cr_2O_3	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Cs_2O	0.05	0.04	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.06	0.05	0.06
CuO	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Fe_2O_3	12.58	11.78	11.68	11.74	11.48	11.80	11.79	11.79	11.63	11.87	11.96	12.05
I	0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K_2O	<0.01	0.11	0.11	0.11	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.10
La_2O_3	0.24	0.26	0.25	0.26	0.25	0.27	0.25	0.26	0.25	0.25	0.27	0.26
Li_2O*	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
MgO	1.17	1.01	1.04	1.07	1.09	1.06	1.06	1.09	1.13	1.11	1.00	1.09
MnO	4.00	3.70	3.70	3.75	3.70	3.77	3.76	3.80	3.69	3.79	3.84	3.85
Na_2O	11.83	11.51	11.69	11.37	11.25	11.38	11.16	11.60	11.35	11.08	11.08	11.07
Nd_2O_3	0.15	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.15
NiO	0.17	0.14	0.14	0.14	0.13	0.14	0.15	0.14	0.13	0.14	0.14	0.14
P_2O_5	0.09	0.10	0.10	0.10	0.11	0.10	0.11	0.11	0.11	0.10	0.10	0.10
PbO	0.14	0.11	0.11	0.12	0.11	0.12	0.12	0.12	0.11	0.12	0.12	0.12
Sb_2O_3	0.25	0.25	0.27	0.30	0.29	0.27	0.30	0.29	0.30	0.31	0.31	0.32
SeO_2	0.37	0.11	0.10	0.11	0.08	0.08	0.09	0.09	0.07	0.07	0.09	0.09
SiO_2	47.05	48.44	48.31	48.50	48.59	48.43	48.29	48.07	48.53	48.44	48.38	48.23
SO_3	<0.01	0.06	0.06	0.06	0.05	0.05	0.07	0.06	0.06	0.05	0.06	0.06
SrO	0.92	0.78	0.79	0.80	0.78	0.80	0.82	0.82	0.80	0.83	0.84	0.84
TiO_2	0.14	0.22	0.22	0.22	0.22	0.21	0.23	0.22	0.21	0.22	0.22	0.22
ZnO	2.07	1.86	1.85	1.85	1.98	1.85	1.87	1.92	1.89	1.96	1.93	1.96
ZrO_2	0.26	0.44	0.43	0.44	0.33	0.43	0.45	0.40	0.42	0.38	0.36	0.35
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values
< = less than

Table 2.7. Comparison of XRF Analyses of Vitrified Melter Feed Samples to Target Composition (wt%).

-	Target	DM100 (5 samples)		DM1200 (11 samples)		All Feed (16 samples)	
		Average	%Dev.	Average	%Dev.	Average	%Dev.
Al_2O_3	5.29	6.03	13.91	5.75	8.66	5.84	10.30
As_2O_3	0.19	0.18	NC	0.19	NC	0.18	NC
B_2O_3*	9.39	9.39	NC	9.39	NC	9.39	NC
CaO	0.30	0.45	NC	0.47	NC	0.47	NC
Cl	0.11	0.05	NC	0.05	NC	0.05	NC
Cr_2O_3	0.08	0.08	NC	0.08	NC	0.08	NC
Cs_2O	0.05	0.05	NC	0.05	NC	0.05	NC
CuO	0.04	0.04	NC	0.05	NC	0.05	NC
Fe_2O_3	12.58	11.39	-9.50	11.78	-6.39	11.66	-7.36
I	0.10	<0.01	NC	<0.01	NC	<0.01	NC
K_2O	<0.01	0.11	NC	0.11	NC	0.11	NC
La_2O_3	0.24	0.25	NC	0.26	NC	0.25	NC
Li_2O*	3.01	3.01	NC	3.01	NC	3.01	NC
MgO	1.17	1.06	-9.12	1.07	-8.56	1.07	-8.74
MnO	4.00	3.53	-11.74	3.76	-6.03	3.69	-7.82
Na_2O	11.83	11.76	-0.61	11.32	-4.31	11.46	-3.16
Nd_2O_3	0.15	0.14	NC	0.15	NC	0.15	NC
NiO	0.17	0.14	NC	0.14	NC	0.14	NC
P_2O_5	0.09	0.10	NC	0.10	NC	0.10	NC
PbO	0.14	0.11	NC	0.12	NC	0.11	NC
Sb_2O_3	0.25	0.29	NC	0.29	NC	0.29	NC
SeO_2	0.37	0.09	NC	0.09	NC	0.09	NC
SiO_2	47.05	48.49	3.06	48.38	2.83	48.42	2.91
SO_3	<0.01	0.06	NC	0.06	NC	0.06	NC
SrO	0.92	0.76	-17.86	0.81	-12.21	0.79	-13.98
TiO_2	0.14	0.21	NC	0.22	NC	0.22	NC
ZnO	2.07	1.81	-12.77	1.90	-8.19	1.87	-9.62
ZrO_2	0.26	0.42	NC	0.40	NC	0.41	NC
Sum	100.00	100.00	NC	100.00	NC	100.00	NC

* Target values.
NC = Not calculated
< = less than

Table 3.1. Summary of DM100 C-106/AY-102 Test Conditions and Results.

Time	Feed Start	12/16/02, 15:43
	Feed End	12/20/02, 20:07
	Interval	100.4 hr
Water Feeding for Cold Cap		0.3 min
Slurry Feeding		100.1 hr
Average Bubbling Rate		17.3 lpm
Melt Pool Surface Area		0.108 m^2
Feed	Used	1364 kg
	Glass yield	557.5@ g/l
		0.372# kg/kg
	Average Rate	13.6 kg/hr
Glass Produced	Poured	518.4 kg
	Average Rate$	1151 kg/m^2/day
	Average Rate*	1128 kg/m^2/day

@ - Measured values.
# - Target values.
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.

Table 3.2. Glass Discharged, Masses, and Analysis Performed on DM100 Samples.

Date	Sample I.D.	Analysis	Mass (kg)	Cum. Mass (kg)
12/16/02	BLE-G-82A	XRF	14.40	14.40
	BLE-G-84A	-	20.00	34.40
	BLE-G-85A	XRF		
	BLE-G-86A	-	24.00	58.40
12/17/02	BLE-G-89A	XRF		
	BLE-G-94A	XRF	15.20	73.60
	BLE-G-94B	-	26.10	99.70
	BLE-G-94C	XRF		
	BLE-G-96A	-	16.60	116.30
	BLE-G-99A	-		
	BLE-G-99B	XRF		
	BLE-G-100A	-	26.20	142.50
	BLE-G-100B	-		
	BLE-G-105A	XRF		
12/18/02	BLE-G-106A	-	20.00	162.50
	BLE-G-107A	XRF		
	BLE-G-109A	-	22.60	185.10
	BLE-G-110A	XRF		
	BLE-G-110B	-	24.80	209.90
	BLE-G-114A	-		
	BLE-G-116A	XRF		
	BLE-G-118A	-	25.90	235.80
	BLE-G-119A	-		
	BLE-G-119B	XRF		
	BLE-G-122A	-	22.30	258.10
	BLE-G-124A	-		
	BLE-G-124B	XRF		
	BLE-G-124C	-	24.60	282.70
12/19/02	BLE-G-125A	XRF		
	BLE-G-126A	-	25.50	308.20
	BLE-G-129A	XRF		
	BLE-G-132A	-	23.90	332.10
	BLE-G-133A	XRF		
	BLE-G-135A	-	23.90	356.00
	BLE-G-135B	XRF		
	BLE-G-136A	-	17.70	373.70
	BLE-G-137A	XRF		
	BLE-G-140A	-	19.10	392.80
	BLE-G-140B	XRF		

- Empty data field

Table 3.2. Glass Discharged, Masses, and Analysis Performed on DM100 Samples (Continued).

Date	Sample I.D.	Analysis	Mass (kg)	Cumulative Mass (kg)
12/20/02	BLE-G-141A	-	27.10	419.90
	BLE-G-143A	XRF		
	BLE-G-144A	-	25.60	445.50
	BLE-G-145A	XRF		
	BLF-G-6A	-	22.40	467.90
	BLF-G-6B	XRF		
	BLF-G-8A	-	28.50	496.40
	BLF-G-10A	XRF		
	BLF-G-11A	-	22.00	518.40
	BLF-G-14A	XRF		

- Empty data field

Table 3.3. XRF Analyzed Compositions for Glass Discharged from DM100 (wt%).

Glass (kg)		14.4	34.4	58.4	73.6	99.7	116.3	142.5	162.5	185.1	209.9
-	Target	BLE-G-82A	BLE-G-85A	BLE-G-89A	BLE-G-93A	BLE-G-94C	BLE-G-99B	BLE-G-105A	BLE-G-107A	BLE-G-110A	BLE-G-116A
Al_2O_3	5.29	6.00	5.96	5.93	5.92	5.99	5.80	5.80	5.73	5.73	5.76
As_2O_3	0.19	<0.01	0.02	0.04	0.05	0.05	0.07	0.09	0.10	0.10	0.11
B_2O_3*	9.39	11.71	11.46	11.20	11.06	10.83	10.71	10.53	10.41	10.29	10.17
CaO	0.30	0.37	0.37	0.38	0.38	0.39	0.40	0.41	0.42	0.43	0.43
CdO	<0.01	0.10	0.10	0.08	0.08	0.08	0.07	0.06	0.05	0.05	0.04
Cl	0.11	<0.01	<0.01	0.01	0.02	0.02	0.02	0.03	0.04	0.04	0.04
Cr_2O_3	0.08	0.12	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11
Cs_2O	0.05	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.06
CuO	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04
Fe_2O_3	12.58	11.04	11.12	11.09	11.13	10.99	11.30	11.10	11.24	11.40	11.23
I	0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K_2O	<0.01	0.14	0.14	0.14	0.14	0.14	0.13	0.12	0.12	0.12	0.12
La_2O_3	0.24	0.40	0.39	0.38	0.37	0.35	0.35	0.33	0.31	0.32	0.29
Li_2O*	3.01	3.48	3.43	3.38	3.35	3.30	3.28	3.24	3.22	3.19	3.17
MgO	1.17	0.21	0.32	0.40	0.41	0.42	0.51	0.66	0.69	0.65	0.77
MnO	3.99	0.54	0.85	1.14	1.25	1.35	1.66	1.96	2.19	2.30	2.45
Na_2O	11.83	11.07	10.61	11.05	11.38	11.38	11.16	11.62	11.38	11.07	11.66
Nd_2O_3	0.15	0.26	0.26	0.24	0.24	0.23	0.22	0.20	0.20	0.20	0.19
NiO	0.17	0.41	0.40	0.38	0.37	0.36	0.34	0.29	0.29	0.28	0.26
P_2O_5	0.09	0.04	0.04	0.06	0.06	0.06	0.06	0.07	0.08	0.08	0.08
PbO	0.14	0.04	0.04	0.05	0.06	0.06	0.06	0.07	0.08	0.08	0.08
Sb_2O_3	0.25	0.02	0.05	0.07	0.08	0.09	0.11	0.15	0.16	0.18	0.18
SeO_2	0.37	<0.01	0.03	0.04	0.05	0.05	0.05	0.05	0.06	0.07	0.06
SiO_2	47.05	47.30	47.82	47.75	47.54	47.99	47.97	48.06	48.19	48.44	48.17
SO_3	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.04
SrO	0.92	0.21	0.26	0.31	0.34	0.35	0.41	0.46	0.51	0.54	0.56
TiO_2	0.14	0.11	0.11	0.13	0.13	0.13	0.15	0.16	0.16	0.17	0.17
ZnO	2.07	1.68	1.70	1.71	1.70	1.68	1.75	1.71	1.76	1.79	1.76
ZrO_2	0.26	4.69	4.30	3.86	3.70	3.50	3.20	2.63	2.41	2.26	1.99
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
< = less than

Table 3.3. XRF Analyzed Compositions for Glass Discharged from DM100 (wt%), (Continued).

Glass (kg)		235.8	258.1	282.7	308.2	332.1	356	373.7	392.8	419.9
-	Target	BLE-G-119B	BLE-G-124B	BLE-G-125A	BLE-G-129A	BLE-G-133A	BLE-G-135B	BLE-G-137A	BLE-G-140B	BLE-G-143A
Al2O3	5.29	5.66	5.74	5.77	5.68	5.61	5.64	5.59	5.61	5.52
As2O3	0.19	0.12	0.13	0.13	0.14	0.14	0.14	0.16	0.16	0.15
B2O3*	9.39	10.07	9.99	9.91	9.84	9.79	9.74	9.70	9.67	9.63
CaO	0.30	0.44	0.43	0.43	0.43	0.43	0.44	0.43	0.44	0.44
CdO	<0.01	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Cl	0.11	0.04	0.04	0.05	0.04	0.05	0.05	0.04	0.05	0.05
Cr2O3	0.08	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09
Cs2O	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06
CuO	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Fe2O3	12.58	11.34	11.17	11.21	11.16	11.03	11.10	11.31	11.36	11.30
I	0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K2O	<0.01	0.12	0.11	0.12	0.10	0.11	0.10	0.10	0.10	0.10
La2O3	0.24	0.30	0.29	0.29	0.28	0.28	0.26	0.27	0.27	0.26
Li2O*	3.01	3.15	3.13	3.12	3.10	3.09	3.08	3.07	3.07	3.06
MgO	1.17	0.78	0.84	0.87	0.90	0.96	0.96	0.95	0.95	0.97
MnO	3.99	2.67	2.75	2.83	2.91	2.95	3.05	3.16	3.20	3.25
Na2O	11.83	11.60	11.65	11.54	12.01	12.12	12.33	11.81	11.60	11.90
Nd2O3	0.15	0.17	0.17	0.17	0.16	0.15	0.16	0.16	0.16	0.15
NiO	0.17	0.25	0.23	0.21	0.21	0.20	0.19	0.19	0.19	0.19
P2O5	0.09	0.08	0.09	0.09	0.10	0.09	0.09	0.09	0.10	0.09
PbO	0.14	0.09	0.09	0.09	0.10	0.09	0.10	0.11	0.11	0.10
Sb2O3	0.25	0.18	0.20	0.23	0.10	0.23	0.10	0.11	0.11	0.10
SeO2	0.37	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06
SiO2	47.05	48.33	48.54	48.65	48.57	48.71	48.50	48.76	48.92	48.86
SO3	<0.01	0.04	0.05	0.04	0.04	0.05	0.05	0.05	0.05	0.05
SrO	0.92	0.60	0.62	0.63	0.63	0.64	0.65	0.68	0.69	0.70
TiO2	0.14	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19
ZnO	2.07	1.78	1.75	1.75	1.74	1.71	1.74	1.77	1.79	1.79
ZrO2	0.26	1.73	1.52	1.41	1.28	1.13	1.07	1.01	0.95	0.87
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Target values
< = less than

Table 3.3. XRF Analyzed Compositions for Glass Discharged from DM100 (wt%), (Continued).

Glass (kg)		445.5	467.9	496.4	518.4	%Dev**
-	Target	BLE-G-145A	BLF-G-6B	BLF-G-10A	BLF-G-14A	
Al_2O_3	5.29	5.56	5.48	5.51	5.53	4.58
As_2O_3	0.19	0.17	0.17	0.16	0.17	NC
B_2O_3*	9.39	9.60	9.58	9.55	9.53	NC
CaO	0.30	0.44	0.44	0.43	0.44	NC
CdO	<0.01	0.02	0.02	0.01	0.01	NC
Cl	0.11	0.05	0.05	0.04	0.05	NC
Cr_2O_3	0.08	0.10	0.10	0.09	0.09	NC
Cs_2O	0.05	0.06	0.06	0.07	0.06	NC
CuO	0.04	0.04	0.04	0.04	0.04	NC
Fe_2O_3	12.58	11.49	11.68	11.33	11.38	-9.56
I	0.10	<0.01	<0.01	<0.01	<0.01	NC
K_2O	0.00	0.10	0.10	0.10	0.10	NC
La_2O_3	0.24	0.26	0.26	0.26	0.26	NC
Li_2O*	3.01	3.05	3.05	3.04	3.04	NC
MgO	1.17	1.00	0.90	1.00	1.01	-13.92
MnO	3.99	3.31	3.41	3.38	3.41	-14.83
Na_2O	11.83	11.29	11.44	11.62	11.66	-1.43
Nd_2O_3	0.15	0.15	0.16	0.15	0.15	NC
NiO	0.17	0.19	0.19	0.18	0.17	NC
P_2O_5	0.09	0.10	0.10	0.09	0.09	NC
PbO	0.14	0.11	0.11	0.11	0.11	NC
Sb_2O_3	0.25	0.11	0.27	0.28	0.27	NC
SeO_2	0.37	0.06	0.06	0.06	0.06	NC
SiO_2	47.05	49.14	48.69	49.04	48.91	3.96
SO_3	0.00	0.05	0.05	0.04	0.05	NC
SrO	0.92	0.72	0.74	0.71	0.73	-20.18
TiO_2	0.14	0.19	0.20	0.20	0.19	NC
ZnO	2.07	1.81	1.87	1.78	1.79	-13.55
ZrO_2	0.26	0.82	0.80	0.71	0.67	NC
Sum	100.00	100.00	100.00	100.00	100.00	NC

* Target values
** Calculated using data for the last discharged glass sample (BLF-G-14A)
NC = Not calculated
< = less than

Table 4.1. Summary of DM1200 C-106/AY-102 Test Conditions and Results.

Test Segment		A	B	C
Time	Feed Start	01/22/03 12:32	01/25/03 13:32	01/28/03 13:37
	Feed End	01/25/03 13:32	01/28/03 13:36	01/31/03 14:04
	Interval	73 hr	72 hr	72.5 hr
Water Feeding for Cold Cap		1.0 hr	NA	NA
Slurry Feeding		72 hr	72 hr	72.5 hr
Cold Cap Burn-Off		NA	NA	2.0 hr
Bubbling Rate		8 lpm	40 lpm	65 lpm
Feed	Used	3181 kg	4689 kg	8704 kg
	Glass yield	557.5@ g/l	557.5@ g/l	557.5@ g/l
		0.372# kg/kg	0.372# kg/kg	0.372# kg/kg
	Average Rate	44.2 kg/hr	65.1 kg/hr	120.1 kg/hr
Glass Produced	Poured	1243 kg	1786 kg	3287 kg
	Average Rate$	345 $kg/m^2/day$	496 $kg/m^2/day$	907 $kg/m^2/day$
	Average Rate*	329 $kg/m^2/day$	484 $kg/m^2/day$	894 $kg/m^2/day$
	Steady State Rate*	330 $kg/m^2/day$	550 $kg/m^2/day$	970 $kg/m^2/day$
	Average Power Use	5.1 kW.hr/ kg glass	4.7 kW.hr/ kg glass	3.5 kW.hr/ kg glass

@ - Measured values.
# - Target values.
$ - 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 4.2. DM1200 Melter System Measured Parameters.

Test Segment			A			B			C		
-			AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
TEMPERATURE (°C)	Glass	13" from floor E	1144	1075	1183	1137	1099	1173	1147	1103	1168
		15.5" from floor E	1139	1071	1186	1132	1091	1177	1142	1096	1168
		18" from floor E	1141	1071	1184	1134	1095	1175	1143	1097	1166
		27" from floor E	1042	644	1135	1087	887	1181	1130	869	1178
		13" from floor W	1141	1097	1174	1141	1114	1176	1147	1119	1169
		15.5" from floor W	1139	1091	1174	1140	1110	1182	1147	1118	1170
		18" from floor W	1136	1083	1178	1140	1104	1188	1147	1116	1174
		27" from floor W	1039	752	1137	1115	951	1189	1143	1038	1183
	Plenum	8" below ceiling	488	343	835	504	341	679	538	467	620
		17" below ceiling	477	350	838	526	360	681	551	464	636
		Exposed	487	332	844	473	31	711	564	482	653
	Discharge	TC 1	987	927	1069	867	36	1038	978	906	1026
		TC 2	1042	992	1119	919	37	1089	1036	1000	1071
		Riser	1044	966	1134	1073	1033	1133	1102	1057	1150
	Electrode	East	1113	1069	1166	1114	1062	1156	1147	1090	1161
		West	1095	1021	1148	1097	1071	1136	1119	1089	1131
		Bottom	1054	1026	1075	1051	1032	1076	1074	1050	1086
	Film Cooler	Added Air	80	77	81	75	26	84	83	80	84
		Outlet	288	61	547	298	27	446	349	70	423
Glass	Density (g/cc)		2.35	2.26	2.46	2.32	2.07	2.42	2.34	2.22	2.43
	Level (inches from floor)		27.78	26.30	29.51	28.55	26.83	30.79	29.52	27.96	30.75
	Resistance (ohms)		0.111	0.000	0.131	0.114	0.103	0.126	0.106	0.100	0.113
Differential Pressure (inches water)	Transition line		2.07	0.60	4.66	2.26	0.69	5.17	1.97	0.36	5.93
	Film Cooler		0.81	0.0	2.73	1.24	0.0	3.17	1.55	0.49	5.28
Electrodes	Current (A)		872	0	957	995	876	1102	1206	1013	1246
	Voltage (V)		96.8	0.0	107.7	113.5	91.1	125.3	128.2	109.6	133.0
	Power (kW)		84.5	0.5	103.1	112.9	79.7	138.1	154.6	111.0	165.8
Lance Bubblers	1	Rate (lpm)	3.13	0.21	4.07	19.29	4.44	23.93	32.67	14.93	36.04
		Temp. (°C)	1152	1081	1193	1131	1097	1173	1128	1107	1145
	2	Rate (lpm)	3.15	0.12	4.95	16.80	4.39	24.54	29.04	14.35	34.61
		Temp. (°C)	1157	1103	1191	1141	1112	1178	1137	1122	1154
Total Bubbling (lpm)			7.43	4.27	8.64	37.29	10.05	40.15	62.92	30.50	67.70

- Empty data field

Table 5.1. DM1200 Measured Off Gas System Parameters.

Test Segment		A			B			C		
-		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Melter	Press. at Level Det. Port ("water)	-3.7	-6.8	-1.2	-3.6	-5.7	0.7	-3.4	-5.3	0.2
	Press. at Instrument Port ("water)	-3.8	-6.8	-1.3	-3.8	-5.9	0.6	-3.6	-5.5	0.1
	Control Air Flow Rate (scfm)	59.9	0.0	90.9	46.8	0.0	102	43.2	0.0	73.7
SBS	Differential Pressure ("water)	37.6	33.6	41.3	38.4	34.2	46.3	40.4	35.4	46.6
	Inlet gas pressure ("water)	-6.8	-11.1	-3.4	-7.3	-12.5	-0.1	-7.4	-12.6	-3.4
	Outlet gas pressure ("water)	-42.6	-46.0	-39.7	-43.8	-49.7	-34.9	-46.1	-58.0	-40.9
	Inlet gas Temp. (°C)	212	97	440	249	130	331	281	156	328
	Outlet gas Temp. (°C)	38.8	23.3	45.6	39.8	33.1	45.9	39.9	28.9	44.4
	Chilled Water Inlet Temp (°C)	13.3	6.2	17.3	13.9	7.9	18.0	14.8	8.3	19.5
	Chilled Water Outlet Temp (°C)	19.8	14.3	37.2	21.5	13.9	44.2	22.2	16.6	33.0
	Submerged 48" Temp (°C)	46.3	32.7	71.0	48.9	39.9	60.9	47.5	30.4	55.9
	Submerged 60" Temp (°C)	45.0	32.0	71.1	47.7	37.4	61.6	46.8	29.8	55.9
	Submerged 72" Temp (°C)	49.0	37.8	72.7	51.9	41.2	67.2	50.9	32.4	60.4
	Submerged 78" Temp (°C)	46.3	35.4	71.0	49.4	40.4	64.6	48.8	31.5	58.1
	Recirc. pump discharge Temp (°C)	38.2	20.6	43.3	39.4	30.5	43.7	38.0	34.3	43.3
	Heat Exchanger Outlet Temp (°C)	35.8	16.8	42.8	36.8	28.1	44.3	33.8	24.9	40.3
	Chilled Water Flow (gal/min)	7.4	2.4	34.8	12.0	2.4	31.1	14.4	2.9	38.5
	Heat Exchanger Flow (gal/min)	3.3	0.5	22.5	3.6	0.5	10.8	9.4	0.5	21.1
	Recirc. pump discharge Pressure	37.5	30.8	39.8	37.5	27.1	39.9	37.7	31.0	39.9
	Inner C. Coil W. Inlet Temp (°C)	34.9	15.3	44.0	34.3	22.9	44.3	27.5	21.5	36.7
	Inner C. Coil W. Outlet Temp(°C)	37.1	17.9	43.9	37.6	29.0	45.4	35.1	25.6	40.7
	Inner C. Coil W. Flow (gal/min)	24.6	23.6	25.3	24.7	24.0	25.3	24.5	23.7	25.1
WESP	Differential Pressure ("water)	2.5	1.4	3.7	2.7	1.4	3.5	2.5	1.3	3.2
	Inlet gas Temp. (°C)	38.7	26.9	48.6	39.4	32.6	45.4	39.6	29.1	43.7
	Outlet gas Temp. (°C)	39.6	19.1	44.1	40.6	15.4	45.4	41.0	18.6	44.6
HEME #1, Outlet Gas Temp. (°C)		38.5	29.8	44.1	38.7	29.2	43.0	38.9	30.9	41.9
HEPA 1	Differential Pressure ("water)	0.2	0.1	0.3	0.2	0.2	0.3	0.2	0.1	0.3
	Outlet Gas Temp. (°C)	61.2	59.6	62.5	61.1	60.1	62.1	61.3	60.2	62.2
PAXTON 1 Outlet Gas Temp. (°C)		79.4	77.6	81.8	80.3	78.9	82.0	81.5	78.5	83.5
TCO-SCR Heater Inlet Gas Temp. (°C)		79.0	77.0	81.4	80.0	78.3	81.6	81.1	78.4	82.9
TCO	Inlet Gas Temp. (°C)	476	465	482	476	467	485	476	464	484
	Differential Pressure ("water)	3.1	2.3	3.7	3.3	2.8	3.5	3.1	2.5	3.4
SCR	Inlet Gas Temp. (°C)	378	371	395	386	375	391	386	373	390
	Outlet Gas Temp. Right (°C)	341	323	353	349	336	359	347	335	357
	Outlet Gas Temp. Left (°C)	334	327	346	344	339	350	342	330	346
	Differential Pressure ("water)	6.6	4.8	7.8	6.9	6.0	7.6	6.6	5.0	7.2
	Post Outlet Gas Temp. (°C)	294	266	313	303	294	308	316	299	330
PBS	Inlet Gas Temp. (°C)	274	261	284	283	268	288	294	279	305
	PBS Sump Temp. (°C)	22.6	18.9	25.1	24.3	21.6	26.6	25.4	20.7	28.4
	Differential Pressure ("water)	3.3	1.4	4.5	3.6	1.5	4.4	3.3	2.1	3.9
HEME #2	Inlet Gas Temp. (°C)	23.9	20.6	26.3	25.7	23.2	27.7	27.1	23.6	29.6
	Outlet Gas Temp. (°C)	26.3	23.6	31.1	27.4	25.2	29.8	28.8	25.1	31.2
Exhaust Stack Absolute Pressure ("water)		-8.5	-9.6	-7.6	-9.3	-9.6	-8.6	-8.7	-9.0	-8.5

Table 5.2. Time Needed to Restore Power After Deluge of WESP.

Date	Time	Time Required To Restore Power (Minutes)
01/23/2003	13:54	~5
01/24/2003	12:49	15
01/25/2003	12:49	6
01/26/2003	12:29	15
01/27/2003	13:34	26
01/28/2003	12:38	20
01/29/2003	12:29	25
01/30/2003	12:17	65

Table 5.3. Nitrogen Oxides and Carbon Monoxide Destruction Across TCO-SCR Catalytic Unit.

Test Segment	Analyte	Input[1] (mol/hr)	Output (mol/hr)	NO_x, CO Reduction[1] (%)	DF
A	N_2O	<0.016	<0.017	-	-
	NO	0.359	0.074	-	-
	NO_2	<0.016	0.060	-	-
	Total NO_x	<0.390	<0.151	-	-
	CO	<0.016	<0.017	-	-
	CO_2	48.6	29.8	-	-
B	N_2O	<0.017	<0.017	-	-
	NO	0.548	<0.017	-	-
	NO2	<0.017	<0.017	-	-
	Total NO_x	<0.581	<0.051	-	-
	CO	<0.017	<0.017	-	-
	CO_2	69.3	34.3	-	-
C	N_2O	<0.016	<0.016	-	-
	NO	1.004	<0.016	-	-
	NO_2	0.016	<0.016	-	-
	Total NO_x	<1.035	<0.049	-	-
	CO	0.048	<0.016	>66.0	>2.9
	CO_2	110.4	19.8	-	-

[1] Negative value indicate % production in the TCO-SCR units.
- Indicates empty data field
< = less than
> = greater than

Table 5.4. Ammonia Slippage from TCO-SCR Catalytic Unit.

Test Segment	Analyte	Input (mol/hr)	Output (mol/hr)	NH_3 slippage (%)
A	NH_3 (in exhaust)	0.032	-	-
	NH_3 injected	0.910	-	-
	Total NH_3	0.942	0.057	6.1
B	NH_3 (in exhaust)	0.019	-	-
	NH_3 injected	1.447	-	-
	Total NH_3	1.466	0.049	3.3
C	NH_3 (in exhaust)	0.121	-	-
	NH_3 injected	0.977	-	-
	Total NH_3	1.099	<0.016	<1.5

- Indicates empty data field.
< = less than

Table 5.5. Listing of Samples from SBS Blow-Downs.

Test Segment	Date	Name	pH	Blow-Down Volume (Gallons)	Cumulative Volume (Gallons)
A	1/22/03	L12-S-135A	8.04	40.01	40.01
	1/23/03	L12-S-145A	7.75	40.05	80.06
		L12-S-154A	7.65	40.09	120.15
		M12-S-20A	7.83	40.20	160.35
	1/24/03	M12-S-35A	7.53	40.04	200.39
		M12-S-53A	7.36	40.00	240.39
		M12-S-58A	7.21	40.00	280.39
	1/25/03	M12-S-74A	6.99	40.07	320.46
		M12-S-81A	6.79	39.55	360.01
B		M12-S-100A	6.33	40.00	400.01
	1/26/03	M12-S-117A	7.02	40.11	440.12
		M12-S-136A	7.24	39.90	480.02
		M12-S-142A	7.29	40.02	520.04
	1/27/03	N12-S-11A	7.09	40.05	560.09
		N12-S-17A	6.65	40.05	600.14
		N12-S-32A	6.79	40.01	640.15
	1/28/03	N12-S-47A	6.89	39.92	680.07
		N12-S-54A	6.86	40.02	720.09
C		N12-S-70A	6.52	40.01	760.10
		N12-S-75A	6.93	40.70	800.80
	1/29/03	N12-S-80A	6.97	39.85	840.65
		N12-S-91A	6.83	40.11	880.76
		N12-S-94A	6.85	39.87	920.63
		N12-S-98A	6.71	40.00	960.63
		N12-S-108A	6.80	40.06	1000.69
		N12-S-110A	6.78	40.06	1040.75
		N12-S-115A	6.71	40.02	1080.77
	1/30/03	N12-S-119A	6.89	40.00	1120.77
		N12-S-128A	6.93	40.40	1161.17
		N12-S-134A	6.81	39.49	1200.66
		N12-S-137A	6.83	39.99	1240.65
		N12-S-142A	6.77	40.17	1280.82
		N12-S-144A	6.90	40.01	1320.83
		N12-S-155A	6.73	40.00	1360.83
		O12-S-11A	6.86	40.10	1400.93
		O12-S-14A	6.84	40.02	1440.95
	1/31/03	O12-S-16A	6.9	40.00	1480.95
		O12-S-26A	6.87	39.69	1520.64
		O12-S-30A	6.77	40.15	1560.79
		O12-S-32A	7.29	39.84	1600.63
		O12-S-33A	7.24	40.22	1640.85
		O12-S-37A	7.19	354.75	1995.60

Table 5.6. Analytical Results for Selected SBS and WESP Blow-Down Fluids (mg/l).

I.D.	M12-S-81A SBS (end of segment A)			N12-S-47A SBS (end of segment B)			O12-S-33A SBS (end of segment C)			N12-W-142A WESP			N12-W-142B WESP		
Glass (kg)	1171.0			2698.4			6101.3			4954.7			4954.7		
pH	6.79			6.89			7.24			6.62			6.53		
-	Sus*	Dis.#	Total	Sus.*	Dis.#	Total	Sus.*	Dis.#	Total	Sus*	Dis.#	Total	Sus*	Dis.#	Total
Total	296	1164	1460	952	3052	4004	1944	4604	6548	6	1966	1972	2	548	550
Al	10.13	0.14	10.27	27.99	3.79	31.78	54.74	1.54	56.28	NA	1.29	1.29	NA	0.08	0.08
As	1.07	0.62	1.69	3.87	1.82	5.69	10.16	5.36	15.52	NA	19.13	19.13	NA	3.99	3.99
B	0.75	116.3	117.0	2.26	329.5	331.8	17.35	392.9	410.3	NA	44.32	44.32	NA	9.64	9.64
Ba	0.06	0.03	0.09	0.20	0.02	0.22	0.39	0.02	0.41	NA	0.07	0.07	NA	0.03	0.03
Ca	2.19	26.60	28.79	4.42	21.49	25.91	8.71	13.61	22.32	NA	48.03	48.03	NA	42.88	42.88
Cd	0.20	0.04	0.24	0.35	<0.03	0.35	0.27	<0.03	0.27	NA	0.22	0.22	NA	<0.03	<0.03
Cr	0.13	0.19	0.32	0.70	1.47	2.17	2.16	2.43	4.59	NA	3.38	3.38	NA	0.46	0.46
Cs	NA	1.27	1.27	2.29	3.82	6.11	4.76	4.76	9.52	NA	10.70	10.70	NA	2.12	2.12
Cu	0.08	<0.02	0.08	0.31	0.02	0.33	0.64	0.02	0.66	NA	0.19	0.19	NA	<0.02	<0.02
Fe	62.48	0.31	62.79	193.1	4.09	197.2	352.4	9.08	361.5	NA	0.15	0.15	NA	0.10	0.10
K	0.21	5.88	6.09	0.45	13.42	13.87	0.62	3.44	4.06	NA	8.92	8.92	NA	5.10	5.10
Li	0.42	9.95	10.37	1.28	39.32	40.60	5.01	62.10	67.11	NA	11.00	11.00	NA	2.65	2.65
Mg	1.01	12.09	13.10	3.04	28.61	31.65	11.77	31.04	42.81	NA	9.34	9.34	NA	8.51	8.51
Mn	1.65	0.05	1.70	7.70	1.03	8.73	17.15	1.10	18.25	NA	0.14	0.14	NA	<0.04	<0.04
Na	1.60	135.3	136.9	5.80	530.1	535.9	36.13	577.8	614.0	NA	258.8	258.8	NA	56.01	56.01
Ni	0.78	<0.04	0.78	1.70	0.11	1.81	3.12	0.04	3.16	NA	0.11	0.11	NA	<0.04	<0.04
P	0.02	<0.60	0.02	1.27	<0.60	1.27	2.35	0.76	3.11	NA	<0.60	<0.60	NA	<0.60	<0.60
Pb	0.56	0.17	0.73	1.38	0.55	1.93	3.37	0.77	4.14	NA	<0.10	<0.10	NA	<0.10	<0.10
Sb	0.69	1.17	1.86	2.70	3.76	6.46	7.62	4.73	12.35	NA	1.16	1.16	NA	<0.50	<0.50
Se	7.05	380.2	387.2	51.72	1002	1054	92.66	1152	1246	NA	1170	1170	NA	224.8	224.8
Si	41.87	13.27	55.14	134.9	34.44	169.3	241.7	25.37	267.1	NA	5.50	5.50	NA	3.94	3.94
Sr	2.01	7.24	9.25	8.67	14.33	23.00	22.86	10.98	33.84	NA	0.44	0.44	NA	0.23	0.23
Ti	1.10	<0.02	1.10	3.18	0.08	3.26	5.97	0.21	6.18	NA	<0.02	<0.02	NA	<0.02	<0.02
Zn	7.35	3.54	10.89	23.94	10.47	34.41	57.41	4.86	62.27	NA	4.16	4.16	NA	0.66	0.66
Zr	0.74	<0.02	0.74	1.41	0.08	1.49	1.72	0.07	1.79	NA	<0.02	<0.02	NA	<0.02	<0.02
F	NA	6.47	6.47	NA	14.95	14.95	NA	19.77	19.77	NA	1.98	1.98	NA	1.72	1.72
Cl	NA	174.7	174.7	NA	354.4	354.4	NA	559.0	559.0	NA	132.7	132.7	NA	48.65	48.65
I	NA	74.92	74.92	<0.01	182.4	182.4	<0.01	147.2	147.2	NA	0.80	0.80	NA	3.23	3.23
Ammonium	NA	6.1	6.1	NA	4.3	4.3	NA	2.2	2.2	NA	19.9	19.9	NA	6.6	6.6
Nitrite	NA	7.19	7.19	NA	79.9	79.90	NA	7.04	7.04	NA	<0.01	<0.01	NA	<0.01	<0.01
Nitrate	NA	14.62	14.62	NA	130.5	130.5	NA	0.85	0.85	NA	15.54	15.54	NA	15.98	15.98
Sulfate	NA	68.36	68.36	1.66	139.2	140.8	5.81	168.5	174.3	NA	252.4	252.4	NA	78.54	78.54

* Suspended
# Dissolved
NA - Not analyzed
< = less than

Table 5.7. WESP, PBS, and HEME Blow-down Liquids.

Sample Type	Date	Name	pH	Blow-Down Volume (Gallons)	Cumulative Blow-Down Volume (Gallons)
WESP	01/23/03	L12-W-154A	7.76	49.75	49.8
		L12-W-154B	7.30	35.56	85.3
	1/24/03	M12-W-43A	7.04	42.86	128.2
		M12-W-43B	7.10	40.96	169.1
	01/25/03	M12-W-82A	6.69	53.56	222.7
		M12-W-82B	6.84	40.23	262.9
	01/26/03	M12-W-128A	6.58	55.24	318.2
		M12-W-128B	6.51	40.46	358.6
	01/27/03	N12-W-17A	6.64	58.09	416.7
		N12-W-17B	6.57	40.24	457.0
	01/28/03	N12-W-54A	6.59	55.60	512.6
		N12-W-54B	6.51	46.61	559.2
	01/29/03	N12-W-98A	6.48	57.63	616.8
		N12-W-98B	6.54	40.16	657.0
	01/30/03	N12-W-142A	6.62	58.64	715.6
		N12-W-142B	6.53	40.13	755.7
	01/31/03	O12-W-46A	7.89	78.88	834.6
	02/01/03	O12-W-46B	7.76	40.06	874.7
PBS	01/23/03	L12-P-147A	8.95	33.60	33.60
		M12-P-20A	8.97	21.45	55.05
	01/24/03	M12-P-35A	8.68	27.64	82.69
		M12-P-55A	8.71	20.37	103.06
	01/25/03	M12-P-72A	8.78	32.93	135.99
		M12-P-95A	8.69	26.32	162.31
	01/26/03	M12-P-112A	8.75	29.49	191.80
		M12-P-136A	8.67	35.63	227.43
	01/27/03	M12-P-154A	8.62	34.33	261.76
		N12-P-30A	8.65	30.01	291.77
	01/28/03	N12-P-46A	8.58	37.80	329.57
		N12-P-69A	8.66	24.97	354.54
	01/29/03	N12-P-89A	8.61	34.53	389.07
		N12-P-108A	8.67	22.23	411.30
		N12-P-115A	8.59	15.27	426.57
	01/30/03	N12-P-134A	8.6	33.32	459.89
		O12-P-13A	8.47	23.07	482.96
	01/31/03	O12-P-26A	8.41	28.81	511.77
HEME 1	02/01/03	O12-H1-46A	8.22	57.2	57.2
HEME 2	01/23/03	M12-H2-21A	7.69	40.58	40.58
	01/27/03	N12-H2-10A	8.22	15.68	56.26
	01/28/03	N12-H2-75A	7.71	12.99	69.25
	01/25/03	N12-H2-154A	8.03	16.1	85.35
	02/01/03	O12-H2-46A	7.81	41.92	127.27

Table 5.8. Anion Concentration in PBS Blow-Down Sample (mg/l).

Sample I.D.	pH	F	Cl	I	Nitrite	Nitrate	Sulfate
O12-P-26A	8.41	20.1	63.5	577	2.27	2.15	1.35

Table 5.9. Upper Estimates of Accumulations in Off-Gas Liquids.

Analyte	Feed (kg)	SBS			WESP			PBS	
		Mass (g)	% Feed	% Feed calculated from emissions data	Mass (g)	% Feed	% Feed calculated from emissions data	Mass (g)	% Feed
Al	172.5	351	0.2	0.5	4	< 0.1	< 0.1	NA	NA
As	8.9	97	1.1	1.4	64	0.7	0.2		
B	179.7	2558	1.4	1.6	147	0.1	< 0.1		
Ca	13.2	139	1.1	1.2	160	1.2	< 0.1		
Cr	3.4	29	0.8	0.2	11	0.3	0.2		
Cs	2.9	59	2.0	0.6	36	1.2	0.6		
Cu	2.0	4	0.2	< 0.1	1	< 0.1	< 0.1		
Fe	542.3	2254	0.4	0.7	0	< 0.1	< 0.1		
Li	86.2	418	0.5	0.4	37	< 0.1	< 0.1		
Mg	43.5	267	0.6	0.7	31	0.1	< 0.1		
Mn	191.0	114	0.1	0.2	< 1	< 0.1	< 0.1		
Na	541.1	3828	0.7	0.7	860	0.2	< 0.1		
Ni	8.2	20	0.2	< 0.1	< 1	< 0.1	< 0.1		
P	2.4	19	0.8	0.4	< 2	< 0.1	0.2		
Pb	8.0	26	0.3	0.6	< 1	< 0.1	0.1		
Sb	12.9	77	0.6	< 0.1	4	< 0.1	< 0.1		
Se	16.2	7766	47.8	36.3	3888	24.0	10.7		
Si	1355.7	1666	0.1	< 0.1	18	< 0.1	< 0.1		
Sr	48.0	211	0.4	< 0.1	1	< 0.1	< 0.1		
Ti	5.2	39	0.7	< 0.1	< 1	< 0.1	< 0.1		
Zn	102.5	388	0.4	0.8	14	< 0.1	< 0.1		
Zr	11.9	11	0.1	< 0.1	< 1	< 0.1	< 0.1		
Cl	6.8	3486	51.4	20.3	441	6.5	1.6	123	1.8
I	6.2	918	14.9	6.4	3	< 0.1	6.0	1121	18.2
S*	1.5	441	29.2	NA	183	12.2	NA	0.9	<0.1
Nitrite + Nitrate	0.38	49	13.0	NC	52	13.7	NC	9	2.3

NA – Not analyzed, NC – Not calculated
< = less than
* Present as an impurity in the feed

Table 6.1. Glass Discharged, Masses, and Analysis Performed for DM1200.

