ORP-56287
Revision 0

# Final Report- Testing of Optimized Bubbler Configuration for HLW Melter VSL-13R2950-1, Rev. 0, dated 6/12/2013

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

Office of River Protection

**P.O. Box 450**
**Richland, Washington 99352**

ORP-56287
Revision 0

# Final Report- Testing of Optimized Bubbler Configuration for HLW Melter VSL-13R2950-1, Rev. 0, dated 6/12/2013


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

I. L. Pegg
The Catholic University of America

R. A. Callow
The Catholic University of America

I. Joseph
The Catholic University of America

K. S. Matlack
The Catholic University of America

W. K. Kot
The Catholic University of America



Date Published
June 2013

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

Office of River Protection

**P.O. Box 450**
**Richland, Washington 99352**


APPROVED
By Julia Raymer at 1:37 pm, Nov 13, 2013

Release Approval | Date

**VSL-13R2950-1**

# Final Report

# Testing of Optimized Bubbler Configuration for HLW Melter

*prepared by*

**Keith S. Matlack, Wing K. Kot, Richard A. Callow,**
**Innocent Joseph and Ian L. Pegg**

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

*and*

**Energy*Solutions*, Federal EPC Inc.**
**Columbia, MD 21046**

*for*

**Department of Energy**
**Office of River Protection**
**Richland, WA**

**May 31, 2013**

***Rev. 0, 6/12/13***

**Document Title:** Testing of Optimized Bubbler Configuration for HLW Melter

**Document Number and Revision:** VSL-13R2950-1, Rev. 0

**Issue Date:** 6/12/13

**Performing Organization:** Vitreous State Laboratory, The Catholic University of America

**Test Plan:** Testing of Optimized Bubbler Configuration for HLW Melter, VSL-12T2950-1, Rev. 0

This report describes the results of testing specified by the above Test Plan. The work was performed in compliance with the quality assurance requirements specified in the Test Plan. Results required by the Test Plan are reported. The test results and this report have been reviewed for correctness, technical adequacy, completeness, and accuracy.

**I.L. Pegg:** ______________________ **Date:** 6/12/13
**VSL Program Director/Principal Investigator**

**I. Joseph:** ______________________ **Date:** 6/12/13
**Energy*Solutions* Sub-Contract Manager**

# TABLE OF CONTENTS

## List of Tables

## List of Figures

# List of Abbreviations

| | |
|---|---|
| ADS | Air Displacement Slurry |
| AOD | Air Operated Diaphragm |
| ASME | American Society of Mechanical Engineers |
| BNI | Bechtel National, Inc. |
| DCP-AES | Direct Current Plasma - Atomic Emission Spectroscopy |
| DF | Decontamination Factors |
| DM | DuraMelter |
| DOE | Department of Energy |
| DWPF | Defense Waste Processing Facility |
| FTIR | Fourier Transform Infra-Red Spectroscopy |
| HEME | High-Efficiency Mist Eliminator |
| HEPA | High-Efficiency Particulate Air |
| HLW | High Level Waste |
| LAW | Low Activity Waste |
| NIST | National Institute of Standards and Technology |
| NQA | Nuclear Quality Assurance |
| ORP | Office of River Protection |
| PBS | Packed-Bed Scrubber |
| QARD | Quality Assurance Requirements and Description |
| SBS | Submerged Bed Scrubber |
| SCR | Selective Catalytic Reduction |
| SOP | Standard Operating Procedure |
| TCO | Thermal Catalytic Oxidation |
| VOC | Volatile Organic Compound |
| VSL | Vitreous State Laboratory |
| W.C. | Water Column |
| WESP | Wet Electrostatic Precipitator |
| WTP | Waste Treatment Immobilization Plant |
| XRF | X-ray Fluorescence Spectroscopy |

# SECTION 1.0
# INTRODUCTION

Plans for the treatment of high level waste (HLW) at the Hanford Tank Waste Treatment and Immobilization Plant (WTP) are based upon the inventory of the tank wastes, the anticipated performance of the pretreatment processes, and current understanding of the capability of the borosilicate glass waste form [1]. The WTP HLW melter design, unlike earlier DOE melter designs, incorporates an active glass bubbler system. The bubblers create active glass pool mixing and thereby improve heat and mass transfer and increase glass melting rates. The WTP HLW melter has a melt surface area of 3.75 $m^2$ and depth of ~1.1 m. The two melters in the HLW facility together are designed to produce up to 7.5 MT of glass per day at 100% availability. Further increases in HLW waste processing rates can potentially be achieved by increasing the melter operating temperature above 1150°C and by increasing the waste loading in the glass product. Increasing the waste loading also has the added benefit of decreasing the number of canisters for storage.

Development work for the WTP employed a "tiered" approach to vitrification 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 the Vitreous State Laboratory (VSL) have been used for this purpose, which, in combination with the 3.3 $m^2$ low activity waste (LAW) Pilot Melter operated by Energy*Solutions*, 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), which is the HLW Pilot Melter that has been installed at VSL with an integrated prototypical off-gas treatment system. That system replaced the DM1000 system that was used for HLW throughput testing during Part B1 of the privatization contract [2]. Both melters have similar melt surface areas (1.2 $m^2$), but the DM1200 is prototypical of the present WTP HLW melter design whereas the DM1000 was not. In particular, the DM1200 provides for testing on a vitrification system that includes the specific train of unit operations that has been selected for both HLW and LAW WTP off-gas treatment [3].

Over the course of testing on the DM1200 system, over one and a half million pounds of feed had been processed, producing almost 600,000 pounds of glass by the end of Bechtel national, Inc. (BNI) WTP testing in 2006 [4-19]. These tests were conducted to address several objectives, including determination of glass production rates and melt pool characteristics, as well as evaluation of the prototypical off-gas system. The compositions used for the extensive technology development and design work performed for the WTP baseline were iron limited with respect to waste loading (AZ-101, AZ-102, C-16/AY-102, and C-104/AY-101) [5, 6, 9, 11-15, 17, 18]. More recently however, the DM1200 has been used to process simulated high aluminum [20-22] and high bismuth [23] HLW streams identified by ORP [24]. In these tests, new high waste loading glass formulations were developed and subjected to testing on the DM1200 system, which demonstrated processing rates above the WTP baseline requirement. In all DM1200 testing with HLW simulants to date, no more than four bubbling outlets were used in order to reflect the projected number of bubblers per unit surface area of the WTP HLW melter shown in Figure 1.1 [25]. In previous testing on the DM1200, increasing the number of bubbling outlets from two to four was demonstrated to dramatically increase production rates [15] such that the WTP contract glass production rate requirement could be met; these results were used to define the present WTP HLW melter bubbler configuration. While it would seem reasonable that a further increase in the number of bubbler outlets would lead to a further increase in production rates, this was not pursued under the BNI test program. Thus testing described in this report was designed to investigate the potential increase in production rates associated with increases in the number of bubbler outlets above the current WTP baseline. The work was described in a Test Plan [26], which is one of several prepared in response to a Scope of Work provided by the Department of Energy’s (DOE) Office of River Protection (ORP) [27]. Results from the tests described herein are intended to support the option of a potential future re-design of the WTP HLW melter lid to allow for the additional bubbling outlets. If this option is pursued, it is anticipated that computer modeling of the WTP HLW melter with various possible bubbler configurations will be used as a tool to support the design effort in combination with the results from the present tests.

## 1.1 Test Objectives

The principal objective of this work was to determine the glass production rate increase and ancillary effects of adding more bubbler outlets to the current WTP HLW melter baseline. This was accomplished through testing on the HLW Pilot Melter (DM1200) at VSL. The DM1200 unit was selected for these tests since it was used previously with several HLW waste streams [5, 6, 9, 11-15, 17-23] including the four tank wastes proposed for initial processing at Hanford [5, 6, 9, 11-15, 17, 18]. This melter system was also used for the development and optimization of the present baseline WTP HLW bubbler configuration for the WTP HLW melter [15], as well as for MACT testing for both HLW and LAW [19]. Specific objectives of these tests were to:

- Conduct DM1200 melter testing with the baseline WTP bubbling configuration and as augmented with additional bubblers.
- Conduct DM1200 melter testing to differentiate the effects of total bubbler air flow and bubbler distribution on glass production rate and cold cap formation.
- Collect melter operating data including processing rate, temperatures at a variety of locations within the melter plenum space, melt pool temperature, glass melt density, and melter pressure with the baseline WTP bubbling configuration and as augmented with additional bubblers.
- Collect melter exhaust samples to compare particulate carryover for different bubbler configurations.
- Analyze all collected data to determine the effects of adding more bubblers to the WTP HLW melter to inform decisions regarding future lid re-designs.

The work used a high aluminum HLW stream composition defined by ORP [24], for which an appropriate simulant and high waste loading glass formulation were developed and have been previously processed on the DM1200 [20-22].

## 1.2 Quality Assurance

This work was conducted under a quality assurance program compliant with applicable criteria of 10 CFR 830.120; Office of Civilian Waste Management DOE/RW-0333P, Quality Assurance Requirements and Description (QARD) Revision 20; the American Society of Mechanical Engineers (ASME) Nuclear Quality Assurance (NQA)-1, 2004; and DOE Order 414.1 C, Quality Assurance. This program is supplemented by a Quality Assurance Project Plan for ORP work that is conducted at VSL [28]. Test and procedure requirements by which the testing activities are planned and controlled also are defined in this plan. The program is be supported by VSL standard operating procedures that were used for this work [29]. Since this work is not waste form quality affecting, the requirements of DOE/RW-0333P are not applicable to this work.

## 1.3 DM1200

### 1.3.1 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, 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 additives can be added to the mix tank. Five calibrated load cells directly mounted on the legs of the feed tank are used to measure additions to, and removal from, the feed tank and are 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 are 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 provides additional mixing.

The feed was introduced into the melter using an air operated diaphragm (AOD) pump system in place of an air displacement slurry (ADS) pump. The AOD pump, which simulates the WTP baseline ADS pump, was used to prevent the clogging of the inlet screens observed in previous tests with the high aluminum waste [21, 22]. Only one feed tube is used to represent the planned number of feed tubes per unit melt surface area in the full-scale WTP HLW melter. The 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.

### 1.3.2 Melter System

The DuraMelter 1200 (DM1200), which is the HLW Pilot Melter, was used for these tests. Cross-sectional diagrams of the melter illustrating the discharge chamber and electrode configuration are provided in Figures 1.2 and 1.3. 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 nominal glass depth of 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. 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 $ft^3$.

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. The optimum bubbler configuration established during previous tests with HLW simulants [15], consisting of two double-outlet, top-entering bubblers located in positions to mimic conditions in the WTP HLW melter was used for the first test. Figure 1.4 shows a schematic diagram of the prototypical double-outlet bubbler design that was based on the combination of the results from these DM1200 tests [15] and room-temperature tests that were performed in a transparent fluid simulating the properties of the glass melt [30]. A photograph of the double-outlet bubbler is provided in Figure 1.5. These bubblers have outlets 8 inches apart and were placed on the melter floor. The orientation of the bubblers in the melter, as shown in Figure 1.6, results in one of the bubbling outlets being 11.3 inches from the feed tube. The number of bubbling outlets was increased over the course of the tests by adding single out “L” bubblers, as pictured in Figure 1.7. The orientation of the double and single-outlet bubblers in the melter is shown for five and six total bubbling outlets in Figures 1.8 and 1.9, respectively. Notice that to evenly distribute bubbling outlets on each side of the melter, the double-outlet bubblers are rotated such that bubbling outlets come in closer proximity to the feed tube.

The DM1200 film cooler was replaced immediately prior to the previous tests [22]. The design of the new film cooler is very similar to that used for all previous testing on the DM1200 but it incorporates several changes that were made in the WTP HLW film cooler design after the installation of the DM1200 melter system. As a result, the new DM1200 film cooler is more prototypical of the present WTP HLW design. The original and new DM1200 film coolers are compared with a scaled version of the WTP HLW film cooler in Figure 1.10; it should be noted, however, that a simple directly scaled version would not maintain key air flow characteristics of the design, hence the differences between the new DM1200 film cooler and the scaled WTP HLW design. As compared to the original DM1200 film cooler, the new unit includes the prototypical louver on the outside edge, a modified hole size and pattern on the leading edge, fewer louvers (7 vs. 9), and a shorter louvered section (10” vs. 13”).

### 1.3.3 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 1.11, 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 caustic packed-bed scrubber (PBS); and a second HEME. Note that the PBS and the second HEME are not part of the WTP HLW off-gas train, which effectively ends at the SCR. The HEME is used to limit entrained particle carryover into the balance of the VSL ventilation system. The system can be functionally divided into four subsystems:

Particulate Removal: Components from the 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 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 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 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.

With minor exceptions, the DM1200 off-gas system processing sequence follows the design for the full-scale WTP HLW melter system, except for cooling of the off-gas stream discharged from the SCR unit (which is present in the WTP off-gas train, but absent in the DM1200 system). Per WTP direction, the SBS unit that was used for previous DM1200 testing was modified in early 2004. Installation of the new system was completed in March 2004 and that unit was used for the present tests. The changes were implemented to reflect modifications to the WTP SBS design that have taken place since the original DM1200 unit was installed. These modifications included changes to the diffuser plate design, down-comer jacket and connection to the diffuser plate, bed diameter, bed packing materials, cooling coils, and liquid overflow level.

Initial quenching of the melter exhaust gas stream is effected by the film cooler. Immediately upstream 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 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. These two units were off-line during the present tests due to the low concentrations of these components in the exhaust stream. Finally, the PBS provides acid gas removal. Water sprays are located in the WESP, PBS, and facility HEME 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 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. water column (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.

## 1.4 Feed Sample Analysis

Feed samples were taken directly from the feed recirculation line during each test. Feed samples were poured into a platinum/gold crucible that was placed into a programmed furnace for drying and fusion to form a glass. The glass produced from this fusion was ground to less than 200 mesh and sealed in 20-ml vials for subsequent analysis by X-ray fluorescence spectroscopy (XRF), or by acid digestion followed by direct current plasma - atomic emission spectroscopy (DCP-AES) on the resulting solution. The feed samples were also characterized for their density, pH, water content, and glass yield.

## 1.5 Glass Product Analysis

The glass product from the DM1200 tests was discharged from the melter into 55 gallon drums periodically using an air-lift system. The discharged product glass was sampled by removing sufficient glass from the top of the cans for compositional analysis after the cooling period and visual inspection (see Section 5.0). All of these procedures are routinely conducted at VSL and, therefore, standard operating procedures (SOPs) are in place. Sample preparation for chemical analysis typically involves size reduction and sieving. All samples were subjected to XRF to determine the concentration of all elements except boron and lithium. A series of National Institute of Standards and Technology (NIST) reference materials were used for confirmation of the XRF data. Boron and lithium were determined by total acid dissolution of ground glass samples in $HF/HNO_3$ and subjecting the resulting solutions to DCP-AES analysis.

## 1.6 Emission Samples

Melter emission fluxes were measured to complete the mass balance for each melter test. Isokinetic melter exhaust samples (exhaust gas flow velocity equal to velocity through the gas sample probe tip) were combined with the Fourier Transform Infra-Red Spectroscopy (FTIR) spectroscopy continuous monitoring data for gaseous species to characterize fluxes from the melter. In the DM1200 system, independent sampling ports for particulate and FTIR sampling are available throughout the off-gas treatment train (see Figure 1.11). Standard EPA isokinetic off-gas sampling trains and methods (EPA Methods 1A, 2, 4, 5, 26, 29), composed of particulate filters and liquid impingers, were used to collect materials that were subjected to chemical and physical analyses using the techniques described in Sections 1.4 and 1.5.

## 1.7 Test Overview

Melter testing was conducted in four fifty-hour test segments distinguished by the number of bubbling outlets employed and the total air flow rate applied to the bubblers. The waste and glass composition, feed solids content, glass temperature and extent of cold cap coverage were held constant throughout the tests while the number of bubbling outlets, bubbling outlet distribution, and bubbling rate were varied. The form of aluminum in the waste was aluminum oxide, which is the aluminum source that previous testing has shown to be the slowest to be incorporated into glass [20] and therefore provides the most conservative case for testing. The composition of the glass inventory in the DM1200 melter prior to testing was the same as that employed for the present tests (HWI-Al-19 [22]) and therefore no melt pool turnover was required. In the first test, two double-outlet bubblers were used in the prototypical locations used in previous tests [15, 18-23] to provide a baseline and to determine the amount of bubbling required to produce glass at the target rate of 1050 $kg/m^2$/day[1]. The total bubbling rate from this test was used in two of the subsequent tests as additional bubbling outlets were added to determine the effect of bubbling distribution on glass production rate. In another test, the six-outlet bubbling configuration was used and the bubbling rate was adjusted to achieve the target production rate of 1050 $kg/m^2$/day. The melter feed rate was increased to achieve a complete cold cap throughout the tests, as verified by visual observations and corroborated by measured plenum temperatures. Observations of cold-cap coverage and characteristics were made frequently and are included in Section 3. Particular attention was paid to changes in plenum temperature distribution across the plenum space with changes in bubbling outlet distribution.

Throughout the tests, extensive melter operating data were collected to characterize the effects of bubbling outlet distribution and bubbling rate on measured parameters and implications for future designs of the melter lid. Melter exhaust samples were also taken to provide a connection between bubbling outlet distribution, bubbling rate, and particulate carryover during testing.

[1] The production rate of 1050 $kg/m^2$/day was selected based on the previous requirement of 3 MT/day for the WTP HLW melter and a scaling factor to account for differences in the number of bubbling outlets per unit area in the DM1200 and the WTP HLW melter.

# SECTION 2.0
# WASTE SIMULANT AND GLASS FORMULATIONS

## 2.1 Aluminum Limited Waste Simulant

The waste stream compositions previously provided by ORP [24] are given in Table 2.1 on an oxide basis [31]. Of the four waste compositions listed, the present work focused exclusively on the aluminum limited waste stream as a result of previous processing experience on the DM1200 [20-22].

Actual Hanford tank HLW streams are aqueous solutions with suspended solids and dissolved salts including hydroxides, nitrates, nitrites, halides, and carbonates. For the purpose of the previous [20-22] and present work, the concentrations of the volatile components (i.e., carbonate, nitrite, nitrate, and organic carbon) are assumed to be similar to those found for the AZ-102 HLW [11]. With the waste compositions defined, formulation of the HLW simulant proceeds in a straightforward fashion. In general, oxides and hydroxides are used as the starting materials, with a slurry of iron (III) hydroxide (13% by weight) as one of the major constituents. Volatile inorganic components are added as the sodium salts, whereas organic carbon is added as oxalic acid. Although crucible melts have been prepared using the appropriate radioactive components (i.e., thorium and uranium), substitution of non-radioactive starting materials were required in preparing the simulated waste for melter testing. The exact substitution depended on the measured properties of the radioactive glass prepared in a crucible melt and was determined on a case-by-case basis. Finally, water content was adjusted to target a glass yield of 500 g of glass per liter of feed. The composition of the waste simulant with aluminum oxide as the aluminum source formulated to produce 100 kg of waste oxides is given in Table 2.2. Aluminum oxide was chosen as the aluminum source because previous tests have shown this to produce the slowest melting melter feed as compared to gibbsite and boehmite [20]. A slower melting feed, in addition to providing the most conservative test case, allowed better estimation of the effect of bubbler configuration on feed processing rate without running into potential issues such as melter power limitations that could occur with a faster melting feed.

## 2.2 Glass Formulation

The HWI-Al-19 high waste loading glass formulation was developed for the high aluminum waste composition and was tested on both the DM100 and DM1200 melters to determine processing rates [20- 22]. These tests demonstrated that the formulation exceeded WTP requirements with respect to glass production rate and processed at a faster rate than the previously developed formulation (HLW-E-Al-27 [31]) for the same waste, while maintaining the same 45 wt% waste loading.

The composition and properties of the HWI-Al-19 formulation are listed in Table 2.3 and the melter feed composition with aluminum oxide as the aluminum source is shown in Table 2.4. Based on the results from small-scale melt rate testing, the formulation emphasized increased boron concentrations to improve melt rates and compensating changes to maintain other glass properties within acceptable ranges. The additional constituents required to form the target test glass from the HLW high aluminum waste simulant are boron, calcium, lithium, sodium, and silicon. The corresponding chemical additives that are the sources for these elements were selected based on previous testing and the current baseline chemicals for the WTP Project. The measured viscosity and conductivity of HWI-Al-19 at 1150°C are 33 P and 0.27 S/cm, respectively. No crystalline phases were observed in the as-melted sample, and heat treatment for 72 hours at 950°C resulted in 1.3 vol% crystals. Chemical durability was verified on crucible glasses and product melter glasses with leachate concentrations well below regulatory limits [20]. 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. Additional water to achieve the target glass yield of 500 g glass per liter was added to the feed at VSL.

# SECTION 3.0
# DM1200 OPERATIONS

A series of tests with high aluminum simulants were conducted between 1/15/13 and 2/8/13, producing nearly twelve metric tons of glass. The total duration of waste and water feeding, was 203 hours, during which over 33 metric tons of feed was processed. Summaries of the test conditions and results are provided in Table 3.1. The tests were conducted to determine the relationship between the number and locations of bubbler outlets and production rate. For each test, target or maximum production rates were indicated by complete cold cap coverage visually observed and confirmed by plenum temperature indications. Testing began with bubblers in a previously defined and tested bubbler configuration; this consisted of two double-outlet lance bubblers on the melter floor, 8" apart on the East and West side, with one bubbler outlet a horizontal distance of 11.3" from the feed tube location [4, 15, 18, 20-23]. As testing progressed, bubbling outlets were added while maintaining either constant bubbling rate or feed rate. The high aluminum feed employed glass formulation HWI-Al-19 and has been processed previously on the DM1200 [20- 22]. However, unlike the previous tests, the present feed employed aluminum oxide, which is the slowest melting aluminum source and which therefore provided the most conservative result for feed rates. Feed solids content was targeted at 500 g glass per liter and was confirmed by analysis of feed samples from each test. The tests are listed below in the order in which they were conducted:

- <u>Test 1</u>: 4 bubbling outlets (see Figure 1.6), bubbling rate adjusted to target 1050 $kg/m^2/day$ glass production rate.

- <u>Test 2</u>: 5 bubbling outlets (see Figure 1.8), bubbling rate of 78 lpm (steady state bubbling rate from Test 1) and feed rate adjusted to achieve maximum glass production rate.

- <u>Test 3</u>: 6 bubbling outlets (see Figure 1.9), bubbling rate adjusted to target 1289 $kg/m^2/day$ glass production rate (steady state rate from Test 2).

- <u>Test 4</u>: 6 bubbling outlets (see Figure 1.9), bubbling rate of 78 lpm (steady state bubbling rate from Test 1) and feed rate adjusted to achieve maximum glass production rate.

The tests employed an AOD feed system, a single feed tube in the center of the melter lid, a nominal glass temperature of 1150°C for all tests, and a side-to-side electrode firing pattern. The prototypical ADS feed system was not used due to screen clogging that was observed in previous tests while processing the high aluminum waste feed [20-22]; similar behavior was observed with high solids LAW Sub-Envelope B1 feed [10] and HLW feeds adjusted to higher feed viscosity [18]. Therefore the backup AOD feed system was used to process the high aluminum waste feed and performed without incident. Visual observations of the cold cap were made and recorded and were used as an indicator of complete cold cap coverage. A chronology of melter operations during the tests is provided in Table 3.2; a listing of all the cold cap observations is provided in Table 3.3.

All systems and major components of the melter and off gas systems performed well without need for repair during testing other than the trough in the discharge chamber. In the latter portion of Test 2 and throughout Test 3, spikes in current, voltage, and glass resistance were observed during each discharge. Lower than expected glass resistance resulted in higher than desirable current on the primary side of the electrodes. Also, one of the heating elements in the discharge chamber ceased to function. To address these conditions, the discharge chamber was cooled and opened up for inspection after Test 3. It was determined that the discharge trough had sagged down and was resting on one of the discharge heater sheathes. The affected heater sheath and heater were removed and replaced and the discharge trough was lifted onto additional refractory bricks inserted into the discharge chamber. Once returned to service, consistent supply of power was obtained throughout Test 4 with no difficulties maintaining the desired discharge chamber temperature. Although a portion of the available power was diverted during Tests 2 and 3, sufficient power was available to process feed to achieve steady state production rates in these tests.

## 3.1 Glass Production Rates

A primary objective of these tests was to measure glass production rates with added bubbling outlets. Glass production rates are illustrated in Figures 3.1.a - 3.1.d to address this question. Also of interest are the test average and steady state values, which are provided in Table 3.1. Steady state values were determined by eliminating portions of tests that were not indicative of the operating conditions, such as startup as the cold cap is developed and prior to achieving a consistent bubbling rate. The production rates were calculated from feed rate data and the analyzed solids content of the feed samples taken during each test (see Section 5.1). All of the measured feed solids contents approximated the target value except for the sample from the terminal portion of Test 1, which therefore is not considered as steady state. Evidently, the last feed transfer from the mix tank to the feed tank was lower in solids, presumably due to excess water with the transfer, which resulted in material with a lower solids content and lower glass yield being fed to the melter towards the end of Test 1. During this latter portion of Test 1, the melter was fed at the target rate in terms of kilograms of feed per hour; however, since the amount of glass per unit mass of feed decreased, the glass production rate and the amount of bubbling required to maintain a complete cold cap decreased below the target and steady state values.

Feed and bubbling rates were increased gradually during the last test to achieve steady state conditions during the latter half of the test in order to achieve the highest production rate of the test series without exceeding the available power to the electrodes. Steady state operation with respect to processing rates and bubbling rates was achieved for at least 20 hours of each test.

The results from these tests clearly show increasing glass production rates with increasing number of bubbler outlets while processing at the same constant bubbling rate and with increasing bubbling rate when using the same number of bubbling outlets. Over Tests 1, 2, and 4, conducted at 78 lpm bubbling, the glass production rate increased from about 1060 $kg/m^2$/day using 4 bubbling outlets to about 1290 $kg/m^2$/day using 5 outlets to nearly 1400 $kg/m^2$/day using six outlets, as shown in Figure 3.2. During Tests 3 and 4, conducted with 6 bubbling outlets, glass production rates increased from about 1250 kg/$m^2$/day when flowing 60 lpm air through the bubblers, to nearly 1400 kg/$m^2$/day when flowing 78 lpm through the bubblers. Specific increases in response to the varied test parameters were as follows:

- 32% increase in production rate (1062 vs. 1398 kg/$m^2$/day) at constant bubbling rate in response to increasing the number of bubbling outlets from 4 to 6.
- 21% increase in production rate (1062 vs. 1289 kg/$m^2$/day) at constant bubbling rate in response to increasing the number of bubbling outlets from 4 to 5.
- 8% increase in production rate (1289 vs. 1398 kg/$m^2$/day) at constant bubbling rate in response to increasing the number of bubbling outlets from 5 to 6.
- 12% increase in production rate (1251 vs. 1398 kg/$m^2$/day) using 6 bubbling outlets in response to increasing the bubbling rate from 60 to 78 lpm.

It should be noted that bubbling rates were fixed at values obtained while processing with the fewest number of bubbling outlets and that bubbling rates were not optimized for any of the tests. If higher bubbling rates were used in these tests, higher production rates would likely have been obtained. In previous tests processing with the same glass composition and feeds containing faster melting forms of aluminum (hydroxide and boehmite) using four bubbling outlets, bubbling rates of 101 and 124 lpm were required to achieve production rates between 1450 and 1500 kg/$m^2$/day, respectively [20, 21]. In comparison, the amount of bubbling distributed amongst 6 outlets required to achieve a production rate of nearly 1400 kg/$m^2$/day with a slower melting form of aluminum was only 78 lpm. Increasing bubbling from 78 lpm to 101 or 124 lpm with the six bubbler outlet configuration can be expected to result in production rates well exceeding1500 kg/$m^2$/day given the improvement observed in response to the modest increase in bubbling from 60 to 78 lpm.

Comparison of the data from the current tests with data collected from previous tests processing high aluminum wastes [20, 21] corroborates the relative melt rates of the various forms of aluminum. Depicted in Figure 3.3 is the amount of bubbling required to produce glass on the DM1200 melter at 1050 kg/$m^2$/day using the nominal four bubbler outlet configuration using aluminum oxide, aluminum hydroxide, and boehmite as the aluminum source. All the tests targeted the same glass composition with a target concentration of 24 wt% $Al_2O_3$. The amount of bubbling was the least with boehmite (62 lpm), most with aluminum oxide (78 lpm), and intermediate with aluminum hydroxide (71 lpm), indicating that boehmite is the easiest to process and aluminum oxide is the most difficult to process. This trend corroborates melt rate results obtained at constant bubbling rates on the DM100 melter [20, 21].

## 3.2 Monitored Melter Parameters

Measured plenum temperatures, given in Figure 3.4.a - 3.4.d, spanned a wide range during the testing, from near 300 to over 900°C. Plenum temperatures measured at five of the six locations were above 600°C only at the beginning of each test, as the cold cap was being formed, and at the conclusion of each test after feeding was discontinued as the cold was incorporated into the glass melt. Plenum temperatures were mostly below 550°C during steady state portions of the first two tests and mostly below 500°C during steady state portions of the last two tests, indicative of a complete cold cap in accordance with the visual observations recorded in Table 3.3. Measured plenum temperatures in Port B2 were about a hundred degrees higher than those measured in the other five locations, suggesting that Port B2 is in immediate proximity to an opening in the cold cap directly above a bubbler outlet. The test average steady state plenum temperatures are graphically illustrated in Figures 3.5.a – 3.5.d. The temperature gradient across the plenum space ranged from about 100 to 150°C and was relatively consistent over the four tests, suggesting that the addition of bubbling outlets did not result in openings in the cold cap around the added bubblers. It is important to note that with bubblers being added in Ports A1 and D3, there is no direct monitoring of plenum temperature in these corners of the melter. In the previous test sequence, which had monitoring in these ports [22], the highest plenum temperatures were measured in Port D3, near the exhaust outlet. The higher measured temperatures at Port D3 were not attributable to closer proximity to bubbling outlet locations but due to air from the airlift, which can flow between the melter wall and the cold cap to produce an opening in the cold cap and increased radiant heat at this location. It is suspected that measured temperatures around Port D3 in the current tests would also have been similarly elevated, thus obscuring any effect from the added bubblers.

A variety of other operational parameter measurements recorded during these tests, including temperatures throughout the melter system, are given in Table 3.4. The target glass temperature of 1150ºC was successfully averaged for most of the glass pool during each test, as illustrated in Figures 3.6.a - 3.6.d. Exceptions were near the surface (27" from the floor), where temperatures were lower due to the thermocouples being in or near the cold cap. A 10 – 20ºC gradient across the East and West side of the melter was observed throughout the tests, complicating power adjustments to maintain desired temperature. In the first three tests, the West side was hotter than the East; this trend was reversed in Test 4 after the discharge chamber was repaired. The East and West side electrode temperatures varied mostly over the narrow range of 1100 – 1160ºC while feeding with an established cold cap; the two side electrode temperatures were the same in the first two tests while the East electrode was about 20ºC higher than the West in tests employing six bubbling outlets. The bottom electrode, which was not powered in these tests, was about 90ºC cooler than the West side electrode while feeding. The discharge chamber was largely maintained above 1000ºC throughout most of the tests, with temperatures about 50ºC higher after the discharge chamber was repaired after Test 3. Temperatures in one portion of the discharge chamber averaged only 941ºC during Test 3 due to the loss of one of the heating elements.

Gas temperatures after the film cooler averaged between 235 and 385ºC depending on the plenum temperature during each test segment. The film cooler was cleaned by a water spray every 12 hours during most of the testing, resulting in a short-duration reduction of about 75ºC in the film cooler outlet temperature.

Conditions in the glass pool are illustrated for voltage and current in Figures 3.7.a - 3.7.d, electrode power and glass resistance in Figures 3.8.a – 3.8.d, and level and density in Figures 3.9.a - 3.9.d. Voltage and current in the glass pool increased to steady state values over the course of each test; voltage to 120 -135 volts and current 1450 to 1700 amps, depending on feed rate and condition of the discharge trough. The spikes in voltage and drops in current in the latter portion of Test 2 and all of Test 3 are associated with the discharging of glass and the contact between the discharge trough and the heater sheath. Once the discharge chamber was repaired, the amount of current actually decreased from an average of about 1700 amps in Test 3 to about 1600 amps in Test 4, even though the production rate increased. Power supplied to the electrodes was relatively constant once the cold cap was established during steady state for each test. Power usage largely varied between 175 and 215 kW, increasing with increasing production rate. This level of power utilization is consistent with the 200 and 225 kW used while processing the high aluminum waste at the higher feed rates [22]. Glass pool resistance decreased from 0.09 to 0.07 ohms over the course of the first three tests in part due to the shorting out of the glass during discharging as a result of the trough being in contact with the heater sheath in the discharge chamber. During Test 4, the glass resistance varied little from 0.08 ohms and better reflects the resistance based on the glass composition. The glass pool density varied little around the average value of 2.26 g/cc due to the lack of compositional change during testing and the absence of foaming during the tests. The glass pool level varied between 28 and 31 inches, with frequent decreases in height of about two inches in response to glass discharging.

Bubbling rates used to provide melt pool agitation for the four tests are depicted in Figures 3.10.a – 3.10.d and listed in Table 3.4. In Tests 1 and 3, bubbling was adjusted to achieve a target production rate, while in Tests 2 and 4 bubbling was held constant at rates used to achieve a target specific production rate in a preceding test. The air flow through each outlet was the same within each test. A flow of 1.2 lpm is assumed through the electrode bubblers throughout the tests. Bubbling rates from the two double ported bubblers were adjusted to a flow of 78 lpm during the initial test to achieve a complete cold cap while processing feed at 1050 $kg/m^2/day$. The target total flow rate was distributed between five and six bubbling outlets in Tests 2 and 4, respectively. Bubbling rates decreased in the latter portion of Test 1 as the solids content of the feed decreased. Target bubbling was achieved in Test 2 in a short amount of time, while during Test 4, bubbling and feed rates were increased gradually over the first day of testing to ensure that enough power was available to conduct the test.

# SECTION 4.0
# DM1200 OFF-GAS SYSTEM PERFORMANCE

Tests on the DM1200 system at VSL have been used extensively to evaluate the performance of a pilot scale off-gas system that is prototypical of that designed for the WTP by BNI engineering [4-22]. In the present tests, the objective of the work was to determine the glass production rate increase and ancillary effects of adding more bubbler outlets to the current WTP HLW melter baseline. Thus, the performance of the off-gas system, although important to support the operation of the melter, was not a primary objective for investigation during the present tests. However, data for each of the off-gas system components were collected and evaluated and are provided in this report. Data are collected and electronically logged every two minutes and data and observations are also recorded manually throughout the tests. The average, minimum, and maximum values of the measured off-gas system parameters are given in Table 4.1. Target operational conditions for the system components such as sump temperatures, unit spray rates, and sump pH values that were not specified were adapted from previous tests conducted on the DM1200 [15]. For these tests the silver mordenite / activated carbon system was not used and the catalytic unit was bypassed.

Plots of the typical sequence of gas temperatures through the DM1200 off-gas system at various locations are given in Figures 4.1- 4.4 for the four tests. The SBS cooling system, as discussed below, acts to maintain SBS outlet temperatures at a selected operational value. In summary, plenum gas from the melter is cooled by dilution with film cooler air to about 364°C, drops approximately another 69°C by control air dilution and heat loss along the transition line, is quenched to about 44°C in the SBS, and reheated to about 60°C to prevent condensation in the HEPA filtration unit. The exhaust is typically heated by another 25°C by the Paxton blowers. A slight piping heat loss occurs from that point to the PBS inlet. The gas temperature is about 81°C at the PBS inlet.

## 4.1 Melter Pressure

A vacuum on the melter of between two to three and a half inches of water was targeted and maintained throughout the majority of the tests. This is achieved by setting blower speeds and using a control air system that constantly monitors the vacuum on the melter and injects sufficient air into the transition line immediately downstream of the film cooler to maintain a relatively constant vacuum on the melter. The melter pressures measured at the instrument port and by the level detector are shown in Figures 4.5-4.8. The melter pressure fluctuated between 0.7 and -6.3 in W.C. throughout the tests in response to changes in feeding and cold cap conditions. During all four tests, positive melter pressure spikes were observed before and after off-gas sampling events when ports were opened. Melter pressure fluctuates constantly, mostly between -0.5 and -4 inches water, and does not directly correlate with feed rate or plenum temperature within the parameters used in these tests. Similarly, the calculated control air flow rates, as shown in Figures 4.9-4.12, do not appear to directly correlate with melter feed rate or plenum temperature within the ranges investigated in these tests. The range of control air flow rates reflect the changes of melter exhaust volume in response to changes in the cold cap and feed rate, including pulsing of the feed throughout the tests.

Differential pressure measurements across the film cooler are provided in Figures 4.13- 4.16. During Test 2 at 10.1 hours of operations, the film cooler differential pressure exceeded 8.0 in W.C., and rodding of the film cooler was required. The single occurrence of clogging in the film cooler (for the entire four-test period) indicates relatively small amounts of solids carryover from the melter resulting from more complete cold cap coverage and/or a greater effectiveness of the new film cooler at preventing solids accumulations.

## 4.2 SBS

The SBS quenches the melter exhaust, condenses much of the water from the melter feed, and removes the majority of the particulate in the exhaust stream. Many parameters of the SBS were recorded during testing, including inlet and outlet gas temperatures, pressures, pressure drops, sump temperature, heat exchanger inlet and outlet water temperatures, and flow rates. The amounts of heat removed by the SBS jacket and the SBS inner cooling coil were calculated from the measured data using the hourly averaged cooling water temperature increases (outlet temperature minus supply temperature) across the SBS inner cooling coil and cooling jacket multiplied by the same time-averaged water flow rate through each.

The SBS inlet and outlet gas temperatures are plotted in Figures 4.17-4.20. The average SBS inlet and outlet gas temperatures were 289°C and 45.3°C during Test 1, 305°C and 43.6°C during Test 2, 301°C and 43.7°C during Test 3, and 286°C and 43.9 °C during Test 4. SBS inlet, outlet, and differential pressures are plotted in Figure 4.21 for Test 1 and in Figure 4.24 for Test 4. The SBS outlet gas pressure indicator did not work properly during Tests 2 and 3. SBS inlet and differential pressures are plotted in Figure 4.22 for Test 2 and in Figure 4.23 for Test 3. Differential pressure averages were 33.3 and 41.1 in W.C., and inlet pressures averages were -9.6 and -7.9 in W.C. for Tests 2 and 3, respectively. Differential pressure averages were 30.1 and 30.5 in W.C., inlet pressures averages were -8.8 and -8.6 in W.C., and outlet pressures averages were -38.6 and -38.4 in W.C. for Tests 1 and 4, respectively.

The SBS off-gas temperatures in the down-comer measured at various depths (from 3 to 53 inches) and the SBS sump water temperature are given in Figures 4.25-4.28. During Test 3, after 31.9 hours of operations, the thermocouple at 43 inches failed. The average SBS sump temperatures were 40.1°C (Test 1), 37.7°C (Test 2), 37.4°C (Test 3) and 38.6°C (Tests 4), which are each about 5 to 6°C lower than the corresponding SBS outlet gas temperature. The measured off-gas temperatures decrease as the depth from the SBS lid increases due to cooling of the gas in the down-comer pipe by the surrounding SBS liquid.

Water temperatures at the SBS inner cooling coil inlet, inner cooling coil outlet/jacket inlet, and jacket outlet are given in Figures 4.29-4.32. The average water temperature differences were 20.0°C (Test 1), 15.6°C (Test 2), 14.5°C (Test 3) and 17.2°C (Test 4) across the SBS inner cooling coil, and 2.3°C (Test 1 and Test 2), 2.8°C (Test 3) and 2.1°C (Test 4) across the jacket. The SBS cooling coil and jacket water flow rates are plotted in Figures 4.33- 4.36, and averaged 19.9 gal/min (Test 1), 33.0 gal/min (Test 2), 33.8 gal/min (Test 3), and 29.4 gal/min (Test 4).

Figures 4.37-4.40 show the calculated heat loads during all four tests. During Test 1, heat removal averaged 85.3 kW by the SBS inner cooling coil and 10.1 kW by the cooling jacket. This corresponds to about 89.4 % of the heat load to the SBS being removed by the inner cooling coil and about 10.6 % by the cooling jacket. During Test 2, heat removal averaged 109.0 kW by the SBS inner cooling coil and 16.6 kW by the cooling jacket. This corresponds to about 86.8 % of the heat load to the SBS being removed by the inner cooling coil and about 13.2 % by the cooling jacket. During Test 3, heat removal averaged 103.3 kW by the SBS inner cooling coil and 21.0 kW by the cooling jacket. This corresponds to about 83.1 % of the heat load to the SBS being removed by the inner cooling coil and about 16.9 % by the cooling jacket. During Test 4, heat removal averaged 105.8 kW by the SBS inner cooling coil and 14.2 kW by the cooling jacket. This corresponds to about 88.2 % of the heat load to the SBS being removed by the inner cooling coil and about 11.8 % by the cooling jacket.

One of the functions of the SBS is to condense water that originated in the melter feed. In Figures 4.41- 4.44, the amount of water fed is compared to the total volumetric accumulations in the SBS during testing. The difference between the amounts of water coming from the feed and the amounts blown down from the SBS sump represent the amount of water carried out in the off-gas stream as a result of it being saturated at the SBS sump temperature, as well as a small amount of entrained droplets. This amount is largely determined by the SBS sump water temperature. In Test 1, of the 1223 gal of water entering the SBS as part of the melter exhaust stream, 481 gal or 39 % was condensed in the SBS. For Test 2, of the 1385 gal of water entering the SBS as part of the melter exhaust stream, 690 gal or 50 % was condensed in the SBS. In Test 3, of the 1376 gal of water entering the SBS as part of the melter exhaust stream, 661 gal or 48 % was condensed in the SBS. For Test 4, of the 1472 gal of water entering the SBS as part of the melter exhaust stream, 1000 gal or 68 % was condensed in the SBS. Total blow-down volumes for the SBS (and other components) are summarized in Table 4.2. Since the sump temperature was relatively constant throughout the four tests, the percent of feed water condensed in the SBS increased with the feed rate.

## 4.3 WESP

The primary function of the WESP is to remove fine, often water soluble, particles from the exhaust stream that are not efficiently removed by the SBS. The inlet and outlet gas temperatures, differential pressure across the WESP, and the WESP current and voltage were measured and recorded by the computer data acquisition system. The WESP inlet and outlet gas temperatures for the test are plotted in Figures 4.45-4.48. Temperature increases of 0.2ºC (Test 1), 1.5 ºC (Test 2), 3.0 ºC (Test 3) and 2.6 ºC (Test 4) were observed in the exhaust as gas passed through the WESP.

The periodic downward spikes in the WESP outlet temperature are a result of the daily deluge of the WESP to wash collected deposits off the electrodes and into the WESP sump. The WESP outlet gas flow rates are plotted in Figures 4.49-4.52. The measured differential pressure across the WESP averaged 3.6 in W.C. for Test 1, 4.0 in W.C. for Test 3, 3.2 in W.C. for Test 3, and 3.4 in W.C. for Test 4. The typical average wet gas flow rate exiting the WESP was between 233 and 259 scfm during these tests. The WESP voltage and current are plotted as functions of run time in Figures 4.53-4.56. During Test 1, the voltage averaged 29.6 kV and the current averaged 8.9 mA. During Test 2, the voltage averaged 30.4 kV and the current averaged 10.8 mA. During Test 3, the voltage averaged 30.0 kV and the current averaged 11.4 mA. During Test 4, the voltage averaged 30.2 kV and the current averaged 10.0 mA. The current and voltage increased after deluges in the middle of each test. These increases were minimal after Test 1 suggesting a minimal amount of solids accumulation on the WESP elements at this stage of testing.

## 4.4 Secondary Off-Gas System

A HEME filtration unit (HEME 1) follows the WESP in the off-gas system to remove water droplets that may be present in the water-saturated gas exiting the WESP. The outlet gas temperature and differential pressure are plotted in Figures 4.57- 4.60. The typical pressure drop across HEME 1 during testing was between 1.6 and 1.9 in W.C.

The HEME is followed in the off-gas system by a heater, a HEPA filter (HEPA 1), and a Paxton blower (Blower 1). The purpose of the heater is to ensure that water-saturated gas exiting HEME 1 is heated above its dew point before passing through the HEPA filter in order to prevent moisture condensation in the HEPA filter. The outlet gas temperature and the pressure differential across the HEPA filter are the two parameters monitored by the off-gas data acquisition system; these are shown in Figures 4.61-4.64. During Test 4 the heater inadvertently was not turned on until 7.5 hours of run time. The typical pressure drop across the HEPA filter was 0.2 in W.C. throughout testing. A vacuum is maintained on the melter by a pair of redundant Paxton blowers (Blowers 701 and 702) immediately downstream of the HEPA filtration unit and a blower (Blower 801) downstream of the packed bed scrubber. The thermal catalytic oxidizer (TCO) and selective catalytic reduction unit (SCR) are located downstream of the HEPA filter and Paxton blowers in the off-gas train; however, these units were bypassed during the present tests.

A packed bed caustic scrubber (PBS) is used near the end of the off-gas train to remove acid gases from the off-gas stream. The PBS sump solution is derived from process water; caustic solution (25% NaOH) is added to control the solids content and pH of the scrubber liquid. The PBS inlet gas temperatures and pressure drops across the PBS are shown in Figures 4.65-4.68. The average pressure drops across the PBS were 3.6 in W.C. during Test 1, 3.8 in W.C. during Test 2, 3.1 in W.C. during Test 3, and 3.2 in W.C. during Test 4. The average inlet gas temperature of about 77 – 84$^{o}$C was quenched to about 26 - 28$^{o}$C in the PBS during these tests. The pH for the PBS is plotted in Figures 4.69-4.72. In all four tests the pH was generally maintained above 8.2, as shown in Figures 4.69-4.72 with little addition of caustic needed. The PBS was periodically blown down as required to maintain constant volume. The PBS total blow-down volumes are included in Table 4.2.

A second HEME (HEME 2) is present near the end of the off-gas train, upstream of the stack blower, to prevent entrained water droplets from entering the stack. The HEME 2 total blow-down volumes are included in Table 4.2.

# SECTION 5.0
# FEED SAMPLE AND GLASS PRODUCT ANALYSIS

## 5.1 Analysis of Feed Samples

### 5.1.1 General Properties

Samples from each of the six as-received feed batches were analyzed to adjust feed solids content and to verify chemical composition. Feed sampled while testing was also analyzed to confirm physical properties and chemical composition. Sample names, sampling dates, and measured properties are given in Table 5.1. Density, pH, water content, glass conversion ratio, boron and lithium content by DCP, and oxide composition by XRF were measured for all samples. The average measured solids content of the as-received feed served as the basis for determining the amount of water required to achieve the target solids content of 500 g glass per liter of feed. The measured feed to glass ratios varied from 0.381 to 0.44, illustrating the variability in solids content between the six as-received feed batches. This variability was addressed by transferring equal numbers of drums from each batch for each test to ensure uniformity in feed solids content over the four tests. The measured glass conversion ratios for feed samples taken during testing were relatively uniform, varying around 0.35 to 0.36 except for the sample taken at the end of Test 1, which had a measured feed to glass conversion ratio of only 0.25. Feed processing changed dramatically after the last feed transfer during Test 1, which is consistent with the addition of feed with a lower solids content (see Section 3.1) confirming the low solids analysis. Based on the feed sample analysis, feed to glass conversion ratios of 0.36 for Test 2 and most of Test 1, 0.35 for Tests 3 and 4, and 0.25 for the latter portion of Test 1 were used to calculate feed rates during the melter tests. The measured water content and density are consistent with the solids content measured on a weight per weight basis; the as-received feed has a lower water content and higher density than the feed from tests, which was diluted with water to the target solids content. Measured pH values were about half a unit higher for diluted feed from tests than the as-received feed. The feed from the end of Test 1 had the highest pH as a result of the greater degree of dilution.

### 5.1.2 Chemical Composition

The methods used for analysis of feed sample chemical compositions are described in Section 1.4. The boron and lithium oxide concentrations measured using the DCP procedure and a fluorine concentration indicative of the typical retention in glass were used for normalizing the XRF data since their concentrations were not determined by XRF. These results, compared to the target composition in Tables 5.2 and 5.3, generally corroborate the consistency of the feed compositions and show good agreement with the target compositions for the major elements. Of the oxides with target concentrations greater than one percent, only average melter feed sample concentrations of bismuth exceed 10% from target. All other oxide concentrations deviated by less than five and a half percent and aluminum deviated by less than three percent. The absolute deviations for bismuth are less than 0.14 percent. Other than the feed sample taken at the conclusion of Test 1 which contains an excess of aluminum and a greater than average deficiency of boron, there are no obvious differences between the analyses of as-received and test feed samples. The composition of this feed is further corroborated by comparison to the product glasses (see Section 5.2), which shows all oxides with concentrations greater than 1 wt% in the target composition to be within 9% of the target. Low concentrations of manganese were measured even though manganese was not included in the target composition. Also, magnesium and titanium were targeted at low concentrations and were well above these targets. These positive deviations are often observed in melter feeds due to the ubiquity of these elements in the raw materials used to make up the simulants and in the glass forming additives. None of these relatively small deviations would significantly affect the glass processing rates.

## 5.2 Analysis of Glass Samples

Over eleven and a half metric tons of glass was produced in the present tests. The glass was discharged from DM1200 into 55 gallon drums using an airlift system. The discharged product glass was sampled at the end of each test by removing sufficient glass from the top of the cans for total inorganic analysis. Product glass masses and discharge date are given in Table 5.4.

All discharge glass samples were crushed and analyzed directly by XRF. The measured boron and lithium concentrations for the glass pool prior to testing and the average measured concentrations for boron and lithium oxides in feed samples were used to calculate boron and lithium concentrations that were subsequently used for normalizing the XRF data to 100 wt%. Fluorine analysis by XRF required a polished monolith as opposed to the standard ground glass preparation used for the other elements. Half the glass samples discharged were directly analyzed for fluorine; fluorine concentrations of other glasses were interpolated between the measured values. The XRF analyzed compositions of discharged glass samples are provided in Table 5.5. The melt pool composition at the beginning of testing was very similar to the target composition and therefore the composition of the discharged glasses approximated the target composition. The average XRF analysis of glass discharged over the course of the tests compared very favorably to the target values and feed sample analyses (see Section 5.1.2). Oxides with a target concentration greater than one weight percent all showed below 10% deviation from the target values. Compositional trends for selected constituents shown in Figures 5.1.a - 5.1.f show the consistency in melt pool composition throughout the tests. At the onset of testing, small increases in chromium, nickel, and calcium at the expense of silicon and zirconium were observed as the glass pool even more closely approached the target composition. Sulfur and fluorine are below target for discharged glasses due to volatilization from the glass pool and cold cap. Over the course of the tests, fluorine and sulfur increase to steady state concentrations of about forty five and eighty percent of the target values, respectively.

# SECTION 6.0
# MONITORED OFF-GAS EMISSIONS

## 6.1 Particulate Sampling

The melter exhaust was sampled for metals/particles according to 40-CFR-60 Methods 3, 5, and 29 at steady-state operating conditions during each test segment. The concentrations of off-gas species that are present as particulates and gaseous species that are collected in impinger solutions were derived from laboratory data on solutions extracted from air samples (filters and various solutions) together with measurements of the volume of air sampled. Particulate collection required isokinetic sampling, which entails removing gas from the exhaust at the same velocity that the air is flowing in the duct (40-CFR-60, Methods 1-5). Typically, a sample size of 30 dscf was taken at a rate of between 0.5 and 0.75 dscfm. Total particulate loading was determined by combining gravimetric analysis of the standard particle filter and chemical analysis of probe rinse solutions. An additional impinger containing 2 N NaOH was added to the sampling train to ensure complete scrubbing of all acid gases. The collected materials were analyzed using direct current plasma atomic emission spectroscopy for the majority of the constituents and ion chromatography (IC) for anions. Melter emission fluxes are compared to feed fluxes in Table 6.1. Notice the distinction that is made between constituents sampled as particles and as "gas". The "gaseous" constituents are operationally defined as those species that are scrubbed in the impinger solutions after the air stream has passed through a 0.3 µm heated filter. All samples are well within the 90 – 110% limits for isokinetic sampling.

Particulate emissions from the DM1200 constituted 0.13 to 0.18 percent of feed over the four tests. These results are within the range of 0.1 to 0.46 percent measured while processing the same waste and glass composition using the nominal four-outlet bubbler configuration over a variety of feed solids contents, glass temperatures, operational strategies, aluminum sources, and bubbling rates [20-22]. Particulate carryover while processing with the nominal four-outlet bubbler configuration at the production rate of 1050 kg/m$^2$/day was 0.13 percent of feed, similar to the 0.1 percent of feed previously measured with feed containing aluminum hydroxide and boehmite as the aluminum source [20, 21]. At production rates between 1400 and 1500 kg/m$^2$/day, particulate carryover while processing with six bubbling outlets in the current tests was only 0.17 percent of feed as compared to 0.16 and 0.46 percent of feed during previous tests processing with the nominal four-outlet bubbler configuration. At production rates around 1300 kg/m$^2$/day, particulate carryover while processing with five and six bubbling outlets in the current tests was 0.14 and 0.18 percent of feed as compared to 0.12 percent of feed during previous tests processing with the nominal four-outlet bubbler configuration [22]. These comparisons and the relatively narrow range of particulate carryover, 0.13 – 0.18 percent of feed, suggest that the aluminum form and the number of bubbling outlets used have little effect on the amount of solids carryover from the melter.

As expected, the feed elements emitted at the lowest melter decontamination factors (DF) were clearly fluorine and sulfur. Other elements exhibiting some volatile behavior were boron, alkali metals, cadmium, chromium, and lead. The relative volatility of magnesium and titanium are difficult to evaluate due to their low target concentrations in the feed and the ubiquity of these constituents as trace level contaminants in additives and chemicals used to make the waste simulants. Boron, sulfur, and fluorine were the only elements detected in the impinger solutions collected downstream of the heated particle filter in the sampling train, which constitutes the "gas" fraction of the melter emissions.

## 6.2 Gases Monitored by FTIR

Melter emissions were monitored in each test for a variety of gaseous components, most notably CO and nitrogen species, by FTIR. The off-gas system temperature is maintained well above 100°C beyond the sampling port downstream of the DM100 HEPA filter to prevent analyte loss due to condensation prior to monitoring. The data, therefore, represent the relative concentrations of volatile gaseous species in the melter exhaust. The exhaust stream was sampled at the outlets of several prototypical components (melter, SBS, WESP, and HEPA filter) to discern the effect these components have on the volatiles in the exhaust stream. It should be noted, however, that the off-gas system component most responsible for the removal of nitrogen oxide and volatile organics, the TCO-SCR catalyst unit, was bypassed in these tests due to the relatively low concentrations of these components in the exhaust stream. Also, a single FTIR unit was used for all of the measurements and, therefore, locations were sampled sequentially and not simultaneously.

A summary of the range and average concentrations of gaseous species monitored is provided in Tables 6.2 - 6.5. The concentrations of two of the monitored species illustrating the two types of behavior observed during the tests are plotted in Figures 6.1.a - 6.2.d. The analytes listed in Tables 6.2 - 6.5 are those that were thought likely to be observed during the tests based on previous work; no other species were detected in the off-gas stream by FTIR. The concentration of water in the melter exhaust increased with increasing feed rate and was mostly consistent with the amounts determined using the Method 5-type sampling (see Section 6.1). Moisture is condensed in the SBS and therefore the water content measured downstream of the SBS depends on the SBS sump temperature. Small reductions in water concentrations are observed further downstream due to minor air dilution through the WESP and immediately upstream of the HEPA filter. Generally, emissions were relatively low as a result of the low concentrations of nitrogen, organic carbon, ammonia, and halogens in the feed. The most abundant nitrogen species monitored was NO, with $NO_2$ being about seven times lower in concentration than NO, which is in keeping with previous melter tests with both HLW and LAW feeds. Low concentrations of ammonia, $N_2O$, nitric acid, nitrous acid, and HCN were also observed in the tests. Consistent with the gaseous fluorine concentrations observed using the Method 5-type sampling (see Section 6.1), HF was observed throughout the testing by FTIR in response to fluorine being targeted at two thirds of a weight percent in the glass product. Carbon monoxide was detected at around 2 ppm as a byproduct of incomplete combustion of the feed carbon in the presence of nitrates. The variability in the NO and $NO_2$ concentrations are attributable to the dynamic conditions in the cold cap and is in keeping with previous melter tests;

the increase in concentration over the course of the tests reflects the increase in feed rate. Measured concentrations for most constituents at different locations in the DM1200 exhaust system were very similar. This confirms the expectation that the SBS, WESP, HEME, and HEPA do not remove significant proportions of nitrogen and carbon oxides.

# SECTION 7.0
# SUMMARY AND CONCLUSIONS

A series of tests was conducted on the DM1200 Pilot Melter system to determine the relationship between the number and locations of bubbler outlets and the glass production rate. The tests were performed with a high aluminum HLW stream with aluminum oxide as the aluminum source. Aluminum oxide was chosen as the aluminum source because previous tests have shown this to produce the slowest melting melter feed as compared to gibbsite and boehmite [20]. A slower melting feed, in addition to providing the most conservative test case, allowed better estimation of the effect of bubbler configuration on feed processing rate without running into potential issues such as melter power limitations that could occur with a faster melting feed. For each test, target or maximum production rates were indicated by complete cold cap coverage visually observed and confirmed by plenum temperature readings. Testing began with bubblers in a previously defined and tested bubbler configuration; this consisted of two double-outlet lance bubblers on the melter floor, 8” apart on the East and West side, with one bubbler outlet a horizontal distance of 11.3” from the feed tube location [4, 15, 18, 20-23]. As testing progressed, bubbling outlets were added while maintaining either constant bubbling rate or constant feed rate. The bubbler air was equally divided between the bubbling outlets during each test. No significant processing problems were encountered during these tests. The DM1200 tests produced nearly twelve metric tons of glass from over 33 metric tons of feed.

The results from these tests clearly show increasing glass production rates with increasing number of bubbler outlets while processing at the same constant bubbling rate and with increasing bubbling rate when using the same number of bubbling outlets. During tests conducted at 78 lpm total lance bubbling, the glass production rate increased from about 1060 $kg/m^2/day$ using four bubbling outlets to about 1290 $kg/m^2/day$ using five outlets and to nearly 1400 $kg/m^2/day$ using six outlets. During the test conducted with six bubbling outlets, the glass production rate increased from about 1250 $kg/m^2/day$ when flowing 60 lpm air through the bubblers to nearly 1400 $kg/m^2/day$ when flowing 78 lpm through the bubblers. Increasing the number of bubbling outlets from four to five and from four to six resulted in increases in production rate of 21 and 32%, respectively. It should be noted that these increases are lower than can be realized with optimization of bubbler flow rates in conjunction with the addition of bubbling outlets. In the present tests, bubbling rates were fixed at values obtained while processing with the fewest number of bubbling outlets and not optimized for any of the tests. Considerably higher bubbling rates were used with four bubbling outlets in previous tests processing feeds containing easier forms of aluminum to melt than in present tests with six bubbling outlets to achieve comparable production rates. Comparison of the data from the current tests with data collected from previous tests processing high aluminum wastes [20, 21] corroborates the relative melt rates of the various forms of aluminum: aluminum oxide is the slowest to melt followed by aluminum hydroxide then boehmite.

Melter exhaust was sampled for particulate and gaseous species during each test to determine the effect of the number of bubbling outlets used and bubbler configuration on emissions. Total particulate carryover into the off-gas stream ranged between 0.1 and 0.15 percent of feed and was within the range previously measured while processing the same glass composition. Collectively, the past and present emission monitoring data indicate no significant differences in percent carryover with the number of bubbling outlets and aluminum source in the waste. Melter DFs were determined for most elements in the feed. The most volatile species were sulfur and fluorine, which is typical. Gaseous emissions of nitrogen oxides and byproducts of incomplete combustion, such as carbon monoxide and ammonia, were very low due to low concentrations of nitrates and organic carbon in the feed.

The results of the testing presented herein clearly demonstrate the increases in glass production rates by adding more bubblers to WTP HLW melter. These data can be used to support a decision on potential future modifications to the WTP HLW melter system such as a re-design of the melter lid to allow the inclusion of additional bubblers. Such a change would increase the glass production rate that is achievable and add robustness to the WTP HLW vitrification system. Some additional testing would be useful to further underpin such a decision. Some of the elements recommended for development are summarized below.

- *Other WTP HLW Waste Types:* The present testing was based on one HLW high aluminum waste composition from the Hanford tanks. Waste and melter feed compositions have a significant effect on cold cap formation and processing rate. While these results are also relevant to waste from several tanks, the diversity of the Hanford tank wastes has the potential to result in a variety of different cold cap conditions and therefore glass production rates. Therefore the extent of production rate increase with the addition of more bubblers has yet to be demonstrated over the range of wastes and melter feed compositions projected for HLW WTP operations, particularly those that tend to be slower melting.

- *Maximum Attainable Production Rates*: The results from the present tests demonstrate that increases in production rate are possible at constant bubbling by adding bubbler outlets. However, it is known from previous testing that for a given number of bubbler outlets, optimization of the bubbler flow rate will lead to yet further increases in glass production rates. It would be useful to quantify the extent of that increase for each bubbler configuration in order to better define the potential glass production rate improvements that are possible.

- *Lid Design for WTP HLW Melter*: As noted above, inclusion of additional bubblers into the WTP HLW melter system would require a re-design of the melter lid. It is likely that such design work would be supported by computer modeling of the WTP HLW melter with various possible bubbler configurations, as was done for previous WTP melter designs as well as for the Defense Waste Processing Facility (DWPF) bubbler retro-fit.

# SECTION 8.0
# REFERENCES

[1] “River Protection Project System Plan 6,” P.J. Certa and P.A. Empey, ORP-11242, Rev. 6, Washington River Protection Solutions, LLC, Richland, WA, 99352, 10/5/11.

[2] “Determination of Processing Rate of RPP-WTP HLW Simulants using a DuraMelter™ 1000 Vitrification System,” K.S. Matlack, W.K. Kot, F. Perez-Cardenas, and I.L. Pegg, Final Report, VSL-00R2590-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 8/21/00.

[3] “Design and Installation of a Prototypical Off-Gas Treatment System for the DM1200 RPP-WTP HLW Pilot Melter,” R.T. Anderson, M. Brandys, and R. Jung, Final Report, VSL-01R2510-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 2/22/01.

[4] “Summary of DM1200 Operation at VSL,” K.S. Matlack, G. Diener, T. Bardakci, and I.L. Pegg, Final Report, VSL-06R6710-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/7/06.

[5] "Start-Up and Commissioning Tests on the DM1200 HLW Pilot Melter System Using AZ-101 Waste Simulants," K.S. Matlack, M. Brandys, and I.L. Pegg, Final Report, VSL-01R0100-2, Rev. 1, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/31/01.

[6] "Tests on the DuraMelter 1200 HLW Pilot Melter System Using AZ-101 HLW Simulants," K.S. Matlack, W.K. Kot, T. Bardakci, T.R. Schatz, W. Gong, and I.L. Pegg, Final Report, VSL-02R0100-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 6/11/02.

[7] “Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope C1 Simulants,” K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, and I.L. Pegg, Final Report, VSL-02R8800-1, Rev. 1, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/23/03.

[8] “Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope A1 Simulants,” K.S. Matlack, W. Gong, T. Bardakci, N. D’Angelo, and I.L. Pegg, Final Report, VSL-02R8800-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/03/02.

[9] "DM1200 Tests with AZ-101 HLW Simulants," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, W.K. Kot, and I.L. Pegg, Final Report, VSL-03R3800-4, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 2/17/04.

[10] "Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope B1 Simulants," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, and I.L. Pegg, Final Report, VSL-03R3851-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/17/03.

[11] "Integrated DM1200 Melter Testing of HLW AZ-102 Compositions Using Bubblers," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, W. Kot and I.L. Pegg, Final Report, VSL-03R3800-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/24/03.

[12] "Integrated DM1200 Melter Testing of HLW C-106/AY-102 Composition Using Bubblers," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, W. Kot and I.L. Pegg, Final Report, VSL-03R3800-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/15/03.

[13] "Integrated DM1200 Melter Testing of HLW C-104/AY-101 Compositions Using Bubblers," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, W. Kot and I.L. Pegg, Final Report, VSL-03R3800-3, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 11/24/03.

[14] "Integrated DM1200 Melter Testing of Redox Effects Using HLW AZ-101 and C-106/AY-102 Simulants," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, W. Lutze, P. M. Bizot, R. A. Callow, M. Brandys, W.K. Kot, and I.L. Pegg, Final Report, VSL-04R4800-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 5/6/04.

[15] "Integrated DM1200 Melter Testing of Bubbler Configurations Using HLW AZ-101 Simulants," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, W. Lutze, R. A. Callow, M. Brandys, W.K. Kot, and I.L. Pegg, Final Report, VSL-04R4800-4, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/5/04.

[16] "Bubbling Rate and Foaming Tests on the DuraMelter 1200 with LAWC22 and LAWA30 Glasses," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, P.M. Bizot, R.A. Callow, M. Brandys, and I.L. Pegg, Final Report, VSL-04R4851-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 7/1/04.

[17] "Destruction of Alcohols in DM1200 Melter System During LAW and HLW Vitrification," K.S. Matlack and I.L. Pegg, Letter Report, VSL-03L4850-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/16/03.

[18] "Integrated DM1200 Melter Testing Using AZ-102 and C-106/AY-102 HLW Simulants: HLW Simulant Verification," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, M. Brandys, W.K. Kot, and I.L. Pegg, Final Report, VSL-05R5800-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 6/27/05.

[19] "Regulatory Off-Gas Emissions Testing on the DM1200 Melter System Using HLW and LAW Simulants," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, M. Brandys, W. Kot, and I.L. Pegg, Final Report VSL-05R5830-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/31/05.

[20] "Melt Rate Enhancement for High Aluminum HLW Glass Formulations," K.S. Matlack, H. Gan, M. Chaudhuri, W.K Kot, W. Gong, T. Bardakci, I. Joseph, and I.L. Pegg, Final Report, VSL-08R1360-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/19/08.

[21] "DM100 and DM1200 Melter Testing with High Waste Loading Glass Formulations for Hanford High-Aluminum HLW Streams," K.S. Matlack, H. Gan, M. Chaudhuri, W.K Kot, W. Gong, T. Bardakci, I. Joseph, and I.L. Pegg, Final Report, VSL-10R1690-1, Rev. A, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 5/17/10.

[22] "HLW Melter Control Strategy Without Visual Feedback," K.S. Matlack, W.K. Kot, H. Abramowitz, R. A. Callow, M. Brandys, I. Joseph, and I.L. Pegg, Final Report, VSL-12R2500-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 11/9/11.

[23] "Tests with High-Bismuth HLW Glasses," K.S. Matlack, H. Gan, W.K. Kot, M. Chaudhuri, R.K. Mohr, D. A. McKeown**,** T. Bardakci, W. Gong, A. C. Buechele, and I.L. Pegg, Final Report, VSL-10R1780-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/13/10.

[24] "Test and Evaluate High Level Waste (HLW) Vitrification System Improvements," Contract Number DE-AC27-06RV14790, US Department of Energy, Office of River Protection, Richland, WA, April, 2006.

[25] **"**High Level Waste Vitrification Plant Enhancement Study," C. Chapman., 24590-HLW - RTP-PE-07-001, Rev 0, The River Protection Project, Waste Treatment Plant, Richland Washington, Feb. 28 2007.

[26] "Testing of Optimized Bubbler Configuration for HLW Melter," K.S. Matlack, W.K. Kot, I.L. Pegg, and I. Joseph, Test Plan, VSL-12T2950-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 11/29/12.

[27] "Development and Testing of High-Level Waste Glass Compositions," Contract Number DE-EM0002103, US Department of Energy, Office of River Protection, Richland, WA.

[28] "Quality Assurance Project Plan for ORP/ RPP-WTP Support Activities Conducted by VSL," Vitreous State Laboratory, QAPP-ORP, Rev. 3, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/22/12.

[29] "Master List of Controlled VSL Manuals and Standard Operating Procedures in Use," QA-MLCP, Rev. 90, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/3/12.

[30] "High-Level Waste Melter Alternate Bubbler Configuration Testing," R.K Mohr, C.C. Chapman and I.L. Pegg, Final Report, VSL-04R4800-3, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 6/18/04.

[31] "High Level Waste Vitrification System Improvements," K.S. Matlack, H. Gan, W. Gong, I.L. Pegg, C.C. Chapman and I. Joseph, VSL-07R1010-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 4/16/07.