Test Segment	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
A	01/22/03	L12-G-136A	-	511.0	511.0
		L12-G-138A	-		
		L12-G-141A	-		
	01/23/03	L12-G-143A	-		
		L12-G-146A	-		
		L12-G-148A	-		
		L12-G-150A	-		
		L12-G-155A	-		
	01/23/03	M12-G-15A	-		
		M12-G-19A	XRF		
		M12-G-22A	-	538.5	1049.5
	01/24/03	M12-G-33A	-		
		M12-G-36A	-		
		M12-G-38A	-		
		M12-G-42A	-		
		M12-G-53A	-		
		M12-G-57A	-		
		M12-G-59A	-		
	01/25/03	M12-G-64A	-		
		M12-G-73A	XRF		
		M12-G-78A	-	533	1582.5
		M12-G-80A	-		
		M12-G-82A	-		
		M12-G-92A	-		
B		M12-G-95A	-		
		M12-G-96A	-		
		M12-G-102A	-		
	01/26/03	M12-G-113A	-		
		M12-G-116A	-		
		M12-G-119A	-		
		M12-G-119B	XRF		
		M12-G-122A	-	506.5	2089.0
		M12-G-128A	-		
		M12-G-137A	-		
		M12-G-139A	-		
		M12-G-140A	-		
		M12-G-142A	-		
	01/27/03	M12-G-145A	-		
		M12-G-154A	-		
		M12-G-155A	-		
		N12-G-10A	XRF		

- Indicates empty data field

Table 6.1. Glass Discharged, Masses, and Analysis Performed for DM1200 (Continued).

Test Segment	Date	Name	Analysis	Mass (kg)	Cumulative Mass (kg)
B	01/27/03	N12-G-12A	-	522.5	2611.5
		N12-G-12B	-		
		N12-G-14A	-		
		N12-G-16A	-		
		N12-G-18A	-		
		N12-G-29A	-		
		N12-G-30A	-		
		N12-G-31A	-		
		N12-G-33A	-		
		N12-G-34A	XRF		
	01/28/03	N12-G-45A	-	521.5	3133.0
		N12-G-48A	-		
		N12-G-49A	-		
		N12-G-49B	-		
		N12-G-51A	-		
		N12-G-53A	-		
		N12-G-54A	-		
		N12-G-68A	-		
		N12-G-70A	-		
		N12-G-72A	XRF		
C		N12-G-74A	-	509.5	3642.5
		N12-G-78A	-		
	01/29/03	N12-G-79A	-		
		N12-G-80A	-		
		N12-G-89A	-		
		N12-G-89B	-		
		N12-G-91A	-		
		N12-G-92A	-		
		N12-G-92B	-		
		N12-G-93A	XRF		
		N12-G-94A	-	516	4158.5
		N12-G-94B	-		
		N12-G-95A	-		
		N12-G-98A	-		
		N12-G-99A	-		
		N12-G-107A	-		
		N12-G-108A	-		
		N12-G-110A	-		
		N12-G-110B	-		
		N12-G-113A	XRF		
		N12-G-113B	-	-	-
		N12-G-116A	-		

- Indicates empty data field

Table 6.1. Glass Discharged, Masses, and Analysis Performed for DM1200 (Continued).

Test Segment	Date	Name	Analysis		Mass (kg)	Cumulative Mass (kg)
C	01/29/03	N12-G-116B	-		511.5	4670.0
	01/30/03	N12-G-119A	-			
		N12-G-119B	-			
		N12-G-120A	-			
		N12-G-128A	-			
		N12-G-133A	-			
		N12-G-134A	XRF			
		N12-G-136A	-	Bulk Density	508.5	5178.5
		N12-G-137A	-			
		N12-G-138A	-			
		N12-G-138B	-			
		N12-G-139A	-			
		N12-G-144A	-			
		N12-G-144B	-			
		N12-G-145A	-			
		N12-G-153A	-			
		N12-G-155A	XRF			
		O12-G-6A	-	Bulk Density	518.0	5696.5
		O12-G-10A	-			
		O12-G-12A	-			
		O12-G-12B	-			
		O12-G-14A	-			
		O12-G-15A	-			
	01/31/03	O12-G-16A	-			
		O12-G-17A	-			
		O12-G-17B	-			
		O12-G-25A	XRF			
		O12-G-26A	-	Bulk Density	520.5	6217.0
		O12-G-29A	-			
		O12-G-30A	-			
		O12-G-31A	-			
		O12-G-32A	-			
		O12-G-32B	-			
		O12-G-33A	-			
		O12-G-33B	-			
		O12-G-36A	XRF			
		O12-G-37A	XRF	Bulk Density	98.5	6315.5

- Indicates empty data field

Table 6.2. XRF Analyzed Compositions for Glass Discharged from DM1200 (wt%).

Test Segment		A		B			C				
Glass Produced (kg)		511.0	1049.5	1582.5	2089.0	2611.5	3133.0	3642.5	4158.5	4670.0	5178.5
Analyte	Target	M12-G-19A	M12-G-73A	M12-G-119B	N12-G-10A	N12-G-34A	N12-G-72A	N12-G-93A	N12-G-113A	N12-G-134A	N12-G-155A
Al_2O_3	5.29	6.03	5.94	5.84	6.00	5.72	5.77	5.72	5.73	5.69	5.66
As_2O_3	0.19	0.04	0.08	0.11	0.11	0.15	0.15	0.15	0.18	0.17	0.18
B_2O_3*	9.39	11.78	11.20	10.76	10.45	10.20	10.01	9.86	9.75	9.67	9.60
CaO	0.30	0.42	0.43	0.44	0.43	0.44	0.45	0.44	0.45	0.45	0.45
CdO	<0.01	0.10	0.07	0.05	0.05	0.03	0.02	0.02	0.01	0.01	0.01
Cl	0.11	0.02	0.03	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05
Cr_2O_3	0.08	0.03	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.08
Cs_2O	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06
CuO	0.04	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05
Fe_2O_3	12.58	11.67	11.92	11.92	11.33	11.87	11.51	11.67	11.90	11.40	11.72
I	0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K_2O	<0.01	0.12	0.13	0.12	0.13	0.12	0.11	0.11	0.12	0.11	0.11
La_2O_3	0.24	0.40	0.37	0.33	0.30	0.30	0.29	0.28	0.28	0.26	0.27
Li_2O*	3.01	3.20	3.16	3.12	3.09	3.07	3.06	3.05	3.04	3.03	3.03
MgO	1.17	0.34	0.45	0.64	0.77	0.77	0.83	0.88	0.91	1.03	1.01
MnO	4.00	1.10	1.78	2.28	2.49	2.91	3.03	3.24	3.44	3.38	3.56
Na_2O	11.83	11.57	10.88	10.96	11.62	11.35	11.85	11.40	10.97	12.02	11.34
Nd_2O_3	0.15	0.16	0.16	0.17	0.15	0.16	0.15	0.16	0.15	0.15	0.14
NiO	0.17	0.35	0.31	0.27	0.23	0.22	0.19	0.18	0.18	0.16	0.16
P_2O_5	0.09	0.05	0.07	0.08	0.08	0.09	0.09	0.10	0.09	0.10	0.10
PbO	0.14	0.07	0.08	0.10	0.09	0.11	0.10	0.11	0.11	0.11	0.11
Sb_2O_3	0.25	0.07	0.11	0.15	0.18	0.19	0.22	0.25	0.27	0.26	0.29
SeO_2	0.37	0.05	0.07	0.08	0.08	0.08	0.08	0.06	0.06	0.06	0.06
SiO_2	47.05	48.16	48.64	48.50	48.67	48.34	48.39	48.58	48.56	48.37	48.50
SO_3	<0.01	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.05	0.06	0.05
SrO	0.92	0.18	0.34	0.46	0.50	0.59	0.63	0.68	0.73	0.71	0.76
TiO_2	0.14	0.13	0.15	0.16	0.17	0.19	0.19	0.20	0.20	0.19	0.20
ZnO	2.07	1.85	1.88	1.88	1.77	1.89	1.81	1.87	1.94	1.83	1.90
ZrO_2	0.26	1.96	1.58	1.31	1.07	0.93	0.80	0.72	0.64	0.56	0.53
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 were calculated based on simple well-stirred tank model
< = less than

Table 6.2. XRF Analyzed Compositions for Glass Discharged from DM1200 (wt%) (Continued).

Test Segment		C			Statistics	
Glass Produced (kg)		5696.5	6217.0	6315.5	Average (>6000kg)	%Dev
-	Target	O12-G-25A	O12-G-36A	O12-G-37A		
Al_2O_3	5.29	5.71	5.65	5.78	5.71	8.01
As_2O_3	0.19	0.18	0.18	0.18	0.18	NC
B_2O_3*	9.39	9.55	9.51	9.51	9.51	NC
CaO	0.30	0.45	0.46	0.45	0.45	NC
CdO	<0.01	0.01	<0.01	<0.01	<0.01	NC
Cl	0.11	0.05	0.05	0.06	0.05	NC
Cr_2O_3	0.08	0.08	0.08	0.08	0.08	NC
Cs_2O	0.05	0.06	0.06	0.05	0.06	NC
CuO	0.04	0.05	0.05	0.05	0.05	NC
Fe_2O_3	12.58	11.66	11.85	11.44	11.65	-7.43
I	0.10	<0.01	<0.01	<0.01	<0.01	NC
K_2O	<0.01	0.11	0.10	0.11	0.11	NC
La_2O_3	0.24	0.26	0.27	0.26	0.27	NC
Li_2O*	3.01	3.02	3.02	3.02	3.02	NC
MgO	1.17	1.03	1.06	1.01	1.04	-11.43
MnO	4.00	3.58	3.69	3.57	3.63	-9.35
Na_2O	11.83	11.45	11.34	11.55	11.45	-3.24
Nd_2O_3	0.15	0.15	0.15	0.14	0.15	NC
NiO	0.17	0.16	0.16	0.15	0.16	NC
P_2O_5	0.09	0.10	0.10	0.10	0.10	NC
PbO	0.14	0.11	0.12	0.11	0.11	NC
Sb_2O_3	0.25	0.27	0.30	0.27	0.28	NC
SeO_2	0.37	0.06	0.07	0.07	0.07	NC
SiO_2	47.05	48.54	48.27	48.76	48.52	3.12
SO_3	<0.01	0.05	0.05	0.05	0.05	NC
SrO	0.92	0.76	0.79	0.75	0.77	-16.06
TiO_2	0.14	0.20	0.21	0.20	0.21	NC
ZnO	2.07	1.88	1.91	1.83	1.87	-9.52
ZrO_2	0.26	0.47	0.47	0.44	0.45	NC
Sum	100.00	100.00	100.00	100.00	100.00	NC

* Target values were calculated based on simple well-stirred tank model
NC – Not calculated
< = less than

Table 6.3. Drum Dimensions and Bulk Density for Glass Discharged from DM1200.

Glass Drum Information			Drum Dimension (inches)			Net Glass Volume in Drum (cm^3)	Calculated Density (g/cm^3)
Name	Date	Glass (kg)	Total Height	Inner Diameter	Depth to Glass		
N12-G-155A	01/30/03	508.5	33.25	22.50	2.75	198727.021	2.559
O12-G-36A	01/31/03	520.5	34.00	22.50	3.38	199541.476	2.608
O12-G-25A	01/31/03	518.0	34.00	22.50	3.50	198727.021	2.607
O12-G-37A	01/31/03	98.5	34.00	22.50	28.00	39093.840	2.520
Average (C-106/AY-102)							2.573
Average (AZ-101)*							2.578

* From reference [28]

Table 7.1. Summary of Method 29 Particulate Matter Results.

-	Outlet Location/Run	Total wt. gain (mg)	Meter Volume (dscf)	Concentration (mg/dscf)	Flow Rate (dscfm)	Emission Rate (mg/min)	Moisture (% vol.)	% Isokinetic
Total PM by Method 29 (Teflon Filter)	Melter R1 (S3)	1097	26.789	41.0	207.77	8510	23.83	100.5
	Melter R2 (S3)	642.4	25.573	25.1	203.48	5111	23.48	97.9
	Melter R3 (S3)	535.2	18.470	29.0	198.49	5752	23.58	101.2
	SBS-R1 (S5)	130.1	60.914	2.14	236.04	504	8.58	99.3
	SBS-R2 (S5)	228.7	71.085	3.22	238.31	767	7.77	101.2
	SBS-R3 (S5)	109.7	69.659	1.57	229.17	361	12.24	105.2
	WESP R2 (S7)	30.2	794.775	0.04	239.74	9.11	7.05	99.9

Note: Rx refers to off-gas sampling run number
Sx refers to sampling location, see Figure 1.3

Table 7.2. Results from Melter Emissions Sampling.

-		Average Feed Flux (mg/min)	Run 1 (mg/min)	Run 2 (mg/min)	Run 3 (mg/min)	Average (mg/min)	Percent of Feed	DF Across Melter
Particles	Total[$]	954700	8510	5111	5752	6458	0.67	148
	Al	22690	163.94	86.63	65.32	105.30	0.46	215.5
	As	1167	31.72	13.82	13.44	19.66	1.68	59.4
	B	23628	316.04	136.99	119.86	190.96	0.81	123.7
	Ca	1739	31.55	17.32	14.52	21.13	1.22	82.3
	Cl	892	272	202	NA	237	26.57	3.76
	Cr	444	6.76	4.28	4.68	5.24	1.18	84.7
	Cs	382	12.86	7.99	10.54	10.46	2.74	36.5
	Cu	259	2.06	1.07	0.71	1.28	0.49	202.3
	Fe	71322	768.61	393.29	353.48	505.13	0.71	141.2
	I	811	< 0.10	< 0.10	< 0.10	< 0.10	< 0.01	> 8110
	Li	11337	76.41	34.91	31.02	47.45	0.42	238.9
	Mg	5720	59.82	29.45	25.67	38.31	0.67	149.3
	Mn	25117	89.17	41.71	26.49	52.46	0.21	478.8
	Na	71165	737.47	384.50	372.57	498.18	0.70	142.8
	Ni	1083	9.82	5.33	3.86	6.34	0.59	170.9
	P	319	4.87	0.35	0.45	1.89	0.59	168.8
	Pb	1054	11.32	5.85	4.82	7.33	0.70	143.8
	Sb	1694	19.44	10.80	6.35	12.20	7.20	138.9
	Se	2135	952.07	876.09	1051.16	959.77	44.95	2.2
	Si	178291	718.73	420.54	304.82	481.36	0.27	370.4
	Sr	6308	64.66	29.94	26.11	40.24	0.64	156.8
	Ti	681	13.36	7.01	5.75	8.71	1.28	78.2
	Zn	13484	178.68	71.85	66.02	105.52	0.78	127.8
	Zr	1561	10.18	4.37	2.95	5.83	0.37	267.6
Gas	B	23628	203.58	168.53	178.11	183.41	0.78	128.8
	Cl	892	98.72	202.87	287.48	196.36	22.01	4.5
	I	811	692.58	656.02	720.10	689.57	85.03	1.2
	Se	2135	32.60	62.71	53.94	49.75	2.33	42.9

NA – Not available
[$] - From gravimetric analysis of filters and rinse dry downs
< = less than
> = greater than
Calculated values in this table should be considered to have a maximum of three significant figures accuracy.

Table 7.3. Results from SBS Emissions Sampling.

-		Average Melter Outlet Flux (mg/min)	Run 1 (mg/min)	Run 2 (mg/min)	Run 3 (mg/min)	Average (mg/min)	Percent of Melter Emissions	DF Across SBS
Particles	Total[$]	6458	504	767	361	544	8.42	11.9
	Al	105.30	0.16	0.40	0.50	0.35	0.34	298
	As	19.66	< 0.10	2.84	2.73	< 1.89	< 9.61	> 10.4
	B	190.96	0.39	1.03	1.13	0.85	0.45	224.7
	Ca	21.13	0.16	0.57	0.70	0.48	2.26	44.3
	Cl	237	NA	NA	NA	NA	NA	NA
	Cr	5.24	< 0.10	0.96	0.85	< 0.63	< 12.15	> 8.2
	Cs	10.46	2.11	2.49	2.05	2.22	21.19	4.7
	Cu	1.28	< 0.10	< 0.10	< 0.10	< 0.10	< 7.81	> 12.8
	Fe	505.13	0.58	0.65	0.96	0.73	0.14	692
	I	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	NC	NC
	Li	47.45	0.19	2.43	2.06	1.56	3.29	30.4
	Mg	38.31	< 0.10	< 0.10	0.11	< 0.10	< 0.26	> 383.1
	Mn	52.46	0.59	< 0.10	< 0.10	< 0.26	< 0.50	> 199.2
	Na	498.18	4.46	40.78	37.23	27.49	5.52	18.1
	Ni	6.34	< 0.10	< 0.10	< 0.10	< 0.10	< 1.58	> 63.4
	P	1.89	0.75	< 0.10	< 0.10	< 0.32	< 16.75	> 6.0
	Pb	7.33	< 0.10	0.60	0.49	< 0.40	< 5.41	> 18.5
	Sb	12.20	0.41	0.39	0.30	0.37	3.03	33
	Se	959.77	15.06	194.68	122.43	110.72	11.54	8.7
	Si	481.36	0.51	0.89	0.72	0.71	0.15	681.2
	Sr	40.24	< 0.10	< 0.10	< 0.10	< 0.10	< 0.25	> 402.4
	Ti	8.71	< 0.10	< 0.10	< 0.10	< 0.10	< 1.15	> 87.1
	Zn	105.52	0.34	0.95	1.25	0.85	0.80	124.6
	Zr	5.83	< 0.10	< 0.10	< 0.10	< 0.10	< 1.72	> 58.3
Gas	B	183.41	6.46	6.90	5.91	6.42	3.50	28.6
	Cl	196.36	13.96	20.17	12.90	15.68	7.98	12.5
	I	689.57	630.44	707.64	574.96	637.68	92.48	1.1
	Se	49.75	60.27	82.27	42.05	61.53	123.7	0.8

NC – Not calculated
NA – Not available
[$] - From gravimetric analysis of filters and rinse dry downs
< = less than
> = greater than
Calculated values in this table should be considered to have a maximum of three significant figures accuracy.

Table 7.4. Results from WESP Emissions Sampling.

-		Average Feed Flux (mg/min)	Average SBS Outlet Flux (mg/min)	Run 1 (mg/min)	DF Across WESP	Cumulative DF Across Melter, SBS, WESP
Particles	Total[$]	954700	544	9.11	59.7	104797
	Al	22690	0.35	< 0.10	> 3.5	> 226900
	As	1167	2.79	< 0.10	> 27.9	> 11670
	B	23628	0.85	< 0.10	> 8.5	> 236300
	Ca	1739	0.48	< 0.10	> 4.8	> 17390
	Cl	892	NA	NA	NA	NA
	Cr	444	0.91	< 0.10	> 9.1	> 4440
	Cs	382	2.22	< 0.10	> 22.2	> 3820
	Cu	259	< 7.81	< 0.10	NC	> 2590
	Fe	71322	0.73	< 0.10	> 7.3	> 713200
	I	811	NA	NA	NA	NA
	Li	11337	1.56	< 0.10	> 15.6	> 113400
	Mg	5720	0.11	< 0.10	> 1.1	> 57200
	Mn	25117	0.59	< 0.10	> 5.9	> 251170
	Na	71165	27.49	1.20	22.9	59304
	Ni	1083	< 0.10	< 0.10	NC	> 10830
	P	319	0.75	< 0.10	> 7.5	> 3190
	Pb	1054	0.55	< 0.10	> 5.5	> 10540
	Sb	1694	0.37	< 0.10	> 3.7	> 16940
	Se	2135	110.72	4.45	24.9	480
	Si	178291	0.71	< 0.10	> 7.1	> 1783000
	Sr	6308	< 0.10	< 0.10	NC	> 63080
	Ti	681	< 0.10	< 0.10	NC	> 6810
	Zn	13484	0.85	< 0.10	> 8.5	> 134800
	Zr	1561	< 0.10	< 0.10	NC	> 15610
Gas	B	23628	6.42	0.51	12.6	46330
	Cl	892	15.68	1.78	8.8	501
	I	811	637.68	588.95	1.1	1.4
	Se	2135	61.53	3.35	18.4	637

NC – Not calculated
NA – Not available
[$] - From gravimetric analysis of filters and rinse dry downs
< = less than
> = greater than
Calculated values in this table should be considered to have a maximum of three significant figures accuracy.

Table 7.5. Melter Emissions Particle Size Distribution Results.

-	Cutpoint (μm)	Net Weight (mg)	Concentration (mg/dscf)	Mass Fraction
Sample 1	> 12.9	42.28	23.62	62.0
	12.9-9.77	7.62	4.26	11.2
	9.77-3.78	6.29	3.51	9.2
	3.78-1.90	3.50	1.96	5.1
	1.90-1.09	2.09	1.17	3.1
	1.09-0.62	1.17	0.65	1.7
	0.62-0.37	2.62	1.46	3.8
	< 0.37	2.61	1.46	3.8
Sample 2	> 13.0	21.7	15.94	56.5
	13.0-9.84	3.08	2.26	8.0
	9.84-3.80	2.99	2.19	7.8
	3.80-1.91	1.87	1.37	4.9
	1.91-1.10	1.31	0.96	3.4
	1.10-0.62	2.10	1.54	5.5
	0.62-0.37	2.80	2.05	7.3
	< 0.37	2.58	1.89	6.7
Sample 3	> 12.6	20.2	13.9	57.6
	12.6-9.53	3.04	2.09	8.7
	9.53-3.68	2.76	1.90	7.9
	3.68-1.85	1.88	1.30	5.4
	1.85-1.07	1.02	0.70	2.9
	1.07-0.60	1.16	0.80	3.3
	0.60-0.36	2.39	1.65	6.8
	< 0.36	2.59	1.78	7.4

< = less than
> = greater than

Table 7.6. Average Concentrations [ppmv] of Selected Species in Off-Gas Measured by FTIR Spectroscopy.

Port	Melter Outlet (sampling port: S3)			SBS Outlet (sampling port: S5)			WESP Outlet (sampling port: S7)			TCO Outlet (sampling port: S9)		
Test Segment	A	B	C	A	B	C	A	B	C	A	B	C
N_2O	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
NO	29	33	59	23	40	76	23	33	64	4.5	< 1.0	< 1.0
NO_2	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	3.6	< 1.0	< 1.0
NH_3	2.6	2.8	9.0	< 1.0	< 1.0	7.0	2.0	1.1	7.7	3.4	2.8	< 1.0
H_2O [%]	9.2	12	21	6.6	8.0	7.1	6.6	7.0	7.0	3.6	3.0	1.2
CO_2	3800	4500	7400	2900	4700	7900	3100	4200	7000	1800	2000	1200
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	4.0	< 1.0	5.8	2.8	< 1.0	1.5	2.9	< 1.0	2.1	< 1.0	< 1.0	< 1.0
CO	< 1.0	1.4	2.8	< 1.0	1.1	3.7	< 1.0	< 1.0	3.1	< 1.0	< 1.0	< 1.0
HCl	< 1.0	< 1.0	5.2	< 1.0	< 1.0	4.4	< 1.0	< 1.0	3.0	< 1.0	< 1.0	< 1.0
HF	2.4	2.8	8.1	2.1	2.2	5.6	1.9	1.8	7.4	1.2	< 1.0	1.1
H_2 *	-	-	-	-	-	-	< 5.0	16	31	-	-	-

* Measured by gas chromatography
< = less than

Table 7.7. Iodine Mass Balance Summary.

Location:	Product Glass	Melter Emissions	SBS Blow-Down Solutions	SBS Emissions	WESP Blow-Down Solutions	WESP Emissions	TCO/SCR* Emissions	PBS Blow-Down Solutions
% Feed Iodine	< 1%	85%	15%	77%	< 1%	73%	60%	18%

* - Extrapolated from slip stream entering silver mordenite system.
< = less than

Table 7.8. Iodine Removal from Off-Gas Slipstream by Silver Mordenite Column.

Sampling Point	01/27/03 16:03 – 00:06		01/28/03 11:30 – 19:30		01/29/03 08:00 – 16:00	
	Conc. (µg/dscf)	DF	Conc. (µg/dscf)	DF	Conc. (µg/dscf)	DF
Inlet	1160	1	1700	1	2040	1
1/3 into column	453	2.6	700	2.4	1260	1.6
2/3 into column	2.16	537	< 1*	> 1700	< 1*	> 2040
Outlet	NS	NS	< 1*	> 1700	< 1*	> 2040

NS – No sample due to failed leak check.
* - No iodine was detected. Value provided is an estimate based on current analytical detection limit.
< = less than
> = greater than

Table 8.1. Completion of Test Objectives.

Test Objective	Objective Met?	Discussion Section
Perform analyses and laboratory testing, as required, to assess and specify "working glass" compositions, glass forming chemicals, and additives utilizing the estimated C-104/AY-101 feed composition in this specification.	Yes	Section 2.0 provides "working glass" compositions and feed formulations. Section 3.0 describes DM100 support testing.
Utilizing the DM1200 melter and associated feed handling and off-gas treatment equipment, design and conduct testing in which representative C-106/AY-102 simulant is processed. The duration of tests shall be sufficient to achieve at least four melter glass inventory turnovers (8 MT) for each composition.	Yes/ No	Table 4.1 provides glass production rate data and summary data for melter testing. The production rates attained were sufficient to produce only 6.3 MT as opposed to 8 MT of glass in the designated testing interval.
Determine the effect of bubbling rate on melter production rate and operating stability for C-104/AY-101 melter feed.	Yes	Data provided in Table 4.1 and Figure 4.1.
Fabricate, install and evaluate the performance of the HLW bubbler design and placement recommended by the Duratek design staff.	Yes	The recommended bubbler design and placement was employed for these tests.
Characterize the melter emissions (particulate, aerosol, and gaseous) under nominal steady-state operating conditions for inorganic and organic compounds including the effect of air displacement slurry (ADS) pump operation on feed entrainment. Measurement of organic compounds will be satisfied through the use of Fourier Transform Infrared (FTIR) spectrometry and gas chromatography (including H_2).	Yes	Section 7.0 provides data and detailed description of melter emissions.
Quantify and document the occurrence and associated operating conditions of any melter off-gas volume surging events.	Yes	Section 5.0 provides melter pressure data and control air flow rates during testing.
Characterize the performance of the primary off-gas treatment equipment (submerged bed scrubber (SBS), wet electrostatic precipitator (WESP) and high-efficiency mist eliminator (HEME)) to remove particulate, aerosol and gas phase emissions under steady-state melter conditions.	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.
Characterize the chemical and physical characteristics of the aqueous streams (feed, SBS, WESP, and caustic scrubber).	Yes	Section 2.3 provides detailed feed analysis. Section 5.2 provides detailed off-gas solution analysis.
Characterize the performance of the secondary off-gas treatment equipment (selective catalytic reduction (SCR), thermal catalytic oxidizer (TCO), and small-scale silver mordenite column) to treat NOx, organics, and iodine under steady-state melter conditions.	Yes	Section 5.0 provides operational details of off-gas system components. Table 7.6 and Figures 7.5-7.8 provide SCR/TCO inlet (WESP outlet) and outlet emission data. Silver mordenite column performance is provided in Section 7.5 and Table 7.8.

Table 8.1. Completion of Test Objectives (continued).

Test Objective	Objective Met?	Discussion Section
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.	Yes	Data for measured melter parameters is provided in Section 4.0 and data for measured off-gas parameters is in Section 5.0.
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, 4.0, and 5.0.
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.	Yes	Off-gas system inspection information is provided in Section 5.0. Inspection downstream of the SCR was covered in a previous report [27].
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.	Yes	Sections 3.0, 4.0, and 5.0 discuss melter pressure data and control air flow rates during testing.
Operate and evaluate the performance of the air-displacement slurry (ADS) pump under operating conditions that are applicable to expected WTP plant operations.	Yes/No	The ADS pump was employed for about 75% of the testing time. A manufacturing defect on an actuator valve caused failure and the backup AOD pump was used during the run times of 93-217 hr while the ADS pump was repaired.

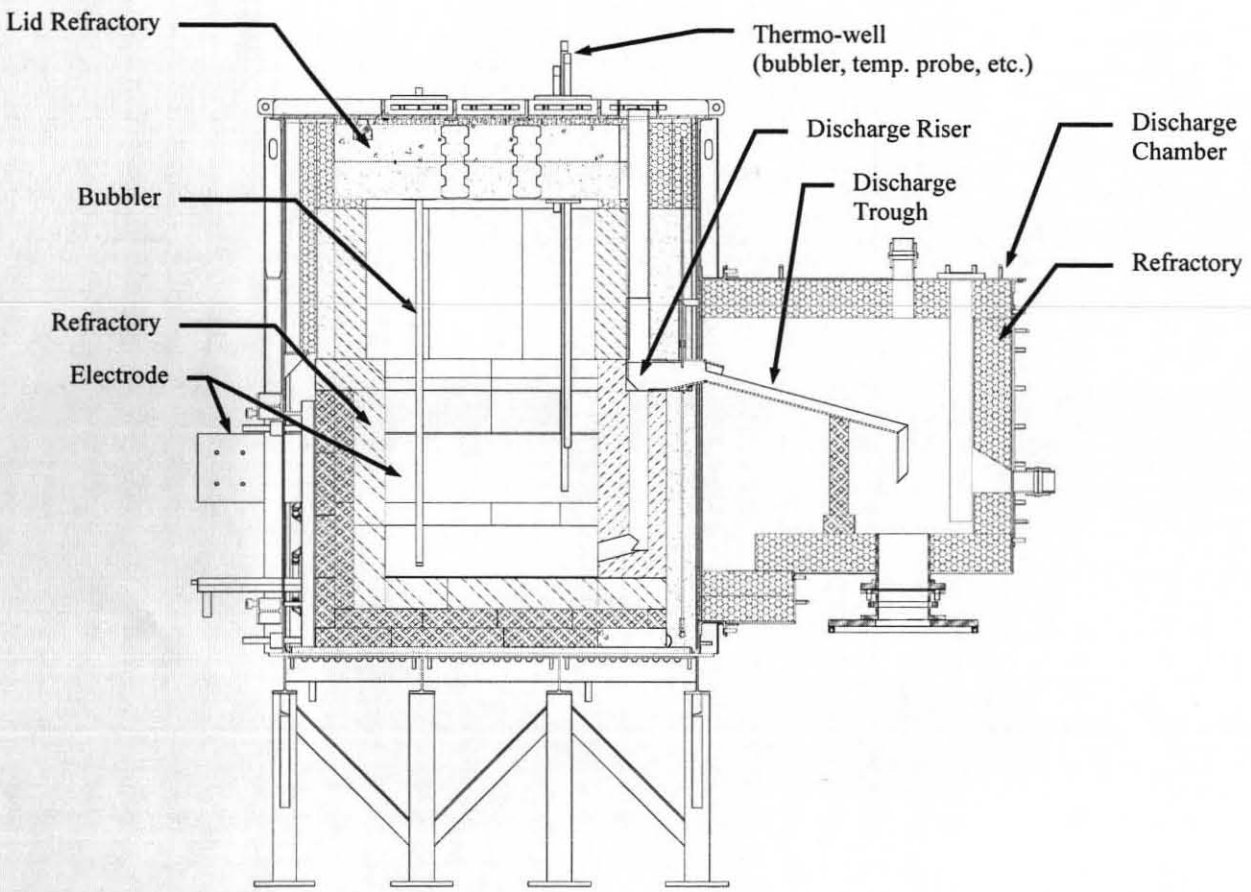

Figure 1.1. Cross-section of the DM1200 melter through the discharge chamber.

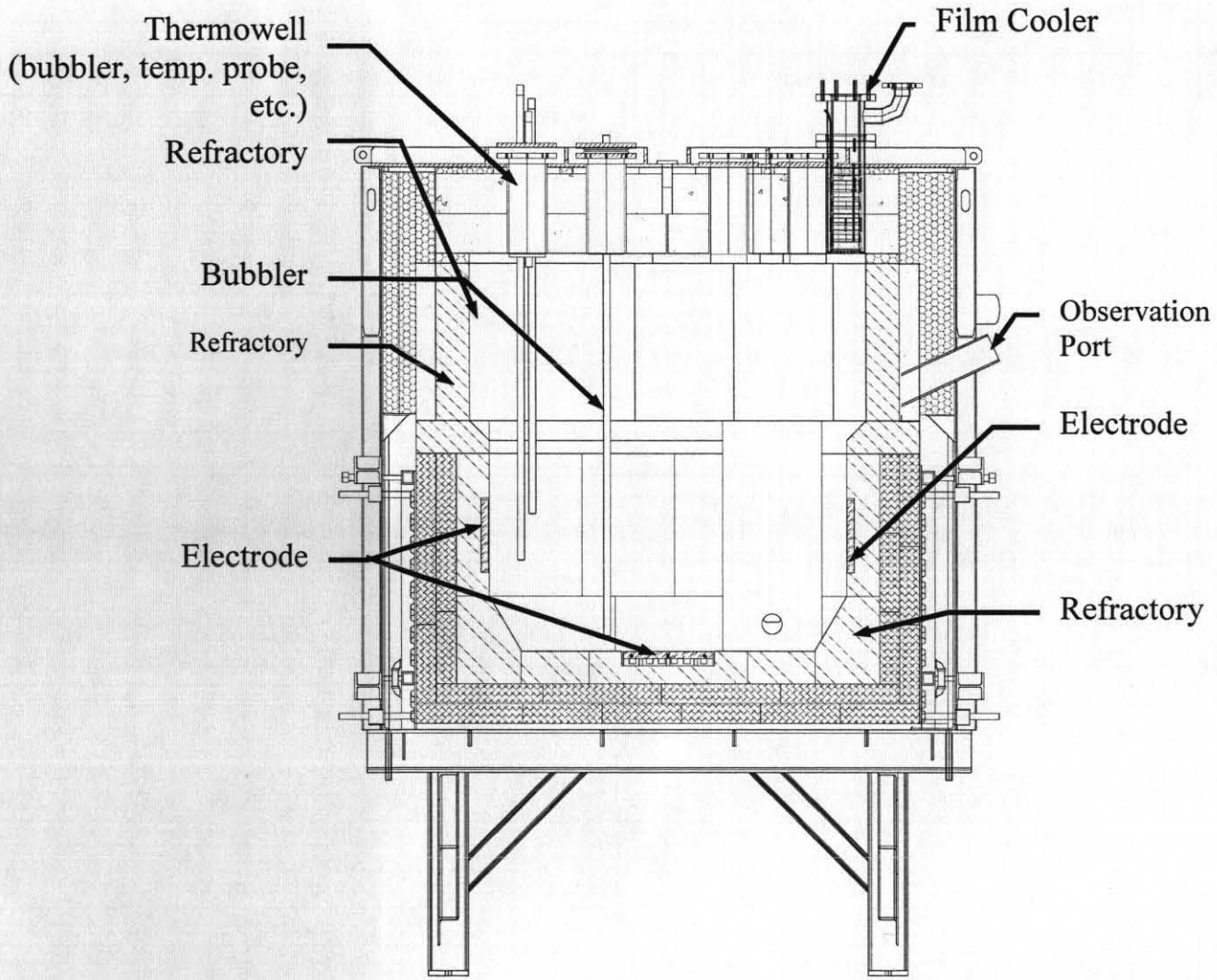

Figure 1.2. Cross-section through the DM1200 melter showing electrodes.

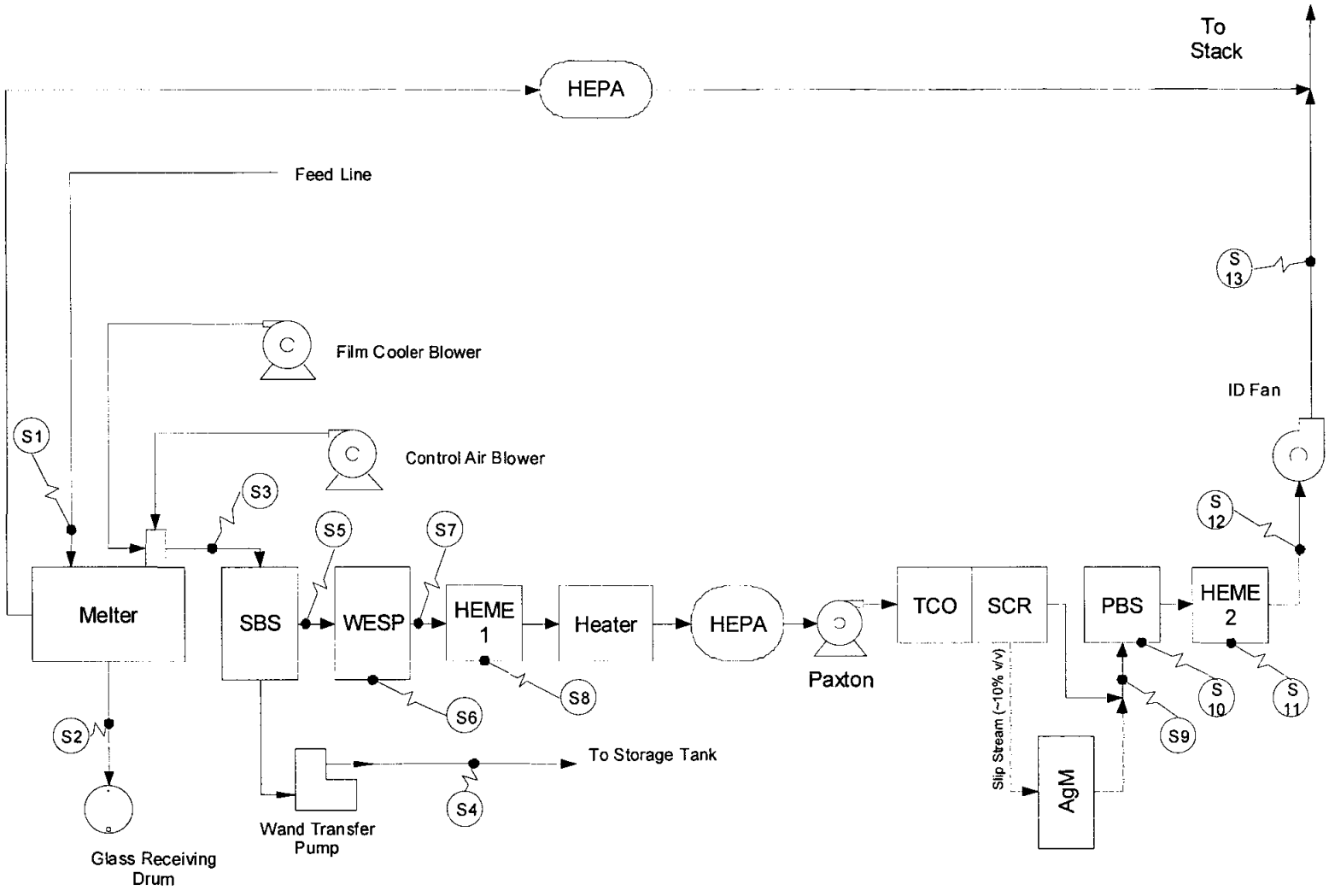

Figure 1.3. Schematic diagram of DM1200 off-gas system. "Sx" indicates sampling point.

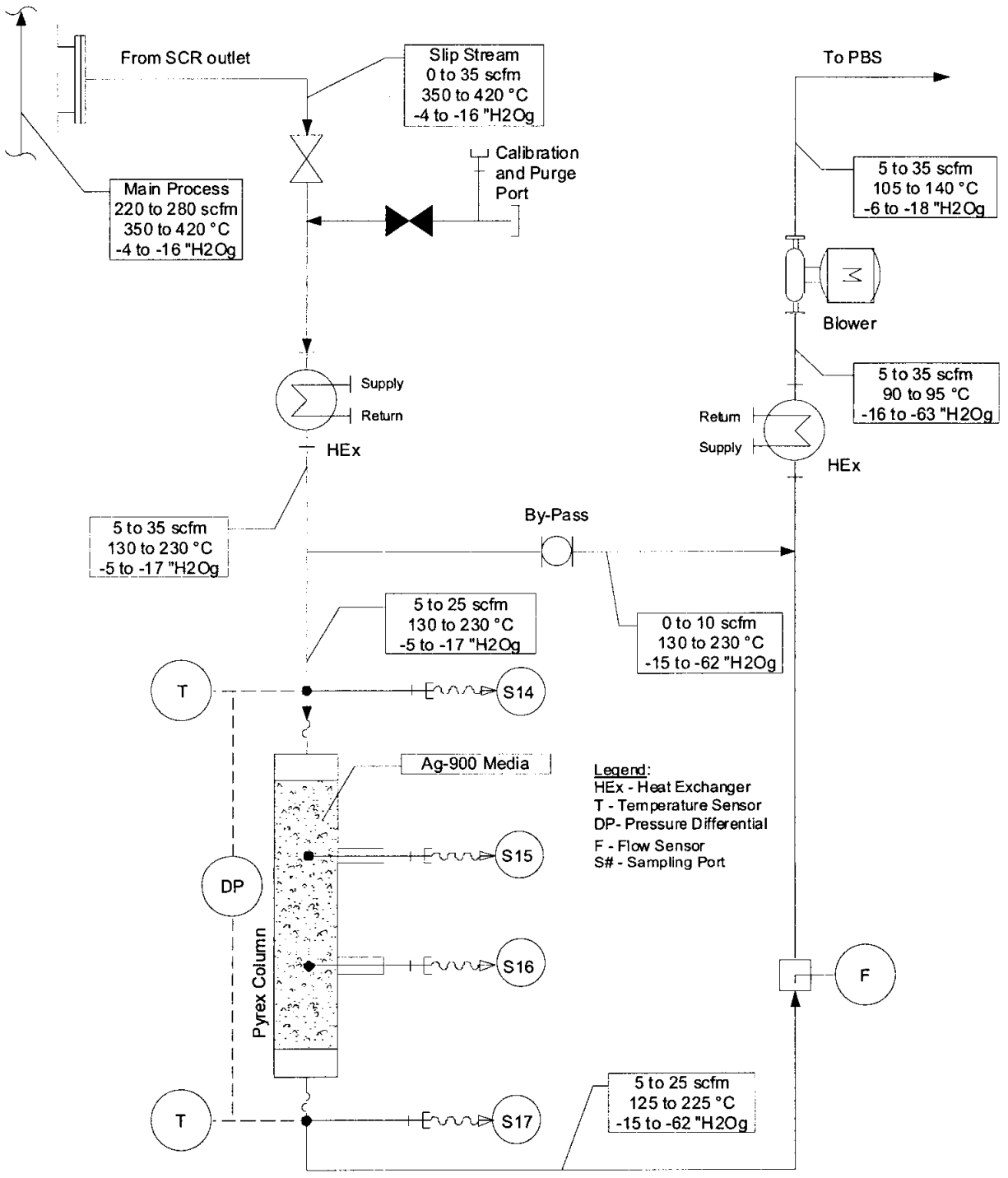

Figure 1.4. Schematic diagram of silver mordenite system. "Sx" indicates sampling point.