## Table 2.1. Oxide Compositions of Limiting Waste Streams.

| Waste Component | Bi Limited Glass | Cr Limited Glass | Al Limited Glass | Al and Na Limited Glass |
|---|---|---|---|---|
| $Al_2O_3$ | 22.45% | 25.53% | 49.21% | 43.30% |
| $B_2O_3$ | 0.58% | 0.53% | 0.39% | 0.74% |
| CaO | 1.61% | 2.47% | 2.21% | 1.47% |
| $Fe_2O_3$ | 13.40% | 13.13% | 12.11% | 5.71% |
| $Li_2O$ | 0.31% | 0.36% | 0.35% | 0.15% |
| MgO | 0.82% | 0.16% | 0.24% | 0.44% |
| $Na_2O$ | 12.97% | 20.09% | 7.35% | 25.79% |
| $SiO_2$ | 12.04% | 10.56% | 10.05% | 6.22% |
| $TiO_2$ | 0.30% | 0.01% | 0.02% | 0.35% |
| ZnO | 0.31% | 0.25% | 0.17% | 0.36% |
| $ZrO_2$ | 0.40% | 0.11% | 0.81% | 0.25% |
| $SO_3$ | 0.91% | 1.52% | 0.41% | 0.44% |
| $Bi_2O_3$ | 12.91% | 7.29% | 2.35% | 2.35% |
| $ThO_2$ | 0.25% | 0.04% | 0.37% | 0.04% |
| $Cr_2O_3$ | 1.00% | 3.07% | 1.07% | 1.44% |
| $K_2O$ | 0.89% | 0.37% | 0.29% | 1.34% |
| $U_3O_8$ | 3.48% | 7.59% | 7.25% | 4.58% |
| BaO | 0.02% | 0.03% | 0.11% | 0.06% |
| CdO | 0.00% | 0.01% | 0.05% | 0.02% |
| NiO | 3.71% | 1.06% | 0.82% | 0.20% |
| PbO | 0.48% | 0.48% | 0.84% | 0.18% |
| $P_2O_5$ | 9.60% | 3.34% | 2.16% | 4.10% |
| F- | 1.58% | 2.00% | 1.37% | 0.46% |
| Total | 100.00% | 100.00% | 100.00% | 100.00% |

**Table 2.2. Compositions of the Al-Limited Waste (Oxide Basis) and the HLW Waste Simulant to Produce 100 kg of Waste Oxides (20 wt% suspended solids).**

| Al-Limited Waste Composition | | Al-Limited HLW Waste Simulant | |
|---|---|---|---|
| **Waste Oxide** | **Wt%** | **Starting Materials** | **Target Weight (kg)** [1] |
| $Al_2O_3$ | 49.21% | $Al_2O_3$ | 49.707 |
| $B_2O_3$ | 0.39% | $H_3BO_3$ | 0.700 |
| CaO | 2.21% | CaO | 2.255 |
| $Fe_2O_3$ | 12.11% | $Fe(OH)_3$ (13% Slurry) | 99.643 |
| $Li_2O$ | 0.35% | $Li_2CO_3$ | 0.888 |
| MgO | 0.24% | MgO | 0.253 |
| $Na_2O$ | 7.35% | NaOH | 4.235 |
| $SiO_2$ | 10.05% | $SiO_2$ | 10.152 |
| $TiO_2$ | 0.02% | $TiO_2$ | 0.020 |
| ZnO | 0.17% | ZnO | 0.172 |
| $ZrO_2$ | 0.81% | $Zr(OH)_4 \cdot xH_2O$ | 2.093 |
| $SO_3$ | 0.41% | $Na_2SO_4$ | 0.735 |
| $Bi_2O_3$ | 2.35% | $Bi_2O_3$ | 2.374 |
| $ThO_2$ | 0.37% | Omitted | |
| $Cr_2O_3$ | 1.07% | $Cr_2O_3 \cdot 1.5H_2O$ | 1.273 |
| $K_2O$ | 0.29% | $KNO_3$ | 0.632 |
| $U_3O_8$ | 7.25% | Omitted | |
| BaO | 0.11% | $BaCO_3$ | 0.143 |
| CdO | 0.05% | CdO | 0.051 |
| NiO | 0.82% | $Ni(OH)_2$ | 1.055 |
| PbO | 0.84% | PbO | 0.848 |
| $P_2O_5$ | 2.16% | $FePO_4 \cdot xH_2O$ | 5.738 |
| F | 1.37% | NaF | 3.044 |
| Carbonate | 1.20[2] | $Na_2CO_3$ | 0.806 |
| Nitrite | 0.50 | $NaNO_2$ | 0.769 |
| Nitrate | 2.00 | $NaNO_3$ | 2.230 |
| Organic Carbon | 0.05 | $H_2C_2O_4 \cdot 2H_2O$ | 0.264 |
| — | — | Water | 279.400 |
| TOTAL | 100.0% | TOTAL | 469.478 |

[1] Target weights adjusted for assay information of starting materials
[2] Unit for volatile components is g/100 g of waste oxide
— Empty data field

**Table 2.3. Composition and Properties of Aluminum Limited Waste and Glass Formulation HWI-Al-19 with 45% Waste Loading (wt%).**

| - | Al-Limited Waste* | Waste in Glass | Glass Forming Additives | Target Glass HWI-Al-19 |
|---|---|---|---|---|
| $Al_2O_3$ | 53.27 | 23.97 | - | 23.97 |
| $B_2O_3$ | 0.42 | 0.19 | 19.00 | 19.19 |
| BaO | 0.12 | 0.05 | - | 0.05 |
| $Bi_2O_3$ | 2.54 | 1.14 | - | 1.14 |
| CaO | 2.39 | 1.08 | 4.50 | 5.58 |
| CdO | 0.05 | 0.02 | - | 0.02 |
| $Cr_2O_3$ | 1.16 | 0.52 | | 0.52 |
| F | 1.48 | 0.67 | - | 0.67 |
| $Fe_2O_3$ | 13.11 | 5.90 | - | 5.90 |
| $K_2O$ | 0.31 | 0.14 | - | 0.14 |
| $Li_2O$ | 0.38 | 0.17 | 3.40 | 3.57 |
| MgO | 0.26 | 0.12 | - | 0.12 |
| $Na_2O$ | 7.96 | 3.58 | 6.00 | 9.58 |
| NiO | 0.89 | 0.40 | - | 0.40 |
| $P_2O_5$ | 2.34 | 1.05 | - | 1.05 |
| PbO | 0.91 | 0.41 | - | 0.41 |
| $SO_3$ | 0.44 | 0.20 | - | 0.20 |
| $SiO_2$ | 10.88 | 4.90 | 22.10 | 27.00 |
| $TiO_2$ | 0.02 | 0.01 | - | 0.01 |
| ZnO | 0.18 | 0.08 | - | 0.08 |
| $ZrO_2$ | 0.88 | 0.39 | - | 0.39 |
| Sum | 100.0 | 45.0 | 55.0 | 100.0 |

* Renormalized from Ref. [24] after removal of radioactive components.

| | | | |
|---|---|---|---|
| Viscosity @1150ºC, P | | | 33 |
| Conductivity @1150ºC, S/cm | | | 0.27 |
| Crystal Content, As Melted | | | None |
| Crystal Content, 72 hr at 950 ºC | | | 1.3 |
| Crystal Content, CCC | | | 1.9 |
| TCLP | | | Pass |
| PCT, g/L | - | DWPF-EA | HWI-Al-19 |
| | B | 16.7 | 0.654 |
| | Li | 9.6 | 0.794 |
| | Na | 13.3 | 0.624 |

- Empty data field

**Table 2.4. Composition of Melter Feed to Produce 100 kg of Target Glass HWI-Al-19 (Target Glass Yield = 500 g/L Feed) from the Al-Limited Waste Simulant.**

| Al-Limited Waste Simulant | | Glass-Forming Additives | |
|---|---|---|---|
| **Starting Materials** | **Target Weight (kg)** * | **Starting Materials** | **Target Weight (kg)** * |
| $Al_2O_3$ | 23.97 | — | — |
| $H_3BO_3$ | 0.341 | $H_3BO_3$ | 34.089 |
| $BaCO_3$ | 0.070 | — | — |
| $Bi_2O_3$ | 1.156 | — | — |
| CaO | 1.099 | $CaSiO_3$ (Wollastonite) | 9.798 |
| CdO | 0.025 | — | — |
| $Cr_2O_3$ | 0.532 | — | — |
| NaF | 1.483 | — | — |
| $Fe(OH)_3$ (13% Slurry) | 48.539 | — | — |
| $KNO_3$ | 0.308 | — | — |
| $Li_2CO_3$ | 0.432 | $Li_2CO_3$ | 8.625 |
| MgO | 0.121 | — | — |
| NaOH | 2.190 | $Na_2CO_3$ | 10.364 |
| $Ni(OH)_2$ | 0.514 | — | — |
| $FePO_4{\cdot}xH_2O$ $ | 2.795 | — | — |
| PbO | 0.413 | — | — |
| $Na_2SO_4$ | 0.358 | — | — |
| $SiO_2$ | 4.945 | $SiO_2$ | 17.276 |
| $TiO_2$ | 0.010 | — | — |
| ZnO | 0.084 | — | — |
| $Zr(OH)_4{\cdot}xH_2O$ $ | 1.020 | — | — |
| $H_2O$ | 97.687 | — | — |
| $Na_2CO_3$ | 0.314 | — | — |
| $NaNO_2$ | 0.346 | — | — |
| $NaNO_3$ | 0.984 | — | — |
| $H_2C_2O_4{\cdot}2H_2O$ | 0.119 | — | — |
| — | — | — | — |
| Simulant Total | 189.855 | Additives Total | 80.152 |
| — | — | FEED TOTAL | 277.300 |

* Target weights adjusted for assay information of starting materials
$ The water content of these compounds is variable; the recipe is based on the nominal assay for the particular source materials used, which is 20% water for the iron phosphate and 50% zirconium for the zirconium hydroxide
— Empty data field

## Table 3.1. Summary of Test Conditions and Results.

| Test | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Time | Feed Start | 1/15/2013 10:05 | 1/22/2013 14:00 | 1/29/2013 9:30 | 2/6/2013 12:00 |
| | Feed End | 1/17/2013 12:31 | 1/24/2013 17:01 | 1/31/2013 10:30 | 2/8/2013 17:00 |
| | Interval (hr) | 50.4 | 51.0 | 49.0 | 53.0 |
| Water Feeding for Cold Cap (hr) | | 1.7 | 1.0 | 1.0 | 1.0 |
| Slurry Feeding (hr) | | 48.7 | 50.0 | 48.0 | 52.0 |
| Slurry Feeding at Steady State (hr) | | 20.9 | 44.3 | 28.9 | 29.6 |
| Target Production Rate (kg/m$^2$/day) | | 1050 | None | 1289 | None |
| Bubbling | Outlets | 4 | 5 | 6 | 6 |
| | Bubbler Set Point (lpm) | None | 78 | None | 78 |
| | Steady State Total Lance Bubbling (lpm) | 78 | 78 | 60 | 78 |
| Average Steady State Plenum Temperature all 6 locations (°C) | | 556 | 543 | 471 | 453 |
| Average Steady State Glass Temperature lower 6 locations (°C) | | 1143 | 1143 | 1148 | 1155 |
| Feed | Used (kg) | 7010 | 8823 | 8449 | 9054 |
| | Measured Glass percentage | 0.36 / 0.25* | 0.36 | 0.35 | 0.35 |
| | Average Rate (kg/hr) | 95 | 94 | 109 | 79 |
| Glass Produced | Discharged | 2366 | 3255 | 3010.5 | 3188.5 |
| | From Feed (kg) | 2276 | 3352 | 2957 | 3169 |
| | Average Rate (kg/m$^2$/day) | 935 | 1270 | 1232 | 1218 |
| | Average Steady state rate (kg/m$^2$/day) | 1062 | 1289 | 1251 | 1398 |

* At the end of Test 1

## Table 3.2. Summary of Operational Events.

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 1 | 1/14/13 | 11:00 | - | Transferred feed to mix tank. Tank mass is 2949.5 kg. This mass includes 10 kg water. |
| | | 19:20 | - | Transferred feed from mix tank to feed tank. Net mass of feed transferred to feed tank is 3398.5 kg. This mass includes 498 kg water. |
| | 1/15/13 | 0:40 | - | Completed feed transfer to mix tank. Tank mass at the start is 55.0 kg, tank mass at the end is 3005.5 kg. Net mass of feed transferred to mix tank is 2950.5 kg. This mass includes 10 kg flush water. |
| | | 10:05 | 0.0 | Start water feeding at 0.5 liter/min. |
| | | 10:17 | 0.2 | Increased power from 90 kW to 100 kW. Average glass temperature is 1155°C. |
| | | 10:19 | 0.2 | Increased bubbling on L1 and L2 from 1.5 lpm to 2.5 lpm each. |
| | | 10:25 | 0.3 | Water flow rate was raised to 1.0 liter/min. |
| | | 10.27 | 0.4 | Increased power from 100 kW to 110 kW. Average glass temperature is 1144°C. |
| | | 10:37 | 0.5 | Increased power from 110 kW to 115 kW. Average glass temperature is 1142°C. |
| | | 10:45 | 0.7 | Water flow rate was raised to 2.0 liter/min. |
| | | 10:47 | 0.7 | Increased power from 115 kW to 125 kW. |
| | | 10:57 | 0.9 | Increased power from 125 kW to 130 kW. |
| | | 11:00 | 0.9 | Decreased bubbling on L1 and L2 from 2.5 to 2.0 lpm each. |
| | | 11:12 | 1.1 | Increased power from 130 kW to 135 kW. |
| | | 11:25 | 1.3 | Water flow rate was raised to 2.5 liter/min. |
| | | 11:43 | 1.6 | Water flow rate was raised to 3.0 liter/min. Average plenum temperature is 745°C. |
| | | 11:50 | 1.7 | Secured feeding water. Started feeding HWI-Al-19 feed**.** Decreased power from 135 kW to 130 kW. |
| | | 11:55 | 1.8 | Increased bubbling on L1 and L2 from 2.0 to 10.0 lpm each. |
| | | 12:02 | 1.9 | Increased power from 130 kW to 135 kW. Average glass temperature is 1134°C. |
| | | 12:12 | 2.1 | Increased power from 130 kW to 135 kW. Average glass temperature is 1142°C. |
| | | 12:14 | 2.1 | Decreased T4 to 50 seconds. |
| | | 12:25 | 2.3 | Decreased T4 from 50 to 40 seconds. |
| | | 12:35 | 2.5 | Average glass temperature is 1147°C. Average power is 139 kW and current is 1219 Amps. Glass resistance is 0.093 Ω. |
| | | 12:41 | 2.6 | Increased T1 from 1.0 second to 1.2 seconds. |
| | | 13:20 | 3.2 | Bubbling on L1 and L2 are @15.0 lpm each. |
| | | 13:35 | 3.5 | Average glass temperature is 1149°C. Plenum temperature is 666 - 707°C. |
| | | 13:50 | 3.7 | Average glass temperature is 1156°C. Plenum temperature is 657 - 698°C. |
| | | 14:04 | 4.0 | Increased discharge power from 16 to 18 kW. |
| | | 14:12 | 4.1 | Reduced power from 140 to 135 kW. |
| | | 14:20 | 4.2 | Average glass temperature is 1159°C. Plenum temperature is 644 - 665°C. |

# Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | Run time note |
|---|---|---|---|---|
| 1 | 1/15/13 | 14:35 | 4.5 | Average glass temperature is 1159°C. |
| | | 14:46 | 4.7 | Increased bubbling from 15 to 17 lpm. |
| | | 14:52 | 4.8 | Plenum temperature is 617 - 640°C. |
| | | 15:12 | 5.1 | Reduced power to 133 kW. Average glass temperature is 1158°C. |
| | | 15:15 | 5.2 | Plenum temperature is 576 - 615°C. |
| | | 15:32 | 5.4 | Increased bubbling from 17 lpm to 20 lpm. Plenum temperature is 573 - 599°C. Also adjusted Blower #801 from 19 to 24 Hz. |
| | | 16:20 | 6.2 | Plenum temperature is 545 - 580°C. |
| | | 16:42 | 6.6 | Plenum temperature is 526 - 557°C. |
| | | 16:53 | 6.8 | Reduced feeding by changing T4 from 32 to 33 seconds and increased bubbling from 20 to 22 lpm. Plenum temperature is 519 - 549°C. Feed rate is 151 kg/hr. |
| | | 17:01 | 6.9 | Increased power from 133 kW to 135 kW. Average glass temperature is 1143°C. |
| | | 17:44 | 7.6 | Dilution air on WESP was lowered from 20 scfm to 16 scfm for both south and north air injectors. |
| | | 17:51 | 7.8 | Increased bubbling on L1 and L2 from 22 lpm to 25 lpm respectively. |
| | | 18:04 | 8.0 | Increased power from 135 kW to 140 kW. |
| | | 18:13 | 8.1 | Increased bubbling on L1 and L2 from 25 lpm to 27 lpm respectively. |
| | | 18:28 | 8.4 | Increased power from 140 kW to 145 kW. Average glass temperature is 1132°C. |
| | | 18:55 | 8.8 | Increased power from 145kW to 150 kW. |
| | | 19:29 | 9.4 | Increased power from 150 kW to 155 kW. Average glass temperature is 1127°C. |
| | | 19:46 | 9.7 | Performing film cooler rinse. |
| | | 20:09 | 10.1 | Turned on Lances 1B and 2B mass flow controllers. |
| | | 20:18 | 10.2 | Increased bubbling to 60 lpm total. |
| | | 20:21 | 10.3 | Increased power from 155 kW to 160 kW. Average glass temperature is 1140°C. |
| | | 20:23 | 10.3 | Plenum temperature is 449 - 485°C. |
| | | 20:40 | 10.6 | Increased bubbling on all four bubbler mass flow controllers from 15 to 17 lpm, total bubbling is at 68 lpm. |
| | | 21:05 | 11.0 | Plenum temperature is 457 - 479°C. |
| | | 21:20 | 11.2 | Increased power from 160 kW to 165 kW. Average glass temperature is 1134°C. |
| | | 21:27 | 11.4 | Plenum temperature is 473 – 491°C. |
| | | 21:37 | 11.5 | Plenum temperature is 473 – 494°C. |
| | | 21:52 | 11.8 | Plenum temperature is 466 – 493°C. |
| | | 21:59 | 11.9 | Increased power from 165kW to 167 kW. Average glass temperature is 1140℃ |
| | | 22:22 | 12.3 | Plenum temperature is 475 – 495°C. |
| | | 22:25 | 12.3 | Feed tank recirculation pump is stopped. Increased pressure from 20 to 25 psi. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 1 | | 22:34 | 12.5 | Plenum temperature is 499 – 504°C. |
| | | 22:37 | 12.5 | Average glass temperature is 1139°C. Increased power from 167 to 169 kW. Glass resistance is 0.090 Ω. |
| | | 22:54 | 12.8 | Increased power from 169 to 171 kW. Average glass temperature is 1141°C. Glass resistance is 0.091 Ω. |
| | | 22:55 | 12.8 | Observed feed rate at a steady rate of 1226 $kg/m^2$/day. |
| | | 23:00 | 12.9 | Plenum temperature is 481 – 493°C. Average glass temperature is 1140°C. |
| | | 23:06 | 13.0 | Increased power from 171 to 173 kW. Average glass temperature is 1136°C. Glass resistance is 0.092 Ω. |
| | | 23:17 | 13.2 | Increased power from 173 to 176 kW. Average glass temperature is 1134°C. |
| | | 23:16 | 13.2 | Average glass temperature is 1134°C. Plenum temperature is 474 – 475°C. |
| | | 23:38 | 13.5 | Average glass temperature is 1137°C. Plenum temperature is 460 – 465°C. |
| | | 23:46 | 13.7 | Increased power from 176 to 179 kW. Average glass temperature is 1138°C. |
| | | 23:53 | 13.8 | CC collapses. Low pressure alarm. |
| | | 23:55 | 13.8 | Reduced bubbling from 17.1 lpm to 15.0 lpm on all bubbler mass flow controllers. |
| | | 23:58 | 13.9 | Increased power from 179 to 181 kW. Average glass temperature is 1137°C. Glass resistance is 0.090 Ω. |
| | 1/16/13 | 0:02 | 13.9 | Average glass temperature is 1141°C. Plenum temperature is 447 – 456°C. |
| | | 0:12 | 14.1 | Found MM-AR-FI-201 and MM-AR-FI-202 slightly higher than 0.5 SCFH, adjusted back to 0.5SCFH. At the same time, MM-AR-FI-203 was lower than 0.5 SCFH and reset correctly. During the change the level meter was reading 28.7” prior to and 28.4” after. |
| | | 0:13 | 14.1 | Increased bubbling from 15.0 lpm to 16.0 lpm on all bubbling mass flow controllers. |
| | | 0:15 | 14.2 | Increased power from 182 to 185 kW. Average glass temperature is 1139°C. Glass resistance is 0.090 Ω. |
| | | 0:31 | 14.4 | Increased bubbling from 16.0 lpm to 17.0 lpm on all bubbler mass flow controllers. Average glass temperature is 1142°C. Plenum temperature is 457 – 442°C. |
| | | 0:38 | 14.5 | Increased bubbling from 17.0 lpm to 19.0 lpm on all bubbler outlets. |
| | | 0:40 | 14.6 | Average glass temperature is 1146°C. Plenum temperature is 454 – 444°C. |
| | | 1:02 | 14.9 | Average glass temperature is 1146°C. Glass resistance is 0.089 Ω. Plenum temperature is 451 – 456°C. |
| | | 1:22 | 15.3 | Increased bubbling from 19.0 lpm to 20.0 lpm on all bubbler mass flow controllers. |
| | | 1:28 | 15.4 | Average glass temperature is 1142°C. Glass resistance is 0.091 Ω. Plenum temperature is 463 – 455°C. |
| | | 1:38 | 15.5 | Initiated caustic pump to neutralization tank. pH is 5.3. |
| | | 1:41 | 15.6 | Combined flow to both Lance bubblers now total 79.2 lpm. |
| | | 1:43 | 15.6 | Performing film cooler rinse. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 1 | 1/16/13 | 1:45 | 15.7 | Secured caustic pump, pH of neutralization tank is 7.0. |
| | | 1:55 | 15.8 | Average glass temperature is 1141°C. Glass resistance is 0.090 Ω. Plenum temperature is 470 – 453°C. |
| | | 1:58 | 15.9 | Increased power from 185 to 183x kW. T/W #1 reads 1109-1133°C. T/W #2 reads 1125-1153°C. Plenum temperature is 450 – 469°C. Glass resistance is 0.091 Ω. |
| | | 2:15 | 16.2 | T/W #1 reads 1105-1133°C. T/W #2 reads 1134-1157°C. Plenum temperature is 452 – 460°C. |
| | | 2:41 | 16.6 | Mixer tank blade rotation is increased to 30 Hz. |
| | | 2:43 | 16.6 | Average glass temperature is 1143°C. Glass resistance is 0.090 Ω. Plenum temperature is 461 – 477°C. |
| | | 3:01 | 16.9 | Average glass temperature is 1144°C. Glass resistance is 0.089 Ω. Plenum temperature is 477 – 498°C. |
| | | 3:19 | 17.2 | Average glass temperature is 1137°C. Plenum temperature is 485 – 536°C. |
| | | 3:32 | 17.4 | Plenum temperature is 493 – 534°C. |
| | | 3:50 | 17.7 | Average glass temperature is 1139°C. Glass resistance is 0.092 Ω. Plenum temperature is 501 – 550°C. |
| | | 4:11 | 18.1 | Average glass temperature is 1140°C. Plenum temperature is 494 – 539°C. |
| | | 4:24 | 18.3 | Average glass temperature is 1140°C. Plenum temperature is 491 – 527°C. |
| | | 4:42 | 18.6 | Observed slight leak coming from SBS blow down valve, will continue to monitor. |
| | | 5:08 | 19.0 | Plenum temperature is 491 – 503°C. |
| | | 5:10 | 19.1 | After investigation HEME #2 differential pressure transmitter is non-functional. Repair/replacement is pending. |
| | | 5:15 | 19.2 | Repaired HEME#2 differential transmitter. |
| | | 5:19 | 19.2 | Average glass temperature is 1138°C. Plenum temperature is 493 – 500°C. |
| | | 5:34 | 19.5 | Plenum temperature is 478 – 510°C. |
| | | 5:48 | 19.7 | Plenum temperature is 485 – 518°C. |
| | | 6:04 | 20.0 | Plenum temperature is 483 – 533°C. |
| | | 6:19 | 20.2 | Plenum temperature is 498 – 529°C |
| | | 8:09 | 22.1 | Decreased from 34 to 33 seconds. Feed rate is 145.0 kg/hr. |
| | | 8:20 | 22.2 | Power is at 186 kW. Current is 1449 Amps. Total bubbling is 80 lpm. Glass resistance is 0.089 Ω. |
| | | 8:40 | 22.6 | Power is at 186 kW, 128 volts. Current is 1451 Amps. Glass resistance is 0.088 Ω. |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 1 | 1/16/13 | 9:10 | 23.1 | Transferred feed from mix tank to feed tank. Tank mass at the start is 3011.0 kg, tank mass at the end is 505.0 kg. Net mass of feed transferred to feed tank is 2506.0 kg. Total of 2936.0 kg feed plus 430 kg water added to the feed rank. |
| | | 10:05 | 24.0 | Average glass temperature is 1138°C. |
| | | 10:20 | 24.2 | Average glass temperature is 1142°C. Plenum temperature is 509 – 526°C |
| | | 10:35 | 24.5 | Average glass temperature is 1145°C. |
| | | 10:50 | 24.7 | Average glass temperature is 1143°C. |
| | | 11:05 | 25.0 | Average glass temperature is 1143°C. |
| | | 11:39 | 25.6 | Paused feeding for feed sample. |
| | | 11:49 | 25.7 | Average glass temperature is 1143°C. |
| | | 12:05 | 26.0 | Performed WESP blow down, deluge and blow down. |
| | | 12:24 | 26.3 | Performed SBS blow down. Flow totalizer is not functioning. Broken lead repaired. |
| | | 13:20 | 27.2 | Total bubbling is 80 lpm, Power is at 186 kW. Current is 1437 Amps. Average glass temperature is 1142°C. Glass resistance is 0.090 Ω. |
| | | 14:23 | 28.3 | Average glass temperature is 1146°C. |
| | | 14:41 | 28.6 | Plenum temperature is 539 – 548°C |
| | | 14:45 | 28.7 | Equalized storage tanks, neutralization tank at 500gal. |
| | | 15:05 | 29.0 | Plenum temperature is 520 – 543°C |
| | | 15:16 | 29.2 | Increased power from 188 to 190 kW. Average glass temperature is 1142°C. |
| | | 15:31 | 29.4 | Due to melter pressure spikes higher than normal T1 has been changed from 1.2 to 1.1 second and T4 from 37 to 36 seconds. |
| | | 15:49 | 29.7 | Plenum temperature is 527 – 564°C |
| | | 15:58 | 29.9 | Reduced bubbling mass flow controllers from 20 lpm to 19 lpm each, total bubbling from 80 lpm to 76 lpm. Plenum temperature is 536 – 569°C |
| | | 16:09 | 30.1 | Plenum temperature is 542 – 576°C. Increased feed rate by changing T4 from 34 to 33 seconds. |
| | | 16:19 | 30.2 | Plenum temperature is 550 – 578°C. |
| | | 16:34 | 30.5 | Plenum temperature is 537 – 573°C. |
| | | 16:49 | 30.7 | Plenum temperature is 534 – 582°C. |
| | | 17:04 | 31.0 | Plenum temperature is 545 – 589°C |
| | | 17:22 | 31.3 | Plenum temperature is 539– 592°C. |
| | | 17:35 | 31.5 | Plenum temperature is 539– 584°C. |
| | | 17:49 | 31.7 | Plenum temperature is 541– 575°C. |
| | | 17:57 | 31.9 | Opened pitot tube port in transition line. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 1 | 1/16/13 | 18:11 | 32.1 | Plenum temperature is 535– 581°C. |
| | | 18:21 | 32.3 | Off gas testing in transition line started. Emergency off gas, EOG is tripped. |
| | | 18:28 | 32.4 | Plenum temperature is 545– 573°C. |
| | | 18:37 | 32.5 | Plenum temperature is 536– 560°C. |
| | | 18:52 | 32.8 | Plenum temperature is 546– 576°C. |
| | | 19:09 | 33.1 | Plenum temperature is 528– 584°C. |
| | | 19:21 | 33.3 | Off gas testing is done, EOG tripped again. |
| | | 19:24 | 33.3 | Transferred feed from mix tank to feed tank. Starting tank mass 495.5 kg, ending tank mass 53.0 kg. Net mass of feed transferred to feed tank is 442.5 kg. Total of 527.5 kg feed including 85 kg water added to the feed rank. |
| | | 20:04 | 34.0 | Performing film cooler rinse. |
| | | 23:39 | 37.6 | Electrode high temperature was alarmed. Power was reduced from 192 kW to 189 kW. |
| | | 23:43 | 37.6 | Observed that lower level sight glass for HEME #1 appears to have air bubbling through it. Will continue to monitor. |
| | | 19:45 | 33.7 | Plenum temperature is 537– 583°C. |
| | | 19:56 | 33.8 | Increased feed tank mixer from 25 to 30 Hz. |
| | | 20:04 | 34.0 | Performed a film cooler rinse. |
| | | 20:12 | 34.1 | Plenum temperature is 544– 600°C. |
| | | 20:27 | 34.4 | Plenum temperature is 543– 606°C. |
| | | 20:53 | 34.8 | Plenum temperature is 566 – 586°C. |
| | | 21:03 | 35.0 | Increased power from 190 kW to 192 kW. Average glass temperature is 1145°C. |
| | | 21:09 | 35.1 | Plenum temperature is 584 – 588°C. |
| | | 21:13 | 35.1 | Feed system was paused. |
| | | 21:21 | 35.3 | Resumed feeding. |
| | | 21:33 | 35.5 | Increased T1 from 1.1 to 1.3 second and T4 from 32 to 28 seconds for 12 minutes to get the feed rate back up. |
| | | 21:38 | 35.5 | Average glass temperature is 1150°C. Glass resistance is 0.085 Ω. Plenum temperature is 563 – 623°C. |
| | | 21:54 | 35.8 | Average glass temperature is 1148°C. Glass resistance is 0.086 Ω. Plenum temperature is 572 – 656°C. |
| | | 22:12 | 36.1 | Caustic pump to neutralization tank turned off. pH meter showed 7.7. |
| | | 22:25 | 36.3 | 1A + 1B bubbler mass flow controllers are reduced from 19.0 lpm to 17.0 lpm each. 2A + 2B bubbler mass flow controllers are reduced from 19.0 lpm to 17.0 lpm each. |
| | | 22:26 | 36.3 | Average glass temperature is 1136°C. Glass resistance is 0.089 Ω. Plenum temperature is 550 – 639°C. |
| | | 22:43 | 36.6 | Average glass temperature is 1143°C. Glass resistance is 0.087 Ω. Plenum temperature is 567 – 621°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 1 | 1/16/13 | 23:03 | 37.0 | Average glass temperature is 1147°C. Glass resistance is 0.087 Ω. Plenum temperature is 568 – 598°C |
| | | 23:06 | 37.0 | 1A + 1B bubbler mass flow controllers are reduced from 17.0 lpm to 16.0 lpm each. 2A + 2B bubbler mass flow controllers are reduced from 17.0 lpm to 16.0 lpm each. |
| | | 23:10 | 37.1 | 1A + 1B bubbler mass flow controllers are reduced from 16.0 lpm to 15.0 lpm each. 2A + 2B bubblers mass flow controller are reduced from 16.0 lpm to 15.0 lpm each. |
| | | 23:15 | 37.2 | Change/reduce SBS chill water temperature set point from 45 to 42°C. CW temperature presently 48°C. |
| | | 23:18 | 37.2 | Average glass temperature is 1148°C. Glass resistance is 0.086 Ω. Plenum temperature is 577 – 588°C |
| | | 23:39 | 37.6 | Electrode high alarm sounded. Reduced power from 192 kW to 189 kW. Average glass temperature is 1154°C. |
| | | 23:41 | 37.6 | Plenum temperature is 581 – 566°C. |
| | | 23:43 | 37.6 | Observed lower level sight glass on HEME#1 appears to have air bubbling through it. Will continue to monitor. |
| | | 23:50 | 37.7 | Reduced power from 189 kW to 186 kW. Average glass temperature is 1152°C |
| | | 23:59 | 37.9 | 1A + 1B bubbler mass flow controllers are reduced from 15.0 lpm to 14.0 lpm each. 2A + 2B bubbler mass flow controllers are reduced from 15.0 lpm to 14.0 lpm each. |
| | | 24:00 | 37.9 | Reduced power from 186 kW to 183 kW. Average glass temperature is 1155°C. |
| | 1/17/13 | 0:05 | 38.0 | Plenum temperature is 582 – 560°C. |
| | | 0:08 | 38.0 | Electrode high temperature was alarm sounded. Power was reduced from 183 kW to 180 kW. Average glass temperature is 1157°C. |
| | | 0:18 | 38.2 | Reduced power from 180 kW to 177 kW. Average glass temperature is 1158°C |
| | | 0:19 | 38.2 | Plenum temperature is 568 – 576°C. |
| | | 0:23 | 38.3 | Changed T4 from 36 seconds to 38 seconds. |
| | | 0:28 | 38.4 | Reduced power from 177 kW to 174 kW. Average glass temperature is 1159°C. |
| | | 0:32 | 38.4 | Changed T4 from 38 seconds to 40 seconds. |
| | | 0:39 | 38.6 | Reduced power from 174 kW to 171 kW. Average glass temperature is 1157°C. |
| | | 0:44 | 38.6 | Average glass temperature is 1160°C. Glass resistance is 0.080 Ω. Plenum temperature is 559 – 562°C |
| | | 0:55 | 38.8 | Reduced power from 171 kW to 168 kW. Average glass temperature is 1160°C |
| | | 1:02 | 38.9 | 1A + 1B bubbler mass flow controllers are reduced from 14.0 lpm to 12.0 lpm each. 2A + 2B bubbler mass flow controllers are reduced from 14.0 lpm to 12.0 lpm each. |
| | | 1:04 | 39.0 | Average glass temperature is 1159°C. Glass resistance is 0.080 Ω. Plenum temperature is 567 – 559°C. |
| | | 1:07 | 39.0 | Reduced power from 168 kW to 165 kW. Average glass temperature is 1160°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 1 | 1/17/13 | 1:09 | 39.1 | Reduced T4 from 38 to 36 seconds. |
| | | 1:14 | 39.1 | Reduced T4 from 36 to 33seconds. |
| | | 1:16 | 39.2 | Increased 1A + 1B bubbler mass flow controllers from 12.0 lpm to 13.0 lpm each. Increased 2A + 2B bubbler mass flow controllers from 12.0 lpm to 13.0 lpm each. |
| | | 1:19 | 39.2 | Average glass temperature is 1162°C. Glass resistance is 0.079 Ω. Plenum temperature is 562 – 546°C |
| | | 1:23 | 39.3 | Reduced power from 165 kW to 162 kW. Average glass temperature is 1161°C. |
| | | 1:31 | 39.4 | Average glass temperature is 1160°C. Glass resistance is 0.080 Ω. Plenum temperature is 562 – 541°C |
| | | 1:34 | 39.5 | Changed T4 from 33 seconds to 32 seconds. |
| | | 1:35 | 39.5 | Reduced power from 162 kW to 159 kW. Average glass temperature is 1159°C |
| | | 1:42 | 39.6 | Reduced 1A + 1B bubbler mass flow controllers from 13.0 lpm to 12.0 lpm. Reduced 2A + 2B bubbler mass flow controllers from 13.0 lpm to 12.0 lpm. Increasing feed rate by changing T4 from 32 to 31 seconds. Targeting 146 kg/hr. Average glass temperature is 1158°C. Plenum temperature is 565–534°C |
| | | 1:47 | 39.7 | Reduced power from 159 kW to 156 kW. |
| | | 1:52 | 39.8 | Average glass temperature is 1156°C. Plenum temperature is 530 – 567°C. |
| | | 2:10 | 40.1 | Average glass temperature is 1150°C. Plenum temperature is 520 – 537°C. |
| | | 2:37 | 40.5 | Average glass temperature is 1149°C. Plenum temperature is 502 – 507°C. Glass resistance is 0.082 Ω. |
| | | 2:51 | 40.8 | Plenum temperature is 495 – 499°C. |
| | | 3:02 | 40.9 | Average glass temperature is 1146°C. |
| | | 3:09 | 41.1 | Plenum temperature is 481 – 495°C. |
| | | 3:25 | 41.3 | Plenum temperature is 473 – 499°C. |
| | | 3:31 | 41.4 | Increased power from 156 kW to 159 kW. Average glass temperature is 1139°C. |
| | | 3:41 | 41.6 | Average glass temperature is 1139°C. Plenum temperature is 461 – 483°C. |
| | | 3:42 | 41.6 | Plenum temperature is 460 – 480°C. |
| | | 4:05 | 42.0 | Glass level is at 30.2”. |
| | | 4:22 | 42.3 | Glass level is at 27.8”, Average glass temperature is 1137°C. Plenum temperature is 433 – 451°C. |
| | | 4:32 | 42.4 | Increased power from 159 to 162 kW. All four Lances are at 11.0 lpm. |
| | | 4:47 | 42.7 | Plenum temperature is 433 – 452°C. |
| | | 5:10 | 43.1 | Average glass temperature is 1150°C. Plenum temperature is 427 – 445°C. |
| | | 5:35 | 43.5 | Neutralizing neutralization tank, pH is at 5.40. (All 3 tanks are equalized with acid tank at pH of 7.63) |
| | | 5:40 | 43.6 | Stopped caustic pump to neutralization tank after pH increased from 5.4 to 6.8. |
| | | 5:44 | 43.6 | Average glass temperature is 1153°C. Plenum temperature is 407 – 417°C. |

### Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 1 | 1/17/13 | 6:42 | 44.6 | Decreased power from 162 to 160 kW. Average glass temperature is 1153°C. |
| | | 7:06 | 45.0 | Total bubbling is 44 lpm, feed rate is 144 kg/hr. |
| | | 7:08 | 45.0 | Decreased power from 160 kW to 158 kW. Average glass temperature is 1158°C |
| | | 7:51 | 45.8 | Average glass temperature is 1154°C. Feed rate is 147.1 kg/hr. Power is 157 kW, secondary current is 1412 Amps. Total bubbling is 44 lpm. Glass resistance is 0.079 Ω. Glass level is 29.7”. |
| | | 9:08 | 47.0 | Average glass temperature is 1150°C. Glass level is 28.5”. |
| | | 9:31 | 47.4 | Average glass temperature is 1150°C. Glass level is 29.3”. |
| | | 10:02 | 47.9 | Transferred feed 247.0 kg feed and 5 kg water to feed tank. |
| | | 12:30 | 50.4 | Secured feeding, End of the test. No longer able to maintain feeding. |
| | | 12:35 | 50.5 | Feed tank mass in recirculation is 34.5 kg. Cleared recirculation line. Feed tank mass is 61.5 kg. Flushed recirculation line. |
| | | 12:55 | 50.8 | Removed residual feed from feed tank. Starting mass is 61.5 kg. Ending mass is 25.5 kg. Total removed feed mass is 36.0 kg. |
| | | 12:47 | 50.7 | Decreased power from 158 kW to 150 kW. Average glass temperature is 1155°C. |
| | | 12:51 | 50.8 | Decreased power from 150 kW to 140 kW. Average glass temperature is 1159°C. |
| | | 12:55 | 50.8 | Removed residual feed from feed tank. Starting mass is 61.5 kg, end mass is 25.5 kg. Net mass removed is 36.0 kg. |
| | | 12:58 | 50.9 | Decreased power from 140 kW to 130 kW. Average glass temperature is 1164°C. |
| | | 13:05 | 51.0 | Decreased power from 130 kW to 110 kW. Average glass temperature is 1161°C. |
| | | 13:15 | 51.2 | Decreased power from 110 kW to 90 kW. Average glass temperature is 1162°C |
| | | 14:00 | 51.9 | Reduced bubbling from 11 lpm on Lance Bubbler mass flow controllers L1 and L2 to 1.5 lpm on 1A, and 2A. De-energized 1B and 2B. |
| | | 14:20 | 52.2 | Decreased power from 90 kW to 80 kW. Average glass temperature is 1161°C |
| | | 14:27 | 52.4 | Increased bubbling mass flow controllers 1A and 2A to 10 lpm. A cold cap has reformed. |
| | | 15:19 | 53.2 | Reduced bubbling on 1A and 2A from 10 lpm to 5 lpm each. |
| | | 15:30 | 53.4 | CC is gone. |
| | | 16:30 | 54.4 | Started melter and off gas shut down procedures. |
| | | 17:00 | 54.9 | Performed WESP blow down, deluge and blow down. |
| | | 17:14 | 55.1 | Reduced bubbling from 5 to 1.5 lpm each. |
| | | 18:10 | 56.1 | Melter and off gas shut downs are completed. |
| 2 | 1/22/13 | 10:35 | - | Transferred feed from mix tank to feed tank. Tank mass at the start is 40.5 kg, tank mass at the end is 2951.5 kg. Net mass of feed transferred to feed tank is 2911.0 kg. This mass includes 500.7 kg water. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 2 | 1/22/13 | 13:15 | - | Transferred feed to mix tank. Tank mass is 3001.5 kg. This mass includes 10 kg water. Initial tank mass is 40.5 kg. Final tank mass is 3001.0 kg. Net mass transferred is 2960.5 kg. |
| | | 13:48 | - | Increased power to 140 kW. Average glass temperature is 1142°C. |
| | | 14:00 | 0.0 | Started feeding water at 0.7 l/min. |
| | | 14:15 | 0.3 | Increased water flow rate to 1.4 l/min. |
| | | 14:30 | 0.5 | Increased water flow rate to 2.1 l/min. Plenum temperature is 941 - 946°C. Average glass temperature is 1152°C. Placed SBS cooling water booster pump in service. |
| | | 14:37 | 0.6 | Increased power from 140 kW to 145 kW. Avg. glass temperature is 1147°C. |
| | | 14:42 | 0.7 | Increased water flow rate to 2.8 l/min. |
| | | 14:52 | 0.9 | Increased power from 145 kW to 155 kW. Avg. glass temperature is 1143°C. |
| | | 15:00 | 1.0 | Secured water flow and starting feeding slurry. |
| | | 15:05 | 1.1 | Increased bubbling as follows: Lance 1 mass flow controllers A&B changed from 1.5 to 5. lpm each, Lance 2 mass flow controllers A & B changed from 1.5 to 5 lpm each. Lance 3 mass flow controller A and B from 1.5 to 5 lpm. Total is 30 lpm. |
| | | 15:07 | 1.1 | Thermocouple TR-08 not functional; it is out of service now. |
| | | 15:12 | 1.2 | Increased power from 155 kW to 160 kW. Average glass temperature is 1147°C. |
| | | 15:27 | 1.5 | Increased T4 from 28 to 32 seconds and T1 from 1.1 to 1.2 second. Plenum temperature is 880 – 864°C |
| | | 15:44 | 1.7 | Plenum temperature is 768 – 806°C. |
| | | 16:03 | 2.1 | Increased bubbling on Lance 1 mass flow controllers A&B and Lance 2 mass flow controllers A&B from 5 to 10 lpm, Lance 3 mass flow controllers A&B from 5 to 7.5 lpm. Total bubbling is 55 lpm. |
| | | 16:17 | 2.3 | Increased power from 160 to 170 kW. |
| | | 16:23 | 2.4 | Plenum temperature is 718 – 748°C. |
| | | 16:32 | 2.5 | Increased power from 170 to 175 kW. Average glass temperature is 1143°C. Plenum temperature is 691 – 714°C. |
| | | 17:07 | 3.1 | Increased bubbling on Lances 1A, 2A (was 10 lpm each), 3A (was 7.5 lpm) to 12.0 lpm and on Lances 1B, 2B from 10.0 to 12.0 lpm. |
| | | 17:12 | 3.2 | Plenum temperature is 657 – 695°C. |
| | | 17:14 | 3.2 | Increased power from 180 to 183 kW. |
| | | 17:24 | 3.4 | Plenum temperature is 666 – 710°C. |
| | | 17:28 | 3.5 | Increased power from 183 to 188 kW. Average glass temperature is 1145°C |
| | | 17:38 | 3.6 | Plenum temperature is 667 – 695°C. |
| | | 17:42 | 3.7 | Increased power from 188 to 193 kW. Average glass temperature is 1138°C. |
| | | 17:58 | 4.0 | Plenum temperature is 660 – 682°C. |
| | | 17:59 | 4.0 | Increased bubbling on Lance mass flow controllers 1A, 2A from 12.0 to 16.0 lpm. Total bubbling is 78.5 lpm. Increased power from 188 to 193 kW. Average glass temperature is 1134°C |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 2 | 1/22/13 | 18:30 | 4.5 | Increased power from 192 to 197 kW. |
| | | 19:04 | 5.1 | Plenum temperature is 632 – 675°C. |
| | | **19:20** | 5.3 | Paused feeding to collect feed sample. |
| | | 19:26 | 5.4 | Plenum temperature is 650 – 669°C. |
| | | 19:34 | 5.6 | Plenum temperature is 647 – 686°C. |
| | | 19:48 | 5.8 | Plenum temperature is 645 – 683°C. |
| | | 20:00 | 6.0 | Adjusted T4 from 27 seconds to 25 seconds. |
| | | 20:20 | 6.3 | Plenum temperature is 636 – 666°C. |
| | | 20:35 | 6.6 | Plenum temperature is 637 – 638°C. |
| | | 21:04 | 7.1 | Increased power from 197 to 202 kW. Average glass temperature is 1135°C |
| | | 21:09 | 7.2 | Plenum temperature is 604 – 645°C. |
| | | 21:11 | 7.2 | Increased power from 202 to 207 kW. Average glass temperature is 1138°C |
| | | 21:19 | 7.3 | Plugged pump for caustic tank, pH was 4.0. |
| | | 21:49 | 7.8 | Average glass temperature is 1143°C. Glass resistance is 0.085 Ω. Plenum temperature is 611– 637°C. |
| | | 21:54 | 7.9 | Emergency off gas alarm is tripped. |
| | | 22:04 | 8.1 | Average glass temperature is 1146°C. Plenum temperature is 608 – 620°C |
| | | 22:20 | 8.3 | Average glass temperature is 1147°C. Glass resistance is 0.085 Ω. Plenum temperature is 624 – 625°C. |
| | | 22:36 | 8.6 | Average glass temperature is 1149°C. Glass resistance is 0.083 Ω. Plenum temperature is 604 – 630°C |
| | | 22:58 | 9.0 | Plenum temperature is 598 – 624°C |
| | | 23:03 | 9.1 | Increased power from 207 to 210 kW. Average glass temperature is 1140°C. Plenum temperature is 593 – 613°C. Feed rate is ~180 kg/hr. |
| | | 23:11 | 9.2 | Plenum temperature is 596 – 604°C |
| | | 23:26 | 9.4 | Average glass temperature is 1148°C. Plenum temperature is 594 – 610°C. |
| | | 23:41 | 9.7 | Plenum temperature is 581 – 602°C |
| | 1/23/13 | 0:01 | 10.0 | Reduced power from 210 to 207 kW. High temperature alarm. Average glass temperature is 1156°C. Plenum temperature is 597 – 613°C. |
| | | 0:05 | 10.1 | Average glass temperature is 1155°C. Plenum temperature is 596 – 611°C. Observed film cooler differential pressure is greater than 8.0 in W.C. Transition line differential pressure is ~25 in W.C. Upon visual inspection found build up at the bottom opening of the film cooler. Attempted to clear with two water flush sequences. Attempt was not successful. |
| | | 0:11 | 10.2 | Film cooler rinse may have caused melter pressure spike. Emergency off gas alarm is tripped. |
| | | 0:21 | 10.4 | Average glass temperature is 1144°C. Plenum temperature is 585 – 605°C. |
| | | 0:29 | 10.5 | Paused feeding, rodded film cooler. |
| | | 0:32 | 10.5 | Resumed feeding. Film cooler differential pressure is 2.0 in W.C. |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 2 | 1/23/13 | 0:39 | 10.7 | Plenum temperature is 579 – 612°C. |
| | | 0:52 | 10.9 | Plenum temperature is 572 – 615°C. |
| | | 1:06 | 11.1 | Plenum temperature is 571 – 615°C. |
| | | 1:21 | 11.4 | Average glass temperature is 1152°C. Plenum temperature is 565 – 606°C. |
| | | 1:33 | 11.6 | Average glass temperature is 1147°C. Glass resistance is 0.083 Ω. Plenum temperature is 564 – 588°C. Glass density is 2.27 g/cc. |
| | | 1:36 | 11.6 | Increased electric power from 207 to 210 kW. Average glass temperature is 1145°C |
| | | 1:42 | 11.7 | Changed T4 from 24 seconds to 25 seconds. |
| | | 1:43 | 11.7 | Average glass temperature is 1141°C. Glass resistance is 0.085 Ω. Plenum temperature is 560 – 594°C. |
| | | 1:47 | 11.8 | Increased electrical power from 210 kW to 213 kW. |
| | | 1:48 | 11.8 | Decreased electrical power from 213 to 212 kW. Electrical current is 1577 Amps. |
| | | 1:50 | 11.8 | Decreased T4 from 25 seconds to 24 seconds. |
| | | 2:04 | 12.1 | Average glass temperature is 1141°C. Glass resistance is 0.085 Ω. Plenum temperature is 558 – 587°C. |
| | | 2:20 | 12.3 | Average glass temperature is 1146°C. Glass resistance is 0.082 Ω. Plenum temperature is 546 – 572°C. |
| | | 2:37 | 12.6 | Average glass temperature is 1149°C. Glass resistance is 0.082 Ω. Plenum temperature is 553 – 579°C. |
| | | 2:45 | 12.8 | Reduced power from 212 to 210 kW. Electrical current is 1601 Amps. |
| | | 2:52 | 12.9 | Plenum temperature is 544 – 574°C. |
| | | 3:02 | 13.0 | Reduced power from 210 to 207 kW. Electrical current is 1603 Amps. Average glass temperature is 1153°C |
| | | 3:17 | 13.3 | Average glass temperature is 1144°C. Plenum temperature is 544 – 568°C. Feed rate is ~180 kg/hr. |
| | | 3:27 | 13.5 | Reduced electrical power from 207 to 205 kW. Electrical current is above 1571 Amps. Average glass temperature is 1142°C. Plenum temperature is 548 –567°C. |
| | | 3:38 | 13.6 | Reduced electrical power from 205 to 203 kW. Electrical current is 1168 Amps. Plenum temperature is 557 – 573°C. |
| | | 3:41 | 13.7 | Average glass temperature is 1145°C. Plenum temperature is 558 – 574°C. |
| | | 4:03 | 14.1 | Average glass temperature is 1150°C. Plenum temperature is 559 – 574°C. |
| | | 4:19 | 14.3 | Average glass temperature is 1148°C. Glass resistance is 0.081 Ω. Plenum temperature is 567 – 571°C. |
| | | 4:36 | 14.6 | Average glass temperature is 1148°C. Plenum temperature is 554 – 568°C. |
| | | 4:51 | 14.9 | Average glass temperature is 1145°C. Glass resistance is 0.083 Ω. Plenum temperature is 560 – 575°C, glass density is 2.28 g/cc. |
| | | 5:15 | 15.3 | Glass resistance is 0.084 Ω. Plenum temperature is 537 – 601°C, glass density is 2.28 g/cc. |
| | | 5:32 | 15.5 | Plenum temperature is 528 – 598°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 2 | 1/23/13 | 5:39 | 15.7 | Glass resistance is 0.085 Ω, glass density is 2.25 g/cc. |
| | | 5:44 | 15.7 | Increased power from 203 to 206 kW. Average glass temperature is 1142°C. Electrical current is 1540 Amps. Glass resistance is 0.086 Ω. |
| | | 5:54 | 15.9 | Plenum temperature is 501 – 566°C. |
| | | 6:23 | 16.4 | Increased power from 206 to 209 kW. Average glass temperature is 1132°C. |
| | | 6:40 | 16.7 | Average glass temperature is 1137°C. Glass resistance is 0.083 Ω. Plenum temperature is 513 – 553°C. |
| | | 7:02 | 17.0 | Average glass temperature is 1141°C. |
| | | 7:16 | 17.3 | Average glass temperature is 1147°C. Plenum temperature is 515 – 545°C. Decreased power from 209 to 205 kW, the electrical current is 1594 Amps. |
| | | 7:33 | 17.6 | Plenum temperature is 497 – 539°C. |
| | | 7:50 | 17.8 | Plenum temperature is 529 – 553°C. |
| | | 8:06 | 18.1 | Plenum temperature is 533 – 584°C. |
| | | 8:15 | 18.3 | Feed is stopped flowing into melter. Tank mass is steady at 397.5 kg, reduced mixer speed to 11 Hz. AOD pump reset and pumping resumed at 8:21. |
| | | 8:21 | 18.4 | Feeding is resumed. |
| | | 8:23 | 18.4 | Feed transfer is started. Beginning mass is 3005.0 kg. End mass is 50.5 kg. The net mass transferred is 2954.5 kg. Adding 493.0 kg water to the feed tank. Total mass transferred is 3447.5 kg. |
| | | 9:15 | 19.3 | Increased power from 205 to 207 kW. Electrical current is 1510 Amps. Average glass temperature is 1120°C. Plenum temperature is 457 – 513°C. |
| | | 9:52 | 19.9 | Increased power from 209 to 211 kW. The electrical current is 1547 Amps. Average glass temperature is 1135°C. |
| | | 9:55 | 19.9 | Average glass temperature is 1146°C. Glass resistance is 0.083 Ω. Plenum temperature is 435 – 493°C, electrical power is 211 kW, current is 1568 Amps. |
| | | 10:05 | 20.1 | Average glass temperature is 1145°C. Plenum temperature is 415 – 487°C, current is 1573 Amps. Feed rate is ~180 kg/hr. |
| | | 10:20 | 20.3 | Average glass temperature is 1145°C. Plenum temperature is 443 – 496°C, electrical power is 210 kW, current is 1579 Amps. Feed rate is ~180 kg/hr. |
| | | 10:44 | 20.7 | Decreased power from 211 to 209 kW, current is 1584 Amps. Average glass temperature is 1149°C. Feed rate is ~180 kg/hr. LabVIEW rebooted. |
| | | 11:00 | 21.0 | After rebooting LabVIEW, average glass temperature is 1156°C. Power is 211 kW, current is 1630 Amps. Decreased power from 211 to 200 kW. |
| | | 11:20 | 21.3 | Average glass temperature is 1147°C. |
| | | 11:35 | 21.6 | Average glass temperature is 1147°C. |
| | | 11:50 | 21.8 | Average glass temperature is 1151°C. |
| | | 12:04 | 22.1 | Average glass temperature is 1155°C. |
| | | 12:40 | 22.7 | Average glass temperature is 1139°C. Increased electrical power from 200 to 203 kW, current is 1530 Amps. Feed rate is ~182 kg/hr. |
| | | 13:39 | 23.7 | Plenum temperature is 418 – 513°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 2 | 1/23/13 | 13:54 | 23.9 | Average glass temperature is 1146°C. Increased electrical power is 201 kW, current is 1564 Amps. Plenum temperature is 448 – 493°C. |
| | | 14:35 | 24.6 | Average glass temperature is 1149°C. |
| | | 14:44 | 24.7 | Transfer feed to mix tank. Starting mass is 50.5 kg, ending mass is 2957 kg. Mixer is set @30 Hz. |
| | | 15:04 | 25.1 | Plenum temperature is 496 - 531°C. |
| | | 15:19 | 25.3 | Plenum temperature is 506 - 520°C. |
| | | 15:39 | 25.7 | Plenum temperature is 514 - 539°C. |
| | | 15:51 | 25.9 | Increased power from 203 to 205 kW. Average glass temperature is 1145°C. |
| | | 15:53 | 25.9 | Plenum temperature is 477 - 556°C. |
| | | 16:09 | 26.2 | Plenum temperature is 485 - 556°C. |
| | | 16:18 | 26.3 | Increased power from 205 to 208 kW. Average glass temperature is 1141°C. |
| | | 16:25 | 26.4 | Performed WESP pre-deluge and blow downs. |
| | | 16:30 | 26.5 | Melter went positive and tripped emergency off gas, immediately reset, cause unknown. |
| | | 16:39 | 26.7 | Increased power from 208 to 209 kW. Average glass temperature is 1141°C, the current is 1556 Amps. |
| | | 16:49 | 26.8 | Plenum temperature is 509 - 512°C. |
| | | 17:01 | 27.0 | Reduced power from 209 to 207 kW. Average glass temperature is 1148°C. Melter current is 1584 Amps. |
| | | 17:21 | 27.4 | Average glass temperature is 1144°C. Plenum temperature is 509 - 523°C. |
| | | 17:39 | 27.7 | Plenum temperature is 507 - 527°C |
| | | 17:46 | 27.8 | Melter pressure went positive and tripped emergency off gas, immediately reset, caused by off gas sampling. |
| | | 17:50 | 27.8 | Plenum temperature is 486 - 512°C. |
| | | 18:04 | 28.1 | Plenum temperature is 518 - 521°C. Electrical current is 1572 Amps. |
| | | 18:07 | 28.1 | Stopped off gas sampling which caused melter pressure spike when probed removed from transition line. |
| | | 18:27 | 28.5 | Emergency off gas is tripped, CC is shifted. |
| | | 18:39 | 28.7 | Average glass temperature is 1132°C. Melter current is 1163 Amps. Plenum temperature is 517 - 524°C. |
| | | 18:49 | 28.8 | Average glass temperature is 1135°C. Melter current is 1571 Amps. Plenum temperature is 523 - 525°C. |
| | | 19:04 | 29.1 | Average glass temperature is 1137°C. Melter current is 1571 Amps. Plenum temperature is 524 - 526°C. |
| | | 19:20 | 29.3 | Plenum temperature is 514 - 525°C. |
| | | 19:29 | 29.5 | Paused feeding to collect feed sample. |
| | | 19:35 | 29.6 | Reduced power from 207 to 204 kW, current limited is 1592 Amps. Average glass temperature is 1144°C. |
| | | 19:39 | 29.7 | Current is limited @1575Amps. Average glass temperature is 1145°C. Plenum temperature is 530 - 544°C. |

# Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | Run time note |
|---|---|---|---|---|
| 2 | 1/23/13 | 19:54 | 29.9 | Average glass temperature is 1147°C. Melter current is 1581 Amps. Plenum temperature is 531 - 552°C. |
| | | 20:00 | 30.0 | Reduced power from 204 to 202 kW. Average glass temperature is 1147°C. Melter current is 1574 Amps |
| | | 20:12 | 30.2 | Plenum temperature is 518 - 539°C. |
| | | 20:26 | 30.4 | Off gas sampling has started. |
| | | 20:49 | 30.8 | Average glass temperature is 1152°C. Melter current is 1574 Amps. Plenum temperature is 534 - 542°C. |
| | | 21:00 | 31.0 | End of off gas testing, melter pressure spiked. |
| | | 21:04 | 31.1 | Average glass temperature is 1153°C. Melter current is 1574 Amps. Plenum temperature is 527 - 546°C. |
| | | 21:07 | 31.1 | Reduced power from 202 to 201 kW, current limited 1574 Amps. Average glass temperature is 1153°C. |
| | | 21:25 | 31.4 | Plenum temperature is 528 - 543°C. |
| | | 21:39 | 31.7 | Plenum temperature is 528 - 545°C. |
| | | 21:54 | 31.9 | Plenum temperature is 519 - 542°C. |
| | | 22:08 | 32.1 | Plenum temperature is 521 - 548°C. |
| | | 22:24 | 32.4 | Plenum temperature is 523 - 534°C. |
| | | 22:44 | 32.7 | Average glass temperature is 1150°C. Glass density is 2.25 g/cc. |
| | | 22:48 | 32.8 | Average glass temperature is 1144°C. Plenum temperature is 513 - 533°C. |
| | | 23:08 | 33.1 | Plenum temperature is 512 - 537°C. |
| | | 23:23 | 33.4 | Plenum temperature is 512 - 548°C. Average glass temperature is 1145°C. Glass resistance is 0.081 Ω |
| | | 23:38 | 33.6 | Plenum temperature is 516 - 534°C. Glass density is 2.24 g/cc. |
| | | 23:42 | 33.7 | SBS outlet gas pressure indicator is back in service after temporary problem. It is fixed reading -37.9 in W.C. now. |
| | | 23:50 | 33.8 | Plenum temperature is 524 - 536°C. |
| | | 23:54 | 33.9 | Glass density is 2.26 g/cc. |
| | 1/24/13 | 0:04 | 34.1 | Increased power from 201 to 204 kW, plenum temperature is 525 - 545°C. Average glass temperature is 1130°C. Glass resistance is 0.084 Ω. |
| | | 0:08 | 34.1 | Plenum temperature is 524 - 544°C. Average glass temperature is 1132°C. Electrical current is 1550 Amps. |
| | | 0:14 | 34.2 | Increased power from 204 to 206 kW, current is 1554 Amps. Plenum temperature is 524 - 545°C. Average glass temperature is 1134°C. Glass resistance is 0.084 Ω. |
| | | 0:20 | 34.3 | Plenum temperature is 524 - 540°C. |
| | | 0:37 | 34.6 | Average glass temperature is 1138°C, current is 1581 Amps. Lowered T4 from 27.4 to 27.0 seconds. |
| | | 0:39 | 34.7 | Reduced power from 206 to 204 kW, current is 1580 Amps, Average glass temperature is 1140°C. |
| | | 0:43 | 34.7 | Plenum temperature is 513 - 530°C. |
| | | 0:54 | 34.9 | Plenum temperature is 508 - 520°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 2 | 1/24/13 | 1:04 | 35.1 | Average glass temperature is 1140°C. Plenum temperature is 509 - 516°C. Glass resistance is 0.081 Ω. Power is 204 kW, current is 1568 – 1572 Amps. |
| | | 1:11 | 35.2 | Reducing power from 204 kW to 202 kW, current is 1580 Amps and average glass temperature is 1140°C. Glass resistance is 0.081 Ω. |
| | | 1:19 | 35.3 | Plenum temperature is 514 - 520°C, glass level is 29.8 in. |
| | | 1:27 | 35.5 | LabVIEW re-started. |
| | | 1:43 | 35.7 | Reduced electric power from 202 to 200 kW, 100 Amps. |
| | | 1:45 | 35.8 | Average glass temperature is 1142°C. Plenum temperature is 522 - 529°C. Glass resistance is 0.078 Ω. Glass density is 2.26 g/cc. |
| | | 1:46 | 35.8 | Performed film cooler rinse. |
| | | 2:06 | 36.1 | Glass density is 2.27 g/cc. Current is 1588 Amps. |
| | | 2:18 | 36.3 | Reduced power from 200 to 198 kW, current is 1587 Amps, Average glass temperature is 1147°C. Glass resistance is 0.078 Ω. |
| | | 2:19 | 36.3 | Changed T4 from 27.0 to 26.5 seconds. |
| | | 2:34 | 36.6 | Plenum temperature is 524 - 534°C. Glass resistance is 0.079 Ω. Glass density is 2.27 g/cc, current is 1579 Amps. |
| | | 2:52 | 36.9 | Plenum temperature is 528 - 533°C. Current is 1560 Amps. Average glass temperature is 1139°C. |
| | | 3:08 | 37.1 | Changed T4 from 26.5 to 26.0 seconds. |
| | | 3:09 | 37.2 | Glass resistance is 0.080 Ω. Current is 1562 Amps. Average glass temperature is 1140°C. |
| | | 3:30 | 37.5 | Mixer stopped, start transfer of feed to feed tank from mixing tank. Starting mass of mixing tank is 3003.5 kg, end mass is 73.0 kg. Net mass transferred is 2930.5 kg. Net amount of feed transferred is 3428.5 kg including 498.0 kg water. |
| | | 3:52 | 37.9 | Average glass temperature is 1143°C. Plenum temperature is 510 - 533°C. Glass resistance is 0.079 Ω. Current is 1571 Amps. Glass level is 30.5 in. |
| | | 4:10 | 38.2 | Average glass temperature is 1138°C. Glass resistance is 0.081 Ω. Current is 1561 Amps. Glass density is 2.26 g/cc. |
| | | 4:16 | 38.3 | Increased power from 198 to 201 kW. Average glass temperature is 1138°C. The current is 1560 Amps. |
| | | 4:40 | 38.7 | Increased power from 201 to 204 kW. Average glass temperature is 1132°C. The current is 1550 Amps. |
| | | 4:44 | 38.7 | Changed T4 from 26 to 24 seconds. |
| | | 4:46 | 38.8 | Average glass temperature is 1133°C. Plenum temperature is 475 - 481°C. Glass resistance is 0.081 Ω. Current is 1577 Amps. Glass level is 29.2 in. |
| | | 4:59 | 39.0 | Changed T4 from 24 to 22 seconds. |
| | | 5:07 | 39.1 | Plenum temperature is 477 - 458°C. Average glass temperature is 1134°C. |
| | | 5:33 | 39.6 | Plenum temperature is 425 - 458°C. |
| | | 5:49 | 39.8 | Plenum temperature is 431 - 460°C. |
| | | 6:06 | 40.1 | Plenum temperature is 437 - 468°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | Run time note |
|---|---|---|---|---|
| 2 | 1/24/13 | 6:51 | 40.9 | Decreased power from 204 to 202 kW, Average glass temperature is 1145°C. Glass resistance is 0.078 Ω. |
| | | 7:04 | 41.1 | Decreased power from 202 to 200 kW, current is 1604 Amps, voltage is 124 volts. Average glass temperature is 1145°C. Glass resistance is 0.077 Ω., Glass level is 29.5 in. |
| | | 7:38 | 41.6 | Average glass temperature is 1145°C. |
| | | 7:52 | 41.9 | Average glass temperature is 1147°C. |
| | | 8:06 | 42.1 | Average glass temperature is 1144°C. Plenum temperature is 467 - 519°C. Glass resistance is 0.077 Ω. Current is 1577 Amps. Glass level is 29.2 in. Power is 199 kW, 124 volts. Feed rate is 164 kg/hr. |
| | | 8:20 | 42.3 | Average glass temperature is 1146°C. Plenum temperature is 446 - 576°C, glass resistance is 0.077 Ω. Current is 1607 Amps. Feed rate is 167 kg/hr. Decreased power from 200 to 199 kW. |
| | | 8:40 | 42.7 | Average glass temperature is 1146°C. Plenum temperature is 497 - 513°C, glass resistance is 0.077 Ω. Current is 1601 Amps. Power is 198 kW. |
| | | 8:52 | 42.9 | Decreased power from 199 to 197 kW. Average glass temperature is 1147°C Current is 1609 Amps. |
| | | 8:55 | 42.9 | Average glass temperature is 1144°C, current is 1593 Amps. Power is 195 kW. Feed rate is ~172 kg/hr. |
| | | 9:35 | 43.6 | Average glass temperature is 1143°C, current is 1590 Amps. Power is 195 kW. Glass level is 29.9 in. |
| | | 9:52 | 43.9 | Average glass temperature is 1141°C, current is 1580 Amps. |
| | | 10:10 | 44.2 | Average glass temperature is 1142°C. |
| | | 10:39 | 44.7 | Average glass temperature is 1145°C. |
| | | 10:56 | 44.9 | Average glass temperature is 1145°C. |
| | | 11:11 | 45.2 | Average glass temperature is 1144°C. The current is 1582 Amps. |
| | | 12:05 | 46.1 | Average glass temperature is 1137°C. Melter pressure spike is due to shift of CC on the south east side of the melter. |
| | | 12:14 | 46.2 | Increased power from 196 to 199 kW. Average glass temperature is 1137°C. |
| | | 12:20 | 46.3 | Average glass temperature is 1137°C. |
| | | 12:35 | 46.6 | Average glass temperature is 1141°C. |
| | | 12:47 | 46.8 | Average glass temperature is 1140°C. Feed rate is ~183.9 kg/hr. |
| | | 12:56 | 46.9 | Increased power from 199 to 200 kW. Average glass temperature is 1137°C. |
| | | 13:08 | 47.1 | Average glass temperature is 1140°C, the current is 1593 Amps. |
| | | 13:37 | 47.6 | Average glass temperature is 1138°C. |
| | | 13:55 | 47.9 | Average glass temperature is 1136°C. Current is 1567 Amps. |
| | | 14:09 | 48.2 | Average glass temperature is 1139°C |
| | | 14:13 | 48.2 | Performed film cooler rinse. |
| | | 14:56 | 48.9 | Plenum temperature is 471 – 520°C. |
| | | 15:16 | 49.3 | Plenum temperature is 469 – 497°C. |
| | | 15:39 | 49.7 | Plenum temperature is 473 – 503°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 2 | 1/24/13 | 15:58 | 50.0 | Emergency off-gas is tripped when melter pressure went positive, immediately reset. |
| | | 16:40 | 50.7 | LabVIEW reset and restarted. |
| | | 16:48 | 50.8 | Plenum temperature is 456 – 492°C. |
| | | 17:00 | 51.0 | Secured feeding. End of Test 2. Performed water line flush. |
| | | 17:20 | 51.3 | Reduced power from 202 to 190 kW. Average glass temperature is 1150°C. Current is 1600 Amps |
| | | 17:21 | 51.4 | Removed feed from feed tank. Starting mass is 1473.0 kg. Ending mass is 10.5 kg. Net removed feed mass is 1462.5 kg. |
| | | 17:31 | 51.5 | Reduced power from 190 to 170 kW. Average glass temperature 1163°C. Current is 1643 Amps. |
| | | 17:48 | 51.8 | Reduced power from 170 to 130 kW. Average glass temperature is 1164°C. |
| | | 18:10 | 52.2 | Reduced power from 130 to 120 kW. Average glass temperature is 1157°C. |
| | | 18:12 | 52.2 | Cold Cap is gone. |
| | | 18:59 | 53.0 | Reduced bubblers as follows: Lances L1 A&B and Lances L2 A&B from 16 to 10 lpm, L3 A&B from 8 to 5 lpm. |
| | | 19:11 | 53.2 | Reduced bubblers Lances L1 A&B, L2 A&B and L3 A&B to 1.5 lpm. |
| | | 19:16 | 53.3 | Started melter and off-gas shut downs. |
| | | 19:31 | 53.5 | Reduced power from 120 to 100 kW. Average glass temperature is 1151°C. |
| | | 19:33 | 53.6 | Reduced discharge power from 18 to 12 kW. Discharge temperature is 1065-1086°C. |
| | | 19:37 | 53.6 | Reduced power from 100 to 80 kW. Average glass temperature is 1156°C |
| | | 20:06 | 54.1 | Reduced power from 80 to 75 kW. Average glass temperature is 1155°C |
| | 1/25/13 | 2:00 | - | Blow downs. |
| | | 2:10 | - | Off gas shut down is now complete. |
| 3 | 1/29/13 | 0:30 | - | Transferred 2923.5 kg feed from mix tank to the feed tank. Plus 496.91 kg water added (Recipe #1). 3410.4 kg starting mass, out of recirculation. |
| | | 7:30 | - | Transferred 518.5 kg of Test #2 Al-19 feed plus 5 kg flush water. Mass of feed at start is 3370.5 kg, mass of feed after the transfer is 3898.0 kg. Net mass transferred is 527.5 kg. |
| | | 8:00 | - | Started melter and off gas system checks. |
| | | 9:30 | 0.0 | Started feeding water at 0.8 l/min. |
| | | 9:32 | 0.0 | Rebooted the computer system. |
| | | 9:45 | 0.3 | Rebooted the computer system. |
| | | 9:52 | 0.4 | Increased water flow rate to1.6 l/min. |
| | | 9:53 | 0.4 | Increased power from 135 to 145 kW. |
| | | 9:57 | 0.5 | Increased bubbling L1 and L2 7.0 lpm, L3 and L4 3.5 lpm. |
| | | 10:08 | 0.6 | Increased power from 145 to 150 kW. Average glass temperature is 1145°C. |
| | | 10:10 | 0.7 | Increased water from 1.6 to 2.4 l/min. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/29/13 | 10:21 | 0.9 | Turned on SBS booster pump. |
| | | 10:23 | 0.9 | Increased power from 150 to 155 kW. Average glass temperature is 1140°C. |
| | | 10:30 | 1.0 | Secured water flow and starting feeding slurry. |
| | | 10:34 | 1.1 | Increased power from 155 to 160 kW. Average glass temperature is 1134°C. |
| | | 10:44 | 1.2 | Increased power from 160 to 170 kW. Average glass temperature is 1137°C. |
| | | 11:18 | 1.8 | Increased power from 170 to 175 kW. Average glass temperature is 1146°C. |
| | | 11:20 | 1.8 | Average glass temperature is 1147°C. |
| | | 11:41 | 2.2 | Reduced power from 175 to 170 kW. Average glass temperature is 1162°C |
| | | 11:44 | 2.2 | Increased bubbling L1 and L2 to 8.0 lpm and L3 and L4 to 4.0 lpm. |
| | | 12:07 | 2.6 | Increased bubbling L1 and L2 to 10.0 lpm L3 and L4 to 5 lpm. |
| | | 12:20 | 2.8 | Average glass temperature is 1167°C. |
| | | 12:28 | 3.0 | Reduced power from 170 to 160 kW. Average glass temperature is 11712°C. |
| | | 12:47 | 3.3 | Average glass temperature is 1151°C. Plenum temperature is 654 – 660°C. |
| | | 13:02 | 3.5 | Average glass temperature is 1145°C. Increased power from 160 to 165 kW. |
| | | 13:17 | 3.8 | Average glass temperature is 1144°C. Plenum temperature is 611 – 636°C. |
| | | 13:19 | 3.8 | Increased power from 165 to 170 kW. Average glass temperature is 1144°C. |
| | | 13:35 | 4.1 | Average glass temperature is 1145°C. |
| | | 13:50 | 4.3 | Average glass temperature is 1145°C. |
| | | 14:11 | 4.7 | Average glass temperature is 1148°C. |
| | | 14:29 | 5.0 | Average glass temperature is 1129°C. |
| | | 14:49 | 5.3 | Average glass temperature is 1137°C. Plenum temperature is 544 – 573°C. |
| | | 14:58 | 5.5 | Increased bubbling as follows: L1 and L2 from 12.0 to 14.0 lpm each and L3 and L4 from 6.0 to 7.0 lpm each. |
| | | 15:04 | 5.6 | Plenum temperature is 538 – 565°C. |
| | | 15:07 | 5.6 | Increased power from 170 to 180 kW. Average glass temperature is 1138°C, current is 1546 Amps. |
| | | 15:08 | 5.6 | Melter pressure spiked and caused emergency off gas to trip. Increased speeds of blower 701 from 50 to 51 Hz, blower 801 from 20 to 23 Hz. |
| | | 15:19 | 5.8 | Plenum temperature is 530 – 553°C. |
| | | 15:22 | 5.9 | Increased power from 180 to 190 kW. Average glass temperature is 1129°C, current is 1577 Amps. |
| | | 15:34 | 6.1 | Plenum temperature is 523 – 544°C. Current is 1594 Amps. |
| | | 15:51 | 6.4 | Current is 1605 Amps. Plenum temperature is 500 – 542°C. |
| | | 16:05 | 6.6 | Plenum temperature is 491 – 525°C. |
| | | 16:19 | 6.8 | Plenum temperature is 513 – 539°C. |
| | | 16:21 | 6.9 | Increased bubbling on Lances: L1A from 14.0 to 16.0 lpm, L2A from 14.0 to 16.0 lpm, L3A from 7.1 to 8.1 lpm, L4A from 7.1 to 8.1 lpm. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/29/13 | 16:34 | 7.1 | Plenum temperature is 502 – 539°C. |
| | | 16:45 | 7.3 | Decreased power from 190 to 188 kW due to current limit. |
| | | 16:49 | 7.3 | Plenum temperature is 490 – 529°C. |
| | | 16:56 | 7.4 | Increased bubbling on Lances L1A and L1B from 16.0 to 20.0 lpm, also increased L3A and L4A from 8.1 to 10.1 lpm. Total bubbling for L1A+L1B+L3A+L4A is 60.2 lpm. |
| | | 17:04 | 7.6 | Plenum temperature is 498 – 527°C. |
| | | 17:17 | 7.8 | Plenum temperature is 486 – 529°C. |
| | | 17:34 | 8.1 | Plenum temperature is 453 – 533°C. |
| | | 17:43 | 8.2 | Increased bubbling on Lances L1A and L2A from 20.0 to 24.1 lpm also increased L3A and L4A from 10.1 to 12.1 lpm to increase openings in CC. |
| | | 18:03 | 8.6 | Increased power from 188 to 195 kW. Average glass temperature is 1132°C. Since only secondary current is being monitored on LabVIEW, we will monitor primary current locally. Power will be set by primary current not by LabVIEW (secondary) current. Limit will be 530 Amps on primary current. |
| | | 18:04 | 8.6 | Plenum temperature is 529 – 534°C. |
| | | 18:10 | 8.7 | Increased power from 195 to 200 kW. Average glass temperature is 1130°C. Primary current is at 517 Amps. Secondary current is at 1608 Amps. |
| | | 18:39 | 9.2 | Plenum temperature is 514 – 519°C. |
| | | 18:49 | 9.3 | Plenum temperature is 485 –522°C. |
| | | 18:52 | 9.4 | Increased power from 200 to 210 kW, Average glass temperature is 1129°C. Primary current is 524 Amps, and the secondary current is 1625 Amps. |
| | | 19:05 | 9.6 | Plenum temperature is 485 – 529°C. |
| | | 19:17 | 9.8 | Plenum temperature is 483 – 529°C. |
| | | 19:34 | 10.1 | Average glass temperature is 1139°C. Plenum temperature is 522 – 536°C. Secondary current is 1662 Amps. |
| | | 19:49 | 10.3 | Plenum temperature is 519 – 523°C. Melter pressure went positive and tripped emergency off gas. Changed T4 from 27 to 26.7 seconds. |
| | | 19:50 | 10.3 | Increased power from 210 to 215 kW. Average glass temperature is 1138°C. Primary current is 542 Amps, secondary current is 1984 Amps. |
| | | 20:19 | 10.8 | Reduced bubbling as follows: Lances L1 and L2 from 24 to 22 lpm each, and L3 and L4 from 12 to 11 lpm each. Total is at 66 lpm. |
| | | 20:20 | 10.8 | Average glass temperature is 1145°C. Plenum temperature is 508 – 527°C. Primary current is 550 Amps, and the secondary current is 1705 Amps. |
| | | 20:33 | 11.1 | Plenum temperature is 497 – 528°C. |
| | | 20:53 | 11.4 | Average glass temperature is 1141°C. Plenum temperature is 507 – 532°C. Glass resistance is 0.073 Ω. |
| | | 21:09 | 11.7 | Plenum temperature is 495 – 538°C. Glass resistance is 0.073 Ω. |
| | | 21:19 | 11.8 | Plenum temperature is 504 – 531°C. |
| | | 21:37 | 12.1 | Plenum temperature is 494 – 521°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/29/13 | 21:49 | 12.3 | Plenum temperature is 497 – 522°C. |
| | | 21:54 | 12.4 | Performed film cooler rinse. Film cooler differential pressure was 1.7 in W.C. at the end 1.8 in W.C. |
| | | 22:05 | 12.6 | Observed glass resistance change from 0.073 Ω to 0.076 Ω during glass discharge. |
| | | 22:34 | 13.1 | Experiencing high electrode temperatures and alarming. |
| | | 22:36 | 13.1 | Reduced electric power from 215 to 212 kW, east electrode alarm at 1176°C. Average glass temperature is 1145°C. Plenum temperature is 515 – 519°C. Glass resistance is 0.071 Ω. |
| | | 22:50 | 13.3 | Average glass temperature is 1145°C. Plenum temperature is 514 – 522°C. Glass resistance is 0.071 Ω. |
| | | 23:01 | 13.5 | Plenum temperature is 517 – 518°C. Glass resistance is 0.070 Ω. Glass level is 29.7 in. |
| | | 23:09 | 13.7 | Reducing power from 212 to 209 kW. Average glass temperature is 1152°C. Glass level is 30.0 in, Secondary current is 1711 Amps. |
| | | 23:13 | 13.7 | Changed T4 from 26.7 to 26.9 seconds. Feed rate is 181 kg/hr. |
| | | 23:15 | 13.8 | PBS high pH alarm. Proved to be misaligned probe. |
| | | 23:18 | 13.8 | Plenum temperature is 506 – 513°C. |
| | | 23:20 | 13.8 | Reduced power from 209 to 208 kW. Thermowell #2 temperatures are 1154 and 1160°C. |
| | | 23:22 | 13.9 | Glass resistance is 0.069 Ω. Secondary current is 1727 Amps. |
| | | 23:27 | 14.0 | Feed rate is rising. 10 Minutes average shows 187 kg/hr. |
| | | 23:35 | 14.1 | Average glass temperature is 1149°C. Plenum temperature is 519 – 510°C. Secondary current is 1692 Amps. |
| | | 23:42 | 14.2 | Slowed feeding to maintain target feeding 179 kg/hr. Currently averaging 182 kg/hr. Changed T4 from 26.9 to 27.0 seconds. |
| | | 23:46 | 14.3 | Average glass temperature is 1148°C. Plenum temperature is 507 – 521°C. |
| | | 23:56 | 14.4 | Average glass temperature is 1149°C. Thermo well #1 temperatures are between 1133 and 1149°C, and thermo well #2 temperatures are 1141 -1153°C. |
| | 1/30/13 | 0:08 | 14.6 | 2 Minutes in the ½ hour feed cycle, feed rate started to drop. Adjusting T4 from 28 to 27 seconds. |
| | | 0:16 | 14.8 | Average glass temperature is 1151°C. Plenum temperature is 514 – 524°C. Glass resistance is 0.071 Ω. |
| | | 0:17 | 14.8 | Average glass temperature is 1151°C, glass density is 2.28 g/cc. |
| | | 0:19 | 14.8 | Average glass temperature is 1145°C. Plenum temperature is 515 – 519°C. |
| | | 0:34 | 15.1 | Average glass temperature is 1147°C. Plenum temperature is 518– 523°C. Glass resistance is 0.071 Ω. |
| | | 0:49 | 15.3 | Average glass temperature is 1146°C. Plenum temperature is 519 – 525°C. Secondary current is 1692 Amps, glass level is 29.8 in. |
| | | 1:04 | 15.6 | Average glass temperature 1146°C. Plenum temperature is 515 – 520°C. Glass resistance is 0.071 Ω. Secondary current is 1692 Amps. |
| | | 1:19 | 15.8 | Average glass temperature is 1149°C. Plenum temperature is 518 – 519°C. Glass resistance is 0.071 Ω. Glass level is 30.1 in. |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/30/13 | 1:32 | 16.0 | Changing T4 from 27 to 26.5 seconds. |
| | | 1:34 | 16.1 | Plenum temperature is 507 – 518°C. Glass resistance is 0.072 Ω. |
| | | 1:49 | 16.3 | Plenum temperature is 503 – 521°C. Glass density is 2.29 g/cc and secondary current is 1691 Amps. |
| | | 1:50 | 16.3 | Last hour feed cycle high of 183 kg/hr, low of 174 kg/hr; changes to feed shot frequency made. Watching and will monitor. |
| | | 2:04 | 16.6 | Plenum temperature is 514 – 516°C. Glass level is 30.0 in. |
| | | 2:05 | 16.6 | Increased power from 206 to 209 kW. Secondary current is 1714 Amps, power is 121volts and glass resistance is 0.071 Ω. Glass density is 2.29 g/cc. |
| | | 2:19 | 16.8 | Plenum temperature is 506 – 510°C. Average glass temperature is 1148°C. |
| | | 2:34 | 17.1 | Plenum temperature is 499 – 508°C. |
| | | 2:49 | 17.3 | Plenum temperature is 507 – 509°C. |
| | | 3:04 | 17.6 | Plenum temperature is 508 – 511°C. Secondary current is 1714 Amps, Glass resistance is 0.071 Ω. Secondary current is 1714 Amps. |
| | | 3:20 | 17.8 | Plenum temperature is 507°C. Average glass temperature is 1150°C |
| | | 3:34 | 18.1 | Plenum temperature is 505 – 506°C. Glass temperature is 1158°C. |
| | | 3:50 | 18.3 | Reduced mixer speed from 30 to 25 Hz. |
| | | 3:51 | 18.4 | Plenum temperature is 504 – 506°C. |
| | | 4:02 | 18.5 | Changed T4 from 26.5 to 27.0 seconds. |
| | | 4:04 | 18.6 | Plenum temperature is 502 – 514°C, Glass resistance is 0.070 Ω. Glass level is 29.6 in. Glass temperature is 1148°C. |
| | | 4:21 | 18.9 | Plenum temperature is 496 – 513°C, Glass resistance is 0.070 Ω. Glass level is 29.7in. Glass temperature is 1150°C. Secondary current is 1715 Amps. |
| | | 4:23 | 18.9 | SBS outlet pressure indicator is fixed. Now it reads -37.5 in W.C. |
| | | 4:35 | 19.1 | Plenum temperature is 500 – 508°C. Glass resistance is 0.070 Ω. Glass level is 30.0 in. Glass temperature is 1157°C. Secondary current is 1718 Amps. |
| | | 4:36 | 19.1 | Changed T4 from 27 to 28 seconds. |
| | | 4:37 | 19.1 | SBS outlet pressure indicator appears out of service. |
| | | 4:49 | 19.3 | Plenum temperature is 506 – 508°C. Glass density is 2.28 g/cc. |
| | | 4:57 | 19.5 | Changed T4 from 28.0 to 26.5 seconds. |
| | | 5:02 | 19.5 | Increased power from 209 to 212 kW. Average Glass temperature is 1129°C. Glass resistance is 0.071 Ω. Secondary current is 1718 Amps, 122 volts. |
| | | 5:06 | 19.6 | Plenum temperature is 500 – 501°C. |
| | | 5:19 | 19.8 | Plenum temperature is 500 – 510°C. |
| | | 5:21 | 19.9 | Reduced power from 212 to 209 kW, east electrode temperature is 1179°C. Average Glass temperature is 1142 $^{o}$C |
| | | 5:32 | 20.0 | Reduced bubbling as follows: Lances L1 and L2 from 22.1 to 20.1 lpm, L3 and L4 from 11.2 to 10.1 lpm. Total combined bubbling is 60.4 lpm. |
| | | 5:34 | 20.1 | Plenum temperature is 519 – 511°C. |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/30/13 | 5:52 | 20.4 | Reduced power from 209 to 206 kW. |
| | | 5:53 | 20.4 | Plenum temperature is 510 – 512°C. Average Glass temperature is 1154°C. |
| | | 5:59 | 20.5 | Reduced power from 206 to 203 kW. Average Glass temperature is 1154°C. |
| | | 6:20 | 20.8 | Plenum temperature is 497 – 502°C. |
| | | 6:34 | 21.1 | Plenum temperature is 498 – 501°C. Average Glass temperature is 1153°C. Glass resistance is 0.068 Ω. Thermowell #1 temperatures are between 1123 and 1148°C, and thermo well #2 temperatures are 1157-1162°C. |
| | | 6:45 | 21.3 | Transferred feed from mix tank. Starting mass is 2986 kg, ending mass is 37.5 kg. Net mass transferred is 2948.5 kg. Also added 491.0 kg water. Total mass transferred is 3439.5 kg. |
| | | 7:13 | 21.7 | Transferred 275 kg feed + 5 kg water to feed tank. (Ref: residual feed from Test #2, VSL-1987-12 page 72). Feed tank mass in recirculation is 3797.0 kg, end mass is 4077.0 kg. Net mass transferred is 280.0 kg. |
| | | 7:19 | 21.8 | Plenum temperature is 476 – 480°C. Glass resistance is 0.069 Ω. Average glass temperature is 1153°C. Secondary current is 1715 Amps. Power is 201 kW, 118 volts. |
| | | 7:49 | 22.3 | Plenum temperature is 476 – 485°C. Glass resistance is 0.069 Ω. Average glass temperature is 1149°C. Secondary current is 1705Amps. Power is 202 kW, 118 volts. |
| | | 8:04 | 22.6 | Plenum temperature is 484°C. Glass resistance is 0.069 Ω. Average glass temperature is 1156°C. Secondary current is 1706 Amps. Power is 201 kW, 118 volts. |
| | | 8:19 | 22.8 | Plenum temperature is 474- 497°C. Glass resistance is 0.069 Ω. Average glass temperature is 1152°C. Secondary current is 1713 Amps. Power is 201 kW, 118 volts. |
| | | 8:26 | 22.9 | Emergency off gas is tripped due to CC shifting/collapsing. |
| | | 8:34 | 23.1 | Plenum temperature is 479- 484°C. Glass resistance is 0.070 Ω. Average glass temperature is 1151°C. Secondary current is 1706 Amps. Power is 201 kW, 118 volts. Feed rate is 176 kg/hr. Total bubbling is 60 lpm. |
| | | 8:50 | 23.3 | Plenum temperature is 463- 488°C. Average glass temperature is 1150°C. Secondary current is 1710 Amps. Power is 203 kW. |
| | | 9:04 | 23.6 | Average glass temperature is 1145°C. |
| | | 9:19 | 23.8 | Average glass temperature is 1143°C. Plenum temperature is 463- 487°C. Secondary current is 1694 Amps. Power is 201 kW, 118 volts. |
| | | 9:49 | 24.3 | Average glass temperature is 1145°C. |
| | | 10:04 | 24.6 | Average glass temperature 1142°C. Plenum temperature is 464- 479°C |
| | | 10:19 | 24.8 | Average glass temperature is 1145°C. |
| | | 10:36 | 25.1 | Average glass temperature is 1147°C. |
| | | 11:04 | 25.6 | Average glass temperature is 1152°C. |
| | | 11:19 | 25.8 | Average glass temperature is 1150°C. |
| | | 11:25 | 25.9 | Melter pressure spike due to cold cap shift. |

# Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/30/13 | 11:30 | 26.0 | Transfer feed to mix tank. Starting mass 37.5 kg, ending mass is 1518.5 kg. Net mass transferred is 1481.0 kg including 10 kg water. |
| | | 11:49 | 26.3 | Average glass temperature is 1143°C. Plenum temperature is 457- 492°C. Secondary current is 1689 Amps. Power is 201 kW, 119 volts. Glass resistance is 0.071Ω and feed rate is 180 kg/hr. |
| | | 12:04 | 26.6 | Average glass is temperature 1147°C. Plenum temperature is 447- 498°C. Secondary current is 1699 Amps. Power is 201 kW, 118 volts. Glass resistance is 0.070 Ω. |
| | | 12:34 | 27.1 | Average glass temperature is 1145°C. Plenum temperature is 457- 490°C. Secondary current is 1628 Amps and 122 volts. |
| | | 12:35 | 27.1 | Emergency off gas is tripped due to large amount of feed entering glass pool. |
| | | 12:49 | 27.3 | Average glass temperature is 1141°C. Secondary current is 1685 Amps, 119 volts. Glass resistance is 0.070 Ω. |
| | | 12:50 | 27.3 | Paused feeding to clear feed tube. Manual water line flush, increased air purge time from 3 to 5 seconds, switched from nozzle A purge air to B purge air. |
| | | 13:03 | 27.6 | Decreased purge time from 5 to 3 seconds. |
| | | 13:04 | 27.6 | Average glass temperature is 1152°C. Plenum temperature is 461- 496°C. Secondary current is 1711 Amps. |
| | | 13:08 | 27.6 | Switched back to A side of air purge. Line was clogged with feed. |
| | | 13:19 | 27.8 | Average glass temperature is 1152°C. Secondary current is 1713 Amps. |
| | | 13:34 | 28.1 | Average glass temperature is 1142°C. Secondary current is 1690 Amps. |
| | | 14:04 | 28.6 | Average glass temperature is 1150°C. |
| | | 14:39 | 29.2 | Plenum temperature is 435- 494°C. |
| | | 14:51 | 29.4 | Secured power to neutralization tank caustic pump. |
| | | 14:54 | 29.4 | Plenum temperature is 417- 490°C. |
| | | 14:55 | 29.4 | Performed pre-deluge and blow down of WESP. |
| | | 15:04 | 29.6 | Performed post deluge blow down of the WESP. |
| | | 15:06 | 29.6 | Average glass temperature is 1149°C. Plenum temperature is 445- 484°C. Secondary current is 1698 Amps. |
| | | 15:09 | 29.7 | Melter pressure spiked due to opening port on transition line for off gas sampling. |
| | | 15:19 | 29.8 | Plenum temperature is 444- 478°C. Average glass temperature is 1146°C. Secondary current is 1706 Amps. |
| | | 15:32 | 30.0 | Emergency off gas is tripped 3 times during the glass discharge. |
| | | 15:49 | 30.3 | Plenum temperature is 442- 472°C. Average glass temperature is 1148°C. Secondary current is 1706 Amps. |
| | | 16:04 | 30.6 | Plenum temperature is 398- 473°C. |
| | | 16:10 | 30.7 | Melter pressure is spiked due to the opening of the transition line. Off gas sampling is completed. |
| | | 16:19 | 30.8 | Plenum temperature is 420- 476°C. Average glass temperature is 1146°C. Secondary current is 1690 Amps. Glass resistance is 0.071 Ω. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/30/13 | 16:34 | 31.1 | Plenum temperature is 423- 482°C. Average glass temperature is 1149°C. Secondary current is 1690 Amps. Glass resistance is 0.070 Ω. |
| | | 16:49 | 31.3 | Plenum temperature is 449- 482°C. Average glass temperature is 1151°C. Secondary current is 1714 Amps. Glass resistance is 0.068 Ω. |
| | | 17:04 | 31.6 | Plenum temperature is 454- 476°C. Average glass temperature is 1151°C. Secondary current is 1711 Amps. Glass resistance is 0.068 Ω. |
| | | 17:19 | 31.8 | Plenum temperature is 458 – 474°C. Average glass temperature is 1152°C. Secondary current is 1715 Amps. Glass resistance is 0.069 Ω. |
| | | 17:34 | 32.1 | Plenum temperature is 453- 481°C. Average glass temperature is 1143°C. Secondary current is 1632 Amps. Glass resistance is 0.075 Ω. |
| | | 17:49 | 32.3 | Plenum temperature is 446- 490°C. Also found SBS over flow tank top collapsed, had to use pry bar to pop it out, all satisfactory now. |
| | | 18:04 | 32.6 | Plenum temperature is 429 – 493°C. Average glass temperature is 1150°C. Secondary current is 1704 Amps. Glass resistance is 0.070 Ω. |
| | | 18:22 | 32.9 | Melter pressure went positive 3 times during glass discharge, reset emergency off gas each time. |
| | | 18:24 | 32.9 | Plenum temperature is 452- 501°C. |
| | | 18:36 | 33.1 | Plenum temperature is 438 - 504°C. |
| | | 18:49 | 33.3 | Plenum temperature is 463 – 503°C. Average glass temperature is 1151°C. Secondary current is 1693 Amps. Glass resistance is 0.070 Ω. |
| | | 19:19 | 33.8 | Average glass temperature is 1150°C. Secondary current is 1632 Amps. |
| | | 19:25 | 33.9 | Started off gas sampling. |
| | | 19:34 | 34.1 | Plenum temperature is 455 – 491°C. Average glass temperature is 1151°C. Secondary current is 1691 Amps. Glass resistance is 0.070 Ω. |
| | | 19:49 | 34.3 | Plenum temperature is 462 – 477°C. Average glass temperature is 1153°C. Secondary current is 1703 Amps. Glass resistance is 0.069 Ω. |
| | | 20:14 | 34.7 | Plenum temperature is 399 – 478°C. |
| | | 20:19 | 34.8 | Plenum temperature is 399 – 506°C. |
| | | 20:28 | 35.0 | Off gas sampling is completed. |
| | | 20:32 | 35.0 | Paused feeding to collect a feed sample. |
| | | 20:47 | 35.3 | Transferred feed from mix tank to feed tank. Starting tank mass is 1516.0 kg, ending tank mass is 68.5 kg. Net mass of feed transferred is 1447.5 kg. Plus 246.0 kg water. Total mass transferred is 1693.5 kg. |
| | | 20:54 | 35.4 | Plenum temperature is 474 – 479°C. Average glass temperature is 1146°C. Secondary current is 1681 Amps. Glass resistance is 0.071 Ω. |
| | | 21:04 | 35.6 | Plenum temperature is 478 – 482°C. Average glass temperature is 1144°C. Secondary current is 1684 Amps. Glass resistance is 0.071 Ω. |
| | | 21:19 | 35.8 | Plenum temperature is 406 – 467°C. Average glass temperature is 1147°C. Secondary current is 1704 Amps. Glass resistance is 0.070 Ω. |
| | | 21:34 | 36.1 | Plenum temperature is 443 – 475°C. Average glass temperature is 1140°C. Secondary current is 1620 Amps. Glass resistance is 0.077 Ω. |
| | | 21:44 | 36.2 | Performed a film cooler rinse. Film cooler differential pressure before and after were -1.4 and -1.3 in W.C. respectively. |
| | | 21:49 | 36.3 | Plenum temperature is 447 – 488°C. Average glass temperature is 1145°C. Secondary current is 1680 Amps. Glass resistance is 0.071 Ω. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/30/13 | 22:04 | 36.6 | Plenum temperature is 453 – 500°C. Average glass temperature is 1147°C. Secondary current is 1690 Amps. Glass resistance is 0.071 Ω. |
| | | 22:19 | 36.8 | Plenum temperature is 425 – 477°C. Average glass temperature is 1148°C. Secondary current is 1712 Amps. Glass resistance is 0.069 Ω. |
| | | 22:34 | 37.1 | Plenum temperature is 463 – 473°C. Average glass temperature is 1141°C. Glass resistance is 0.070 Ω. |
| | | 22:47 | 37.3 | Adjusting blower 701/702 from 52 to 54 Hz and 801 from 22 to 20 Hz. This brings blower 701/702 outlet pressures from -8.0 to -2.0 in W.C. |
| | | 22:49 | 37.3 | Plenum temperature is 460 – 470°C. |
| | | 22:53 | 37.4 | Further adjusting blowers: blowers 701/702 are set to 55 Hz and blower 801 is set to 18 Hz. |
| | | 23:05 | 37.6 | Plenum temperature is 467 – 475°C. |
| | | 23:19 | 37.8 | Plenum temperature is 473 – 474°C. |
| | | 23:35 | 38.1 | Plenum temperature is 471 – 478°C. Average glass temperature is 1147°C. |
| | | 23:50 | 38.3 | Plenum temperature is 470 – 478°C. |
| | | 23:54 | 38.4 | Melter emergency off gas is opened momentarily, did not see any collapse of CC. |
| | | 23:56 | 38.4 | Plenum temperature is 466 – 483°C. Average glass temperature is 1152°C. |
| | 1/31/13 | 0:15 | 38.8 | SBS overflow tank implodes: top is no longer convex. SBS outlet pressure -63.5 in W.C. |
| | | 0:21 | 38.9 | Plenum temperature is 471 – 476°C. Secondary current is 1691 Amps. Glass resistance is 0.070 Ω. Glass density is 2.30 g/cc. |
| | | 0:34 | 39.1 | Plenum temperature is 463 – 475°C. |
| | | 0:50 | 39.3 | Plenum temperature is 451 – 474°C. |
| | | 1:04 | 39.6 | Plenum temperature is 462 – 463°C. |
| | | 1:13 | 39.7 | As previously noticed, feed tank AOD pump seemed to stopping a beat or so. Increased AOD pump pressure ~32 psi and will continue to monitor. |
| | | 1:22 | 39.9 | Increased bubbling as follows: Lances 1A from 20.3 to 22.3 lpm, Lance 2A from 19.8 to 21.8 lpm, Lance 3A from 10.1 to 11.1 lpm, Lance 4A from 10.1 to 11.1 lpm. |
| | | 1:23 | 39.9 | Emergency off gas tripped. |
| | | 1:26 | 39.9 | Plenum temperature is 461 – 471°C. Secondary current is 1699 Amps. Glass level is 29.7 in. |
| | | 1:43 | 40.2 | Blower speeds; blower 801 is 24 Hz, blowers 701/702 is 50 Hz, during discharge to avoid positive pressure spike returned to blower 801 to 20 Hz and blower 701/702 to 50 Hz. |
| | | 1:44 | 40.2 | Plenum temperature is 479 – 499°C |
| | | 2:03 | 40.6 | Previously increased bubbling to increase plenum temperatures to help dissolve the ridge. |
| | | 2:04 | 40.6 | Blower 701/702 speed changed from 50 to 55 Hz, blower 801 speed changed from 20 to 23 Hz. Melter vacuum is -2.11 in W.C. and blower outlet is -6.8 in W.C. |
| | | 2:10 | 40.7 | Changed T4 from 25 to 24 seconds. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/31/13 | 2:19 | 40.8 | Plenum temperature is 486 – 522°C. Average glass temperature is 1147°C. |
| | | 2:23 | 40.9 | Reduced bubbling as follows: Lance 1A from 22.3 to 20.3 lpm, Lance 2A from 21.8 to 19.8 lpm, Lance 3A from 11.1 to 10.1 lpm and L4A from 11.1 to 10.1 lpm. |
| | | 2:26 | 40.9 | Average glass temperature is 1147°C. |
| | | 2:36 | 41.1 | Plenum temperature is 482 – 532°C. Average glass temperature is 1144°C. Secondary current is 1686 Amps. |
| | | 2:52 | 41.4 | Plenum temperature is 466 – 539°C. Average glass temperature is 1148°C. Glass density is 2.30 g/cc. |
| | | 3:01 | 41.5 | Changed from 24 to 24.5 seconds. |
| | | 3:19 | 41.8 | Plenum temperature is 463 – 544°C. |
| | | 3:36 | 42.1 | Increased power to 206 kW. Average glass temperature is 1144°C. Secondary current is 1688 Amps. Glass resistance is 0.071 Ω. |
| | | 3:37 | 42.1 | Exposed plenum thermocouple almost touching CC. Plenum temperature is 467 – 494°C. |
| | | 3:47 | 42.3 | Increased power from 206 to 208 kW. Average glass temperature is 1146°C. Thermo well #1 reading is 1115 -1147°C. Thermowell #2 reading is 1142-1152°C. |
| | | 3:50 | 42.3 | Plenum temperature is 469 – 490°C. |
| | | 4:05 | 42.6 | Power is 208 kW, 120 volts, secondary current is 1717 Amps, primary current is 551.7 Amps, and glass resistance is 0.070 Ω. |
| | | 4:07 | 42.6 | Plenum temperature is 445 – 495°C. Average glass temperature is 1147°C. |
| | | 4:20 | 42.8 | Plenum temperature is 438 – 501°C. Secondary current is 1729 Amps. Glass resistance is 0.069 Ω. |
| | | 4:23 | 42.9 | Decreased blower 701/702 from 54 to 51 Hz, blower 801 from 24 to 20 Hz. |
| | | 4:34 | 43.1 | Plenum temperature is 430 – 510°C. Average glass temperature is 1150°C. Glass level is 29.8 in. |
| | | 4:37 | 43.1 | Decreased power from 208 to 206 kW. Primary current is 558.3 Amps, secondary current is 1738 Amps. Average glass temperature is 1152°C. |
| | | 4:46 | 43.3 | Plenum temperature is 428 – 506°C. |
| | | 4:48 | 43.3 | Melter pressure went positive, returned blowers 701/702 from 51 to 54 Hz and blower 801 from 20 to 24 Hz. |
| | | 4:53 | 43.4 | Lowered melter power from 206 to 203 kW. |
| | | 5:05 | 43.6 | Plenum temperature is 436 – 489°C. Average glass temperature is 1147°C. |
| | | 5:14 | 43.7 | Currently bubbling as follows: L1 A and B at 20 lpm, L2A and B at 20 lpm, L3 and L4 at 10 lpm. |
| | | 5:20 | 43.8 | Observing love controller registering temperature of 1172°C. LabVIEW is showing 1168°C. Secondary current is 1707Amps, and Glass resistance is 0.069 Ω. |
| | | 5:22 | 43.9 | Lowered electric power from 203 to 200 kW. |
| | | 5:23 | 43.9 | Plenum temperature is 446 – 485°C. Average glass temperature is 1148°C. |
| | | 5:37 | 44.1 | Plenum temperature is 441 – 486°C. |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/31/13 | 5:55 | 44.4 | Plenum temperature is 427 – 503°C. |
| | | 6:00 | 44.5 | Adjusted T4 from 25 to 25.3 seconds. Feed rate 182.0 kg/hr for 2 readings. |
| | | 6:08 | 44.6 | Reduced power from 200 to 199 kW. Secondary current is 1700 Amps, and glass resistance is 0.068 Ω. |
| | | 6:09 | 44.7 | Plenum temperature is 425 – 518°C. |
| | | 6:49 | 45.3 | Plenum temperature is 431 – 505°C. Average glass temperature is 1142°C. |
| | | 7:04 | 45.6 | Average glass temperature is 1145°C. |
| | | 7:19 | 45.8 | Plenum temperature is 440 – 460°C. Average glass temperature is 1146°C. |
| | | 7:34 | 46.1 | Plenum temperature is 447 – 448°C. Average glass temperature is 1140°C. |
| | | 7:35 | 46.1 | Increased power from 199 to 201 kW. Average glass temperature is 1140°C. |
| | | 7:49 | 46.3 | Plenum temperature is 437 – 443°C. Average glass temperature is 1146°C. Secondary current is 1699 Amps, 118 volts. |
| | | 7:56 | 46.4 | Increased power from 201 to 202 kW. Average glass temperature is 1146°C. Secondary current is 1702 Amps, 118 volts. |
| | | 8:19 | 46.8 | Average glass temperature is 1145°C. |
| | | 8:21 | 46.9 | Switched purge air from A to B due to blockage on A. |
| | | 8:34 | 47.1 | Average glass temperature is 1146°C. |
| | | 8:49 | 47.3 | Average glass temperature is 1150°C. |
| | | 9:04 | 47.6 | Average glass temperature is 1148°C. Secondary current is 1694 Amps. Power is set to 202 kW. |
| | | 9:16 | 47.8 | Decreased AOD pump pressure from 30 to 25 psi to help to control feed rate. |
| | | 9:19 | 47.8 | Average glass temperature is 1148°C. |
| | | 9:34 | 48.1 | Plenum temperature is 452 – 453°C. Average glass temperature is 1151°C. |
| | | 9:49 | 48.3 | Average glass temperature is 1147°C. |
| | | 10:05 | 48.6 | Performed film cooler rinse. |
| | | 10:30 | 49.0 | Stopped feeding. End of Test. |
| | | 10:42 | 49.2 | Reduced power from 202 to 192 kW. Average glass temperature is 1154°C. |
| | | 10:52 | 49.4 | Reduced power from 192 to 185 kW. Average glass temperature is 1175°C. |
| | | 10:58 | 49.5 | Removed feed from the feed tank. Starting mass is 909 kg. Feed sample mass is 1.275 kg. End mass is 10 kg. Net mass removed is 897.72 kg. Feed sample is taken. |
| | | 11:02 | 49.5 | Reduced power to 165 kW and increased bubbling to 5 lpm on all bubblers. High electrode alarm came in. Average glass temperature is 1156°C. |
| | | 11:05 | 49.6 | Moved 800 gallons of waste water from bottom tanks to effluent tank. |
| | | 11:20 | 49.8 | Reduced power to 155 kW. Average glass temperature is 1159°C. |
| | | 11:37 | 50.1 | Reduced power to 145 kW. Average glass temperature is 1158°C. |
| | | 11:46 | 50.3 | Reduced power to 135 kW. Average glass temperature is 1161°C. |
| | | 12:00 | 50.5 | Reduced power to 125 kW. Average glass temperature is 1160°C. |
| | | 12:10 | 50.7 | Reduced power to 115 kW. Average glass temperature is 1157°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 3 | 1/31/13 | 12:41 | 51.2 | Reduced power to 110 kW. Average glass temperature is 1156°C. Also reduced bubbling to 2.5 lpm on all bubblers. |
| | | 13:09 | 51.7 | Reduced power to 105 kW. Average glass temperature is 1156°C. |
| | | 13:23 | 51.9 | Turned off power to discharge chamber for inspection/repair. |
| | | 14:30 | 53.0 | Reduced power to 105 kW. Average glass temperature is 1140°C. |
| | 2/2/13 | 3:58 | - | DM1200 discharge chamber was fixed. The glass discharge was pulled out and sampled. This drum will be utilized at the beginning of Test 4. |
| 4 | 2/6/13 | 0:30 | - | Transferred feed to mix tank. 2957.0 kg that includes 10 kg water is transferred. |
| | | 3:42 | - | Transferred feed from mix tank to feed tank. Starting mass is 2957.0 kg, ending mass is 37.0 kg. Net mass transferred is 2920.0 kg plus 496.4 kg water is transferred. 10 kg of this water is added later as flush water. |
| | | 4:25 | - | Secured mix tank mixer, energized feed tank mixer, and placed in recirculation. |
| | | 6:40 | - | Decreased power from 97 to 96 kW. Average glass temperature is 1169°C. |
| | | 7:13 | - | Decreased power from 96 to 95 kW. Average glass temperature is 1171°C. |
| | | 7:16 | - | Increased discharge power from 13 kW to 14 kW. Temperature is 794°C. |
| | | 7:40 | - | Decreased power from 95 to 94 kW. Average glass temperature is 1171°C. |
| | | 8:17 | - | Increased discharge chamber power from 14.0 to 15.0 kW. Temperature is 783°C. |
| | | 8:40 | - | Added the remaining residual feed from Test #2 (Ref. VSL 1987-12 Page 72). Feed tank mass in recirculation is 3370.0 kg, end feed tank mass in recirculation is 4024.5 kg. Mass transferred that includes 10 kg water is 654. 5 kg. |
| | | 9:01 | - | Increased discharge chamber power from 15 to 16 kW. Temperature is 799°C. |
| | | 9:30 | - | Increased discharge chamber power from 16 to 17 kW. Temperature is 820°C. |
| | | 9:58 | - | Increased power to electrodes from 94 to 97 kW. Average glass temperature is 1162°C. |
| | | 10:00 | - | Increased discharge chamber power from 17 to 18 kW. Temperature is 841-863°C. |
| | | 10:02 | - | Adjusted Lances 1 and 2 to 6.0 lpm, and Lances 3 and 4 to 3.0 lpm. |
| | | 11:47 | - | Increased power from 97 to 100 kW. Average glass temperature is 1160°C. |
| | | 12:00 | 0.0 | Started feeding water at 0.8 l/min. Average glass temperature is 1161°C. |
| | | 12:10 | 0.2 | Increased power from 100 to 105 kW. Average glass temperature is 1159°C. |
| | | 12:10 | 0.2 | Increased water feed from 0.8 to 1.6 l/min. |
| | | 12:25 | 0.4 | Increased power from 105 to 110 kW. Average glass temperature 1154°C. |
| | | 12:30 | 0.5 | Increased water feed from 1.6 to 2.4 l/min. |
| | | 12:35 | 0.6 | Increased power from 110 to 115 kW. Average glass temperature is 1148°C. |
| | | 12:43 | 0.7 | Increased power from 115 to 125 kW. Average glass temperature is 1140°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/6/13 | 12:46 | 0.8 | Increased water feed from 2.46 to 3.0 l/min. Plenum temperature is 800-864°C. |
| | | 12:53 | 0.9 | Increased power from 125 to 130 kW. Average glass temperature is 1135°C. Plenum temperature is 726-825°C. |
| | | 13:00 | 1.0 | Secured feeding water. Started feeding slurry. |
| | | 13:17 | 1.3 | Increased power from 130 to 135 kW. Average glass temperature is 1135°C. |
| | | 13:24 | 1.4 | Average glass temperature is 1141°C. |
| | | 13:32 | 1.5 | Increased power from 135 to 140 kW. Average glass temperature is 1140°C. |
| | | 13:35 | 1.6 | Average glass temperature 1140°C. |
| | | 13:47 | 1.8 | Increased power from 140 to 145 kW. Average glass temperature is 1145°C. |
| | | 14:02 | 2.0 | Increased bubbling on Lances 1A and 2A from 6.0 to 7.0 lpm, and Lances 3A and 4A from 3.0 to 3.5 lpm. |
| | | 14:23 | 2.4 | Average glass temperature is 1161°C. Plenum temperature is 705-714°C. |
| | | 14:26 | 2.4 | Decreased power from 145 to 140 kW. Average glass temperature is 1163°C. |
| | | 14:37 | 2.6 | Average glass temperature is 1163°C. |
| | | 14:55 | 2.9 | Primary current is 428 Amps and secondary current is 1344 Amps. Average glass temperature is 1167°C. |
| | | 15:02 | 3.0 | Increased bubbling on Lance 1A from 7.2 to 8.2 lpm to maintain 8.0 lpm, Lance 2A from 7.0 to 8.0 lpm to maintain 8.0 lpm, Lance 3A from 3.6 to 4.1 lpm to maintain 4.0 lpm, and Lance 4A from 3.6 to 4.1 lpm to maintain 4.0 lpm. |
| | | 15:04 | 3.1 | Decreased power from 140 to 137 kW. Primary current is 426 Amps. |
| | | 15:11 | 3.2 | Primary current is 427 Amps and secondary current is 1341 Amps. Average glass temperature is 1172°C |
| | | 15:13 | 3.2 | Decrease power from 137 to 132 kW. Primary current 420 Amps. |
| | | 15:20 | 3.3 | Primary current is 420 Amps and secondary current is 1335 Amps. Average glass temperature is 1172°C. |
| | | 15:32 | 3.5 | Decrease power from 132 to 130 kW. Primary current 419 Amps. |
| | | 15:36 | 3.6 | Completed clearing SBS blow down lance. |
| | | 15:37 | 3.6 | Decrease power from 130 to 125 kW. Primary current 412 Amps. |
| | | 15:49 | 3.8 | Primary current is 411 Amps and secondary current is 1315 Amps. Average glass temperature is 1175°C. |
| | | 16:00 | 4.0 | Increased bubbling on Lance 1A from 8.2 to 9.2 lpm to maintain 9.0 lpm, Lance 2A from 8.0 to 9.0 lpm to maintain 9.0 lpm, Lance 3A from 4.1 to 4.6 lpm to maintain 4.5 lpm, and Lance 4A from 4.1 to 4.6 lpm to maintain 4.5 lpm. |
| | | 16:05 | 4.1 | Primary current is 411 Amps and secondary current is 1314 Amps. Average glass temperature is 1173°C. |
| | | 16:18 | 4.3 | Reduced power from 125 to 120 kW. Primary current 403 Amps. Average glass temperature is 1174°C. |
| | | 16:20 | 4.3 | Primary current is 403 Amps and secondary current is 1290 Amps. Average glass temperature is 1172°C. |
| | | 16:42 | 4.7 | Primary current is 397 Amps and secondary current is 1269 Amps. Average glass temperature is 1167°C. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/6/13 | 17:02 | 5.0 | Changed bubbling on Lance 1A from 9.2 to 10.1 lpm to maintain 10.0 lpm, Lance 2A from 9.0 to 10.0 lpm to maintain 10.0 lpm, Lance 3A from 4.6 to 5.1 lpm to maintain 5.0 lpm, and Lance 4A from 4.6 to 5.1 lpm to maintain 5.0 lpm. |
| | | 17:19 | 5.3 | Plenum temperature is 601 – 604°C. Average glass temperature is 1157°C. |
| | | 17:35 | 5.6 | SBS blow down totalizer indicated 27.20 gallons at the start of blow down, when it reached 35.58 gallons it “froze”, continued pumping for about 3 minutes and blow down tank appeared to rise by visual indication. |
| | | 18:01 | 6.0 | Changed bubbling on Lance 1A from 10.1 to 11.0 lpm to maintain 11.0 lpm, Lance 2A from 10.0 to 11.0 lpm to maintain 11.0 lpm, Lance 3A from 5.1 to 5.5 lpm to maintain 5.5 lpm, and Lance 4A from 5.1 to 5.5 lpm to maintain 5.5 lpm. |
| | | 18:37 | 6.6 | Increased power from 120 to 125 kW. Average glass temperature is 1139°C. Primary current is 390 Amps. |
| | | 18:40 | 6.7 | Increased power from 125 to 130 kW. Average glass temperature is 1138°C. Primary current is 398 Amps. |
| | | 18:42 | 6.7 | Average glass temperature is 1138°C. Primary current is 406 Amps. |
| | | 18:50 | 6.8 | Increased power from 130 to 135 kW. Average glass temperature is 1138°C. Primary current is 406 Amps. |
| | | 19:00 | 7.0 | Changed bubbling on Lance 1A from 11.0 to maintain 12.0 lpm, Lance 2A from 11.0 to maintain 12.0 lpm, Lance 3A from 5.5 to maintain 6.0 lpm, and Lance 4A from 5.5 to maintain 6.0 lpm. |
| | | 19:04 | 7.1 | Increased power from 135 to 140 kW. Average glass temperature is 1140°C. Primary current is 414 Amps. Thermocouple 03 is not spiking any more. |
| | | 19:09 | 7.2 | Average glass temperature is 1141°C. Primary current is 415 Amps. Secondary current is 1302 Amps. Plenum temperature is 536 – 546°C. |
| | | 19:16 | 7.3 | Increased power from 140 to 150 kW. Average glass temperature is 1141°C. Primary current is 430 Amps. Plenum temperature is 532 – 544°C. |
| | | 19:19 | 7.3 | Average glass temperature is 1144°C. Primary current is 432 Amps. Plenum temperature is 524 – 547°C. Glass resistance is 0.084 Ω. |
| | | 19:32 | 7.5 | Found process heater is not set to 68°C, increased temperature set point to 68°C. |
| | | 19:47 | 7.8 | Average glass temperature is 1146°C. Primary current is 432 Amps. Secondary current is 1349 Amps. |
| | | 19:48 | 7.8 | Increased power from 150 to 153 kW. Average glass temperature is 1146°C. Primary current is 436 Amps. Glass resistance is 0.083 Ω. |
| | | 20:09 | 8.2 | Average glass temperature is 1153°C. Primary current is 440 Amps. Secondary current is 1382 Amps. |
| | | 20:16 | 8.3 | Changed bubbling on Lance 1A from 12.2 to 13.2 lpm to maintain 13.0 lpm, Lance 2A from 12.0 to 13.0 lpm to maintain 13.0 lpm, Lance 3A from 6.1 to 6.6 lpm to maintain 6.5lpm, and Lance 4A from 6.1 to 6.6 lpm to maintain 6.5 lpm. |
| | | 20:23 | 8.4 | Decreased power from 153 to 150 kW. Average glass temperature is 1155°C. Primary current is 438 Amps. Secondary current is 1369 Amps. |
| | | 20:26 | 8.4 | Average glass temperature is 1154°C. Primary current is 437 Amps. Secondary current is 1372 Amps. |

# Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/6/13 | 20:35 | 8.6 | Paused feeding to collect feed sample. |
| | | 20:39 | 8.7 | Resumed feeding. |
| | | 20:55 | 8.9 | Decreased power from 150 to 145 kW. Average glass temperature is 1156°C. Primary current is 435 Amps. Glass resistance is 0.080 Ω. |
| | | 21:00 | 9.0 | Changed bubbling on Lance 1A from 13.2 to 14.2 lpm to maintain 14.0 lpm, Lance 2A from 13.0 to 14.0 lpm to maintain 14.0 lpm, Lance 3A from 6.6 to 7.1 lpm to maintain 7.0 lpm, and Lance 4A from 6.6 to 7.1 lpm to maintain 7.0 lpm. |
| | | 21:04 | 9.1 | Average glass temperature is 1159°C. Primary current is 435 Amps. Glass resistance is 0.079 Ω. Plenum temperature is 487 – 505°C. |
| | | 21:19 | 9.3 | Average glass temperature is 1156°C. Primary current is 434 Amps. Glass resistance is 0.080 Ω. Plenum temperature is 489 – 499°C. |
| | | 21:24 | 9.4 | Average glass temperature is 1160°C. Secondary current is 1365 Amps. Glass density is 2.33g/cc. Plenum temperature is 484 – 503°C. |
| | | 21:52 | 9.9 | Average glass temperature is 1156°C. Glass resistance is 0.081 Ω. Plenum temperature is 445 – 501°C. Electrode voltage is 109 volts. |
| | | 21:59 | 10.0 | Increased bubbling on Lance 1A from 14.2 to 15.2 lpm, Lance 2A from 14.0 to 15.0 lpm, Lance 3A from 7.1 to 7.6 lpm, and Lance 4A from 7.1 to 7.6 lpm. Primary current is 431 Amps. |
| | | 22:05 | 10.1 | Average glass temperature is 1114°C. Glass density is 2.34g/cc. Plenum temperature is 460 – 494°C. |
| | | 22:33 | 10.5 | Increased power from 145 to 148 kW. Average glass temperature is 1146°C. Glass resistance is 0.084 Ω. Primary current is 430 Amps, and secondary current is 1346 Amps. |
| | | 22:34 | 10.6 | Average glass temperature is 1148°C. Secondary current is 1348 Amps. Glass resistance is 0.083 Ω. Plenum temperature is 461 – 485°C. |
| | | 22:42 | 10.7 | Measured primary current using Amp probe; 433Amps. Indicator shows 431 Amps. |
| | | 22:49 | 10.8 | Average glass temperature is 1150°C. Plenum temperature is 465 – 477°C. |
| | | 22:59 | 11.0 | Increased bubbling on Lance 1A from 15.2 to 16.2 lpm, Lance 2A from 15.0 to 16.0 lpm, Lance 3A from 7.6 to 8.1 lpm, and Lance 4A from 7.6 to 8.1 lpm. |
| | | 23:05 | 11.1 | Upon changing discharge can, found a 5”x3”x10” glass chunk hanging from discharge chamber floor, was able to dislodge into a new can. Looked up, appeared that glass flow was even and coming from the floor, will watch closely. |
| | | 23:18 | 11.3 | Increased power from 148 to 151 kW. Average glass temperature is 1142°C. Voltage is 114 volts. |
| | | 23:20 | 11.3 | Average glass temperature is 1139°C. Plenum temperature is 449 – 478°C. |
| | | 23:26 | 11.4 | Performed film cooler rinse. |
| | | 23:35 | 11.6 | Average glass temperature is 1145°C. Plenum temperature is 458– 477°C. Glass level is 28.9 in. |
| | | 23:42 | 11.7 | Increased power from151 to 154 kW. Average glass temperature is 1143°C. Glass resistance is 0.086 Ω. Glass density is 2.30 g/cc. |
| | | 23:49 | 11.8 | Average glass temperature is 1143°C. Plenum temperature is 447 – 473°C. |
| | | 23:51 | 11.9 | Increased power from 154 to 157 kW. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/6/13 | 23:59 | 12.0 | Increased bubbling on Lance 1A from 16.2 to 17.2 lpm, Lance 2A from 16.0 to 17.0 lpm, Lance 3A from 8.1 to 8.6 lpm, and Lance 4A from 8.1 to 8.6 lpm. |
| | 2/7/13 | 0:14 | 12.2 | Increased power 157 to 160 kW. Average glass temperature is 1146°C. Glass resistance is 0.085 Ω. Plenum temperature is 433 – 457°C. |
| | | 0:19 | 12.3 | Average glass temperature is 1147°C. Glass level is 28.9 in. Plenum temperature is 433 – 453°C. |
| | | 0:34 | 12.6 | Average glass temperature is 1150°C. Glass resistance is 0.083 Ω. Plenum temperature is 431 – 452°C. |
| | | 0:49 | 12.8 | Plenum temperature is 423 – 448°C. |
| | | 0:59 | 13.0 | Increased power from 160 to 163 kW. Average glass temperature is 1143°C. |
| | | 1:05 | 13.1 | Increased bubbling on Lance 1A from 17.2 to 18.2 lpm, Lance 2A from 17.0 to 18.0 lpm, Lance 3A from 8.6 to 9.1 lpm, and Lance 4A from 8.6 to 9.1 lpm. |
| | | 1:08 | 13.1 | Plenum temperature is 415 – 450°C. |
| | | 1:14 | 13.2 | Increased power from 163 to 166 kW. Average glass temperature is 1145°C. Primary current is 452 Amps. |
| | | 1:21 | 13.4 | Average glass temperature is 1137°C. Plenum temperature is 420 – 456°C. |
| | | 1:26 | 13.4 | Increased power from 166 to 169 kW. Primary current is 458 Amps. |
| | | 1:34 | 13.6 | Plenum temperature is 426 – 458°C. Glass resistance is 0.084 Ω. Glass density is 2.32 g/cc. |
| | | 1:49 | 13.8 | Average glass temperature is 1152°C. Plenum temperature is 429 – 457°C. |
| | | 1:54 | 13.9 | Found Lance 2A set at 17.0 lpm changed to 18.0 lpm. |
| | | 1:55 | 13.9 | Physical review of thermo well temperatures performed. No problems noted. |
| | | 2:05 | 14.1 | Average glass temperature is 1155°C. Plenum temperature is 427 – 453°C. |
| | | 2:09 | 14.2 | Increased bubbling on Lance 1A from 18.2 to 19.2 lpm, Lance 2A from 18.0 to 19.0 lpm, Lance 3A from 9.1 to 9.6 lpm, and Lance 4A from 9.1 to 9.6 lpm. |
| | | 2:11 | 14.2 | Transfer of six drums of feed to mix tank. Energizing mixer blade to 30 Hz. Mass is 1515.0 kg. |
| | | 2:20 | 14.3 | Average glass temperature is 1152°C. Plenum temperature is 427 – 456°C. Glass resistance is 0.083 Ω. Glass level is 29.0 in. |
| | | 2:34 | 14.6 | Average glass temperature is 1151°C. Plenum temperature is 423 – 460°C. Glass resistance is 0.081 Ω. Secondary current is 1454 Amps. |
| | | 2:51 | 14.9 | Average glass temperature is 1153°C. Plenum temperature is 439 – 461°C. |
| | | 3:02 | 15.0 | Increased bubbling on Lance 1A from 19.2 to 20.2 lpm, Lance 2A from 19.0 to 20.0 lpm, Lance 3A from 9.6 to 10.1 lpm, and Lance 4A from 9.6 to 10.1 lpm. |
| | | 3:05 | 15.1 | Average glass temperature is 1153°C. Plenum temperature is 443 – 463°C. |
| | | 3:17 | 15.3 | Changed T4 from 34 to 33.5 seconds. |
| | | 3:19 | 15.3 | Average glass temperature is 1157°C. Plenum temperature is 444 – 467°C. Glass level is 29.5 in. |
| | | 3:35 | 15.6 | Average glass temperature is 1150°C. Plenum temperature is 447 – 472°C. Glass resistance is 0.083 Ω. Secondary current is 1445 Amps. Glass density is 2.30 g/cc. |
| | | 3:44 | 15.7 | Average glass temperature is 1152°C. Plenum temperature is 453 – 478°C |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/7/13 | 4:03 | 16.0 | Increased bubbling on Lance 1A from 20.2 to 21.2 lpm, Lance 2A from 20.0 to 21.0 lpm, Lance 3A from 10.1 to 10.6lpm, and Lance 4A from 10.1 to 10.6 lpm. Average glass temperature is 1155°C. |
| | | 4:07 | 16.1 | Average glass temperature is 1155°C. Plenum temperature is 454 – 476°C. Glass density is 2.29 g/cc. |
| | | 4:19 | 16.3 | Average glass temperature is 1154°C. Plenum temperature is 451 – 471°C. Secondary current is 1442 Amps. |
| | | 4:31 | 16.5 | Changed T4 from 33.0 to 32.5 seconds. |
| | | 4:34 | 16.6 | Average glass temperature is 1157°C. Plenum temperature is 454 – 472°C. |
| | | 4:49 | 16.8 | Average glass temperature is 1152°C. Plenum temperature is 457 – 471°C. |
| | | 5:00 | 17.0 | Increased bubbling on Lance 1A from 21.2 to 22.2 lpm, Lance 2A from 21.0 to 22.0 lpm, Lance 3A from 10.6 to 11.1 lpm, and Lance 4A from 10.6 to 11.1 lpm. Average glass temperature is 1155°C. |
| | | 5:04 | 17.1 | Plenum temperature is 456 – 477°C. |
| | | 5:28 | 17.5 | Plenum temperature is 459 – 475°C. |
| | | 5:42 | 17.7 | Plenum temperature is 451 – 456°C. |
| | | 5:48 | 17.8 | Average glass temperature is 1146°C. Plenum temperature is 454 – 458°C. |
| | | 6:00 | 18.0 | Increased power from 169 to 172 kW. Average glass temperature is 1147°C. Primary current is 460 Amps. |
| | | 6:03 | 18.0 | Increased bubbling on Lance 1A from 22.2 to 23.2 lpm, Lance 2A from 22.0 to 23.0 lpm, Lance 3A from 11.1 to 11.6 lpm, and Lance 4A from 11.0 to 11.6 lpm. |
| | | 6:04 | 18.1 | Plenum temperature is 447 – 467°C. |
| | | 6:10 | 18.2 | Increased power from 172 to 175 kW. Average glass temperature is 1142°C. Primary current is 465 Amps. |
| | | 6:20 | 18.3 | Increased power from 175 to 178 kW. Average glass temperature is 1136°C. Primary current is 467 Amps. |
| | | 6:31 | 18.5 | Increased power from 178 to 181 kW. Average glass temperature is 1138°C. Primary current is 473 Amps. |
| | | 6:59 | 19.0 | Average glass temperature is 1141°C. |
| | | 7:03 | 19.0 | Increased bubbling on Lance 1A from 23.2 to 24.2 lpm, Lance 2A from 23.0 to 23.9 lpm, Lance 3A from 11.6 to 12.1 lpm, and Lance 4A from 11.6 to 12.1 lpm. |
| | | 7:13 | 19.2 | Increased power from 181 to 184 kW. Average glass temperature is 1142°C. Primary current is 478 Amps. |
| | | 7:15 | 19.3 | Average glass temperature is 1141°C. Plenum temperature is 460 – 481°C. |
| | | 7:32 | 19.5 | Increased power from 184 to 187 kW. Average glass temperature is 1142°C. Primary current is 483 Amps. |
| | | 7:34 | 19.6 | Plenum temperature is 472 – 483°C. Primary current 484 Amps. |
| | | 7:44 | 19.7 | Increased power from 187 to 192 kW. Average glass temperature is 1140°C. Primary current is 491 Amps. |
| | | 7:48 | 19.8 | Average glass temperature is 1137°C. Plenum temperature is 462 – 468°C. |
| | | 8:02 | 20.0 | Increased bubbling on Lance 1A from 24.3 to 25.3 lpm, Lance 2A from 23.9 to 24.9 lpm, Lance 3A from 12.1 to 12.6 lpm, and Lance 4A from 12.1 to 12.6 lpm. |
| | | 8:03 | 20.1 | Average glass temperature is 1144°C. Plenum temperature is 469 – 481°C. Primary current is 498 Amps. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | Run time note |
|---|---|---|---|---|
| 4 | 2/7/13 | 8:19 | 20.3 | Average glass temperature is 1151°C. Power is 196 kW. Primary current is 498 Amps. Secondary current is 1544 Amps. Glass resistance is 0.082 Ω. |
| | | 9:03 | 21.0 | Increased bubbling on Lance 1A from 25.3 to 26.3 lpm, Lance 2A from 24.9 to 25.9 lpm, Lance 3A from 12.6 to 13.1 lpm, and Lance 4A from 12.6 to 13.1 lpm. Total bubbling is 78.0 lpm. |
| | | 9:04 | 21.1 | Average glass temperature is 1149°C. |
| | | 9:19 | 21.3 | Now at maximum bubbling rate of 78 lpm. Average glass temperature is 1144°C. Primary current is 494 Amps. |
| | | 9:25 | 21.4 | Transferred 887.5 kg of Test 3 residual feed. Transferred feed from mix tank to feed tank. Starting tank mass is 1510.0 kg, ending tank mass is 36.0 kg. Net mass transferred is 1474.0 kg. Plus 250 kg water in addition to 887.5 kg (from Test 3 residue) add up to total of 2611.5 kg net mass transfer. |
| | | 9:35 | 21.6 | Average glass temperature is 1143°C. |
| | | 9:48 | 21.8 | Decreased feed rate by changing T4 from 26 to 30 seconds. Feed rate increased due to feed transfer. |
| | | 9:50 | 21.8 | Increased power from 192 to 195 kW. Average glass temperature is 1141°C. Primary current is 496 Amps. |
| | | 9:52 | 21.9 | Average glass temperature is 1139°C. |
| | | 10:06 | 22.1 | Increased power from 195 to 199 kW. Average glass temperature is 1140°C. |
| | | 10:21 | 22.4 | Increased power from 199 to 201 kW. Average glass temperature is 1138°C. |
| | | 10:22 | 22.4 | Average glass temperature is 1138°C. |
| | | 10:35 | 22.6 | Increased power from 204 to 209 kW. Average glass temperature is 1139°C. |
| | | 10:36 | 22.6 | Average glass temperature is 1143°C. |
| | | 11:03 | 23.1 | Increased power from 209 to 215 kW. Average glass temperature is 1140°C. |
| | | 11:12 | 23.2 | Increased power from 215 to 220 kW. Average glass temperature is 1142°C. Primary current is 527 Amps. |
| | | 11:49 | 23.8 | Average glass temperature is 1145°C. Primary current is 534 Amps. |
| | | 12:12 | 24.2 | Average glass temperature is 1142°C. Plenum temperature is 432 – 456°C. Primary current is 530 Amps. |
| | | 12:32 | 24.5 | Average glass temperature is 1148°C. Plenum temperature is 444 – 472°C. |
| | | 13:14 | 25.1 | Increased power from 220 to 221 kW. Average glass temperature is 1149°C. |
| | | 13:34 | 25.6 | Average glass temperature is 1154°C. Plenum temperature is 444 – 461°C. Primary current is 540 Amps. |
| | | 13:49 | 25.8 | Average glass temperature is 1155°C. |
| | | 14:04 | 26.1 | Average glass temperature is 1155°C. Primary current is 541Amps. |
| | | 14:19 | 26.3 | Average glass temperature is 1156°C. |
| | | 14:40 | 26.7 | Average glass temperature is 1151°C |
| | | 14:47 | 26.8 | Performed WESP blow down, pre-deluge post deluge. |
| | | 15:00 | 27.0 | Starting off gas sampling, observed melter pressure spike. |
| | | 15:19 | 27.3 | Average glass temperature is 1157°C. Plenum temperature is 453 – 468°C. Primary current is 546 Amps. Glass resistance is 0.081 Ω. |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/7/13 | 15:33 | 27.6 | Average glass temperature is 1159°C. Plenum temperature is 403 – 473°C. Primary current is 548 Amps. Glass resistance is 0.080 Ω. |
| | | 15:49 | 27.8 | Average glass temperature is 1161°C. Plenum temperature is 452 – 472°C. Primary current is 545 Amps. Secondary current is 1660 Amps. Glass resistance is 0.081 Ω. |
| | | 16:01 | 28.0 | Melter pressure spike due to off gas sampling in transition line. |
| | | 16:04 | 28.1 | Average glass temperature is 1159°C. Plenum temperature is 457 – 473°C. Primary current is 548 Amps. |
| | | 16:19 | 28.3 | Average glass temperature is 1159°C. Plenum temperature is 459 – 477°C. Primary current is 548 Amps. Secondary current is 1667 Amps. Glass resistance is 0.080 Ω. |
| | | 16:45 | 28.7 | Average glass temperature is 1157°C. Plenum temperature is 409 – 473°C. Primary current is 543 Amps. Secondary current is 1634 Amps. Glass resistance is 0.082 Ω. |
| | | 16:46 | 28.8 | Melter pressure went positive due to CC collapsing. |
| | | 16:49 | 28.8 | Average glass temperature is 1156°C. Plenum temperature is 409 – 473°C. Primary current is 546 Amps. Secondary current is 1655 Amps. |
| | | 17:02 | 29.0 | Transferred feed to mix tank. Starting mass is 34.5 kg, ending mass is 2726.5 kg. Net transferred feed mass is 2692.0 kg. Net mass includes 10 kg water. |
| | | 17:04 | 29.1 | Average glass temperature is 1164°C. Plenum temperature is 464 – 477°C. Primary current is 549 Amps |
| | | 17:11 | 29.2 | Reduced power from 221 to 218 kW. Average glass temperature is 1163°C. Primary current is 545 Amps |
| | | 17:34 | 29.6 | Average glass temperature is 1161°C. Plenum temperature is 460 – 484°C. Primary current is 546 Amps. Secondary current is 1661 Amps. |
| | | 17:40 | 29.7 | Reduced power from 218 to 216 kW. Average glass temperature is 1161°C. Primary current is 544 Amps. Secondary current is 1667 Amps. |
| | | 18:19 | 30.3 | Average glass temperature is 1159°C. Plenum temperature is 461 – 486°C. Primary current is 539 Amps. |
| | | 18:34 | 30.6 | Average glass temperature is 1158°C. Plenum temperature is 464 – 495°C. Primary current is 535 Amps. |
| | | 18:41 | 30.7 | Plenum temperature is 464 – 476°C. Primary current is 533 Amps. |
| | | 18:49 | 30.8 | Average glass temperature is 1152°C. Plenum temperature is 466 – 476°C. Primary current is 535 Amps. |
| | | 19:04 | 31.1 | Average glass temperature is 1153°C. Plenum temperature is 468 – 475°C. Primary current is 534 Amps. |
| | | 19:19 | 31.3 | Changed T4 from 25.5 to 25 seconds. Average glass temperature is 1148°C. Plenum temperature is 469 – 489°C. Primary current is 530 Amps. |
| | | 19:34 | 31.6 | Average glass temperature is 1156°C. Plenum temperature is 463 – 488°C. Primary current is 531 Amps. Glass resistance is 0.082 Ω. |
| | | 19:49 | 31.8 | Average glass temperature is 1152°C. Primary current is 533 Amps. Secondary current is 1152 Amps. |
| | | 20:02 | 32.0 | Collected a feed sample. |
| | | 20:07 | 32.1 | Average glass temperature is 1153°C. Plenum temperature is 452 – 495°C. Primary current is 537 Amps. |
| | | 20:19 | 32.3 | Average glass temperature is 1157°C. Plenum temperature is 454 – 499°C. Primary current is 536 Amps. Glass resistance is 0.080 Ω. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/7/13 | 20:36 | 32.6 | Average glass temperature is 1154°C. Plenum temperature is 462 – 488°C. Secondary current is 1627 Amps. Glass level is 29. in. |
| | | 20:49 | 32.8 | Average glass temperature is 1157°C. Plenum temperature is 467 – 489°C. |
| | | 21:04 | 33.1 | Plenum temperature is 468 – 479°C. Primary current is 532 Amps. Secondary current is 1627 Amps. Glass resistance is 0.081 Ω |
| | | 21:20 | 33.3 | Average glass temperature is 1158°C. Primary current is 533 Amps. Secondary current is 1623 Amps. Glass resistance is 0.081 Ω |
| | | 21:28 | 33.5 | Change Lance bubbler 1A from 26.3 to 26.4 lpm to maintain flow. |
| | | 21:34 | 33.6 | Average glass temperature is 1153°C. Plenum temperature is 468 – 481°C Secondary current is 1620 Amps. |
| | | 21:49 | 33.8 | Average glass temperature is 1149°C. Plenum temperature is 467 – 469°C. Primary current is 531 Amps. Secondary current is 1618 Amps. Glass density is 2.27 g/cc. |
| | | 22:05 | 34.1 | Average glass temperature is 1153°C. Plenum temperature is 462 – 460°C. Primary current is 532 Amps. Secondary current is 1626 Amps. Glass density is 2.27 g/cc. |
| | | 22:19 | 34.3 | Average glass temperature is 1154°C. Plenum temperature is 452 – 472°C. |
| | | 22:25 | 34.4 | Changed T4 from 24 to 23.5 seconds. |
| | | 22:34 | 34.6 | Average glass temperature is 1153°C. Plenum temperature is 465 – 469°C. Primary current is 531 Amps. Glass density is 2.26 g/cc. |
| | | 22:49 | 34.8 | Average glass temperature is 1150°C. Plenum temperature is 460 – 466°C. |
| | | 23:04 | 35.1 | Average glass temperature is 1149°C. Plenum temperature is 457 – 473°C. Primary current is 527 Amps. Glass resistance is 0.084 Ω. |
| | | 23:05 | 35.1 | Performed a film cooler rinse. |
| | | 23:16 | 35.3 | Plenum temperature is 458 – 469°C |
| | | 23:34 | 35.6 | Average glass temperature is 1145°C. Plenum temperature is 445 – 456°C. Primary current is 530 Amps. Secondary current is 1613 Amps. Glass resistance is 0.082 Ω. |
| | | 23:49 | 35.8 | Plenum temperature is 437 – 441°C. Secondary current is 1601 Amps. |
| | 2/8/13 | 0:04 | 36.1 | Changed T4 from 23.5 to 23.0 seconds. |
| | | 0:05 | 36.1 | Average glass temperature is 1153°C. Plenum temperature is 438 – 440°C. Primary current is 534 Amps. Glass resistance is 0.081 Ω. |
| | | 0:11 | 36.2 | Reduced power from 213 to 211 kW. Average glass temperature is 1169°C. Primary current is 532 Amps. Secondary current is 1620 Amps. |
| | | 0:19 | 36.3 | Average glass temperature is 1154°C. Plenum temperature is 436 – 447°C. Secondary current is 1628 Amps. Glass resistance is 0.080 Ω. |
| | | 0:34 | 36.6 | Average glass temperature is 1156°C. Plenum temperature is 434 – 447°C. |
| | | 0:49 | 36.8 | Plenum temperature is 436 – 446°C. |
| | | 1:03 | 37.0 | Plenum temperature is 434 – 444°C. Investigating SBS overflow tank vent pressure. Discovered that rubber hose between the overflow tank and the gauge has water, cleared and reinstalled. All is satisfactory now. |
| | | 1:19 | 37.3 | Average glass temperature is 1151°C. Plenum temperature is 433 – 453°C. Primary current is 530 Amps. Glass resistance is 0.082 Ω. |
| | | 1:32 | 37.5 | Begin transfer of feed from mix tank to feed tank. |

## Table 3.2. Summary of Operational Events (continued).

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/8/13 | 1:30 | 37.5 | Transferred feed to feed tank. Starting tank mass is 2731.5 kg. Ending mass tank is 33.0 kg. Net feed mass transferred is 2698.5 kg. Plus 458.5 kg water is added. Total mass transferred is 3157.0 kg. |
| | | 1:36 | 37.6 | Plenum temperature is 439 – 457°C. Secondary current is 1620 Amps, and glass level is 30.0 in. |
| | | 1:41 | 37.7 | Changed T4 from 23.0 to 25.0 seconds. |
| | | 1:43 | 37.7 | Secured mix tank mixer blade. Feed transfer to feed tank is completed. |
| | | 1:49 | 37.8 | Average glass temperature is 1149°C. Plenum temperature is 450 – 464°C. Primary current is 531 Amps. |
| | | 2:04 | 38.1 | Average glass temperature is 1151°C. Plenum temperature is 449 – 476°C. Secondary current is 1616 Amps. |
| | | 2:19 | 38.3 | Average glass temperature is 1137°C. Plenum temperature is 443 – 478°C. Primary current is 526 Amps. Glass resistance is 0.083 Ω. Glass density is 2.27 g/cc. |
| | | 2:24 | 38.4 | Increased power from 211 to 214 kW. Average glass temperature is 1140°C. |
| | | 2:31 | 38.5 | Plenum temperature is 443 – 471°C. |
| | | 2:49 | 38.8 | Plenum temperature is 442 – 460°C. |
| | | 3:04 | 39.1 | Average glass temperature is 1144°C. Plenum temperature is 439 – 447°C. Primary current is 531 Amps. Glass resistance is 0.082 Ω. Glass density is 2.29 g/cc. |
| | | 3:16 | 39.3 | Increased power from 214 to 217 kW. Average glass temperature is 1145°C. Primary current is 536 Amps. |
| | | 3:19 | 39.3 | Average glass temperature is 1148°C. Plenum temperature is 441 – 450°C. Secondary current is 1629 Amps. Glass resistance is 0.082 Ω. |
| | | 3:34 | 39.6 | Average glass temperature is 1148°C. Plenum temperature is 448 – 449°C. Secondary current is 1619 Amps. Glass resistance is 0.082 Ω. |
| | | 3:48 | 39.8 | Secured all bottom effluent blow down tanks. Neutralization tank has 510 gallons, caustic tank has 525 gallons and acid tank has 525 gallons fluids. |
| | | 3:49 | 39.8 | Plenum temperature is 443 – 450°C. |
| | | 4:04 | 40.1 | Average glass temperature is 1151°C. Plenum temperature is 451 – 459°C. Secondary current is 1638 Amps, voltage is 133 volts. |
| | | 4:12 | 40.2 | During the last SBS blow down totalizer changed 29.19 gallons, actual liquid taken out was 40 gallons. |
| | | 4:34 | 40.6 | Average glass temperature is 1148°C. Plenum temperature is 449 – 469°C. |
| | | 4:38 | 40.6 | Changed T4 from 25.0 to 25.5 seconds. |
| | | 4:50 | 40.8 | 4 drums (~220 gallons) of liquid are removed from the neutralization tank. Current bottom tank status: Acid tank (secured) has 525 gallons, caustic tank (secured) has 525 gallons, and neutralization tank (in service) is 410 gallons. |
| | | 5:12 | 41.2 | Plenum temperature is 456 – 468°C. |
| | | 5:39 | 41.7 | Plenum temperature is 470 – 477°C. |
| | | 5:41 | 41.7 | LabVIEW is stopped. Restarted. |
| | | 5:54 | 41.9 | Reduced power from 217 to 214 kW. Average glass temperature is 1154°C. Primary current is 540 Amps. |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/8/13 | 6:08 | 42.1 | Reduced power from 214 to 211 kW. Average glass temperature is 1163°C. Primary current is 533 Amps. |
| | | 6:12 | 42.2 | Plenum temperature is 471 – 491°C. |
| | | 6:26 | 42.4 | Reduced power from 211 to 208 kW. Average glass temperature is 1162°C. Primary current is 528 Amps. |
| | | 6:49 | 42.8 | Feed rate is ~190 kg/hr. Power is 210 kW. Primary current is 521 Amps. Secondary current is 1593Amps. Voltage is 132 volts. Glass resistance is 0.082 Ω. |
| | | 7:04 | 43.1 | Feed rate is ~190 kg/hr. Power is 209 kW. Primary current is 524 Amps. Secondary current is 1602 Amps. Voltage is 131 volts. Glass resistance is 0.081 Ω. |
| | | 7:21 | 43.4 | Average glass temperature is 1162°C. Plenum temperature is 470 – 478°C. |
| | | 7:35 | 43.6 | Increased AOD pump pressure to 30 psi. |
| | | 7:40 | 43.7 | Average glass temperature is 1157°C. |
| | | 7:55 | 43.9 | Average glass temperature is 1161°C. Plenum temperature is 468 – 476°C. |
| | | 8:10 | 44.2 | Feed rate is ~200 kg/hr. Power is 209 kW. Primary current is 523 Amps. Secondary current is 1587 Amps. Voltage is 132 volts. Average glass temperature 1157°C. |
| | | 9:10 | 45.2 | Average glass temperature is 1163°C. |
| | | 9:35 | 45.6 | Average glass temperature is 1156°C. Plenum temperature is 464 – 476°C. Feed rate is 195 kg/hr. |
| | | 10:09 | 46.2 | Average glass temperature is 1161°C. Plenum temperature is 430 – 480°C. Feed rate is 194 kg/hr. |
| | | 10:33 | 46.5 | Paused feeding to collect feed sample. |
| | | 10:49 | 46.8 | Power is 210 kW. Primary current is 528 Amps. Secondary current is 1617 Amps. Voltage is 130 volts. Average glass temperature 1159°C. |
| | | 11:04 | 47.1 | Power is 210 kW. Primary current is 530 Amps. Secondary current is 1622 Amps. Voltage is 130 volts. Average glass temperature 1165°C. Glass resistance is 0.080 Ω. |
| | | 11:32 | 47.5 | LabVIEW rebooted. |
| | | 12:34 | 48.6 | Average glass temperature is 1162°C. |
| | | 12:49 | 48.8 | Average glass temperature is 1155°C. Plenum temperature is 470 – 500°C. |
| | | 13:04 | 49.1 | Average glass temperature is 1158°C. |
| | | 13:19 | 49.3 | Power is 209 kW. Primary current is 520 Amps. Secondary current is 1589 Amps. Voltage is 132 volts. Average glass temperature 1158°C. Glass resistance is 0.084 Ω. |
| | | 13:49 | 49.8 | Average glass temperature is 1156°C. |
| | | 14:04 | 50.1 | Average glass temperature is 1153°C. |
| | | 14:19 | 50.3 | Average glass temperature is 1159°C. |
| | | 14:38 | 50.6 | Average glass temperature is 1159°C. Primary current is 525 Amps. Secondary current is 1608 Amps. |
| | | 14:41 | 50.7 | All effluent tanks are emptied. |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/8/13 | 14:58 | 51.0 | Average glass temperature is 1142°C. Primary current is 519 Amps. Secondary current is 1598 Amps. |
| | | 15:00 | 51.0 | Increased power from 208 to 211 kW. Average glass temperature is 1142°C. Possible discharge caused temperatures to drop. Primary current is 513 Amps. |
| | | 15:04 | 51.1 | Average glass temperature is 1147°C. Primary current is 520 Amps. |
| | | 15:19 | 51.3 | Average glass temperature is 1155°C. Plenum temperature is 435 – 488°C Primary current is 520 Amps. Secondary current is 1582 Amps. |
| | | 15:30 | 51.5 | LabVIEW rebooted. |
| | | 15:34 | 51.6 | Average glass temperature is 1154°C. Primary current is 522 Amps. Secondary current is 1598 Amps. |
| | | 15:49 | 51.8 | Average glass temperature is 1152°C. Primary current is 524 Amps. Secondary current is 1598 Amps. |
| | | 16:03 | 52.0 | Average glass temperature is 1151°C. Primary current is 520 Amps. Secondary current is 1569 Amps. |
| | | 16:20 | 52.3 | Average glass temperature is 1152°C. Primary current is 521 Amps. Secondary current is 1582 Amps. Changed T4 from 25 to 25.3 seconds. |
| | | 16:34 | 52.6 | Average glass temperature is 1147°C. Primary current is 516 Amps. Secondary current is 1562 Amps. |
| | | 16:46 | 52.8 | Increased power from 211 to 214 kW. Primary current is 521 Amps. Secondary current is 1579 Amps. Average glass temperature is 1147°C. Glass resistance is 0.086 Ω. |
| | | 16:49 | 52.8 | Primary current is 522 Amps. Secondary current is 1579 Amps. Average glass temperature is 1150°C. Glass resistance is 0.085 Ω. Plenum temperature is 394 – 473°C |
| | | 17:02 | 53.0 | Stopped feeding slurry. End of Test 4. |
| | | 17:12 | 53.2 | Reduced power from 214 kW to 200 kW. Average glass temperature is 1163°C. Primary current is 518 Amps. Secondary current is 1590 Amps. |
| | | 17:15 | 53.3 | Reduced power from 200 to 190 kW. Average glass temperature is 1167°C. Primary current is 506 Amps. Secondary current is 1557 Amps. |
| | | 17:20 | 53.3 | Reduced power from 190 to 180 kW. Average glass temperature is 1170°C. Primary current is 494 Amps. Secondary current is 1531 Amps. |
| | | 17:26 | 53.4 | Average glass temperature is 1171°C. Reduced power from 180 to 150 kW. |
| | | 17:34 | 53.6 | Removed feed from the feed tank. Starting tank mass is 784.0 kg. Ending tank mass is 16.0 kg. Net mass of feed removed is 768.0 kg. |
| | | 18:26 | 54.4 | Reduced bubbling as follows: Lance 1A from 26.4 to 15.4 lpm, Lance 2A from 24.9 to 14.9 lpm, Lance L3A from 13.1 to 8.1 lpm, Lance 4A from 13.1 to 8.1 lpm. |
| | | 18:29 | 54.5 | Reduced power from 150 to 120 kW. Average glass temperature is 1160°C. |
| | | 18:39 | 54.7 | Reduced bubbling as follows: Lance 1A from 15.4 to 8.4 lpm, Lance 2A from 14.9 to 8.9 lpm, Lance L3A from 8.1 to 5.1 lpm, Lance 4A from 8.1 to 5.1 lpm. |
| | | 18:47 | 54.8 | Reduced power from 120 to 100 kW. Average glass temperature is 1162°C. |
| | | 19:02 | 55.0 | Reduced power from 100 to 90 kW. Average glass temperature is 1162°C. |
| | | 19:27 | 55.5 | Cold cap is gone. |