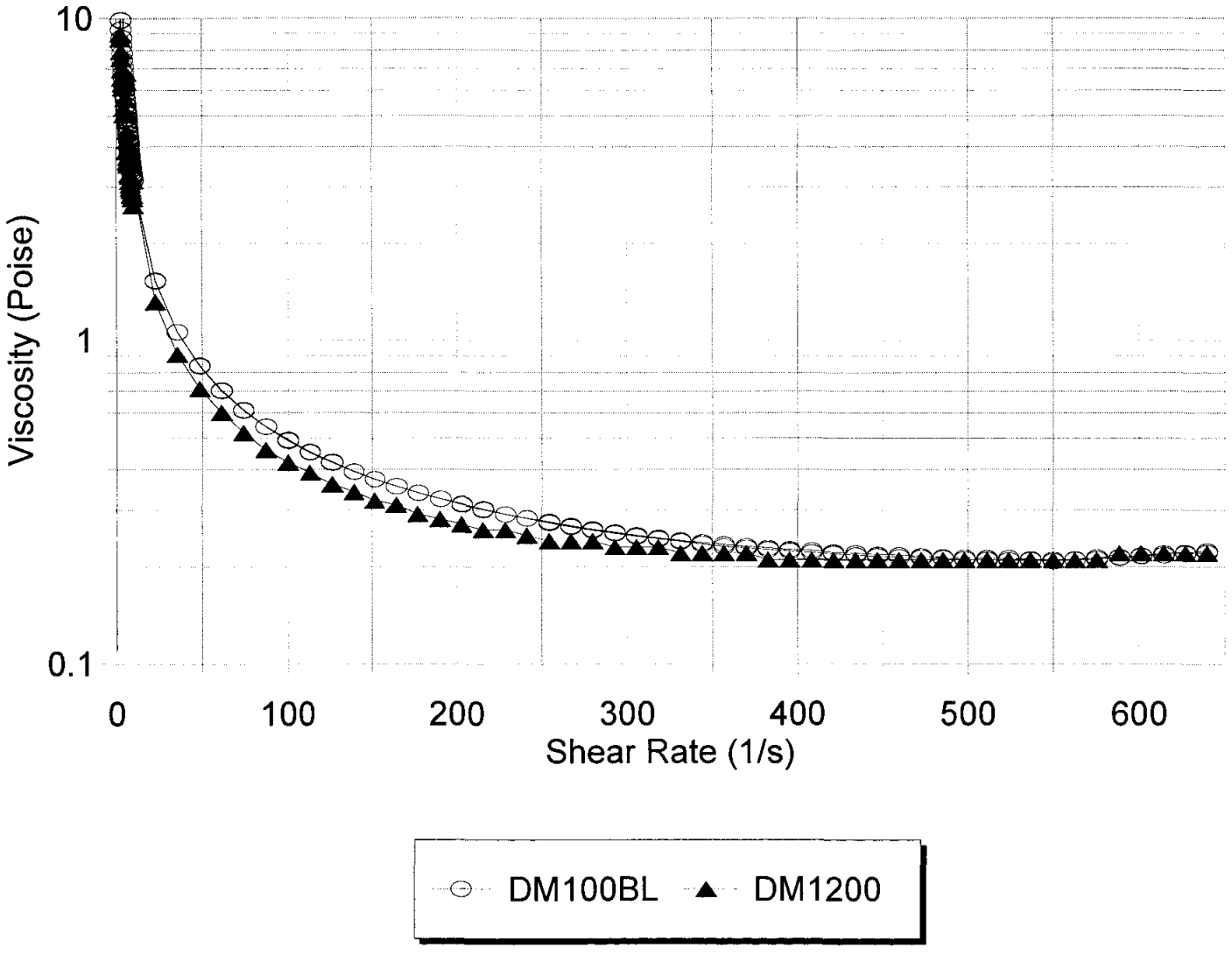

Figure 2.1. Viscosity vs. shear rate for melter feed samples.

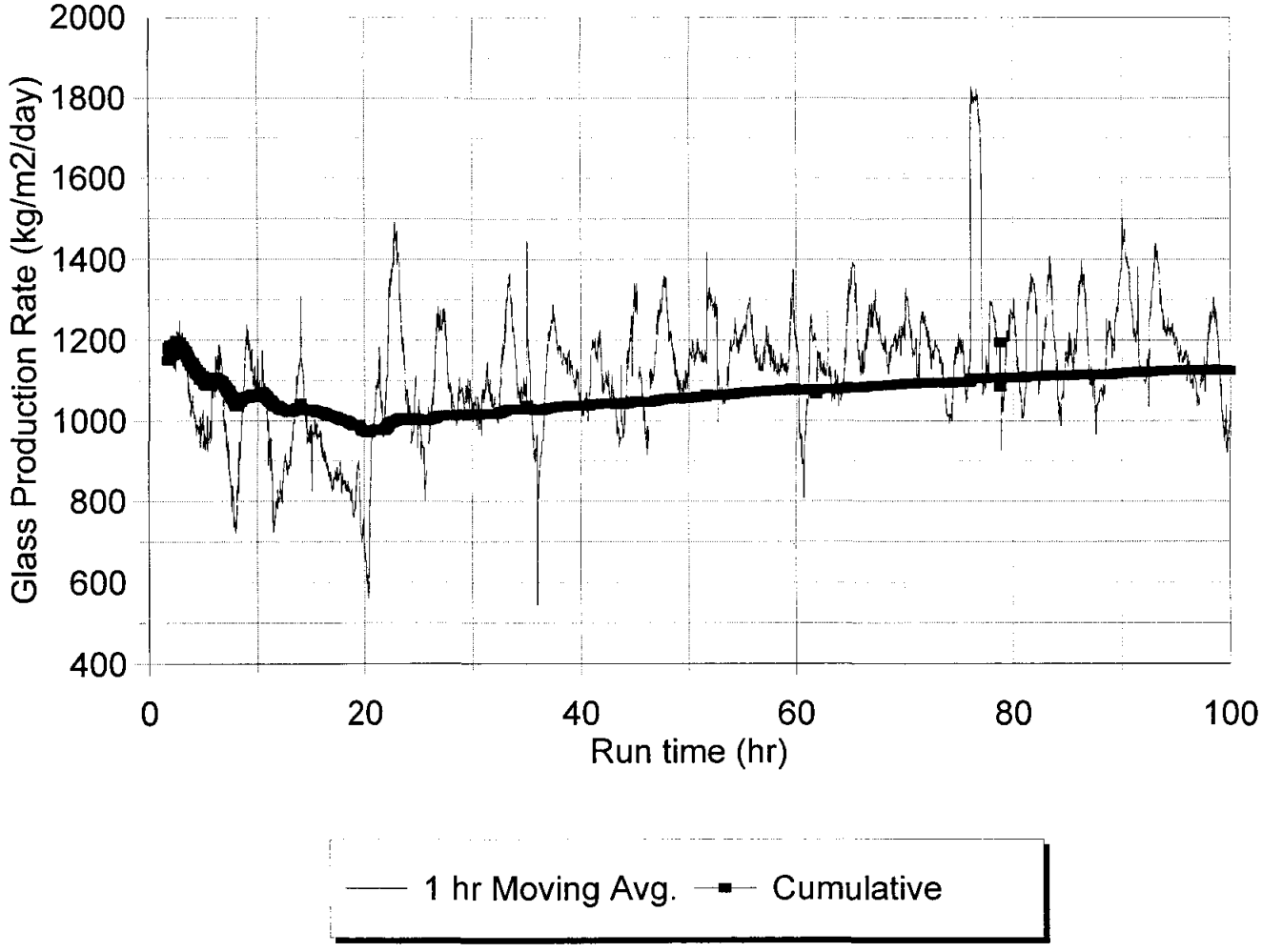

Figure 3.1. Production rates for DM100 test.

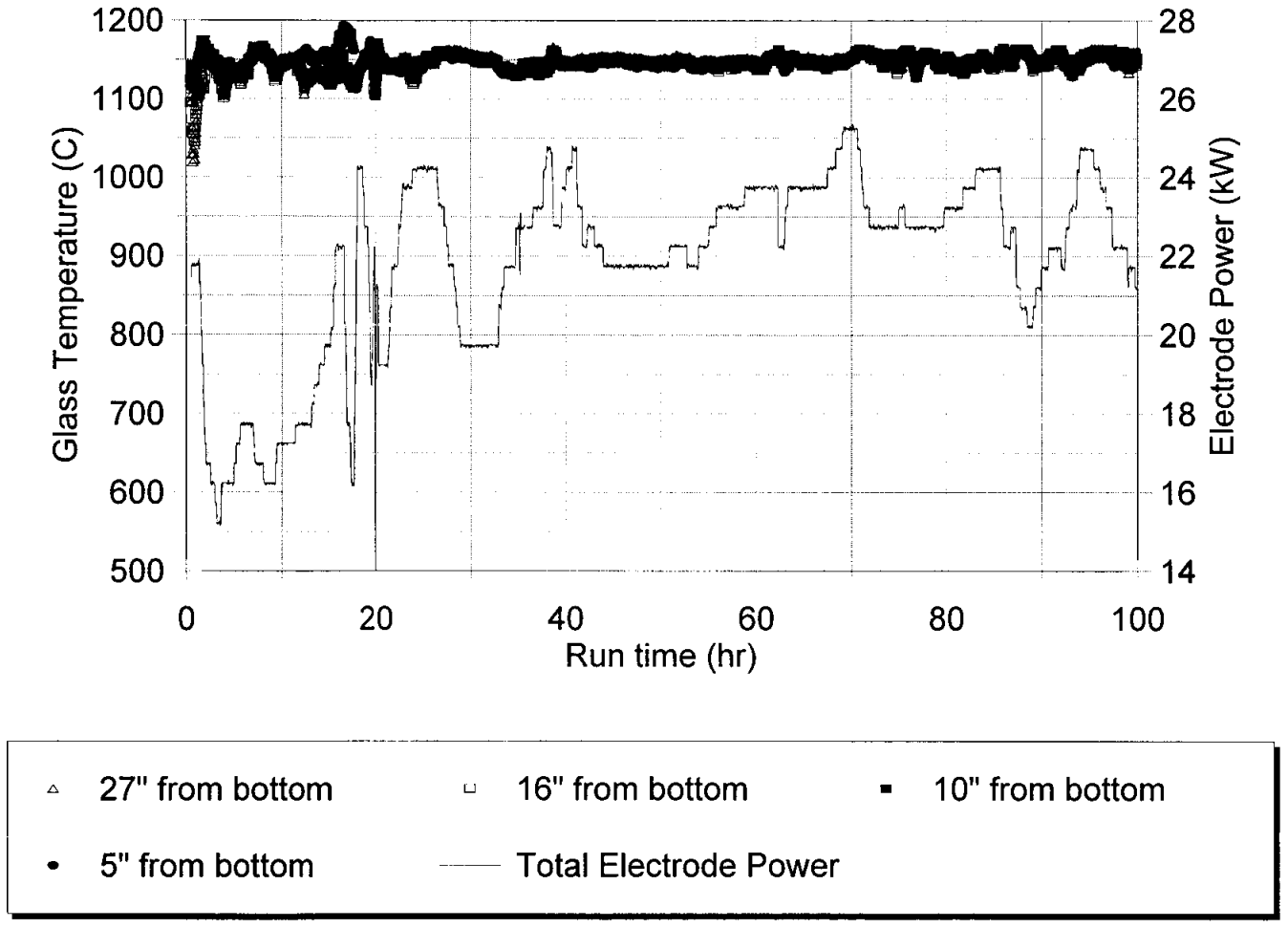

Figure 3.2. Glass temperatures and electrode power for DM100 test.

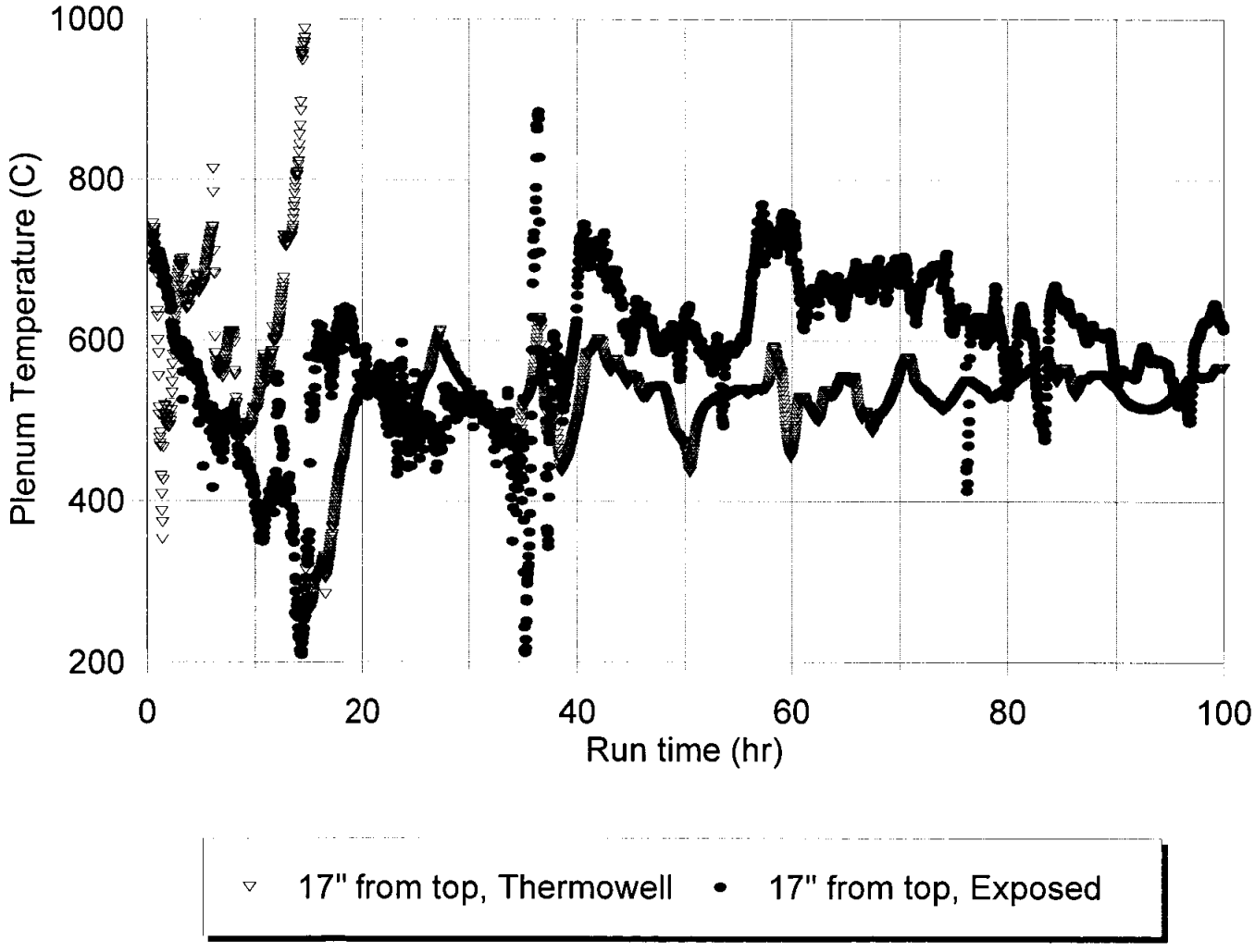

Figure 3.3. Plenum temperatures for DM100 test.

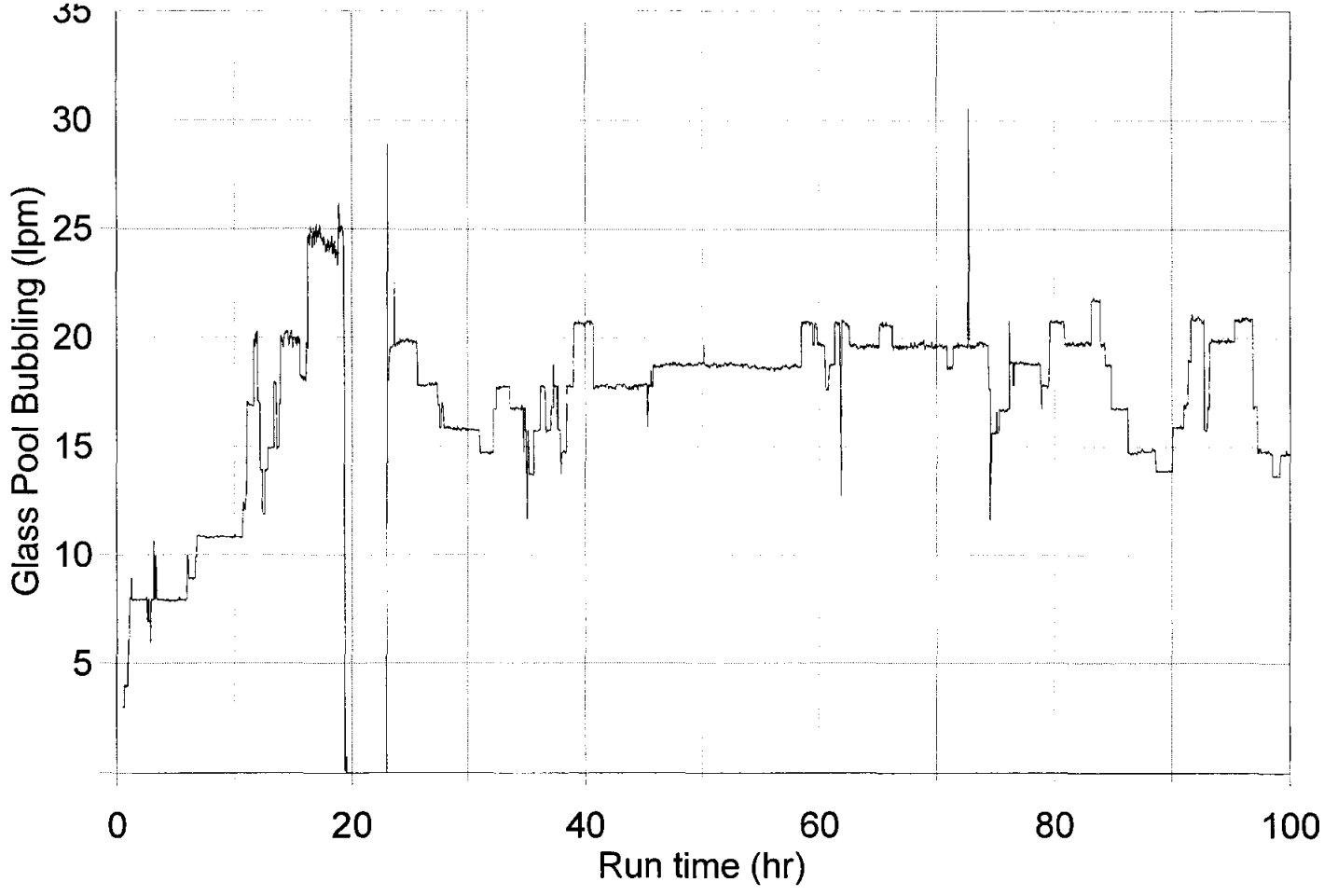

Figure 3.4. Glass pool bubbling for DM100 test.

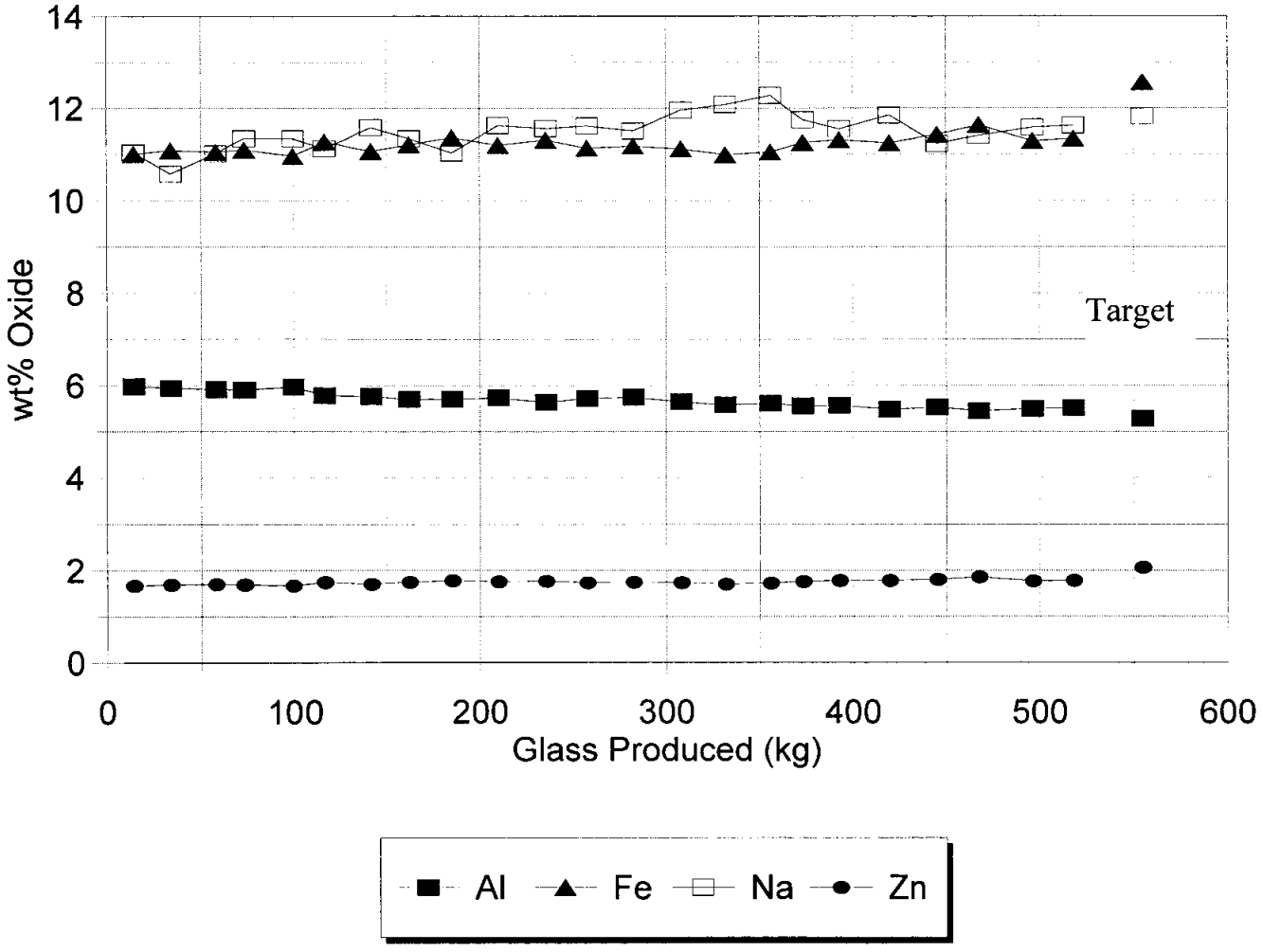

Figure 3.5. XRF analysis of selected oxides in DM100 glasses.

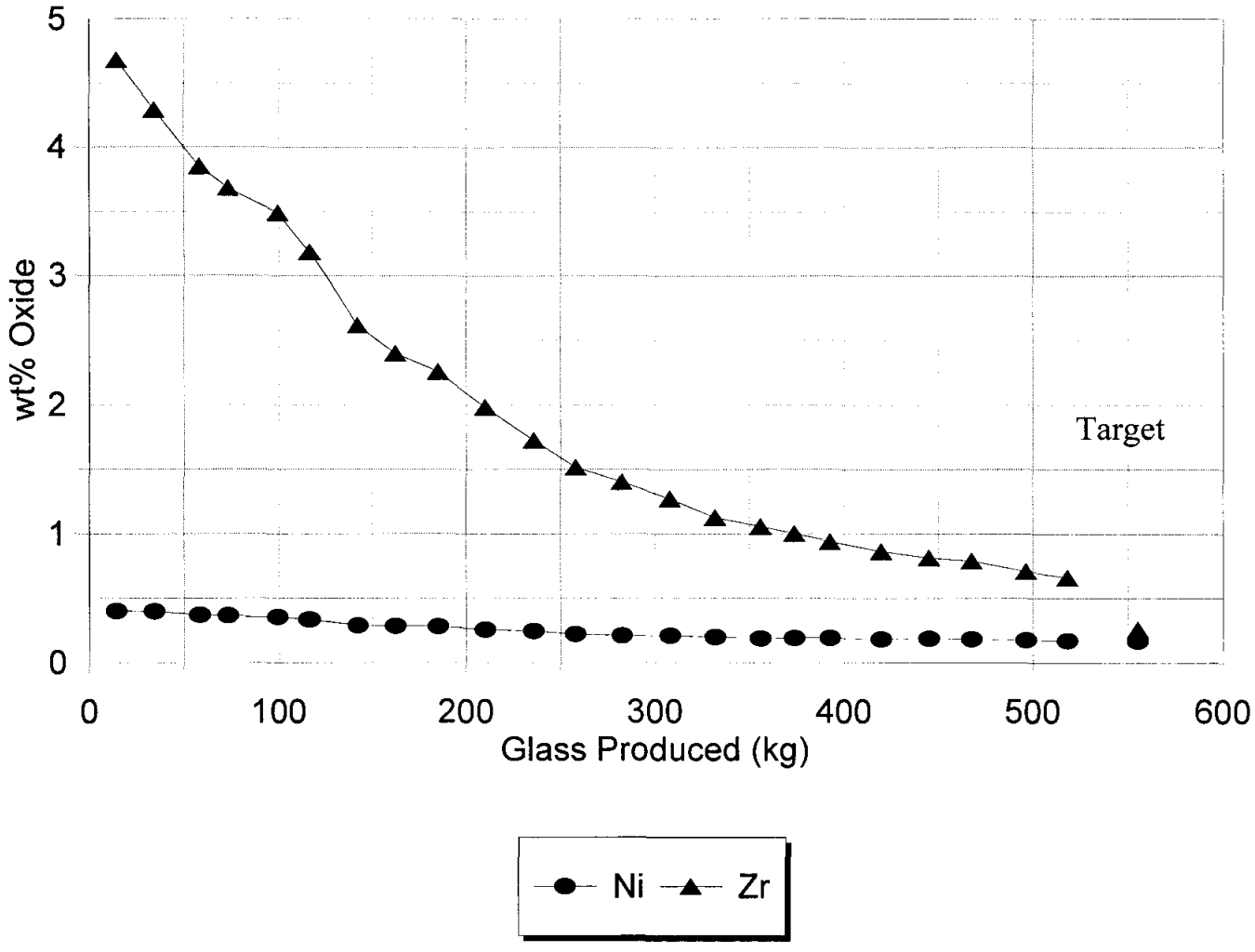

Figure 3.6. XRF analysis of oxides decreasing in concentration during DM100 test.

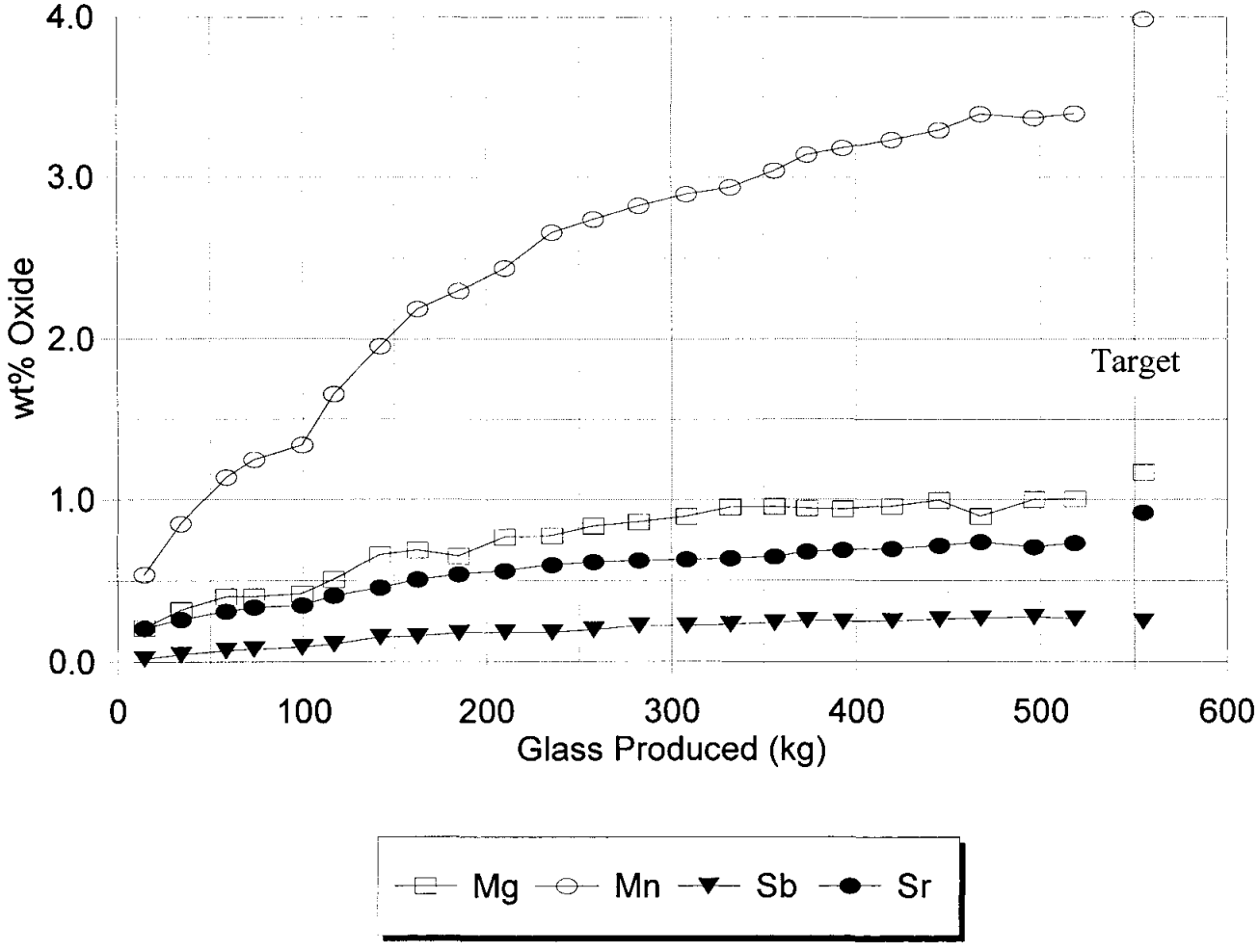

Figure 3.7. XRF analysis of oxides increasing in concentration during DM100 test.

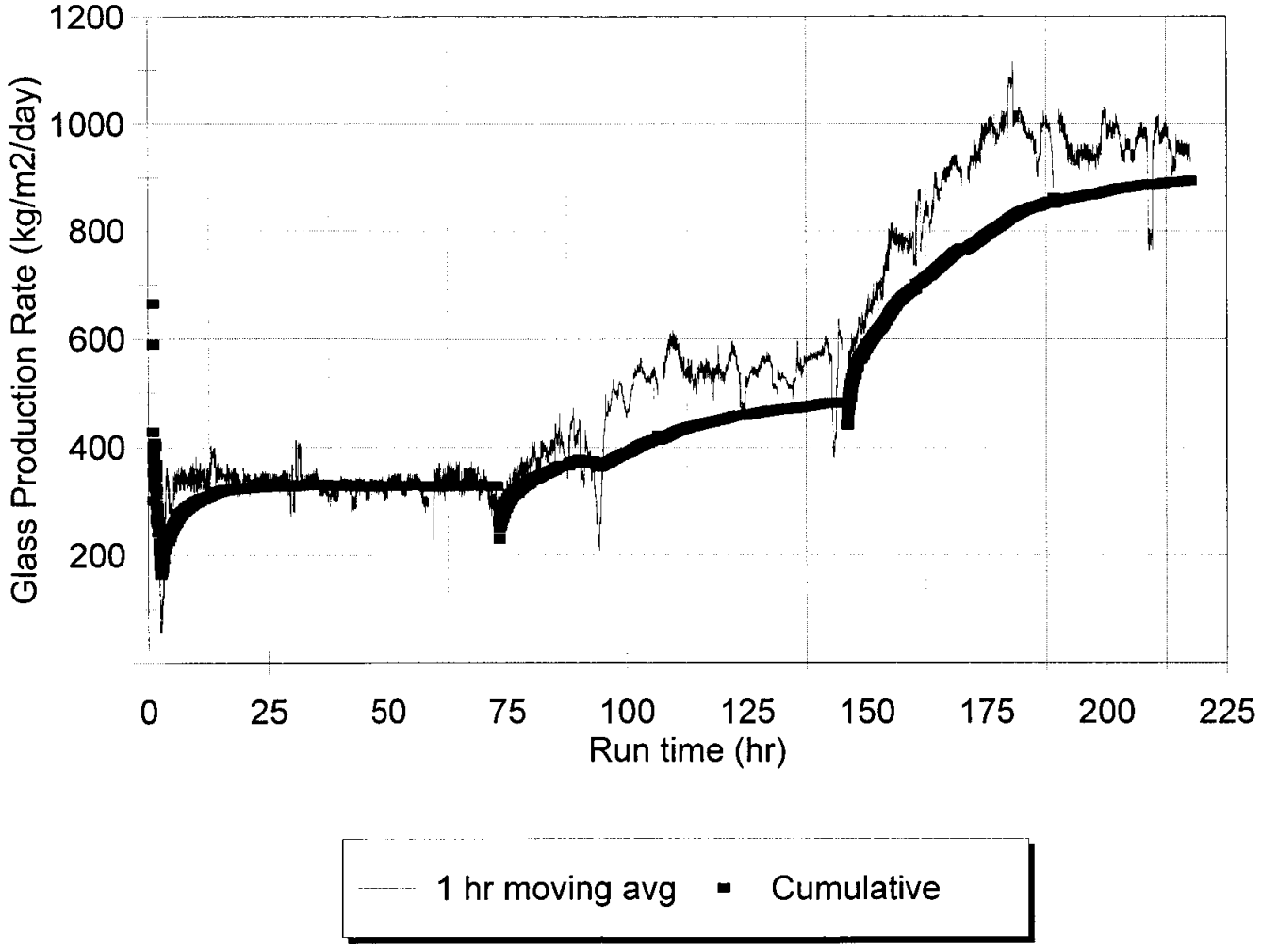

Figure 4.1. Glass production rates for DM1200 tests.

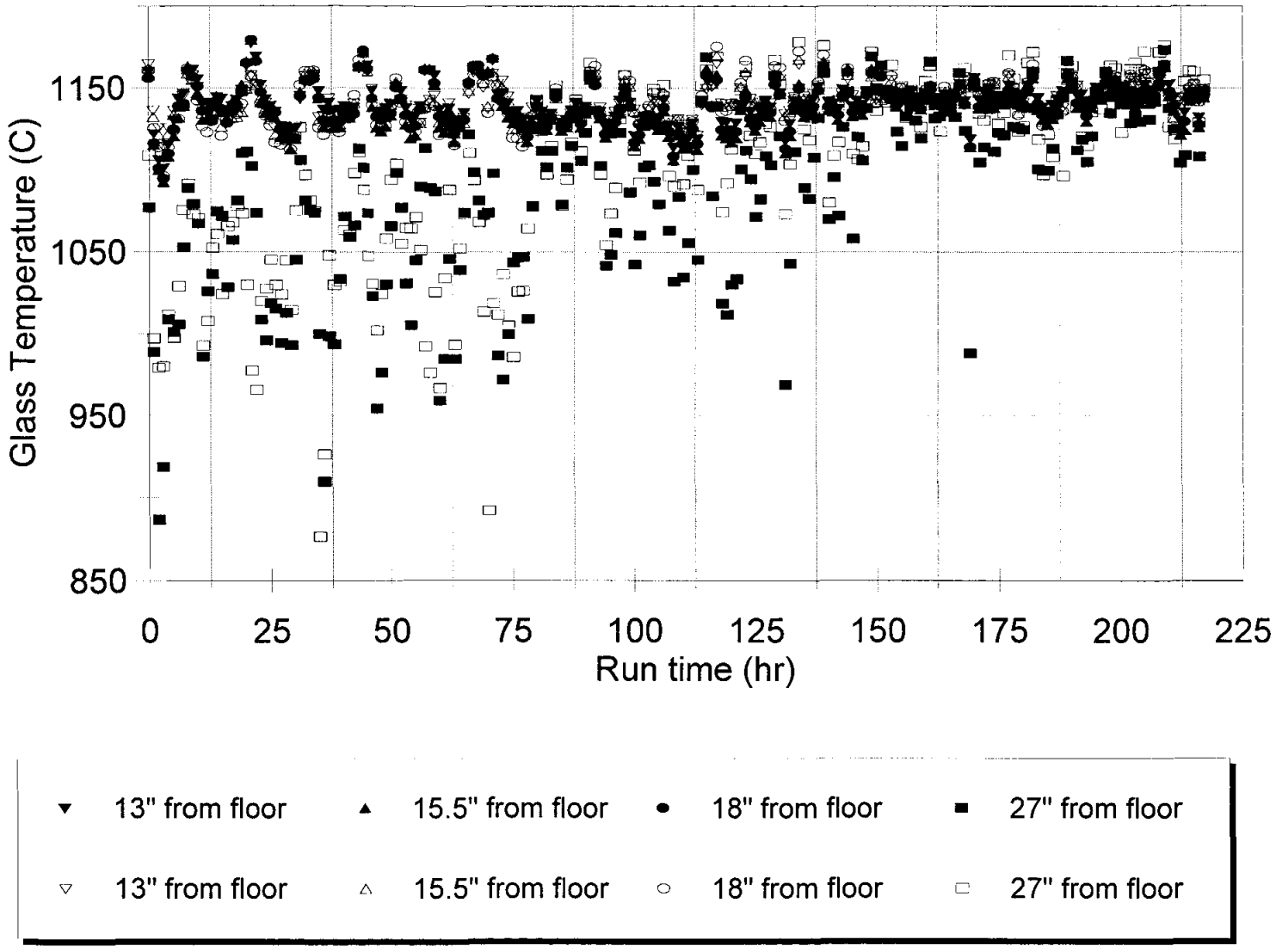

Figure 4.2. Glass temperatures for DM1200 tests (hourly averaged).

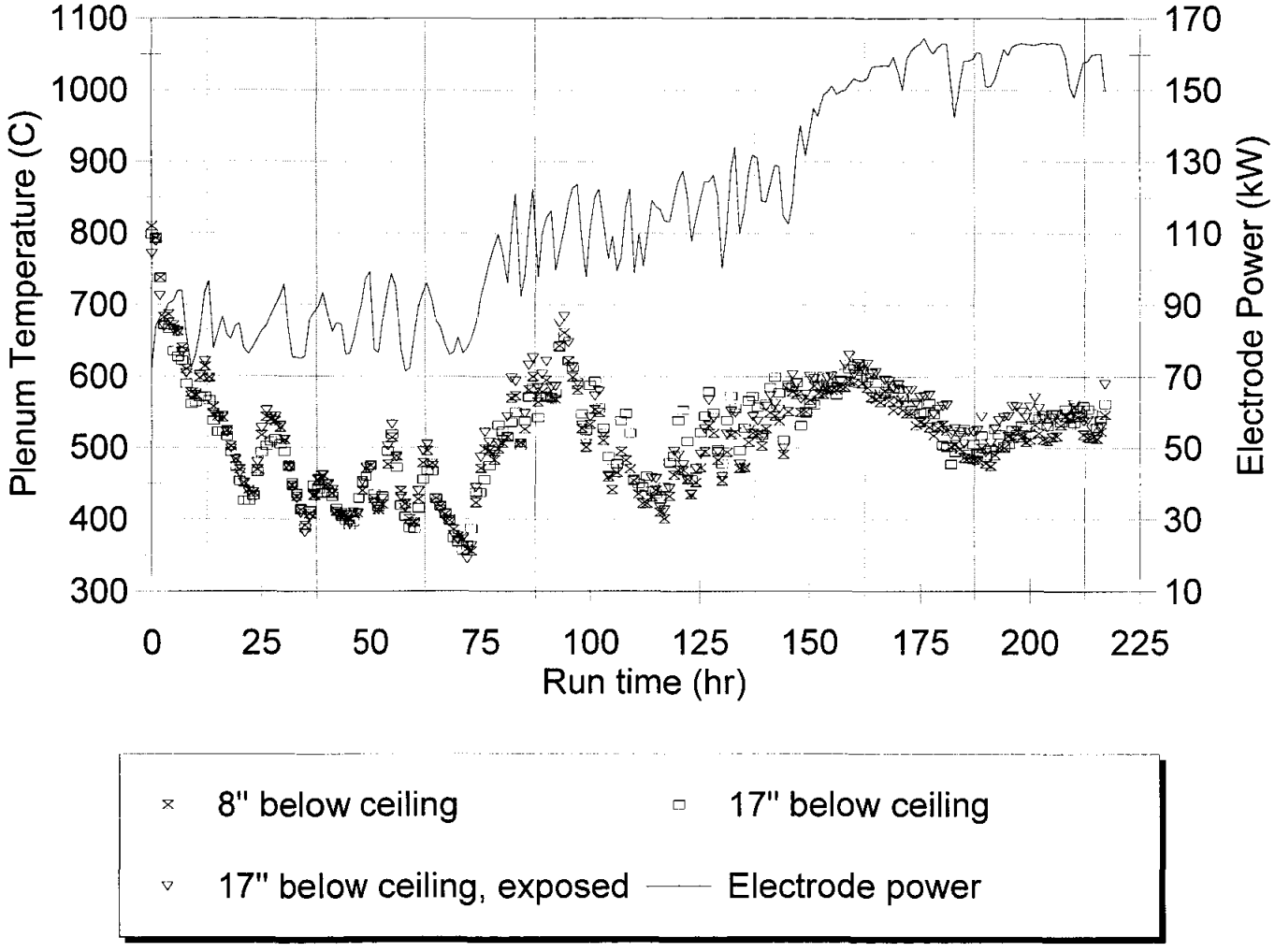

Figure 4.3. Plenum temperatures and electrode power for DM1200 tests (hourly averaged).