**Table 3.2. Summary of Operational Events (continued).**

| Test | Date | Time | Run Time (hours) | **Run time note** |
|---|---|---|---|---|
| 4 | 2/8/13 | 19:33 | 55.5 | Reduced bubbling in all Lances to 1.5 lpm and turned on the bypass rotameters. All 4 set to 0.5 scfh. |
| | | 20:30 | 56.5 | Will start off gas and melter shut down. |
| | | 20:58 | 57.0 | Reduced power from 90 to 80 kW. Average glass temperature is 1149°C. |
| | | 21:05 | 57.1 | Performed WESP blow down. Performed deluge and post-deluge blow down. |
| | | 21:45 | 57.8 | Melter and off gas shutdown are completed. |

## Table 3.3. Cold Cap Observations.

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 1 | 1/15/13 | 10:05 | 0.0 | Start water feeding at 0.5 liter/min. |
| | | 10:25 | 0.3 | Water flow rate was raised to 1.0 liter/min. |
| | | 10:45 | 0.7 | Water flow rate was raised to 2.0 liter/min. |
| | | 11:25 | 1.3 | Cold cap is slightly foamy. Water flow rate was raised to 2.5 liter/min |
| | | 11:43 | 1.6 | Water flow rate was raised to 3.0 liter/min. |
| | | 11:50 | 1.7 | Secured feeding water. Started feeding HWI-Al-19 feed. |
| | | 12:20 | 2.2 | ~50%, large openings on east and west sides. |
| | | 12:35 | 2.5 | ~60%, openings on north east and south west corners. |
| | | 12:55 | 2.8 | ~70%, openings on north east and south west corners. |
| | | 13:20 | 3.2 | ~80%, openings on north east and south west corners. CC is ~3” thick at openings. Feed is boiling on surface. |
| | | 13:35 | 3.5 | ~80-85%, openings on east and west sides with boiling feed on top of CC. |
| | | 13:50 | 3.7 | ~85%, openings are still visible on east and west sides. Feed is flowing into melt pool. |
| | | 14:05 | 4.0 | ~85%, same as last reading. |
| | | 14:20 | 4.2 | ~85%, flat, openings on east and west sides. |
| | | 14:35 | 4.5 | ~85%, flat and soft, visible openings and east and west sides. |
| | | 14:52 | 4.8 | ~90%, east side opening is larger than the west side. CC is floating. |
| | | 15:15 | 5.2 | ~90%, openings on north west and south east corners. South east opening is larger. Feed is boiling on surface between openings. |
| | | 15:32 | 5.4 | ~ 95%, both openings are closing up with ridges. |
| | | 15:52 | 5.8 | ~95%, cone shaped openings with thick CC is visible. |
| | | 16:04 | 6.0 | ~95%, is about 4” thick and flat. |
| | | 16:20 | 6.2 | ~90%, the ridges are slightly lower than last observation. |
| | | 16:42 | 6.6 | ~90%, very little to no change in CC conditions. |
| | | 17:18 | 7.2 | ~95%, mounding around bubblers, pooling feed in the center. |
| | | 17:41 | 7.6 | ~98%. |
| | | 18:03 | 8.0 | ~95%. |
| | | 18:21 | 8.3 | ~95%. |
| | | 18:40 | 8.6 | ~95%, lots of glass wool hanging near the north view port. Appears as two volcanoes with lots of molten glass splashing over the entire plenum area. |
| | | 19:02 | 9.0 | ~95%. CC is closing up but held open by bubblers. Still lots of splattered glass. |
| | | 19:18 | 9.2 | ~95%, large pool of feed liquid is visible in center. CC has shifted and middle has started to reopen. |
| | | 19:47 | 9.7 | ~95%, very foggy in plenum, large pooling and less spitting of molten glass. |
| | | 20:23 | 10.3 | ~95%, not be able to see east side due to large ridge blocking. |
| | | 20:40 | 10.6 | ~95%, starting to see east side since glass discharge. Both openings still have large ridges. |
| | | 21:05 | 11.0 | ~98%, dark inside, spitting glass out like spider webs. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 1 | 1/15/13 | 21:27 | 11.4 | ~90%, flat, spider web look. |
| | | 21:37 | 11.5 | ~90%, flat, two openings, spider web look is gone. |
| | | 21:52 | 11.8 | ~95%, flat, 5" thick one opening. |
| | | 22:02 | 11.9 | ~90%. |
| | | 22:22 | 12.3 | ~90%, flat. |
| | | 22:34 | 12.5 | ~90%, two openings. |
| | | 22:48 | 12.7 | ~90%, openings on east and west sides. Feed is boiling on surface. |
| | | 23:00 | 12.9 | ~90% with two openings visible from north view port. Slight ridges around each opening. Bubbling on the surface exists. |
| | | 23:16 | 13.2 | ~90%, ridges around openings are starting to become more pronounced. Liquid on the flat surface is boiling. |
| | | 23:38 | 13.5 | ~90, two openings, east side more open than west side. |
| | | 23:53 | 13.8 | CC collapses. Low pressure alarm. |
| | | 23:55 | 13.8 | Reduced bubbling from 17.1 lpm to 15.0 lpm on each bubbler attempting to reduce ridges along CC and to increase openings. |
| | 1/16/13 | 0:05 | 14.0 | ~95%, two openings on east and west, boiling liquid on surface. |
| | | 0:13 | 14.1 | ~95%, east opening is not visible. |
| | | 0:31 | 14.4 | ~95%, west side is slightly open, east side is open liquid on top of CC. |
| | | 0:40 | 14.6 | East side opening is not visible and west side opening is increasing. |
| | | 1:02 | 14.9 | ~90%, east opening is visible and west side opening expanding. |
| | | 1:28 | 15.4 | ~95%, covered some liquid on top of CC. |
| | | 1:41 | 15.6 | ~85-90%, both openings are surrounded by ridges. Liquid boiling vigorously on the surface. |
| | | 1:55 | 15.8 | ~95%, covered with thick wet surface, slight splashing. Opening on north west side. |
| | | 2:15 | 16.2 | ~90%, ridge at the opening persists. Vigorous liquid boiling on the surface. |
| | | 2:43 | 16.6 | East and west sides are open, boiling liquid on top of CC. |
| | | 3:01 | 16.9 | Both east and west sides are open, ridge is visible after glass discharge. Boiling liquid on top of CC. |
| | | 3:19 | 17.2 | ~85%, opening on east and west sides, ridge exists behind east side. |
| | | 3:32 | 17.4 | ~80-85%, ridges at the opening starting to dissolve. Observed liquid rushing to the opening. Similarly the east opening is visibly available. |
| | | 3:50 | 17.7 | ~80-85%. |
| | | 4:11 | 18.1 | ~85, openings of east and west sides and a small ridge around opening. Lots of feed boiling on surface. |
| | | 4:24 | 18.3 | ~85%, evenly flat, ridges almost non-existent. Boiling on the surface, both openings are visible. |
| | | 5:08 | 19.0 | ~85%, openings on east and west sides. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 1 | 1/16/13 | 5:19 | 19.2 | ~85%, similar to last observation. |
| | | 5:34 | 19.5 | !85%, heavily boiling on flat surface. |
| | | 5:35 | 19.5 | Build up from feed spray on the instrument port observed, will continue to monitor. No impact on data and feed shots. |
| | | 5:48 | 19.7 | ~85%, ridge building up on west side opening. Feed on surface is pooling and boiling. |
| | | 6:04 | 20.0 | ~85%, ridge on west side opening. Feed is flowing into east opening. |
| | | 6:19 | 20.2 | ~80-85%, still ridge on west side opening. East side opening has feed flowing into it. |
| | | 8:20 | 22.2 | ~85-90%, openings are on east and west sides with slight mounds around each. Boiling feed on surface. CC is moving. |
| | | 8:40 | 22.6 | ~85-90%, conditions are the same as before. |
| | | 9:00 | 22.9 | ~85-90%, conditions are unchanged from last observation. |
| | | 9:51 | 23.8 | ~75-80%, conditions unchanged from last observation. Openings are increased due to drop of feed rate. |
| | | 10:05 | 24.0 | ~85%, looks flat with boiling feed on top. Openings on east and west sides are visible. |
| | | 10:20 | 24.2 | ~85%, openings on east and west sides are visible with feed boiling on top of CC. |
| | | 10:35 | 24.5 | ~85%, unchanged since last reading. |
| | | 10:50 | 24.7 | ~85%, unchanged since last reading. |
| | | 11:05 | 25.0 | ~85%, openings on east and west sides are visible with feed flowing into opening. |
| | | 11:49 | 25.7 | ~85%, openings on east and west sides are still visible. |
| | | 12:25 | 26.3 | ~85-90%, openings in north east and south west corners. CC is fairly flat with feed boiling on surface. |
| | | 12:40 | 26.6 | ~85-90%, conditions are unchanged from previous observation. |
| | | 13:00 | 26.9 | ~85-90%, openings in north east and south west corners. Slight ridge around both openings. Feed is boiling on surface. |
| | | 13:20 | 27.2 | ~85-90%, conditions are unchanged from previous observation. |
| | | 13:40 | 27.6 | ~85-90%, conditions are unchanged from previous observation. |
| | | 14:23 | 28.3 | ~85-90%, conditions are unchanged from previous observation. |
| | | 14:41 | 28.6 | ~90%, two openings are flat on top. |
| | | 15:05 | 29.0 | ~85%, CC opened up some; liquid feed is boiling. |
| | | 15:26 | 29.3 | ~85%, conditions are unchanged from previous observation. |
| | | 15:49 | 29.7 | ~80%, two large openings. |
| | | 15:58 | 29.9 | ~80%, CC has been slowly opening up. |
| | | 16:09 | 30.1 | ~80%, CC has thinned out some and ridges are smaller around openings. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 1 | 1/16/13 | 16:19 | 30.2 | ~80% and 5” thick and flat. |
| | | 16:34 | 30.5 | ~80%, starting to close up somewhat. More feed is flowing into openings. |
| | | 16:49 | 30.7 | ~80%, very little to no change for this observation. |
| | | 17:04 | 31.0 | ~80%, 5” thick and flat. |
| | | 17:22 | 31.3 | ~80%, still the same. |
| | | 17:35 | 31.5 | ~80%, still the same. |
| | | 17:49 | 31.7 | 80%, two openings with a flat surface. |
| | | 18:11 | 32.1 | ~80%, flat, openings are in north west and south east corners. |
| | | 18:28 | 32.4 | ~85%, flat two openings. Feed pooling on top. |
| | | 18:37 | 32.5 | ~80%, same as above. |
| | | 18:52 | 32.8 | ~80%, flat, two openings, feed is pooling on top of CC and boiling. |
| | | 19:09 | 33.1 | ~85%, CC has closed up slightly, CC is mostly level. The openings have feed flowing in. |
| | | 19:45 | 33.7 | ~80%, same as above. |
| | | 20:12 | 34.1 | ~80%, ridges have grown somewhat. |
| | | 20:27 | 34.4 | ~80%, west side opening has shifted slightly to the north, closer to thermo well #2. |
| | | 20:53 | 34.8 | ~80%, CC is thinner than last observation. |
| | | 21:09 | 35.1 | ~80%, east side has thinned out. Most of the liquid feed is flowing into the west side opening. |
| | | 21:38 | 35.5 | ~60-65%, east and west sides are wide open. |
| | | 21:54 | 35.8 | ~70%, east side is closing faster than the west side. Boiling liquid seen on top of CC. |
| | | 22:26 | 36.3 | ~75%, east side opening migrates south and west side opening is receiving boiling liquid. |
| | | 22:43 | 36.6 | ~80%, east side closing up and west side still open. |
| | | 23:03 | 37.0 | ~80%, east side opening migrates south, west side receives boiling liquid. |
| | | 23:18 | 37.2 | 80%, east side is open, west side is open. |
| | | 23:41 | 37.6 | ~80%, east side opening is larger than west side opening. Feed is flowing into both openings. |
| | 1/17/13 | 0:05 | 38.0 | ~80%, east side has soft cap, west side open and has feed flowing into it. |
| | | 0:19 | 38.2 | ~80%, east side opening has hardened up, west side open with feed flowing in it. |
| | | 0:44 | 38.6 | ~85%, east side is closing up and west side opening receiving liquid flow. |
| | | 1:02 | 38.9 | ~70%. |
| | | 1:04 | 39.0 | ~70%. |
| | | 1:19 | 39.2 | 80%, East portion of CC is floating, liquid flows to all openings. |
| | | 1:31 | 39.4 | 80%, less flexing in CC. |
| | | 1:42 | 39.6 | ~80%, no changes from the previous observation. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 1 | 1/17/13 | 1:52 | 39.8 | ~80%, maintaining similar conditions. |
| | | 2:10 | 40.1 | 85%, east side opening is showing a ridge build up. |
| | | 2:37 | 40.5 | ~85%, east side is steady, west side migrates south. |
| | | 2:51 | 40.8 | ~80-85%, west side opening much is greater than east opening, ridges are present around the openings. |
| | | 3:09 | 41.1 | ~90%, ridge on the east opening. |
| | | 3:25 | 41.3 | ~90%, similar to last observation. North east north west openings and ridge appear the same with some boiling feed. |
| | | 3:41 | 41.6 | ~85%, reduced bubbling on Lances 1A, 2A, 1B and 2B from 12 lpm to 11 lpm. |
| | | 3:42 | 41.6 | ~85%, remains similar to previous observation, ridge reduced slightly and surface appears wetter. |
| | | 4:05 | 42.0 | ~85%, remains open on north east and north west and CC level is rising. |
| | | 4:22 | 42.3 | ~85%, east side of CC holds boiling liquid, west side open. |
| | | 4:32 | 42.4 | ~90%, east side appears to have closed. |
| | | 4:47 | 42.7 | ~85%, east side still seems closed west side still open. West center viewport nearly shut and little build up upon exposed plenum. |
| | | 5:10 | 43.1 | ~85-90%, no major change except CC level is rising and appears wetter with boiling feed. |
| | | 5:44 | 43.6 | ~90%, one opening on west side, wet feed on surface. |
| | | 5:44 | 43.6 | ~90%, one opening on west side, wet feed on the surface. |
| | | 7:06 | 45.0 | ~90%, opening on northwest side, light is visible on south east side. |
| | | 7:21 | 45.3 | ~90-95%, opening on west side, light is visible on east side. CC is thick with feed boiling on surface. |
| | | 7:36 | 45.5 | ~90-95%, conditions unchanged from previous observation. |
| | | 7:51 | 45.8 | ~95%, conditions unchanged from previous observation. |
| | | 8:07 | 46.0 | ~95%, conditions are unchanged from the previous observation. |
| | | 8:21 | 46.3 | ~95%, opening on west side, light is visible on east side, ridge exists around opening on west side. Feed is boiling on the surface. |
| | | 8:36 | 46.5 | ~95%, opening on west side, light is visible on east side, feed is boiling on surface. |
| | | 8:51 | 46.8 | ~95%, unchanged from previous observation, some light is visible on east. |
| | | 9:08 | 47.0 | ~95% with opening on west side, feed is boiling on surface with ridge at opening. |
| | | 9:31 | 47.4 | ~95%, no change from previous observation. |
| | | 9:46 | 47.7 | ~95%, opening on west mid side, light is visible on south east corner. |
| | | 10:07 | 48.0 | ~95%, conditions are unchanged from previous condition. |
| | | 10:26 | 48.3 | ~95%, conditions are unchanged from previous condition. |
| | | 10:53 | 48.8 | ~95%, conditions are unchanged from previous condition. |
| | | 11:04 | 49.0 | ~95%, conditions are unchanged from previous condition. |
| | | 11:19 | 49.2 | ~95% with feed pooled on top, light is visible in east view port. |
| | | 11:34 | 49.5 | ~95% with no change from previous conditions. |

## Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 1 | 1/17/13 | 11:46 | 49.7 | ~95%, flat, east side is closed west side is open. |
| | | 12:04 | 50.0 | ~95%, is no change from last observation, very faint light is visible in east view port, |
| | | 12:19 | 50.2 | ~94%, no change in east view port. |
| | | 12:30 | 50.4 | Secured feeding, End of the test. No longer able to maintain feeding. |
| | | 15:30 | 53.4 | CC is gone. |
| 2 | 1/22/13 | 14:00 | 0.0 | Started feeding water at 0.7 l/min. |
| | | 14:15 | 0.3 | Increased water flow rate to1.4 l/min. |
| | | 14:42 | 0.7 | Increased water flow rate to 2.8 l/min. |
| | | 15:00 | 1.0 | Secured water flow and starting feeding slurry. |
| | | 15:27 | 1.5 | ~60%, mostly a hot cap. |
| | | 15:44 | 1.7 | ~75%, thin and mostly liquid boiling on surface. |
| | | 16:03 | 2.1 | ~85%, with openings and feed boiling on flat surface. |
| | | 16:23 | 2.4 | ~90%, 2 openings, feed is boiling on surface. |
| | | 16:49 | 2.8 | ~80%, flat two openings exist. |
| | | 17:12 | 3.2 | ~75%, flat three openings exist. |
| | | 17:24 | 3.4 | ~80%, very thick shelf. |
| | | 17:38 | 3.6 | ~80%, 4” thick shelf and flat. |
| | | 17:58 | 4.0 | ~80%, same as above. |
| | | 18:05 | 4.1 | ~85%, very strong boiling below feed tube, bubbler ports open and reveal a thick cap. |
| | | 18:19 | 4.3 | ~85%, bubbler below feed tube is starting to open. Vigorous bubbling and very wet cap in places. |
| | | 18:33 | 4.6 | ~85%, glass is splashing over edge of bubbler holes, very vigorous splashing. |
| | | 18:50 | 4.8 | ~80%, opening closest to west wall has reopened. |
| | | 19:04 | 5.1 | ~80%, same as above. |
| | | 19:26 | 5.4 | ~80%, CC is thin but has ridges around the openings |
| | | 19:34 | 5.6 | ~75%, CC has opened up due to taking feed sample. The ridges are gone and feed is flowing into the opening. |
| | | 19:48 | 5.8 | ~75%, openings at north east and southwest corners, feed is boiling on the surface between the openings, feed is flowing into the openings. |
| | | 20:20 | 6.3 | ~80%, feed is boiling on surface, flowing into north east and southwest corner openings. |
| | | 20:35 | 6.6 | ~80%, there is more liquid feed on CC. |
| | | 20:55 | 6.9 | ~80%, one small and one large opening exist, feed is boiling on surface. |
| | | 21:09 | 7.2 | ~80%, same as above. |
| | | 21:24 | 7.4 | ~80%, feed is boiling on top of surface. |
| | | 21:49 | 7.8 | ~80%, east and west sides are open, migrating north. |
| | | 21:54 | 7.9 | Emergency off gas alarm is tripped, possibly due to CC circumstance. |
| | | 22:04 | 8.1 | ~85%, east side opening closing, west side maintains boiling and flowing liquid. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| | 1/22/13 | 22:36 | 8.6 | ~80%, same as above. |
| | | 22:58 | 9.0 | ~75-80%, north east and north west corners both have lots of boiling feed on surface with openings. |
| | | 23:11 | 9.2 | ~85%, openings are on east and west sides, both openings have small ridges built around them. Wet feed is boiling on surface. |
| | | 23:26 | 9.4 | ~85%, heavy boiling is observed, CC is evenly flat, east and west openings are visible. |
| | | 23:41 | 9.7 | ~85%, openings on west and east sides. |
| | 1/23/13 | 0:05 | 10.1 | ~80%, ridges on east and west sides. Boiling liquid is flowing north. |
| | | 0:21 | 10.4 | ~80%, ridge on west side dissipates. Liquid flows to the west side opening. |
| | | 0:39 | 10.7 | ~80%, ridge reforms on east edge of the CC, boiling liquid flows west. West side opens towards north side. |
| | | 0:52 | 10.9 | ~80%, ridge on east side remains with wet boiling feed flowing toward north east corner. |
| | | 1:06 | 11.1 | ~80%, east side opening is larger than the west side opening. Feed is boiling on surface. |
| | | 1:21 | 11.4 | ~80-85%, evenly flat with heavy boiling, slight ridge at the opening. |
| | | 1:43 | 11.7 | ~80-85%, east side opening is smaller than the west side. |
| | | 2:04 | 12.1 | ~90%, east side opening slightly larger than west side. |
| | | 2:20 | 12.3 | ~85-90%, east side opening migrates north, narrows. West side is open receiving liquid flow. |
| | | 2:37 | 12.6 | East side opening dwindles, west side is open, boiling liquid sits on top of CC. |
| | | 2:52 | 12.9 | ~85-90%, openings on east and west sides. Deep pool of liquid feed is visible between openings. |
| | | 3:17 | 13.3 | ~85%, openings on east and west sides, both openings have a small ridge around them. Large pool of liquid feed is boiling between openings. |
| | | 3:25 | 13.4 | ~85%, similar to previous observation, large boiling feed remains as well. West side opening appears slightly more open. |
| | | 3:41 | 13.7 | ~85%, ridge building up on east side opening, west side opening is the same. |
| | | 4:03 | 14.1 | ~85%, ridge has developed on east side, west side opening is larger. Boiling liquid sits on top of CC which is moving to the north west corner. |
| | | 4:19 | 14.3 | ~85%, east side migrates south, ridge is gone, and west side is open receiving flow. |
| | | 4:36 | 14.6 | Flow of boiling liquid exist to east side, ridge is formed on the west side, opens north. |
| | | 4:51 | 14.9 | ~80%, east side is closing, west side is open. |
| | | 5:15 | 15.3 | ~80%, east side remains slightly closed with heavy boiling, feed is rushing into west side which remains roughly the same with lots of wet boiling feed on CC surface with slight ridge between east and west sides. |
| | | 5:32 | 15.5 | ~80%, same conditions as before. |
| | | 5:54 | 15.9 | ~80%, lots of wet boiling feed splashing and rushing in openings on east and west sides. West opening appears slightly smaller and east appears the same. |
| | | 7:02 | 17.0 | ~90% with opening in north west and north east corners. Feed is boiling on surface. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 2 | 1/23/13 | 7:16 | 17.3 | ~90%, opening in north east and north west corners. Light is visible from south east corner. Feed is boiling on surface and flowing into openings. |
| | | 7:33 | 17.6 | ~85%, opening in north east and north west corners. Light is visible in south east corner. CC is thinner with feed boiling on surface and flowing into openings. |
| | | 8:06 | 18.1 | ~85-90%, feed is boiling on surface, vigorous bubbling is present with a thick CC. |
| | | 8:54 | 18.9 | ~95%, lots of boiling feed on top, very vigorous bubbling, splashing up through a thick CC. |
| | | 9:30 | 19.5 | ~90%, openings exist in north east and north west corners, light is visible in south east corner, large ridges exist around each opening. |
| | | 9:41 | 19.7 | ~90-95%, Opening in north east and north west corners with 4 inch ridges around the openings. Feed is boiling in center on surface. |
| | | 9:55 | 19.9 | ~90-95%, visual observations are unchanged from previous observation. |
| | | 10:05 | 20.1 | ~95%, openings on north east and northwest corners, light is visible in south east corner, feed is boiling in center on top of CC. |
| | | 10:20 | 20.3 | ~90-95%, conditions are unchanged from previous observation. |
| | | 10:35 | 20.6 | ~95%, feed is boiling on the surface, hole is visible on west side of view port. |
| | | 11:20 | 21.3 | ~90-95%, looks about 6 in thick with boiling feed on top, opening on east and west sides are still visible. |
| | | 11:35 | 21.6 | ~95%, west side is visible with boiling feed on CC. |
| | | 11:50 | 21.8 | ~95%, same as the last observation. |
| | | 12:04 | 22.1 | ~95% with feed boiling on top, openings in north east and north west corners with ridges. |
| | | 12:25 | 22.4 | ~90-95%, openings are visible in north west and south east corners. |
| | | 12:40 | 22.7 | ~90-95%, conditions are unchanged from previous observation. |
| | | 12:55 | 22.9 | ~90-95%, conditions are unchanged. |
| | | 13:15 | 23.3 | ~90-95%, opening is visible in northwest corner with light visible from north east and south east corners. Feed is boiling on surface. |
| | | 13:39 | 23.7 | ~90-95%, ~6” thick, single opening in north west corner, feed is boiling on surface and flowing into opening. |
| | | 13:54 | 23.9 | ~90-95%, opening in north west corner, light is visible on surface. |
| | | 14:15 | 24.3 | ~90-95%, conditions are unchanged from previous observation |
| | | 14:35 | 24.6 | ~95%, opening on west side still visible with ridge, visible light on east side. |
| | | 15:04 | 25.1 | ~85%, not able to see east side opening. There is large ridge on the west side. |
| | | 15:19 | 25.3 | ~85%, no visible changes for this observation. |
| | | 15:39 | 25.7 | ~85%, west side ridge has melted down and closed the CC somewhat. |
| | | 15:53 | 25.9 | ~90%, ~ 8” thick, not able to see feed flowing into single opening on west side. |
| | | 16:09 | 26.2 | Unchanged from previous observation. |
| | | 16:49 | 26.8 | ~90%, feed is flowing into the west opening. |

# Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 2 | 1/23/13 | 17:21 | 27.4 | ~85%, east side ridge has broken down some, now able to see the opening on that side. Feed is flowing into both openings that can be seen. |
| | | 17:39 | 27.7 | ~90%, ~6" thick, feed is flowing into single west side opening through ridge breakdown. |
| | | 17:50 | 27.8 | ~85%, two openings. |
| | | 18:04 | 28.1 | ~85%, large amount of feed is flowing into the openings. |
| | | 18:20 | 28.3 | ~90%, same as above. |
| | | 18:27 | 28.5 | Emergency off gas is tripped, CC is shifted. |
| | | 18:39 | 28.7 | ~85%, has dropped down. Able to see east side through north view port. Feed is flowing heavily into the openings. |
| | | 18:49 | 28.8 | ~85%, conditions unchanged. |
| | | 19:04 | 29.1 | ~85%, no visible changes for this observation. |
| | | 19:20 | 29.3 | ~85%, two openings, feed is boiling on top. |
| | | 19:39 | 29.7 | ~80%, it has opened up due to feed sample being collected. |
| | | 19:54 | 29.9 | ~85%, there are small ridges around east and west openings. |
| | | 20:12 | 30.2 | ~85%, openings on west side and north east corner, feed boiling on surface between the openings. |
| | | 20:26 | 30.4 | Off gas sampling has started. |
| | | 20:49 | 30.8 | ~85%, small ridges around both openings with feed flowing into each opening. |
| | | 21:00 | 31.0 | End of off gas testing, melter pressure spiked. |
| | | 21:04 | 31.1 | ~85%, no visible changes for this observation. |
| | | 21:25 | 31.4 | ~85%, two openings exist. |
| | | 21:39 | 31.7 | ~85%, two openings, flat about 5" thick CC. |
| | | 21:54 | 31.9 | ~85%, same as before. |
| | | 22:08 | 32.1 | ~85%, flat, feed is boiling on top. |
| | | 22:24 | 32.4 | ~85%, same as above. |
| | | 22:48 | 32.8 | ~80-85%, heavy boiling on the surface, observed liquid freely flowing from the surface to both east and west openings. |
| | | 23:08 | 33.1 | ~80-85%, ridge on west side near opening and feed is easily rushing in on east side, heavy boiling on surface. |
| | | 23:38 | 33.6 | ~80%, ridge along west edge of CC. Liquid flow in east side, east opening expands. |
| | | 23:50 | 33.8 | ~85%, lots of boiling feed, ridge remains on west side with boiling feed between east and west openings. Thick CC with some splashing. |
| | 1/24/13 | 0:08 | 34.1 | ~80%, east opening grows, west is steady, liquid flow on east side. |
| | | 0:20 | 34.3 | ~80%, same as prior observation. |
| | | 0:37 | 34.6 | ~80%. |
| | | 0:43 | 34.7 | ~85%, opening on east side shrunk slightly, heavy boiling of feed on surface with splashing. |
| | | 0:54 | 34.9 | ~85%, similar to prior conditions. |

## Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 2 | 1/24/13 | 1:04 | 35.1 | ~80-85%, consistently the same from the last observation. |
| | | 1:19 | 35.3 | ~80%, ridge along west side of CC forces boiling liquid to east side, opening which has been reduced, west side is open and enlarging. |
| | | 1:45 | 35.8 | East side opening diminishes, west side closing also. CC appears thick on the east side, softer on west side. |
| | | 2:06 | 36.1 | ~80%, east side opening holding steady, west side opening migrates south. |
| | | 2:34 | 36.6 | ~85%, ridge on east side, west side of CC grows and is fixed, not moving, boiling liquid on surface. |
| | | 2:52 | 36.9 | ~80%, ridges on east and west edges of CC, boiling liquid pools on top of CC. West side is more open. |
| | | 3:09 | 37.2 | ~75-80%, ridges still exist on east and west edge. Losing north edge of CC as east side migrates south. Boiling liquid on top of CC. |
| | | 3:25 | 37.4 | ~80%, east side opening dwindles, west side has ridge, still receives boiling flow. CC is thick not spreading southward. |
| | | 3:52 | 37.9 | ~85%, west side closes, east side narrows. Ridge on west side causes boiling liquid to flow north west corner. |
| | | 4:10 | 38.2 | ~85%, no major change in CC, west side edge still has ridge between west and east openings. Lots of boiling feed. Feed flows towards north west. |
| | | 4:46 | 38.8 | ~90%, east side opening is barely seen, west side cap grows, west side liquid boils on top of cap. Fibers are seen dangling from interior roof. |
| | | 5:07 | 39.1 | ~90%, east and west opening have small ridges around them. Feed is boiling on surface. |
| | | 5:33 | 39.6 | ~90%, east side closed up west side is open, lots of feed on the surface. |
| | | 5:49 | 39.8 | ~90%, east side is closed, west side is open with a small ridge around it. Lots of feed boiling on surface. |
| | | 6:06 | 40.1 | ~90%, one opening on the west side, feed is boiling on surface. |
| | | 6:35 | 40.6 | ~90%, same, one opening on west side, feed is boiling on surface. CC is thick. |
| | | 7:02 | 41.0 | ~95% with opening at north west corner, feed is boiling on surface with ridge opening. |
| | | 7:18 | 41.3 | ~95%, conditions are same as the previous observation. |
| | | 7:38 | 41.6 | ~95%, feed is boiling on surface, opening in north west corner with a ridge. |
| | | 7:52 | 41.9 | ~95% with small openings in northwest and north west corners. Feed is boiling on surface, ridges exist at openings. |
| | | 8:06 | 42.1 | ~95%, with openings on north east and north west corners with ridges around openings. Feed is boiling on surface. |
| | | 8:20 | 42.3 | ~95% with a small opening on north east corner, Two small openings on north west side. Light is visible from south east corner. Feed is boiling on surface. |
| | | 8:40 | 42.7 | ~95%, conditions are unchanged from previous observation. |
| | | 8:55 | 42.9 | ~95%, openings on east and west sides visible via north view port. Light is visible on south east corner via south port. |
| | | 9:14 | 43.2 | ~95%, openings in north east and north west corners with ridges. Feed is boiling on surface. |
| | | 9:35 | 43.6 | ~95% with openings in north east and north west corners. Feed is boiling on surface. |

## Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 2 | 1/24/13 | 9:52 | 43.9 | ~95%, feed is boiling on surface, openings in north east and north west corners. |
| | | 10:10 | 44.2 | ~95%, feed is boiling on surface opening at north east and north west corners. Feed is flowing into melt pool through the hole in ridge. |
| | | 10:39 | 44.7 | ~95%, east side and west side openings are still visible, west side has small ridge with boiling feed on top. |
| | | 10:56 | 44.9 | ~95%, two openings in north east and north west corners with no ridges. Feed is flowing into openings. |
| | | 11:11 | 45.2 | ~95% with openings in north east and north west corners. Feed is boiling on surface. |
| | | 11:32 | 45.5 | ~95%, no changes from the previous reading. |
| | | 11:49 | 45.8 | ~95% with openings in north east and north west corners. Feed is boiling on surface. Ridges exist at openings. |
| | | 12:05 | 46.1 | ~85%, with visible opening on east and west sides, still have boiling feed on CC. |
| | | 12:20 | 46.3 | ~95%, no visible changes since last reading. |
| | | 12:35 | 46.6 | ~95% with visible openings on east and west sides of the melter CC. Surface is flat with ridge on west side, feed is flowing into both openings. |
| | | 12:47 | 46.8 | ~95%, with openings at north east and north west corners. Feed is boiling on surface. |
| | | 13:08 | 47.1 | ~95%, feed is boiling on surface and flowing into north west corner opening. |
| | | 13:23 | 47.4 | ~95%, same as previous reading. |
| | | 13:37 | 47.6 | ~95% with openings at north east and north west corners. Feed is boiling on surface and flowing into melt pool via northwest opening. |
| | | 13:55 | 47.9 | ~95%, openings in north east and north west corners, feed is boiling on surface. |
| | | 14:09 | 48.2 | ~95% with north west opening smaller and north east opening is opening up more. Feed is boiling on surface. |
| | | 14:56 | 48.9 | ~95%, two small openings. |
| | | 15:16 | 49.3 | ~95%, still the same as above. |
| | | 15:39 | 49.7 | ~95%, small openings in north east and south west corners, feed is boiling on surface between openings. |
| | | 16:10 | 50.2 | ~90%, difficulty to see past view ports but light is visible in background indicating larger openings. |
| | | 16:35 | 50.6 | ~95%, light is visible in background, no openings are visible at west wall below the view ports. Vigorous bubbling, stalactite hanging from thermocouple. |
| | | 17:00 | 51.0 | Secured feeding. End of the Test 2. |
| 3 | 1/29/13 | 9:30 | 0.0 | Started feeding water at 0.8 l/min. |
| | | 9:52 | 0.4 | Increased water flow rate to1.6 l/min. |
| | | 10:10 | 0.7 | Increased water from 1.6 to 2.4 l/min. |
| | | 10:30 | 1.0 | Secured water flow and starting feeding slurry |
| | | 10:35 | 1.1 | ~60%, flat and soft. |
| | | 11:05 | 1.6 | ~80%, visible opening on east and west sides. CC is flat. |

## Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 3 | 1/29/13 | 11:20 | 1.8 | ~85-90%, CC is still flat. |
| | | 11:35 | 2.1 | ~85-90%, no visible change. |
| | | 11:54 | 2.4 | ~85-90%, looks soft and opening on west side and east sides. |
| | | 12:20 | 2.8 | ~85-90%, small ridge on east side with opening about 12", visible opening on east side with feed flowing to melt pool. |
| | | 12:47 | 3.3 | ~95% with opening on north east and mid north west sides. Feed is boiling on surface with ridges at openings. |
| | | 13:02 | 3.5 | ~95%, no changes from previous reading. |
| | | 13:17 | 3.8 | ~95% with openings on north east corner and north west-mid melter. Feed is flowing into melt pool through north west opening. |
| | | 13:35 | 4.1 | ~95%, large ridge on west side opening and east side opening has small ridge with feed flowing to opening. |
| | | 13:50 | 4.3 | ~95%, no visible changes from last reading. |
| | | 14:11 | 4.7 | ~95%, two openings at north east and north west-mid melter with ridges at openings. |
| | | 14:29 | 5.0 | ~95%, opening on east and west sides, visible both openings have a ridge at east opening side, feed is flowing through ridge. |
| | | 14:49 | 5.3 | ~95% is very thick. The two openings are visible and small. The openings are 10"-12" thick in CC. |
| | | 15:04 | 5.6 | ~95%, no visible changes yet since increasing bubbling. |
| | | 15:08 | 5.6 | CC is shifted since increasing bubbling. In turn caused liquid feed to flow into the opening. |
| | | 15:19 | 5.8 | ~95%, is not as thick now due to lower liquid level. Also the two ridges that are visible look taller now. |
| | | 15:34 | 6.1 | ~95%, the surface has more liquid boiling on it. |
| | | 15:51 | 6.4 | ~95%, very thick CC is visible at bubbler openings. Spitting glass at openings, no liquid is visible. |
| | | 16:05 | 6.6 | ~95%, lots of spitting, bubbler holes might be closing on CC surface. |
| | | 16:19 | 6.8 | ~95%, spitting glass, darker, CC bubbler holes are tighter. |
| | | 16:34 | 7.1 | ~95%, openings appear to be holding the same sizes. |
| | | 16:49 | 7.3 | ~95%, two small openings. |
| | | 17:04 | 7.6 | ~95%, very thick two openings. |
| | | 17:17 | 7.8 | ~95%, one very small and one larger opening dark inside, also very thick. |
| | | 17:34 | 8.1 | ~95%, one opening. |
| | | 17:48 | 8.3 | ~95%, saw hot glass spilling over from the east side, but could not see on east opening. Also saw second small opening beginning to form on north west side. |
| | | 18:04 | 8.6 | ~95%, not able to see east side at this time. Able to see west side, with three openings running along the wall, two of the openings are about to merge. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 3 | 1/29/13 | 18:16 | 8.8 | ~95%, two west side openings have merged into single opening. CC is 5" thick and no opening is visible on east side. |
| | | 18:39 | 9.2 | ~90%. |
| | | 18:49 | 9.3 | ~90%, no change from the previous observation. |
| | | 19:05 | 9.6 | ~90%, there is a ridge on the north to east side about 8 in. thick and going to the west. |
| | | 19:17 | 9.8 | ~90%, west wall opening, large ridge in center, significant light is visible beyond. |
| | | 19:34 | 10.1 | ~90%, able to see a small portion of the east side openings, very little to no change on west side. |
| | | 19:49 | 10.3 | ~85% opened up since feed rate is a little low, 172 kg/hr. |
| | | 20:04 | 10.6 | ~85, able to see more of the east opening. |
| | | 20:20 | 10.8 | ~85%, reduced bubbling to close the CC up. |
| | | 20:33 | 11.1 | ~85%, still separated from melt pool. |
| | | 20:53 | 11.4 | ~85%, west side is more open than the east side, flows to south west side. |
| | | 21:09 | 11.7 | ~90%, opening on north east, large pool of liquid in center is boiling. |
| | | 21:19 | 11.8 | ~85%, feed is boiling on top, two large openings exist. |
| | | 21:37 | 12.1 | ~85%, heavy boiling and steam exist, openings are larger. |
| | | 21:49 | 12.3 | ~85%, feed is boiling on top. |
| | | 22:34 | 13.1 | ~85-90%, observed buildups on east side, west side opening is slightly ridged. |
| | | 22:50 | 13.3 | ~90%, flow of hot liquid moving eastward observed. West side is open. |
| | | 23:01 | 13.5 | ~90%, hot boiling feed on CC flowing to north east corner with west side opening and thick CC is apparent. |
| | | 23:18 | 13.8 | ~95%, thick CC with heavy splashing, build up on east plenum increasing slightly. |
| | | 23:35 | 14.1 | ~85-90%, east side opens slightly, west side opening grows. |
| | | 23:46 | 14.3 | ~90%, heavy boiling present. Ridges around the openings, east opening is slightly visible in between bubbling, build up exist on the exposed plenum thermocouple, visible from the south port. |
| | 1/30/13 | 0:16 | 14.8 | ~90% remains unchanged. |
| | | 0:19 | 14.8 | ~90%, west opening is slightly larger. |
| | | 0:34 | 15.1 | ~85-90%, west side opening grows. East side is barely visible due to dangling filaments of glass. |
| | | 0:49 | 15.3 | ~80-85%, west edge of CC recedes eastward, east side is opening is minimal, melt pool is visible south and west edges. |
| | | 1:04 | 15.6 | ~80-85%, east side opens slightly, west side edge of CC forms as a shelf. South end of melt pool is opening. |
| | | 1:19 | 15.8 | 85%, west and south portions of the CC contracted, east side 85% opening remains constant, splashing hot liquid flows east and south. |
| | | 1:34 | 16.1 | 85%, east side opening is slightly greater. CC grows west and south. |
| | | 1:49 | 16.3 | East side opening grows north, west side closes. |

# Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 3 | 1/30/13 | 2:04 | 16.6 | ~85%, east opening is the same, west closes slightly; splashing, boiling liquid flows west. |
| | | 2:19 | 16.8 | ~90%, ridge at west opening is slightly reduced; liquid from the surface is flowing into opening. |
| | | 2:49 | 17.3 | ~90%, no change. |
| | | 3:04 | 17.6 | East opening migrates south, ridge on west edge sends boiling liquid east. |
| | | 3:20 | 17.8 | ~90%, openings on east and west sides, both openings have a small ridge around them. Feed is boiling on CC. |
| | | 3:51 | 18.4 | ~90%, unchanged. |
| | | 4:04 | 18.6 | ~90%, ridges exits on both east and west edges of CC. Boiling liquid flows south. |
| | | 4:21 | 18.9 | ~85%, ridges remain, CC dwindles on west edge boiling flows goes south. Liquid sits atop of CC. |
| | | 4:35 | 19.1 | ~85%, west edge receded eastward, ridge remains. |
| | | 4:49 | 19.3 | ~80-85%, mostly unchanged, boiling liquid flows south. Due to large discharge a shelf exists. |
| | | 5:06 | 19.6 | ~85%, east opening is larger than west opening. Feed is boiling between openings. |
| | | 5:19 | 19.8 | ~85%, feed is flowing into east opening, west opening has slight ridge, build up around it. Feed is boiling on CC surface. |
| | | 5:34 | 20.1 | ~85%, heavy boiling on the CC surface, two openings exists on east and west sides. |
| | | 5:53 | 20.4 | ~85-90%. |
| | | 6:20 | 20.8 | ~85%, heavy boiling on the surface. |
| | | 6:34 | 21.1 | ~85%, no change from last observation. |
| | | 7:19 | 21.8 | ~95%, openings with ridges visible via north west & center view ports. Light is visible via south west view port. Feed collecting on top of cap and boiling. |
| | | 7:34 | 22.1 | ~95% with feed boiling on top, ridges and stalactites viable in the view ports. |
| | | 7:49 | 22.3 | ~90%, openings are visible via north west and center view ports. Light is visible via south west view port. Ridges have decreased in size. Feed is boiling on surface. |
| | | 8:04 | 22.6 | ~90%, visual observations unchanged from previous observation. |
| | | 8:19 | 22.8 | ~90%, opening is visible via north and center view ports. Light is visible on south east corner via south port. Ridges have reduced in size allowing feed to flow into openings. Feed is boiling on surface. |
| | | 8:26 | 22.9 | Emergency off gas is tripped due to CC shifting/collapsing. |
| | | 8:34 | 23.1 | ~90%, visual observations are unchanged from previous observation. |
| | | 8:50 | 23.3 | ~95%, no visual change. |
| | | 9:04 | 23.6 | ~95% with two openings at north east corner that is barely visible and at north west corner. Feed is boiling on surface. |
| | | 9:19 | 23.8 | ~95% with no visual changes. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 3 | 1/30/13 | 9:36 | 24.1 | ~95% with ridges around the bubbler openings and feed is boiling on surface. |
| | | 9:49 | 24.3 | ~95%, openings on east and west sides are visible with feed flowing to melt pool. |
| | | 10:04 | 24.6 | ~95%, both east and west side openings are still visible. |
| | | 10:19 | 24.8 | ~95%, no visible changes. |
| | | 10:36 | 25.1 | ~95%, large ridge on west side is visible; east side is still visible with feed flowing to melt pool. |
| | | 10:49 | 25.3 | 95%, no visible changes at this time. |
| | | 11:04 | 25.6 | ~95%, still large ridge/build up on west side, east side is still visible with boiling feed on cap. |
| | | 11:19 | 25.8 | ~95%, no visible changes. |
| | | 11:25 | 25.9 | Melter pressure spike due to cold cap shift. |
| | | 11:34 | 26.1 | ~90%, openings on north east and north west corners are visible via north view port. Openings have small ridges around them. Opening on west side center is visible via center view port. Light is visible in south east corner via south view port. |
| | | 11:49 | 26.3 | ~90-95%, openings in north east and west corners with small ridge. Opening on west side center. Light is visible in south east corner. |
| | | 12:04 | 26.6 | ~90-95%, visual observations unchanged from previous observation. |
| | | 12:19 | 26.8 | ~95%, north east corner opening is barely visible; feed is boiling on surface and flowing into melt pool via north west opening. |
| | | 12:34 | 27.1 | ~90-95%, no visual change from previous reading. |
| | | 12:49 | 27.3 | ~95%, north east opening is no longer visible. Ridge around north west opening, feed is boiling on surface. |
| | | 13:04 | 27.6 | ~95%, no visual change from previous reading. |
| | | 13:19 | 27.8 | ~95%, ridge around north west opening with feed boiling on surface. Light is visible in north east and south east corners. |
| | | 13:34 | 28.1 | ~95%, no visible changes from previous reading. |
| | | 13:49 | 28.3 | ~95% with opening in north west corner, light is visible in south east corner. Feed is boiling on surface. |
| | | 14:04 | 28.6 | ~95% with opening in north west corner. Light is visible in south east and north east corners. |
| | | 14:39 | 29.2 | ~95%, opening is near view port at north west side, dark inside, very thick CC. |
| | | 14:54 | 29.4 | ~95%, very thick, single opening in north west corner. |
| | | 15:06 | 29.6 | ~95%, able to see light emitting from the east side. West side has a small opening that is spitting glass out. |
| | | 15:19 | 29.8 | ~95%, no visible changes at this time. |
| | | 15:49 | 30.3 | ~95%, not able to see any changes in CC conditions. |
| | | 16:04 | 30.6 | ~95%, thick, opening on north west corner. |
| | | 16:19 | 30.8 | ~95%, thick and dark inside. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 3 | 1/30/13 | 16:34 | 31.1 | ~95%, same as before. |
| | | 16:49 | 31.3 | ~95%, west side opening is slightly larger with a cone shape mound. The face of the mound is glazed (shiny). |
| | | 17:04 | 31.6 | ~95%, no visible changes for this observation. |
| | | 17:19 | 31.8 | ~95%, west side opening has opened up more to the south. |
| | | 17:34 | 32.1 | ~95%, west side is slowly closing back up. The cone shaped mound is more of a ridge and it looks dry at this time. |
| | | 17:49 | 32.3 | ~90% and looks flat. |
| | | 18:04 | 32.6 | ~90%, it is flat, 8" thick, feed is boiling on surface. |
| | | 18:24 | 32.9 | ~90%, very thick and single opening exist in west side. |
| | | 18:36 | 33.1 | ~90%, unchanged from the last observation. |
| | | 18:49 | 33.3 | ~95%, no visual of the east side, west side has closed up a little more. |
| | | 19:19 | 33.8 | ~95%. |
| | | 19:34 | 34.1 | ~90%, still not able to see east side opening. Large amount of liquid that boils between shots. Able to see liquid feed flowing into west side opening. |
| | | 20:14 | 34.7 | ~90%, single opening exist in west side, very thick CC. |
| | | 20:19 | 34.8 | ~90%, single opening exists in west side, has opened up slightly since last observation. |
| | | 20:54 | 35.4 | ~90%, no visual of east side, west side opening ridge is melting down some. |
| | | 21:04 | 35.6 | ~90%, no visible changes. |
| | | 21:19 | 35.8 | ~90%, thick, flat, feed is boiling on top. |
| | | 21:34 | 36.1 | ~90%, unchanged for this observation. |
| | | 21:49 | 36.3 | ~90%, 8" thick, glazed on opening. |
| | | 22:04 | 36.6 | ~90%, same as above. |
| | | 22:19 | 36.8 | ~90%, thick, glazed, feed is boiling on surface. |
| | | 22:34 | 37.1 | ~90%, only west opening is visible. Feed overflows to the opening. |
| | | 22:49 | 37.3 | ~90%, glazed wall/ridge at west opening and heavy boiling. |
| | | 23:05 | 37.6 | ~90%, very thick, west side has single opening with heavy boiling and some splashing. |
| | | 23:19 | 37.8 | ~90%, ridge at west opening appears to be shifting towards the melt pool. |
| | | 23:35 | 38.1 | ~90%, one opening on west side, thick around opening. |
| | | 23:50 | 38.3 | ~90%, opening on west side, CC looks about 12 in thick. |
| | | 23:56 | 38.4 | ~90%, can only see west side opening. |
| | 1/31/13 | 0:21 | 38.9 | ~90%, west side is open; east side is not visible, thick CC. |
| | | 0:34 | 39.1 | ~90%, thick cap and lots of boiling feed. |
| | | 0:50 | 39.3 | ~90% no appreciable change in CC. |
| | | 1:04 | 39.6 | ~90%, west wall ridge persist to exist. |
| | | 1:26 | 39.9 | ~85%, very thick, edge of CC is seen on west side extending south. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 3 | 1/31/13 | 1:44 | 40.2 | ~85%, west side opening grows towards east side, flow goes south. |
| | | 2:03 | 40.6 | ~90%, wall ridge persists. Previously increased bubbling to increase plenum temperatures to help dissolve the ridge. |
| | | 2:19 | 40.8 | ~80%, opening on west side, grows south, very thick. Ridge on west edge, flow of boiling liquid goes south. |
| | | 2:36 | 41.1 | ~80%, remains the same as before. |
| | | 2:52 | 41.4 | ~80-85%, ridge on west of CC sends boiling liquid south, south end is open, collection of feed is seen on bubblers. |
| | | 3:19 | 41.8 | ~85%, ridge built up around west opening. |
| | | 3:37 | 42.1 | ~90-95%, opening remains on west side with splashing feed boiling. |
| | | 3:50 | 42.3 | ~90-95%, no appreciable change in CC. |
| | | 4:07 | 42.6 | ~90-85%, ridge on west edge diminished. North edge grows. |
| | | 4:20 | 42.8 | ~90-95%, opening moving south, ridge on west edge of CC flows liquid to south. |
| | | 4:34 | 43.1 | ~90-95%, mostly unchanged, splashing causes build up of feed on bubblers. |
| | | 4:46 | 43.3 | ~90-95%, remains the same. |
| | | 5:05 | 43.6 | ~90%, heavy boiling at surface, feed overflows to west opening in between shots. |
| | | 5:23 | 43.9 | ~90%, same as last observation. |
| | | 5:37 | 44.1 | ~90%, opening on west side has ridge around it. |
| | | 5:55 | 44.4 | ~90-95%, unchanged. |
| | | 6:09 | 44.7 | ~90-95%, buildup on C2 increased slightly along with the south side. |
| | | 6:49 | 45.3 | ~95%, unchanged. Feed is boiling on surface. |
| | | 7:04 | 45.6 | ~90-95%, feed is boiling on surface and flowing into glass pool via north west opening. Light is visible in south east corner. |
| | | 7:19 | 45.8 | ~90% with visible opening in north east corner. Ridge is around opening in north west. Feed is boiling on surface. |
| | | 7:34 | 46.1 | ~90% with no visible changes from previous observation. |
| | | 7:49 | 46.3 | ~90% with openings in north east and north west corners. Feed is boiling on surface and flowing into north east opening. |
| | | 8:04 | 46.6 | ~90%, no significant change since the last reading. |
| | | 8:19 | 46.8 | ~90%, only one opening is visible in view in northeast port. |
| | | 8:34 | 47.1 | ~90%, feed is boiling on surface with openings in north east and north west corners. |
| | | 8:49 | 47.3 | ~90%, feed is boiling on surface and flowing into melt pool via north west opening. |
| | | 9:04 | 47.6 | ~90% with openings in north east and north west corners. Light is visible in south east corner. Ridges at openings. |
| | | 9:19 | 47.8 | ~90% with no visual change. |
| | | 9:34 | 48.1 | ~90% with feed boiling on surface. Openings in north west and north west corners. |

## Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 3 | 1/31/13 | 9:49 | 48.3 | ~95%, both east and west side openings are visible, west side has visible ridge boiling feed on top. |
| | | 10:04 | 48.6 | ~90%, openings are visible on north east and north west via first view port. Faint light is visible in second view port. Thick CC is visible. |
| | | 10:30 | 49.0 | Stopped feeding. End of Test. |
| 4 | 2/6/13 | 12:00 | 0.0 | Started feeding water at 0.8 l/min. |
| | | 12:10 | 0.2 | Increased water feed from 0.8 to 1.6 l/min. |
| | | 12:30 | 0.5 | Increased water feed from 1.6 to 2.4 l/min. |
| | | 12:46 | 0.8 | Increased water feed from 2.46 to 3.0 l/min. |
| | | 13:00 | 1.0 | Secured feeding water. Started feeding slurry. |
| | | 13:05 | 1.1 | ~75-80%, openings are visible in north west corner and north west side and wst side center. Light is visible from south east and south west corners. CC is flat and fluid feed is boiling on surface. |
| | | 13:24 | 1.4 | ~80%, openings in north east corner and west side with feed boiling on surface. |
| | | 13:35 | 1.6 | ~80-85% with openings in north east corner and west side. Feed is boiling on surface and flowing into melt pool in both openings. |
| | | 13:49 | 1.8 | ~85-90%. Feed is boiling on top with feed boiling into the melt pool. |
| | | 14:08 | 2.1 | ~90-95% with openings smaller on north east corner and west side. Feed is boiling on surface and flowing into melt pool via west opening. |
| | | 14:23 | 2.4 | ~90-95% with feed flowing into north east opening, small opening on west side. |
| | | 14:37 | 2.6 | ~95% with two openings at north west corner and west side with feed flowing into the melt pool via north east corner. |
| | | 14:55 | 2.9 | ~95%, dry in some spots. Liquid is boiling in the center underneath feed tube. |
| | | 15:11 | 3.2 | ~95%, small area of boiling, bubbling is steady, not vigorous. |
| | | 15:20 | 3.3 | ~95%, is visibly heaving up and down. |
| | | 15:49 | 3.8 | ~95% and very wet. |
| | | 16:05 | 4.1 | ~95%, very wet and having small splatter. |
| | | 16:20 | 4.3 | %95% and no change from last observation. |
| | | 16:42 | 4.7 | 95%, north west opening is starting to close. |
| | | 16:59 | 5.0 | ~95%, very wet. |
| | | 17:19 | 5.3 | ~90%, there is more feed boiling on surface. Glass is splashing out of openings. |
| | | 17:52 | 5.9 | ~95%, north west opening is closed slightly, west side is opening larger. |
| | | 18:42 | 6.7 | ~95%, openings are at north east and south west corners. |
| | | 19:09 | 7.2 | ~90%, much darker and fixed (not floating). The openings have ridges that are higher than before. |
| | | 19:19 | 7.3 | ~90%, no visible changes. |
| | | 19:47 | 7.8 | ~95%, deep wells for each bubbler port. |
| | | 20:09 | 8.2 | ~95%, bubbler opening at west has very thick ridge, barely open. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 4 | 2/6/13 | 20:26 | 8.4 | ~95% with violent splashing of glass, visible liquid spills into bubbler well. |
| | | 21:04 | 9.1 | ~90%, is fixed to the walls. Ridges around openings are 3.4” taller than the cap. Liquid is flowing over ridge. |
| | | 21:19 | 9.3 | ~90-95%, no visible changes. |
| | | 21:34 | 9.6 | ~95%, ridges hold boiling liquid atop CC. Openings at east and west sides. |
| | | 21:52 | 9.9 | ~95%, west side opening is reduced, east side remains constant. |
| | | 22:05 | 10.1 | ~95%, large pool of boiling liquid tops cap. Ridges exits on east and west edges. |
| | | 22:34 | 10.6 | ~95%, ridges persist. Boiling liquid flows towards east side opening. West side opening grows slightly. |
| | | 22:49 | 10.8 | ~95%, ridge remains on west edge opening. East opening receives boiling liquid, grows towards CC center. Ridge on east side opening is reduced. |
| | | 23:04 | 11.1 | ~95%, west side opening grows, east side opening remains the same. |
| | | 23:20 | 11.3 | ~95%, boiling liquid is no longer on top of CC. CC is fixed, east side is consistent, west side is reduced. Ridge is still on west side. |
| | | 23:35 | 11.6 | ~95%, prominent ridge on west side edge of the CC. Boiling liquid starts to pool: east side opening is the same, west side opening is reduced. |
| | | 23:49 | 11.8 | ~95%, ridges make CC appear very thick, pooling liquid flows east, west opening shrinks. |
| | 2/7/13 | 0:04 | 12.1 | ~95%, increase of bubbling results in build-up of ridges at east and west openings in the CC. Boiling liquid pools between ridges. |
| | | 0:19 | 12.3 | ~95% unchanged from last observation. |
| | | 0:34 | 12.6 | ~95%, east side opening remains consistent, west side ridge diverts flow west and south, west side opening migrates south. |
| | | 0:49 | 12.8 | ~95, east side is open, west side is closing up slightly with ridge around it. CC is thick with feed boiling on surface. |
| | | 1:08 | 13.1 | ~95%, thick and east side is still open, west side opening is closing up. |
| | | 1:21 | 13.4 | ~95%, ridges persist. West side opening migrates south. East side opening remains constant. |
| | | 1:34 | 13.6 | ~95%, east side is constant, west side opening ridge causes pooling of liquid feed from the middle of the cap to north end. |
| | | 1:49 | 13.8 | ~95%, west side opening grows, east side remains. Large pool of liquid between ridges. |
| | | 2:05 | 14.1 | ~95%, west side opening gains towards south side. Boiling liquid still pools between ridges. East side remains steady. |
| | | 2:20 | 14.3 | ~95%, east side opening is constant, west side opening is steady. |
| | | 2:34 | 14.6 | ~95%, ridge plus dangling fibers obscure east opening visually. West side opening is steady. Liquid pools between the ridges. |
| | | 2:51 | 14.9 | ~90-95%, west side opening increases towards south end, east side remains open. |
| | | 3:05 | 15.1 | ~90%, west side opening grows south east, CC reduces to 90%. East end of CC unchanged. CC is thick and has boiling liquid on top. |
| | | 3:19 | 15.3 | ~85-90%, east side opening exists, but it is difficult to view as the east side ridge is high. West side opening grows towards south east. |

## Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 4 | 2/7/13 | 3:35 | 15.6 | ~85-90%, after glass discharge boiling liquid flowed into west side opening, east side opening appears the same size. West side opening increases. |
| | | 3:44 | 15.7 | ~90-95, east and west sides are open. Both have ridges, feed is boiling on surface between openings. |
| | | 4:07 | 16.1 | East side unchanged, west side is open on west and south edges. Strong bubbling builds a ridge on west side of CC. Boiling liquid pools on top of CC. |
| | | 4:19 | 16.3 | ~85-90%, south side is open, north side is fixed to melter wall. East side opening remains constant and west side is visible to south. |
| | | 4:34 | 16.6 | ~90%, east side opening unchanged, west side edge of CC is seen towards south side. Ridges are prominent. |
| | | 4:49 | 16.8 | ~85-90%, east side opening grows, ridges persist, opening on west side enlarges. |
| | | 5:04 | 17.1 | ~85-90%, no appreciable change. |
| | | 5:28 | 17.5 | ~85%, openings are getting larger. Ridges are increased. |
| | | 5:42 | 17.7 | ~85%, no change. |
| | | 5:48 | 17.8 | ~85-90%, openings on east and west sides. Large ridge on east side, feed is boiling on surface. |
| | | 6:04 | 18.1 | ~85-90%, east and west side openings are divided by a large ridge that keeps growing in height with feed splashing into melt pool from boiling on CC surface. |
| | | 6:59 | 19.0 | ~95% with opening in north east and north west corners, feed is boiling on surface. |
| | | 7:15 | 19.3 | ~95% with no visible ridges around north east and north west corner openings. Feed is boiling on surface. |
| | | 7:34 | 19.6 | ~95% with no visible changes from previous observation. |
| | | 7:48 | 19.8 | ~90% with north east corner opening up and allowing feed into melt pool, slight ridge around north west opening. |
| | | 8:19 | 20.3 | ~90%, openings are visible via north view port in north east and north west corners. Opening is visible via center view port on west center and light is visible in south east and south west corners via south view port. Feed is boiling on surface. |
| | | 8:34 | 20.6 | ~90%, feed is visible, boiling on top and pouring into both open holes into the melt pool. |
| | | 8:49 | 20.8 | ~90-95%, a single ridge is starting to develop around the cold cap opens up boiling feed which is pooling on top of CC. |
| | | 9:04 | 21.1 | ~90%, openings are visible in north east and north west corners with ridges. Feed is boiling on surface. Light is visible in south east corner via south view port. |
| | | 9:19 | 21.3 | ~90%, no visual changes from last observation. Now at maximum bubbling rate of 78 lpm. |
| | | 9:35 | 21.6 | ~90% with no visible ridges on north east corner allowing feed to flow into melt pool. Open in north west with ridges. |
| | | 9:52 | 21.9 | ~90-95% with visible openings in north east and north west corners. Ridges are visible around both openings. Feed is boiling on surface. |
| | | 10:06 | 22.1 | ~90%, west side opening has a ridge east side opening is visible with boiling feed on cap. |
| | | 10:22 | 22.4 | ~90%, no visible changes. |

## Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 4 | 2/7/13 | 10:36 | 22.6 | ~90%, openings on east and west side of the melter, visible both openings have ridges with boiling feed on top of cap. |
| | | 11:04 | 23.1 | ~90-95%, feed is boiling on top with low ridge around the east bubbler are with some feed entering the hole plus a high ridge around the west hole. |
| | | 11:19 | 23.3 | ~90-95%, north east hole opened slightly, north west hole is unchanged. Feed is boiling on top with slight increase in the flow going into the north east hole. |
| | | 11:34 | 23.6 | ~90%, north east hole has feed flowing into it, north east hole is unchanged. |
| | | 11:49 | 23.8 | ~90-95% with ridges around north east and north west openings. Feed is boiling on surface. |
| | | 12:12 | 24.2 | ~95% with 10” ridge around north west, smaller ridge around north east corner. Feed is boiling on surface. |
| | | 12:32 | 24.5 | ~95% with large ridges above both openings. North east opening is barely visible from view port. Feed is boiling on surface. |
| | | 12:49 | 24.8 | ~95% with ridges around both openings. North east opening is barely visible from openings. Feed is boiling on top of the cold cap. |
| | | 13:04 | 25.1 | ~95%, north east opening is no longer visible in first view port. The visible opening has a ridge and feed is boiling on top of the cap. |
| | | 13:34 | 25.6 | ~95%, north east opening is barely visible, large ridge around north west opening making feed and surface not visible. |
| | | 13:49 | 25.8 | ~95% with feed no visible boiling on surface, north east opening is still barely visible. Large ridge around north west opening with glass bubbling out. |
| | | 14:04 | 26.1 | ~95% with no visible change from previous observation. |
| | | 14:19 | 26.3 | ~90-95% with opening in north east and north west corners. North east corner is barely visible. North west opening is visually larger than before with glass bubbling out of melt pool. |
| | | 14:40 | 26.7 | ~95%, north east opening is no longer visible from view port. North west corner opening still has ridge around opening. Feed is boiling on surface. |
| | | 15:04 | 27.1 | ~95%, no visual of the east side, west side opening has a large ridge around it. |
| | | 15:19 | 27.3 | ~95%, same as last observation. |
| | | 15:33 | 27.6 | ~95%, flat with large opening. |
| | | 15:49 | 27.8 | ~95-97%, north east side opening is very small. |
| | | 16:04 | 28.1 | ~95%, west side has opened up slightly to a cone shaped opening. Glass is spitting out. Feed is boiling briefly between the shots. |
| | | 16:19 | 28.3 | ~95%, unchanged for this observation. |
| | | 16:45 | 28.7 | ~95%. |
| | | 16:49 | 28.8 | ~95%, now can see inside after CC collapsed. |
| | | 17:04 | 29.1 | ~95%, opened up on the west side. |
| | | 17:19 | 29.3 | ~95%, thick and feed is boiling on top and there are ridges around the west opening, west opening is not visible. |
| | | 17:34 | 29.6 | ~95%, able to see east side at this time. The ridge has melted down somewhat, west side is slightly opened up. |
| | | 17:49 | 29.8 | ~90%, north east opening is visible in the first view port. Feed is visible going into north west opening via second view port. |
| | | 18:04 | 30.1 | ~90%, north west pool no longer is visible in second view port. All else unchanged. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 4 | 2/7/13 | 18:19 | 30.3 | ~90%, still able to see east side opening. Ridges are much lower. |
| | | 18:41 | 30.7 | ~90%, melter pressure went positive due to CC collapsing. |
| | | 18:49 | 30.8 | ~90%, level looks lower since CC collapsed. |
| | | 19:04 | 31.1 | ~90%, no changes. |
| | | 19:19 | 31.3 | ~90%, has opened up somewhat. |
| | | 19:34 | 31.6 | ~85%, east side has a new hole is opening slightly south of the other opening. No other changes. |
| | | 19:49 | 31.8 | ~90%, large liquid basin between openings, lots of visible light but openings appear small. Large stalactite/stalagmite hanging from plenum thermocouple in south view port. |
| | | 20:19 | 32.3 | ~90%. |
| | | 20:36 | 32.6 | ~90%, ridges at east and west openings. Liquid is pooling on top of CC and flowing west. West edge of CC is visible through view port. |
| | | 20:49 | 32.8 | ~85%, west edge of CC extends south. Pronounced ridge on east and west openings. |
| | | 21:04 | 33.1 | ~85-90%, boiling liquid pools between ridges flows into melt pool on south west edge opening. |
| | | 21:20 | 33.3 | ~90%, molten glass is erupting into boiling pool of liquid feed. |
| | | 21:34 | 33.6 | ~85-90%, openings increase towards north edge of CC. Ridges block flow of boiling liquid. Pronounced ridge on west edge opening. |
| | | 21:49 | 33.8 | ~85%, boiling liquid remains on top of cap. North side is opening up. Liquid is coming from south east corner, ridges remain along openings. |
| | | 22:05 | 34.1 | ~85-90%, breech in ridge along east opening sends boiling liquid into east side opening. West edge is seen. |
| | | 22:19 | 34.3 | ~85%, west edge of CC proceeds eastward north. Boiling flow is sent to east opening. |
| | | 22:34 | 34.6 | ~85-90%, liquid pool on top of cap. Ridges around both openings, more light from north edge than south edge of cap. |
| | | 22:49 | 34.8 | ~85%, bubbling allows a breech in east edge ridge: boiling liquid flow to south east side of cap extending east opening southward. West side has a large ridge, dangling fibers are seen. |
| | | 23:04 | 35.1 | ~85-90%, mostly unchanged. |
| | | 23:16 | 35.3 | ~90%, appears mostly unchanged with a lot of liquid feed on cap surface. |
| | | 23:34 | 35.6 | ~90%, east edge loses ridge boiling flow goes east. Space between east edge of cap and west edge of CC narrows. CC appears thinner than before. |
| | | 23:49 | 35.8 | ~85% with glass level reduced during discharge. CC is thick holds boiling liquid which flows into the east opening which is migrating north. A high ridge exists on west of cap. |
| | 2/8/13 | 0:05 | 36.1 | ~80-85%, between east and west opening narrows. Pool of boiling liquid remains. |
| | | 0:19 | 36.3 | ~80-85%, boiling liquid pools atop cap. Ridges east and west edges of cap openings migrate to north wall. West edge is seen. |
| | | 0:34 | 36.6 | ~85% increases towards west wall. High ridges exist around east and west openings. Liquid pools. |
| | | 0:49 | 36.8 | ~85%, ridges on east and west openings persist with lots of feed pooled between them. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 4 | 2/8/13 | 1:03 | 37.0 | ~85%, no apparent change. |
| | | 1:19 | 37.3 | ~90-95%, north edge attached to wall, east opening reduced, hanging fibers and ridges persist. Pooling liquid flows westerly. |
| | | 1:36 | 37.6 | ~90%, splashing and bubbling cause ridge build up around east and west openings. Liquid is boiling on surface. |
| | | 1:49 | 37.8 | ~90%, high ridges make it difficult to see top of CC. No boiling liquid is seen on top CC. Dangling fibers over east opening. |
| | | 2:04 | 38.1 | West edge ridge has grown onto the D1 bubbler pipe. East and west openings diminish. |
| | | 2:19 | 38.3 | ~90-95%, ridge blocks view of east opening. Light is seen in south east corner of melt pool. West edge opening diminishes. |
| | | 2:28 | 38.5 | ~90%, visual obstruction on the north view port. Large accumulation hangs on the Lance bubbler. |
| | | 2:31 | 38.5 | ~90%, east opening is partially visible, heavy boiling on the surface, although not visible west opening exists. |
| | | 2:49 | 38.8 | ~90%, mid-port is totally obstructed, no visual is available. South view port shows D3 bubbler, also coated by solid build up. |
| | | 3:04 | 39.1 | ~90-95%, east opening is difficult to see, west side opening extends southward. Light is seen in south east corner of melt pool. |
| | | 3:19 | 39.3 | ~90-95%, large ridge is on the west. |
| | | 3:34 | 39.6 | ~90-95%, unable to see into east opening due to ridge and dangling fibers, can see emitted light. West opening migrates south. |
| | | 3:49 | 39.8 | ~90-95%, east opening is mostly obscured by ridge and openings remain mostly unchanged. |
| | | 4:04 | 40.1 | ~90-95%, east opening emits light, west opening migrates south. |
| | | 4:34 | 40.6 | Unable to see into east side opening. West opening is narrow, moving southerly and easterly. Light from south east corner of melt pool covers 90-95% melt pool. |
| | | 5:12 | 41.2 | ~95%, east opening is not visible due to ridge. West side has feed dripping into melt pool. Cannot see CC surface due to ridge |
| | | 5:39 | 41.7 | ~95%, west side is open surrounded by a large ridge unable to see east side. |
| | | 6:12 | 42.2 | ~95%, east side is open with a large ridge around it, unable to see west side of melter. |
| | | 6:49 | 42.8 | ~>95%, small opening is visible via north view port. Light is visible via center and south ports. Large mound running length of melter from north to south. Feed is boiling on surface. |
| | | 7:04 | 43.1 | ~>95%, conditions are unchanged from the last observation. |
| | | 7:21 | 43.4 | ~95%, small opening on west side via north view port. Light is visible through south view port. Feed is boiling on surface. |
| | | 7:40 | 43.7 | ~95%, no visual change from the previous observation. |
| | | 7:55 | 43.9 | ~95%, feed is visibly flowing into the north west opening and boiling on surface. Light is visible from south view port. |
| | | 8:10 | 44.2 | ~95%, opening is visible via north view port. Light is visible via center and south view ports. Ridge at center of melt pool has decreased in size. Feed is boiling on surface. |