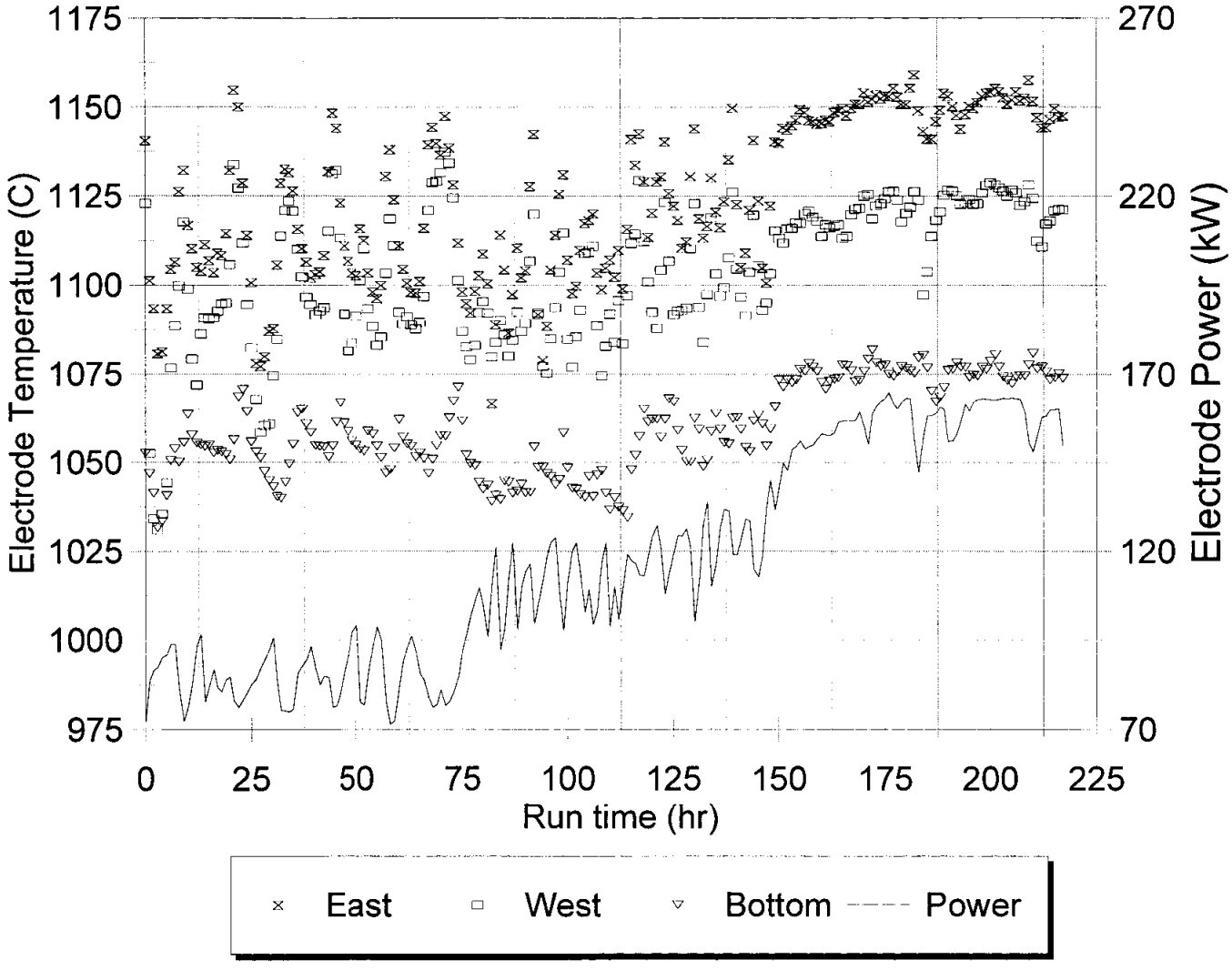

Figure 4.4. Electrode temperatures and power for DM1200 tests (hourly averaged).

Figure 4.5. Electrode power and glass resistance for DM1200 tests.

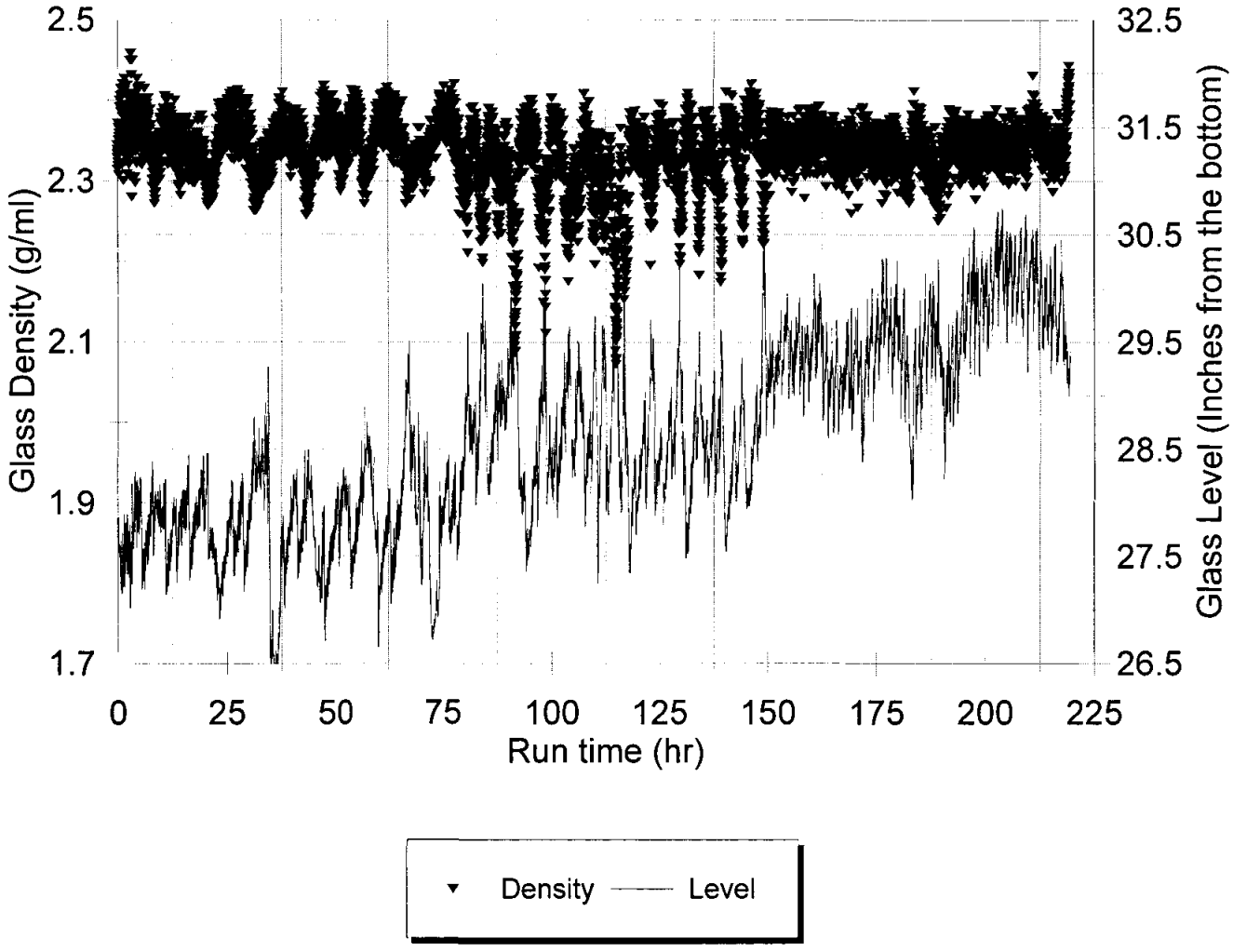

Figure 4.6. Glass density and level for DM1200 tests.

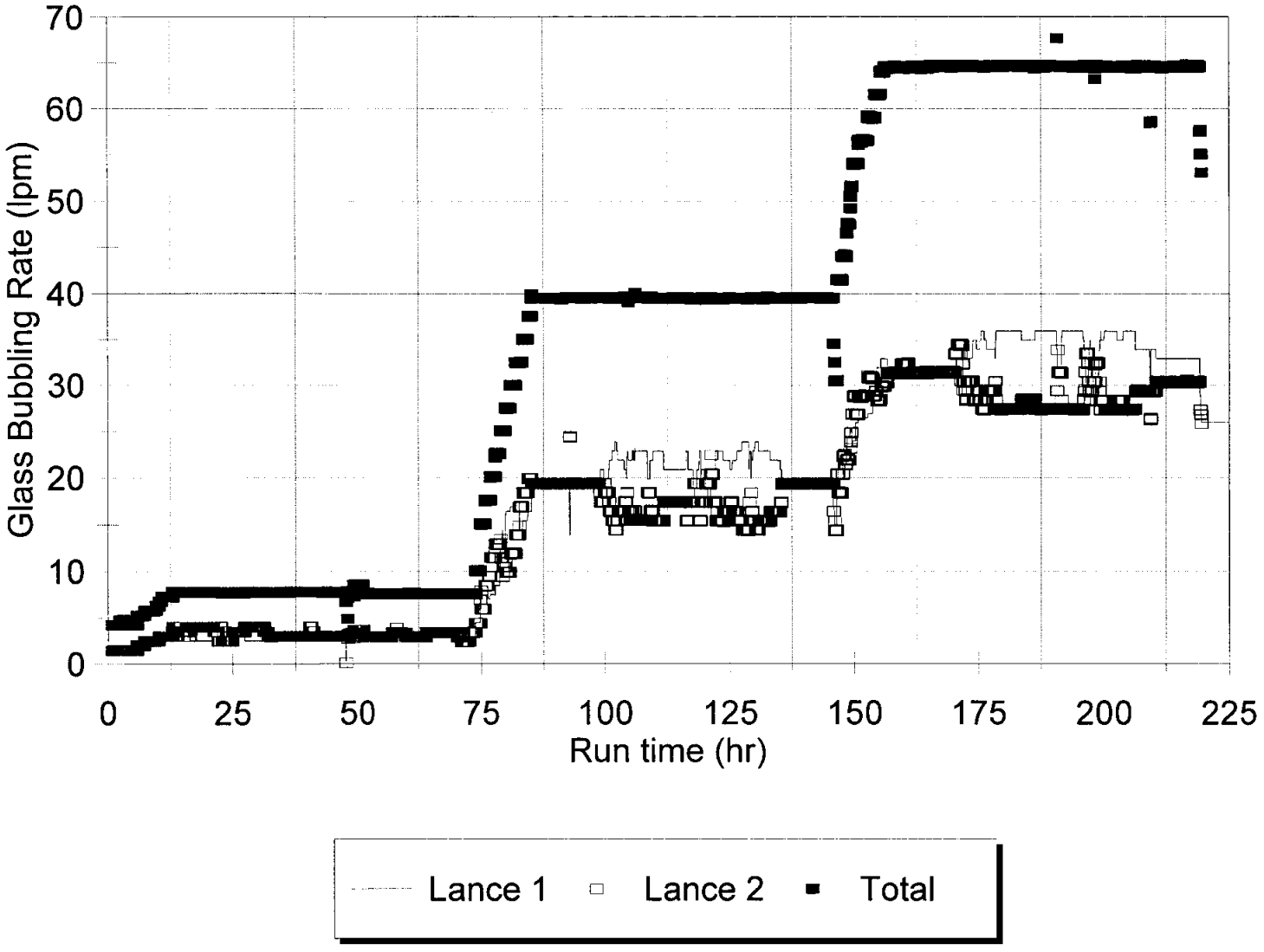

Figure 4.7. Glass pool bubbling for DM1200 tests.

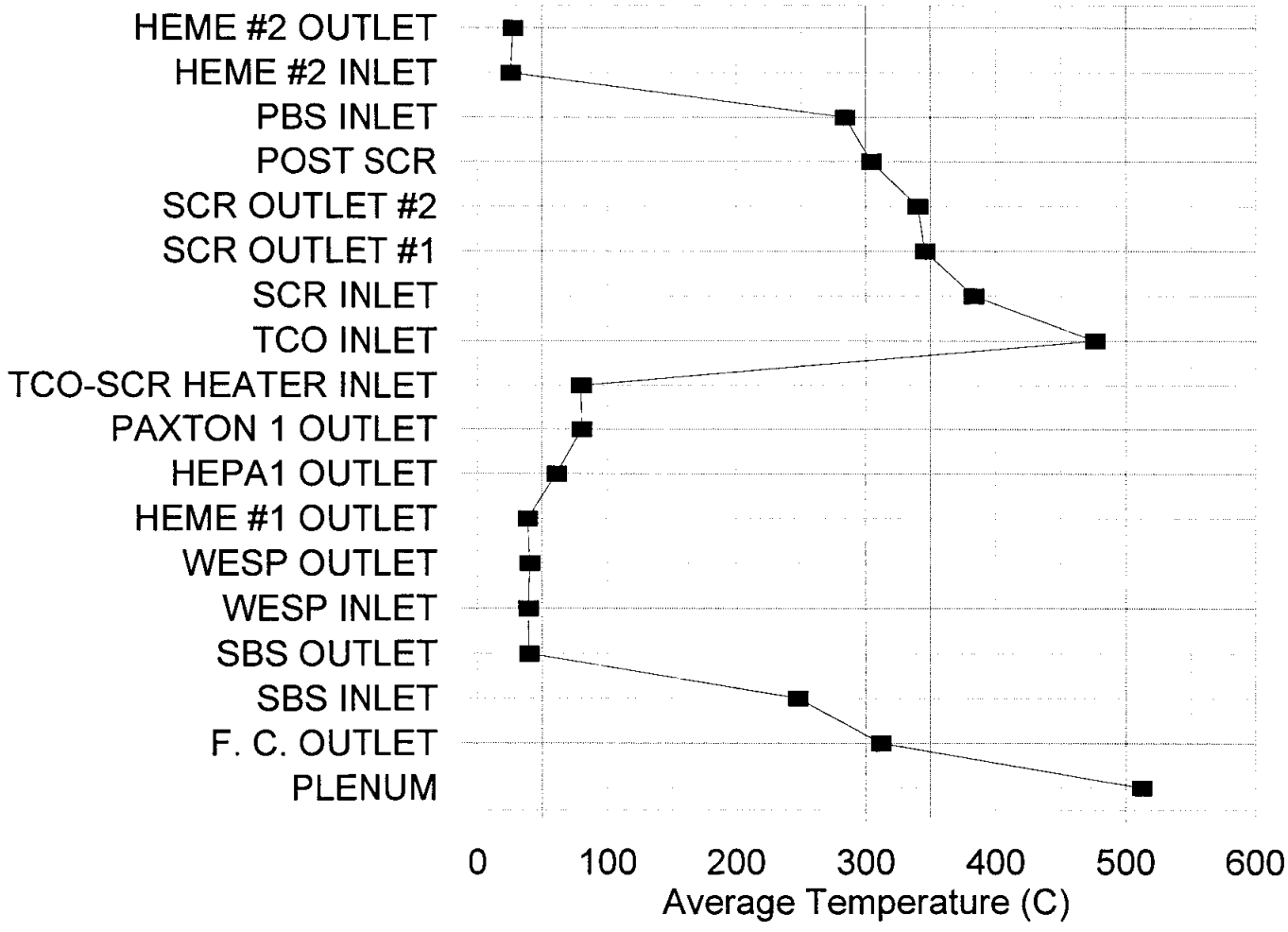

Figure 5.1. Average gas temperatures along the DM1200 off-gas train.

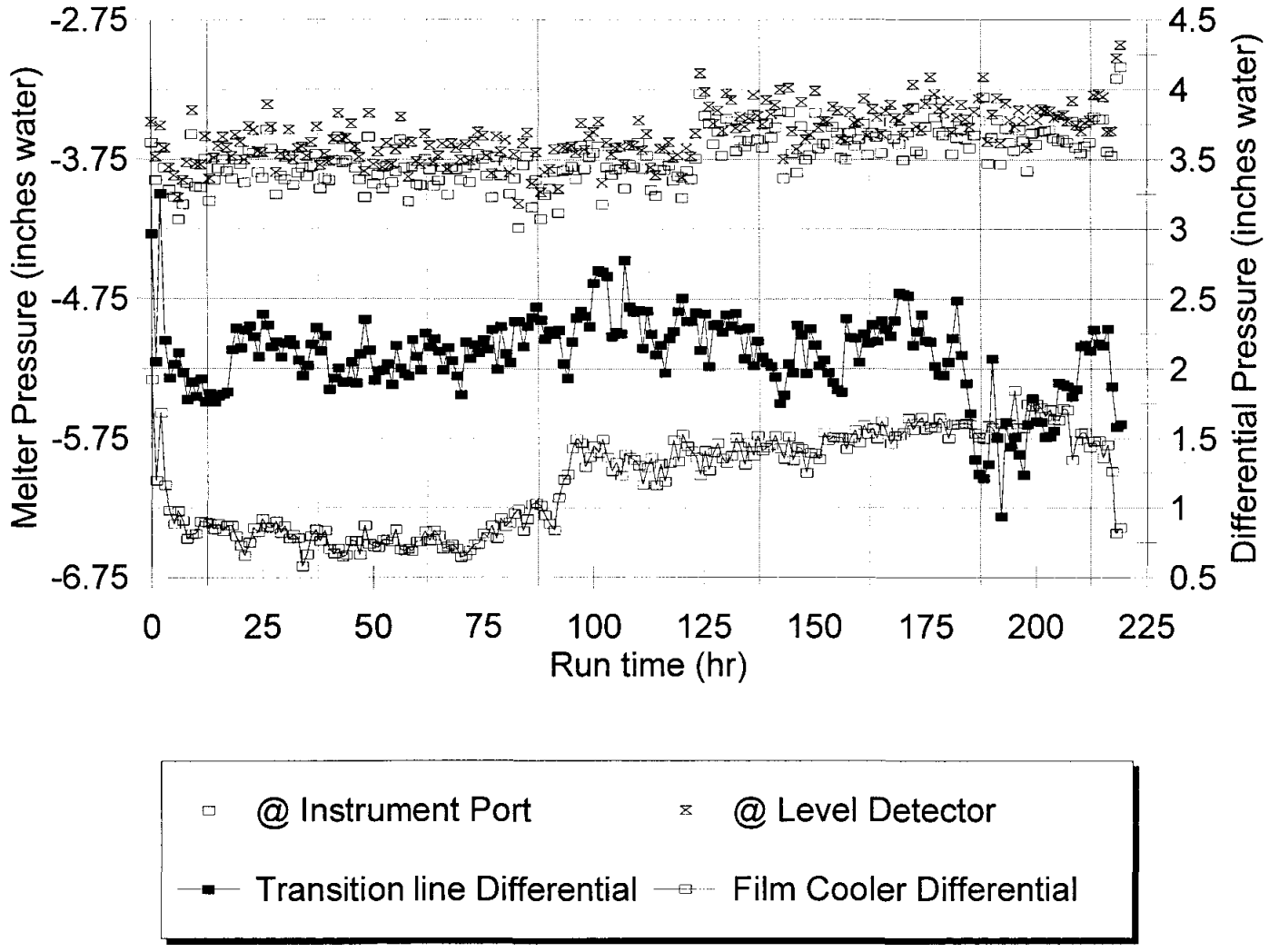

Figure 5.2. Melter pressure (at level detector and instrument ports) and transition line and film cooler differential pressures (hourly average values).

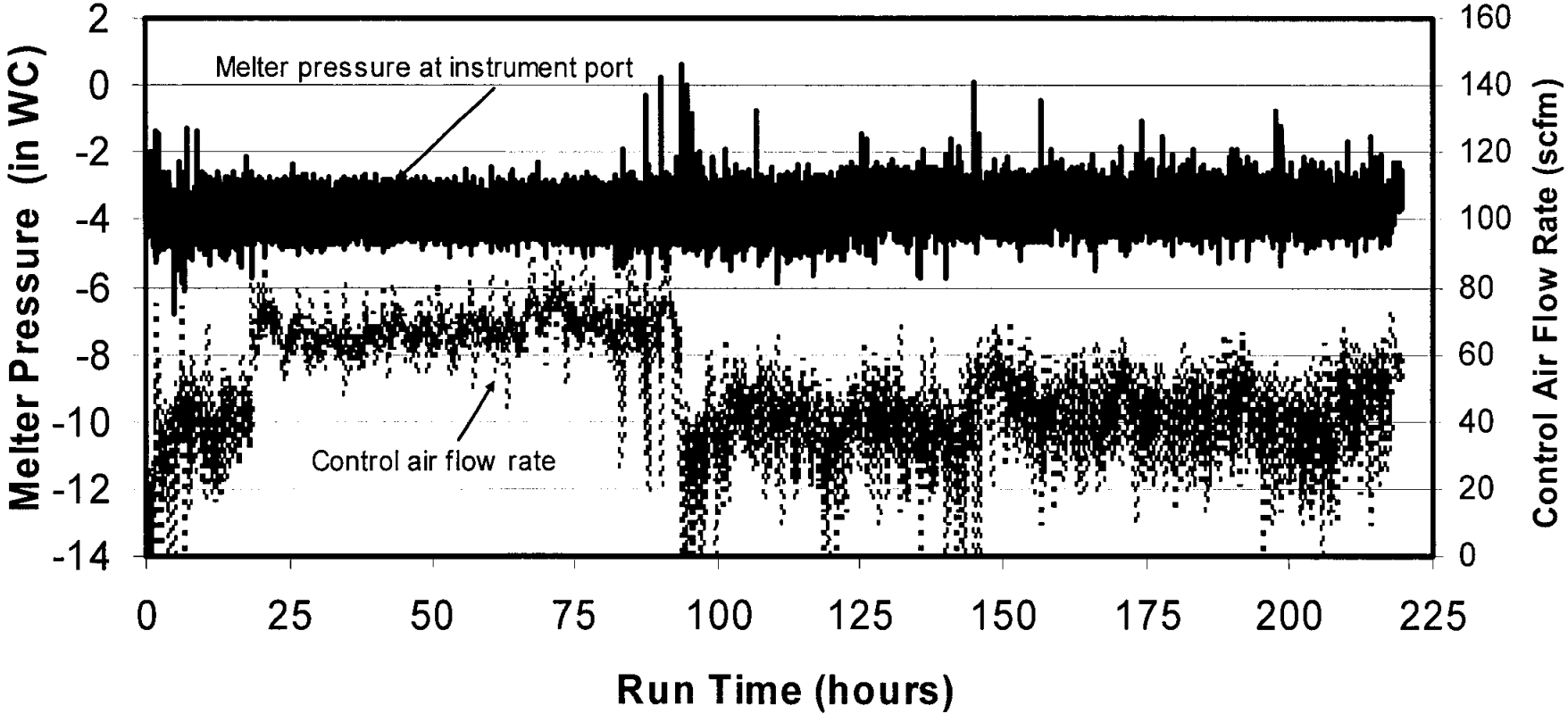

Figure 5.3. Melter pressure at instrument port and control air flow rate.

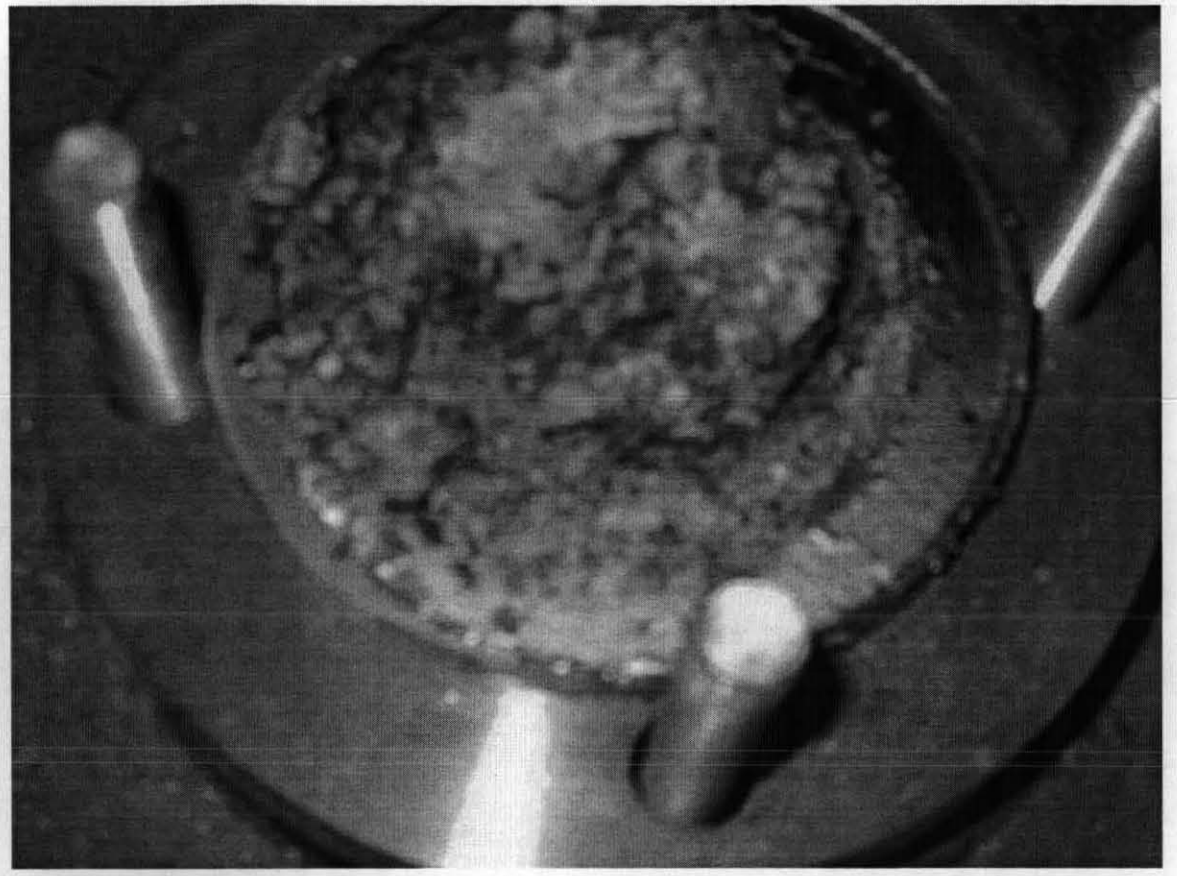

Figure 5.4. Solids on the discharge chamber vent orifice plate (pre-cleaning).

Figure 5.5. Another view of solids on the discharge chamber vent orifice plate (pre-cleaning).

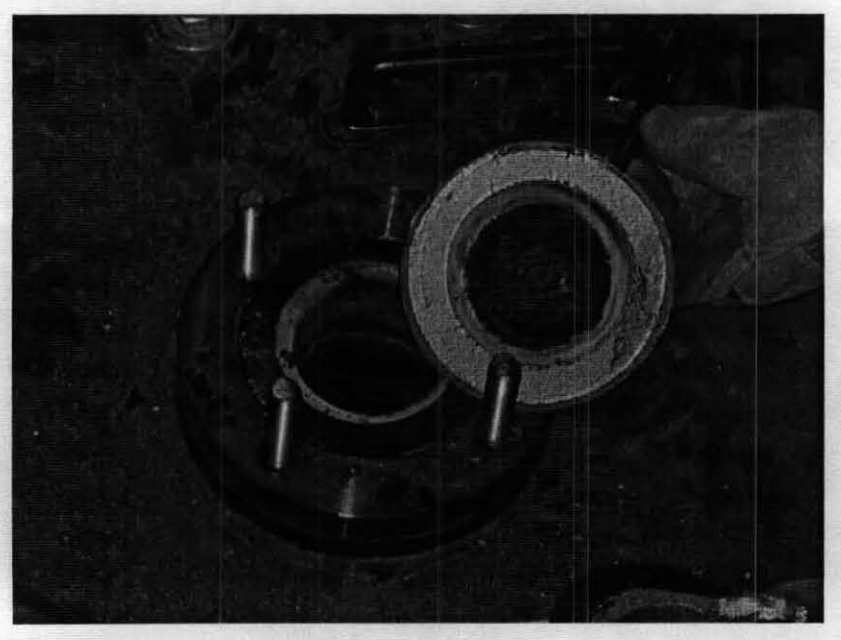

Figure 5.6. Discharge chamber vent orifice plate (post-cleaning).

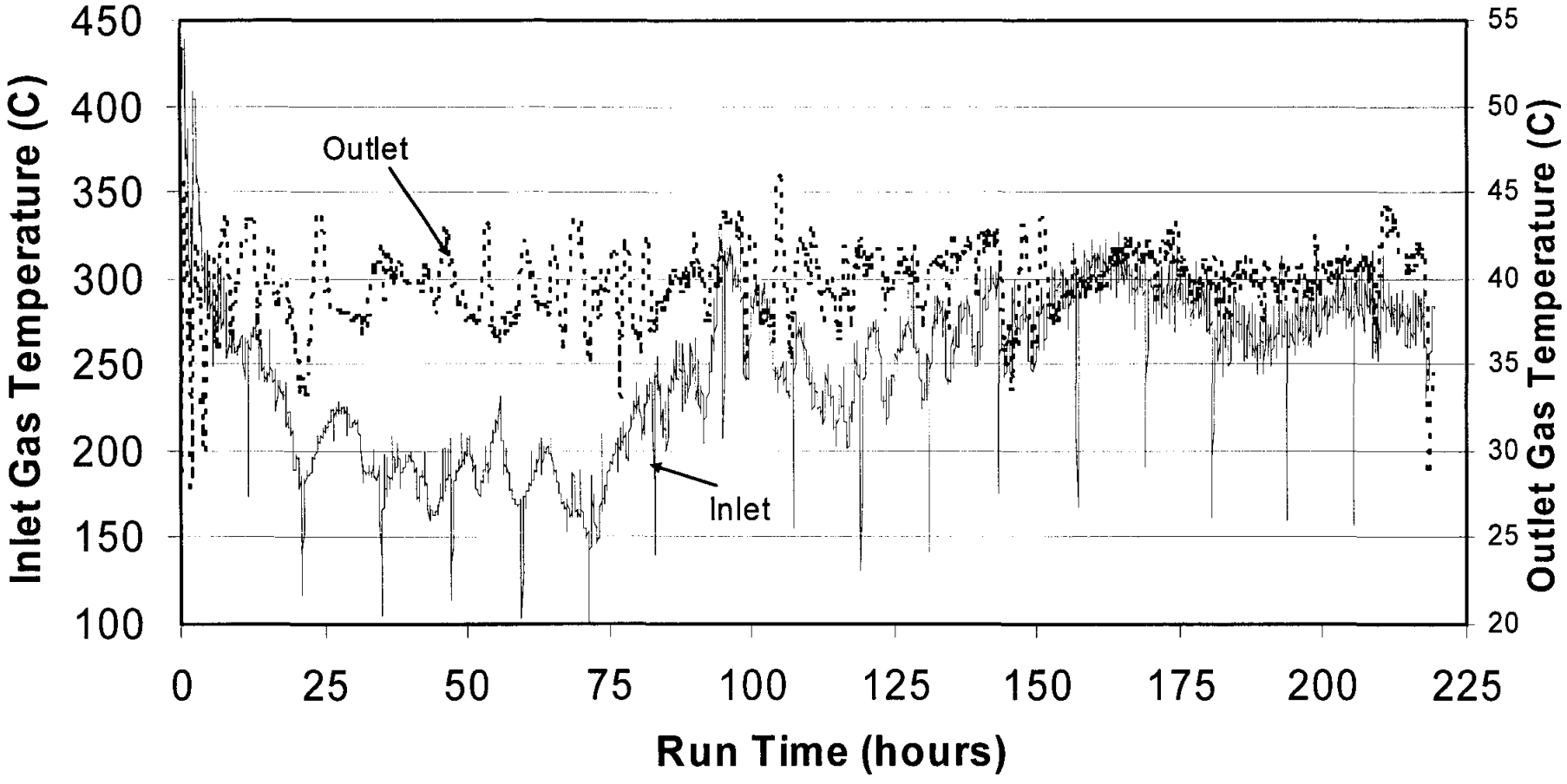

Figure 5.7. SBS inlet and outlet temperatures.

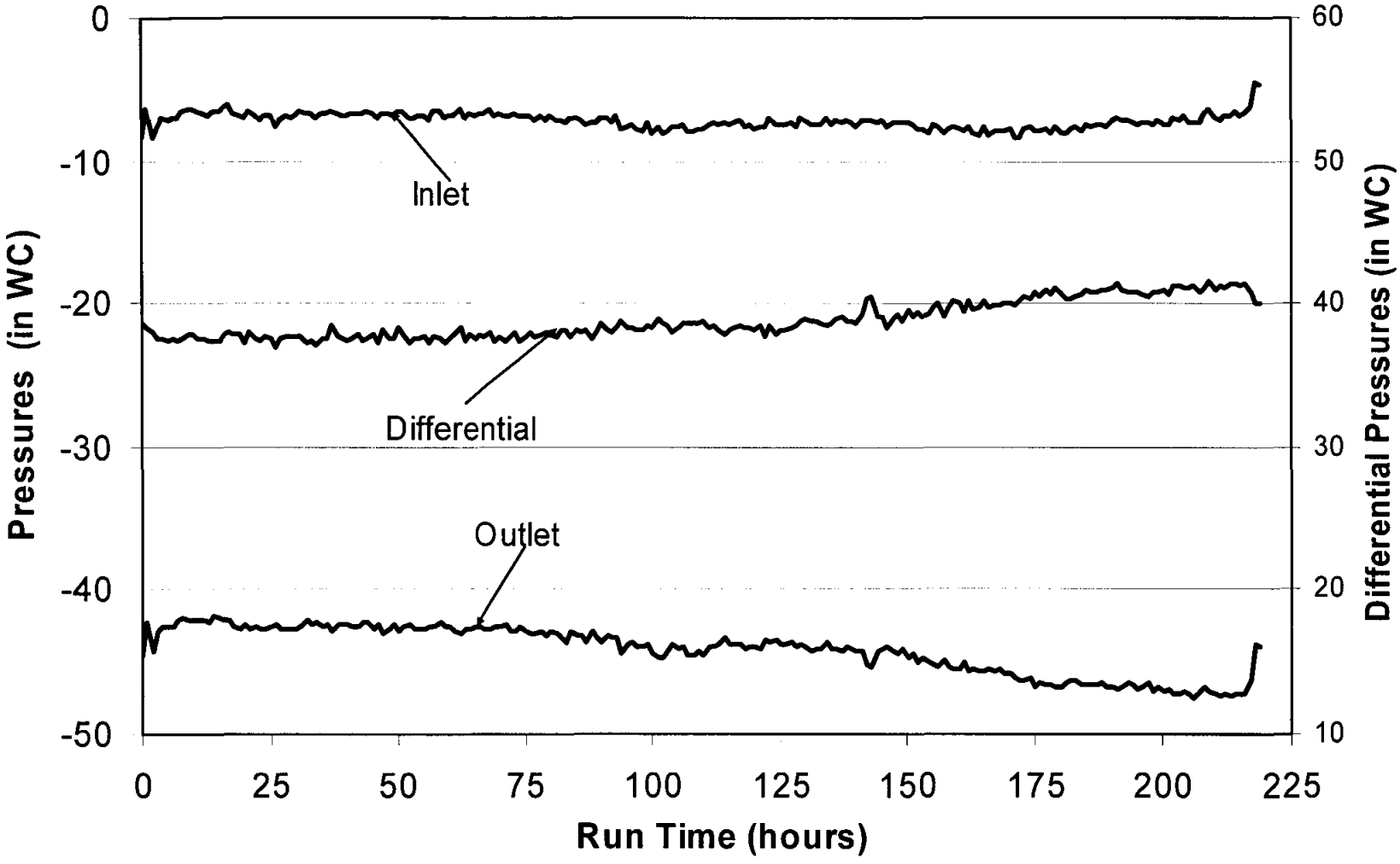

Figure 5.8. SBS inlet, outlet, and differential pressures (hourly average values).

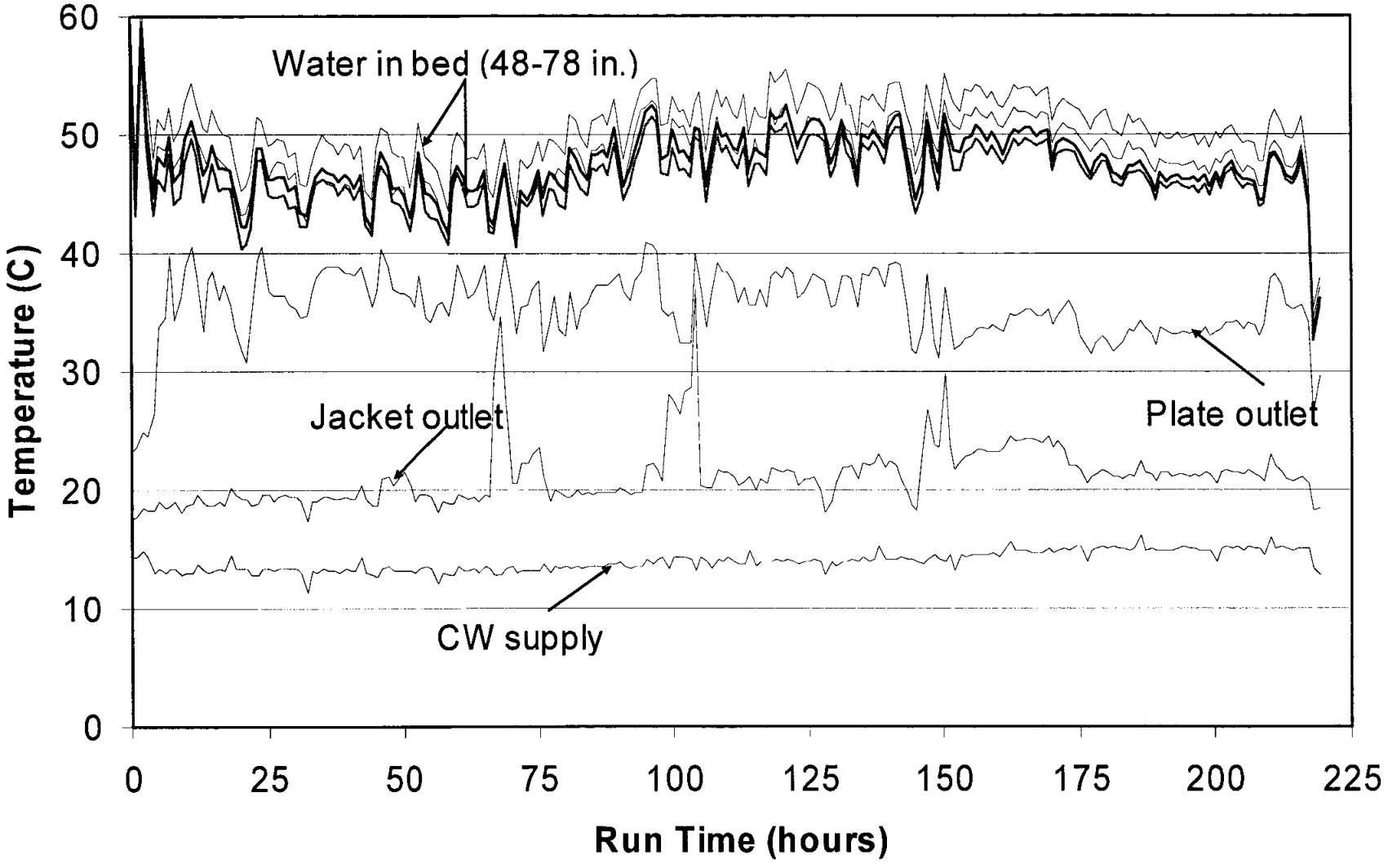

Figure 5.9. SBS cooling water and bed temperatures (hourly average values).

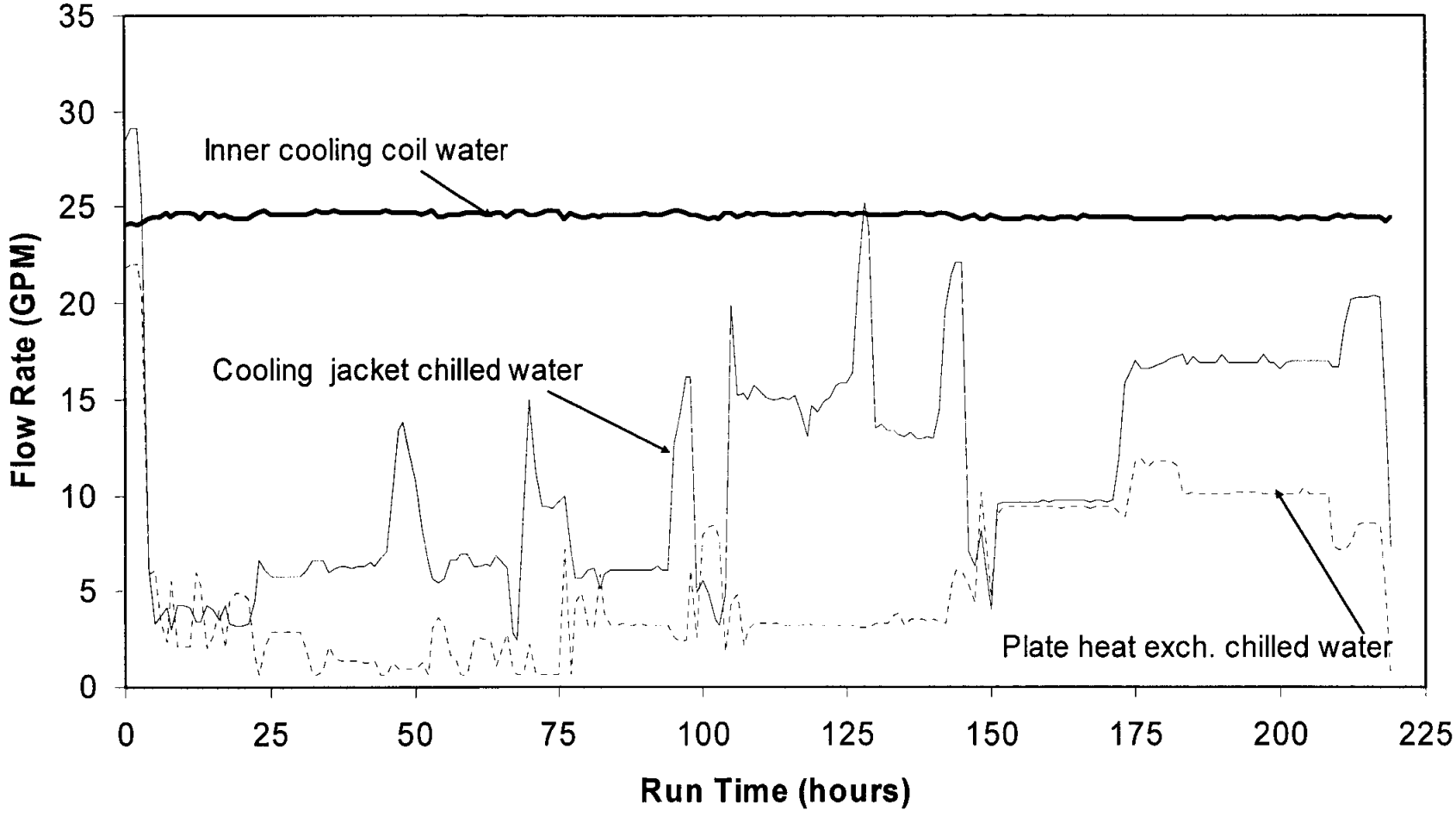

Figure 5.10. SBS jacket, inner coil and heat exchanger water flow rates (hourly average values).