**Table 3.3. Cold Cap Observations (continued).**

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 4 | 2/8/13 | 8:19 | 44.3 | ~95% with feed is boiling on top, a small amount of light is visible in the center view port. CC is still thick but the ridges are surrounding. The west side opening is not too pronounced. |
| | | 8:34 | 44.6 | ~95% with feed boiling on surface, feed is moving it over the rim of the opening into melter. |
| | | 8:49 | 44.8 | ~95%, feed is bale to build up and roll into the melt pool. Feed is bubbling on top of the CC. |
| | | 9:10 | 45.2 | ~95%, feed is boiling on surface and flowing into melt pool through north west opening. |
| | | 9:20 | 45.3 | ~90%, opening on west side is visible from north/center viewport. Light is visible from south view port. |
| | | 9:35 | 45.6 | ~95%, feed is boiling surface, small ridge around north west opening with glass bubbling up out of hole. |
| | | 9:49 | 45.8 | ~95%, no significant changes from the last time. |
| | | 10:09 | 46.2 | ~95%, openings on west side and light are visible from east side. |
| | | 10:27 | 46.5 | ~95%, opening on west side is visible with ridge, opening on east side is visible a little boiling feed on cap. |
| | | 10:49 | 46.8 | ~95% with boiling feed on the surface. Openings in south east and north west corners are visible via north view port. Small opening is visible on west-mid side via center view port. Light is visible via south view port. |
| | | 11:04 | 47.1 | ~95%, conditions are unchanged from last observation. |
| | | 11:20 | 47.3 | ~95%, openings in south east and north west corners are visible via north viewport. Small opening on west-center side is visible via center view port. Light is visible through south port. |
| | | 11:34 | 47.6 | ~95%, conditions are unchanged from last observation. |
| | | 11:49 | 47.8 | ~95%, conditions are unchanged from last observation. |
| | | 12:19 | 48.3 | ~95%, opening is visible in north west corner, west side and center light is visible on east side. |
| | | 12:34 | 48.6 | ~95%, feed is boiling on surface and flowing into the melt pool via north west corner. Light is still visible on east side. |
| | | 12:49 | 48.8 | ~95% with no visual changes from the last observation. |
| | | 13:04 | 49.1 | ~95% with feed boiling on surface. Glass is bubbling out from the opening onto top of CC. |
| | | 13:19 | 49.3 | ~95%, feed is boiling on surface and flowing into openings. Openings are in north west corner and west side center. Light is visible from south view port. |
| | | 13:34 | 49.6 | ~95%, north west is visible, no change at this time. |
| | | 13:49 | 49.8 | ~95%, west side is visible; opening with ridge on east side is not visible at this time. |
| | | 14:04 | 50.1 | ~95%, no visible change. |
| | | 14:19 | 50.3 | ~95%, west side opening is still visible with a ridge, east side has a visible light. |
| | | 14:38 | 50.6 | ~95%, very deep crevice is seen in north view port. No light is visible in mid view port, light is visible beyond. |
| | | 14:58 | 51.0 | ~95%, opening has completely closed via north view port. Very little light is visible. |
| | | 15:04 | 51.1 | ~95%, small opening at west side, little light is visible. |

## Table 3.3. Cold Cap Observations (continued).

| Test | Date | Time | Run Time (hours) | Cold Cap Observations |
|---|---|---|---|---|
| 4 | 2/8/13 | 15:04 | 51.1 | ~95%, small opening on west side, little light is visible. |
| | | 15:19 | 51.3 | ~95%, not able to see east side and there is large ridge around west opening. |
| | | 15:34 | 51.6 | ~95%, north is opening up slightly. Large ridge is visible. |
| | | 15:49 | 51.8 | ~95%, fissure is widening at north viewport. Ridge is still at south view port. |
| | | 16:03 | 52.0 | ~95%, feed is boiling around fissure at north view port. |
| | | 16:20 | 52.3 | ~95%, feed pool is still bubbling hard near fissure. |
| | | 16:34 | 52.6 | ~95%, is very thick with small opening on west side. |
| | | 16:49 | 52.8 | ~95%, very messy inside. |
| | | 17:02 | 53.0 | Stopped feeding slurry. End of Test 4. |
| | | 19:27 | 55.5 | CC is gone. |
| | | 20:30 | 56.5 | Start off gas and melter shut down |
| | | 21:45 | 57.8 | Melter and off gas shutdown are completed. |

## Table 3.4. DM1200 Melter System Measured Parameters.

| **TEST 1** | | | Steady State | Overall | | |
|---|---|---|---|---|---|---|
| | | | avg | avg | min | max |
| TEMPERATURE (°C) | Glass | 13" from floor E | 1135 | 1134 | 1080 | 1158 |
| | | 15.5" from floor E | 1131 | 1130 | 1075 | 1158 |
| | | 18" from floor E | 1130 | 1129 | 1071 | 1161 |
| | | 27" from floor E | 1111 | 1104 | 952 | 1142 |
| | | 13" from floor W | 1154 | 1157 | 1133 | 1177 |
| | | 15.5" from floor W | 1155 | 1158 | 1135 | 1179 |
| | | 18" from floor W | 1155 | 1158 | 1131 | 1175 |
| | | 27" from floor W | 1142 | 1130 | 855 | 1161 |
| | Plenum | T/W Plenum TC 8" below lid (A2) | 517 | 510 | 337 | 848 |
| | | Exp. Plenum TC 17" below lid (B2) | 628 | 580 | 413 | 851 |
| | | Exp. Plenum TC 17" below lid (B3) | 532 | 504 | 286 | 847 |
| | | Exp. Plenum TC 17" below lid (C1) | 557 | 527 | 323 | 833 |
| | | Exp. Plenum TC 17" below lid (C2) | 556 | 525 | 341 | 840 |
| | | T/W Plenum TC 17" below lid (D2) | 547 | 522 | 356 | 834 |
| | Discharge | TC 1 | 1038 | 1017 | 906 | 1070 |
| | | TC 2 | 1071 | 1049 | 937 | 1093 |
| | | Air Flow | 268 | 262 | 216 | 283 |
| | Electrode | East | 1132 | 1128 | 1054 | 1154 |
| | | West | 1129 | 1130 | 1078 | 1155 |
| | | Bottom | 1049 | 1039 | 949 | 1065 |
| | Film Cooler | Added Air | 76 | 76 | 74 | 78 |
| | | Outlet | 367 | 353 | 201 | 493 |
| Glass Resistance (ohms) | | | 0.089 | 0.087 | 0.078 | 0.099 |
| Glass Density (g/ml) | | | 2.26 | 2.29 | 2.20 | 2.48 |
| Glass Pool Depth (inches) | | | 29.4 | 29.2 | 27.4 | 30.4 |
| Electrodes | Current (A) | | 1448 | 1392 | 1139 | 1519 |
| | Voltage (V) | | 129 | 121 | 103 | 131 |
| | Power (kW) | | 187 | 169 | 124 | 191 |
| Lance Bubblers | 1 | Rate (lpm) | 38.5 | 30.2 | 2.0 | 51.2 |
| | 2 | Rate (lpm) | 39.6 | 31.0 | 2.1 | 40.6 |
| | Total Bubbling (lpm) | | 79.3 | 62.5 | 5.3 | 81.0 |

## Table 3.4. DM1200 Melter System Measured Parameters (continued).

| TEST 2 | | | Steady State | Overall | | |
|---|---|---|---|---|---|---|
| | | | avg | avg | min | max |
| TEMPERATURE (°C) | Glass | 13" from floor E | 1135 | 1135 | 1104 | 1153 |
| | | 15.5" from floor E | 1130 | 1131 | 1098 | 1149 |
| | | 18" from floor E | 1128 | 1128 | 1098 | 1147 |
| | | 27" from floor E | 1106 | 1107 | 1071 | 1139 |
| | | 13" from floor W | 1154 | 1154 | 1129 | 1170 |
| | | 15.5" from floor W | 1156 | 1156 | 1129 | 1173 |
| | | 18" from floor W | 1156 | 1156 | 1129 | 1172 |
| | | 27" from floor W | 1143 | 1143 | 1005 | 1168 |
| | Plenum | T/W Plenum TC 8" below lid (A2) | 534 | 555 | 454 | 889 |
| | | Exp. Plenum TC 17" below lid (B2) | 641 | 650 | 530 | 901 |
| | | Exp. Plenum TC 17" below lid (B3) | 506 | 527 | 388 | 883 |
| | | Exp. Plenum TC 17" below lid (C1) | 524 | 543 | 426 | 901 |
| | | Exp. Plenum TC 17" below lid (C2) | 536 | 553 | 410 | 908 |
| | | T/W Plenum TC 17" below lid (D2) | 516 | 537 | 425 | 896 |
| | Discharge | TC 1 | 1060 | 1051 | 919 | 1113 |
| | | TC 2 | 1078 | 1070 | 950 | 1116 |
| | | Air Flow | 257 | 258 | 212 | 285 |
| | Electrode | East | 1142 | 1140 | 1084 | 1153 |
| | | West | 1142 | 1140 | 1040 | 1157 |
| | | Bottom | 1057 | 1049 | 942 | 1072 |
| | Film Cooler | Added Air | 80 | 79 | 75 | 83 |
| | | Outlet | 375 | 385 | 312 | 547 |
| Glass Resistance (ohms) | | | 0.082 | 0.082 | 0.076 | 0.092 |
| Glass Density (g/ml) | | | 2.26 | 2.27 | 2.20 | 2.41 |
| Glass Pool Depth (inches) | | | 29.5 | 29.6 | 27.6 | 31.4 |
| Electrodes | Current (A) | | 1571 | 1556 | 1302 | 1627 |
| | Voltage (V) | | 128 | 128 | 115 | 137 |
| | Power (kW) | | 202 | 199 | 153 | 211 |
| Lance Bubblers | 1 | Rate (lpm) | 31.3 | 30.4 | 2.4 | 31.7 |
| | 2 | Rate (lpm) | 31.6 | 30.7 | 2.9 | 32.1 |
| | 3 | Rate (lpm) | 15.5 | 15.4 | 2.9 | 15.7 |
| | Total Bubbling (lpm) | | 79.6 | 77.7 | 9.4 | 79.9 |

## Table 3.4. DM1200 Melter System Measured Parameters (continued).

| TEST 3 | | | Steady State | Overall | | |
|---|---|---|---|---|---|---|
| | | | avg | avg | min | max |
| TEMPERATURE (°C) | Glass | 13" from floor E | 1145 | 1143 | 1117 | 1173 |
| | | 15.5" from floor E | 1140 | 1137 | 1111 | 1168 |
| | | 18" from floor E | 1137 | 1135 | 1108 | 1164 |
| | | 27" from floor E | 1117 | 1110 | 1021 | 1146 |
| | | 13" from floor W | 1155 | 1154 | 1132 | 1179 |
| | | 15.5" from floor W | 1155 | 1154 | 1132 | 1179 |
| | | 18" from floor W | 1155 | 1154 | 1125 | 1178 |
| | | 27" from floor W | 1137 | 1129 | 942 | 1161 |
| | Plenum | T/W Plenum Tc 8" below lid (A2) | 473 | 507 | 424 | 858 |
| | | Exp. Plenum TC 17" below lid (B2) | 557 | 562 | 461 | 841 |
| | | Exp. Plenum TC 17" below lid (B3) | 437 | 477 | 374 | 838 |
| | | Exp. Plenum TC 17" below lid (C1) | 433 | 474 | 394 | 864 |
| | | Exp. Plenum TC 17" below lid (C2) | 453 | 489 | 391 | 867 |
| | | T/W Plenum TC 17" below lid (D2) | 473 | 504 | 436 | 871 |
| | Discharge | TC 1 | 941 | 942 | 850 | 1057 |
| | | TC 2 | 1015 | 1010 | 948 | 1094 |
| | | Air Flow | 238 | 240 | 210 | 272 |
| | Electrode | East | 1164 | 1161 | 1077 | 1177 |
| | | West | 1139 | 1139 | 1048 | 1165 |
| | | Bottom | 1053 | 1036 | 917 | 1057 |
| | Film Cooler | Added Air | 75 | 76 | 74 | 78 |
| | | Outlet | 353 | 374 | 295 | 628 |
| Glass Resistance (ohms) | | | 0.070 | 0.071 | 0.067 | 0.088 |
| Glass Density (g/ml) | | | 2.29 | 2.29 | 2.22 | 2.40 |
| Glass Pool Depth (inches) | | | 29.5 | 29.5 | 27.6 | 30.8 |
| Electrodes | Current (A) | | 1697 | 1670 | 1318 | 1937 |
| | Voltage (V) | | 119 | 119 | 105 | 139 |
| | Power (kW) | | 201 | 199 | 153 | 270 |
| Lance Bubblers | 1 | Rate (lpm) | 20.1 | 19.4 | 6.8 | 23.9 |
| | 2 | Rate (lpm) | 20.0 | 19.6 | 6.9 | 24.4 |
| | 3 | Rate (lpm) | 10.1 | 9.8 | 3.4 | 12.2 |
| | 4 | Rate (lpm) | 10.1 | 9.8 | 3.3 | 12.2 |
| | Total Bubbling (lpm) | | 61.5 | 59.7 | 21.8 | 73.6 |

## Table 3.4. DM1200 Melter System Measured Parameters (continued).

| TEST 4 | | | Steady State | Overall | | |
|---|---|---|---|---|---|---|
| | | | avg | avg | min | max |
| TEMPERATURE (°C) | Glass | 13" from floor E | 1162 | 1163 | 1130 | 1200 |
| | | 15.5" from floor E | 1166 | 1165 | 1138 | 1195 |
| | | 18" from floor E | 1167 | 1164 | 1053 | 1186 |
| | | 27" from floor E | 1133 | 1117 | 940 | 1164 |
| | | 13" from floor W | 1145 | 1142 | 1118 | 1162 |
| | | 15.5" from floor W | 1145 | 1142 | 1112 | 1163 |
| | | 18" from floor W | 1145 | 1142 | 1109 | 1162 |
| | | 27" from floor W | 1124 | 1115 | 887 | 1162 |
| | Plenum | T/W Plenum TC 8" below lid (A2) | 467 | 494 | 440 | 794 |
| | | Exp. Plenum TC 17" below lid (B2) | 527 | 527 | 418 | 771 |
| | | Exp. Plenum TC 17" below lid (B3) | 420 | 458 | 356 | 768 |
| | | Exp. Plenum TC 17" below lid (C1) | 415 | 450 | 361 | 795 |
| | | Exp. Plenum TC 17" below lid (C2) | 426 | 460 | 345 | 804 |
| | | T/W Plenum TC 17" below lid (D2) | 461 | 484 | 414 | 819 |
| | Discharge | TC 1 | 1088 | 1060 | 897 | 1127 |
| | | TC 2 | 1086 | 1061 | 911 | 1123 |
| | | Air Flow | 248 | 244 | 193 | 262 |
| | Electrode | East | 1157 | 1149 | 1077 | 1171 |
| | | West | 1138 | 1131 | 1074 | 1152 |
| | | Bottom | 1062 | 1036 | 950 | 1074 |
| | Film Cooler | Added Air | 77 | 76 | 73 | 84 |
| | | Outlet | 336 | 344 | 69 | 582 |
| Glass Resistance (ohms) | | | 0.082 | 0.082 | 0.073 | 0.094 |
| Glass Density (g/ml) | | | 2.26 | 2.28 | 2.22 | 2.41 |
| Glass Pool Depth (inches) | | | 29.2 | 29.2 | 27,7 | 30.2 |
| Electrodes | Current (A) | | 1619 | 1521 | 1176 | 1679 |
| | Voltage (V) | | 132 | 125 | 95 | 138 |
| | Power (kW) | | 214 | 191 | 122 | 223 |
| Lance Bubblers | 1 | Rate (lpm) | 26.0 | 21.9 | 6.0 | 26.3 |
| | 2 | Rate (lpm) | 26.1 | 22.0 | 6.0 | 26.3 |
| | 3 | Rate (lpm) | 13.1 | 11.0 | 3.0 | 13.2 |
| | 4 | Rate (lpm) | 13.1 | 11.0 | 3.0 | 13.3 |
| | Total Bubbling (lpm) | | 79.4 | 67.2 | 19.2 | 79.8 |

## Table 4.1. Measured DM1200 Off-Gas System Parameters.

| Test | | **1** | | | **2** | | |
|---|---|---|---|---|---|---|---|
| - | | Avg. | Min. | Max. | Avg. | Min. | Max. |
| Melter | Pressure at Level Detector Port ("water) | -2.2 | -6.1 | 0.6 | -2.1 | -4.1 | 0.0 |
| | Pressure at Instrument Port ("water) | -2.6 | -6.3 | 0.7 | -2.4 | -4.6 | -0.1 |
| | Control Air Flow Rate (scfm) | 31.8 | 24.5 | 57.6 | 26.0 | 18.4 | 70.0 |
| Film Cooler Differential Pressure (“water) | | 1.9 | 1.2 | 3.9 | 2.2 | 1.1 | 10.0 |
| SBS | Differential Pressure (“water) | 30.5 | 19.5 | 34.7 | 33.3 | 21.2 | 44.0 |
| | Inlet gas pressure (“water) | -8.8 | -13.3 | -6.2 | -9.6 | -25.3 | -6.4 |
| | Outlet gas pressure (“water) | -38.4 | -44.6 | -29.2 | NM | NM | NM |
| | Inlet gas Temp. (°C) | 289 | 210 | 402 | 305 | 252 | 420 |
| | Outlet gas Temp. (°C) | 45.3 | 41.0 | 58.6 | 43.6 | 40.4 | 50.7 |
| | C. Coil W. Inlet Temp (°C) | 19.1 | 14.2 | 28.6 | 21.1 | 18.0 | 26.3 |
| | C. Coil W. Outlet Temp (°C) | 39.1 | 33.2 | 53.0 | 36.7 | 31.9 | 43.5 |
| | Jacket W. Outlet Temp (°C) | 41.4 | 36.3 | 55.1 | 39.0 | 34.9 | 45.2 |
| | Sump Temp. (°C) | 40.1 | 35.7 | 54.0 | 37.7 | 35.2 | 46.2 |
| | Off-gas Downcomer Temp @3” (°C) | 222 | 172 | 319 | 235 | 202 | 344 |
| | Off-gas Downcomer Temp @8” (°C) | 238 | 184 | 341 | 252 | 217 | 368 |
| | Off-gas Downcomer Temp @13” (°C) | 242 | 187 | 348 | 256 | 221 | 375 |
| | Off-gas Downcomer Temp @18” (°C) | 235 | 181 | 339 | 248 | 214 | 364 |
| | Off-gas Downcomer Temp @23” (°C) | 232 | 178 | 333 | 243 | 210 | 356 |
| | Off-gas Downcomer Temp @28” (°C) | 226 | 174 | 323 | 239 | 208 | 345 |
| | Off-gas Downcomer Temp @33” (°C) | 222 | 169 | 315 | 233 | 203 | 336 |
| | Off-gas Downcomer Temp @38” (°C) | 215 | 162 | 309 | 223 | 195 | 327 |
| | Off-gas Downcomer Temp @43” (°C) | 184 | 114 | 272 | 181 | 140 | 278 |
| | Off-gas Downcomer Temp @48” (°C) | 115 | 83 | 254 | 97 | 90 | 105 |
| | Off-gas Downcomer Temp @53” (°C) | 79 | 69 | 213 | 73 | 64 | 84 |
| | C. Coil/Jacket W. Flow Rate (gal/min) | 19.9 | 10.3 | 39.5 | 33.0 | 13.4 | 39.2 |
| | Recirc. pump discharge Temp (°C) | 45.2 | 42.1 | 51.7 | 43.0 | 41.4 | 46.0 |
| | Recirc. pump discharge Pressure (psi) | 20.4 | 0.0 | 22.0 | 19.8 | 0.0 | 30.5 |
| WESP | Differential Pressure (“water) | 3.6 | 2.7 | 5.2 | 4.0 | 2.4 | 5.5 |
| | Inlet gas Temp. (°C) | 44.7 | 40.4 | 57.6 | 42.6 | 38.8 | 49.5 |
| | Outlet gas Temp. (°C) | 44.9 | 19.8 | 54.7 | 44.1 | 20.1 | 48.0 |
| | Wet Gas Flow Rate (scfm) | 259 | 226 | 314 | 257 | 186 | 316 |
| | Voltage (kV) | 29.6 | 0.0 | 29.8 | 30.4 | 0.0 | 31.8 |
| | Current (mA) | 8.9 | 0.0 | 11.5 | 10.8 | 0.0 | 13.6 |
| HEME #1 | Differential Pressure (“water) | 1.9 | 1.5 | 2.6 | 1.8 | 1.1 | 2.6 |
| | Outlet gas Temp. (°C) | 43.0 | 33.3 | 53.8 | 41.9 | 31.2 | 46.4 |
| HEPA 1 | Differential Pressure (“water) | 0.2 | 0.0 | 0.3 | 0.2 | 0.0 | 0.4 |
| | Outlet Gas Temp. (°C) | 60.3 | 57.3 | 62.3 | 60.2 | 58.1 | 62.5 |
| PBS | Inlet Gas Temp. (°C) | 82.9 | 80.1 | 84.7 | 83.1 | 80.0 | 86.4 |
| | PBS Sump Temp. (°C) | 26.3 | 21.0 | 32.7 | 27.7 | 24.7 | 30.8 |
| | Differential Pressure (“water) | 3.6 | 2.3 | 6.0 | 3.8 | 1.7 | 6.1 |
| HEME #2 | Inlet Gas Temp. (°C) | 27.6 | 22.5 | 33.4 | 29.0 | 26.6 | 31.5 |
| | Outlet Gas Temp. (°C) | 28.5 | 23.3 | 35.7 | 29.9 | 27.5 | 33.0 |
| Exhaust Stack Absolute Pressure (“water) | | -6.0 | -6.3 | -5.7 | -5.7 | -6.0 | -5.4 |

NM: not measured

## Table 4.1. Measured DM1200 Off-Gas System Parameters (continued).

| Test | | **3** | | | **4** | | |
|---|---|---|---|---|---|---|---|
| - | | Avg. | Min. | Max. | Avg. | Min. | Max. |
| Melter | Pressure at Level Detector Port ("water) | -1.9 | -3.7 | -0.1 | -1.9 | -3.4 | -0.4 |
| | Pressure at Instrument Port ("water) | -2.2 | -4.2 | -0.1 | -2.3 | -4.0 | -0.5 |
| | Control Air Flow Rate (scfm) | 19.7 | 14.3 | 55.5 | 22.4 | 18.9 | 38.8 |
| Film Cooler Differential Pressure (“water) | | 1.6 | 0.8 | 2.9 | 1.7 | 1.0 | 3.4 |
| SBS | Differential Pressure (“water) | 41.1 | 1.5 | 62.8 | 30.1 | 21.5 | 32.9 |
| | Inlet gas pressure (“water) | -7.9 | -13.1 | -3.5 | -8.6 | -14.9 | -4.8 |
| | Outlet gas pressure (“water) | NM | NM | NM | -38.6 | -45.9 | -30.4 |
| | Inlet gas Temp. (°C) | 301 | 241 | 477 | 286 | 232 | 450 |
| | Outlet gas Temp. (°C) | 43.7 | 40.7 | 52.0 | 43.9 | 41.1 | 50.8 |
| | C. Coil W. Inlet Temp (°C) | 21.9 | 19.0 | 30.9 | 21.0 | 16.4 | 29.5 |
| | C. Coil W. Outlet Temp (°C) | 36.4 | 32.5 | 46.0 | 38.2 | 35.2 | 45.6 |
| | Jacket W. Outlet Temp (°C) | 39.2 | 35.9 | 47.5 | 40.3 | 37.2 | 46.9 |
| | Sump Temp. (°C) | 37.4 | 34.7 | 46.4 | 38.6 | 35.5 | 45.7 |
| | Off-gas Downcomer Temp @3” (°C) | 230 | 192 | 367 | 220 | 183 | 356 |
| | Off-gas Downcomer Temp @8” (°C) | 246 | 205 | 393 | 236 | 197 | 382 |
| | Off-gas Downcomer Temp @13” (°C) | 249 | 207 | 398 | 240 | 201 | 390 |
| | Off-gas Downcomer Temp @18” (°C) | 242 | 201 | 387 | 233 | 195 | 381 |
| | Off-gas Downcomer Temp @23” (°C) | 239 | 199 | 379 | 229 | 193 | 375 |
| | Off-gas Downcomer Temp @28” (°C) | 237 | 198 | 369 | 225 | 192 | 363 |
| | Off-gas Downcomer Temp @33” (°C) | 235 | 198 | 361 | 220 | 192 | 360 |
| | Off-gas Downcomer Temp @38” (°C) | 226 | 190 | 348 | 211 | 170 | 355 |
| | Off-gas Downcomer Temp @43” (°C) | 220 | 194 | 334 | 187 | 108 | 347 |
| | Off-gas Downcomer Temp @48” (°C) | 155 | 91 | 281 | 152 | 91 | 336 |
| | Off-gas Downcomer Temp @53” (°C) | 71 | 56 | 95 | 112 | 72 | 273 |
| | C. Coil/Jacket W. Flow Rate (gal/min) | 33.8 | 13.8 | 39.2 | 29.4 | 13.3 | 39.0 |
| | Recirc. pump discharge Temp (°C) | 43.1 | 41.5 | 45.1 | 42.9 | 40.9 | 45.3 |
| | Recirc. pump discharge Pressure (psi) | 16.4 | 0.0 | 22.6 | 24.2 | 0.0 | 30.3 |
| WESP | Differential Pressure (“water) | 3.2 | 1.6 | 5.0 | 3.4 | 1.7 | 4.2 |
| | Inlet gas Temp. (°C) | 41.8 | 38.3 | 51.2 | 41.2 | 38.5 | 48.6 |
| | Outlet gas Temp. (°C) | 44.8 | 19.6 | 50.1 | 43.8 | 18.3 | 47.5 |
| | Wet Gas Flow Rate (scfm) | 233 | 154 | 298 | 245 | 171 | 276 |
| | Voltage (kV) | 30.0 | 0.0 | 32.1 | 30.2 | 0.0 | 30.9 |
| | Current (mA) | 11.4 | 0.0 | 13.6 | 10.0 | 0.0 | 13.2 |
| HEME #1 | Differential Pressure (“water) | 1.6 | 0.9 | 2.3 | 1.7 | 1.0 | 2.0 |
| | Outlet gas Temp. (°C) | 42.4 | 31.9 | 46.8 | 41.9 | 30.7 | 46.6 |
| HEPA 1 | Differential Pressure (“water) | 0.2 | 0.0 | 0.4 | 0.2 | 0.0 | 0.3 |
| | Outlet Gas Temp. (°C) | 60.4 | 58.3 | 62.3 | 58.2 | 37.6 | 66.8 |
| PBS | Inlet Gas Temp. (°C) | 83.9 | 78.1 | 88.2 | 77.3 | 53.2 | 82.4 |
| | PBS Sump Temp. (°C) | 28.3 | 25.4 | 35.1 | 27.2 | 23.4 | 33.1 |
| | Differential Pressure (“water) | 3.1 | 1.4 | 5.5 | 3.2 | 1.2 | 4.2 |
| HEME #2 | Inlet Gas Temp. (°C) | 29.7 | 26.8 | 36.4 | 28.4 | 24.3 | 33.8 |
| | Outlet Gas Temp. (°C) | 30.7 | 28.0 | 35.8 | 29.2 | 26.0 | 34.1 |
| Exhaust Stack Absolute Pressure (“water) | | -6.2 | -6.5 | -5.8 | -6.5 | -6.8 | -6.3 |

NM: not measured

**Table 4.2. Off-Gas Fluid Volumes.**

| | Type of Sample | Number of Blow-downs | Total Blow-down Volume (gal) |
|---|---|---|---|
| Test 1 | SBS | 12 | 481 |
| | WESP | 5 | 122 |
| | HEME 1 | 1 | NM |
| | HEME 2 | 2 | 11 |
| | PBS | 7 | 220 |
| Test 2 | SBS | 17 | 690 |
| | WESP | 4 | 81 |
| | HEME 1 | 1 | NM |
| | HEME 2 | 2 | 46 |
| | PBS | 7 | 194 |
| Test 3 | SBS | 17 | 661 |
| | WESP | 3 | 127 |
| | HEME 1 | 1 | NM |
| | HEME 2 | 1 | 54 |
| | PBS | 6 | 157 |
| Test 4 | SBS | 25 | 1000 |
| | WESP | 4 | 106 |
| | HEME 1 | 1 | NM |
| | HEME 2 | 2 | 26 |
| | PBS | 8 | 203 |

NM: not measured

## Table 5.1. Measured Feed Sample Properties.

| Source | Date | Name | % Water | pH | Density (g/ml) | Glass Yield (g/l) | Glass Yield Measured (kg/kg) | Glass Yield Target (kg/kg) | Glass Yield %Dev. |
|---|---|---|---|---|---|---|---|---|---|
| As Received Lot # 1.3 | 1/7/13 | F-12U-44A | 50.75 | 8.49 | 1.54 | 673 | 0.437 | NC | NC |
| As Received Lot # 1.5 | 1/10/13 | F-12U-44B | 56.48 | 8.77 | 1.41 | 547 | 0.388 | NC | NC |
| As Received Lot # 1.1 | 1/10/13 | F-12U-49A | 52.92 | 8.39 | 1.48 | 616 | 0.416 | NC | NC |
| As Received Lot # 1.2 | 1/10/13 | F-12U-49B | 50.22 | 8.14 | 1.50 | 666 | 0.444 | NC | NC |
| As Received Lot # 1.3 | 1/10/13 | F-12U-49C | 50.88 | 8.44 | 1.52 | 614 | 0.404 | NC | NC |
| As Received Lot # 1.4 | 1/10/13 | F-12U-49D | 51.08 | 8.13 | 1.49 | 637 | 0.428 | NC | NC |
| As Received Lot # 1.5 | 1/10/13 | F-12U-49E | 56.18 | 8.74 | 1.39 | 530 | 0.381 | NC | NC |
| As Received Lot # 1.6 | 1/10/13 | F-12U-49F | 50.86 | 8.11 | 1.49 | 644 | 0.432 | NC | NC |
| Test 1 | 1/16/13 | F-12U-94A | 59.6 | 8.76 | 1.32 | 469 | 0.356 | 0.36 | -1.22 |
| | 1/17/13 | F-12U-125A | 71.72 | 9.23 | 1.23 | 308 | 0.251 | 0.36 | -30.33 |
| Test 2 | 1/22/13 | F-12V-10A | 58.42 | 8.67 | 1.37 | 501 | 0.366 | 0.36 | 1.67 |
| | 1/23/13 | F-12V-42A | 59.76 | 8.78 | 1.36 | 483 | 0.355 | 0.36 | -1.28 |
| | 1/24/13 | F-12V-60A | 57.97 | 8.69 | 1.38 | 500 | 0.362 | 0.36 | 0.67 |
| Test 3 | 1/29/13 | F-12W-34A | 59.57 | 8.76 | 1.37 | 489 | 0.357 | 0.36 | -0.81 |
| | 1/30/13 | F-12W-63A | 60.78 | 8.76 | 1.33 | 453 | 0.341 | 0.36 | -5.33 |
| | 1/31/13 | F-12W-82A | 60.71 | 8.89 | 1.34 | 461 | 0.344 | 0.36 | -4.36 |
| Test 4 | 2/7/13 | F-12W- 115A | 60.32 | 8.70 | 1.37 | 479 | 0.350 | 0.36 | -2.81 |
| | 2/7/13 | F-12X-6A | 60.71 | 8.80 | 1.33 | 455 | 0.342 | 0.36 | -4.89 |
| | 2/8/13 | F-12X-35A | 60.24 | 8.74 | 1.34 | 475 | 0.355 | 0.36 | -1.47 |

NC – Not calculated

**Table 5.2. XRF Analyzed Compositions for As-Received Vitrified Melter Feed Samples; HWI-Al-19 Composition (wt%).**

| Constituent | Target | F-12U-44A | F-12U-44B | F-12U-49A | F-12U-49B | F-12U-49C | F-12U-49D |
|---|---|---|---|---|---|---|---|
| $Al_2O_3$ | 23.97 | 23.33 | 23.54 | 23.18 | 23.31 | 23.41 | 23.44 |
| $B_2O_3$* | 19.19 | 18.26 | 18.19 | 18.18 | 18.21 | 18.23 | 18.31 |
| BaO | 0.05 | 0.05 | 0.08 | 0.09 | 0.09 | 0.08 | 0.09 |
| $Bi_2O_3$ | 1.14 | 1.22 | 1.26 | 1.35 | 1.26 | 1.29 | 1.23 |
| CaO | 5.58 | 5.58 | 5.53 | 5.71 | 5.71 | 5.68 | 5.52 |
| CdO | 0.02 | 0.04 | 0.04 | 0.03 | 0.03 | 0.04 | 0.03 |
| $Cr_2O_3$ | 0.52 | 0.50 | 0.52 | 0.52 | 0.50 | 0.54 | 0.52 |
| F$ | 0.67 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| $Fe_2O_3$ | 5.90 | 6.05 | 6.28 | 6.42 | 6.18 | 6.24 | 6.12 |
| $K_2O$ | 0.14 | 0.22 | 0.19 | 0.12 | 0.16 | 0.12 | 0.15 |
| $Li_2O$* | 3.57 | 3.50 | 3.45 | 3.58 | 3.57 | 3.58 | 3.53 |
| MgO | 0.12 | 0.24 | 0.18 | 0.23 | 0.22 | 0.22 | 0.24 |
| MnO | § | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 |
| $Na_2O$ | 9.58 | 9.99 | 9.28 | 9.32 | 8.97 | 9.48 | 9.57 |
| NiO | 0.40 | 0.45 | 0.46 | 0.46 | 0.44 | 0.45 | 0.44 |
| $P_2O_5$ | 1.05 | 1.08 | 1.08 | 1.15 | 1.12 | 1.12 | 1.10 |
| PbO | 0.41 | 0.42 | 0.46 | 0.45 | 0.39 | 0.45 | 0.40 |
| $SiO_2$ | 27.00 | 28.02 | 28.43 | 28.15 | 28.77 | 28.02 | 28.25 |
| $SO_3$ | 0.20 | 0.20 | 0.21 | 0.21 | 0.19 | 0.20 | 0.19 |
| $TiO_2$ | 0.01 | 0.06 | 0.05 | 0.06 | 0.06 | 0.05 | 0.06 |
| ZnO | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.08 | 0.08 |
| $ZrO_2$ | 0.39 | 0.38 | 0.39 | 0.40 | 0.40 | 0.40 | 0.39 |
| Sum | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

§ - Not a target constituent
* - DCP-AES measured values
$ - F value estimated from XRF measurements on discharge glasses.

**Table 5.2. XRF Analyzed Compositions for As-Received Vitrified Melter Feed Samples; HWI-Al-19 Composition (wt%) (continued).**

| Constituent | Target | F-12U-49E | F-12U-49F | Average | % Dev. |
|---|---|---|---|---|---|
| $Al_2O_3$ | 23.97 | 23.37 | 23.39 | 23.37 | -2.50 |
| $B_2O_3$* | 19.19 | 18.28 | 18.45 | 18.26 | -4.84 |
| BaO | 0.05 | 0.09 | 0.08 | 0.08 | NC |
| $Bi_2O_3$ | 1.14 | 1.24 | 1.28 | 1.27 | 11.0 |
| CaO | 5.58 | 5.59 | 5.55 | 5.61 | 0.50 |
| CdO | 0.02 | 0.04 | 0.04 | 0.04 | NC |
| $Cr_2O_3$ | 0.52 | 0.50 | 0.50 | 0.51 | NC |
| F$ | 0.67 | 0.30 | 0.30 | 0.30 | NC |
| $Fe_2O_3$ | 5.90 | 6.36 | 6.08 | 6.22 | 5.35 |
| $K_2O$ | 0.14 | 0.11 | <0.01 | 0.13 | NC |
| $Li_2O$* | 3.57 | 3.54 | 3.55 | 3.54 | -0.92 |
| MgO | 0.12 | 0.22 | 0.18 | 0.22 | NC |
| MnO | § | 0.03 | 0.02 | 0.02 | NC |
| $Na_2O$ | 9.58 | 9.35 | 9.39 | 9.42 | -1.71 |
| NiO | 0.40 | 0.43 | 0.45 | 0.45 | NC |
| $P_2O_5$ | 1.05 | 1.07 | 1.13 | 1.11 | 5.28 |
| PbO | 0.41 | 0.44 | 0.44 | 0.43 | NC |
| $SiO_2$ | 27.00 | 28.34 | 28.43 | 28.30 | 4.81 |
| $SO_3$ | 0.20 | 0.20 | 0.19 | 0.20 | NC |
| $TiO_2$ | 0.01 | 0.05 | 0.06 | 0.06 | NC |
| ZnO | 0.08 | 0.08 | 0.08 | 0.08 | NC |
| $ZrO_2$ | 0.39 | 0.38 | 0.39 | 0.39 | NC |
| Sum | 100.00 | 100.00 | 100.00 | 100.00 | NC |

§ - Not a target constituent
* - DCP-AES measured values
$ - F value estimated from XRF measurements on discharge glasses.
NC – Not calculated

**Table 5.3. XRF Analyzed Compositions of Vitrified Melter Feed Sampled During DM1200 Tests (wt%).**

| Test | | 1 | | 2 | | | 3 |
|---|---|---|---|---|---|---|---|
| Constituent | Target | F-12U-94A | F-12U-125A | F-12V-10A | F-12V-42A | F-12V-60A | F-12W-34A |
| $Al_2O_3$ | 23.97 | 23.68 | 24.23 | 23.19 | 23.57 | 22.96 | 23.22 |
| $B_2O_3$* | 19.19 | 18.14 | 17.21 | 18.38 | 18.20 | 18.10 | 18.62 |
| BaO | 0.05 | 0.06 | 0.09 | 0.09 | 0.09 | 0.08 | 0.08 |
| $Bi_2O_3$ | 1.14 | 1.26 | 1.31 | 1.25 | 1.28 | 1.25 | 1.24 |
| CaO | 5.58 | 5.60 | 5.71 | 5.45 | 5.63 | 5.74 | 5.48 |
| CdO | 0.02 | 0.03 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |
| $Cr_2O_3$ | 0.52 | 0.50 | 0.52 | 0.47 | 0.47 | 0.47 | 0.51 |
| F$ | 0.67 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| $Fe_2O_3$ | 5.90 | 6.37 | 6.49 | 5.93 | 6.13 | 6.03 | 5.79 |
| $K_2O$ | 0.14 | 0.16 | 0.12 | 0.20 | 0.03 | 0.17 | 0.03 |
| $Li_2O$* | 3.57 | 3.54 | 3.52 | 3.54 | 3.53 | 4.28 | 3.59 |
| MgO | 0.12 | 0.22 | 0.23 | 0.23 | 0.22 | 0.22 | 0.27 |
| MnO | § | 0.02 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 |
| $Na_2O$ | 9.58 | 9.36 | 8.88 | 9.78 | 9.37 | 9.61 | 10.10 |
| NiO | 0.40 | 0.45 | 0.46 | 0.44 | 0.45 | 0.45 | 0.45 |
| $P_2O_5$ | 1.05 | 1.09 | 1.11 | 1.14 | 1.12 | 1.10 | 1.01 |
| PbO | 0.41 | 0.41 | 0.53 | 0.41 | 0.41 | 0.43 | 0.42 |
| $SiO_2$ | 27.00 | 28.08 | 28.52 | 28.44 | 28.44 | 28.07 | 28.11 |
| $SO_3$ | 0.20 | 0.18 | 0.17 | 0.18 | 0.18 | 0.16 | 0.19 |
| $TiO_2$ | 0.01 | 0.06 | 0.04 | 0.06 | 0.05 | 0.05 | 0.05 |
| ZnO | 0.08 | 0.09 | 0.08 | 0.07 | 0.08 | 0.09 | 0.09 |
| $ZrO_2$ | 0.39 | 0.40 | 0.39 | 0.38 | 0.39 | 0.38 | 0.38 |
| Sum | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

§ - Not a target constituent
* - DCP-AES measured values
$ - F value estimated from XRF measurements on discharge glasses.

**Table 5.3. XRF Analyzed Compositions of Vitrified Melter Feed Sampled During DM1200 Tests, (wt%) (continued).**

| Test | | 3 | | 4 | | | Average | % Dev. |
|---|---|---|---|---|---|---|---|---|
| Constituent | Target | F-12W-63A | F-12W-82A | F-12W-115A | F-12X-6A | F-12X-35A | | |
| $Al_2O_3$ | 23.97 | 23.07 | 23.24 | 23.06 | 23.13 | 23.01 | 23.30 | -2.79 |
| $B_2O_3$* | 19.19 | 18.44 | 18.35 | 18.46 | 18.50 | 18.35 | 18.25 | -4.91 |
| BaO | 0.05 | 0.09 | 0.09 | 0.09 | 0.08 | 0.09 | 0.08 | NC |
| $Bi_2O_3$ | 1.14 | 1.28 | 1.28 | 1.25 | 1.22 | 1.29 | 1.26 | 10.9 |
| CaO | 5.58 | 5.64 | 5.65 | 5.68 | 5.59 | 5.69 | 5.62 | 0.78 |
| CdO | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | NC |
| $Cr_2O_3$ | 0.52 | 0.50 | 0.52 | 0.52 | 0.50 | 0.50 | 0.50 | NC |
| F$ | 0.67 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | NC |
| $Fe_2O_3$ | 5.90 | 5.94 | 5.95 | 5.81 | 5.83 | 6.00 | 6.02 | 2.09 |
| $K_2O$ | 0.14 | 0.14 | 0.15 | 0.03 | 0.19 | 0.14 | 0.12 | NC |
| $Li_2O$* | 3.57 | 3.48 | 3.31 | 3.52 | 3.54 | 3.50 | 3.58 | 0.19 |
| MgO | 0.12 | 0.25 | 0.26 | 0.26 | 0.24 | 0.25 | 0.24 | NC |
| MnO | § | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | NC |
| $Na_2O$ | 9.58 | 9.85 | 9.83 | 9.91 | 9.88 | 9.76 | 9.67 | 0.90 |
| NiO | 0.40 | 0.45 | 0.45 | 0.43 | 0.45 | 0.46 | 0.45 | NC |
| $P_2O_5$ | 1.05 | 1.08 | 1.06 | 1.08 | 1.09 | 1.04 | 1.08 | 3.22 |
| PbO | 0.41 | 0.40 | 0.41 | 0.42 | 0.40 | 0.42 | 0.42 | NC |
| $SiO_2$ | 27.00 | 28.30 | 28.35 | 28.38 | 28.26 | 28.41 | 28.30 | 4.82 |
| $SO_3$ | 0.20 | 0.22 | 0.22 | 0.20 | 0.22 | 0.21 | 0.19 | NC |
| $TiO_2$ | 0.01 | 0.05 | 0.05 | 0.06 | 0.05 | 0.04 | 0.05 | NC |
| ZnO | 0.08 | 0.08 | 0.07 | 0.09 | 0.08 | 0.09 | 0.08 | NC |
| $ZrO_2$ | 0.39 | 0.40 | 0.38 | 0.39 | 0.37 | 0.39 | 0.39 | NC |
| Sum | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | NC |

§ - Not a target constituent
* - DCP-AES measured values
$ - F value estimated from XRF measurements on discharge glasses.
NC – Not calculated

## Table 5.4. Listing of Glass and Discharged Masses during DM1200 Tests.

<table>
<tr><th>Test</th><th>Date</th><th>Name</th><th>Mass (kg)</th><th>Cumulative Mass (kg)</th></tr>
<tr><td rowspan="28">1</td><td rowspan="6">1/15/2013</td><td>G-12U-67A</td><td rowspan="7">484.5</td><td rowspan="7">484.5</td></tr>
<tr><td>G-12U-67B</td></tr>
<tr><td>G-12U-68A</td></tr>
<tr><td>G-12U-68B</td></tr>
<tr><td>G-12U-78A</td></tr>
<tr><td>G-12U-80A</td></tr>
<tr><td rowspan="15">1/16/2013</td><td>G-12U-81A</td></tr>
<tr><td>G-12U-81B</td><td rowspan="4">426.5</td><td rowspan="4">911.0</td></tr>
<tr><td>G-12U-83A</td></tr>
<tr><td>G-12U-83B</td></tr>
<tr><td>G-12U-84A</td></tr>
<tr><td>G-12U-85A</td><td rowspan="5">484.0</td><td rowspan="5">1395.0</td></tr>
<tr><td>G-12U-85B</td></tr>
<tr><td>G-12U-94A</td></tr>
<tr><td>G-12U-95A</td></tr>
<tr><td>G-12U-95B</td></tr>
<tr><td>G-12U-96A</td><td rowspan="6">477.0</td><td rowspan="6">1872.0</td></tr>
<tr><td>G-12U-97A</td></tr>
<tr><td>G-12U-97B</td></tr>
<tr><td>G-12U-99A</td></tr>
<tr><td>G-12U-110A</td></tr>
<tr><td rowspan="7">1/17/2013</td><td>G-12U-112A</td></tr>
<tr><td>G-12U-112B</td><td rowspan="6">494.0</td><td rowspan="6">2366.0</td></tr>
<tr><td>G-12U-113A</td></tr>
<tr><td>G-12U-114A</td></tr>
<tr><td>G-12U-114B</td></tr>
<tr><td>G-12U-124A</td></tr>
<tr><td>G-12U-125A</td></tr>
<tr><td rowspan="11">2</td><td rowspan="7">1/22/2013</td><td>G-12U-151A</td><td rowspan="5">467.5</td><td rowspan="5">2833.5</td></tr>
<tr><td>G-12U-151B</td></tr>
<tr><td>G-12V-9A</td></tr>
<tr><td>G-12V-10A</td></tr>
<tr><td>G-12V-10B</td></tr>
<tr><td>G-12V-11A</td><td rowspan="6">482.5</td><td rowspan="6">3316.0</td></tr>
<tr><td>G-12V-12A</td></tr>
<tr><td rowspan="4">1/23/2013</td><td>G-12V-13A</td></tr>
<tr><td>G-12V-14A</td></tr>
<tr><td>G-12V-14B</td></tr>
<tr><td>G-12V-23A</td></tr>
</table>

## Table 5.4. Listing of Glass and Discharged Masses during DM1200 Tests (continued).

| Test | Date | Name | Mass (kg) | Cumulative Mass (kg) |
|---|---|---|---|---|
| 2 | 1/23/2013 | G-12V-24A | 473.5 | 3789.5 |
| | | G-12V-24B | | |
| | | G-12V-25A | | |
| | | G-12V-27A | | |
| | | G-12V-28A | | |
| | | G-12V-28B | 501.0 | 4290.5 |
| | | G-12V-29A | | |
| | | G-12V-39A | | |
| | | G-12V-39B | | |
| | | G-12V-41A | | |
| | | G-12V-42A | | |
| | | G-12V-43A | 490.0 | 4780.5 |
| | | G-12V-43B | | |
| | | G-12V-45A | | |
| | 1/24/2013 | G-12V-46A | | |
| | | G-12V-47A | | |
| | | G-12V-56A | | |
| | | G-12V-56B | | |
| | | G-12V-57A | 435.0 | 5215.5 |
| | | G-12V-57B | | |
| | | G-12V-57C | | |
| | | G-12V-59A | | |
| | | G-12V-59B | | |
| | | G-12V-60A | | |
| | | G-12V-60B | | |
| | | G-12V-61A | | |
| | | G-12V-61B | | |
| | | G-12V-61C | 405.5 | 5621.0 |
| | | G-12V-63A | | |
| | | G-12V-63B | | |
| | | G-12V-63C | | |
| | | G-12V-72A | | |
| | | G-12V-73A | | |
| 3 | 1/29/2013 | G-12W-29A | 482.5 | 6103.5 |
| | | G-12W-30A | | |
| | | G-12W-31A | | |
| | | G-12W-32A | | |
| | | G-12W-32B | | |
| | | G-12W-33A | | |
| | | G-12W-34A | | |
| | | G-12W-35A | | |
| | | G-12W-35B | | |
| | | G-12W-36A | | |

## Table 5.4. Listing of Glass and Discharged Masses during DM1200 Tests (continued).

| Test | Date | Name | Mass (kg) | Cumulative Mass (kg) |
|---|---|---|---|---|
| 3 | 1/30/2013 | G-12W-37A | 495.5 | 6599.0 |
| | | G-12W-38A | | |
| | | G-12W-38B | | |
| | | G-12W-39A | | |
| | | G-12W-39B | 439.0 | 7038.0 |
| | | G-12W-40A | | |
| | | G-12W-43A | | |
| | | G-12W-43B | | |
| | | G-12W-44A | | |
| | | G-12W-44B | | |
| | | G-12W-47A | | |
| | | G-12W-47B | 496.0 | 7534.0 |
| | | G-12W-57A | | |
| | | G-12W-57B | | |
| | | G-12W-58A | | |
| | | G-12W-58B | | |
| | | G-12W-59A | | |
| | | G-12W-59B | | |
| | | G-12W-61A | | |
| | | G-12W-61B | | |
| | | G-12W-62A | 484.0 | 8018.0 |
| | | G-12W-63A | | |
| | | G-12W-63B | | |
| | | G-12W-64A | | |
| | | G-12W-64B | | |
| | 1/31/2013 | G-12W-65A | | |
| | | G-12W-65B | | |
| | | G-12W-66A | | |
| | | G-12W-76A | | |
| | | G-12W-76B | 497.5 | 8515.5 |
| | | G-12W-78A | | |
| | | G-12W-79A | | |
| | | G-12W-79B | | |
| | | G-12W-80A | | |
| | | G-12W-80B | | |
| | | G-12W-81A | | |
| | | G-12W-81B | | |
| | | G-12W-82A | | |
| | | G-12W-82B | | |
| | | G-12W-91A | 116.0 | 8631.5 |
| | | G-12W-91B | | |

## Table 5.4. Listing of Glass and Discharged Masses during DM1200 Tests (continued).

| Test | Date | Name | Mass (kg) | Cumulative Mass (kg) |
|---|---|---|---|---|
| 4 | 2/6/2013 | G-12W-111A | 368.5 | 9000.0 |
| | | G-12W-113A | | |
| | | G-12W-114A | | |
| | | G-12W-115A | | |
| | | G-12W-115B | | |
| | | G-12W-116A | | |
| | | G-12W-125A | | |
| | | G-12W-126A | 443.0 | 9443.0 |
| | 2/7/2013 | G-12W-126B | | |
| | | G-12W-127A | | |
| | | G-12W-128A | | |
| | | G-12W-128B | | |
| | | G-12W-137A | | |
| | | G-12W-138A | | |
| | | G-12W-138B | | |
| | | G-12W-140A | | |
| | | G-12W-140B | | |
| | | G-12W-142A | 494.5 | 9937.5 |
| | | G-12W-143A | | |
| | | G-12W-143B | | |
| | | G-12W-145A | | |
| | | G-12W-146A | | |
| | | G-12W-146B | | |
| | | G-12W-146C | | |
| | | G-12W-147A | | |
| | | G-12W-147B | 479.0 | 10416.5 |
| | | G-12W-149A | | |
| | | G-12W-151A | | |
| | | G-12W-151B | | |
| | | G-12X-6A | | |
| | | G-12X-6B | | |
| | | G-12X-7A | | |
| | | G-12X-7B | | |
| | | G-12X-11A | 468.5 | 10885.0 |
| | | G-12X-11B | | |
| | | G-12X-20A | | |
| | 2/8/2013 | G-12X-20B | | |
| | | G-12X-21A | | |
| | | G-12X-30A | | |
| | | G-12X-30B | | |
| | | G-12X-31A | | |
| | | G-12X-31B | | |
| | | G-12X-32A | | |

**Table 5.4. Listing of Glass and Discharged Masses during DM1200 Tests (continued).**

| Test | Date | Name | Mass (kg) | Cumulative Mass (kg) |
|---|---|---|---|---|
| 4 | 2/8/2013 | G-12X-32B | 456.0 | 11341.0 |
| | | G-12X-33A | | |
| | | G-12X-33B | | |
| | | G-12X-33C | | |
| | | G-12X-34A | | |
| | | G-12X-34B | | |
| | | G-12X-35A | | |
| | | G-12X-35B | | |
| | | G-12X-35C | | |
| | | G-12X-36A | 479.0 | 11820.0 |
| | | G-12X-36B | | |
| | | G-12X-38A | | |
| | | G-12X-38B | | |
| | | G-12X-39A | | |
| | | G-12X-39B | | |
| | | G-12X-41A | | |

**Table 5.5. XRF Analyzed Compositions for Glass Discharged During DM1200 Tests (wt%).**

| Test | 1 | | | | | | 2 | |
|---|---|---|---|---|---|---|---|---|
| Mass (kg) | Target | 484.5 | 911.0 | 1395.0 | 1872.00 | 2366.0 | 2833.50 | 3316.0 |
| Constituents | | G-12U-80A | G-12U-84A | G-12U-95B | G-12U-112A | G-12U-125A | G-12V-10B | G-12V-23A |
| $Al_2O_3$ | 23.97 | 23.69 | 23.79 | 23.61 | 23.68 | 23.65 | 23.68 | 23.85 |
| $B_2O_3$* | 19.19 | 17.21 | 17.43 | 17.62 | 17.77 | 17.90 | 17.99 | 18.06 |
| BaO | 0.05 | 0.11 | 0.08 | 0.07 | 0.07 | 0.09 | 0.08 | 0.09 |
| $Bi_2O_3$ | 1.14 | 1.17 | 1.22 | 1.26 | 1.24 | 1.20 | 1.28 | 1.22 |
| CaO | 5.58 | 5.19 | 5.34 | 5.39 | 5.37 | 5.49 | 5.44 | 5.39 |
| CdO | 0.02 | 0.04 | 0.04 | 0.04 | 0.03 | 0.04 | 0.03 | 0.03 |
| $Cr_2O_3$ | 0.52 | 0.29 | 0.32 | 0.36 | 0.38 | 0.41 | 0.45 | 0.43 |
| F | 0.67 | 0.13# | 0.17 | 0.23# | 0.25 | 0.26# | 0.23# | 0.25 |
| $Fe_2O_3$ | 5.90 | 5.99 | 6.16 | 6.18 | 6.11 | 6.15 | 6.09 | 5.94 |
| $K_2O$ | 0.14 | 0.18 | 0.13 | 0.16 | 0.13 | 0.06 | 0.03 | 0.12 |
| $Li_2O$* | 3.57 | 3.39 | 3.42 | 3.45 | 3.48 | 3.50 | 3.51 | 3.52 |
| MgO | 0.12 | 0.27 | 0.23 | 0.20 | 0.25 | 0.23 | 0.21 | 0.21 |
| MnO | § | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 |
| $Na_2O$ | 9.58 | 10.10 | 9.87 | 9.80 | 9.74 | 9.45 | 9.58 | 9.53 |
| NiO | 0.40 | 0.26 | 0.31 | 0.34 | 0.34 | 0.38 | 0.34 | 0.35 |
| $P_2O_5$ | 1.05 | 1.10 | 1.10 | 1.10 | 1.14 | 1.08 | 1.12 | 1.11 |
| PbO | 0.41 | 0.36 | 0.39 | 0.40 | 0.39 | 0.40 | 0.42 | 0.42 |
| $SiO_2$ | 27.00 | 29.57 | 28.99 | 28.84 | 28.76 | 28.85 | 28.73 | 28.71 |
| $SO_3$ | 0.20 | 0.09 | 0.13 | 0.13 | 0.13 | 0.16 | 0.12 | 0.13 |
| $TiO_2$ | 0.01 | 0.12 | 0.11 | 0.10 | 0.09 | 0.08 | 0.07 | 0.07 |
| ZnO | 0.08 | 0.16 | 0.15 | 0.13 | 0.12 | 0.11 | 0.11 | 0.10 |
| $ZrO_2$ | 0.39 | 0.56 | 0.55 | 0.51 | 0.47 | 0.47 | 0.45 | 0.43 |
| Sum | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

* Values calculated from $B_2O_3$ and $Li_2O$ analysis by DCP-AES on the last discharged glass sample from previous test and average feed sample analysis using a simple well stirred tank model

§ - Not a target constituent

# - F was measured by XRF, values for other samples calculated by interpolation

**Table 5.5. XRF Analyzed Compositions for Glass Discharged During DM1200 Tests (wt%) (continued).**

| Test | 2 | | | | | | 3 | |
|---|---|---|---|---|---|---|---|---|
| Mass (kg) | Target | 3789.5 | 4290.50 | 4780.5 | 5215.50 | 5621.0 | 6103.5 | 6599.0 |
| Constituents | | G-12V-28A | G-12V-42A | G-12V-56B | G-12V-61B | G-12V-73A | G-12W-33A | G-12W-39A |
| $Al_2O_3$ | 23.97 | 23.77 | 23.59 | 23.51 | 23.66 | 23.58 | 23.57 | 23.28 |
| $B_2O_3$* | 19.19 | 18.11 | 18.16 | 18.19 | 18.22 | 18.24 | 18.25 | 18.27 |
| BaO | 0.05 | 0.10 | 0.11 | 0.07 | 0.10 | 0.07 | 0.08 | 0.07 |
| $Bi_2O_3$ | 1.14 | 1.20 | 1.19 | 1.23 | 1.28 | 1.26 | 1.25 | 1.27 |
| CaO | 5.58 | 5.42 | 5.46 | 5.50 | 5.57 | 5.55 | 5.56 | 5.68 |
| CdO | 0.02 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| $Cr_2O_3$ | 0.52 | 0.42 | 0.41 | 0.43 | 0.45 | 0.43 | 0.47 | 0.51 |
| F | 0.67 | 0.28# | 0.28 | 0.29# | 0.28 | 0.28# | 0.27# | 0.29 |
| $Fe_2O_3$ | 5.90 | 6.01 | 5.82 | 5.98 | 5.98 | 5.95 | 5.65 | 5.90 |
| $K_2O$ | 0.14 | 0.15 | 0.15 | 0.21 | 0.19 | 0.16 | 0.11 | 0.04 |
| $Li_2O$* | 3.57 | 3.53 | 3.54 | 3.54 | 3.55 | 3.55 | 3.55 | 3.56 |
| MgO | 0.12 | 0.22 | 0.23 | 0.17 | 0.21 | 0.22 | 0.26 | 0.26 |
| MnO | § | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 | 0.03 | 0.03 |
| $Na_2O$ | 9.58 | 9.55 | 9.63 | 9.63 | 9.33 | 9.56 | 10.03 | 9.76 |
| NiO | 0.40 | 0.35 | 0.33 | 0.38 | 0.37 | 0.36 | 0.33 | 0.38 |
| $P_2O_5$ | 1.05 | 1.09 | 1.11 | 1.11 | 1.12 | 1.12 | 1.06 | 1.14 |
| PbO | 0.41 | 0.37 | 0.40 | 0.40 | 0.41 | 0.40 | 0.40 | 0.41 |
| $SiO_2$ | 27.00 | 28.67 | 28.82 | 28.61 | 28.51 | 28.48 | 28.39 | 28.41 |
| $SO_3$ | 0.20 | 0.13 | 0.14 | 0.13 | 0.14 | 0.16 | 0.14 | 0.16 |
| $TiO_2$ | 0.01 | 0.07 | 0.06 | 0.05 | 0.07 | 0.07 | 0.05 | 0.06 |
| ZnO | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.09 |
| $ZrO_2$ | 0.39 | 0.42 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.42 |
| Sum | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

* Values calculated from $B_2O_3$ and $Li_2O$ analysis by DCP-AES on the last discharged glass sample from previous test and average feed sample analysis using a simple well stirred tank model
§ - Not a target constituent
# - F was measured by XRF, values for other samples calculated by interpolation

**Table 5.5. XRF Analyzed Compositions for Glass Discharged During DM1200 Tests (wt%) (continued).**

| Test | 3 | | | | | | 4 | |
|---|---|---|---|---|---|---|---|---|
| Mass (kg) | Target | 7038.0 | 7534.0 | 8018.0 | 8515.5 | 8631.5 | 9000.0 | 9443.0 |
| Constituents | | G-12W-47A | G-12W-61B | G-12W-76A | G-12W 82B | G-12W-91B | G-12W-125A | G-12W-140B |
| $Al_2O_3$ | 23.97 | 23.19 | 23.31 | 23.54 | 23.57 | 23.27 | 23.19 | 23.28 |
| $B_2O_3$* | 19.19 | 18.28 | 18.29 | 18.29 | 18.30 | 18.30 | 18.30 | 18.30 |
| BaO | 0.05 | 0.10 | 0.06 | 0.07 | 0.09 | 0.08 | 0.08 | 0.12 |
| $Bi_2O_3$ | 1.14 | 1.24 | 1.26 | 1.20 | 1.15 | 1.24 | 1.25 | 1.28 |
| CaO | 5.58 | 5.64 | 5.72 | 5.47 | 5.45 | 5.69 | 5.65 | 5.62 |
| CdO | 0.02 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 |
| $Cr_2O_3$ | 0.52 | 0.47 | 0.46 | 0.46 | 0.46 | 0.46 | 0.44 | 0.45 |
| F | 0.67 | 0.30# | 0.29 | 0.29# | 0.35 | 0.37# | 0.25# | 0.25 |
| $Fe_2O_3$ | 5.90 | 5.83 | 5.81 | 5.50 | 5.35 | 5.74 | 5.81 | 5.70 |
| $K_2O$ | 0.14 | 0.15 | 0.03 | 0.17 | 0.14 | 0.12 | 0.16 | 0.13 |
| $Li_2O$* | 3.57 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 |
| MgO | 0.12 | 0.26 | 0.25 | 0.18 | 0.26 | 0.26 | 0.25 | 0.25 |
| MnO | § | 0.03 | 0.03 | 0.04 | 0.02 | 0.02 | 0.03 | 0.03 |
| $Na_2O$ | 9.58 | 10.01 | 9.86 | 10.17 | 10.20 | 9.64 | 9.96 | 9.91 |
| NiO | 0.40 | 0.40 | 0.39 | 0.38 | 0.34 | 0.41 | 0.40 | 0.37 |
| $P_2O_5$ | 1.05 | 1.08 | 1.07 | 1.12 | 1.07 | 1.09 | 1.09 | 1.04 |
| PbO | 0.41 | 0.42 | 0.41 | 0.40 | 0.38 | 0.40 | 0.39 | 0.41 |
| $SiO_2$ | 27.00 | 28.31 | 28.44 | 28.45 | 28.63 | 28.62 | 28.47 | 28.60 |
| $SO_3$ | 0.20 | 0.15 | 0.16 | 0.16 | 0.16 | 0.16 | 0.14 | 0.14 |
| $TiO_2$ | 0.01 | 0.06 | 0.05 | 0.05 | 0.04 | 0.06 | 0.06 | 0.05 |
| ZnO | 0.08 | 0.10 | 0.09 | 0.09 | 0.08 | 0.09 | 0.08 | 0.08 |
| $ZrO_2$ | 0.39 | 0.40 | 0.42 | 0.39 | 0.37 | 0.40 | 0.39 | 0.40 |
| Sum | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

* Values calculated from $B_2O_3$ and $Li_2O$ analysis by DCP-AES on the last discharged glass sample from previous test and average feed sample analysis using a simple well stirred tank model
§ - Not a target constituent
\# - F was measured by XRF, values for other samples calculated by interpolation

**Table 5.5. XRF Analyzed Compositions for Glass Discharged During DM1200 Tests (wt%) (continued).**

| Test | 4 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass (kg) | Target | 9937.5 | 10416.5 | 10885.0 | 11341.0 | 11820.0 | Average | % Dev. |
| Constituents | | G-12W-147A | G-12X-7B | G-12X-32A | G-12X-35C | G-12X-41A | | |
| $Al_2O_3$ | 23.97 | 23.23 | 23.26 | 23.40 | 23.15 | 23.04 | 23.47 | -2.08 |
| $B_2O_3$* | 19.19 | 18.31 | 18.31 | 18.31 | 18.31 | 18.31 | 18.12 | NC |
| BaO | 0.05 | 0.10 | 0.08 | 0.10 | 0.09 | 0.10 | 0.09 | NC |
| $Bi_2O_3$ | 1.14 | 1.25 | 1.24 | 1.24 | 1.30 | 1.27 | 1.24 | 8.57 |
| CaO | 5.58 | 5.68 | 5.63 | 5.55 | 5.71 | 5.69 | 5.53 | -0.86 |
| CdO | 0.02 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | NC |
| $Cr_2O_3$ | 0.52 | 0.45 | 0.46 | 0.46 | 0.44 | 0.47 | 0.43 | NC |
| F | 0.67 | 0.26# | 0.28 | 0.29# | 0.30 | 0.31# | 0.27 | NC |
| $Fe_2O_3$ | 5.90 | 5.72 | 5.59 | 5.68 | 5.86 | 5.89 | 5.86 | -0.68 |
| $K_2O$ | 0.14 | 0.15 | 0.16 | 0.14 | 0.17 | 0.18 | 0.13 | NC |
| $Li_2O$* | 3.57 | 3.56 | 3.56 | 3.56 | 3.56 | 3.56 | 3.53 | NC |
| MgO | 0.12 | 0.25 | 0.24 | 0.23 | 0.24 | 0.24 | 0.23 | NC |
| MnO | § | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | NC |
| $Na_2O$ | 9.58 | 10.09 | 10.08 | 10.11 | 9.66 | 10.04 | 9.82 | 2.47 |
| NiO | 0.40 | 0.35 | 0.39 | 0.36 | 0.36 | 0.40 | 0.36 | NC |
| $P_2O_5$ | 1.05 | 1.07 | 1.11 | 1.06 | 1.08 | 1.06 | 1.09 | 4.09 |
| PbO | 0.41 | 0.41 | 0.40 | 0.40 | 0.43 | 0.42 | 0.40 | NC |
| $SiO_2$ | 27.00 | 28.40 | 28.44 | 28.40 | 28.58 | 28.25 | 28.61 | 5.96 |
| $SO_3$ | 0.20 | 0.15 | 0.15 | 0.14 | 0.17 | 0.18 | 0.14 | NC |
| $TiO_2$ | 0.01 | 0.06 | 0.07 | 0.05 | 0.07 | 0.05 | 0.07 | NC |
| ZnO | 0.08 | 0.08 | 0.09 | 0.09 | 0.08 | 0.09 | 0.10 | NC |
| $ZrO_2$ | 0.39 | 0.39 | 0.39 | 0.39 | 0.40 | 0.41 | 0.43 | NC |
| Sum | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | NC |

* Values calculated from $B_2O_3$ and $Li_2O$ analysis by DCP-AES on the last discharged glass sample from previous test and average feed sample analysis using a simple well stirred tank model
§ - Not a target constituent
# - F was measured by XRF, values for other samples calculated by interpolation

## Table 6.1. Results from Melter Off-Gas Emission Samples.

| | | Test 1 1/16/2013 18:21 – 19:21 26.3% Moisture, 99.6% Isokinetic | | | | Test 2 1/23/2013 20:01 – 21:01 29.2% Moisture, 101% Isokinetic | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Feed# (mg/min) | Output (mg/min) | % Emitted | DF | Feed# (mg/min) | Output (mg/min) | % Emitted | DF |
| Particulate | Total$ | 2458333 | 3160 | 0.13 | 778 | 2983796 | 4173 | 0.14 | 715 |
| | Al | 112223 | 87.9 | 0.08 | 1277 | 136211 | 130 | 0.10 | 1045 |
| | B | 52706 | 252 | 0.48 | 209 | 63972 | 369 | 0.58 | 173 |
| | Ba | 396 | 0.97 | 0.24 | 410 | 481 | 1.27 | 0.26 | 379 |
| | Bi | 9050 | 46.0 | 0.51 | 197 | 10984 | 57.7 | 0.52 | 191 |
| | Ca | 35299 | 57.6 | 0.16 | 613 | 42844 | 70.9 | 0.17 | 605 |
| | Cd | 158 | 1.08 | 0.68 | 147 | 192 | 1.40 | 0.73 | 137 |
| | Cr | 3149 | 26.1 | 0.83 | 121 | 3822 | 32.0 | 0.84 | 119 |
| | F* | 5930 | 845 | 14.2 | 7.02 | 7197 | 1156 | 16.1 | 6.22 |
| | Fe | 36511 | 103 | 0.28 | 355 | 44315 | 129 | 0.29 | 342 |
| | K | 1029 | 9.29 | 0.90 | 111 | 1248 | 12.1 | 0.97 | 103 |
| | Li | 14676 | 48.3 | 0.33 | 304 | 17813 | 64.7 | 0.36 | 275 |
| | Mg | 640 | 3.66 | 0.57 | 175 | 777 | 4.56 | 0.59 | 171 |
| | Na | 62904 | 259 | 0.41 | 243 | 76349 | 326 | 0.43 | 234 |
| | Ni | 2782 | 6.08 | 0.22 | 458 | 3376 | 7.42 | 0.22 | 455 |
| | P | 4057 | 1.04 | 0.03 | 3893 | 4925 | 1.26 | 0.03 | 3910 |
| | Pb | 3368 | 19.6 | 0.58 | 172 | 4088 | 27.6 | 0.68 | 148 |
| | S* | 709 | 29.4 | 4.14 | 187 | 861 | 114 | 13.2 | 7.58 |
| | Si | 111701 | 150 | 0.13 | 747 | 135577 | 164 | 0.12 | 825 |
| | Ti | 53 | 1.17 | 2.21 | 45.2 | 64 | 1.33 | 2.06 | 48.6 |
| | Zn | 569 | 1.60 | 0.28 | 354 | 690 | 1.37 | 0.20 | 503 |
| | Zr | 2555 | 2.75 | 0.11 | 930 | 3101 | 3.25 | 0.10 | 954 |
| Gas | B | 52706 | 309 | 0.59 | 171 | 63972 | 386 | 0.60 | 166 |
| | F | 5930 | 545 | 9.20 | 10.9 | 7197 | 764 | 10.6 | 9.42 |
| | S | 709 | 181 | 25.5 | 3.93 | 861 | 310 | 36.1 | 2.77 |

$ - From gravimetric analysis of filters and particulate nitric acid rinses
# - Feed rate calculated from target composition and total glass production rate
* - Calculated from analysis of water dissolution of filter particulate and direct analysis of nitric acid rinses

**Table 6.1. Results from Melter Off-Gas Emission Samples (continued).**

| | | Test 3<br>1/29/2013 15:10 – 16:10<br>35.8% Moisture, 105% Isokinetic | | | | Test 4<br>2/7/13 15:01 – 16:01<br>36.6% Moisture, 92.9% Isokinetic | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Feed[#] (mg/min) | Output (mg/min) | % Emitted | DF | Feed[#] (mg/min) | Output (mg/min) | % Emitted | DF |
| Particulate | Total[$] | 2978571 | 5267 | 0.18 | 566 | 3328571 | 5652 | 0.17 | 589 |
| | Al | 132195 | 152 | 0.11 | 871 | 147729 | 212 | 0.14 | 697 |
| | B | 62086 | 611 | 0.98 | 102 | 69382 | 306 | 0.44 | 227 |
| | Ba | 467 | 1.22 | 0.26 | 384 | 522 | 2.16 | 0.41 | 242 |
| | Bi | 10660 | 63.4 | 0.59 | 168 | 11913 | 93.9 | 0.79 | 127 |
| | Ca | 41581 | 83.9 | 0.20 | 496 | 46467 | 125 | 0.27 | 372 |
| | Cd | 187 | 2.48 | 1.33 | 75.3 | 209 | 3.91 | 1.87 | 53.4 |
| | Cr | 3709 | 33.5 | 0.90 | 111 | 4145 | 55.3 | 1.34 | 74.9 |
| | F* | 6985 | 1514 | 21.7 | 4.61 | 7806 | 849 | 10.9 | 9.20 |
| | Fe | 43009 | 149 | 0.35 | 289 | 48063 | 220 | 0.46 | 218 |
| | K | 1212 | 11.9 | 0.98 | 102 | 1354 | 20.8 | 1.53 | 65.2 |
| | Li | 17288 | 68.4 | 0.40 | 253 | 19320 | 109 | 0.56 | 177 |
| | Mg | 754 | 4.76 | 0.63 | 159 | 843 | 8.27 | 0.98 | 102 |
| | Na | 74098 | 354 | 0.48 | 209 | 82805 | 575 | 0.69 | 144 |
| | Ni | 3277 | 9.44 | 0.29 | 347 | 3662 | 13.7 | 0.37 | 268 |
| | P | 4779 | 17.3 | 0.36 | 276 | 5341 | 13.4 | 0.25 | 400 |
| | Pb | 3968 | 27.8 | 0.70 | 143 | 4434 | 46.1 | 1.04 | 96.1 |
| | S* | 836 | 118 | 14.2 | 7.07 | 934 | 175 | 18.8 | 5.32 |
| | Si | 131580 | 213 | 0.16 | 617 | 147041 | 324 | 0.22 | 454 |
| | Ti | 62 | 0.85 | 1.36 | 73.8 | 70 | 1.82 | 2.61 | 38.4 |
| | Zn | 670 | 1.76 | 0.26 | 381 | 749 | 2.90 | 0.39 | 258 |
| | Zr | 3010 | 3.99 | 0.13 | 754 | 3364 | 6.29 | 0.19 | 535 |
| Gas | B | 62086 | 223 | 0.36 | 278 | 69382 | 983 | 1.42 | 70.6 |
| | F | 6985 | 316 | 4.53 | 22.1 | 7806 | 1786 | 22.9 | 4.37 |
| | S | 836 | 247 | 29.5 | 3.39 | 934 | 469 | 50.2 | 1.99 |