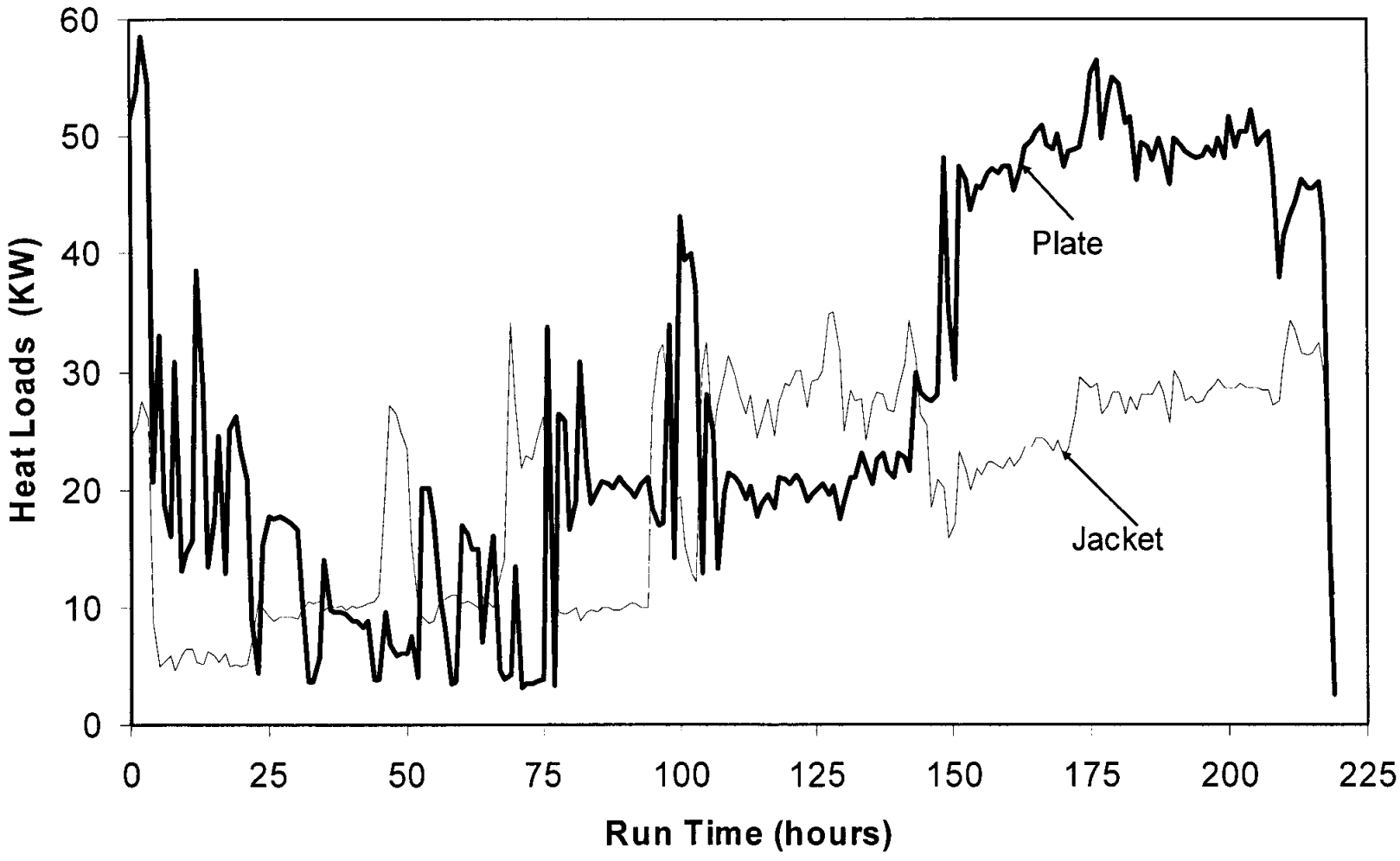

Figure 5.11. Calculated heat loads on the cooling jacket and plate heat exchanger (hourly average values).

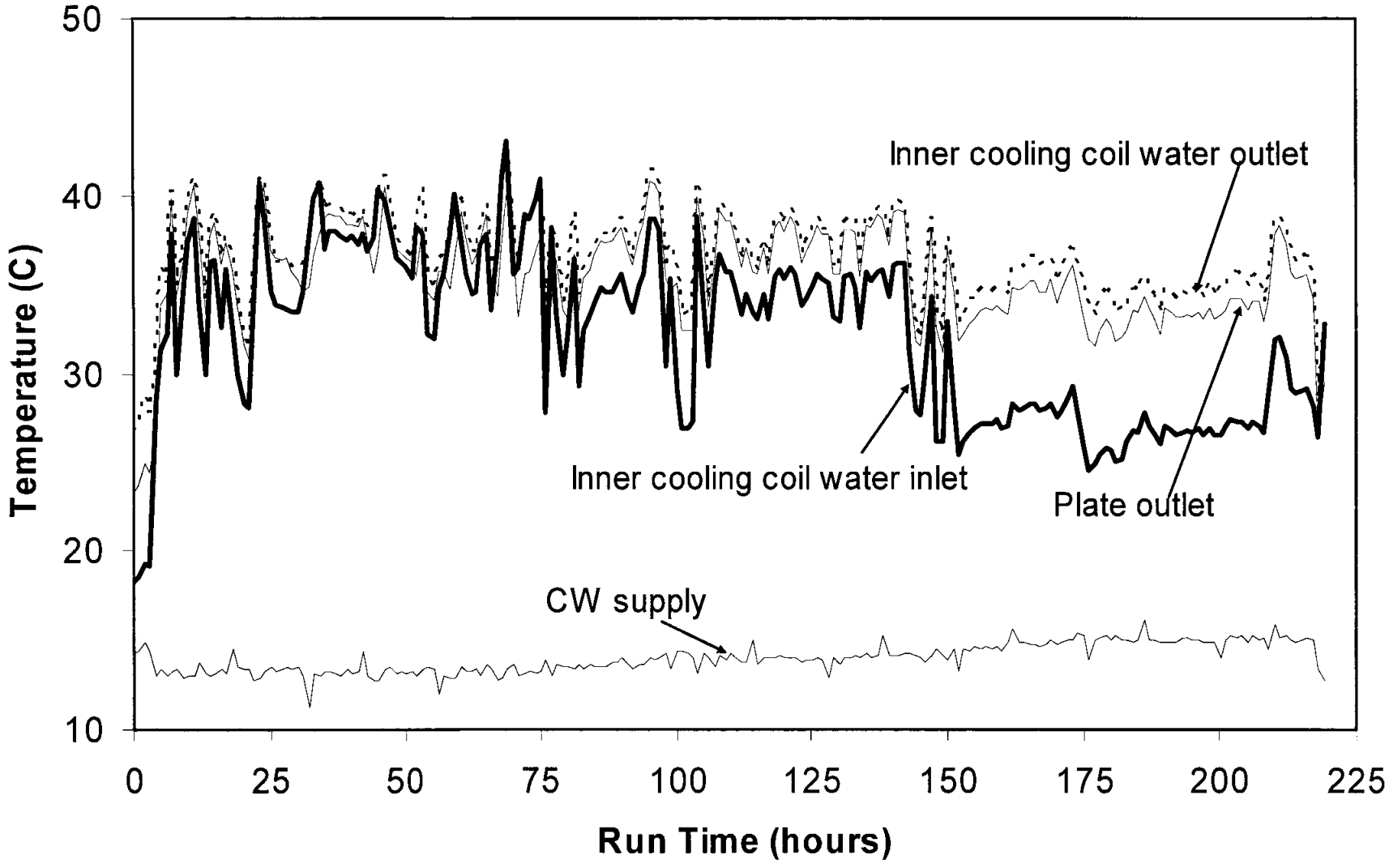

Figure 5.12. SBS inner coil and plate heat exchanger water temperatures (hourly average values).

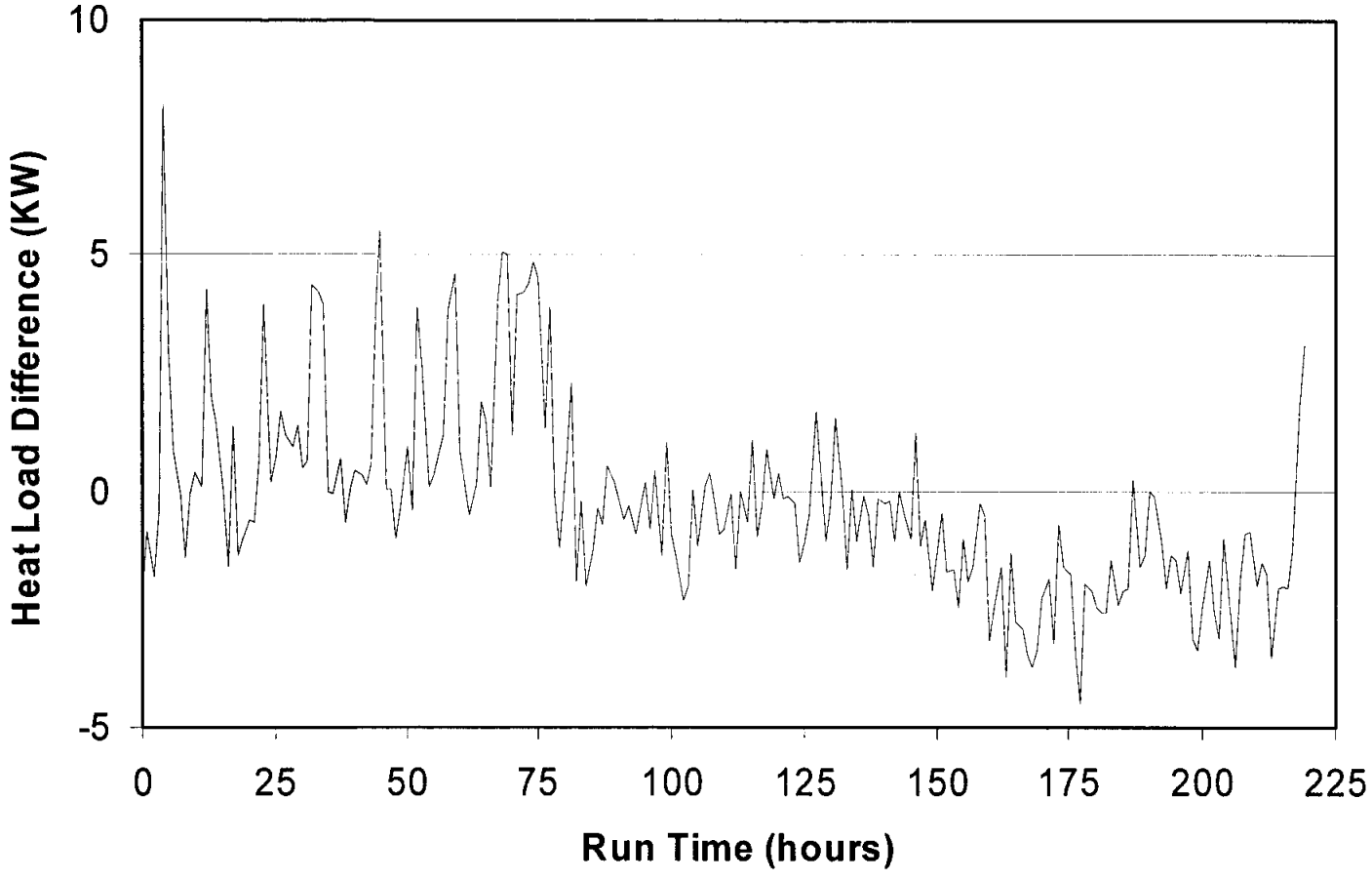

Figure 5.13. Calculated heat load difference between SBS inner coil and plate heat exchanger (hourly average values).

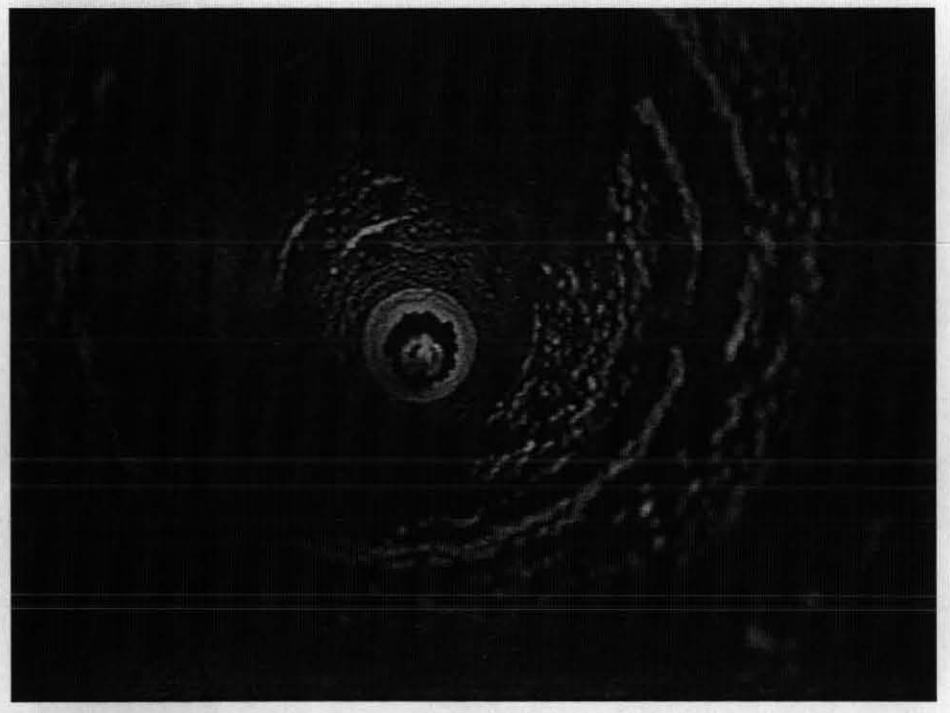

Figure 5.14. View looking downward from inside the SBS down-comer showing ring of solids deposited near the bottom after C-106/AY-102 test.

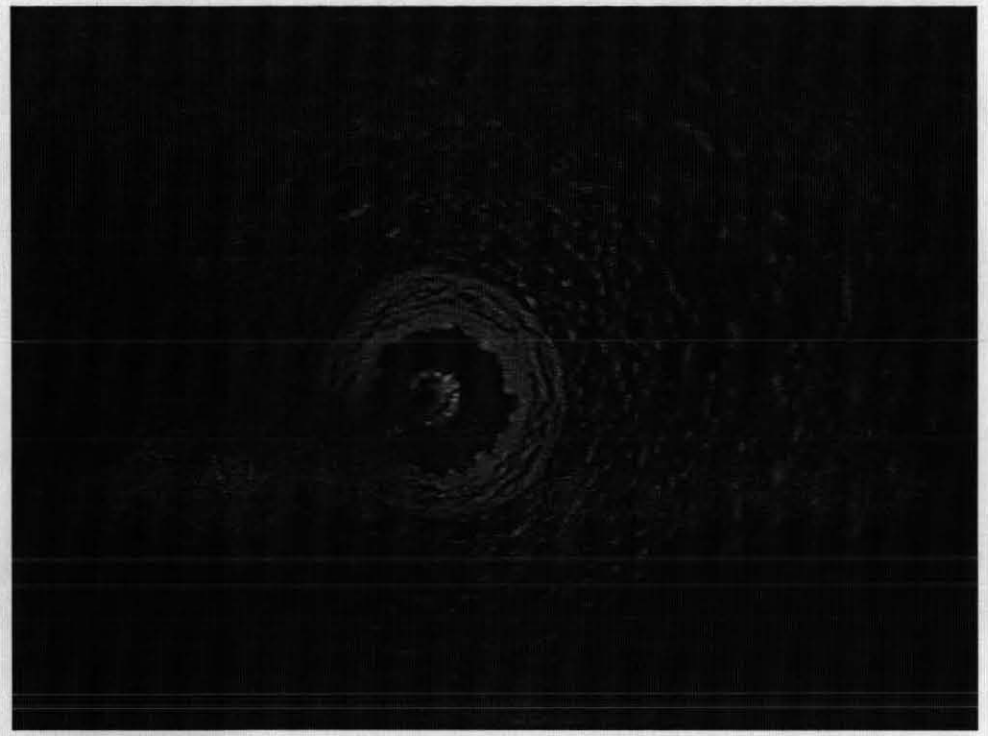

Figure 5.15. Another view looking downward from inside the SBS down-comer showing ring of solids deposited near the bottom after C-106/AY-102 test.

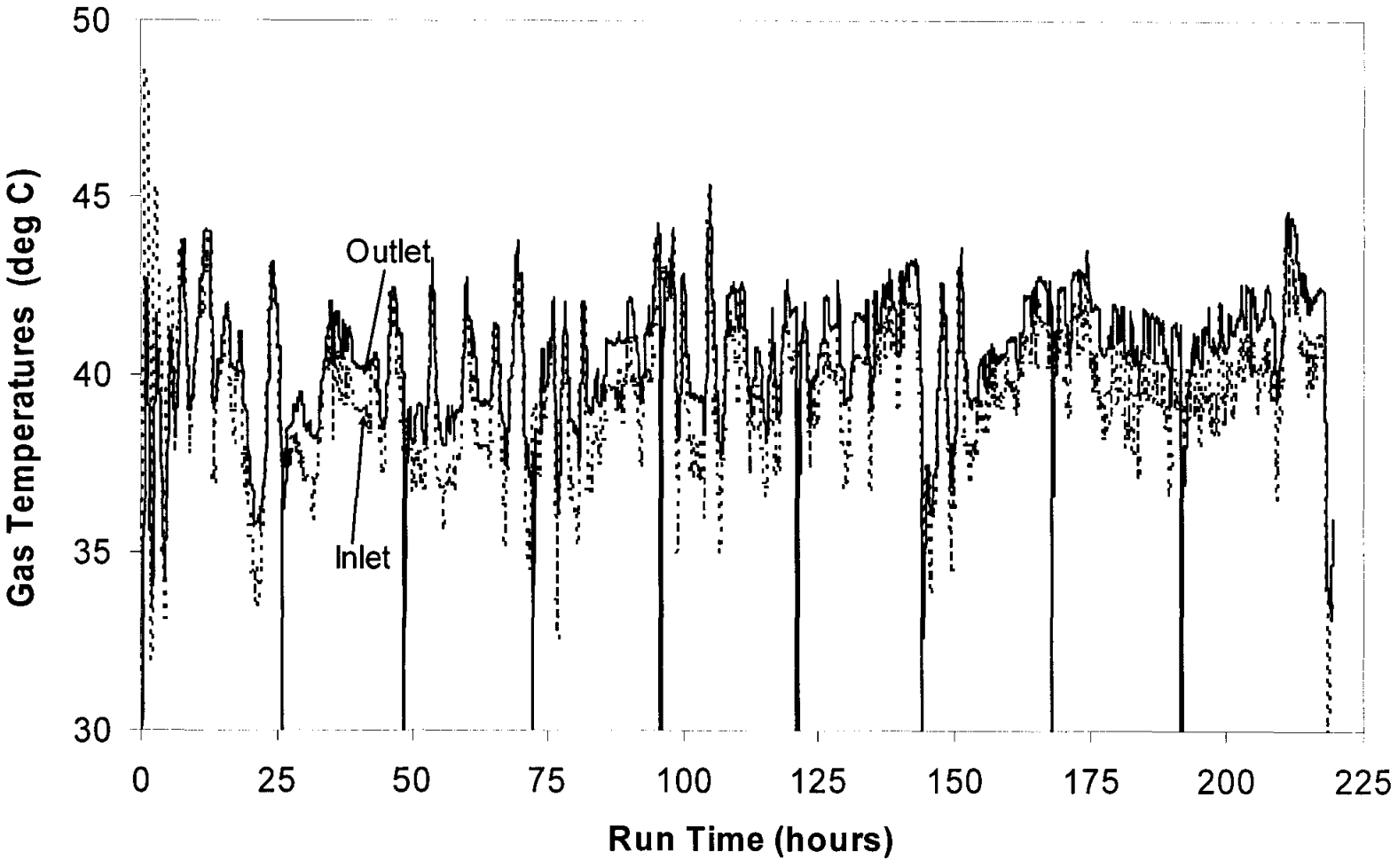

Figure 5.16. WESP inlet and outlet temperatures. (Note: downward outlet temperature spikes are the result of WESP deluges).

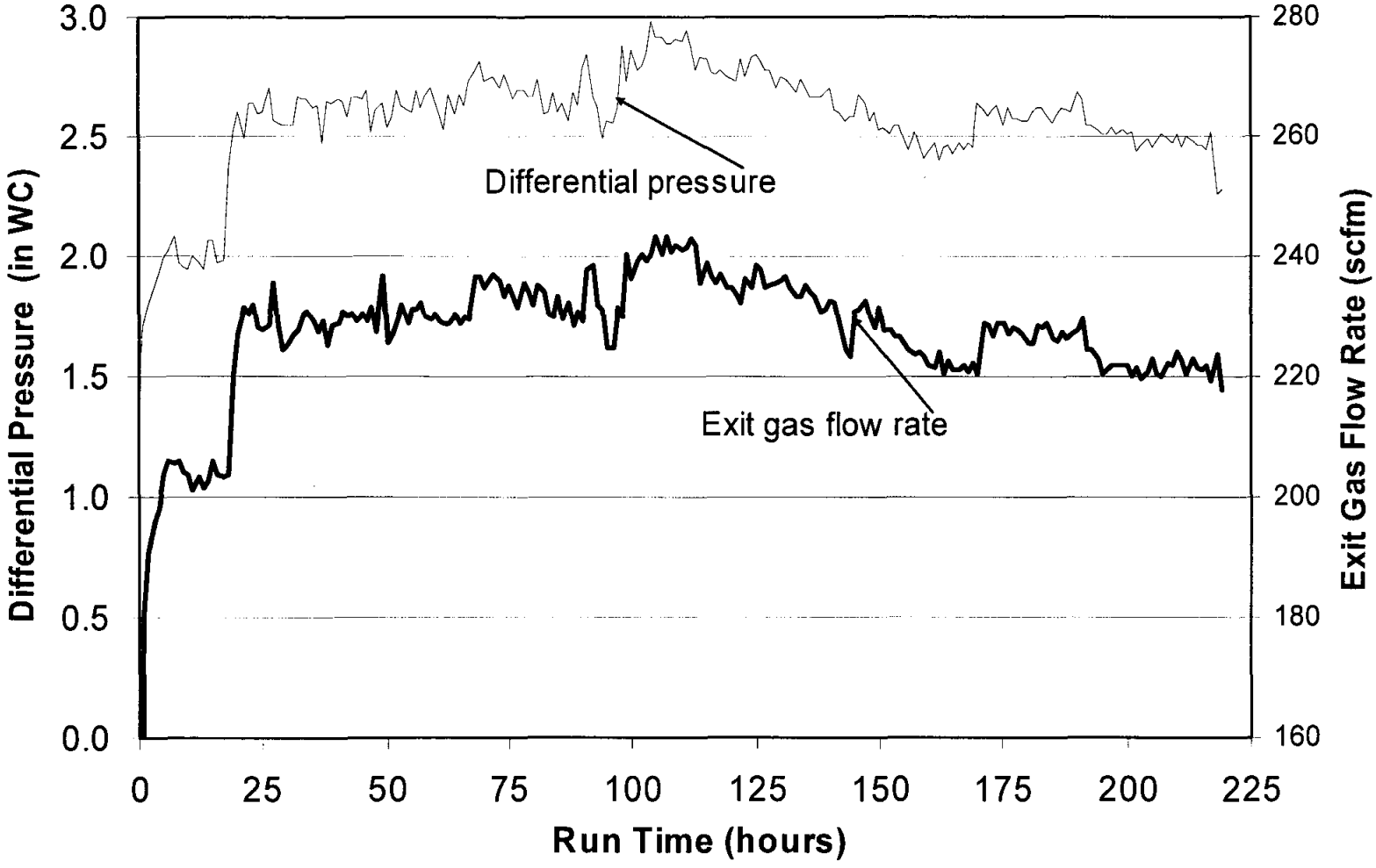

Figure 5.17. WESP differential pressure and outlet gas flow rate (hourly average values).

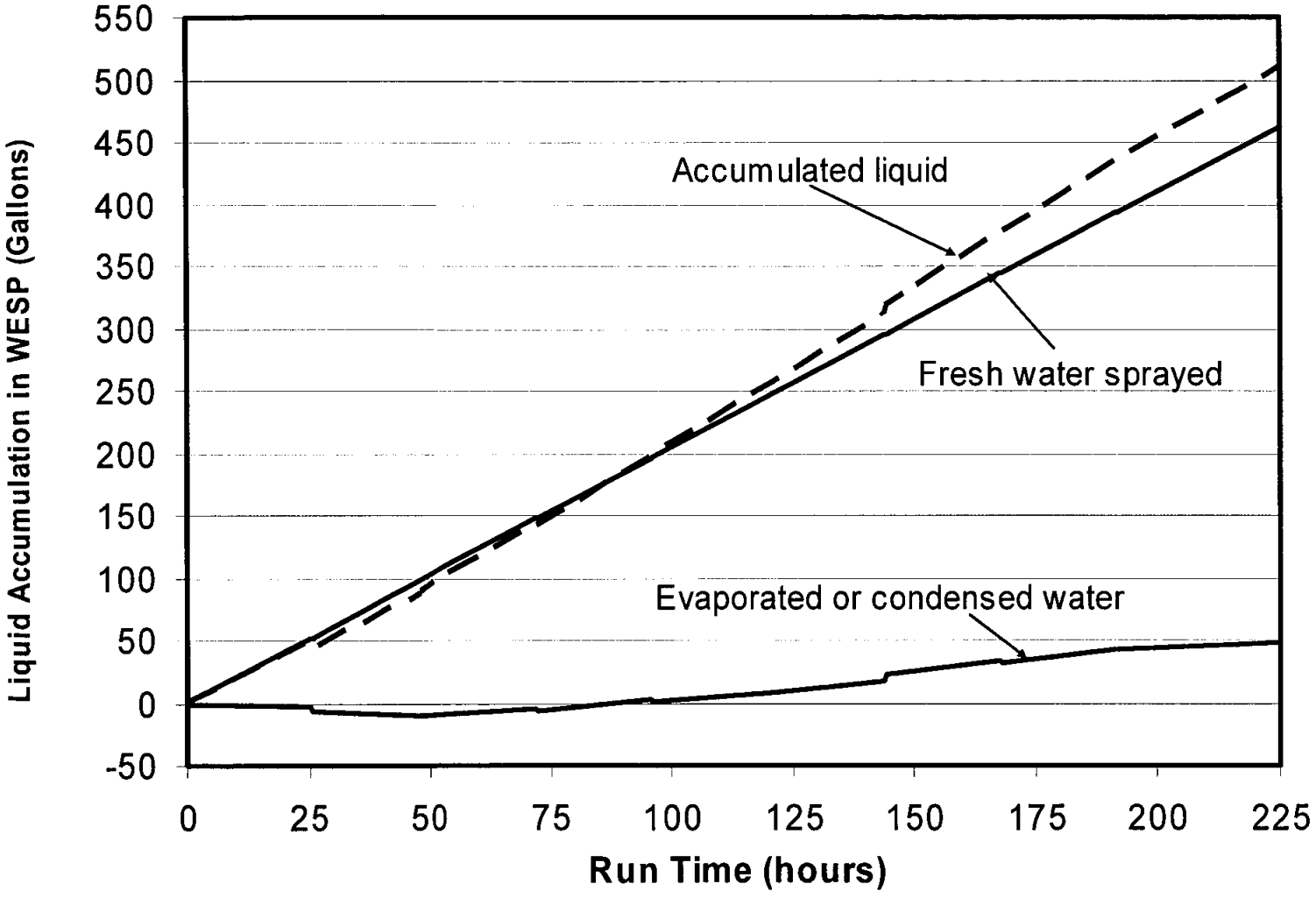

Figure 5.18. Accumulated WESP blow-down volume, accumulated fresh spray water, and evaporated/condensed water.

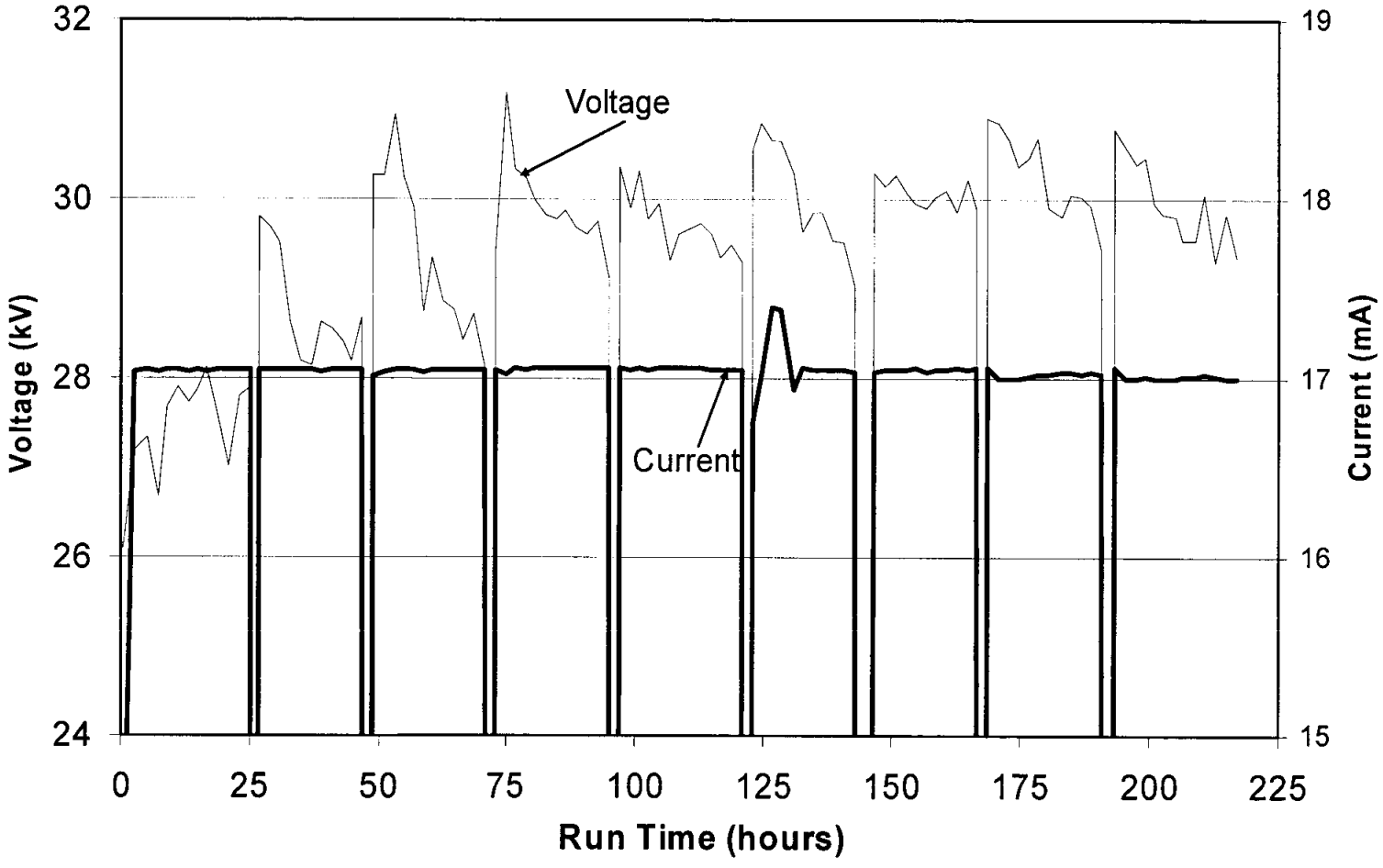

Figure 5.19. Voltage and current across the WESP. (Note: during the deluges, power to WESP was turned off).

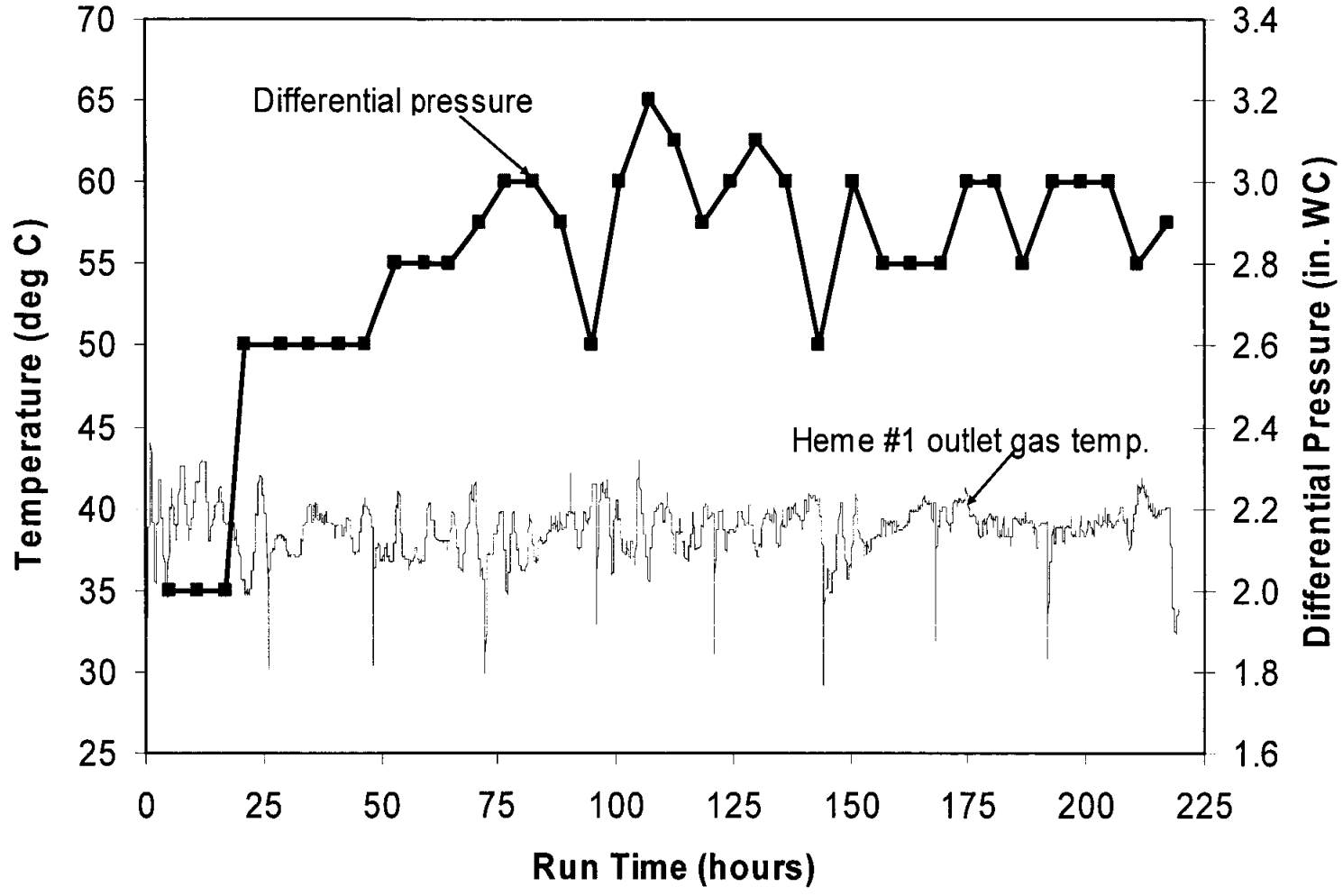

Figure 5.20. Outlet temperature and differential pressure for HEME #1.

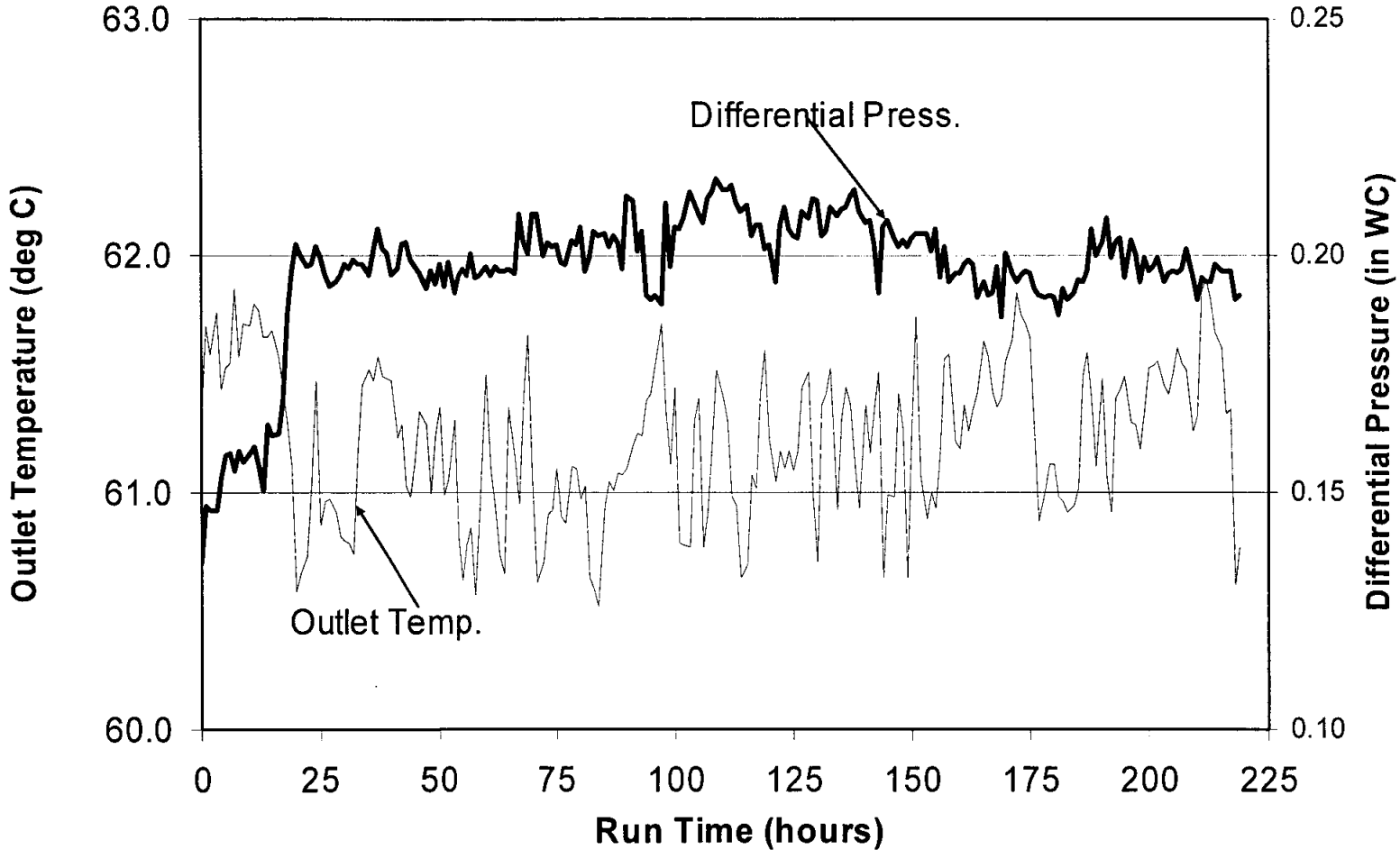

Figure 5.21. Outlet temperature and differential pressure for HEPA #1 (hourly average values).