[$] - From gravimetric analysis of filters and particulate nitric acid rinses
[#] - Feed rate calculated from target composition and total glass production rate
* - Calculated from analysis of water dissolution of filter particulate and direct analysis of nitric acid rinses

**Table 6.2. Concentrations [ppmv] of Selected Species in Off-Gas Measured by FTIR Spectroscopy, Test 1.**

| | Melter outlet | | | SBS outlet | | | WESP outlet | | |
|---|---|---|---|---|---|---|---|---|---|
| | Aver. | Min. | Max. | Aver. | Min. | Max. | Aver. | Min. | Max. |
| $N_2O$ | 1.8 | 1.3 | 2.3 | 2.1 | 1.2 | 5.1 | 2.0 | <1.0 | 4.5 |
| NO | 400 | 292 | 553 | 444 | 252 | 1044 | 397 | 2.8 | 772 |
| $NO_2$ | 63.4 | 45.5 | 89.2 | 66.0 | 29.1 | 209 | 76.1 | <1.0 | 187 |
| $NH_3$ | 1.9 | <1.0 | 4.0 | <1.0 | <1.0 | 2.0 | <1.0 | <1.0 | <1.0 |
| $H_2O$% | 26.7 | 18.8 | 37.3 | 10.2 | 8.1 | 16.1 | 8.7 | 4.9 | 15.9 |
| $CO_2$ % | 0.59 | 0.46 | 0.87 | 0.63 | 0.41 | 1.39 | 0.59 | 0.06 | 1.21 |
| Nitrous Acid | 1.7 | 1.1 | 3.2 | 1.1 | <1.0 | 3.4 | 1.7 | <1.0 | 3.9 |
| Nitric Acid | <1.0 | <1.0 | 1.1 | <1.0 | <1.0 | 14.2 | <1.0 | <1.0 | 1.7 |
| HCN | <1.0 | <1.0 | 2.3 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| CO | 2.9 | 1.7 | 4.8 | 3.5 | <1.0 | 11.3 | 3.1 | <1.0 | 8.6 |
| HCl | <1.0 | <1.0 | 1.0 | <1.0 | <1.0 | 8.1 | <1.0 | <1.0 | <1.0 |
| HF | 16.5 | 7.0 | 28.9 | 9.8 | 4.2 | 25.4 | 4.4 | 2.4 | 10.5 |

**Table 6.3. Concentrations [ppmv] of Selected Species in Off-Gas Measured by FTIR Spectroscopy, Test 2.**

| | Melter outlet | | | SBS outlet | | | WESP outlet | | | HEPA outlet | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aver. | Min. | Max. | Aver. | Min. | Max. | Aver. | Min. | Max. | Aver. | Min. | Max. |
| $N_2O$ | 1.5 | <1.0 | 2.2 | 2.6 | 1.0 | 3.7 | 2.5 | <1.0 | 5.4 | 2.8 | 1.9 | 5.2 |
| NO | 333 | 155 | 540 | 586 | 160 | 835 | 500 | 1.6 | 1102 | 532 | 402 | 903 |
| $NO_2$ | 48.9 | 25.6 | 90.9 | 93.4 | 26.3 | 153 | 92.5 | <1.0 | 266 | 102 | 70.8 | 229 |
| $NH_3$ | 6.4 | 4.6 | 10.0 | 4.7 | 4.4 | 5.9 | 4.6 | 3.0 | 6.7 | 5.1 | 4.5 | 5.5 |
| $H_2O$% | 20.5 | 11.2 | 30.7 | 8.8 | 6.4 | 11.0 | 7.9 | 4.3 | 12.7 | 7.4 | 6.5 | 8.5 |
| $CO_2$ % | 0.49 | 0.26 | 0.75 | 0.84 | 0.29 | 1.17 | 0.77 | 0.05 | 2.02 | 0.84 | 0.62 | 1.65 |
| Nitrous Acid | 1.2 | <1.0 | 2.5 | 1.4 | <1.0 | 1.8 | 2.0 | <1.0 | 6.2 | 3.2 | 2.4 | 6.3 |
| Nitric Acid | 4.5 | <1.0 | 19.2 | 1.7 | <1.0 | 22.7 | <1.0 | <1.0 | 2.4 | 1.0 | <1.0 | 1.8 |
| HCN | <1.0 | <1.0 | 1.6 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| CO | 2.2 | <1.0 | 4.4 | 4.9 | 1.2 | 9.3 | 4.0 | <1.0 | 10.7 | 3.8 | 1.8 | 8.7 |
| HCl | 3.2 | <1.0 | 12.5 | 1.0 | <1.0 | 8.3 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| HF | 27.5 | 6.3 | 67.6 | 14.8 | 5.3 | 22.6 | 4.1 | 2.2 | 16.6 | 2.7 | 2.5 | 3.0 |

**Table 6.4. Concentrations [ppmv] of Selected Species in Off-Gas Measured by FTIR Spectroscopy, Test 3.**

| | Melter outlet | | | SBS outlet | | | WESP outlet | | | HEPA outlet | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aver. | Min. | Max. | Aver. | Min. | Max. | Aver. | Min. | Max. | Aver. | Min. | Max. |
| $N_2O$ | 2.3 | 1.8 | 2.9 | 3.1 | 2.2 | 6.0 | 3.1 | 2.0 | 5.9 | 2.6 | <1.0 | 5.6 |
| NO | 527 | 426 | 692 | 646 | 504 | 1087 | 582 | 398 | 993 | 467 | 1.6 | 885 |
| $NO_2$ | 61.7 | 47.3 | 90.3 | 93.1 | 61.7 | 224 | 104 | 56.5 | 254 | 93.0 | 1.3 | 234 |
| $NH_3$ | 7.9 | 3.3 | 16.2 | 4.7 | 3.9 | 10.0 | 3.1 | 2.3 | 4.2 | 1.8 | <1.0 | 3.9 |
| $H_2O$% | 34.3 | 26.0 | 48.5 | 10.1 | 9.1 | 13.1 | 8.7 | 6.3 | 13.4 | 8.1 | 6.5 | 15.1 |
| $CO_2$ % | 0.77 | 0.62 | 1.04 | 0.92 | 0.75 | 1.82 | 0.88 | 0.59 | 1.79 | 0.75 | 0.06 | 1.67 |
| Nitrous Acid | 1.7 | 1.1 | 3.3 | 1.2 | <1.0 | 4.7 | 2.3 | 1.3 | 5.5 | 2.8 | <1.0 | 6.2 |
| Nitric Acid | 3.1 | <1.0 | 9.6 | 2.1 | <1.0 | 82.2 | <1.0 | <1.0 | 2.0 | 1.2 | <1.0 | 2.3 |
| HCN | 1.2 | <1.0 | 2.1 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| CO | 2.0 | <1.0 | 3.8 | 3.7 | 1.7 | 10.9 | 3.4 | <1.0 | 10.3 | 3.3 | <1.0 | 10.7 |
| HCl | 2.1 | <1.0 | 5.2 | 1.4 | <1.0 | 25.9 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| HF | 29.0 | 5.3 | 57.7 | 22.7 | 12.7 | 79.6 | 6.2 | 3.9 | 12.3 | 2.9 | 2.0 | 8.4 |

**Table 6.5. Concentrations [ppmv] of Selected Species in Off-Gas Measured by FTIR Spectroscopy, Test 4.**

| | Melter outlet | | | SBS outlet | | | WESP outlet | | | HEPA outlet | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aver. | Min. | Max. | Aver. | Min. | Max. | Aver. | Min. | Max. | Aver. | Min. | Max. |
| $N_2O$ | 2.5 | 1.9 | 3.4 | 3.4 | 2.4 | 4.5 | 2.7 | <1.0 | 6.0 | 3.0 | 2.4 | 3.9 |
| NO | 542 | 460 | 734 | 703 | 372 | 914 | 501 | 3.6 | 995 | 555 | 441 | 728 |
| $NO_2$ | 68.4 | 31.7 | 112 | 104 | 40.7 | 151 | 91.4 | <1.0 | 264 | 111 | 75.6 | 259 |
| $NH_3$ | 5.5 | 2.3 | 10.5 | 2.1 | <1.0 | 5.9 | 1.8 | <1.0 | 3.4 | 3.3 | 2.8 | 3.8 |
| $H_2O$% | 34.7 | 27.2 | 50.3 | 9.0 | 7.1 | 11.8 | 8.4 | 7.0 | 13.7 | 7.7 | 6.6 | 9.5 |
| $CO_2$ % | 0.76 | 0.64 | 0.97 | 0.99 | 0.57 | 1.37 | 0.76 | 0.06 | 1.63 | 0.83 | 0.64 | 1.01 |
| Nitrous Acid | 1.4 | <1.0 | 2.9 | 1.3 | <1.0 | 2.6 | 1.8 | <1.0 | 5.1 | 2.9 | 1.3 | 4.0 |
| Nitric Acid | 7.2 | <1.0 | 62.7 | 4.7 | <1.0 | 52.1 | <1.0 | <1.0 | 1.8 | <1.0 | <1.0 | 1.0 |
| HCN | <1.0 | <1.0 | 1.6 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| CO | 2.8 | 1.6 | 5.5 | 4.9 | 2.3 | 8.3 | 3.6 | <1.0 | 12.1 | 4.2 | 2.4 | 7.0 |
| HCl | 3.3 | <1.0 | 22.9 | 9.1 | <1.0 | 26.8 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| HF | 49.6 | 8.9 | 142 | 21.1 | 3.5 | 87.3 | 4.2 | 2.7 | 12.7 | 10.8 | 8.0 | 20.2 |

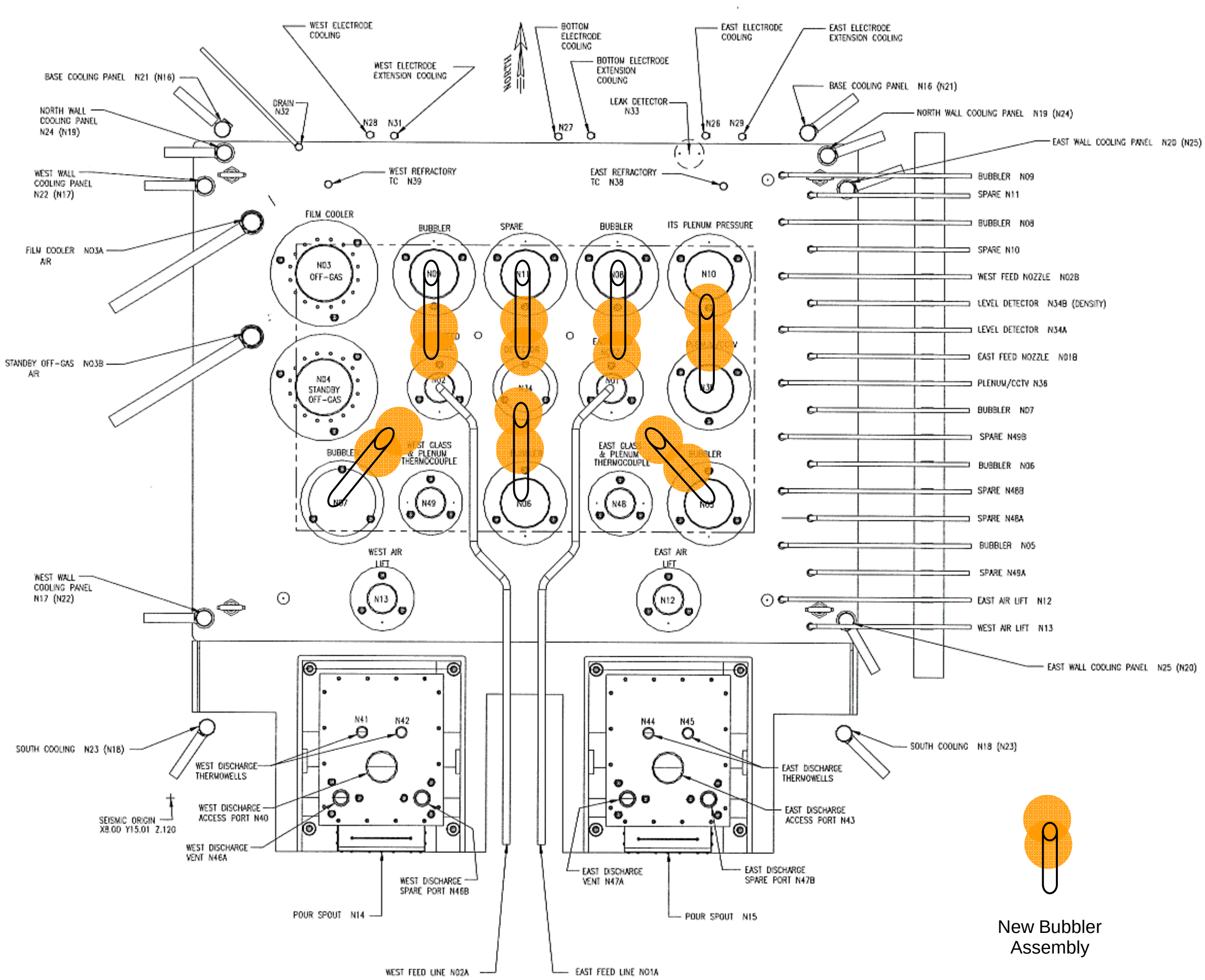



**Figure 1.1. Lid diagram for WTP HLW melter.**

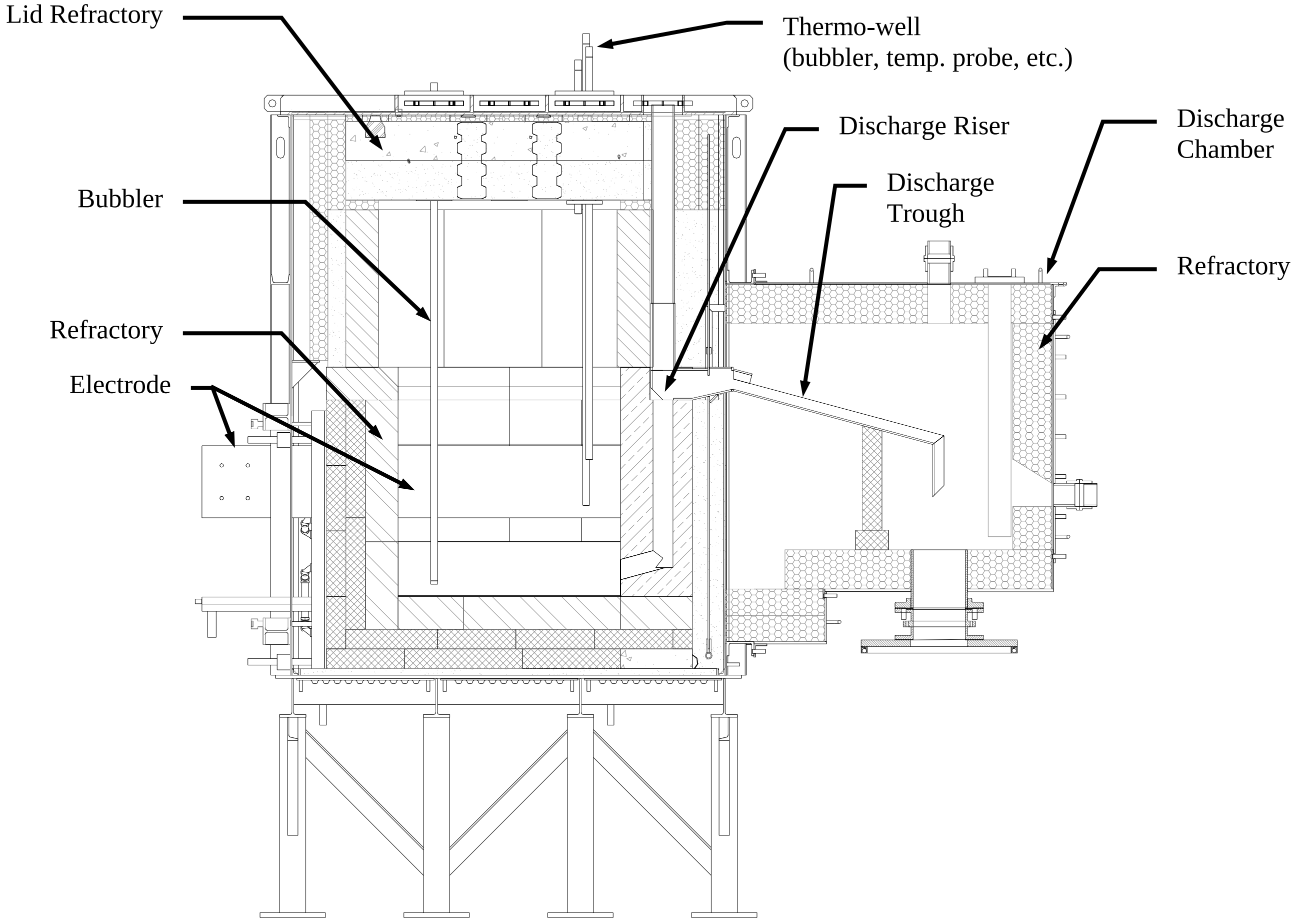



**Figure 1.2. Cross-section of the DM1200 melter through the discharge chamber.**

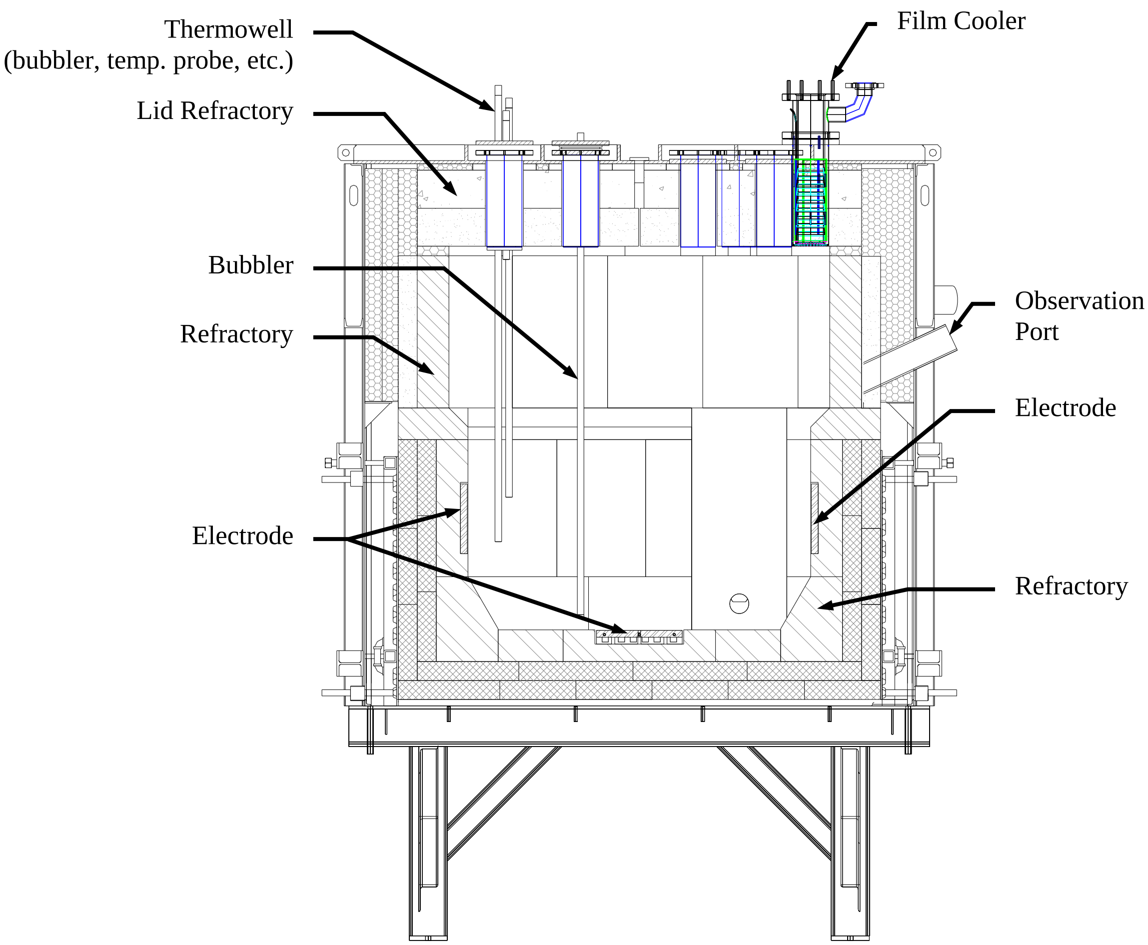



**Figure 1.3. Cross-section through the DM1200 melter showing electrodes.**

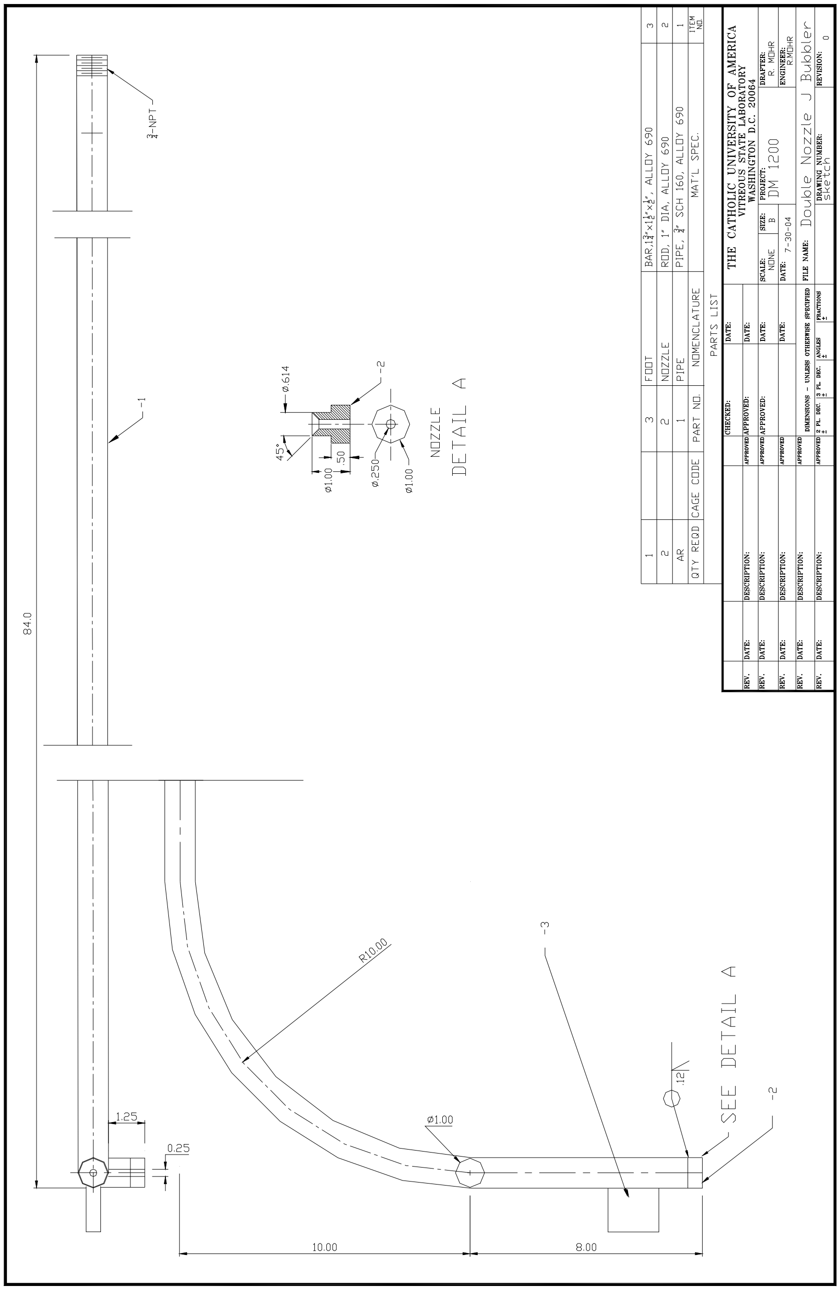
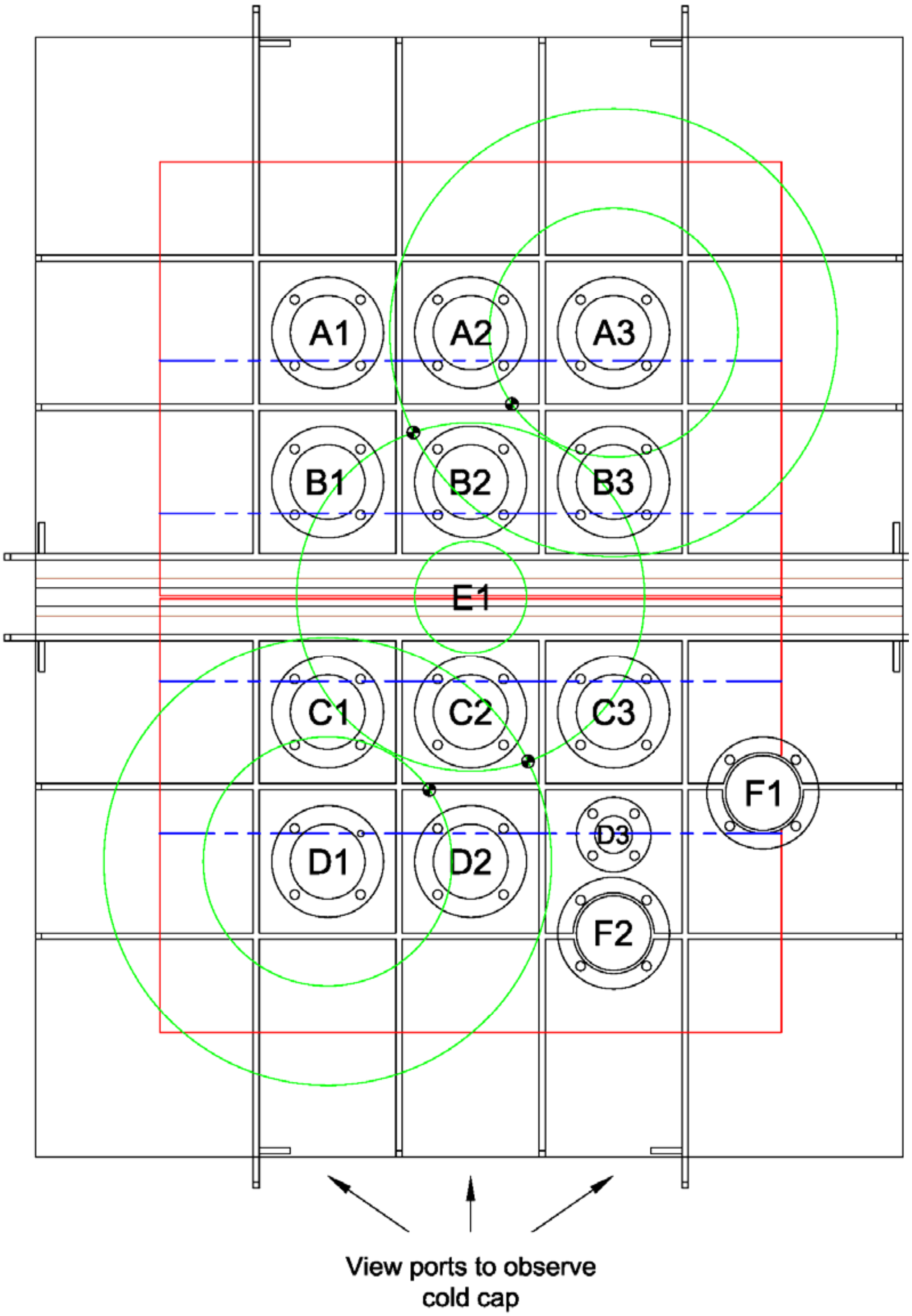



**Figure 1.4. Specifications of Double-Outlet “J” Bubbler.**

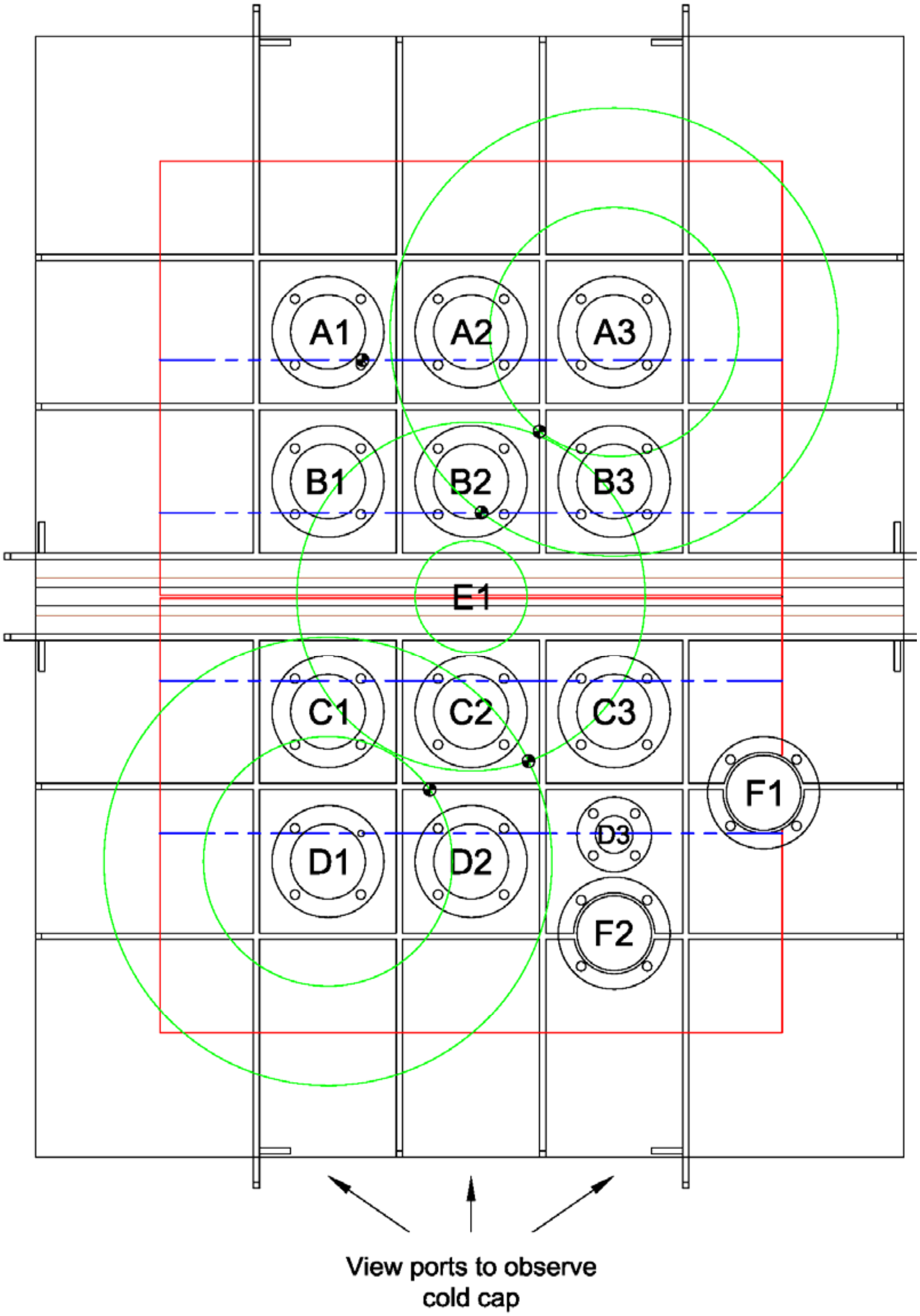
**Figure 1.5. Double-Outlet "J" Bubbler.**




A2: Thermowell 1
A3: Double outlet lance bubbler
B1: Level Detector
B2: Exposed plenum TC
B3: Instrument port/exposed plenum TC
C1: Exposed plenum TC
C2: Exposed plenum TC
C3: Emergency vent port
D1: Double outlet lance bubbler
D2: Thermowell 2
E1: Feed Tube
F1: Airlift
F2: Normal O/G port

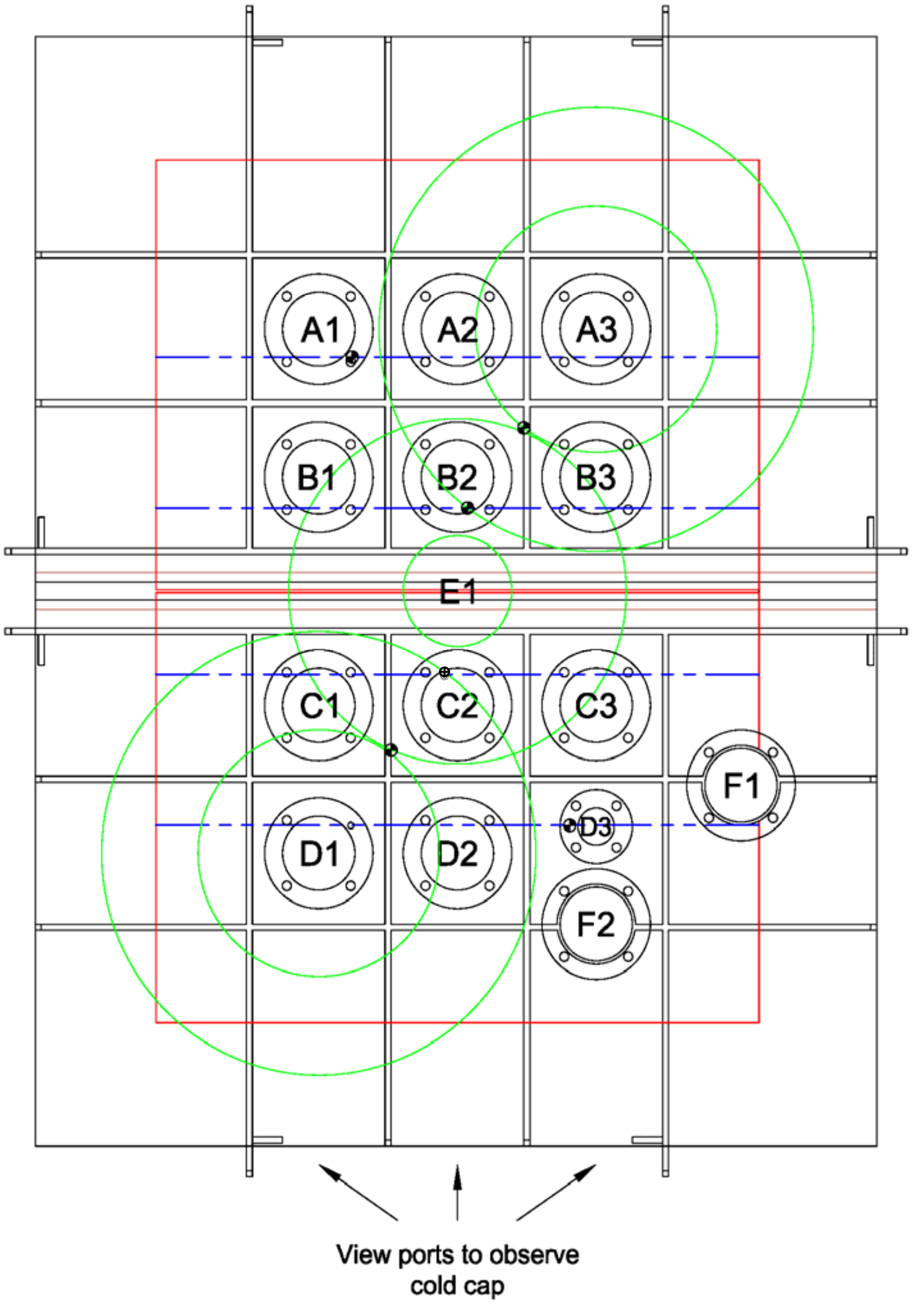
**Figure 1.6. Placement of bubblers in the DM1200 melter, Nominal Configuration – 4 bubbling outlets. Note: Solid circles represent location of bubbler outlet.**

**Figure 1.7. Single-Outlet "L" Bubbler.**




A1: Single outlet bubbler
A2: Thermowell 1
A3: Double outlet lance bubbler
B1: Level Detector
B2: Exposed plenum TC
B3: Instrument port/exposed plenum TC
C1: Exposed plenum TC
C2: Exposed plenum TC
C3: Emergency vent port
D1: Double outlet lance bubbler
D2: Thermowell 2
E1: Feed Tube
F1: Airlift
F2: Normal O/G port

**Figure 1.8. Placement of bubblers in the DM1200 melter, 5 bubbling outlets. Note: Solid circles represent location of bubbler outlet.**




A1: Single outlet bubbler
A2: Thermowell 1
A3: Double outlet lance bubbler
B1: Level Detector
B2: Exposed plenum TC
B3: Instrument port/exposed plenum TC
C1: Exposed plenum TC
C2: Exposed plenum TC
C3: Emergency vent port
D1: Double outlet lance bubbler
D2: Thermowell 2
D3: Single outlet bubbler
E1: Feed Tube
F1: Airlift
F2: Normal O/G port

**Figure 1.9. Placement of bubblers in the DM1200 melter, 6 bubbling outlets. Note: Solid circles represent location of bubbler outlet.**

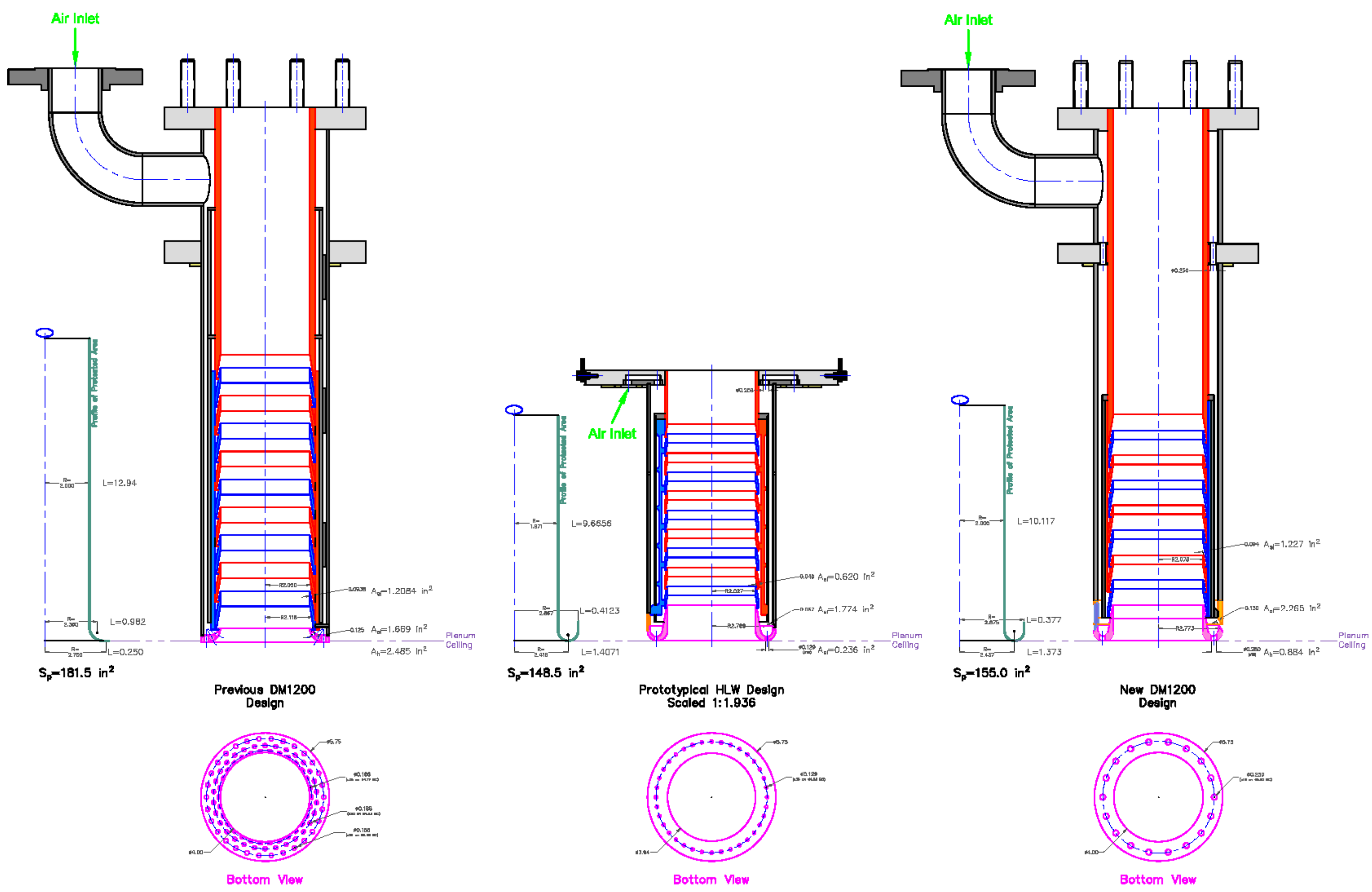



**Figure 1.10. Comparison of original (left) and new (right) DM1200 film cooler designs with a scaled-down version of the WTP HLW design.**

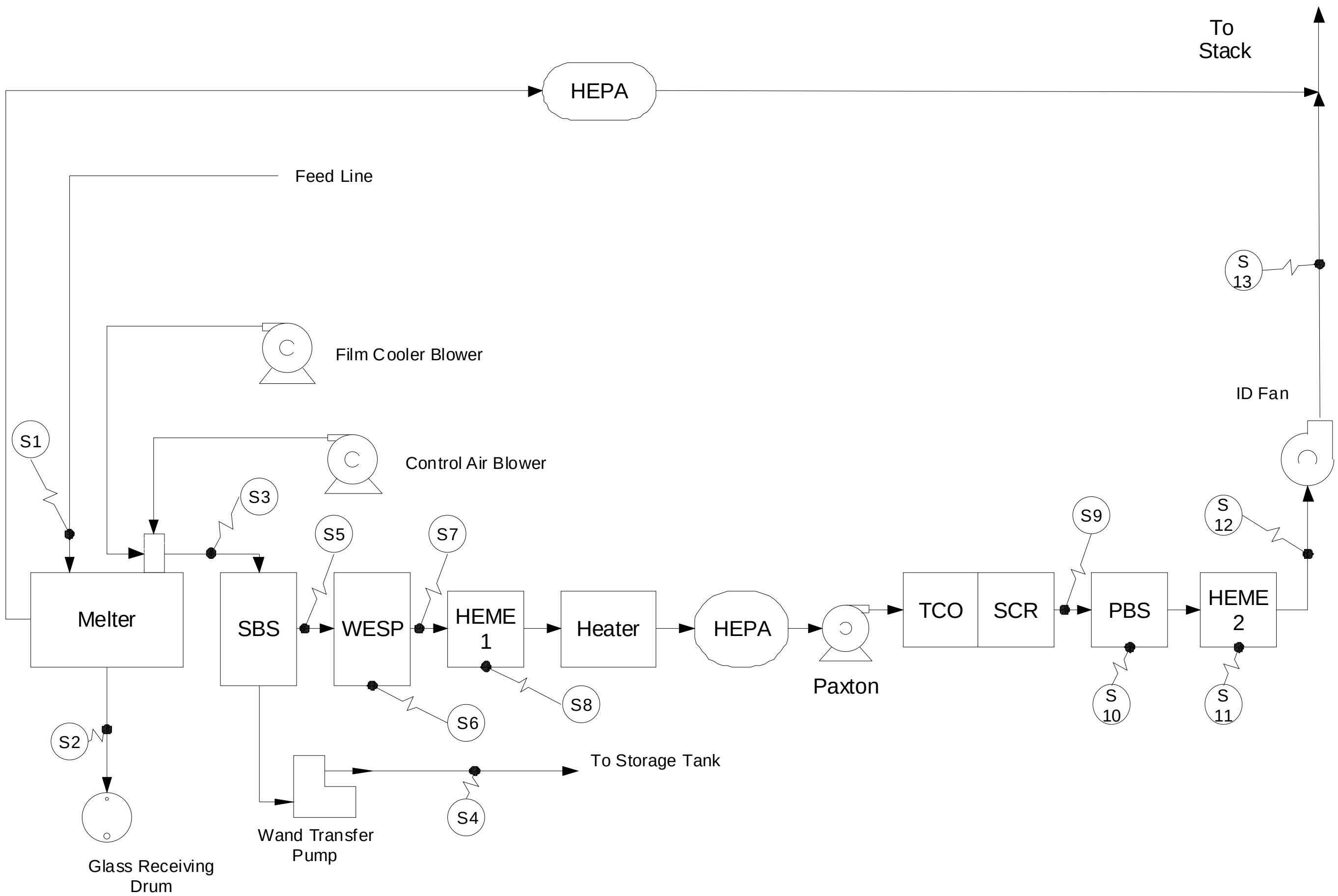



**Figure 1.11. Schematic diagram of DM1200 off-gas system. “Sx” indicates sampling point**

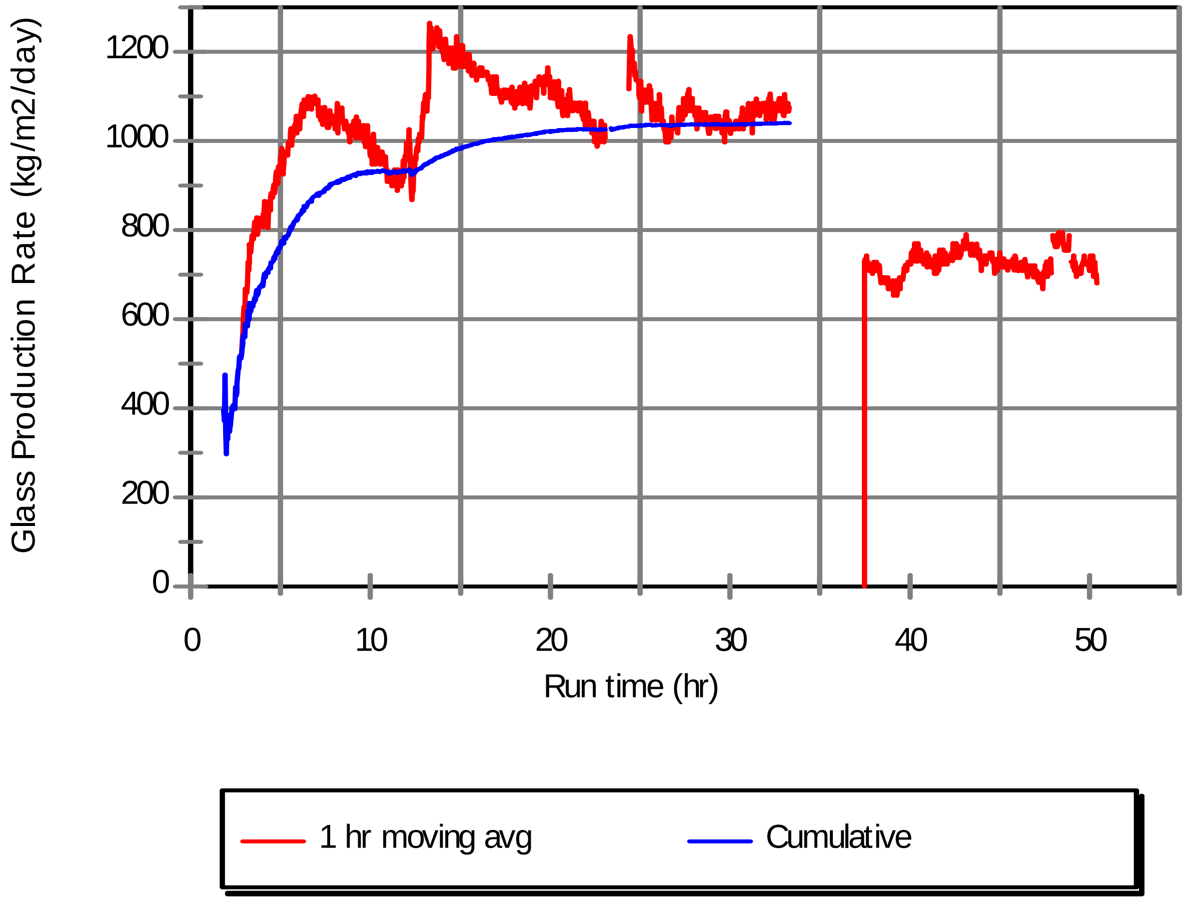



**Figure 3.1.a. Production rates while processing with two double-outlet bubblers, Test 1.**

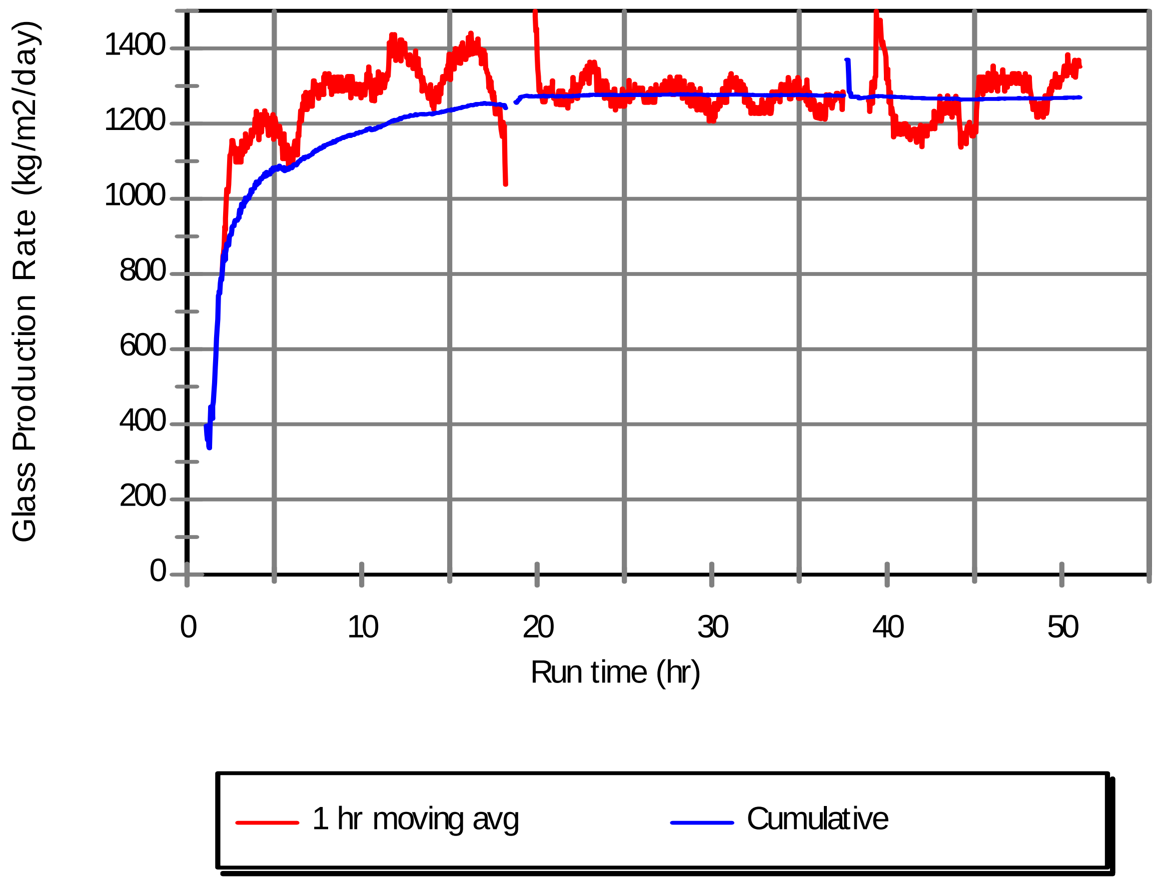



**Figure 3.1.b. Production rates while processing with two double-outlet and one single-outlet bubblers, Test 2.**

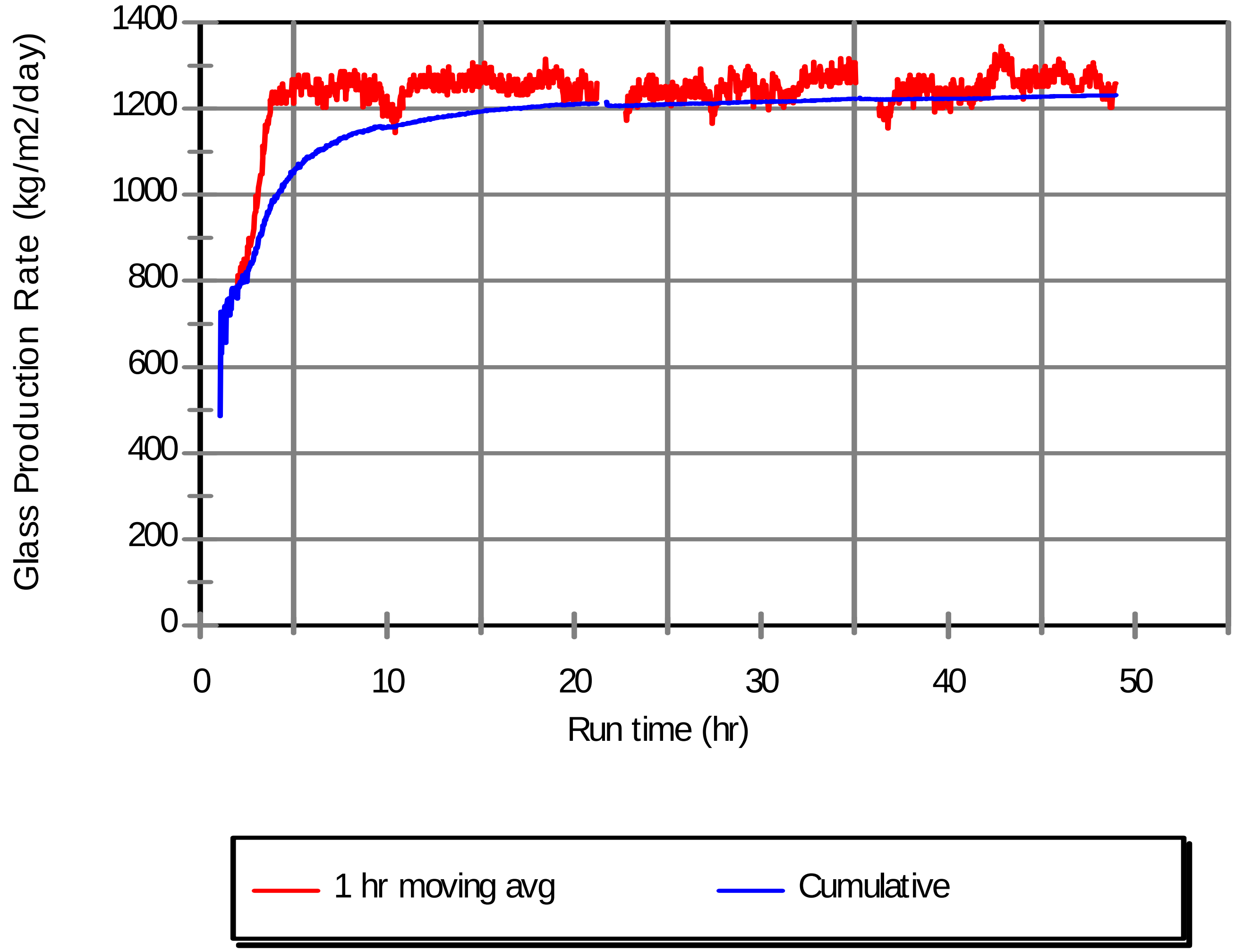



**Figure 3.1.c. Production rates while processing with two double-outlet and two single-outlet bubblers, Test 3.**

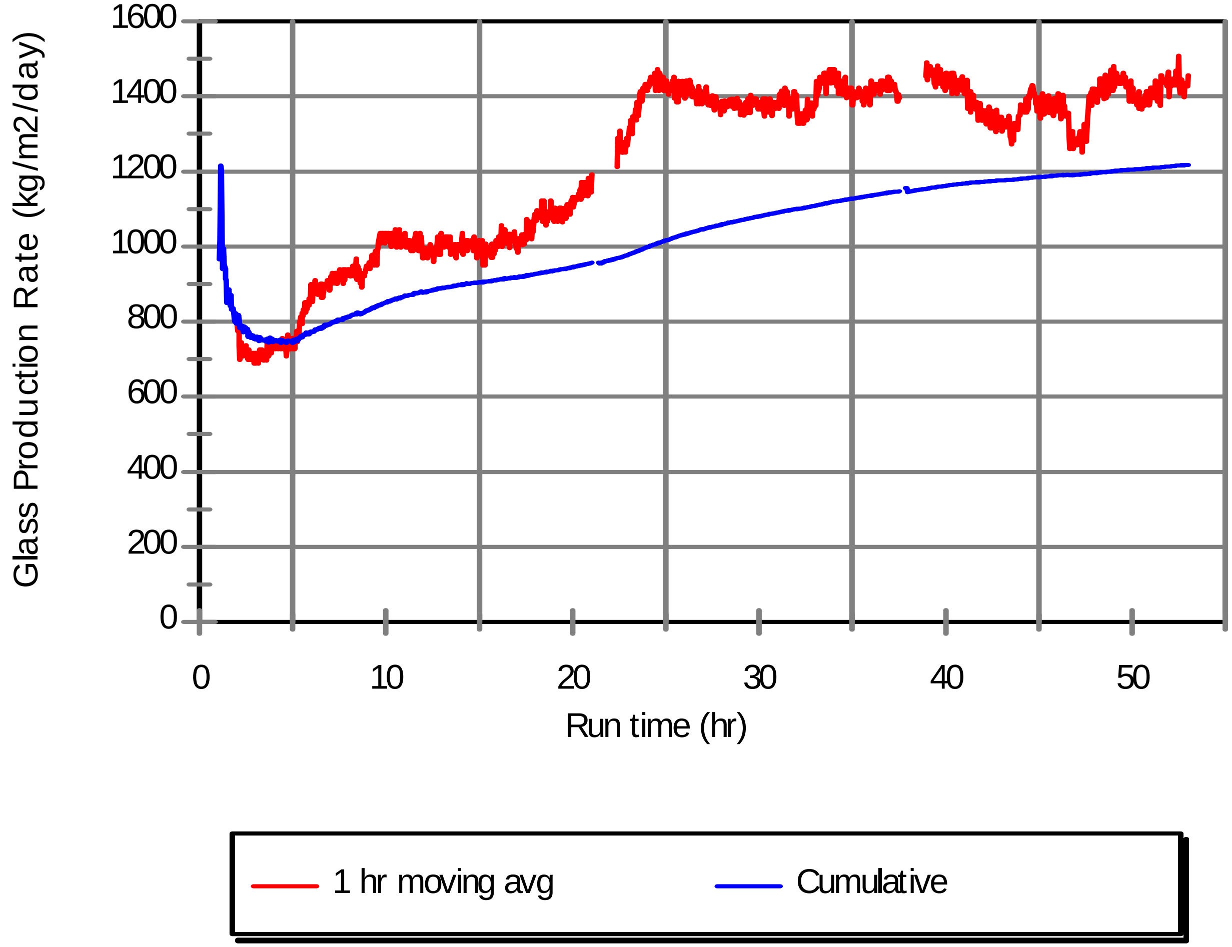



**Figure 3.1.d. Production rates while processing with two double-outlet and two single-outlet bubblers, Test 4.**


**Figure 3.2. Glass production rates while bubbling a total of 78 lpm.**

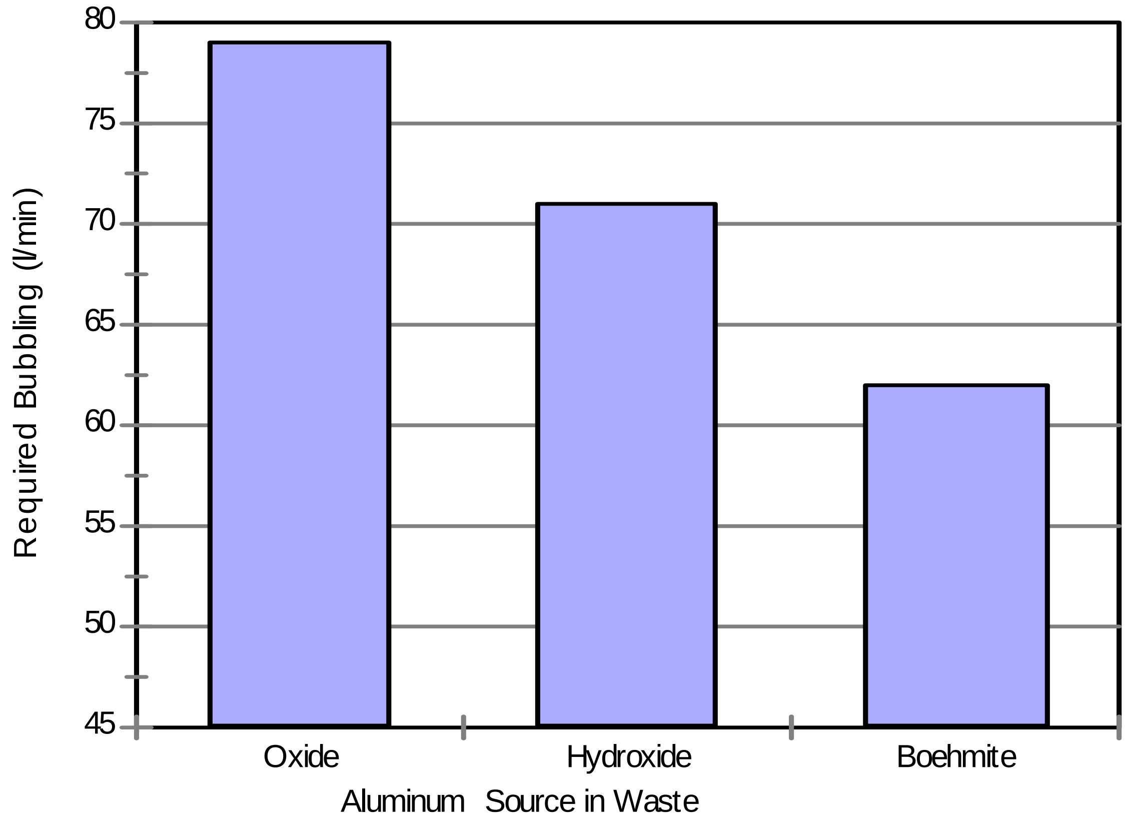



**Figure 3.3. Bubbling rates used to process high aluminum waste at 1050 kg/m$^2$/day with four bubbler outlet nominal configuration.**

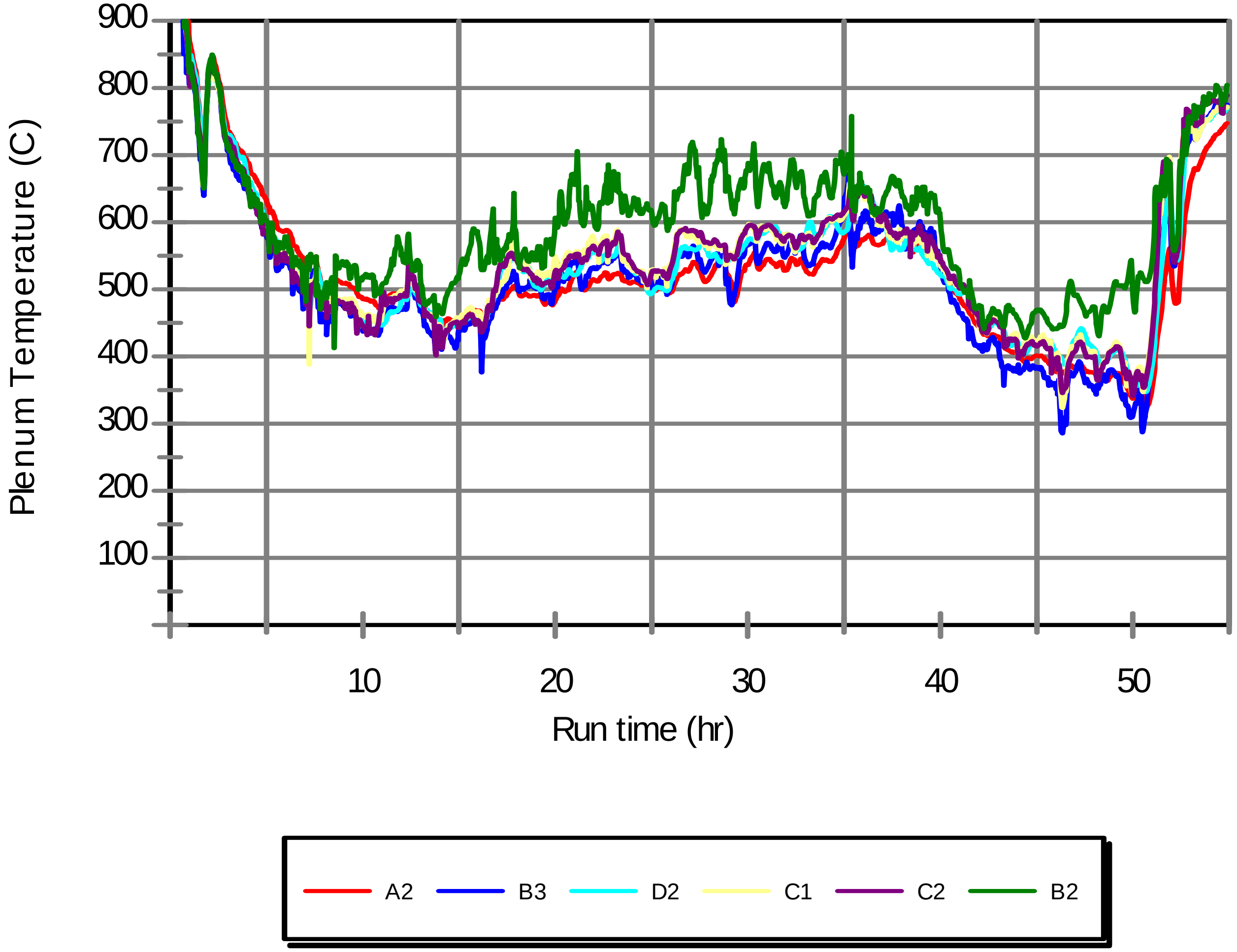



**Figure 3.4.a. Plenum temperatures while processing with two double-outlet bubblers, Test 1.**

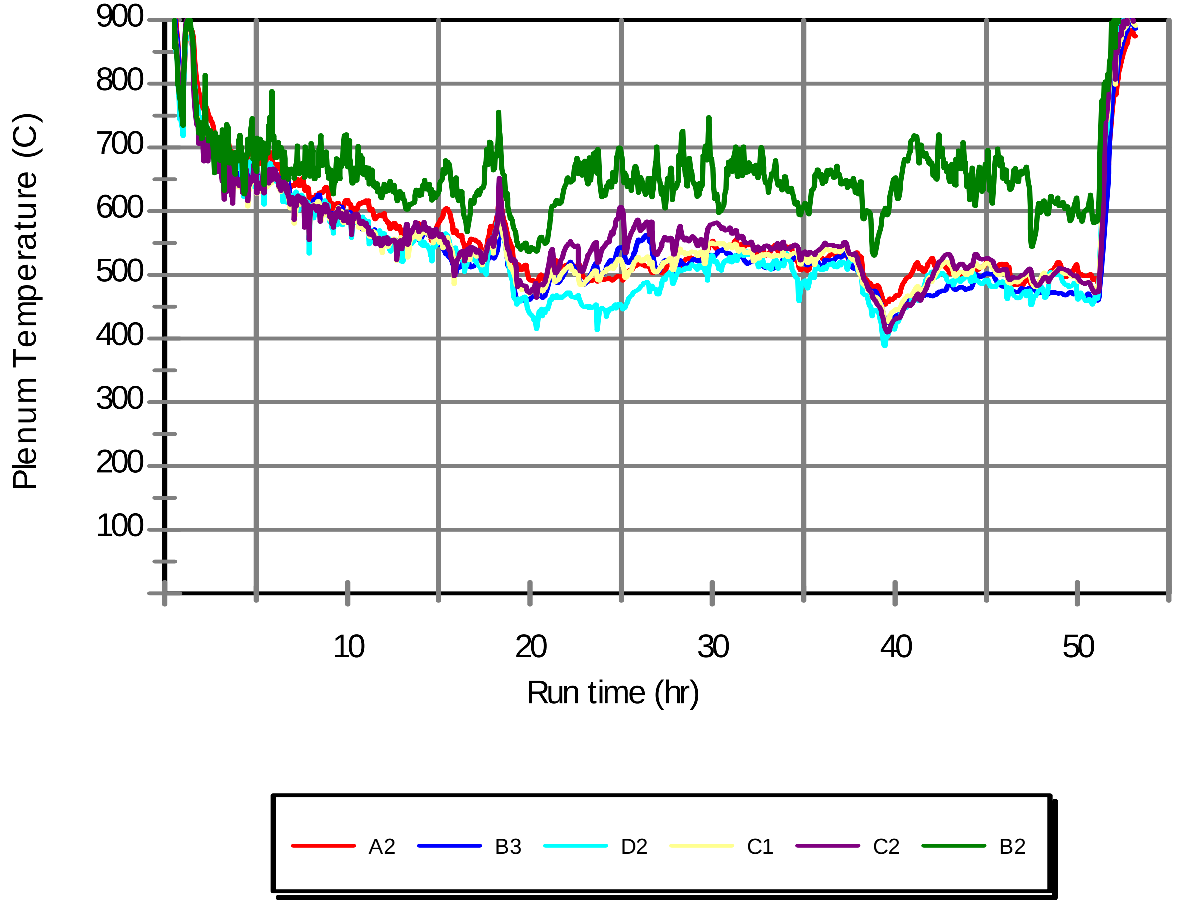



**Figure 3.4.b. Plenum temperatures while processing with two double-outlet and one single-outlet bubblers, Test 2.**

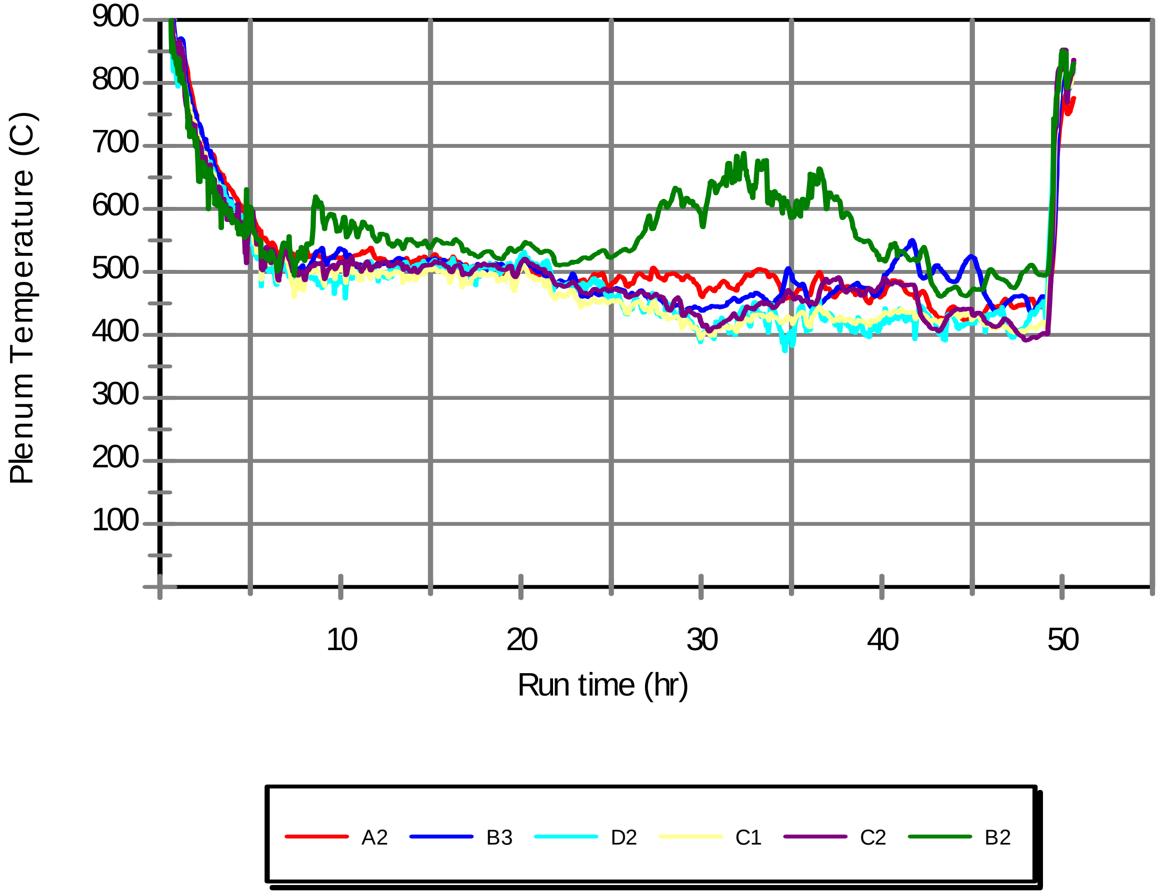



**Figure 3.4.c. Plenum temperatures while processing with two double-outlet and two single-outlet bubblers, Test 3.**

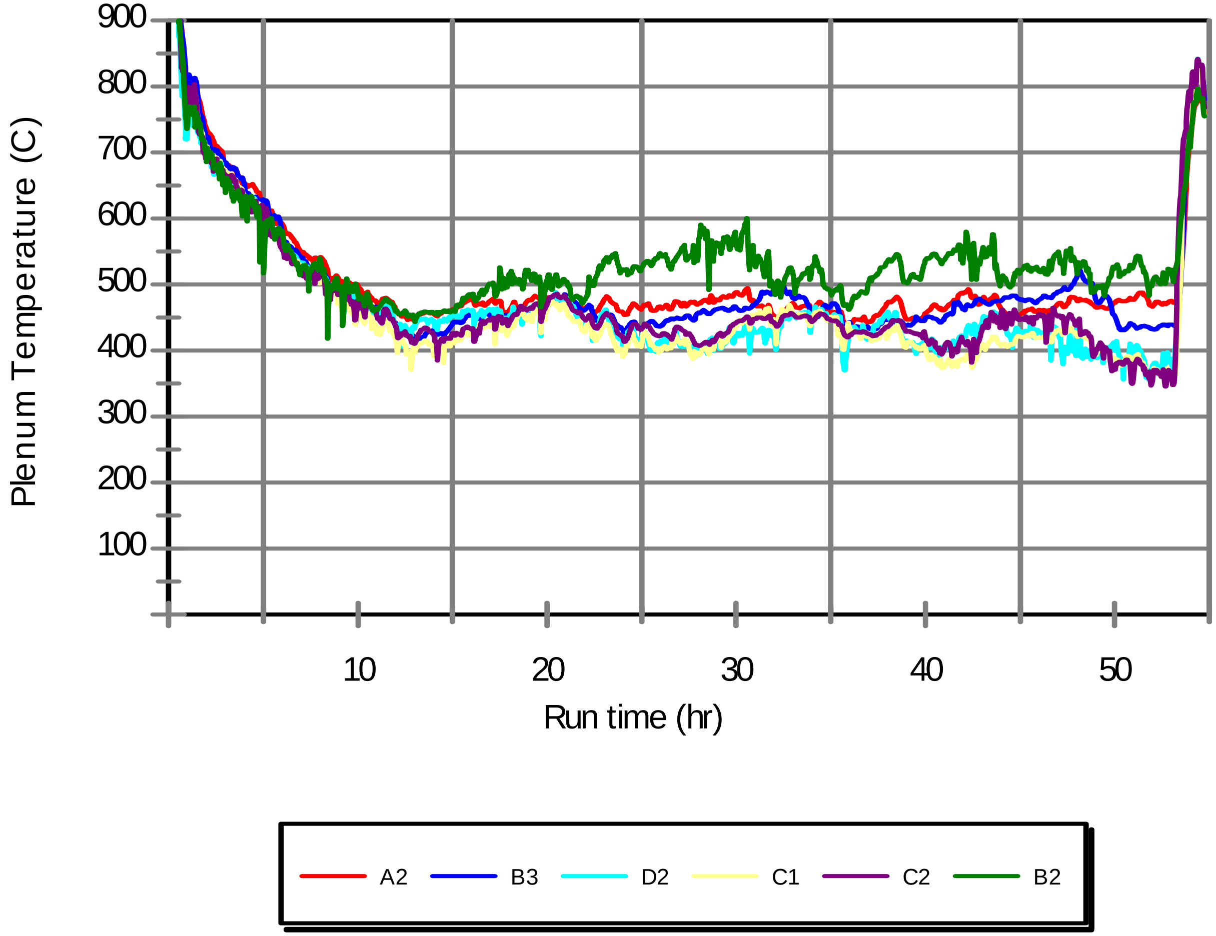



**Figure 3.4.d. Plenum temperatures while processing with two double-outlet and two single-outlet bubblers, Test 4.**

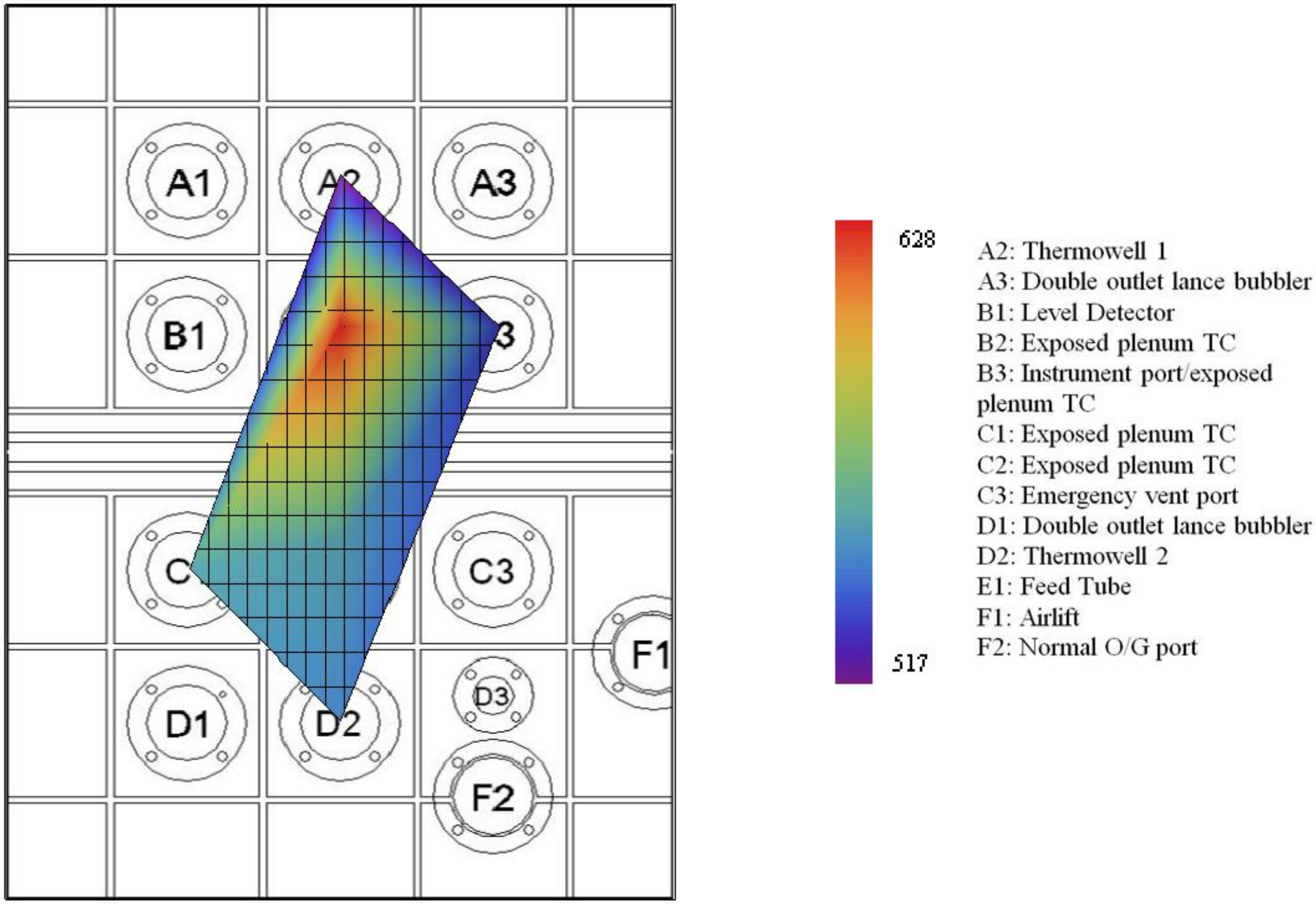



**Figure 3.5.a. Average steady state plenum temperatures (°C) at monitoring locations; two double-outlet bubblers, Test 1.**

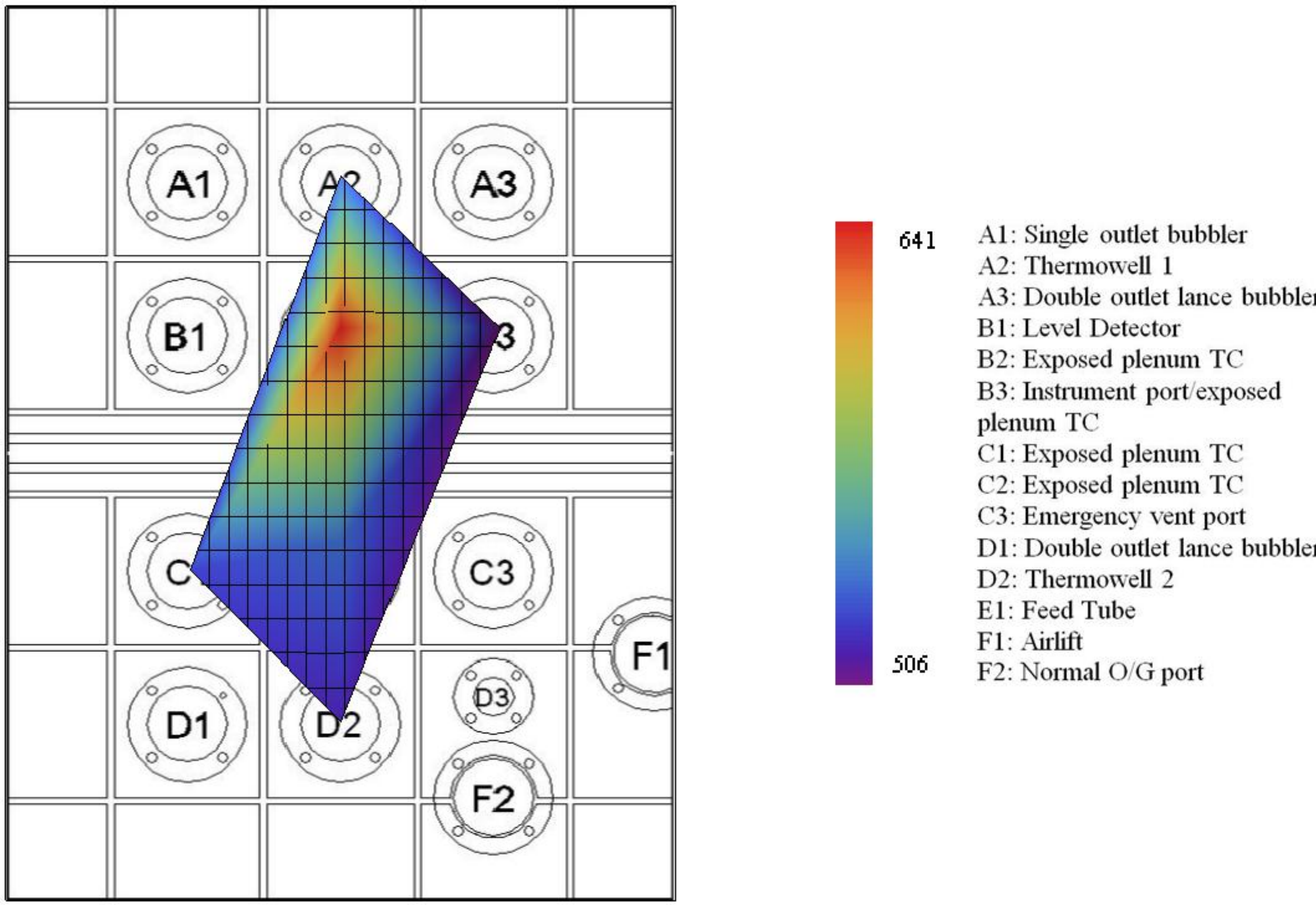



**Figure 3.5.b. Average steady state plenum temperatures (°C) at monitoring locations; two double-outlet and one single-outlet bubblers, Test 2.**

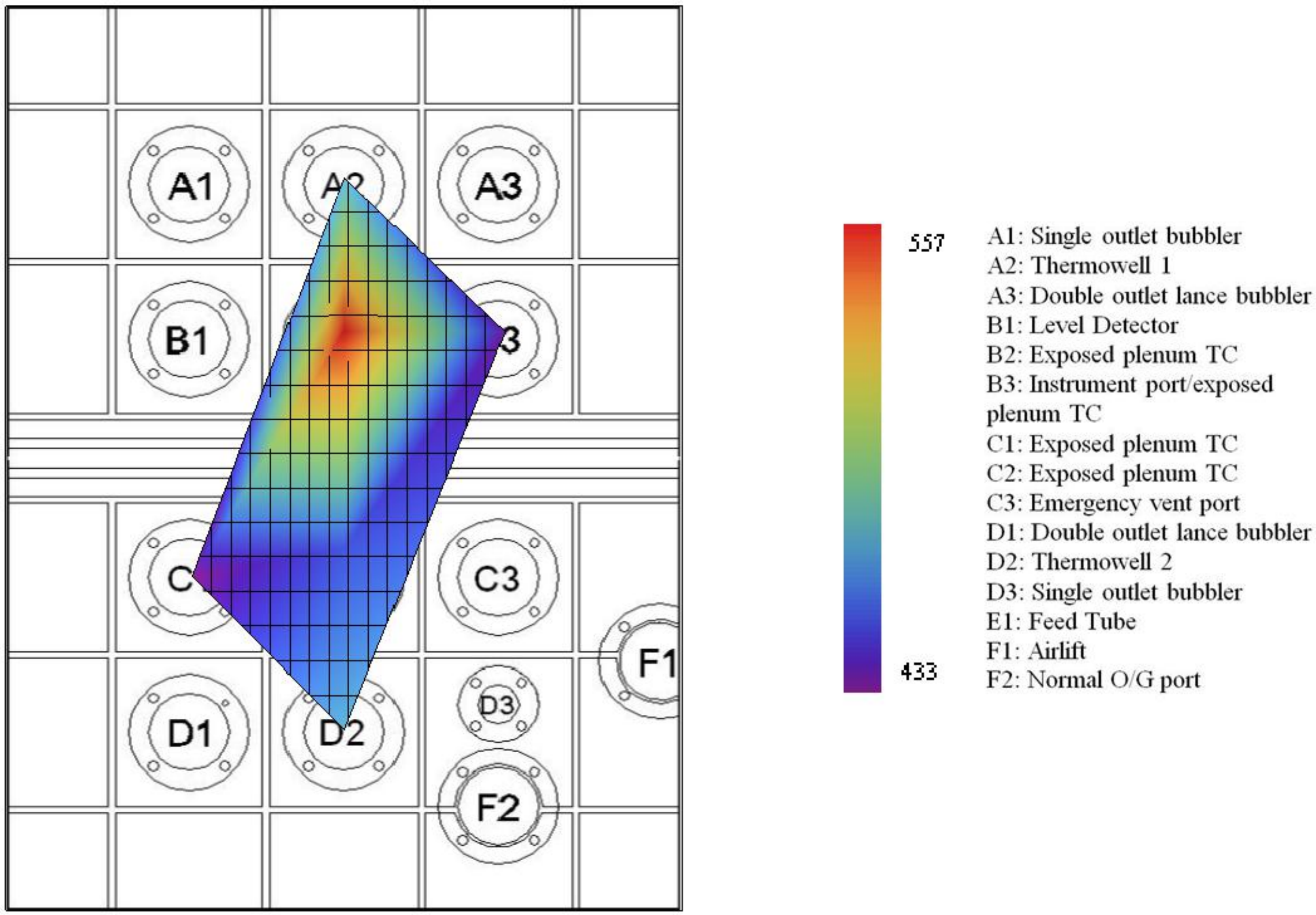



**Figure 3.5.c. Average steady state plenum temperatures ($^oC$) at monitoring locations; two double-outlet and two single-outlet bubblers, Test 3.**

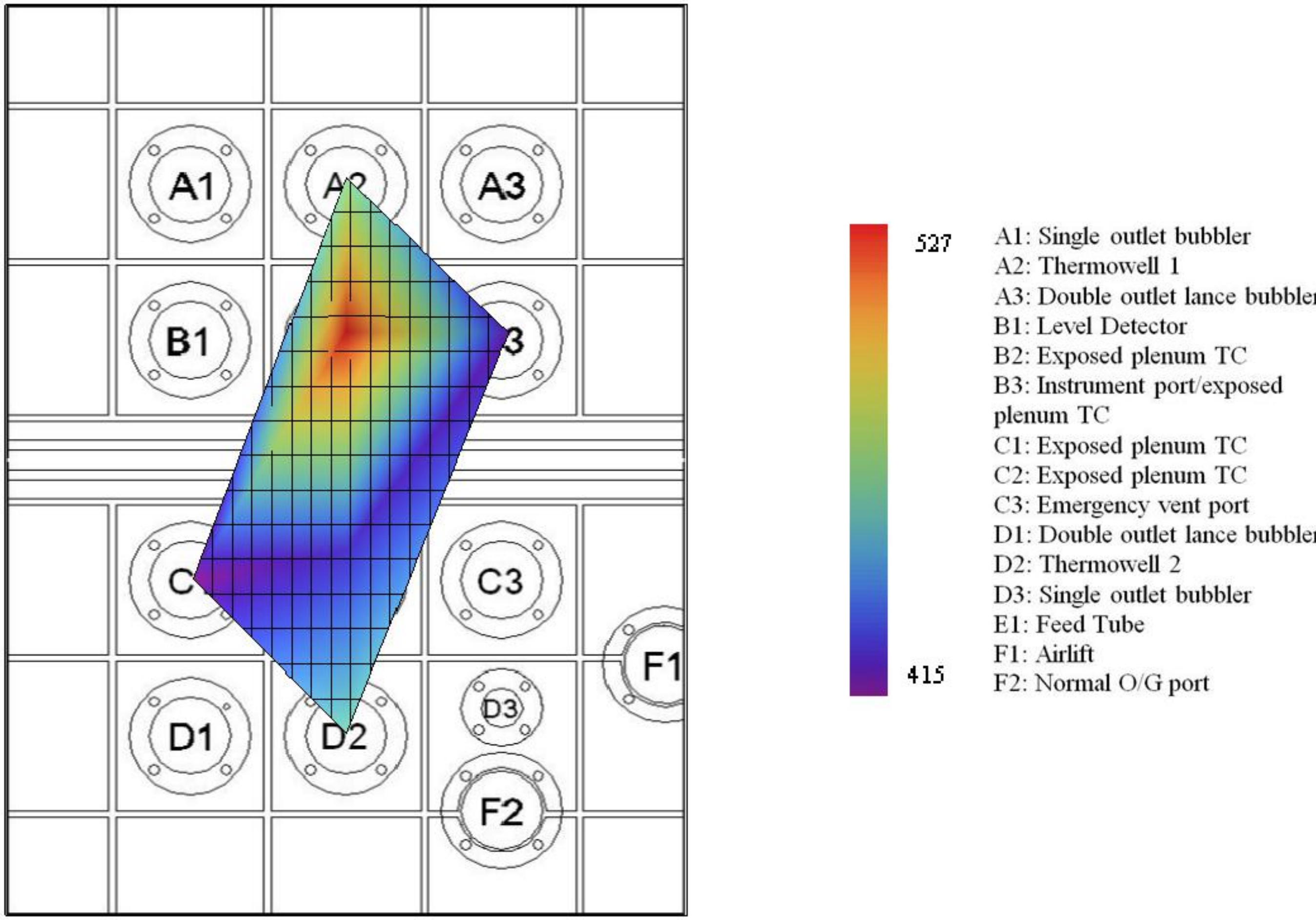



**Figure 3.5.d. Average steady state plenum temperatures ($^oC$) at monitoring locations; two double-outlet and two single-outlet bubblers, Test 4.**

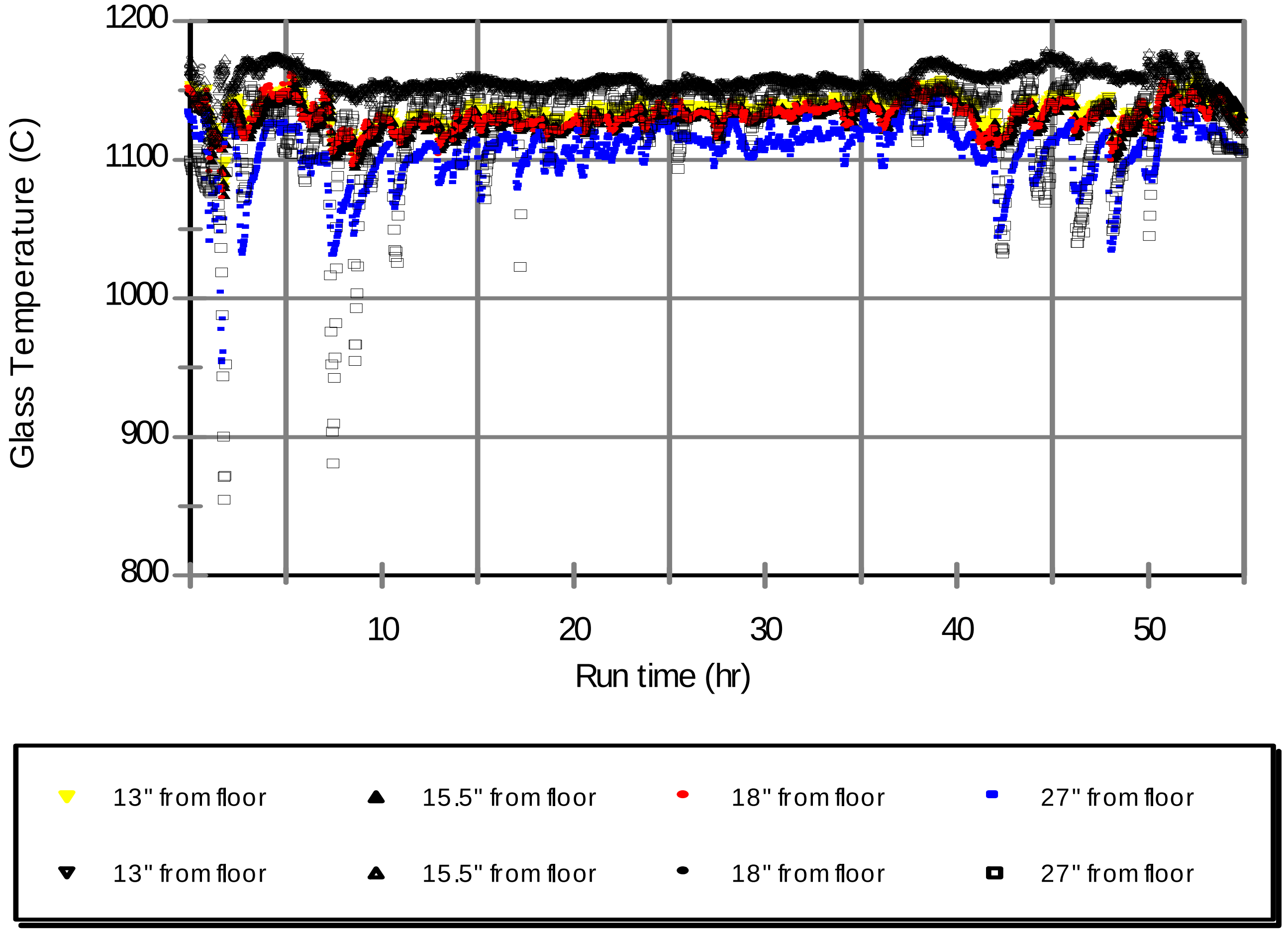



**Figure 3.6.a. Glass temperatures while processing with two double-outlet bubblers, Test 1.**

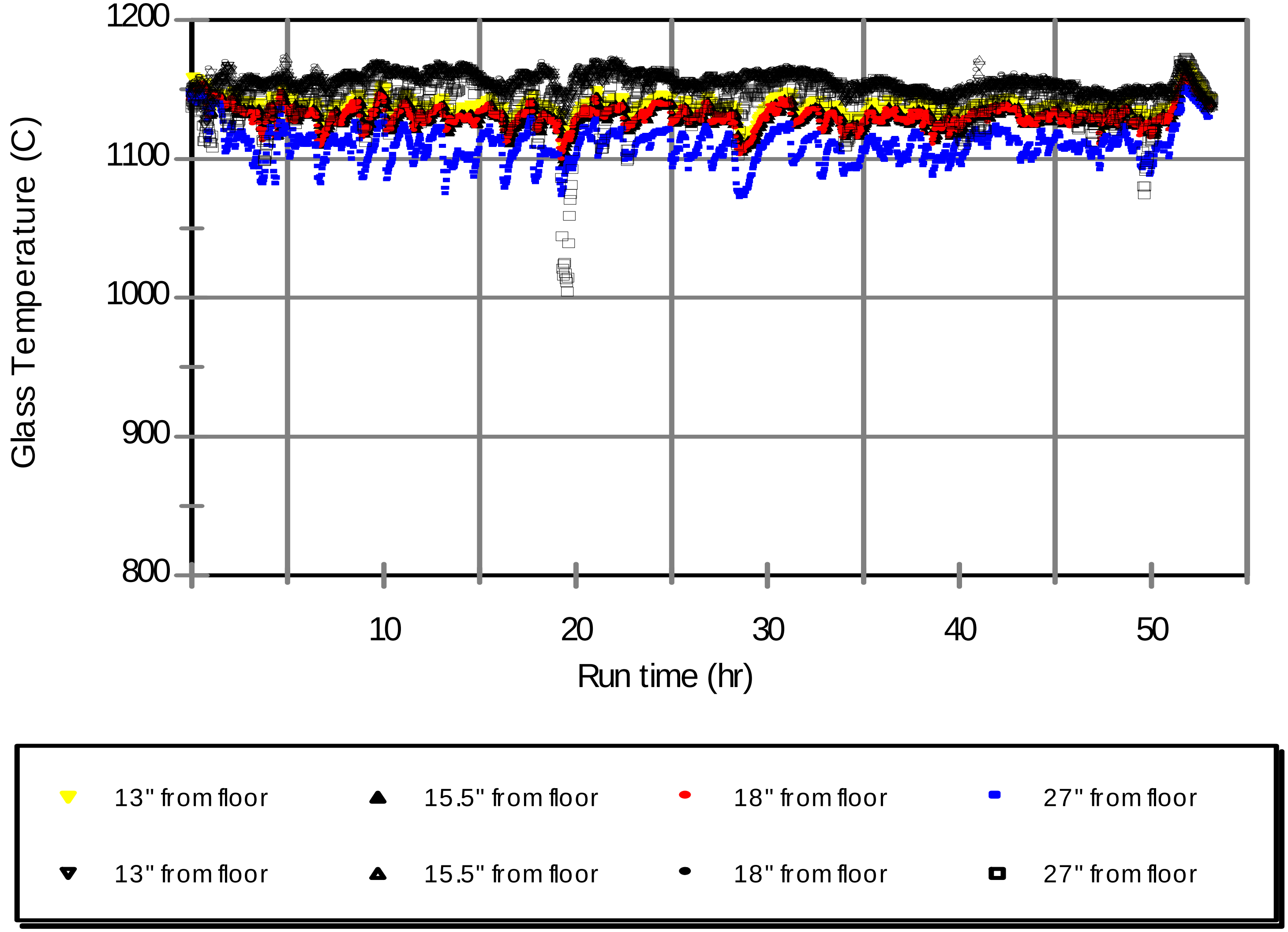



**Figure 3.6.b. Glass temperatures while processing with two double-outlet and one single-outlet bubblers, Test 2.**

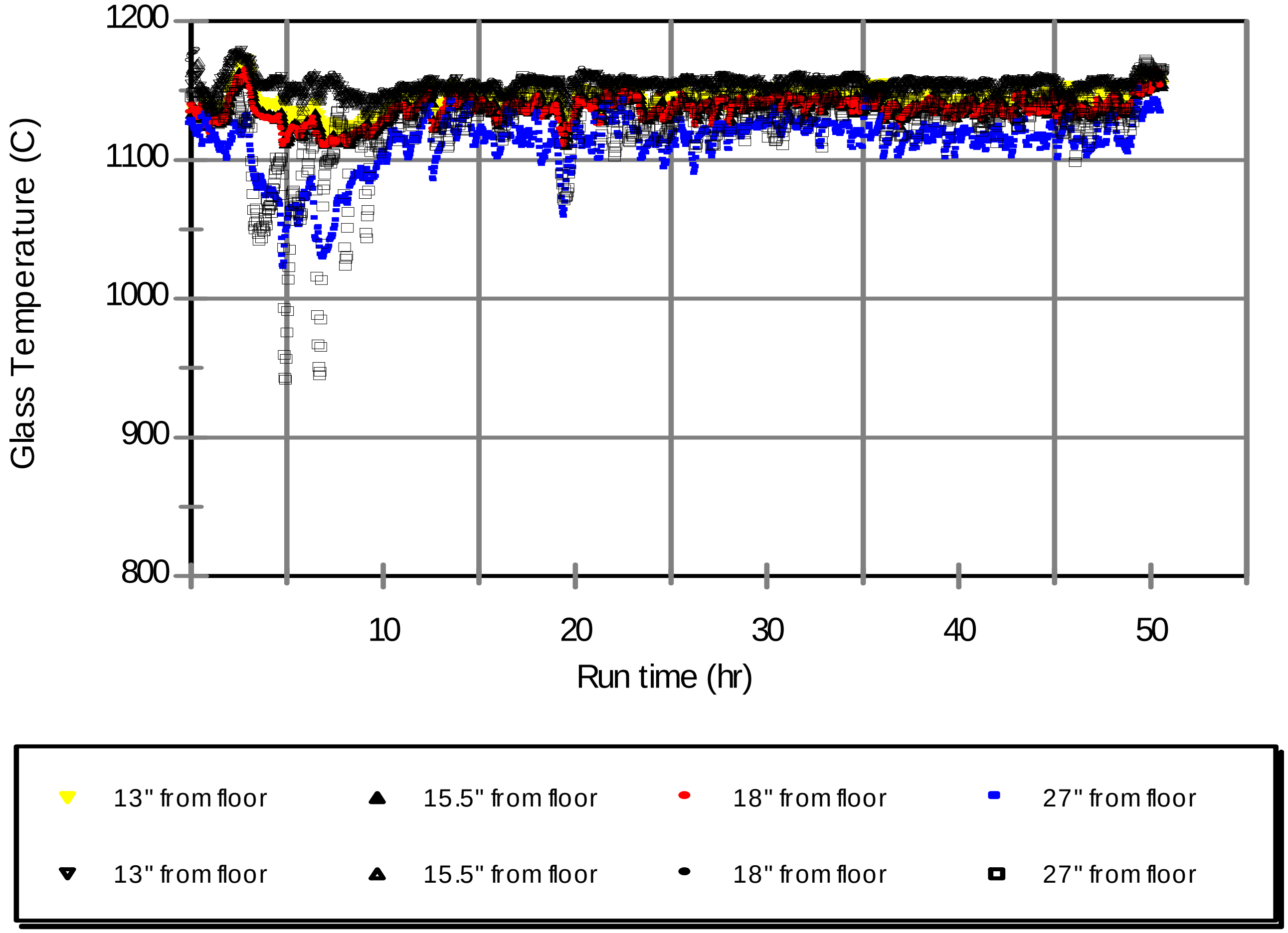



**Figure 3.6.c. Glass temperatures while processing with two double-outlet and two single-outlet bubblers, Test 3.**

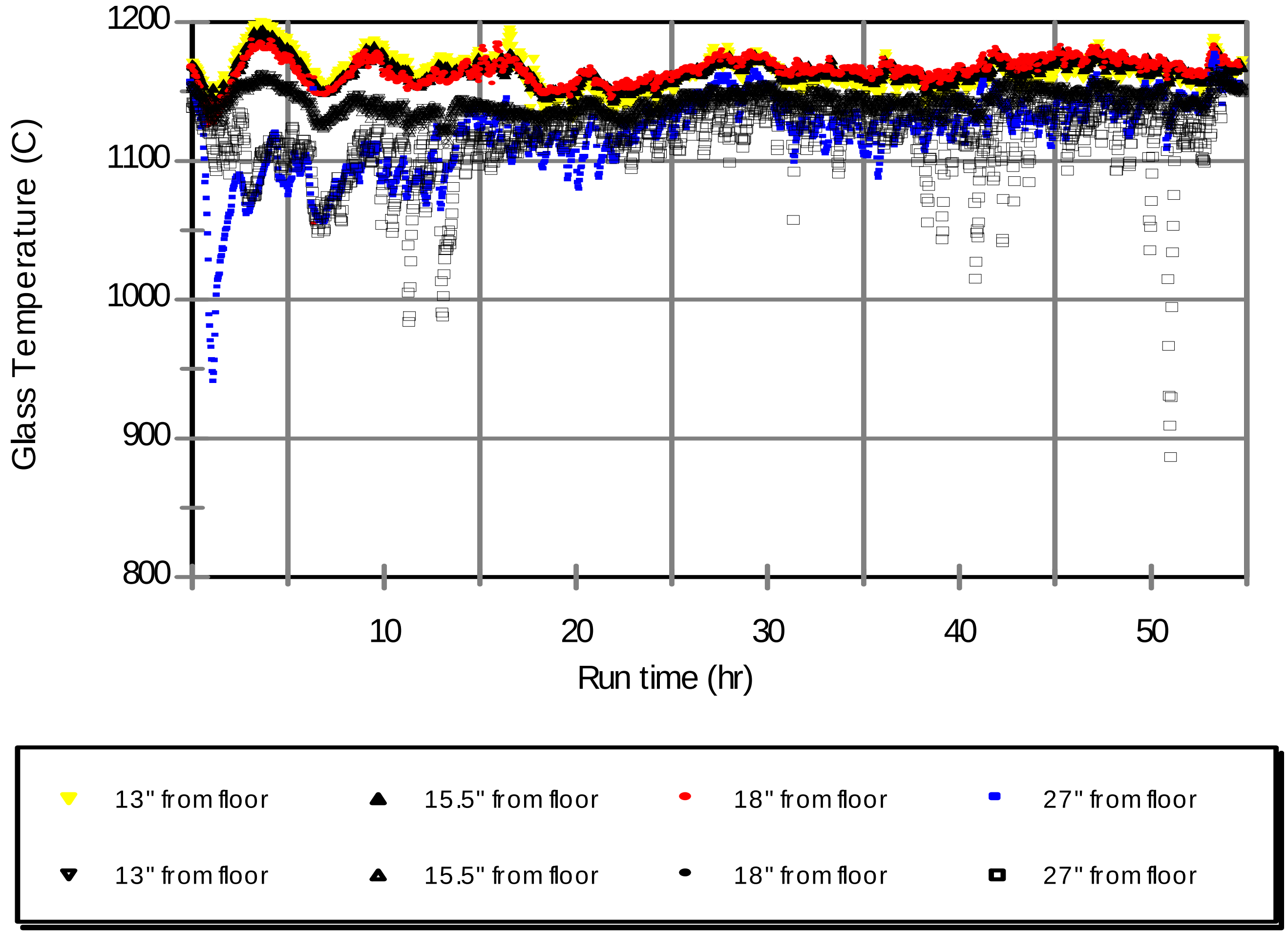



**Figure 3.6.d. Glass temperatures while processing with two double-outlet and two single-outlet bubblers, Test 4.**

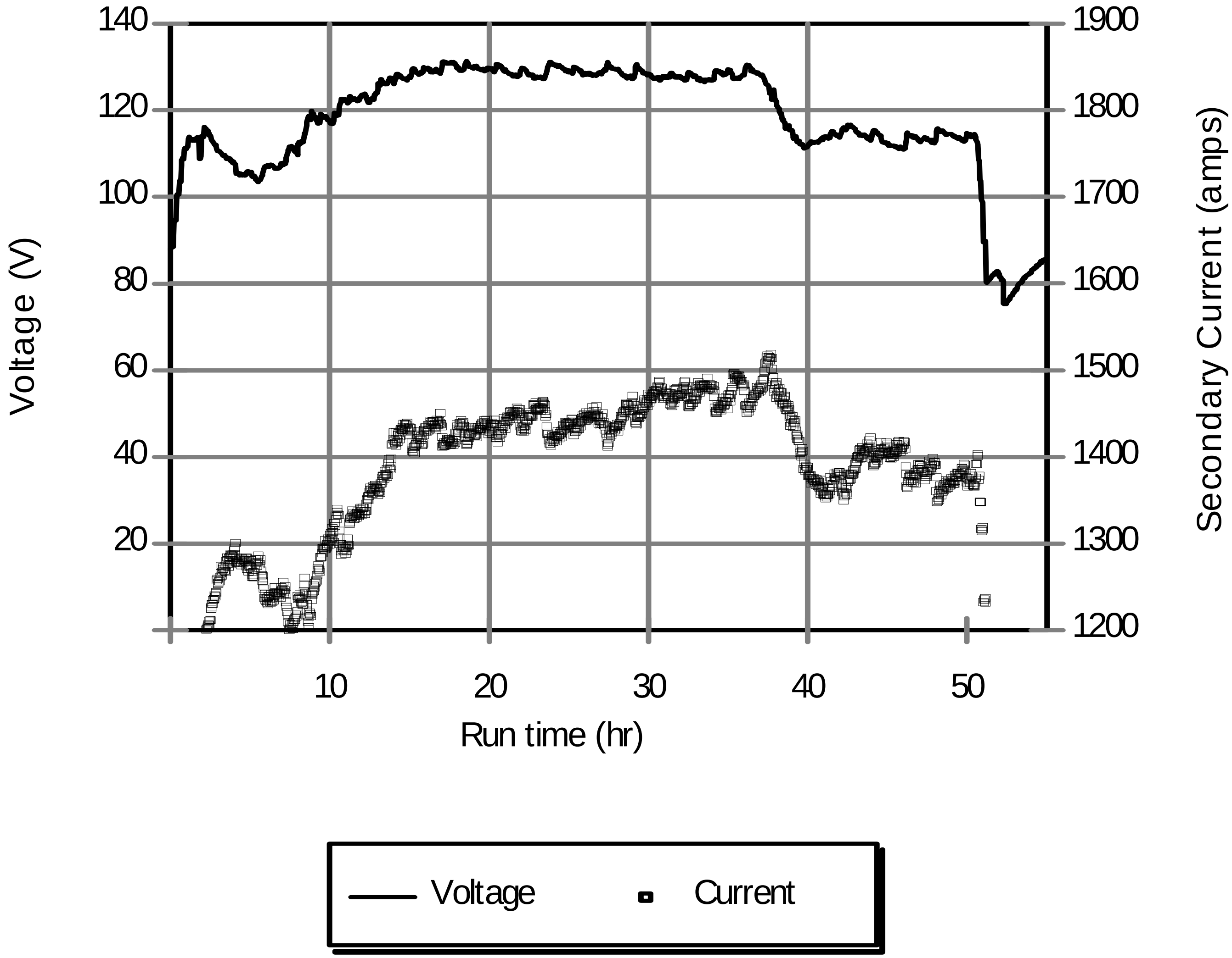



**Figure 3.7.a. Electrode voltage and current while processing with two double-outlet bubblers, Test 1.**

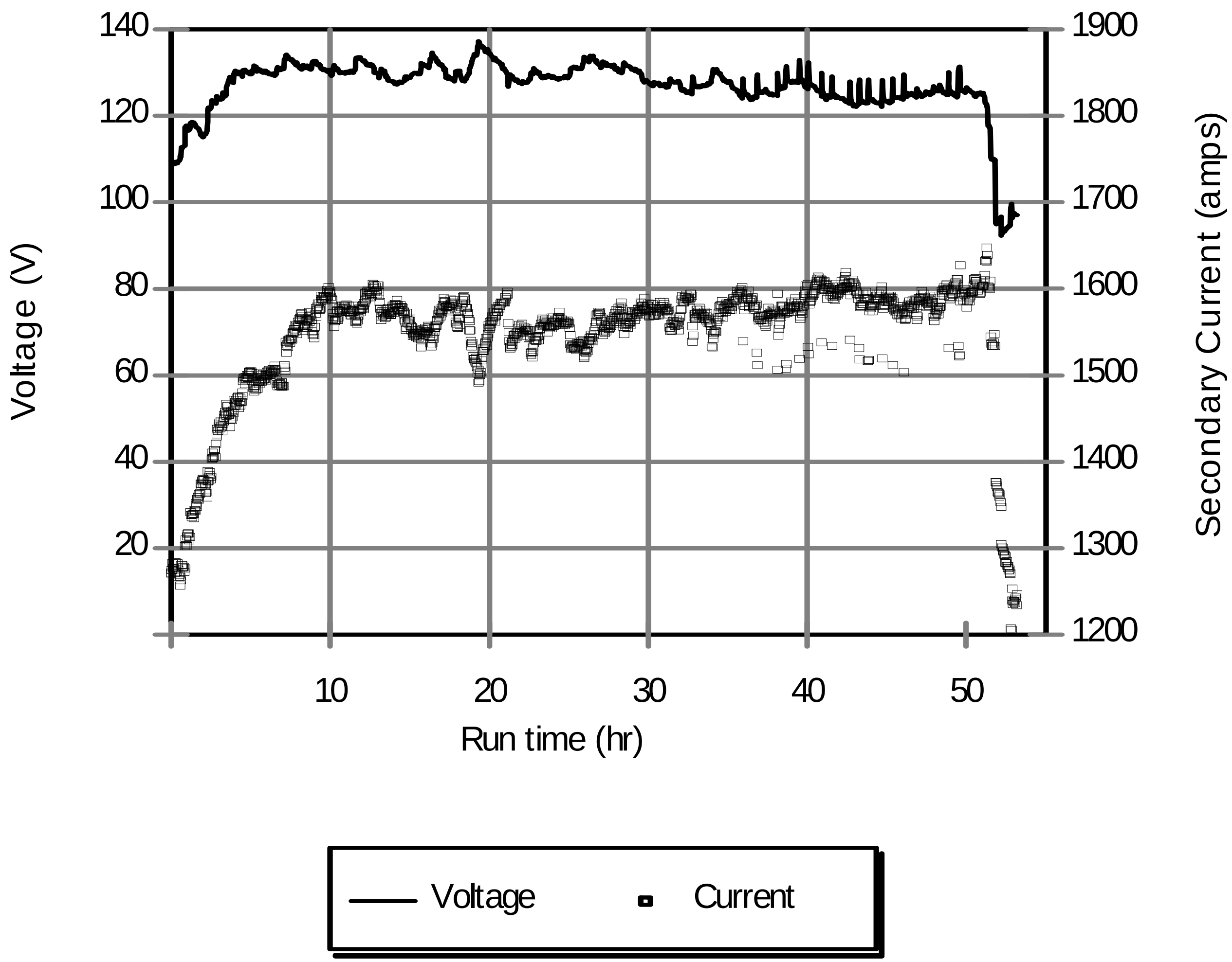



**Figure 3.7.b. Electrode voltage and current while processing with two double-outlet and one single-outlet bubblers, Test 2.**

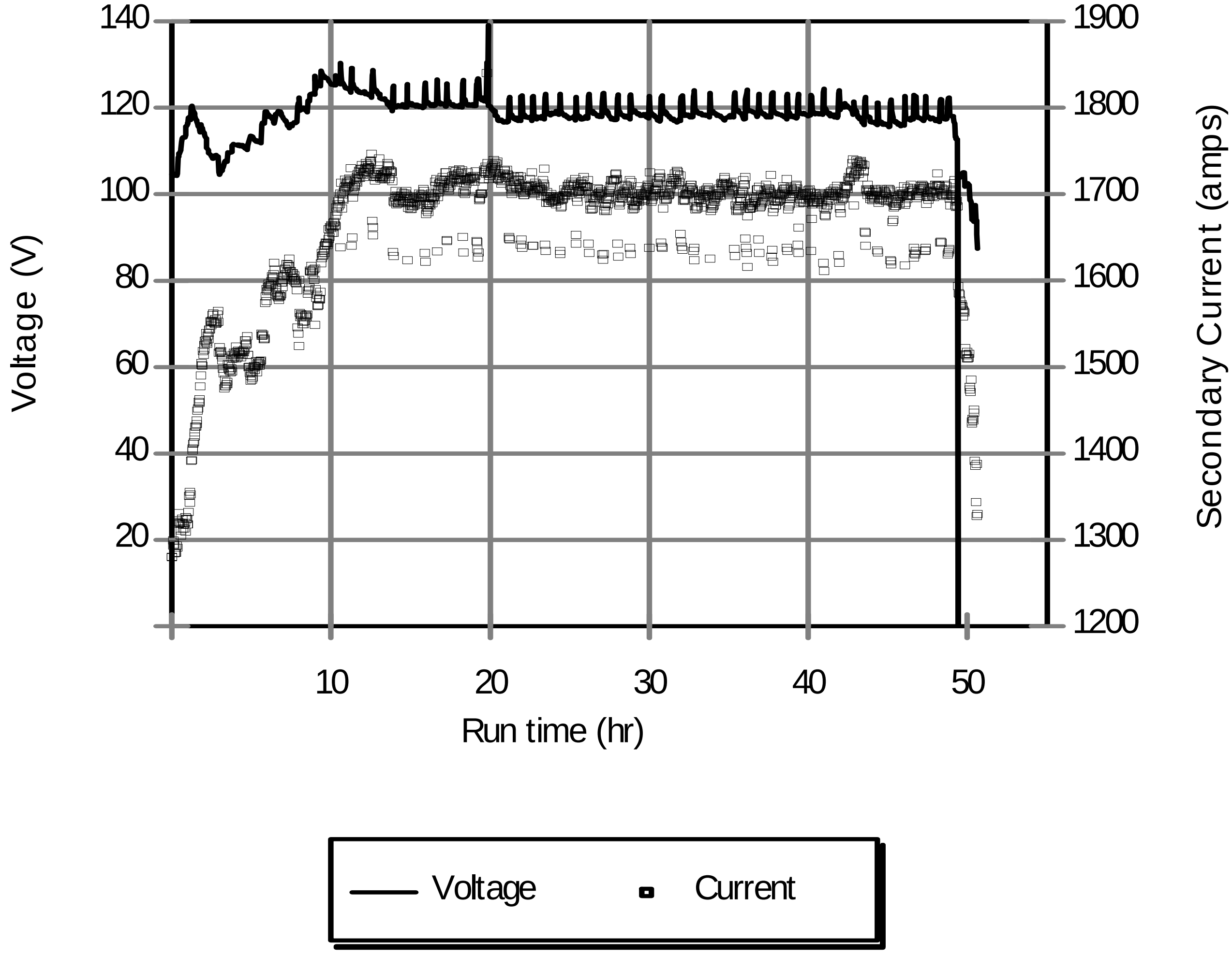



**Figure 3.7.c. Electrode voltage and current while processing with two double-outlet and two single-outlet bubblers, Test 3.**

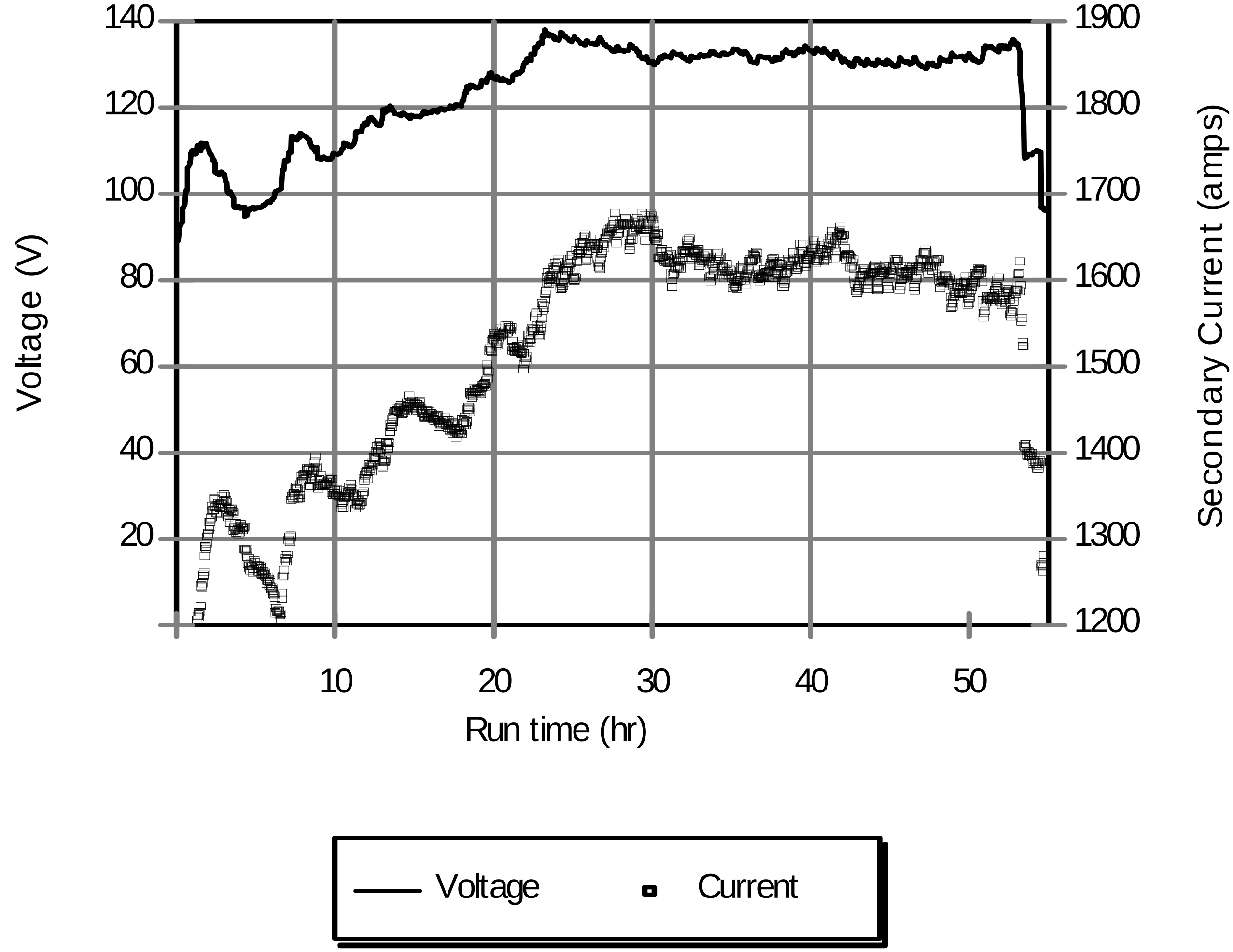



**Figure 3.7.d. Electrode voltage and current while processing with two double-outlet and two single-outlet bubblers, Test 4.**

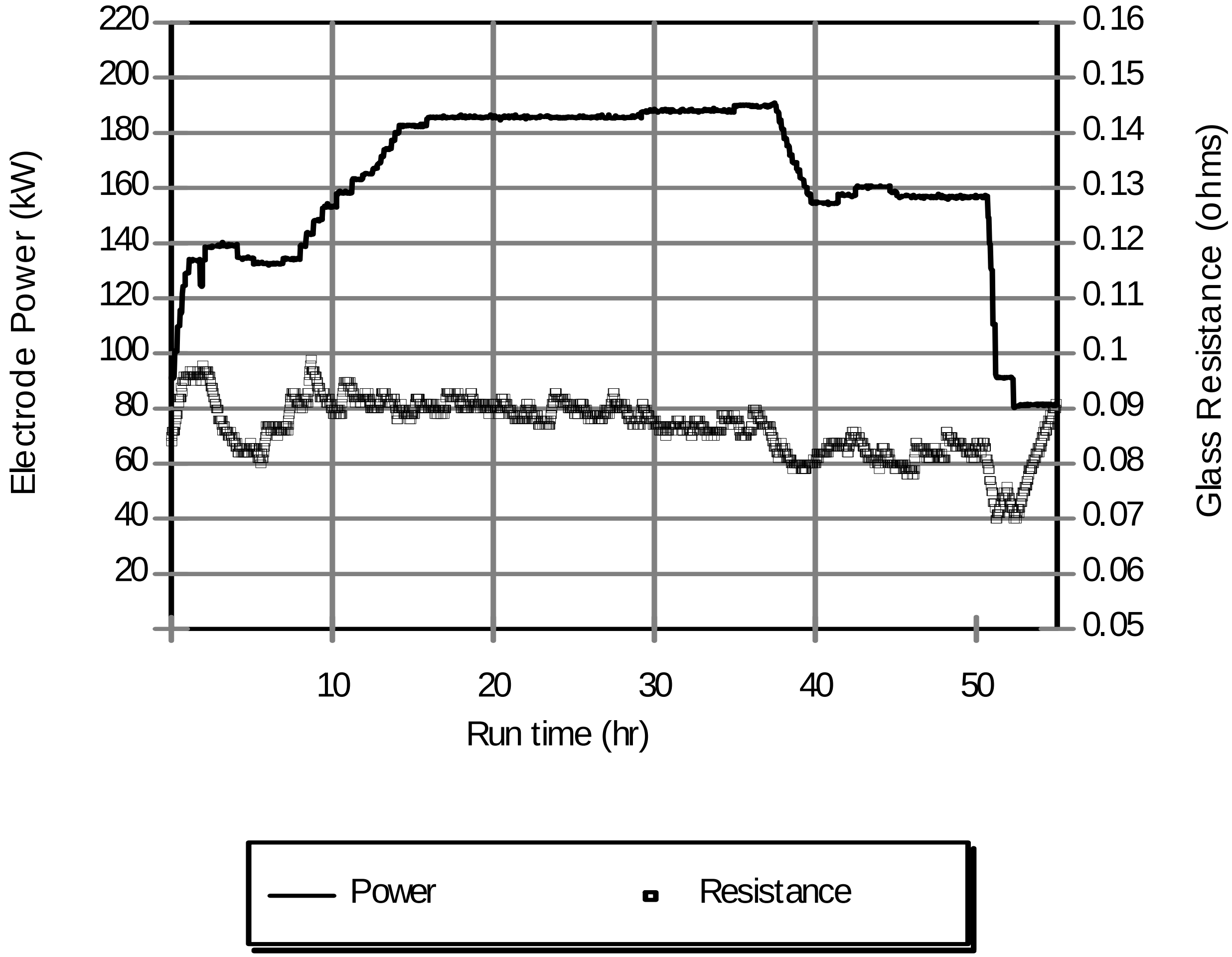



**Figure 3.8.a. Electrode power and glass resistance while processing with two double-outlet bubblers, Test 1.**

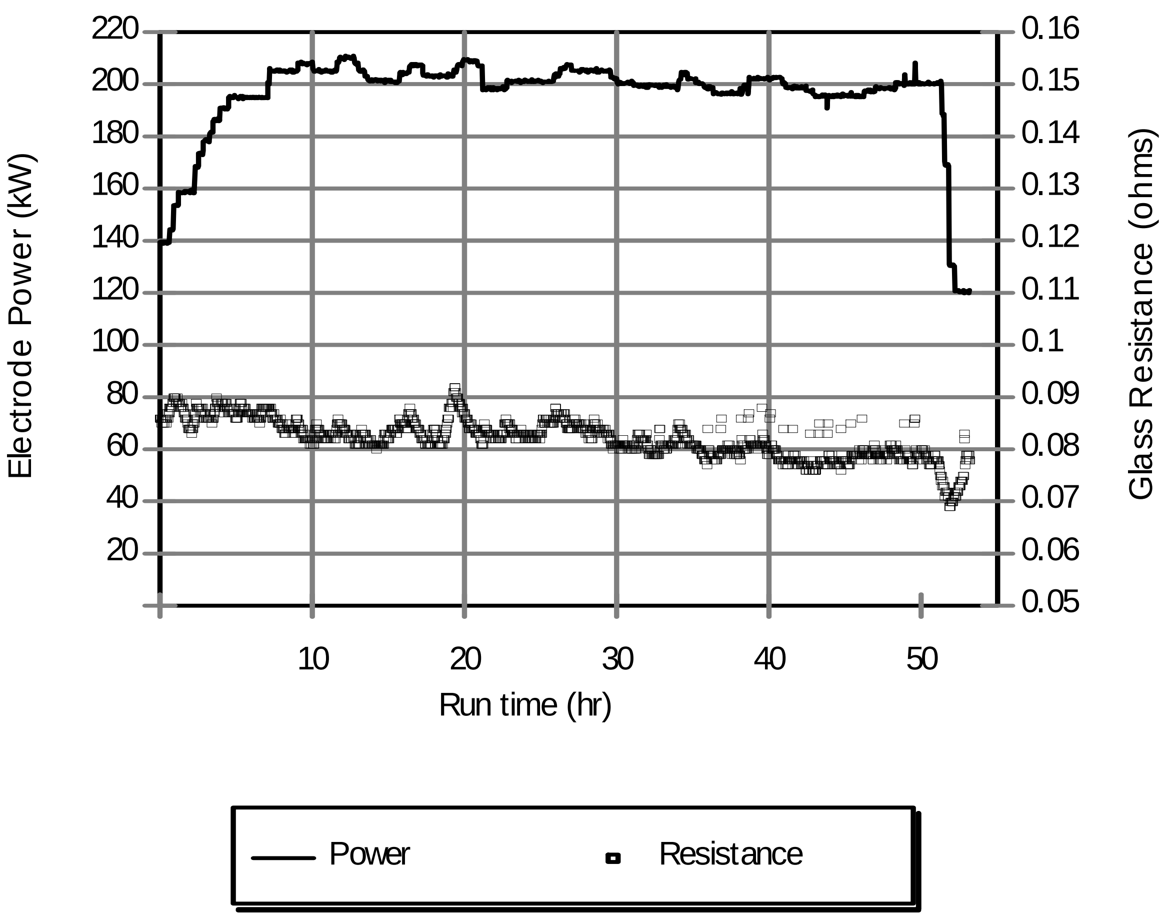



**Figure 3.8.b. Electrode power and glass resistance while processing with two double-outlet and one single-outlet bubblers, Test 2.**

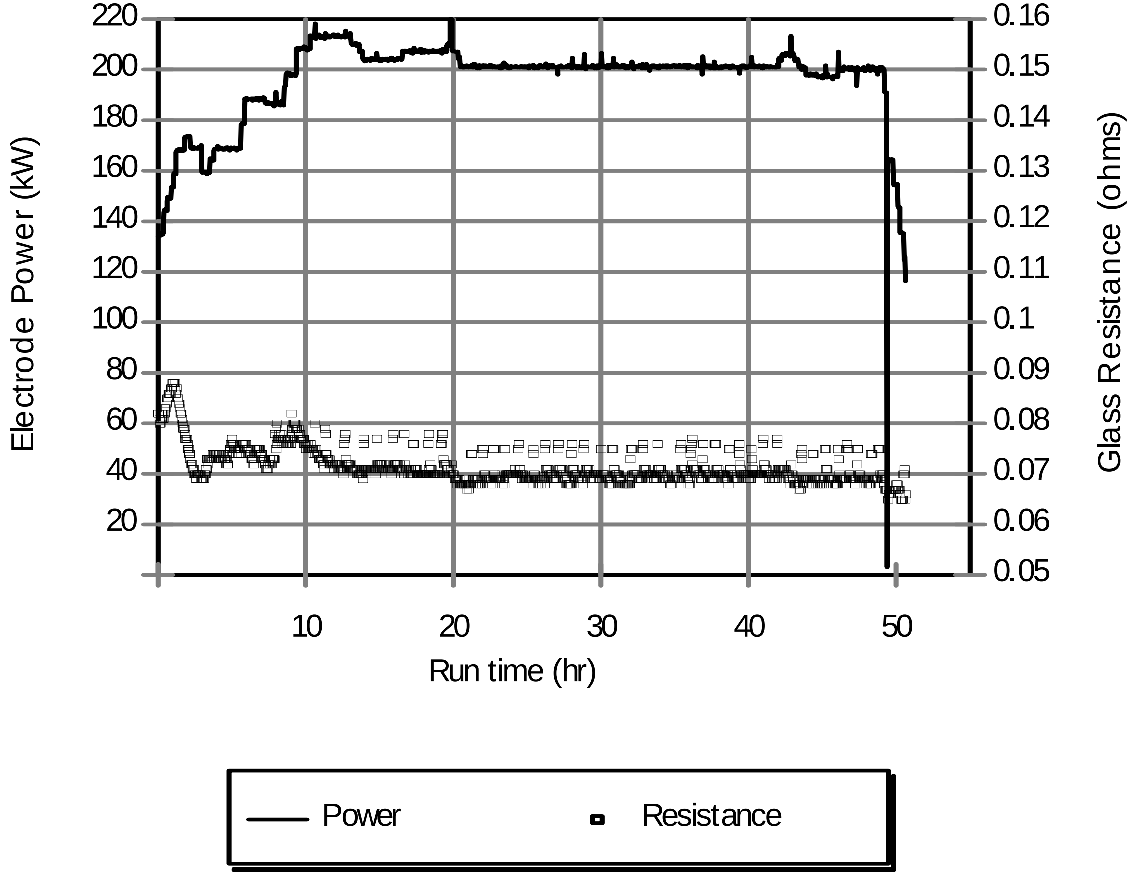



**Figure 3.8.c. Electrode power and glass resistance while processing with two double-outlet and two single-outlet bubblers, Test 3.**

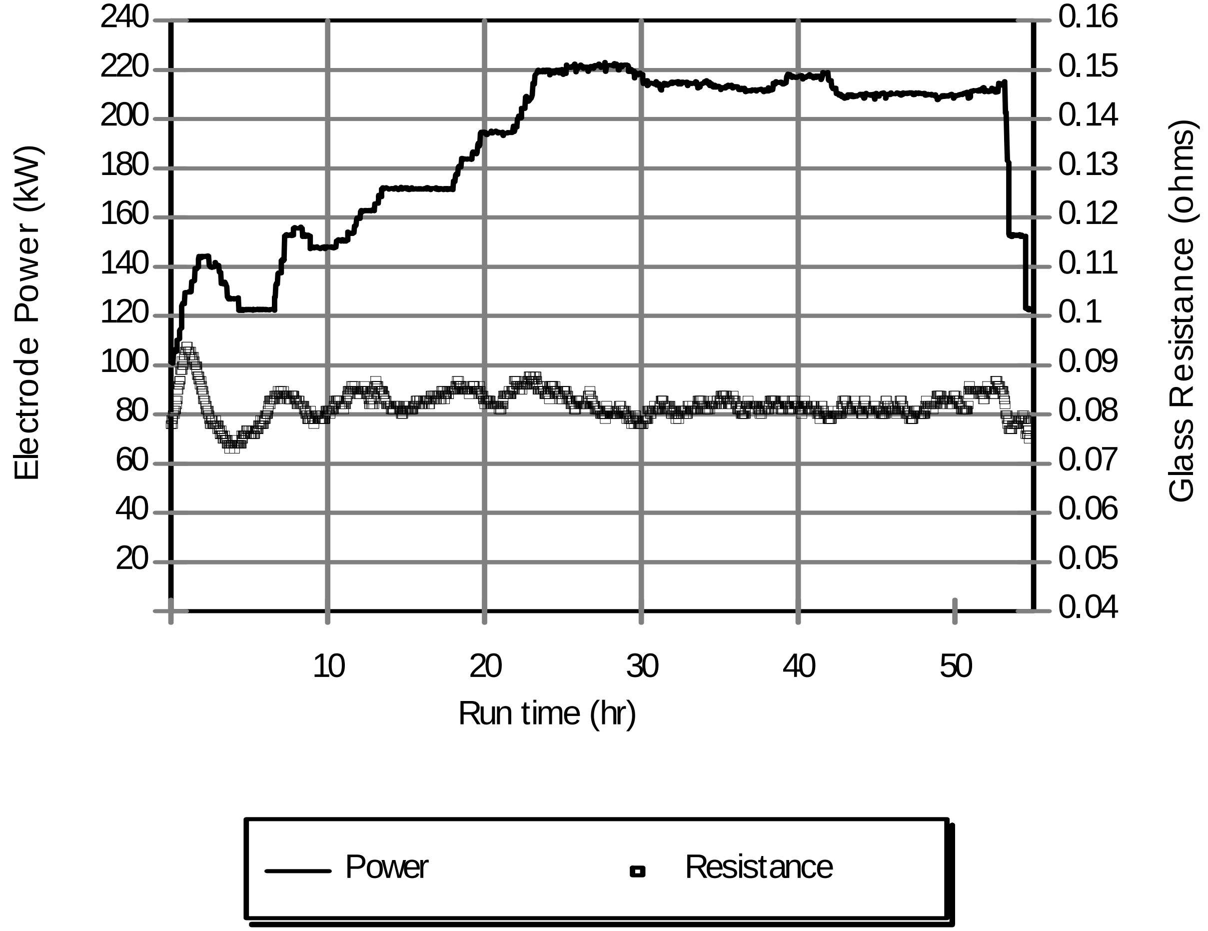



**Figure 3.8.d. Electrode power and glass resistance while processing with two double-outlet and two single-outlet bubblers, Test 4.**

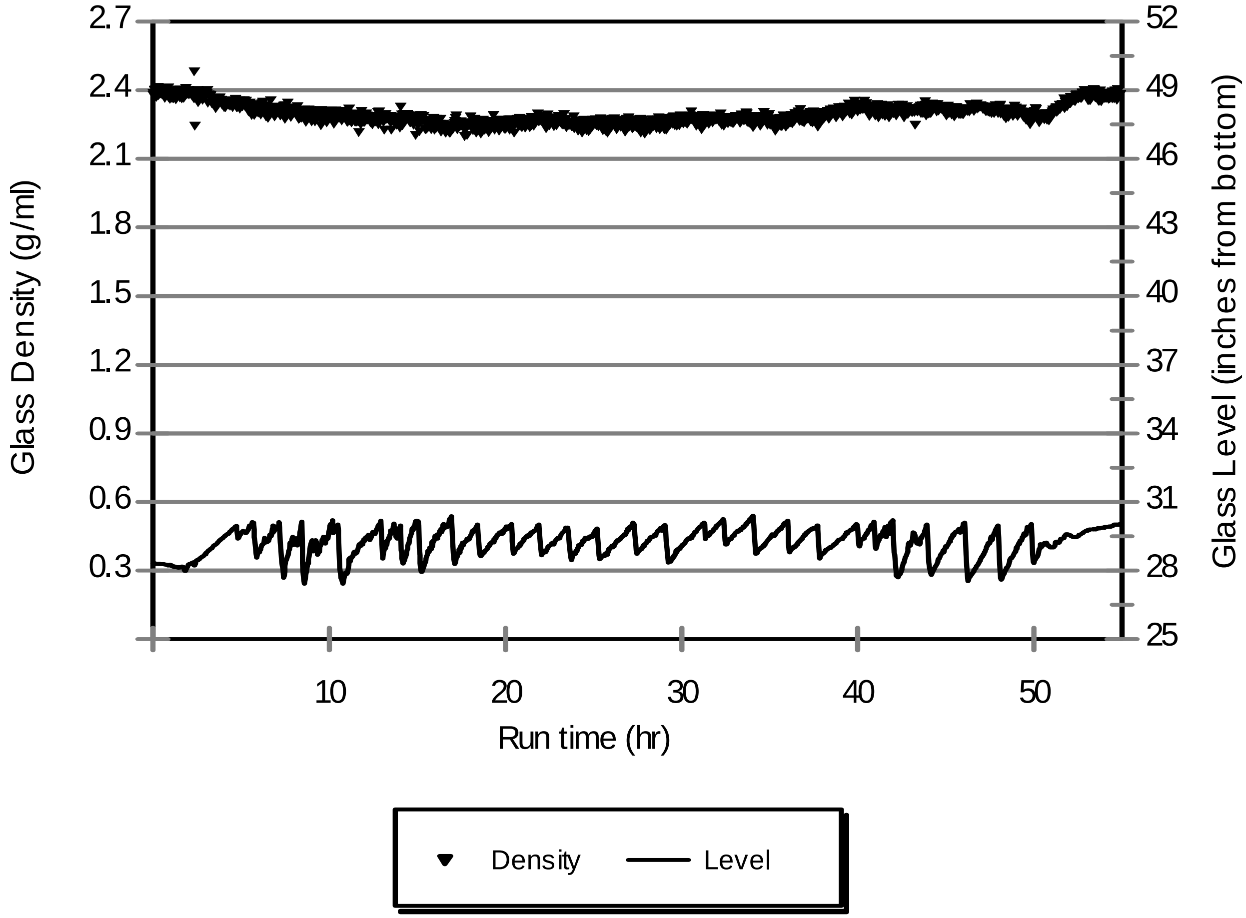



**Figure 3.9.a. Glass density and level while processing with two double-outlet bubblers, Test 1.**

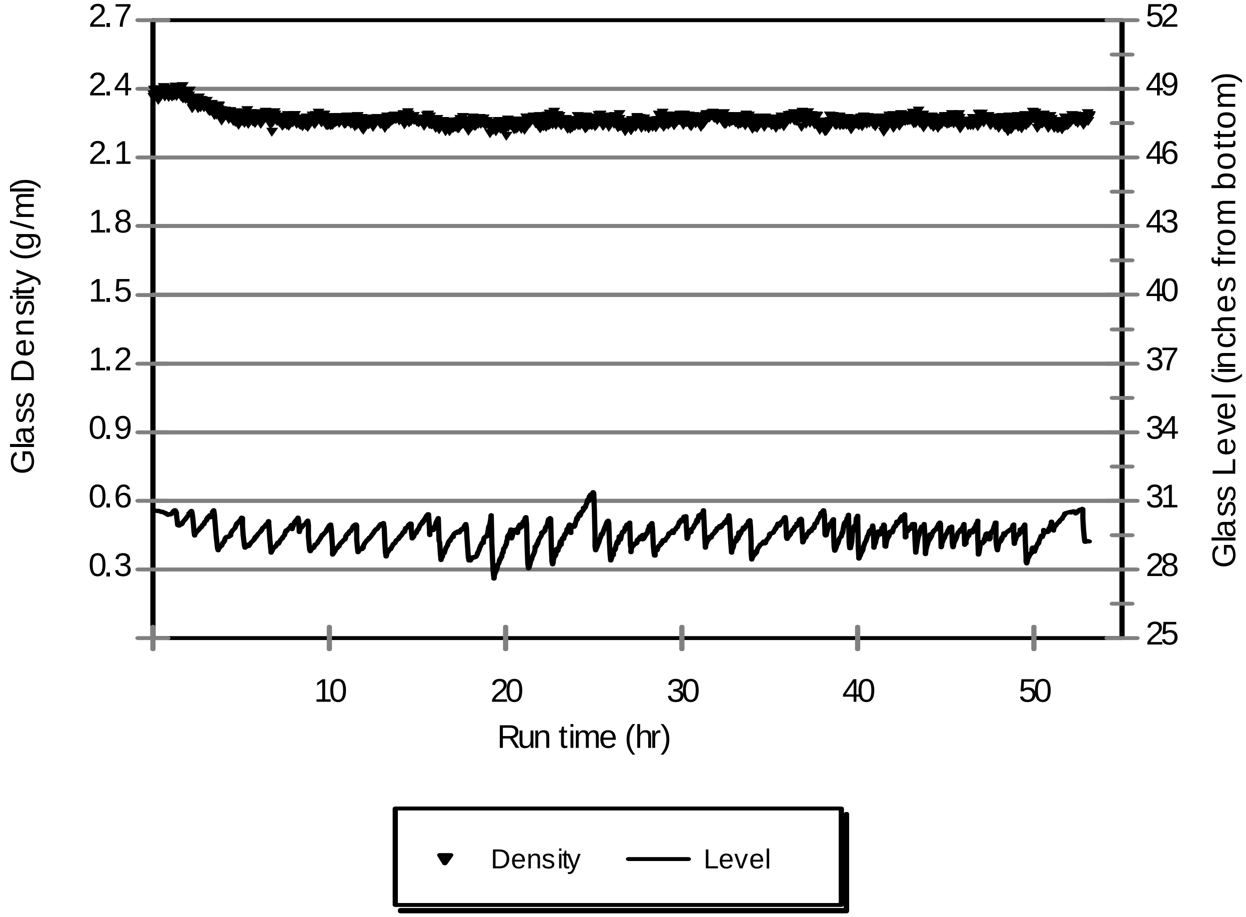



**Figure 3.9.b. Glass density and level while processing with two double-outlet and one single-outlet bubblers, Test 2.**