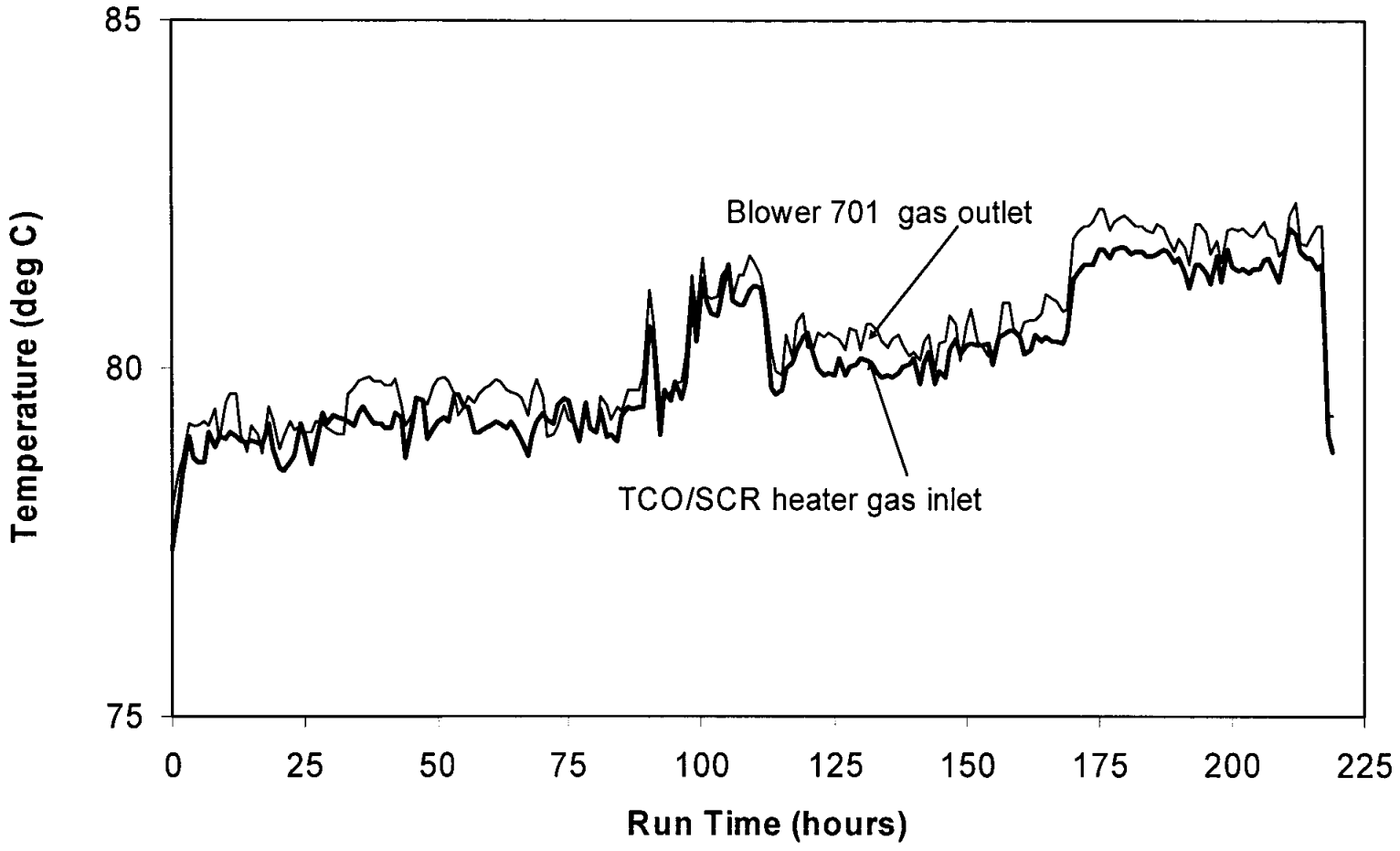

Figure 5.22. Paxton 1 outlet and TCO/SCR heater inlet temperatures (hourly average values).

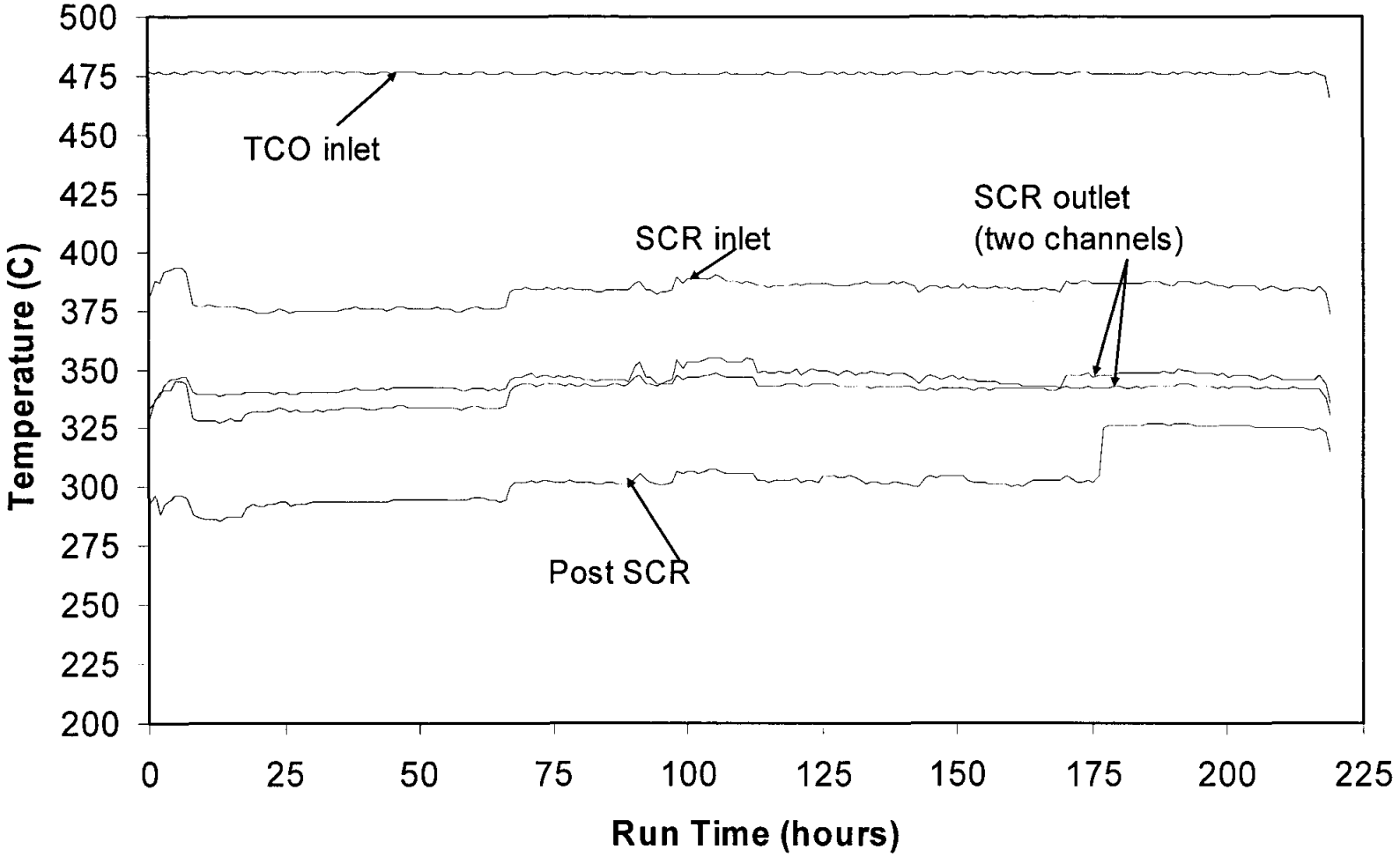

Figure 5.23. TCO/SCR temperatures (hourly average values).

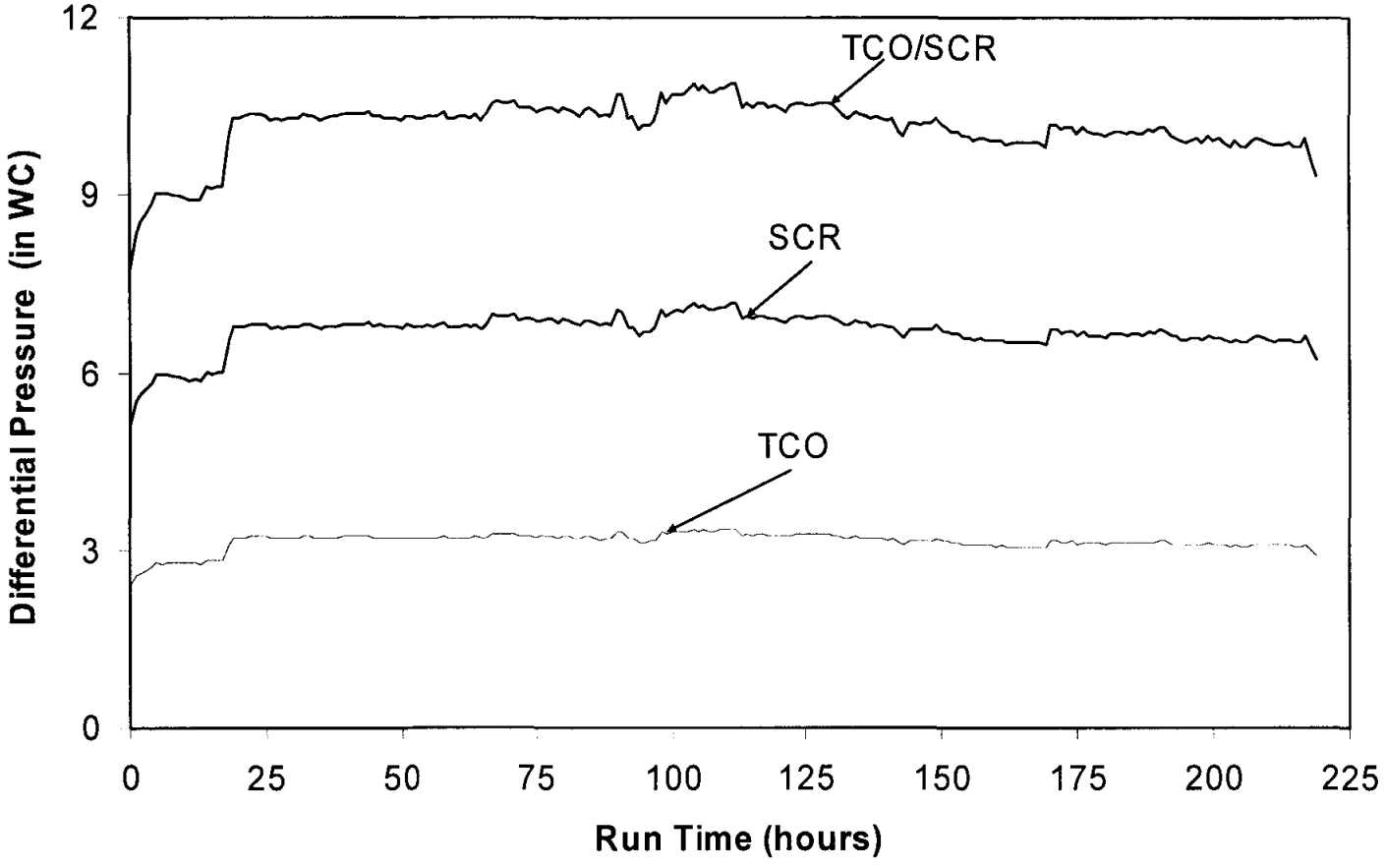

Figure 5.24. TCO/SCR differential pressures (hourly average values).

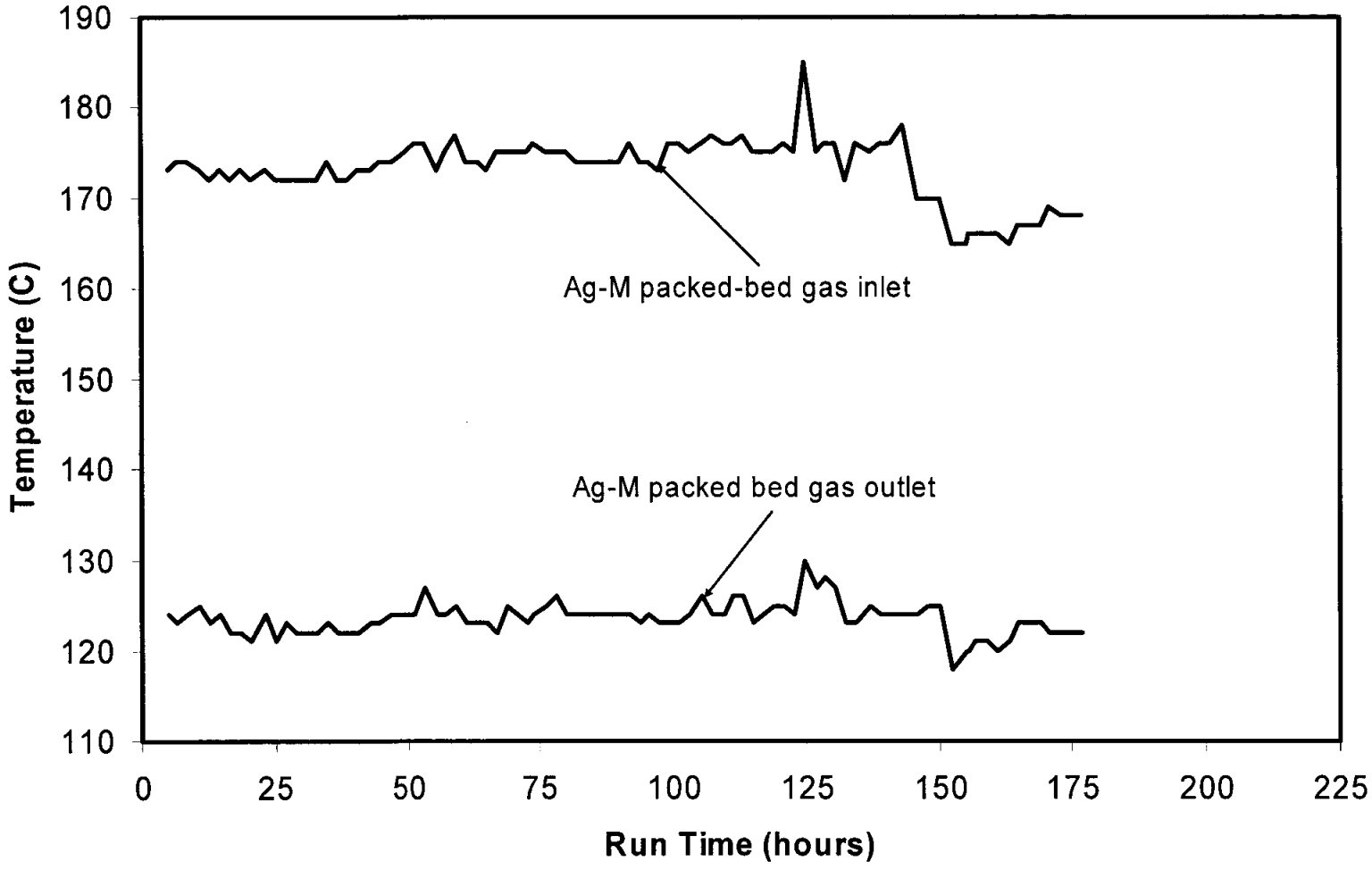

Figure 5.25. Silver mordenite column temperatures.

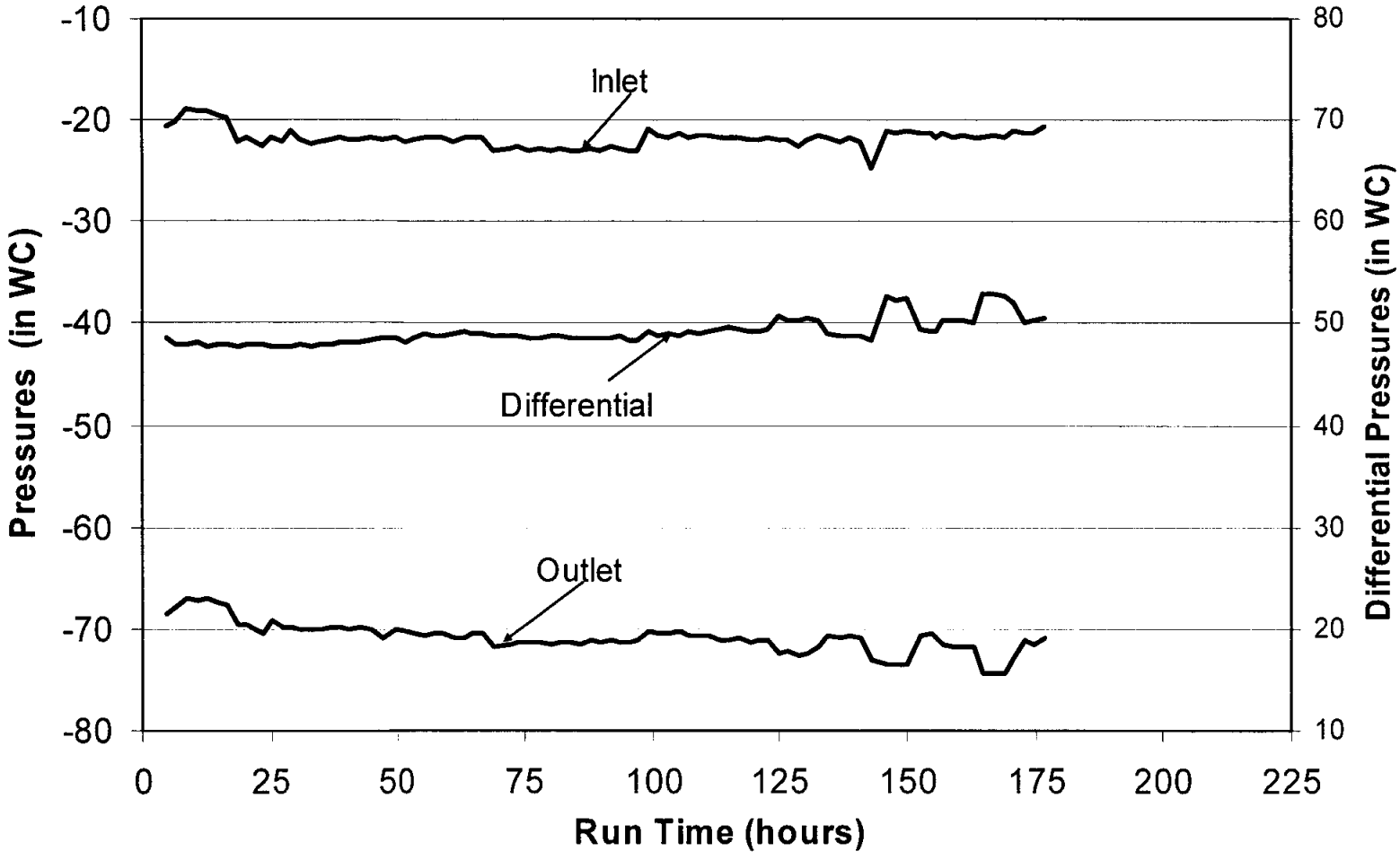

Figure 5.26. Silver mordenite column pressures.

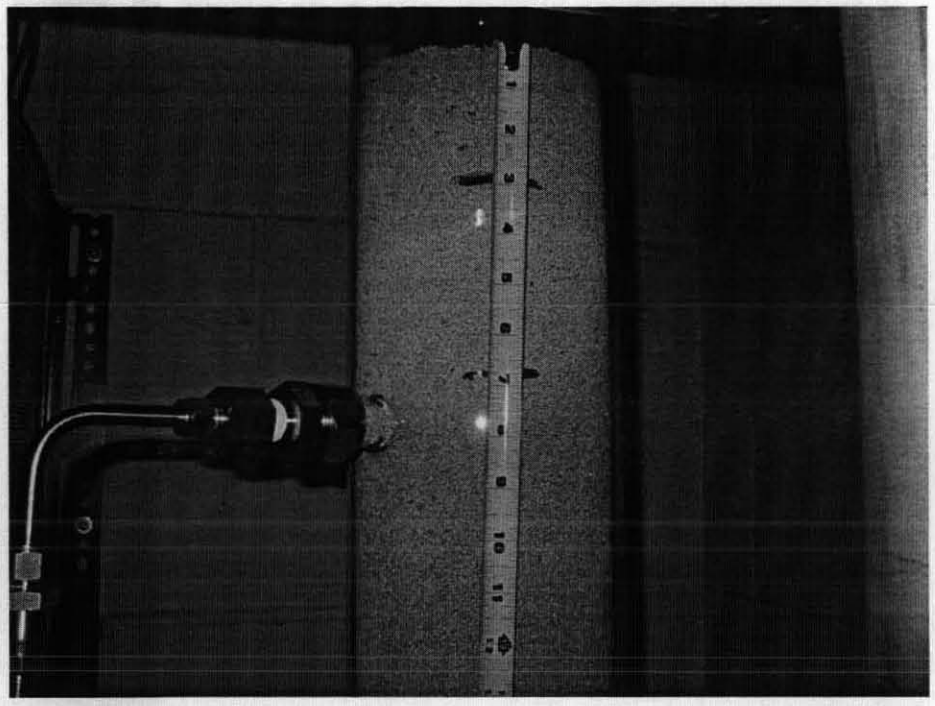

Figure 5.27. Photograph of silver mordenite column showing color change. (Marked at 3" after 6.6 hours and 7" after 27.2 hours of testing).

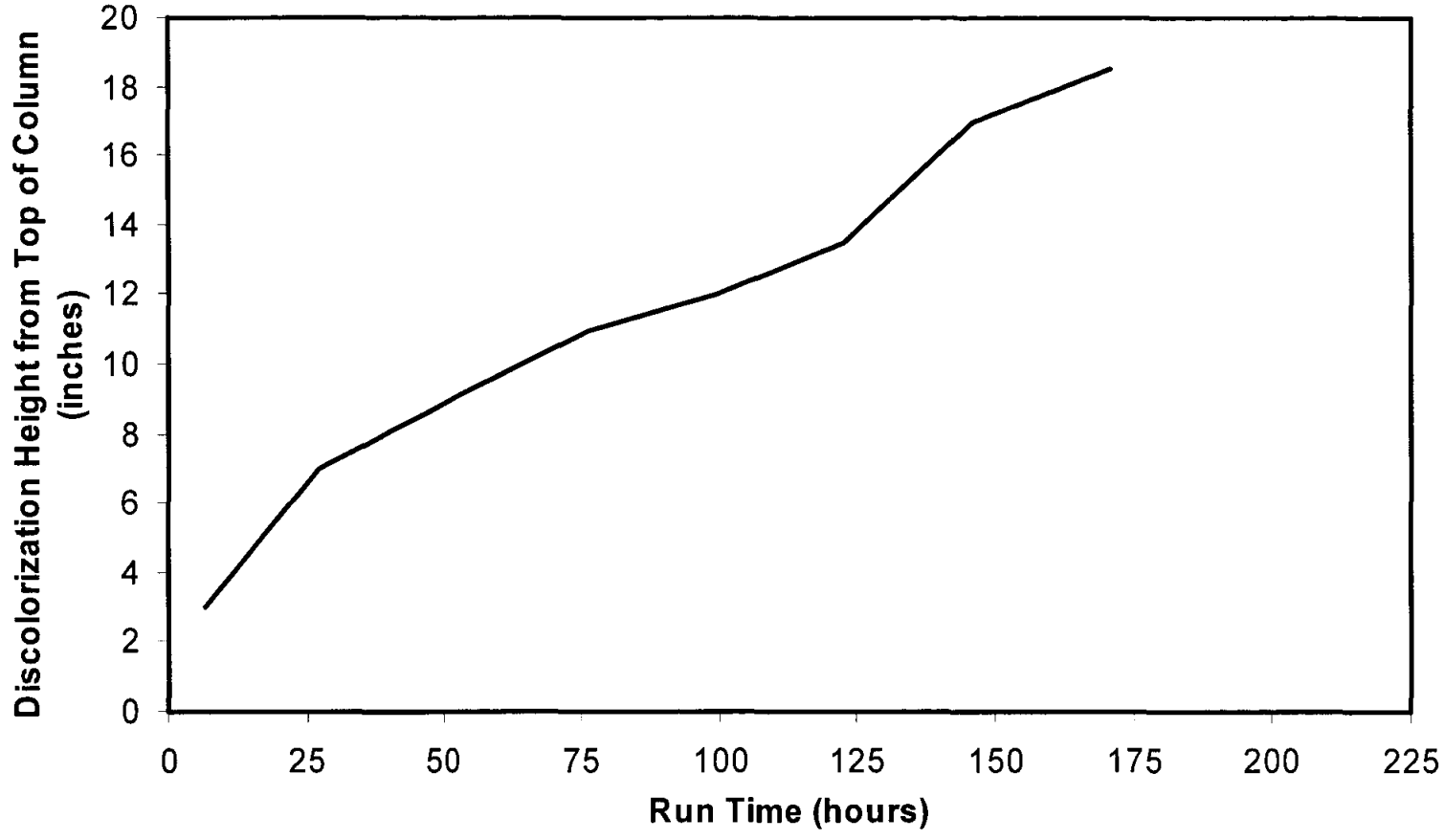

Figure 5.28. Depth of discolored silver mordenite as a function of run time.

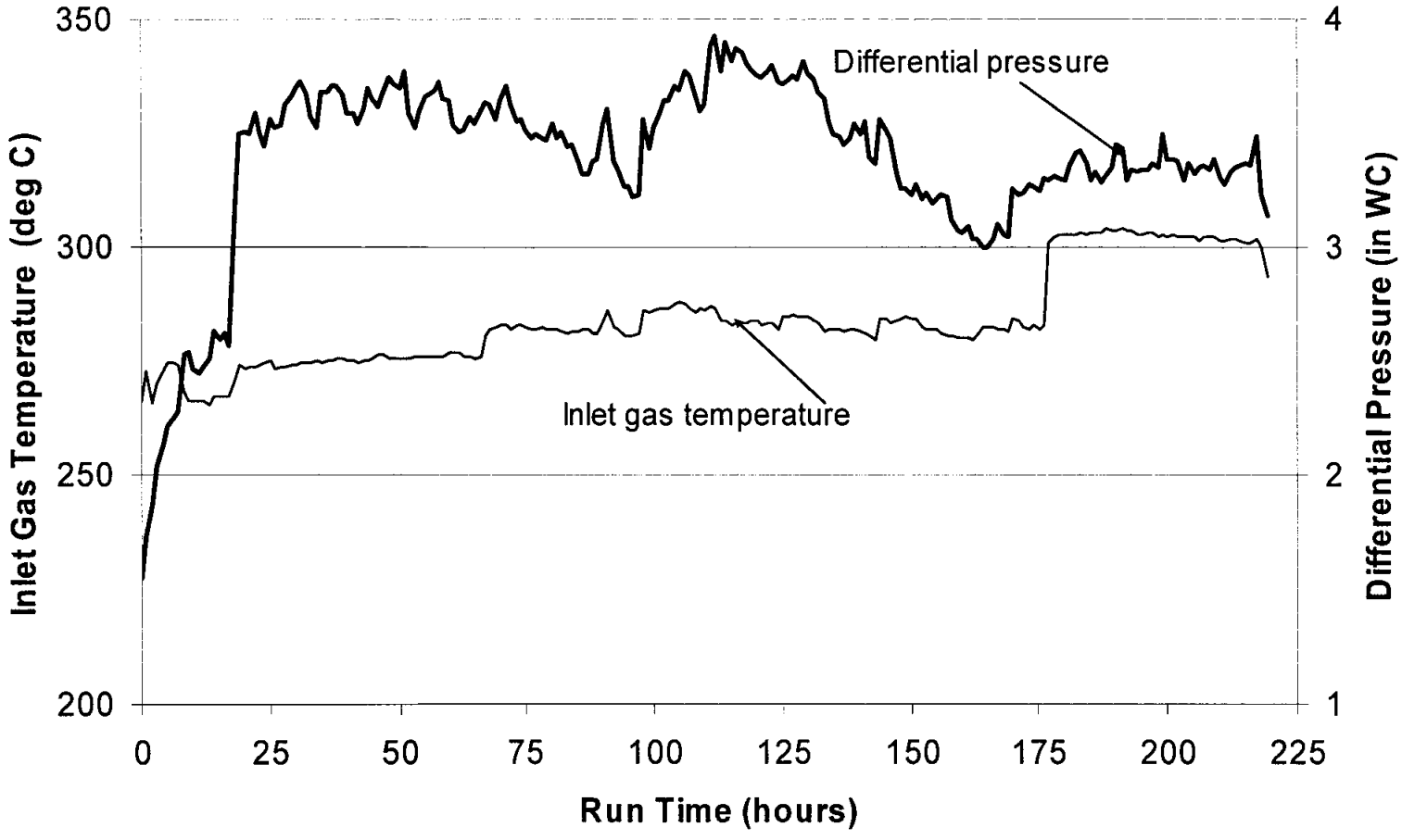

Figure 5.29. Inlet temperature and differential pressure for PBS (hourly average values).

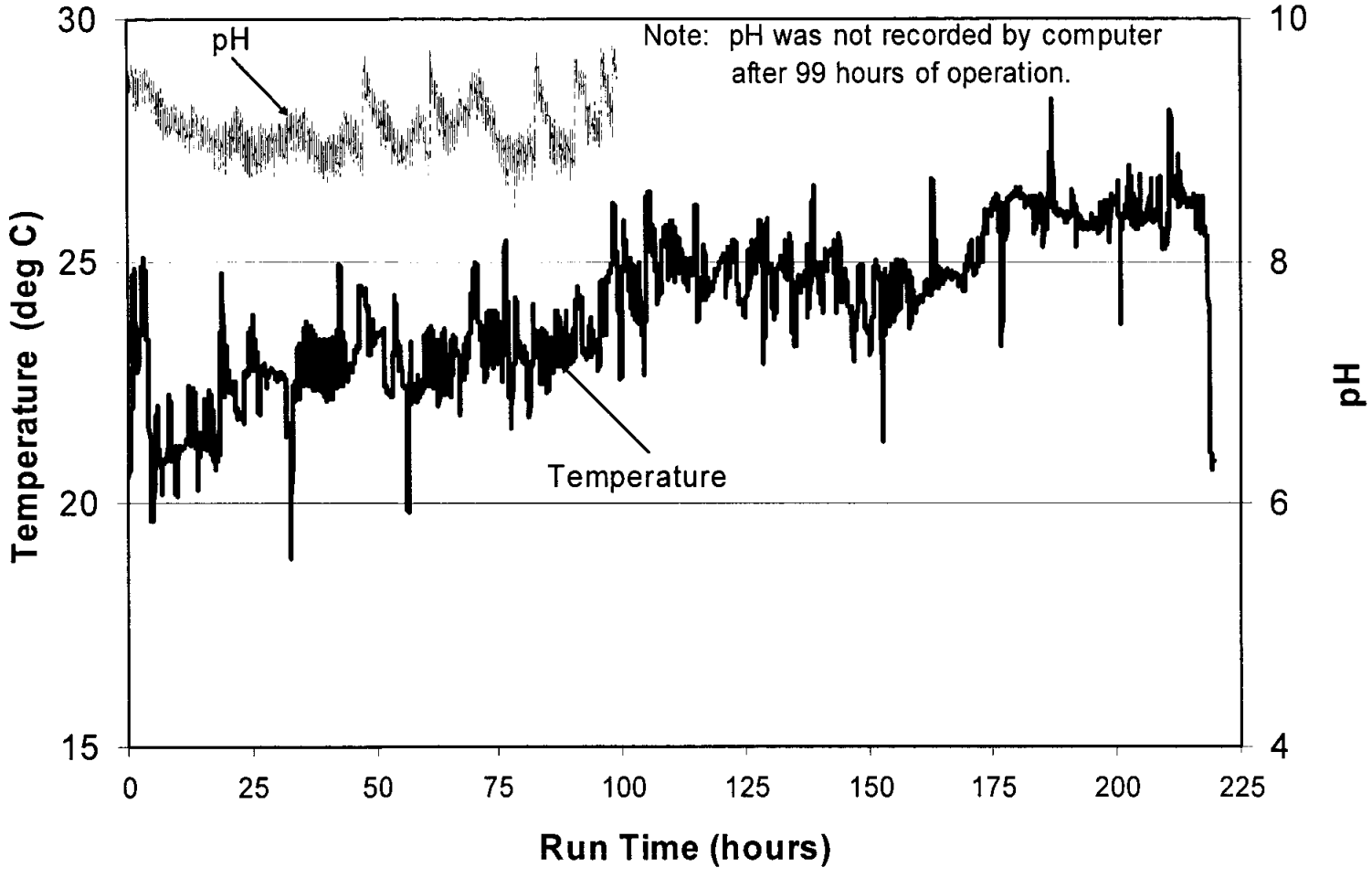

Figure 5.30. Sump temperature and pH for PBS.

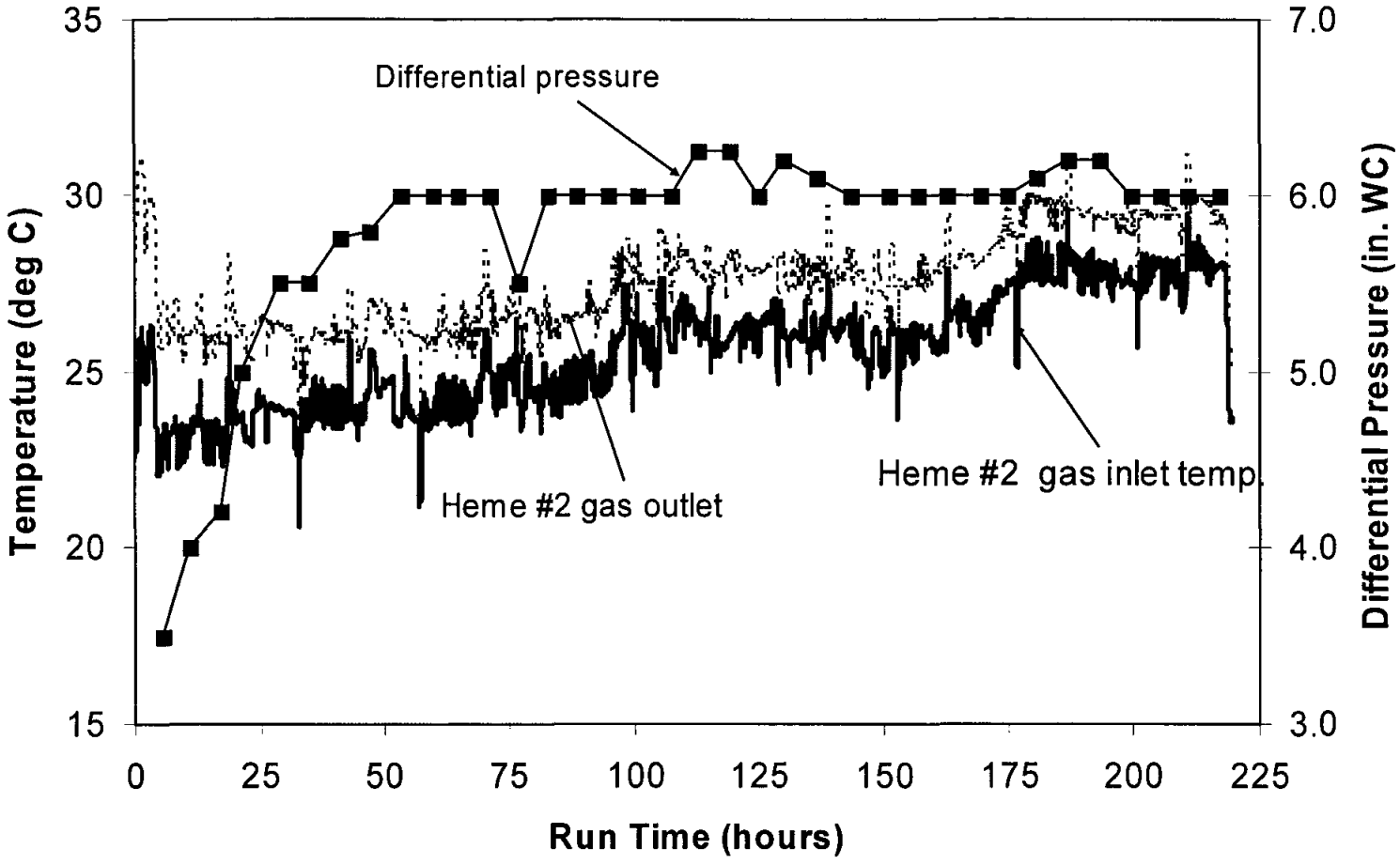

Figure 5.31. Inlet and outlet temperatures and differential pressure for HEME #2.

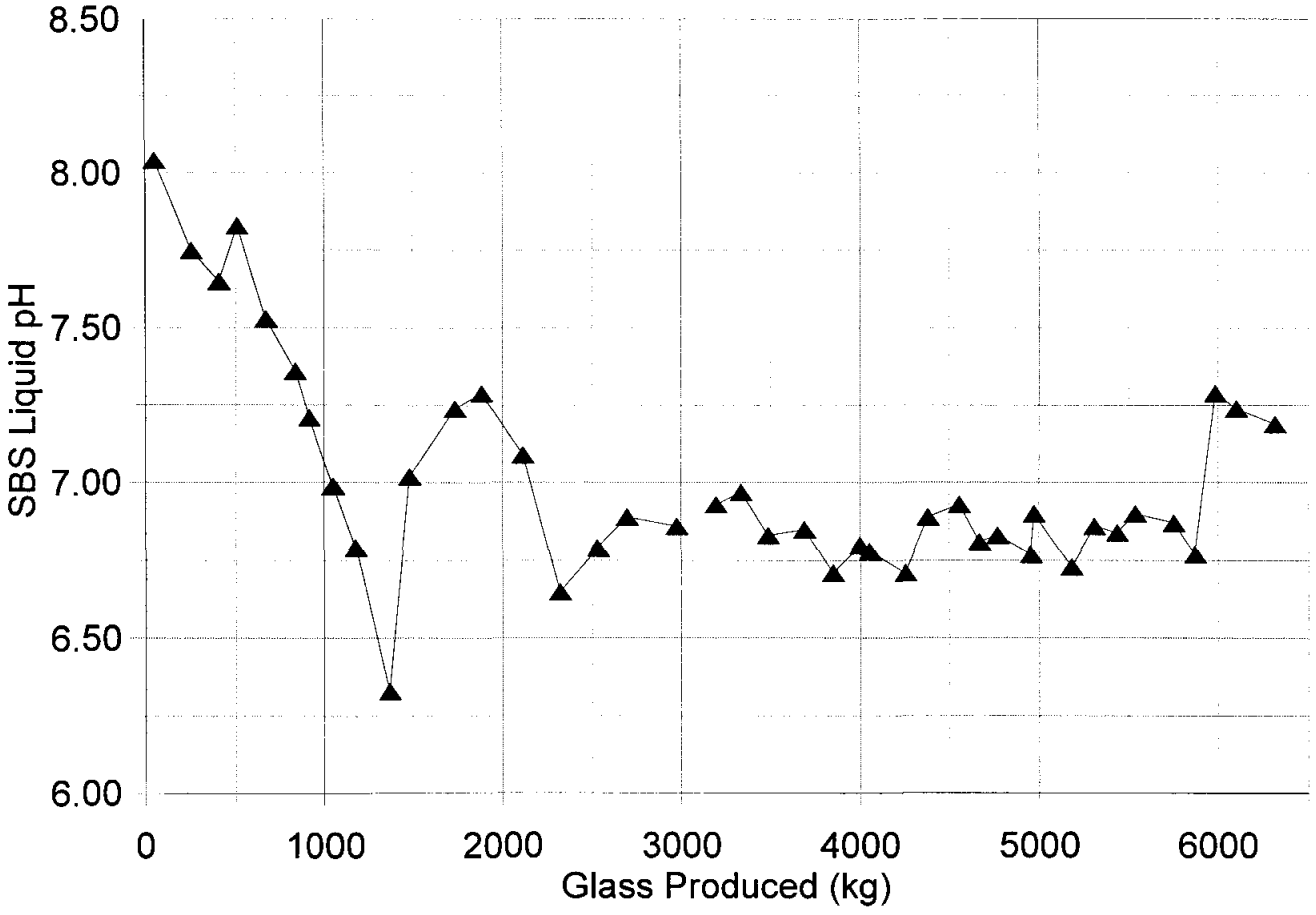

Figure 5.32. pH of SBS blow-down solutions.

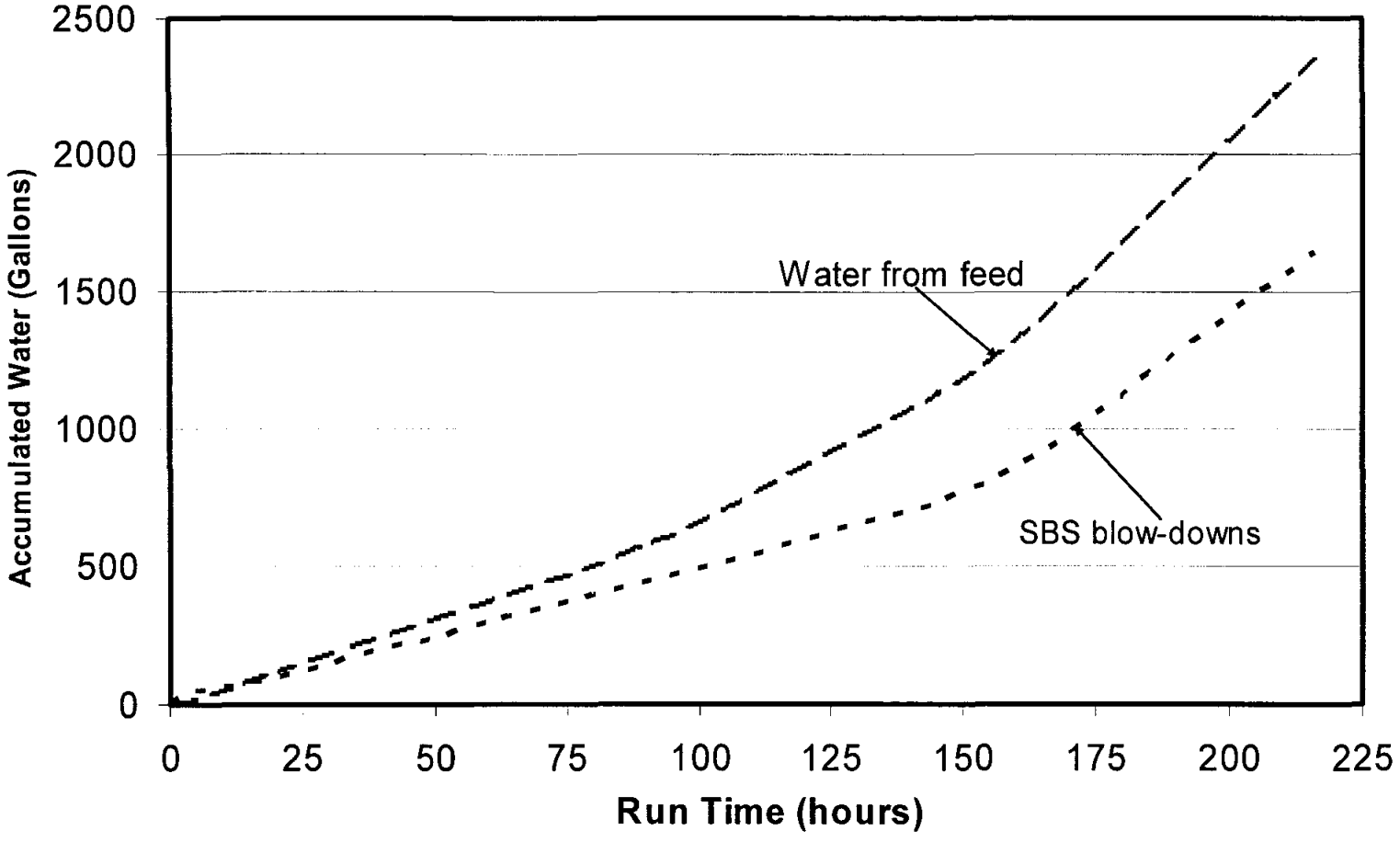

Figure 5.33. Accumulated SBS blow-down volume and average accumulated feed water.

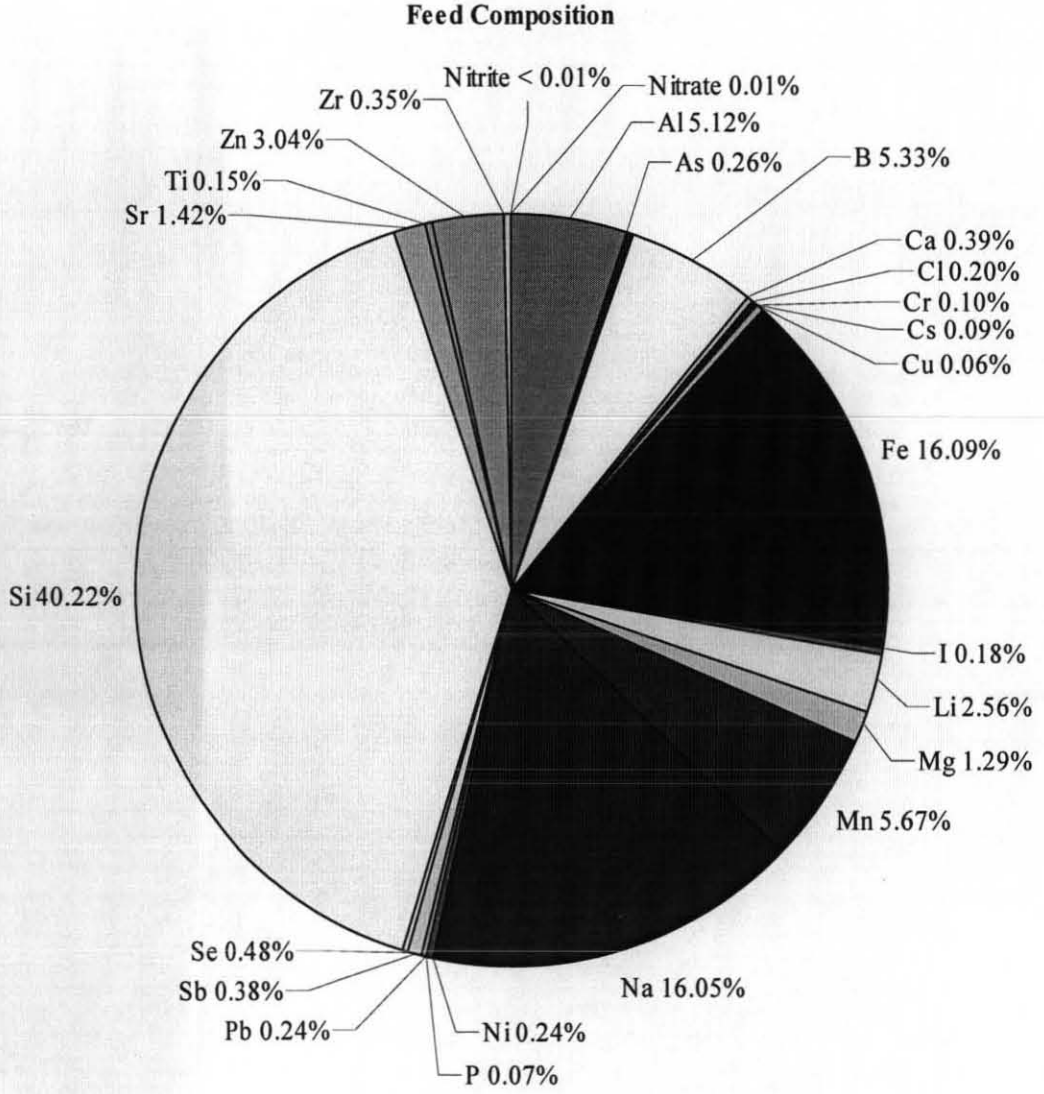

Figure 5.34. Feed composition (excludes oxygen and carbon).

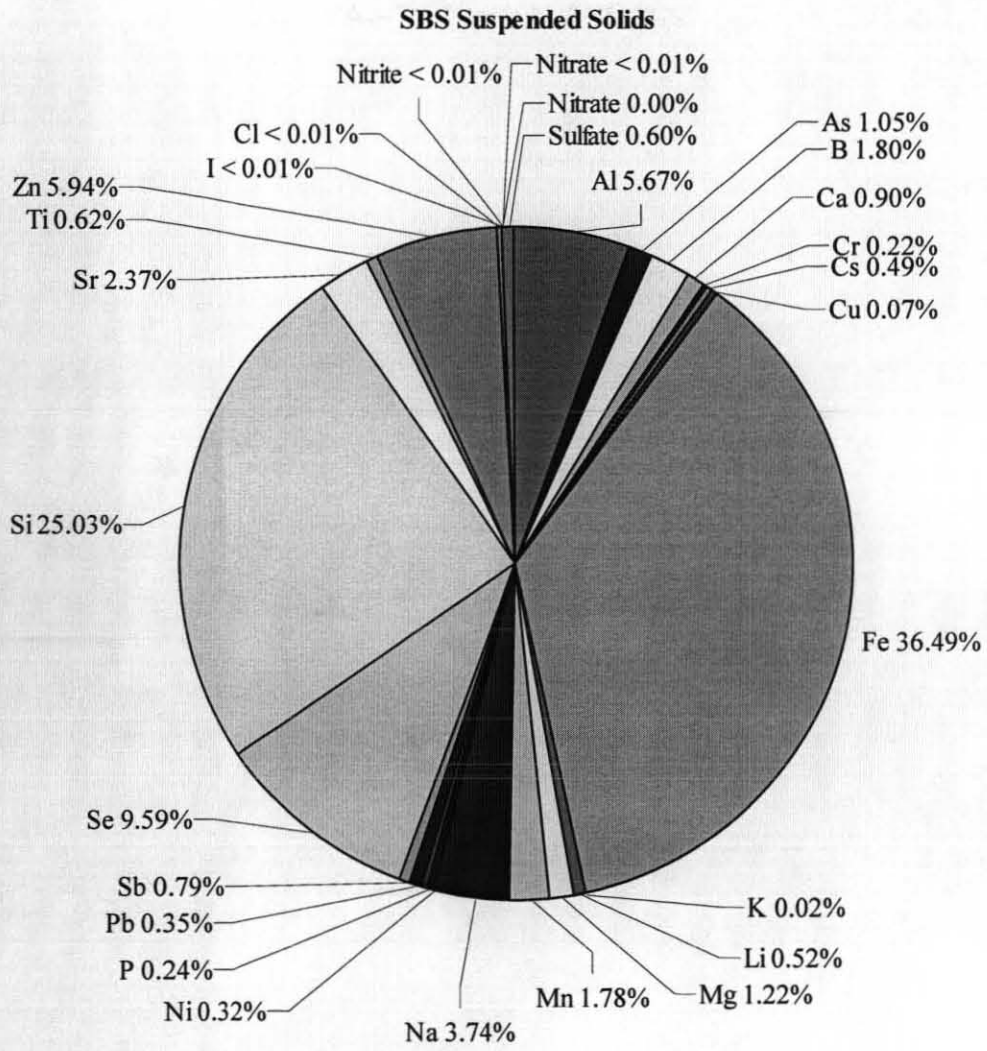

Figure 5.35. Suspended solids composition from SBS sample (012-S-33A)

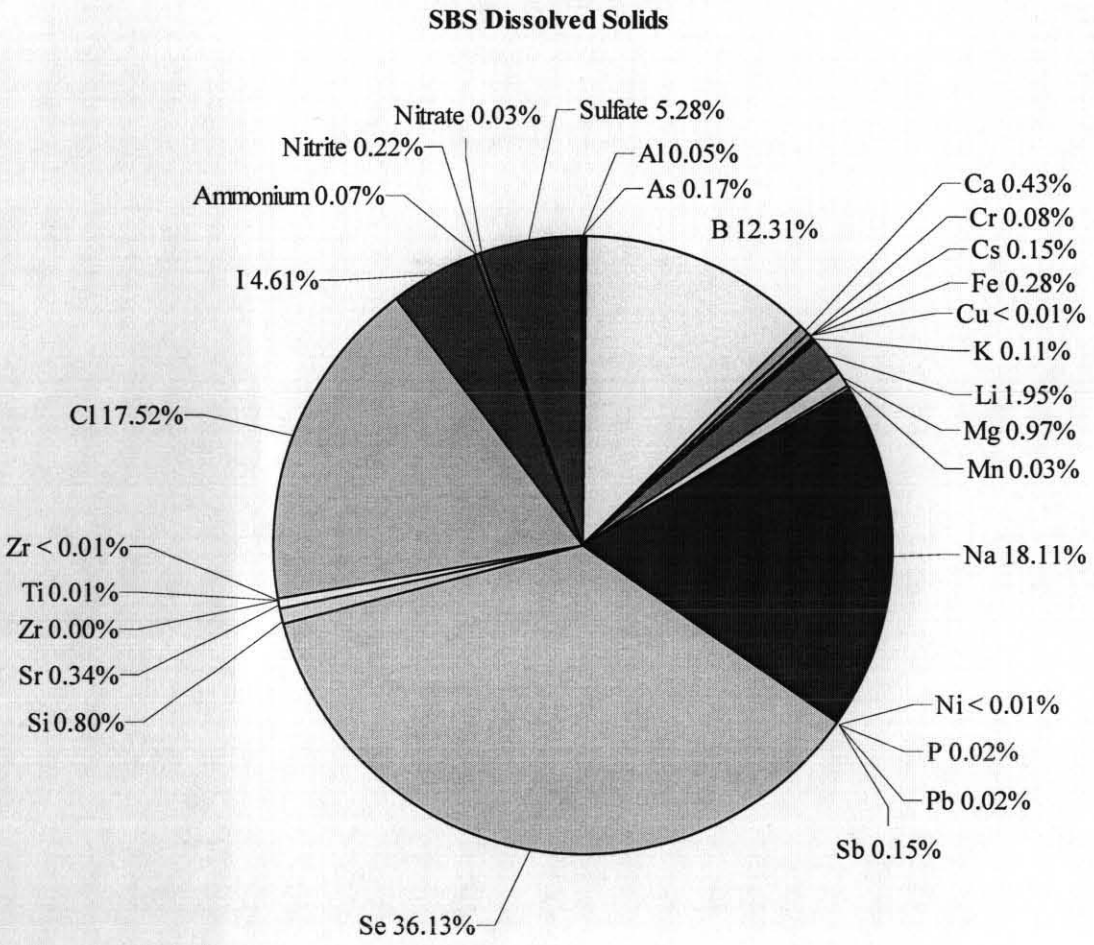

Figure 5.36. Dissolved solids composition from SBS sample (012-S-33A).

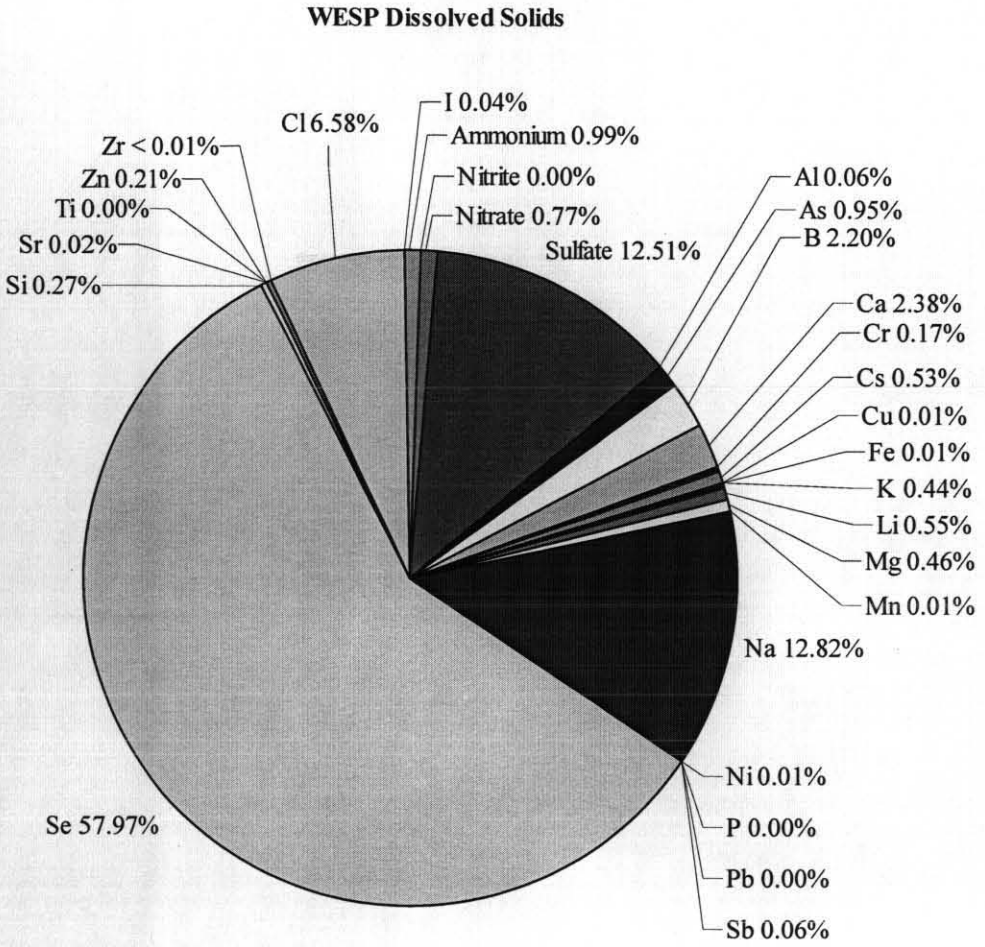

Figure 5.37. Dissolved solids composition from WESP sample (N12-W-142A).

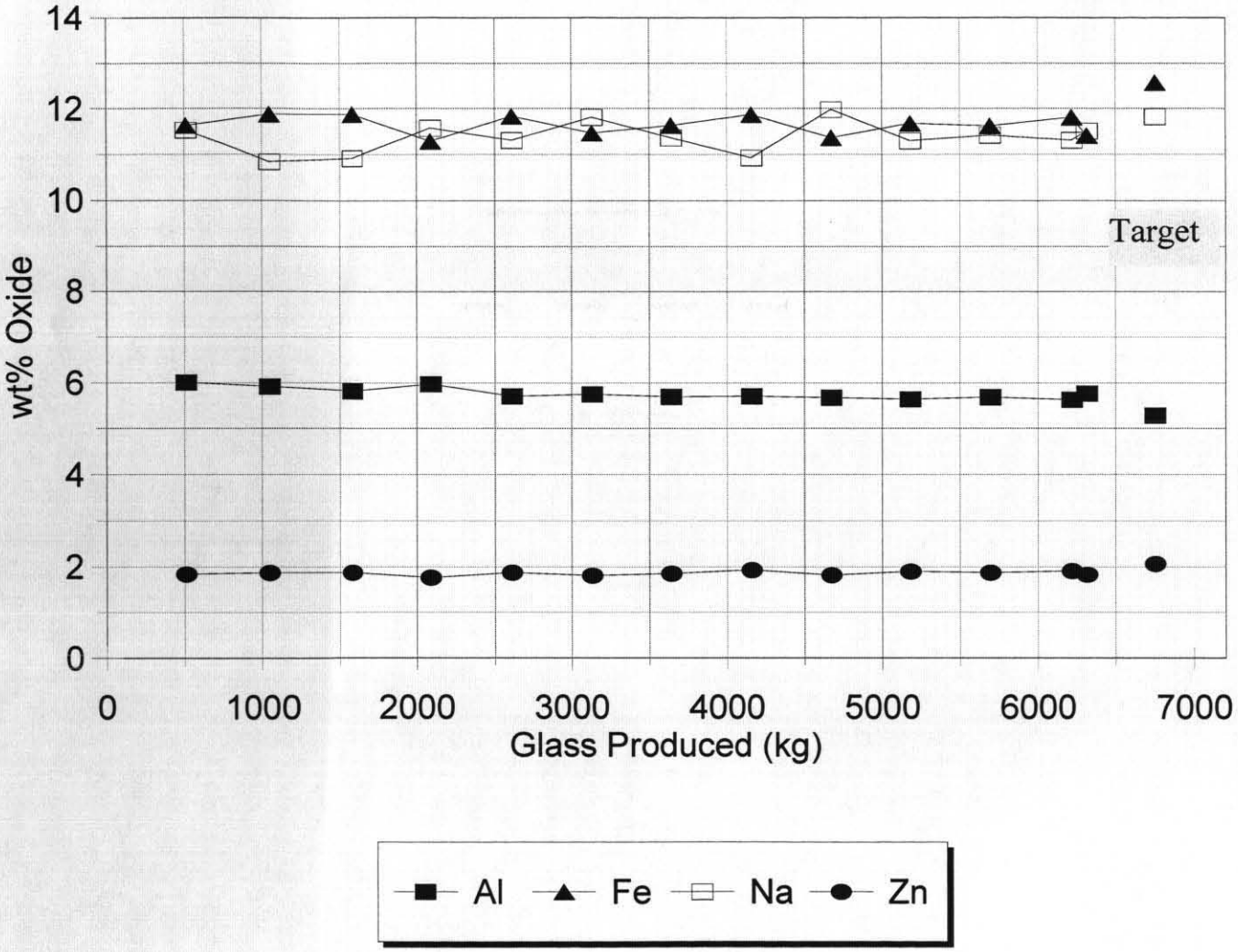

Figure 6.1. XRF analysis of selected DM1200 glasses.

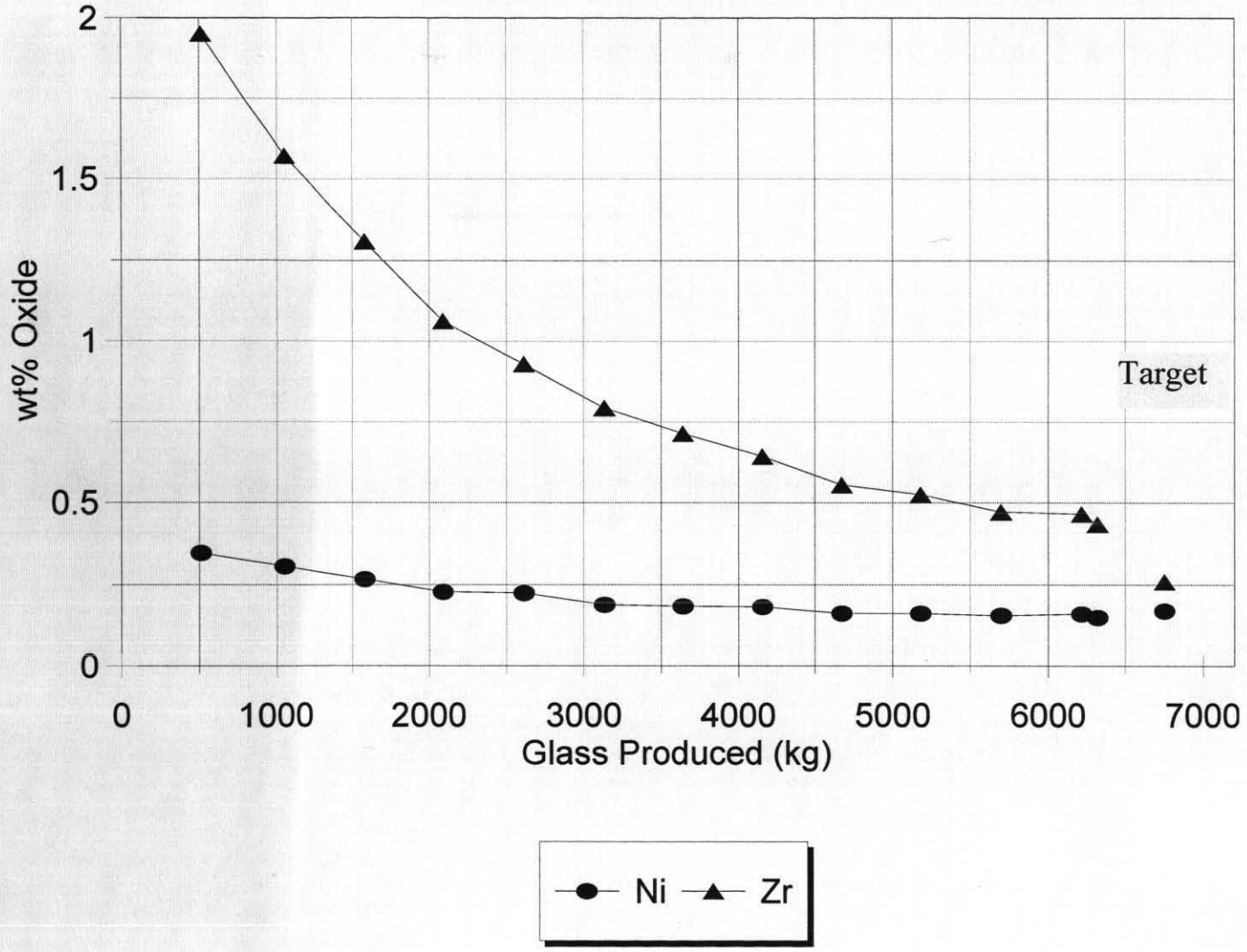

Figure 6.2 XRF analysis of oxides decreasing in concentration during DM1200 test.

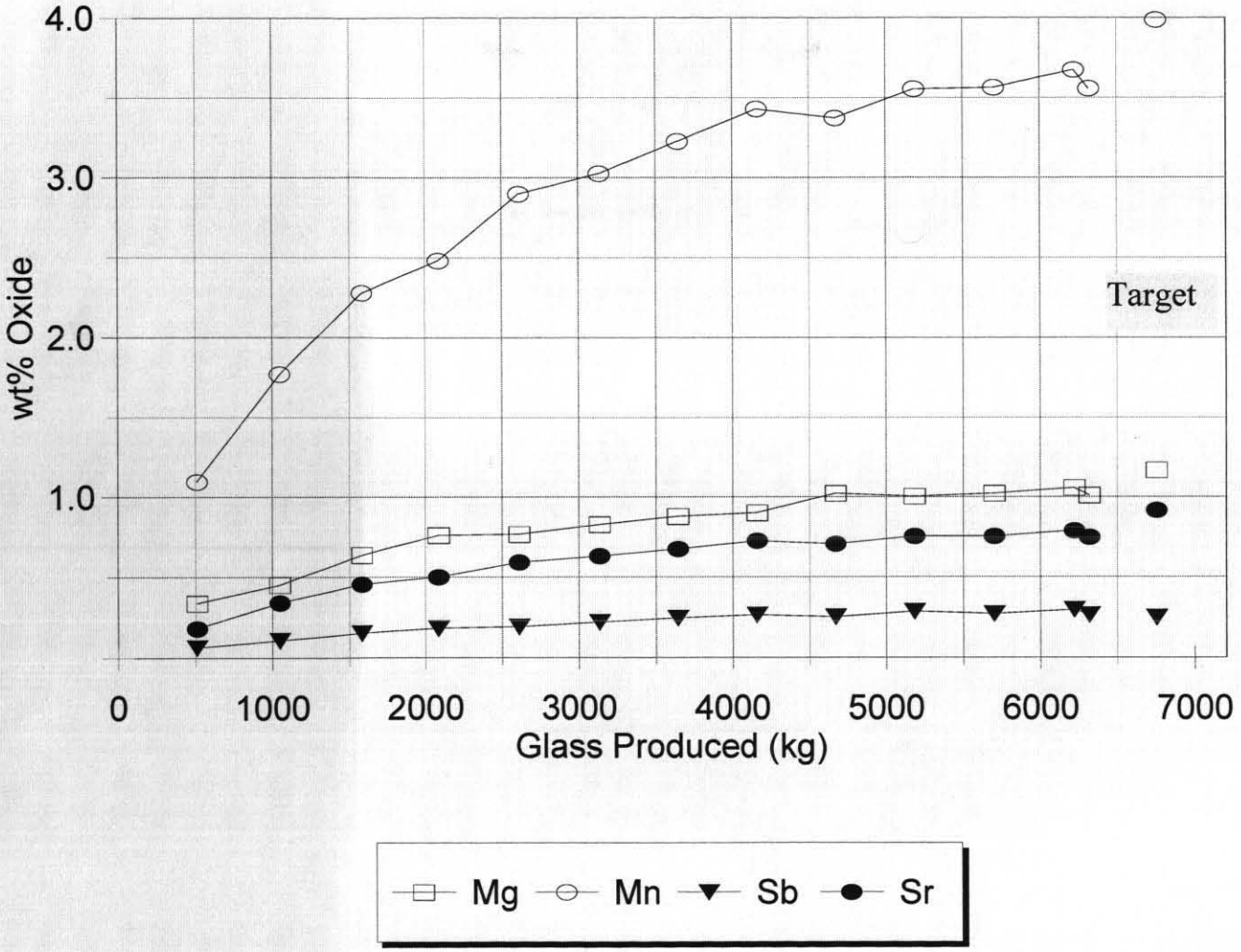

Figure 6.3. XRF analysis of oxides increasing in concentration during DM1200 test.

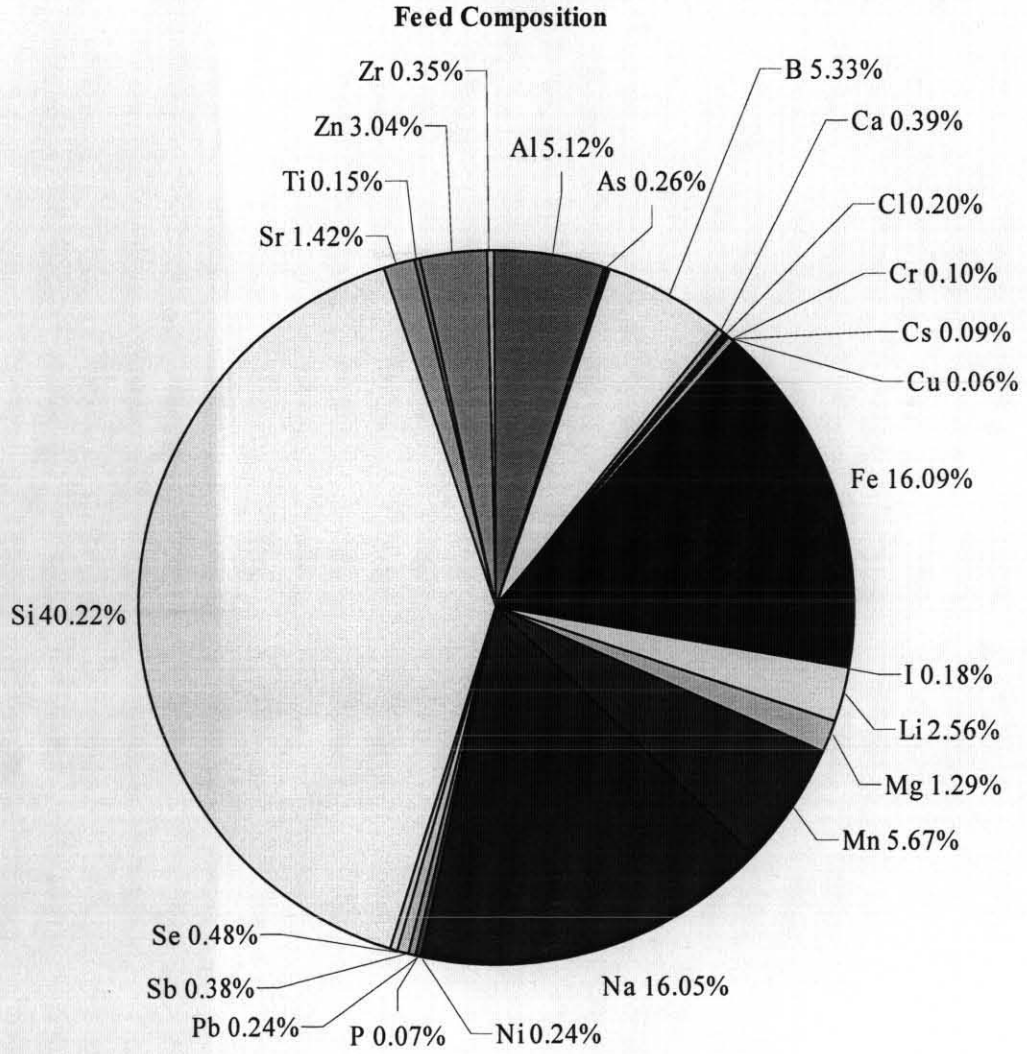

Figure 7.1. Feed composition (excludes oxygen, nitrogen and carbon compounds).

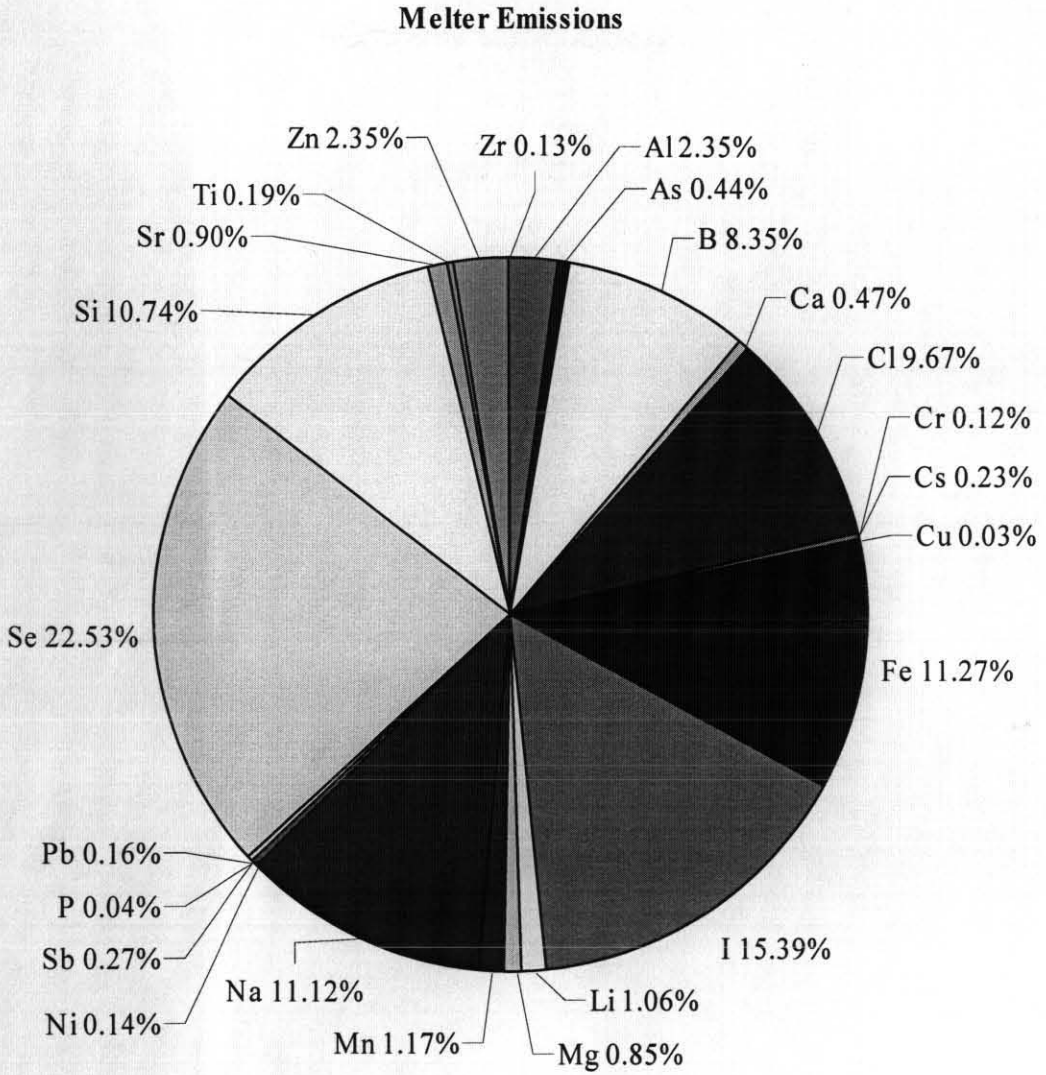

Figure 7.2. Melter exhaust composition (excludes oxygen, nitrogen and carbon compounds) for DM1200 Tests.

SBS Emissions

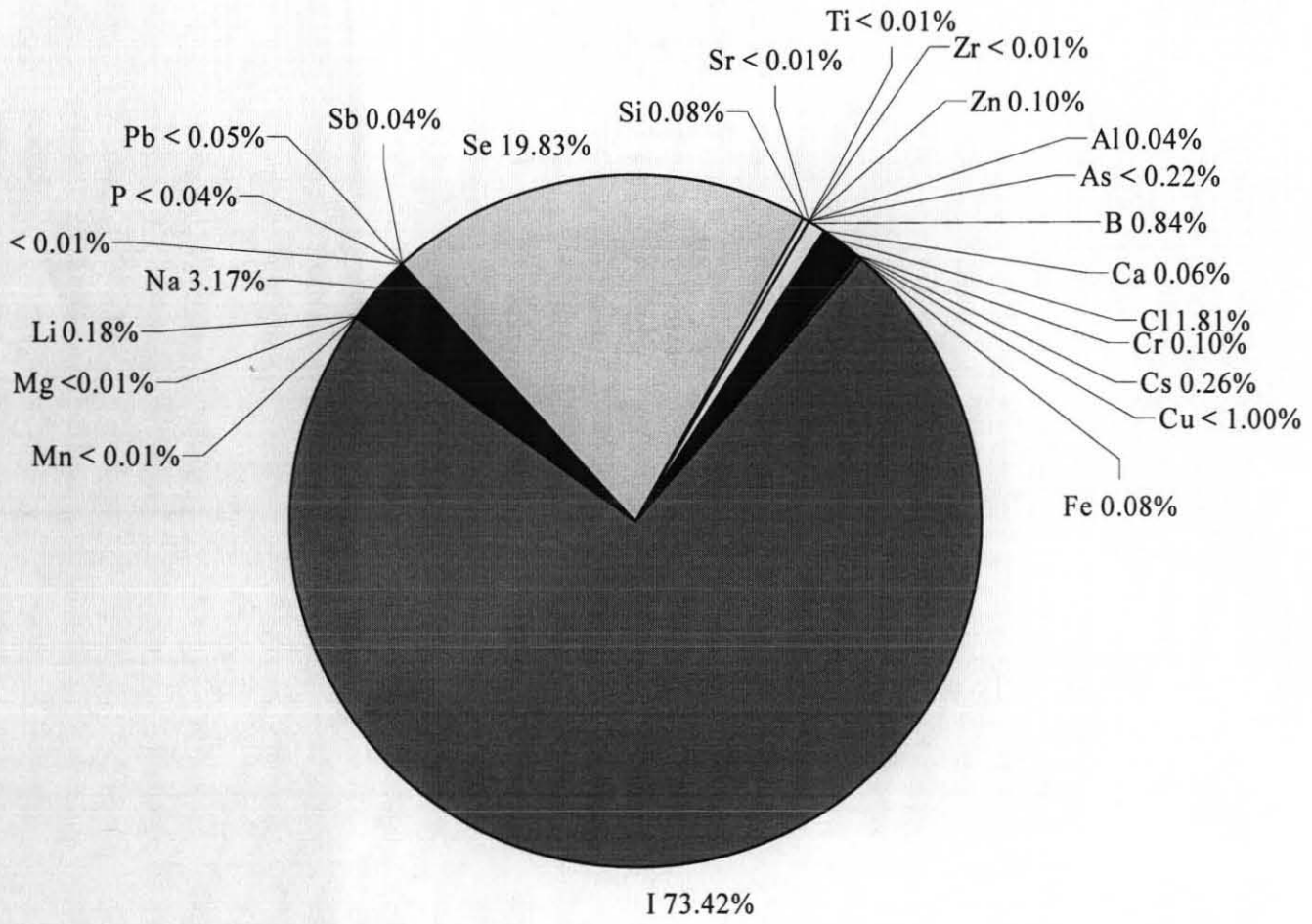

Figure 7.3. SBS exhaust composition (excludes oxygen, nitrogen, and carbon compounds).

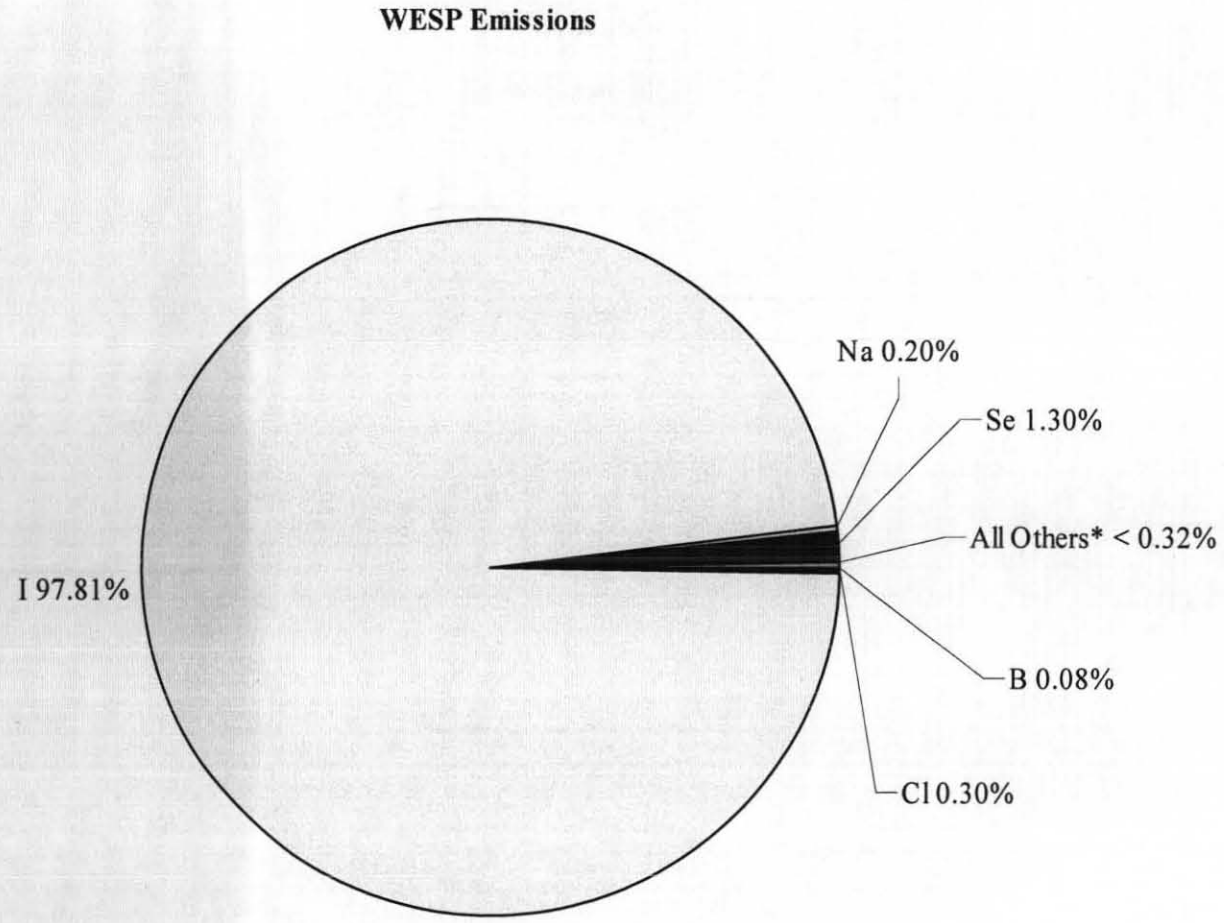

Figure 7.4. WESP exhaust composition (excludes oxygen, nitrogen, and carbon compounds).

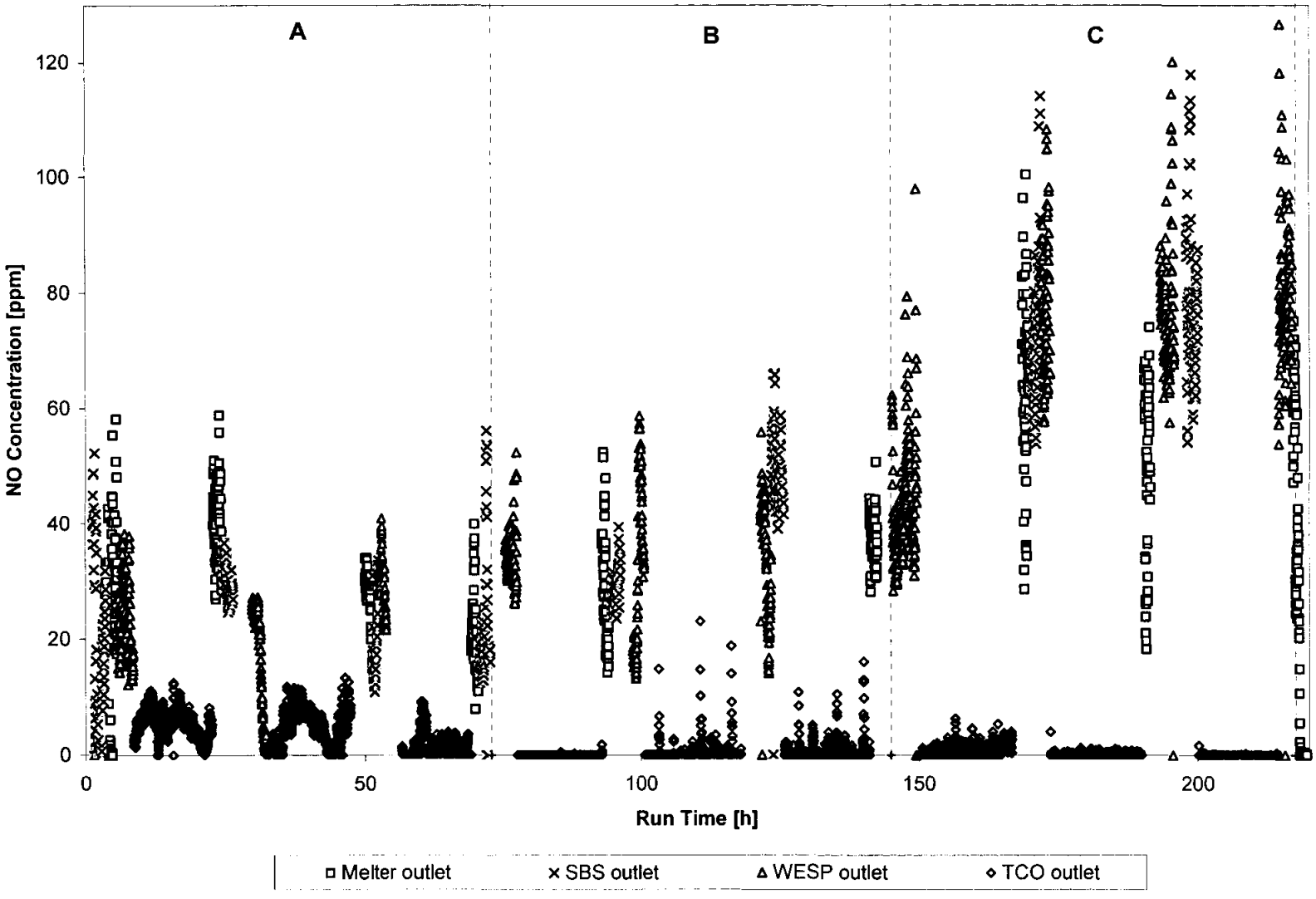

Figure 7.5. Concentration of NO at various points in the off-gas stream.
Sample ports (refer to Figure 1.3): Melter = S3; SBS = S5; WESP = S7; TCO = S9

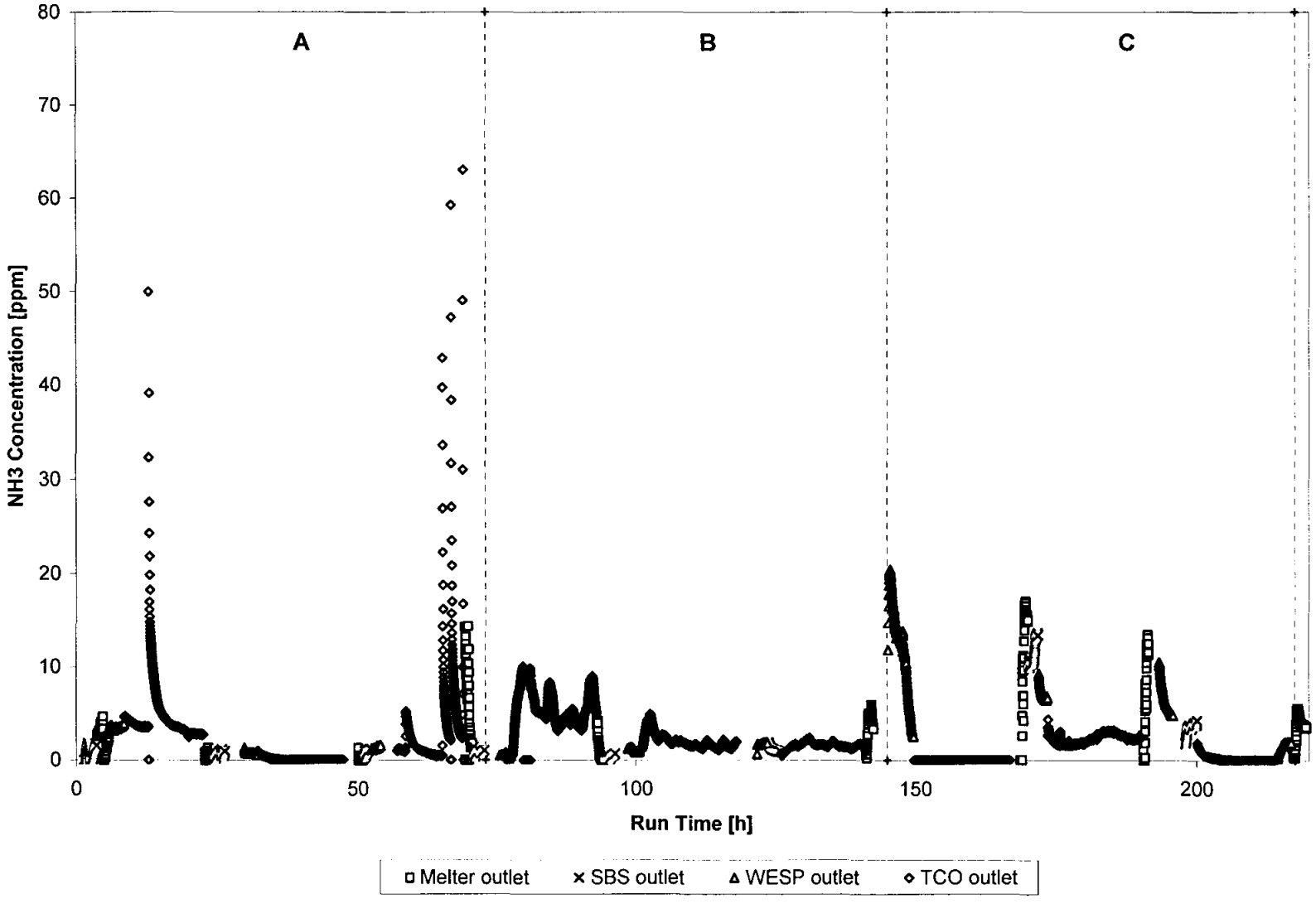

Figure 7.6. Concentration of NH_3 at various points in the off-gas stream.
Sample ports (refer to Figure 1.3): Melter = S3; SBS = S5; WESP = S7; TCO = S9

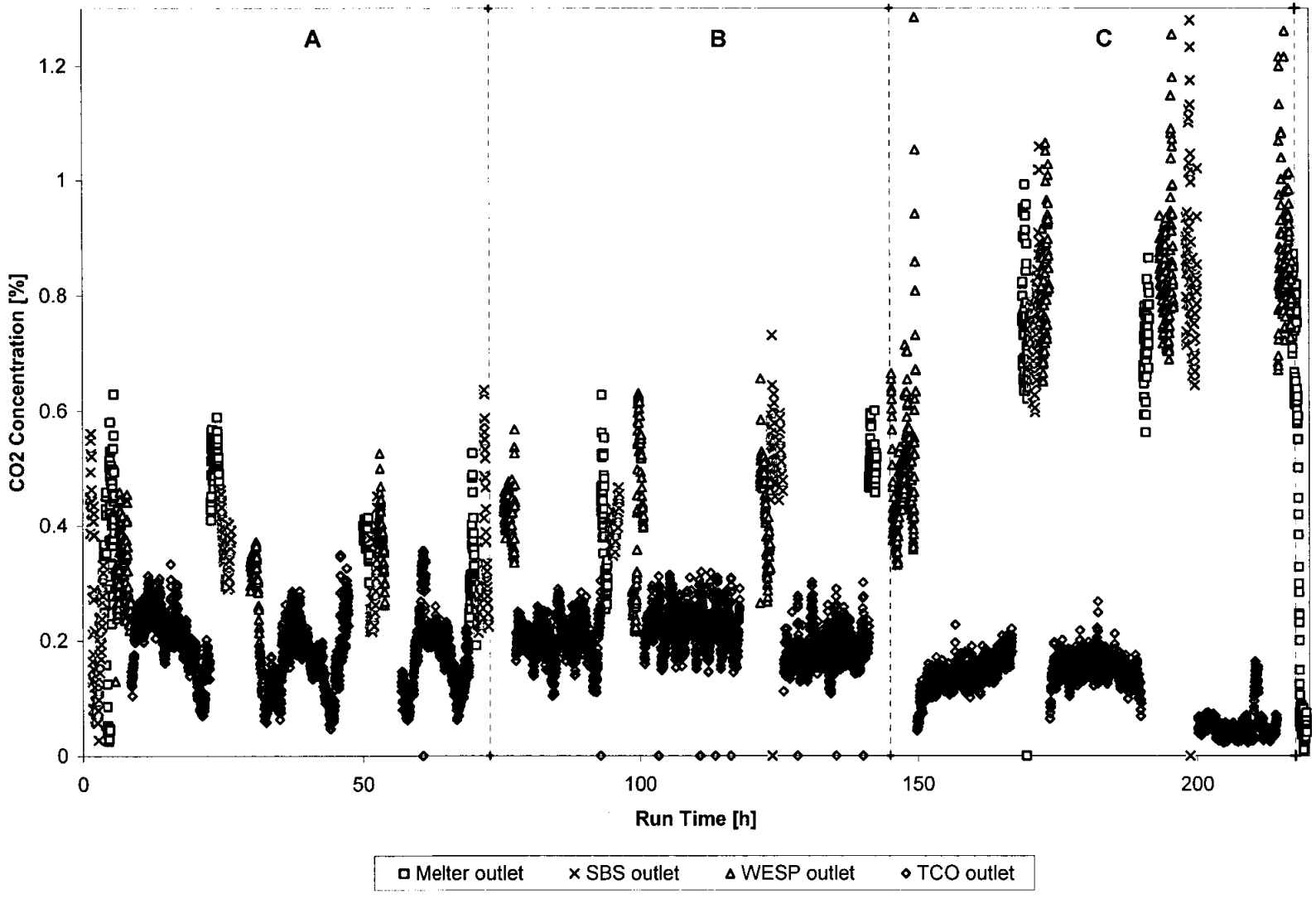

Figure 7.7. Concentration of CO_2 at various points in the off-gas stream.
Sample ports (refer to Figure 1.3): Melter = S3; SBS = S5; WESP = S7; TCO = S9

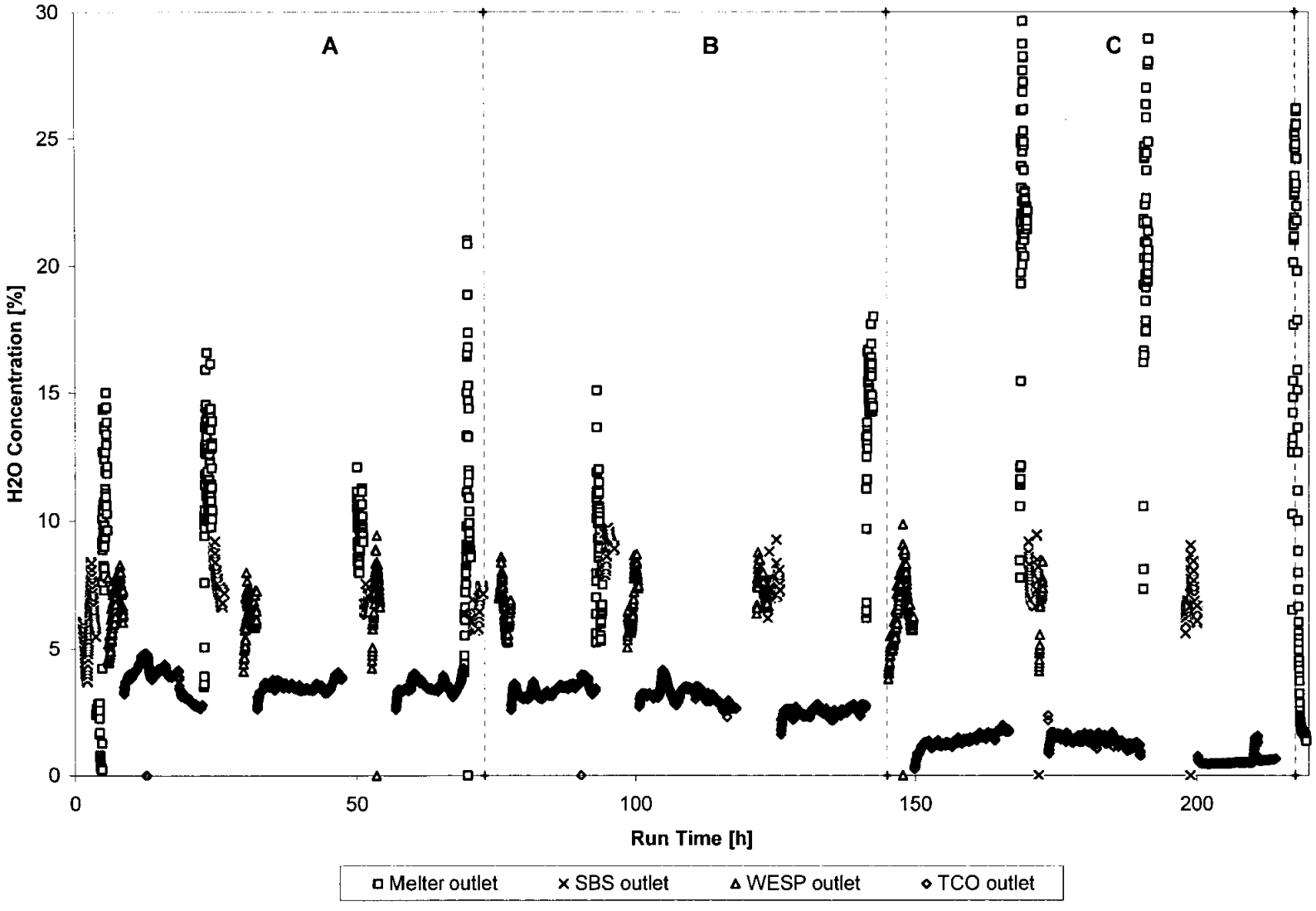

Figure 7.8. Concentration of water at various points in the off-gas stream.
Sample ports (refer to Figure 1.3): Melter = S3; SBS = S5; WESP = S7; TCO = S9

R&T Subcontractor Document Review Record

1) To Be Completed by Cognizant R&T Personnel		
Document Number VSL-03R3800-1	Revision A	Document Title Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers
Test Spec: 24590-HLW-TSP-RT-02-005, Rev 0		Scoping Statement(s): VH-1

R&T Contact:	JM Perez	1-B	371-8444	5/14/03
	Name (Print)	MSIN	Telephone Number	Date

Review Distribution

Organization	Contact	MSIN	Mandatory?
Process Operations	Ernie Lee	MS-1C	Yes ☒ No ☐
Quality Assurance	S Sunday	MS14-4B	Yes ☐ No ☒
Environmental and Nuclear Safety	E Sauceda	MS6-N1	Yes ☒ No ☐
HLW APM	Phil Schuetz	MS5-L	Yes ☐ No ☒
R&T Vitrification	S Barnes	MS1-B	Yes ☐ No ☒
Process Engineering	M Hyman	MS4-B2	Yes ☒ No ☐
Operations	K. Vermillion	MS12-2B	Yes ☒ No ☐

Comments Due By: May 28, 2003

Mandatory Reviewers are required to respond to the R&T Contact.

2) To be Completed by Reviewer

Reviewer _____ (Name (Print)) _____ (Organization) _____ (Date)

☐	☐	☐	☐
Accepted, No Comments	Accepted, Comments Not Significant	Significant Comments, Form 24590-MGT-F00006 Attached	Significant Comments, Comments marked on document.

3) To be Completed by Reviewer*

My significant comments have been addressed.

Acceptance: _____ (*Print/Type Name*) _____ (*Signature*) _____ (*Date*)

* *An E-mail to the R&T contact stating that significant comments are addressed can substitute for this acceptance.*

COMMENT RESOLUTION FORM

Return to: JM Perez

Comments Due: May 28, 2003

Document Title: Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubbler	Document No. VSL-03R3800-1	Revision: A	Date: May 14, 2003
Reviewer: Jacob Reynolds for Proc. Ops. Date: 04/19/03	Response by: Date: None required — LPerez 10/7/03	Comments Resolved: Date:	

Item No.	Section/ Paragraph	Comment	Response	Significance [a]	Resolution	Incorporated?
1	Table 2.4. and section 2.3.2.	The Viscosity should reported as "apparent Viscosity" rather than just viscosity, because apparent viscosity is what is measrured.				

ORP-51439, Rev. 0

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[a] **Significance**: M = Mandatory; Mandatory comments are limited to those comments that are technical or requirements related. Mandatory comments must be resolved. If comments are not mandatory, leave this block blank.

COMMENT RESOLUTION FORM

Return to: JM Perez

Comments Due: May 28, 2003

Document Title: Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubbler	Document No. VSL-03R3800-1	Revision: A	Date: May 14, 2003

Reviewer:	Date:	Response by:	Date:	Comments Resolved:	Date:
David B. MacPherson QA Ronald D. Reed	6/10/2003	None required 10/9/03			

Item No.	Section/ Paragraph	Comment	Response	Significance [a]	Resolution	Incorporated?
1	9.0/5	Reference [5] is incomplete. Missing part of title and Document #.				

ORP-51439, Rev 0

157

[a] **Significance**: M = Mandatory; Mandatory comments are limited to those comments that are technical or requirements related. Mandatory comments must be resolved. If comments are not mandatory, leave this block blank.

Perez, Joseph

From: Sauceda, Ermelinda
Sent: Wednesday, April 16, 2003 1:58 PM
To: Perez, Joseph
Subject: VSL-03T3800-1

E&NS CONCURS WITH VSL-03T3800-1, REV. B, "Integrated DM1200 Melter Testing of Bubbler Configuration and Flow Sheet Changes Using HLW AZ-101 and C-106/AY-102 Compositions"

Note: No comments were submitted
— Perez 4/16/03

Emmy :)~
Administrative Specialist
Environmental & Nuclear Safety
MPF-C105/MS4-C1
Phone: 371-3440
Fax: 371-3511
esauceda@bechtel.com

Perez, Joseph

From: Hyman, Marve
Sent: Tuesday, October 07, 2003 9:22 AM
To: Perez, Joseph
Cc: Blodgett, Stephanie
Subject: FW: Concurrence: VSL-03R3800-1, Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers

Joe: D Mitchell, D Carl, J Rouse and Y Nurdogen have all accepted the responses, and on behalf of Engineering we concur with Document VSL-03R3800-1 Rev 0.
Marve

-----Original Message-----
From: Mitchell, Dolores E
Sent: Monday, September 22, 2003 10:22 AM
To: Hyman, Marve
Subject: RE: Review of comment dispositions for VSL-03R3800-1, Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers

DM1: Concur, but whenever possible when conducting future such tests, prototypic materials need to be considered. This could be as simple as placing coupons, or other specimens in areas of question or concern. In general, Mechanical and Process staff who are working on materials issues should be involved in test plan review.

DM2: Concur

-----Original Message-----
From: Hyman, Marve
Sent: Monday, September 22, 2003 9:50 AM
To: Mitchell, Dolores E; Rouse, James
Cc: Nurdogan, Yakup; Blodgett, Stephanie; Ongpin, Maria
Subject: FW: Review of comment dispositions for VSL-03R3800-1, Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers

Dolores and Jim: please reply or concur for Item No's with initials DM and JR.

Yakup: Please reply or concur - let me know your answers.
Thanks, Marve

-----Original Message-----
From: Perez, Joseph
Sent: Friday, September 19, 2003 9:47 AM
To: Carl, Daniel; Nurdogan, Yakup; Hyman, David (Vernon); Hyman, Marve
Subject: Review of comment dispositions for VSL-03R3800-1, Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers

VSL has returned comment dispositions and a revised report for project review and closure of the comments. Please have the commentors review the dispositions and send me your acceptance or exceptions to the comment responses. The report should not be sent out for re-review but should be used to verify acceptable document revision in response to the comments.

A response is needed by Friday, September 26th.

Marv, I could not discern all of your reviewers initials. Please forward to the one or two others I did not address this message to.

The report and comment responses are at:

wtps0027\Vitrification\HLW Mltr Tstg\DM1200\C106-AY102 Testing\Final Report

<< File: Pro Eng Cmnts VSL-03R3800-1_dc-c.doc >>

COMMENT RESOLUTION FORM

Return to: JM Perez

Comments Due: May 28, 2003

Document Title: Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubbler	Document No. VSL-03R3800-1	Revision: A	Date: May 14, 2003

Reviewer:	Date:	Response by:	Date:	Comments Resolved:	Date:
Y Nurdogen (supplements comments coordinated by M Hyman on 28 May 03)	2 June 03 Engineering	VSL	9/15/03	Yes Per attached email JCraig	10/7/03

Item No.	Section/ Paragraph	Comment	Response	Significance [a]	Resolution	Incorporated?
YN1	Editorial	Add an executive summary, list of tables, and list of figures sections. The letter are merged in some words. See page 18, 1st par, line 8 for the word "half" and page37, 2nd par, line 1 for the word "intended". I checked the electronic version and it is not a printer problem. Section 5.0's title contains the word "Performance". Drop the word "Performance" from Sec 5.1.2 and 5.1.3 or add it to other Sub-Sections to be consistent.	Sections added. Regarding letter merging, this apparently was a problem only in the pdf version; the Word file is OK. This will be checked in the final pdf version. We believe that the title of Section 5 is best left as it. The titles of subsections are not inconsistent.			
YN2	Sec 1.0	Add a sentence explaining test segments A, B, and C. Tables show data from the test segments A, B, and C, but it is difficult to see how these segments differ. Add a description in the text, possibly under Sec 4.0 (DM1200 Operations) or Sec1.2 or Section 1.4.	Added some words to Section 1.0 and 1.2. Added some reminders to Table 4.2 and 4.3.	M		
YN3	Sec 1.1	16 objectives are listed, but we don't know which ones were met at the and of the testing. Report does not discuss test results against the objectives set in the work plan. Conclusions in 2nd par indicates that extensive sets of process engineering data were collected, but it is not clear if any design assumptions were verified with this pilot-scale testing. Please list the design assumptions that verified. Objectives sections would be a good place to list which design assumptions were studied with this pilot testing.	Added Table 8.1 to show which test objectives were met and points to Report Section where information is provided. This Table is referenced in Section 8.0. Note: We don not combine objectives if they are separately called out in the Test Specification itself.	M		

Return to: JM Perez

Comments Due: May 28, 2003

Document Title: Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubbler		Document No. VSL-03R3800-1		Revision: A	Date: May 14, 2003
Reviewer: Y Nurdogen (supplements comments coordinated by M Hyman on 28 May 03)	Date: 2 June 03	Response by: VSL	Date: 9/15/03	Comments Resolved:	Date:

Item No.	Section/ Paragraph	Comment	Response	Significance [a]	Resolution	Incorporated?
		Move objective #5 to #3 position. If objectives #4 and #16 have been completed under another test plan, why do we list it here again? Combine objectives #6 and #15				
MH1	1.4.3	In the paragraph following "Liquid Processing" the opening phrase should read as follows: Except for missing a carbon column for mercury removal and other minor exceptions, . . .	Changes made to Section 1.4.3.	M		
YN4	Sec 1.4.3, Page 9, 1st par	Explain what are the minor exceptions. What is missing?	Same comment as previous.			
DM1	1.4.3, 3rd-to-last para	Where alloys were used, state which of the materials of construction in the off-gas system are not prototypic. For example, C22 (Hastelloy) is to used in the WTP melter off-gas ducting.	Added a sentence to Section 1.4.3 referencing the off-gas report for specific information on off-gas components. The present report does not address prototypicality of materials of construction.	M		
DC 01	2.3.3, etc.	(D. Carl) Add specific description of how the compositions were normalized. Credibility of analytical data for technical use is diminished when the individual analytes sum to 100.00% unless the normalization has logic rules. One such rule would be to flag analyses which have a sum that deviates from 100.00% by more than 1.00% before normalization.	A sum of 100.00% implies nothing about the technical credibility of the data, only that the results are clearly normalized. This comment appears to be motivated by considerations with respect to solution analytical data from ICP etc. However, the data in question are from XRF where normalization is integral to the data analysis. No change made to report.	M		

Perez, Joseph

From: Beaumier, Cynthia
Sent: Wednesday, May 28, 2003 1:14 PM
To: Perez, Joseph
Cc: Vermillion, Karen
Subject: RE: Operations Review of the Integrated DM1200 Bubbler Testing VSL-03R3800-1, Rev A

Comment resolved for the draft VSL-03R3800-1 Revision A. – Operations, C&T 10/7/03

Thanks.

-----Original Message-----
From: Perez, Joseph
Sent: Tuesday, May 27, 2003 1:05 PM
To: Beaumier, Cynthia
Cc: Vermillion, Karen
Subject: RE: Operations Review of the Integrated DM1200 Bubbler Testing VSL-03R3800-1, Rev A

report 9/19/03

Cynthia, attached is the response to your mandatory comment on the subject ~~test plan~~. Please convey whether your comment is resolved either by e:mail or signed hard copies of the comment form and review request form.

Thanks, << File: CRF Integrated DM1200 Melter Testing of HLW C-106 - AY-102 Composition Using Bubblers.doc >>

Joe Perez
R&T/WTP
Ph.: 509.371.8444
Fax: 509.371.8346

-----Original Message-----
From: Beaumier, Cynthia
Sent: Tuesday, May 27, 2003 12:02 PM
To: Perez, Joseph
Cc: Vermillion, Karen
Subject: Operations Review of the Integrated DM1200 Bubbler Testing VSL-03R3800-1, Rev A

Attached are Operations comments on the following document:

Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers, VSL-03R3800-1, Rev A

Thanks.

<< File: CRF Integrated DM1200 Melter Testing of HLW C-106 - AY-102 Composition Using Bubblers.doc >>

C&T COMMENT RESOLUTION FORM

Return to: J. M. Perez

Comments Due: May 28, 2003

Document Title: Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubbler	Document No. VSL-03R3800-1	Revision: A	Date: May 14, 2003

Reviewer:	Date:	Response by:	Date:	Comments Resolved:	Date:
C. W. Beaumier, Operations	5/27/03	JM Perez	5/27/03	Yes - per attached e-mail	5/28/03

Item No.	Section/ Paragraph	Comment	Response	Significance[a]	Resolution	Incorporated?
1	Page 25, Silver Mordenite description	The testing described has the silver mordenite column following the SCR. Comments resolution on the test plan (VSL-03T3800-1) indicated that the silver mordenite column would be relocated to before the SCR. Why was the proposed plant configuration not tested?	The testing conducted and reported here preceeded the decision to relocate the column. The testing being conducted under VSL-03T3800-1 is currently underway and is being conducted with the column upstream of the TCO/SCR unit.	M		
2		ALARA: N/A – I have reviewed this criteria and have determined it is not applicable to this document.	No response required.		N/A	N/A
3		ACCESSIBILITY: N/A – I have reviewed this criteria and have determined it is not applicable to this document.	No response required.		N/A	N/A
4		OPERABILITY: No Comment – I have reviewed this criteria and find the document acceptable.	No response required.		N/A	N/A
5		MAINTAINABILITY: No Comment – I have reviewed this criteria and find the document acceptable.	No response required.		N/A	N/A
6		TESTABILITY: N/A – I have reviewed this criteria and have determined it is not applicable to this document.	No response required.		N/A	N/A
7		OPERATOR ROUNDS: N/A – I have	No response required.		N/A	N/A

ORP-51439, Rev. 0

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Research and Technology Completion Form

R&T Scoping Statement(s):	VH-4, VH-5, VHO-3
Test Specification Number/Title:	24590-HLW-TSP-RT-02-005, Rev 0; Integrated DM1200 Testing of HLW Compositions Using Bubblers, Rev.0
Test Plan Number/Title:	VSL-02T8000-4; Integrated DM1200 Melter Testing of HLW C-106/AY-102 and C-104/AY-101 Compositions Using Bubblers, Rev. 0
Test Report Number/Title:	VSL-03R3800-1; Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers, Rev. 0

Prepared by: J. M. Perez **Date:** 10/07/03

List Test Objectives:	State how objectives were met:
1. Perform analyses, laboratory and small- melter testing, as required, to assess and specify working glass" compositions, glass forming chemicals, and additives utilizing the estimated C-106/AY-102 feed composition in this specification.	Section 2 presents the simulant and glass laboratory testing performed to develop the test compositions. The glass composition selected as the basis for these tests, HLW98-86, is presented in Table 2.2. On an oxide basis, this glass has a total waste loading of 27.75 wt%, of which 25.13 wt% is Envelope D waste. These can be compared with the respective values of 51.00 wt% and 39.42 wt% for HLW98-34, the reference glass used in Part B1. The difference is primarily due to the presence of much more Na_2O in the Part B1 simulant (20.61 wt% vs. 2.11 wt% for the current simulant). The target glass (HLW98-86) is also different from HLW98-34 in that it meets the contract minimum component limit by incorporating 12.56 wt% of Fe2O3 [20], instead of > 21 wt% of ($Al2O_3$+Fe_2O_3+ ZrO_2). Heat treatment at 950°C for over 70 hours of HLW98-86 results in a homogeneous dark brown glass that is free of secondary phases. The viscosity and electrical conductivity measured for HLW98-86AG (at 1150°C), which has the same composition as HLW98-86 except with Ag_2O excluded, are 44 P and 0.36 S/cm, respectively. Finally, the normalized PCT leach rates of HLW98-86 are (in g/(m 2 -day)) 0.058, 0.047, 0.046 and 0.028, respectively, for B, Li, Na, and Si; these values can be compared with those for the reference glass (DWPF-EA) of 1.17, 0.71, 0.80 and 0.27, respectively. The target glass formulation for these tests, which is also given in Table 2.2, differs slightly from HLW98-86, with the removal of silver and the addition of small amounts of cesium and iodine. DM100 testing preceeded DM1200 testing to verify processing characteristics. These results are discussed in Section 3.

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Test Specification Number/Title:	24590-HLW-TSP-RT-02-005, Rev 0; Integrated DM1200 Testing of HLW Compositions Using Bubblers, Rev.0
Test Plan Number/Title:	VSL-02T8000-4; Integrated DM1200 Melter Testing of HLW C-106/AY-102 and C-104/AY-101 Compositions Using Bubblers, Rev. 0
Test Report Number/Title:	VSL-03R3800-1; Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers, Rev. 0

List Test Objectives:	State how objectives were met:
2. Utilizing the DM1200 melter and associated feed handling and off-gas treatment equipment, design and conduct testing in which representative C-106/AY-102 simulant is processed. The duration of tests shall be sufficient to achieve at least four melter glass inventory turnovers (8 MT) for each composition.	Melter tests were conducted on the DM1200 with the HLW C-106/AY-102 simulant between 1/22/03 and 1/31/03, producing over 6,300 kg of glass. Although the required 8 MT of glass was not produced, approx. 3.7 turnovers were achieved and the similarity in glass composition between the preceeding AZ102 composition (see Fig. 6.1 – 6.3) resulted in no observed composition turnover affects. A summary of the test conditions and results is provided in Table 4.1. The total test duration, including the time for water feeding and cold-cap burn-off, was 217.5 hours. Minor foaming occurred on the surface of the glass but diminished as bubbling increased over the course of the test. The exhaust stream was sampled for particles during the last two days of testing after the final steady-state rate was reached.
3. Determine the effect of bubbling rate on melter production rate and operating stability for C-106/AY-102 melter feed.	The test consisted of three 3-day segments of successively higher bubbling rates of 8, 40, and 65 lpm respectively. The measured glass production rate is depicted in Figure 4.1 as cumulative and one- hour moving averages for each of the three segments. The three steady-state production rates (330, 550, and 970 kg/m^2/day) were obtained for at least half of each three-day segment and almost the entirety of the first segment.
4. Fabricate, install and evaluate the performance of the HLW bubbler design and placement recommended by the Duratek design staff.	Two prototypic bubblers were placed in the DM1200 in opposing corners. The depth of the bubblers was also prototypic, placed near the bottom of the side electrodes (19 in. below the glass surface of the DM1200 floor versus 35 in. in the WTP HLW melter), sufficiently away from the walls to prevent wall affects.
5. Characterize the melter emissions (particulate, aerosol, and gaseous) under nominal steady-state operating conditions for inorganic and organic compounds including the effect of air displacement slurry (ADS) pump operation on feed entrainment. Measurement of organic compounds will be satisfied through the use of Fourier Transform Infrared (FTIR) spectrometry and gas chromatography (including H2).	Sections 5 and 7 report the off-gas system performance results. Elemental DF values were determined across the melter, SBS, and WESP. Particle size distributions were determined for the melter emissions. The total solids carryover from the melter (0.67% of feed) was comparable to that observed for tests with other HLW compositions. The ADS pump was used throughout the off-gas sampling period to assure its "contribution" to feed entrainment into the off-gas system was included. Separate testing without the ADS pump was not planned for this test.

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List Test Objectives:	State how objectives were met:
6. Quantify and document the occurrence and associated operating conditions of any melter off-gas volume surging events.	No off-gas surging volume events were reported.
7. Characterize the performance of the primary off-gas treatment equipment (submerged bed scrubber (SBS), wet electrostatic precipitator (WESP) and high-efficiency mist eliminator (HEME)) to remove particulate, aerosol and gas phase emissions under steady-state melter conditions.	Sections 5 and 7 present off-gas characterization results. Calculated DFs across the SBS were the lowest of any of the four HLW compositions, due in part to the much greater amounts of selenium and chlorine in the C-106/AY-102 simulant. Both of these elements exist in the exhaust as fine particles, whereas the SBS is most effective at removing coarse particulate. The WESP, which is effective in collecting finer particles, removed much of the additional particulate material exiting the SBS. As a result, the cumulative DF (Melter+SBS+WESP) was about 105,000 and comparable to other HLW tests conducted while using the daily deluge cleaning procedure of the WESP. Observations during emissions sampling suggest that the majority of the measured particulate exiting the WESP occur while the power is off after the deluge process, rather than as a result of carryover during the deluge. CO levels were measured at the WESP to be <4 ppm. Hydrogen levels were measured to be 31 ppm at the highest feed rate tested (see Table 7.6).
8. Characterize the chemical and physical characteristics of the aqueous streams (feed, SBS, WESP, and caustic scrubber).	Section 5.2 presents aqueous stream characterization results. 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 selenium, halogens, boron, and alkali metals, while the suspended species closely resembled the feed composition. The WESP sump fluid was also in the neutral pH region but had negligible suspended solids. The WESP solutions contained significant concentrations of selenium, sulfate, chloride, and sodium.

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List Test Objectives:	State how objectives were met:
9. Characterize the performance of the secondary off-gas treatment equipment (selective catalytic reduction (SCR) and thermal catalytic oxidizer (TCO) and small-scale silver mordenite column) to treat NOx, organics, and iodine under steady-state melter conditions.	Sections 5.1.7, 5.1.8 and 7.3, 7.4 and 7.5 present secondary off-gas performance results. Sections 5.1.7 and 7.3 present TCO/SCR process and performance results. The silver mordenite column for the removal of iodine installed downstream of TCO/SCR catalyst units was operated for the first time during these tests (see Section 7.5). Off-gas was sampled simultaneously at four locations on the column (inlet, one-third down, two-thirds down, and outlet). Iodine concentrations are given in Table 7.8. No iodine was measured at the column outlet resulting in DF values of over 1000, based on present detection limits.
10. 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.	Feed characterization (section 2), glass characterization (section 6), condensate liquid characterization (section 5.2) and off-gas emissions (section 7) provide adequate data to perform material balance calculations. Process data to support energy balance calculations are provided in sections 4 (melter) and 5 (off-gas equipment).
11. Document general equipment operations (reliability, availability, maintainability, etc.); especially non-routine equipment failure and replacement activities.	Feeding began using the installed, prototypical ADS pump but was switched to the AOD backup system after 93.5 hours into the test. The problem was ultimately traced to the three-way valve actuator which was sticking midway during the purge cycle and that water was constantly leaking into the reservoir. The valve, which it was later determined suffered from a manufacturing defect, was replaced and the ADS system was returned to service at 145 hours into the test (see section 4). Video inspection of the inside of the SBS down-comer was conducted at the end of the test. Views looking downward from inside the SBS inlet pipe showing rings of solids deposited near the bottom are given in Figures 5.14 and 5.15; about 70% of the cross sectional area of the pipe was occluded by solids. All other sysetms operated without difficulty.

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List Test Objectives:	**State how objectives were met:**
12. 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.	For this test, post test video inspections of the SBS off-gas line downcomer (section 5.1.2) and WESP internals (section 5.1.3) were performed. Towards the end of the test it was noticed that the discharge vent air temperature had dropped from about 60°C to about 30°C. An inspection at the end of the test showed large amounts of solids deposited on the discharge chamber vent orifice plate. This is an area that has not been inspected or cleaned during earlier tests. Photographs of the deposits are shown in Figures 5.4 and 5.5. A photograph of the discharge chamber vent orifice plate after cleaning is shown in Figure 5.6.
13. 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.	The melter plenum pressure control using the variable air-injection control method was used for the entire test period. Figure 5.3 documents the control air and plenum pressure throughout the test. Stability was acceptable and is described in section 5.1.1.
14. Operate and evaluate the performance of the air-displacement slurry (ADS) pump under operating conditions that are applicable to expected WTP plant operations.	The ADS pump was used during the test in a prototypic operational mode. Aside from the equipment failures described under Objective #11 above, the pump worked well. Section 4 describes the pump operation. Detailed performance information for the one year of pump operation will be described in a separate report.
List any Test Exceptions:	**Did exceptions impact the objective?** ☐ Yes ☒ No (Explain)
1) None	
List Success Criteria	**Did the test meet the criteria?** ☒ Yes ☐ No (Explain)
1) Conduct testing in which representative simulant of C106/AY102 with Sr/TRU precipitation products and C104/AY101 are processed for periods sufficient to obtain meaningful process data while achieving at least four melter glass inventory turnovers (8 to 9 Mt).	Yes, see Objective #2 summary statements.
2) Submit data defining the effect of bubbler rate on melter production rate and operating stability for each Phase 1 HLW melter feed.	Yes, see Objective #3 summary statements.

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3) Obtain, report and assess melter emissions (particulate, aerosol, and gaseous) data under nominal steady state operating conditions for each test.	Yes, see Objective #5 summary statements.
4) 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.	Yes, see Objective #7 summary statements.
5) Measure and document the chemical and physical characteristics of the aqueous streams (feed, SBS, WESP and caustic scrubber).	Yes, see Objective #8 summary statements.
6) Measure and document the performance of the secondary off-gas treatment equipment (SCR, TCO and small-scale silver mordenite column) to treat NOx and capture iodine emissions under steady state melter conditions.	Yes, see Objective #9 summary statements.
7) Document process measurements that provide mass, energy and momentum 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, see Objective #10 summary statements.
8) Assess and document general equipment operations (reliability, availability, maintainability, etc.), especially non-routine equipment failure and replacement activities.	Yes, see Objective #11 summary statements.
9) Document pre- and post-test inspections of key equipment and process lines to monitor for solids accumulations and corrosion/erosion of materials.	Yes, see Objective #12 summary statements.
10) 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, see Objective #13 summary statements.

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11) Document the performance of the air-displacement slurry pump under operating conditions that are applicable to expected WTP plant operations.	Yes, see Objective #14 summary statements.
List QA Requirements:	**Did the subcontractor meet the requirements?** ☒ Yes ☐ No (Explain)
1) Work to be performed under a NQA-1 approved quality assurance plan.	This work was conducted under an NQA-1 (1989) and NQA-2a (1990) Part 2.7 based quality assurance program. There are no limitations on the use of these data.
List R&T Test Conditions:	**Were test conditions followed?** ☒ Yes ☐ No (Explain)
Melter: • Bulk glass temperature target - 1150°C (typically allowed to vary ± 25°C before power input changes are initiated). • Bubbling rate were determined from the results of AZ-101 tests. • Plenum temperature - 400°C – 450°C (this is a dependent variable whose actual value is the result of cold cap coverage, air in-leakage and other conditions). Film cooler: No special constraints; typically 70 scfm of air at about 100°C. SBS: • Tank temperature - 50°C 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. • Inlet water spray – 2 gph ± 0.2 gph.	Tables 4.2 and 5.1 provide system process measurements. • Test condition met, see Figure 4.2. • Test condition met, 3 bubbler rates; 8, 40 and 65 lpm total bubbler flow were achieved. • Test condition (anticipated) not met but acceptable; average plenum temperatures ranged between 477°C and 564°C (increased with increased bubbler air rate), see Figure 4.3. • Test condition met, film cooler temperature averaged 75°C to 83°C and rates averaged 43 scfm to 60 scfm. • Test condition met, tank temperature averages ranged between 46°C to 52°C, see Figure 5.9. • Test condition met, see Figure 5.19. • Test condition met, see section 5.1.3.

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• As a part of normal operation 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 will be done initially at the normal operating voltage and current. In case an internal discharge develops, the voltage across the electrodes will be adjusted to the point at which a discharge disappears. The time delay before reinstating the initial voltage and current settings will be also investigated and determined. This information will be used to determine the preferred protocol for future deluge operations.	• Test condition met, see section 5.1.3. The information from this test and other DM1200 testing assessing WESP performance will be combined to "determine the preferred protocol for future deluge operations". Testing of the WESP extends through the testing defined under the subject test plan and test specification.
HEMEs: Operate with ~1 gph continuous water spray or per manufacturer's recommendations (< 50 mg/acfm of entrained liquid water).	• Moisture load in off-gas was sufficient to not require the 1gph water spray.
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.	• Test condition met, see section 5.1.5.
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.	• Test condition met, see section 5.1.7.
SCR: • Bed temperature – per the catalyst manufacturer's recommendation (350-400°C) • Ammonia slip (exit concentration) ≤ 25 ppm, if possible.	• Test condition met, see section 5.1.5. • Test condition met, see section 5.1.5.
Silver Mordenite System: • Inlet gas temperature – 130 to 230°C • Inlet gas flow rate – 5 to 35 scfm	• Test condition met, see section 5.1.8.

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

C106/AY102 simulant melter feed was used and is described in Section 2. The composition was based on estimated

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characterization data and expected pretreatment unit operations. The target waste and melter compositions were therefore consistent with radioactive waste within the tolerances of vendor and analytical variability. Actual waste data does not yet exist for key physical properties; pH, rheology, particle size, etc. This comparison will be made when data is available in 2004.

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

Are all subcontractor signoffs completed? ☒ Yes ☐ No

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

This report partially closes the test plan, test specification and scoping statement.

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

1. Throughput rates were demonstrated to exceed the equivalence of 3.0 MT/d assuming a linear scaling of results based on glass surface area and a solids concentration of 20 wt.% undissolved solids (UDS) prior to glass former addition. However, it is projected that the solids concentration will range between 14 and 17 wt.% UDS. Also, R&T has concluded the DM1200 overestimates the expected plant performance by 30% based on the ratio of bubblers per square meter. Future testing will be required to demonstrate alternative bubbler designs to increase the throughput performance.
2. Solids accumulation at the bottom of the SBS off-gas downcomer line continues to occur and is not believed to be due to the attachment to the bottom of the pipe. Further assessment and testing is required to determine SBS performance in this area. Potential modification of the SBS to make this area prototypical of the WTP design may be required to resolve this issue.

Additional comments:

Approved by R&T Manager or Designee:	Date:
for W Tamosaitis	10/17/03