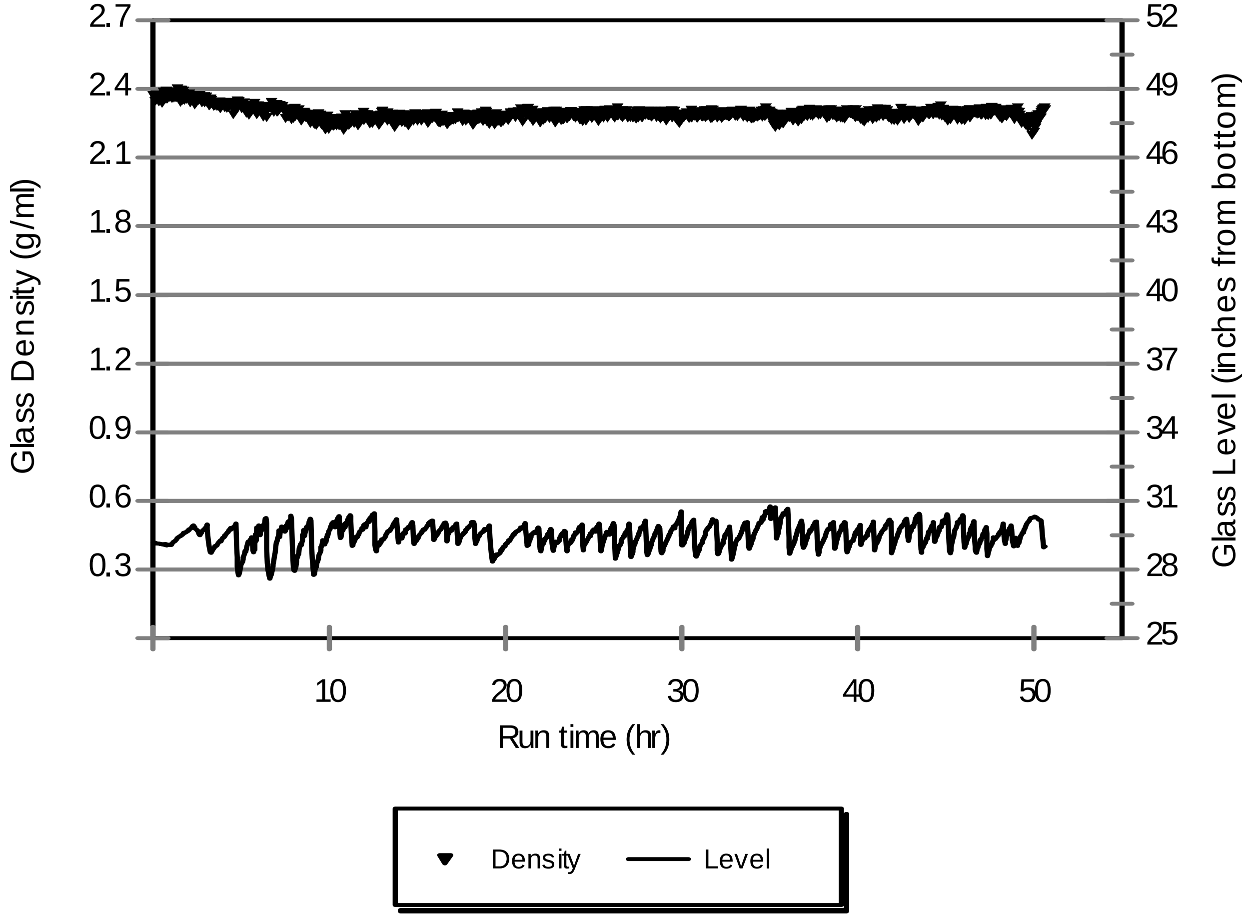



**Figure 3.9.c. Glass density and level while processing with two double-outlet and two single-outlet bubblers, Test 3.**

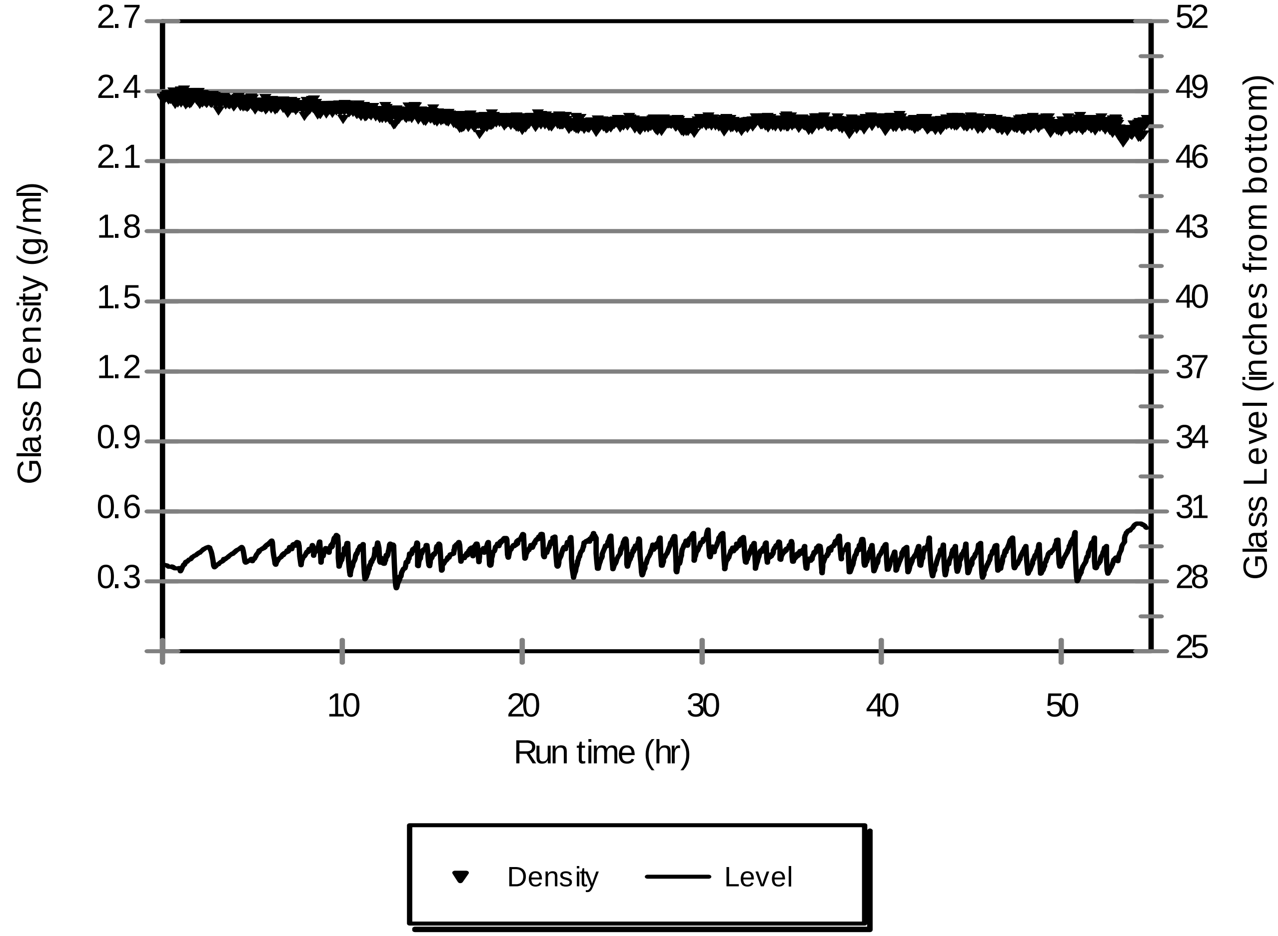



**Figure 3.9.d. Glass density and level while processing with two double-outlet and two single-outlet bubblers, Test 4.**

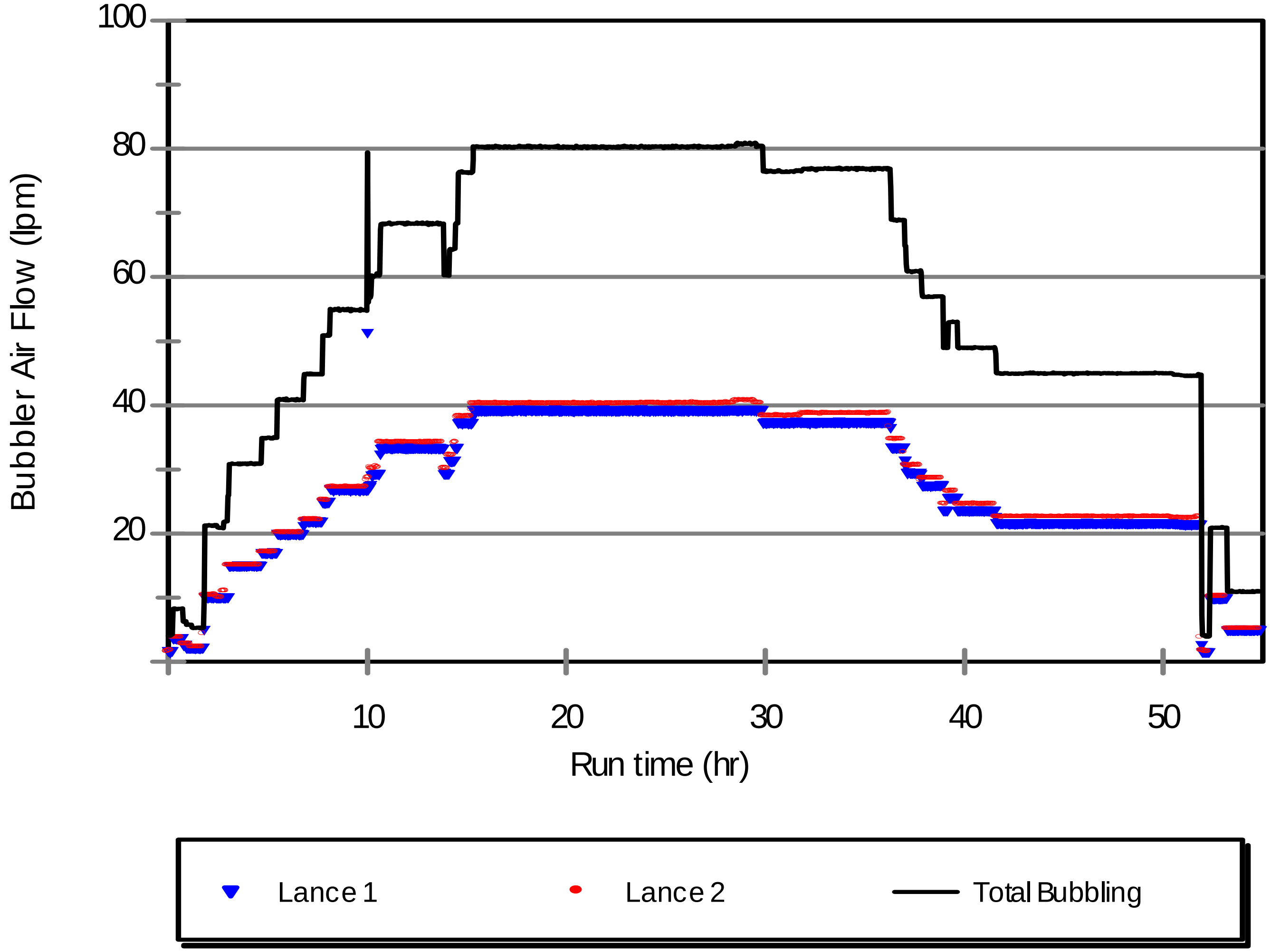



**Figure 3.10.a. Glass pool bubbling while processing with two double-outlet bubblers, Test 1.**

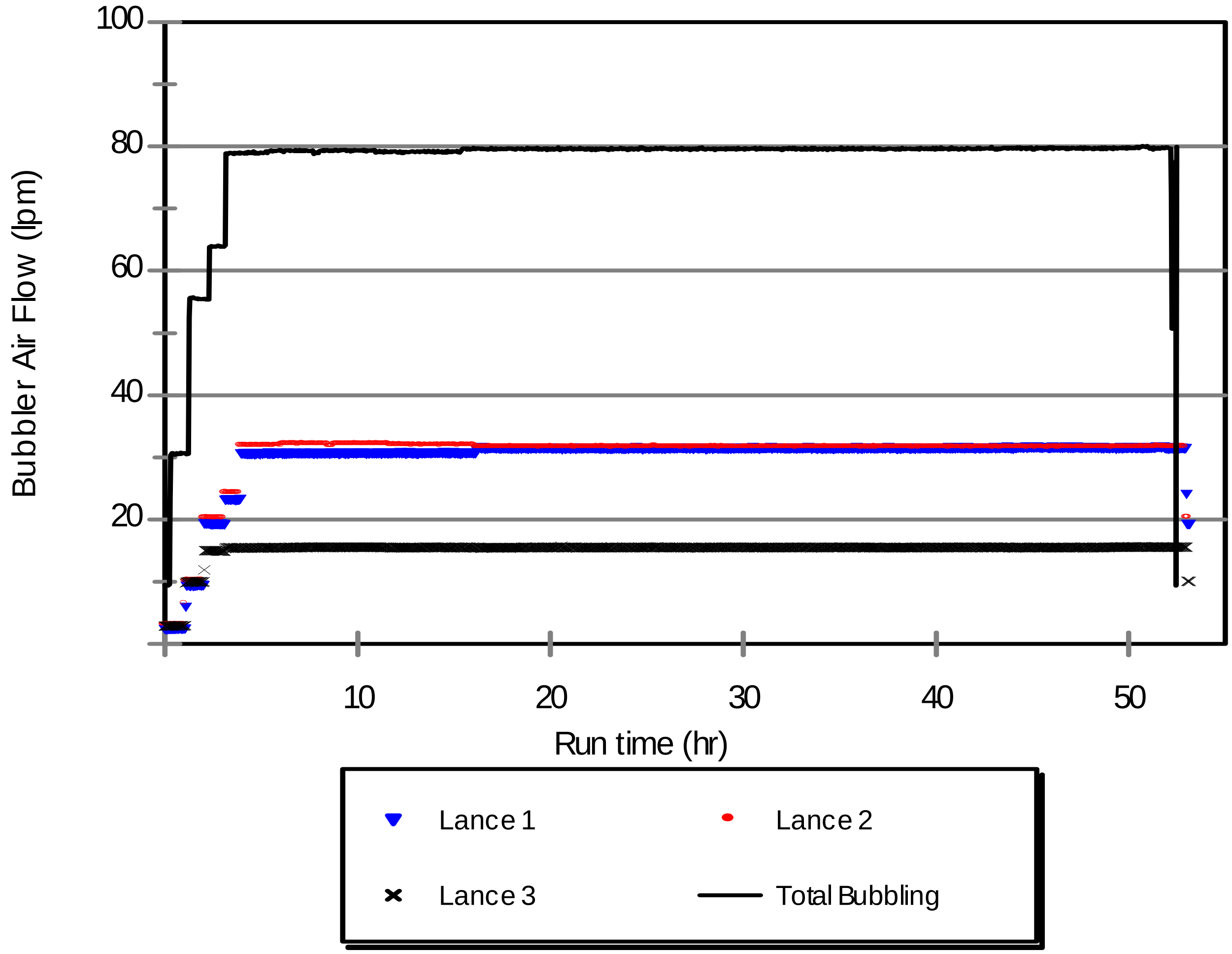



**Figure 3.10.b. Glass pool bubbling while processing with two double-outlet and one single-outlet bubblers, Test 2.**

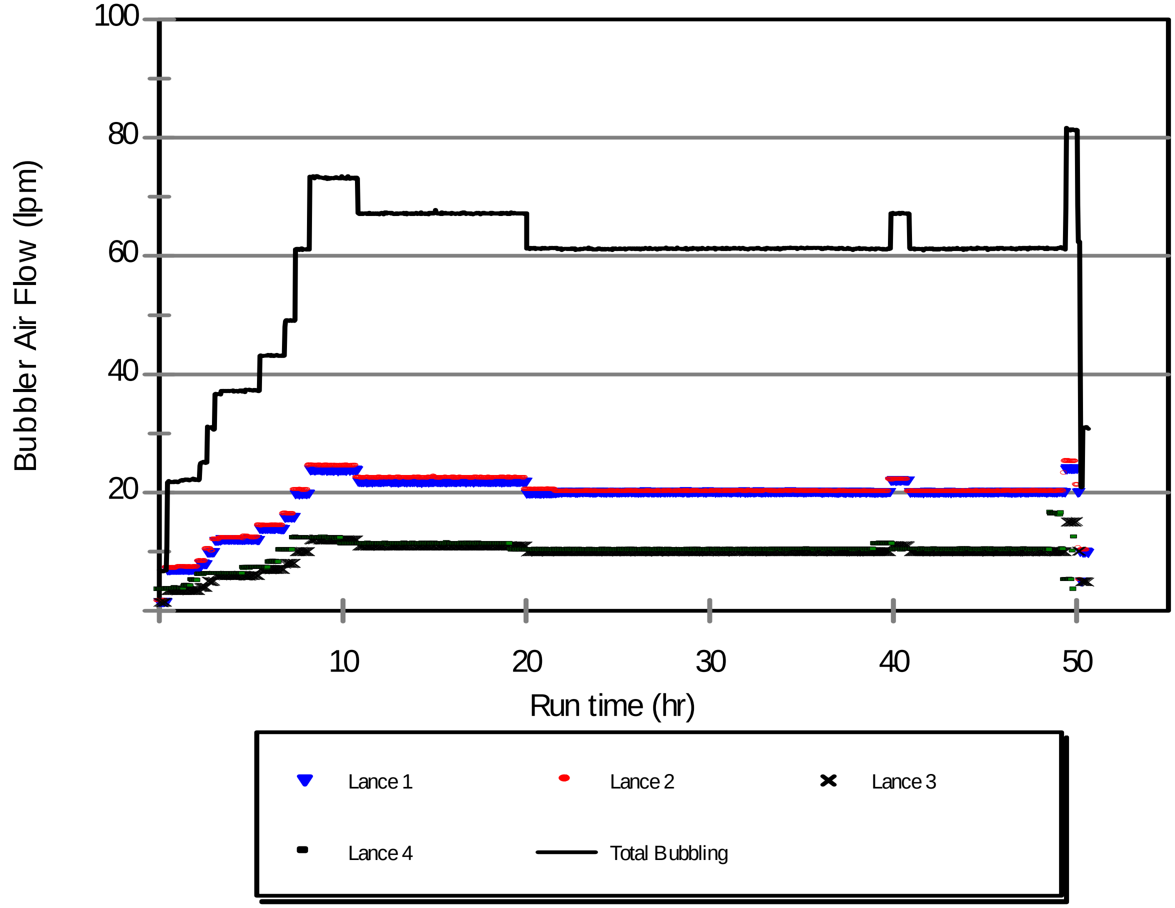



**Figure 3.10.c. Glass pool bubbling while processing with two double-outlet and two single-outlet bubblers, Test 3.**

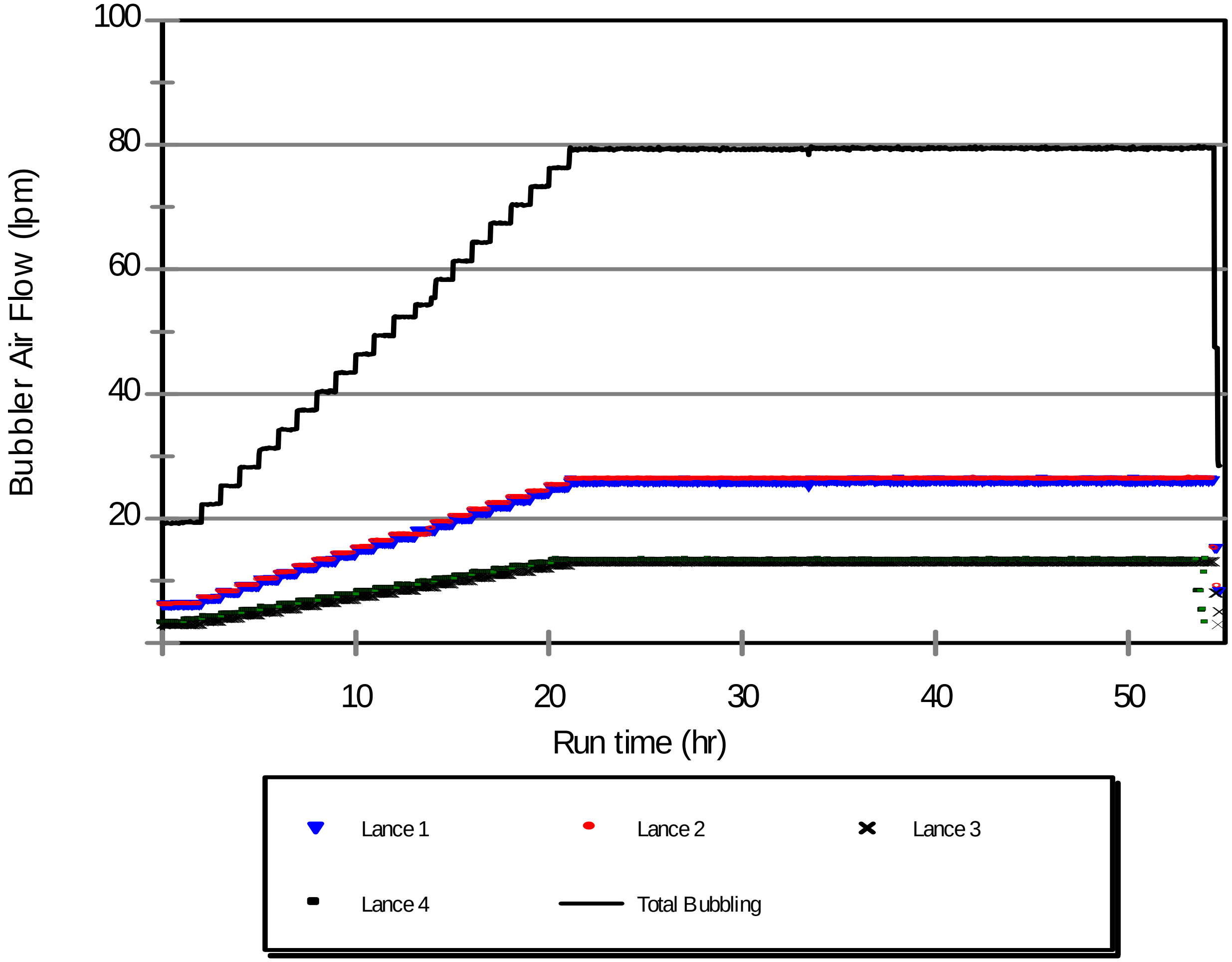



**Figure 3.10.d. Glass pool bubbling while processing with two double-outlet and two single-outlet bubblers, Test 4.**

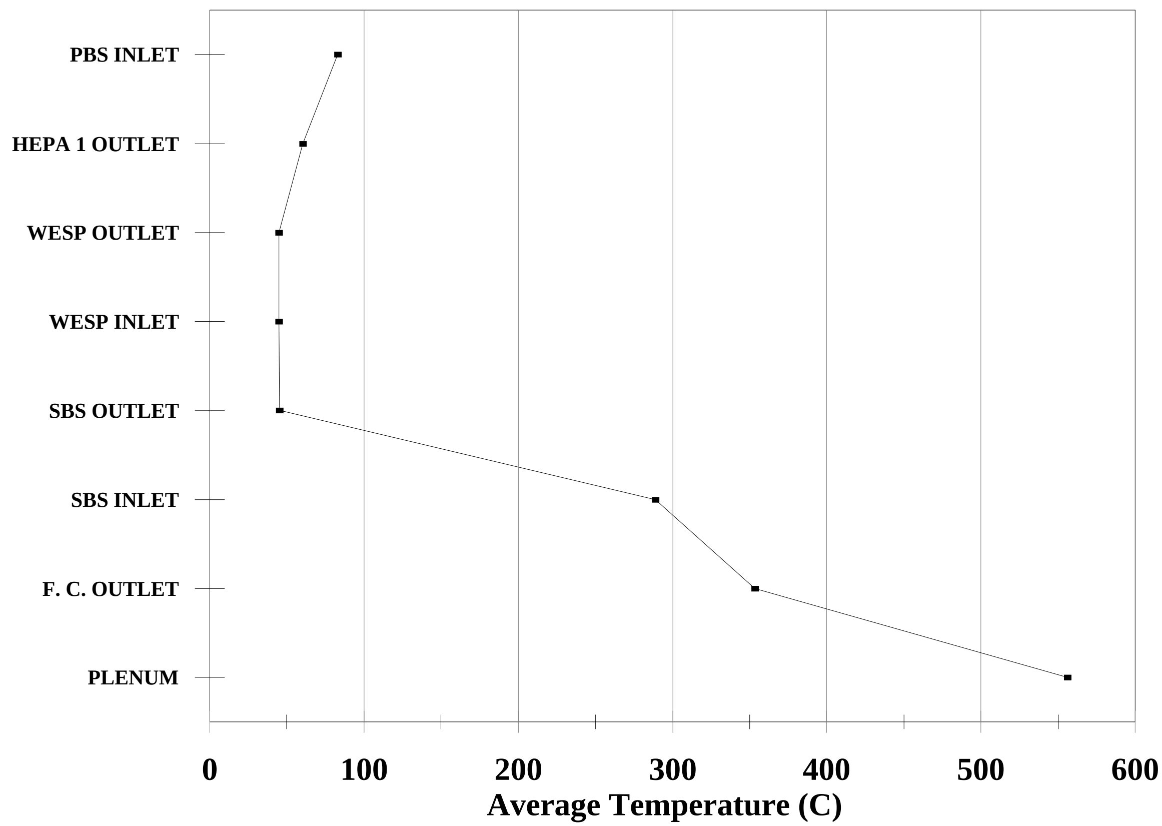



**Figure 4.1. Average gas temperatures along the DM1200 off-gas train while processing with two double-outlet bubblers, Test 1.**

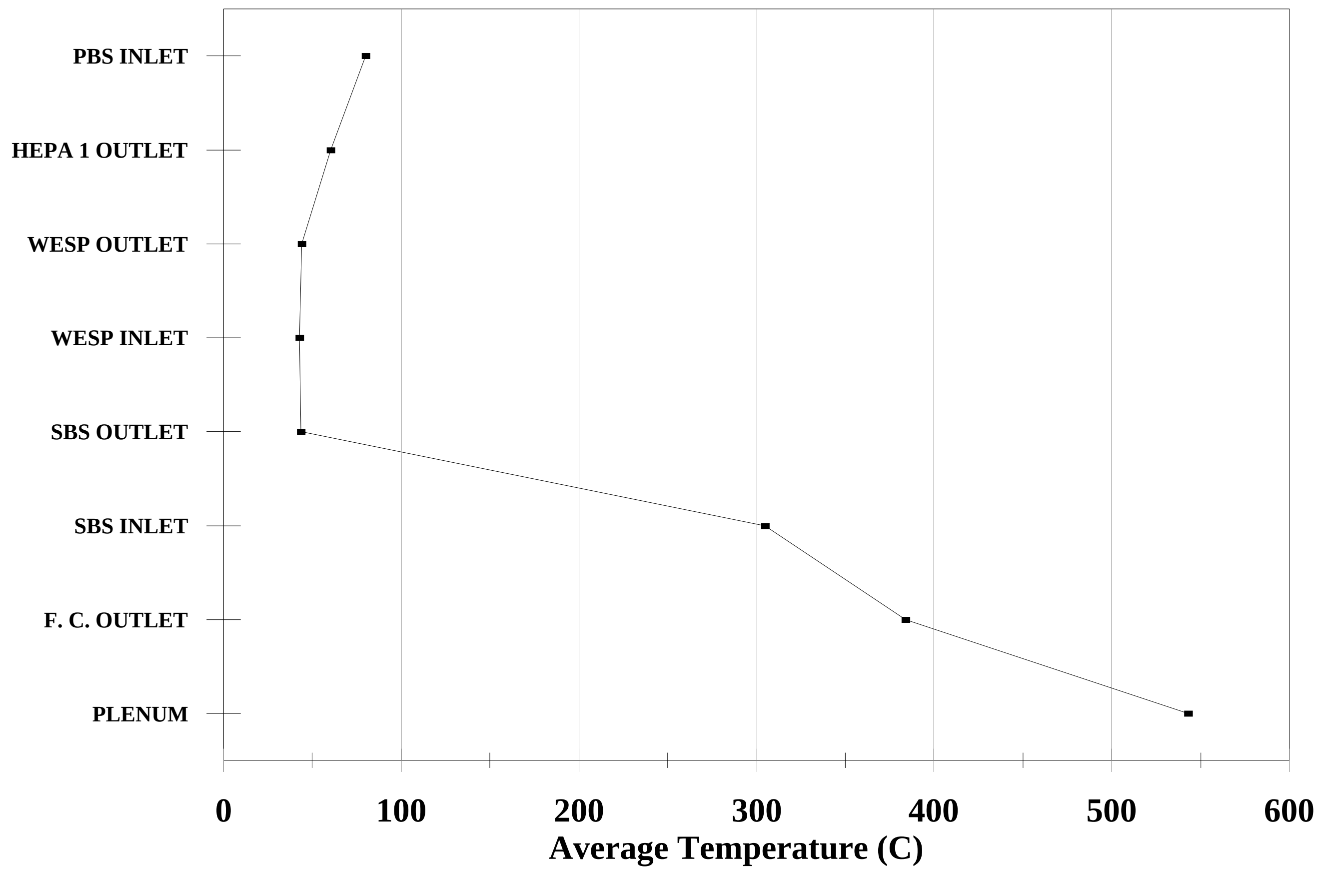



**Figure 4.2. Average gas temperatures along the DM1200 off-gas train while processing with two double-outlet and one single-outlet bubblers, Test 2.**

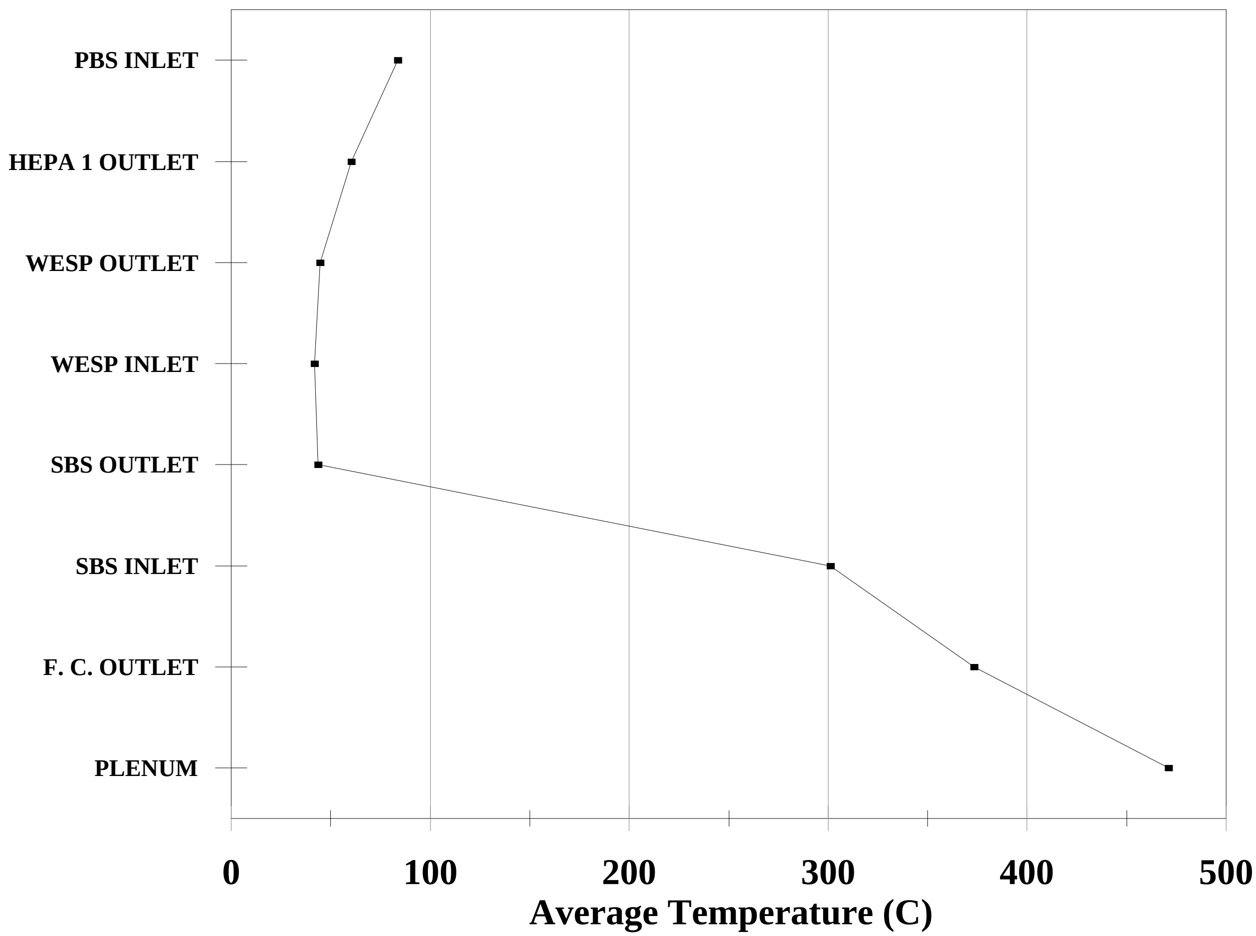



**Figure 4.3. Average gas temperatures along the DM1200 off-gas train while processing with two double-outlet and two single-outlet bubblers, Test 3.**

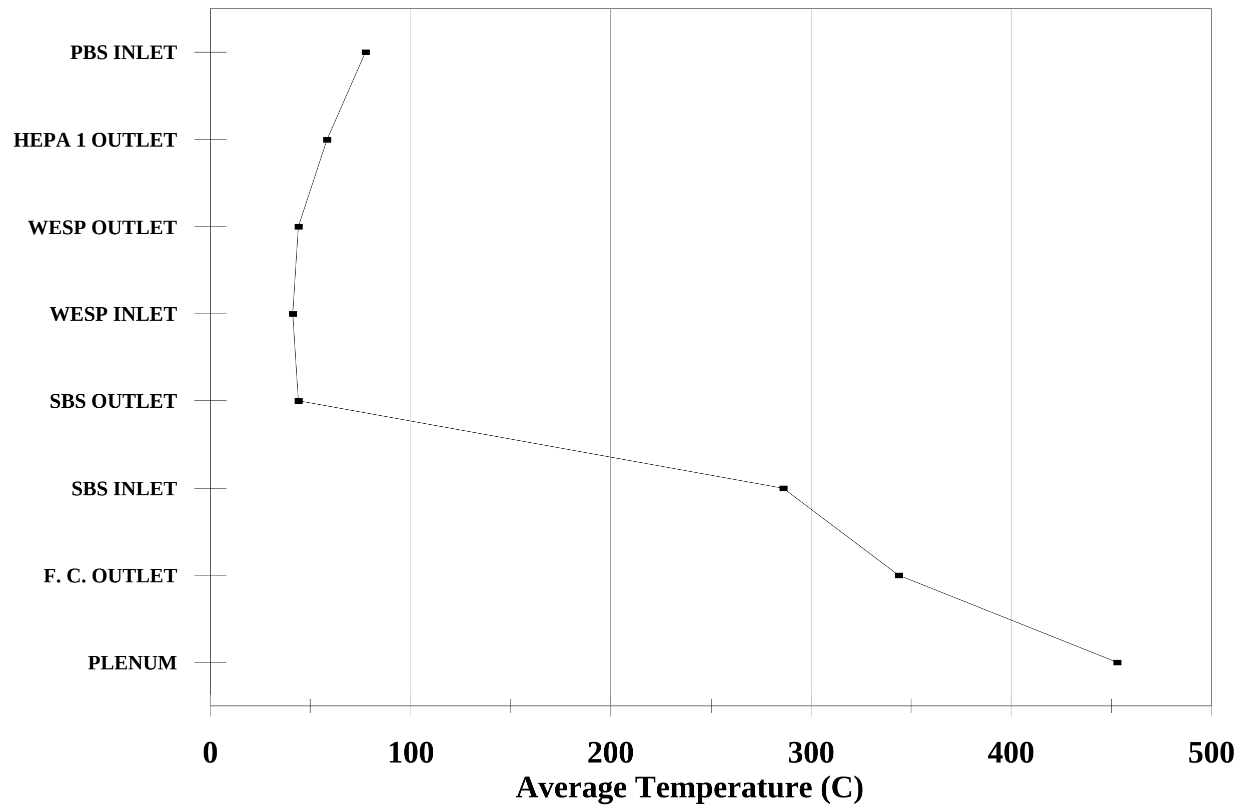



**Figure 4.4. Average gas temperatures along the DM1200 off-gas train rates while processing with two double-outlet and two single-outlet bubblers, Test 4.**

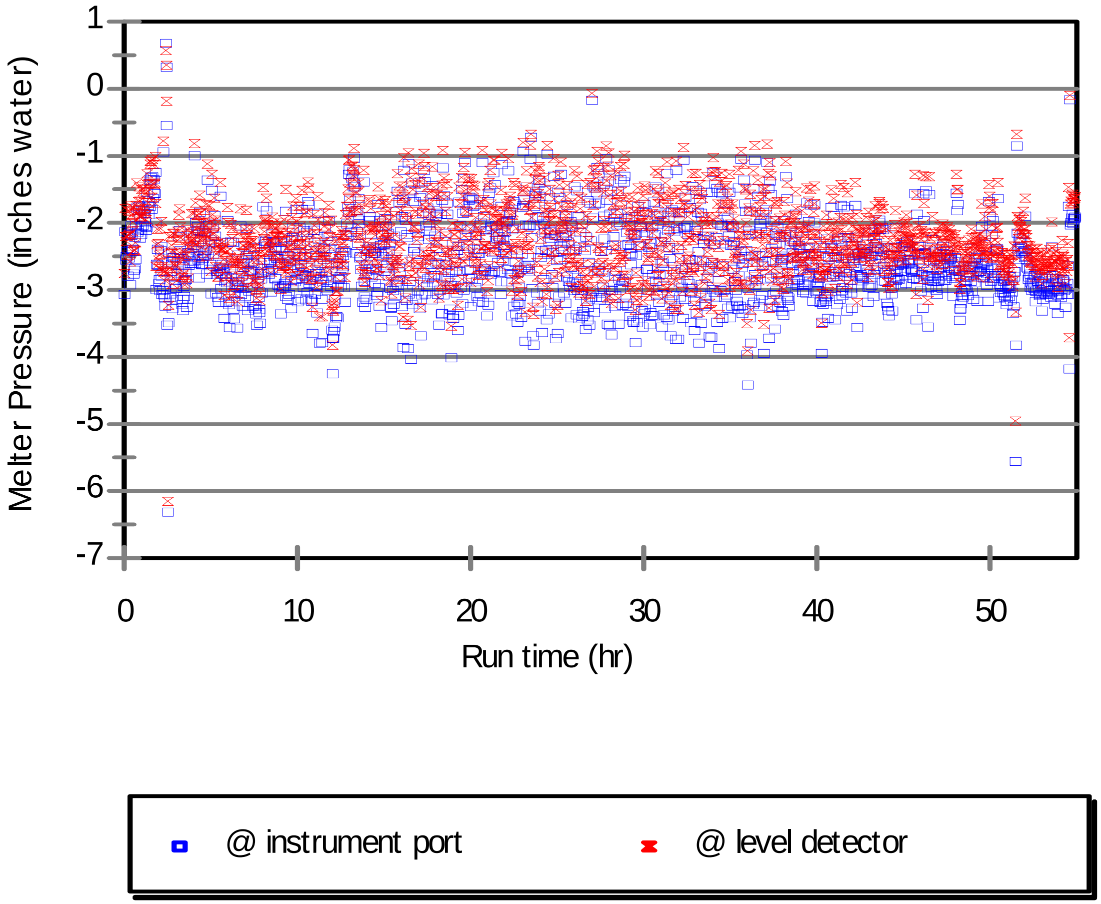



**Figure 4.5. Melter pressure while processing with two double-outlet bubblers, Test 1.**

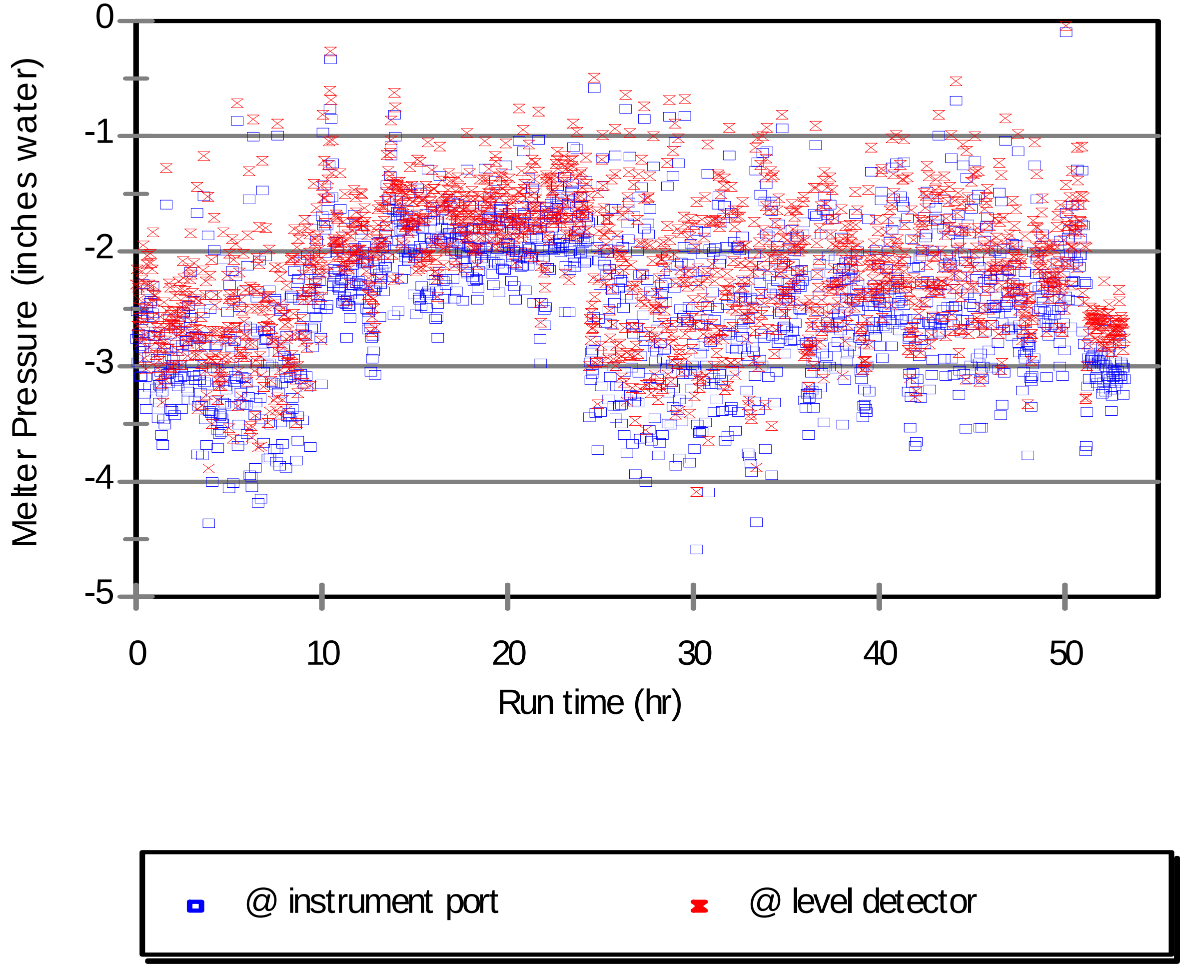



**Figure 4.6. Melter pressure while processing with two double-outlet and one single-outlet bubblers, Test 2.**

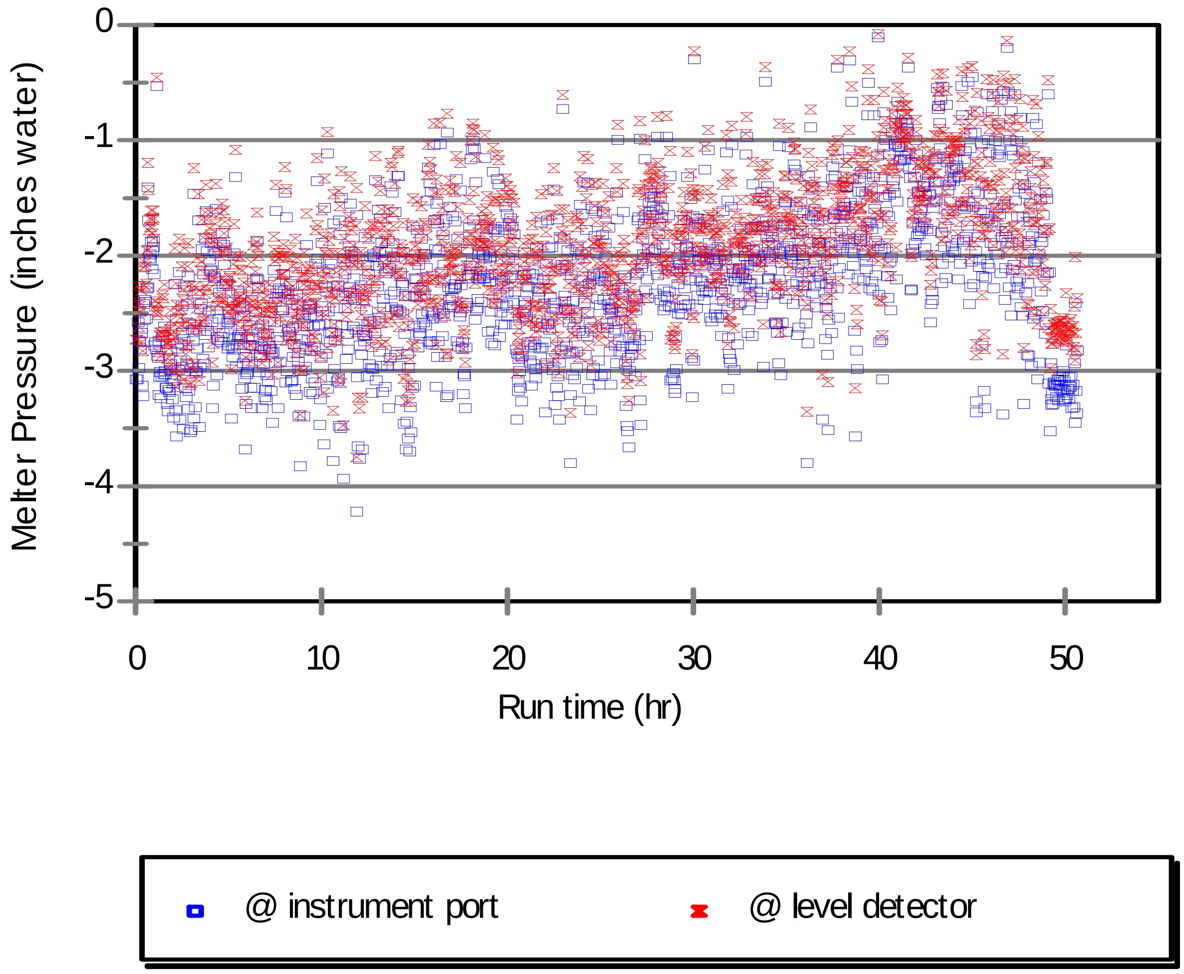



**Figure 4.7. Melter pressure while processing with two double-outlet and two single-outlet bubblers, Test 3.**

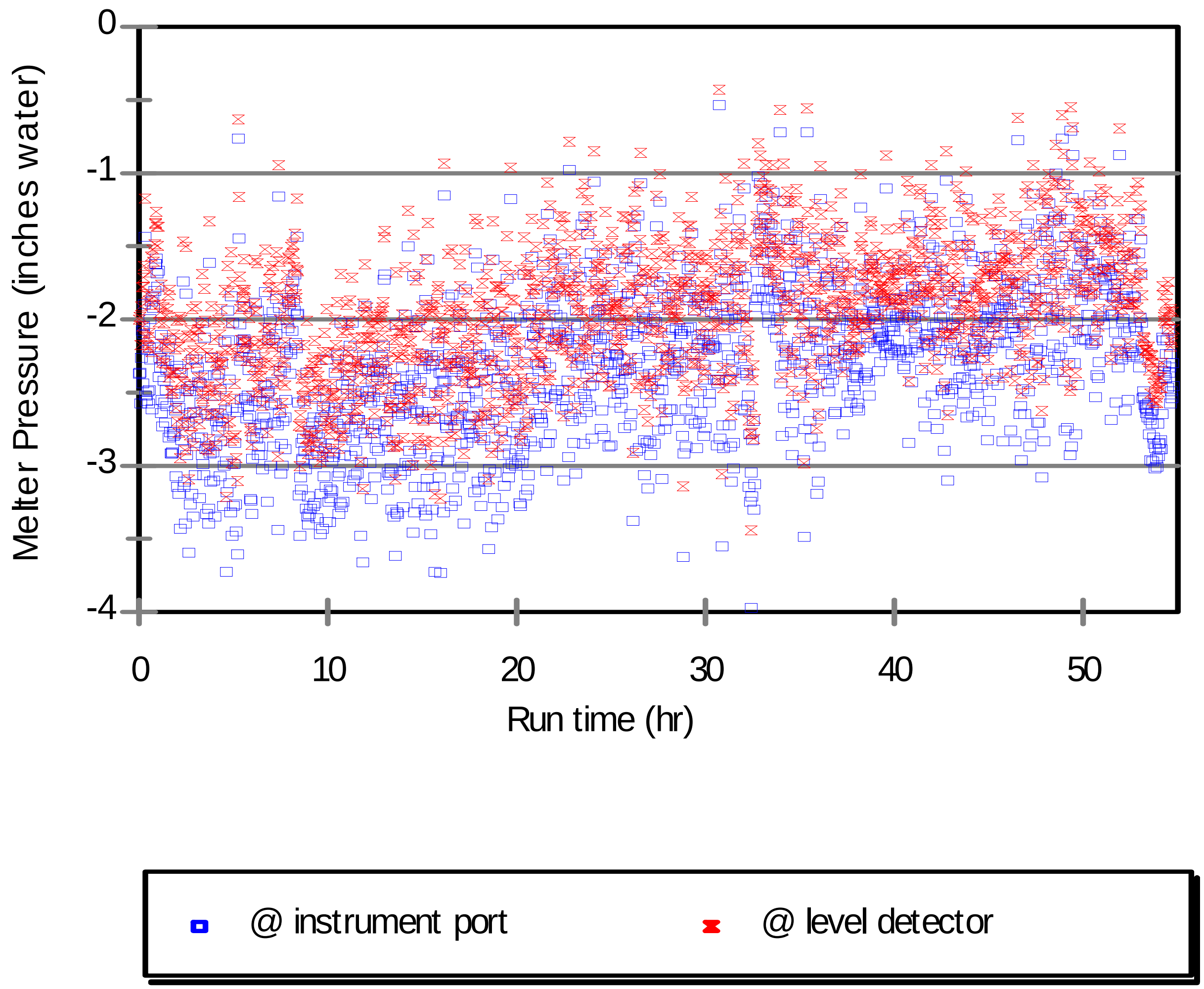



**Figure 4.8. Melter pressure while processing with two double-outlet and two single-outlet bubblers, Test 4.**

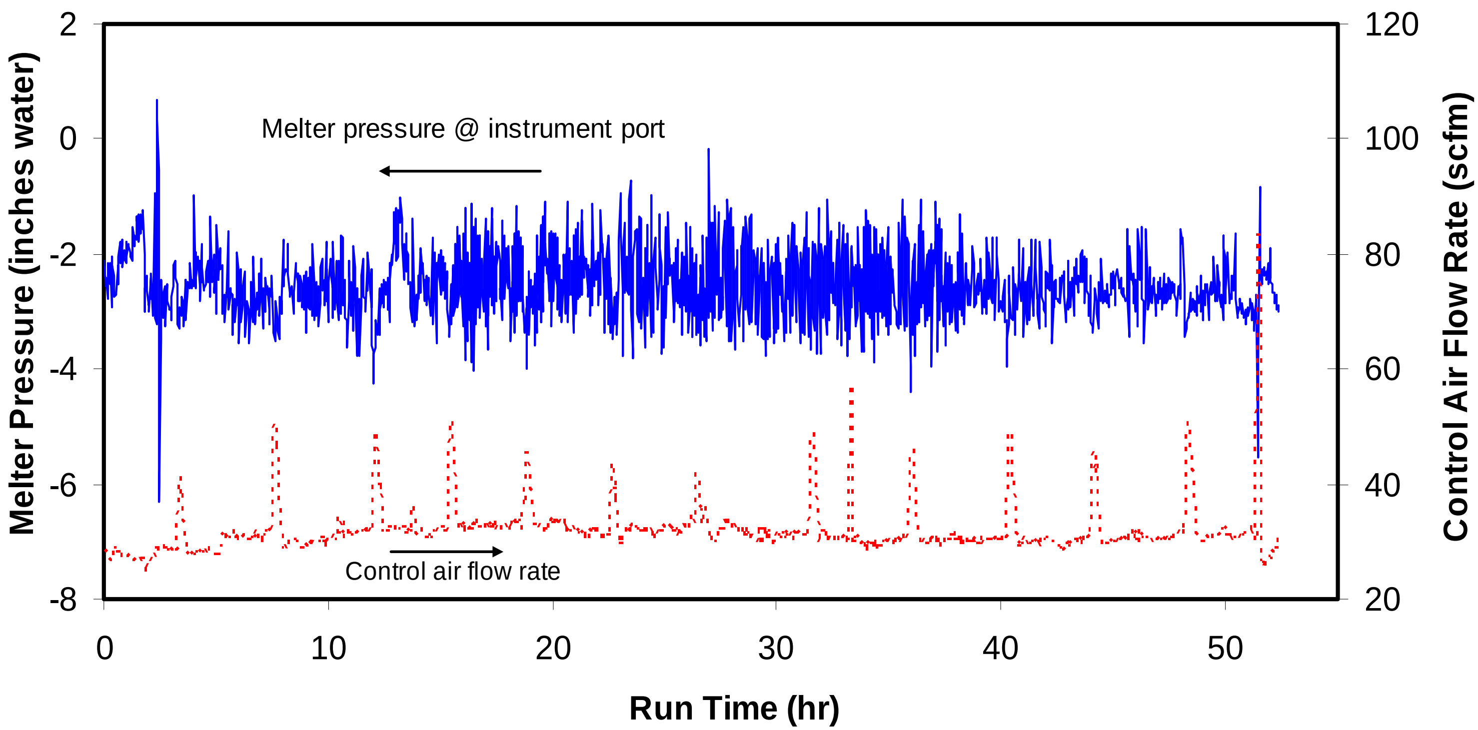



**Figure 4.9. Melter pressure at instrument port and control air flow rate while processing with two double-outlet bubblers, Test 1.**

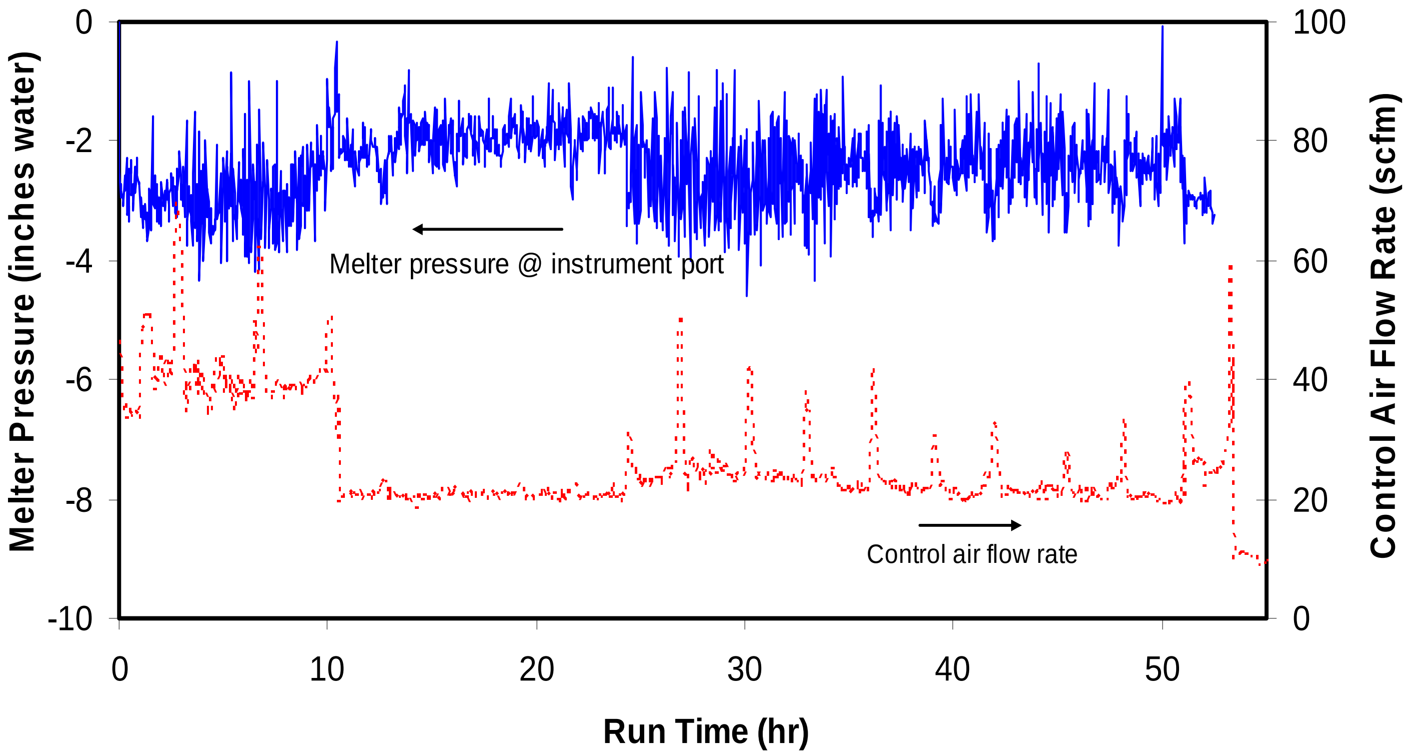



**Figure 4.10. Melter pressure at instrument port and control air flow rate while processing with two double-outlet and one single-outlet bubblers, Test 2.**

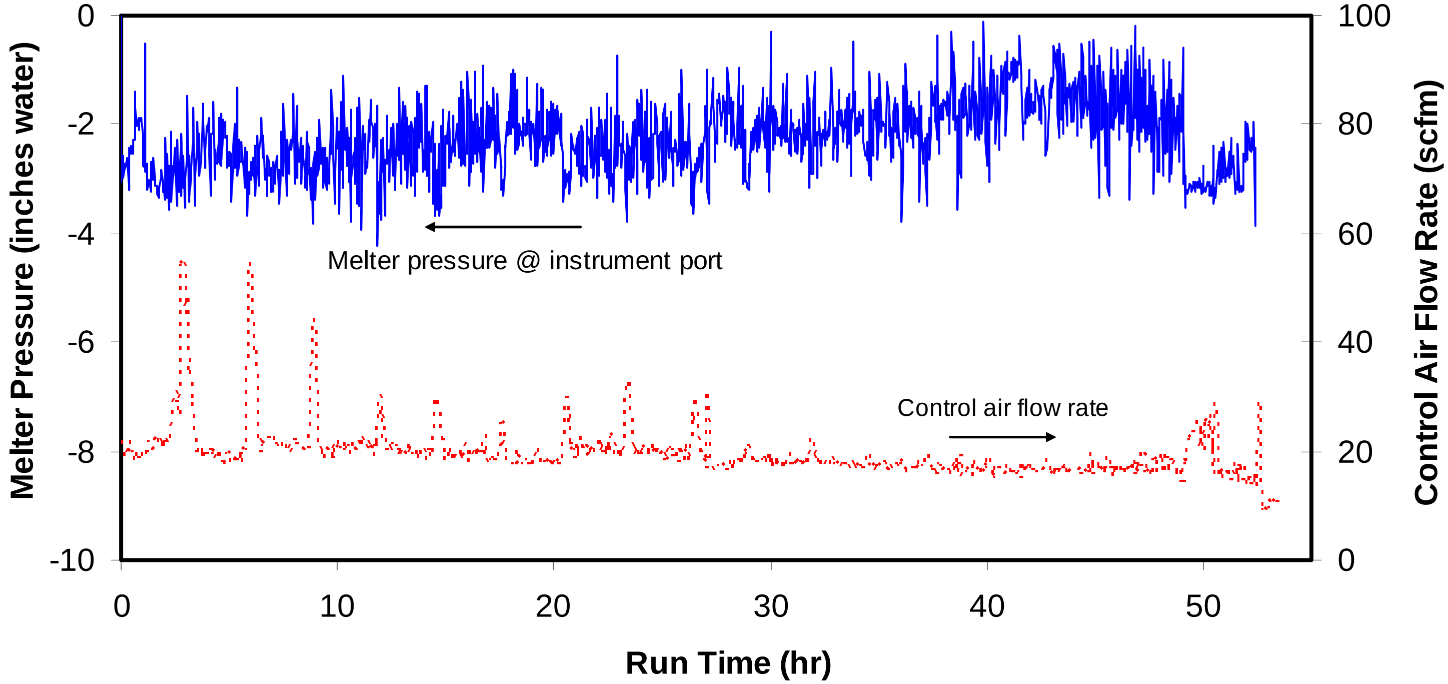



**Figure 4.11. Melter pressure at instrument port and control air flow rate while processing with two double-outlet and two single-outlet bubblers, Test 3.**

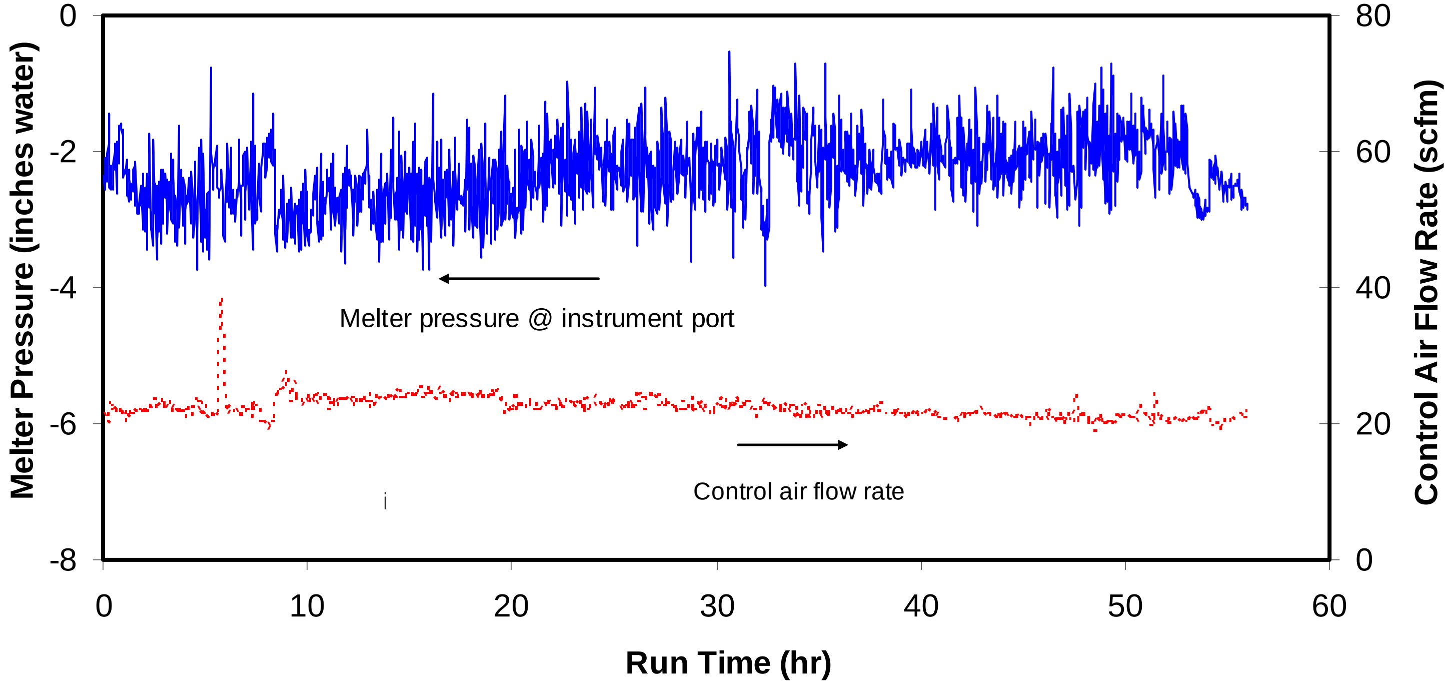



**Figure 4.12. Melter pressure at instrument port and control air flow rate while processing with two double-outlet and two single-outlet bubblers, Test 4.**

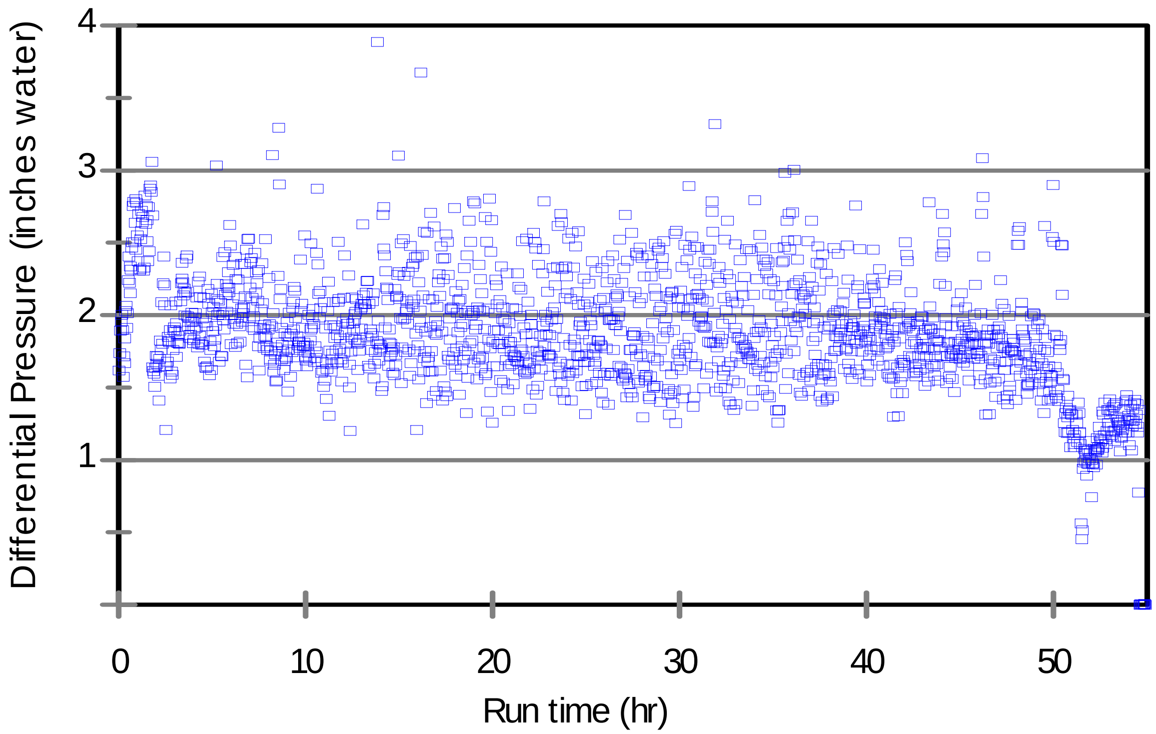



**Figure 4.13. Differential pressure across the film cooler while processing with two double-outlet bubblers, Test 1.**

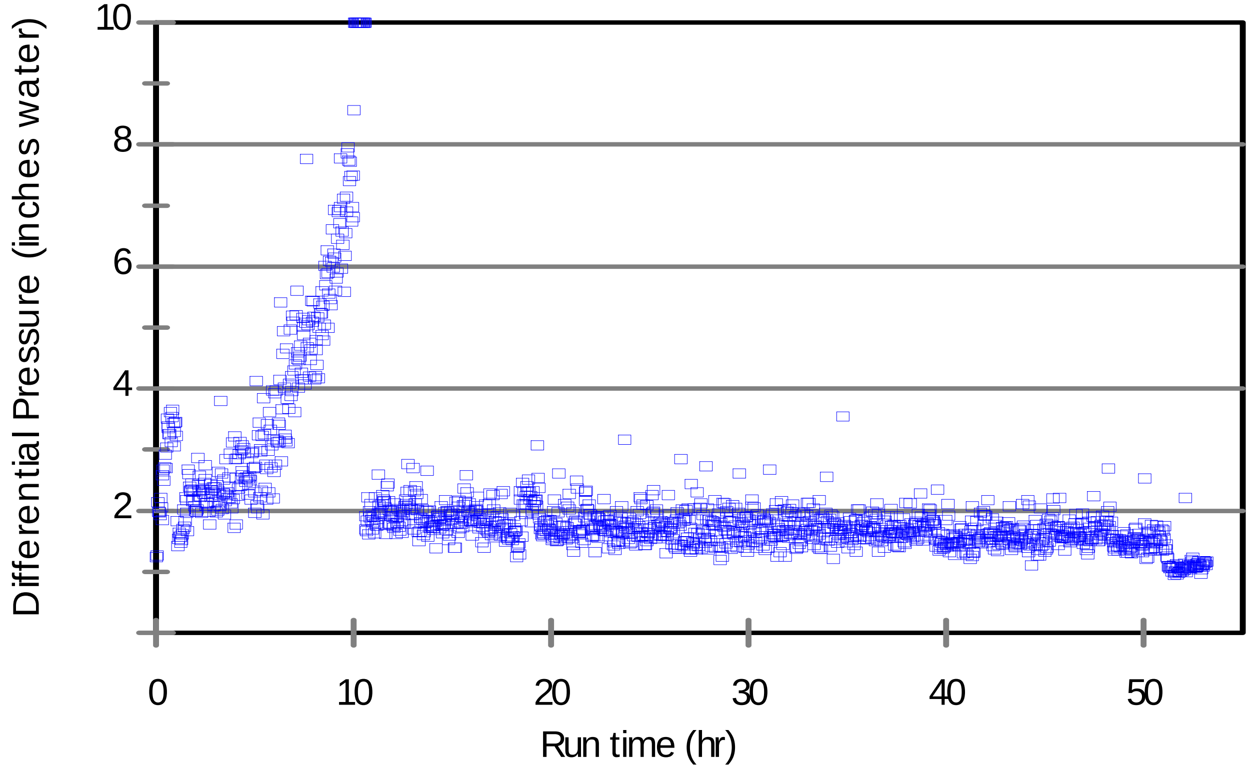



**Figure 4.14. Differential pressure across the film cooler while processing with two double-outlet and one single-outlet bubblers. Test 2.**

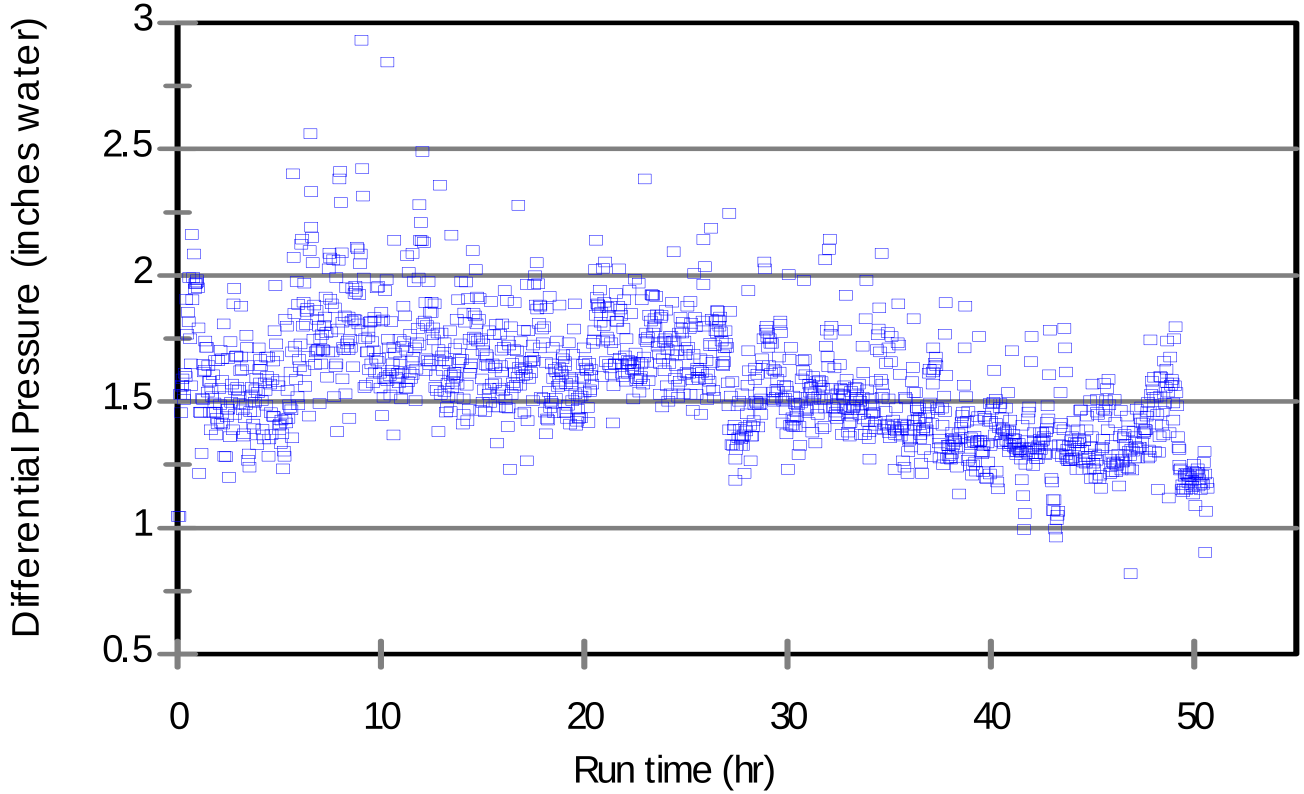



**Figure 4.15. Differential pressure across the film cooler while processing with two double-outlet and two single-outlet bubblers. Test 3.**

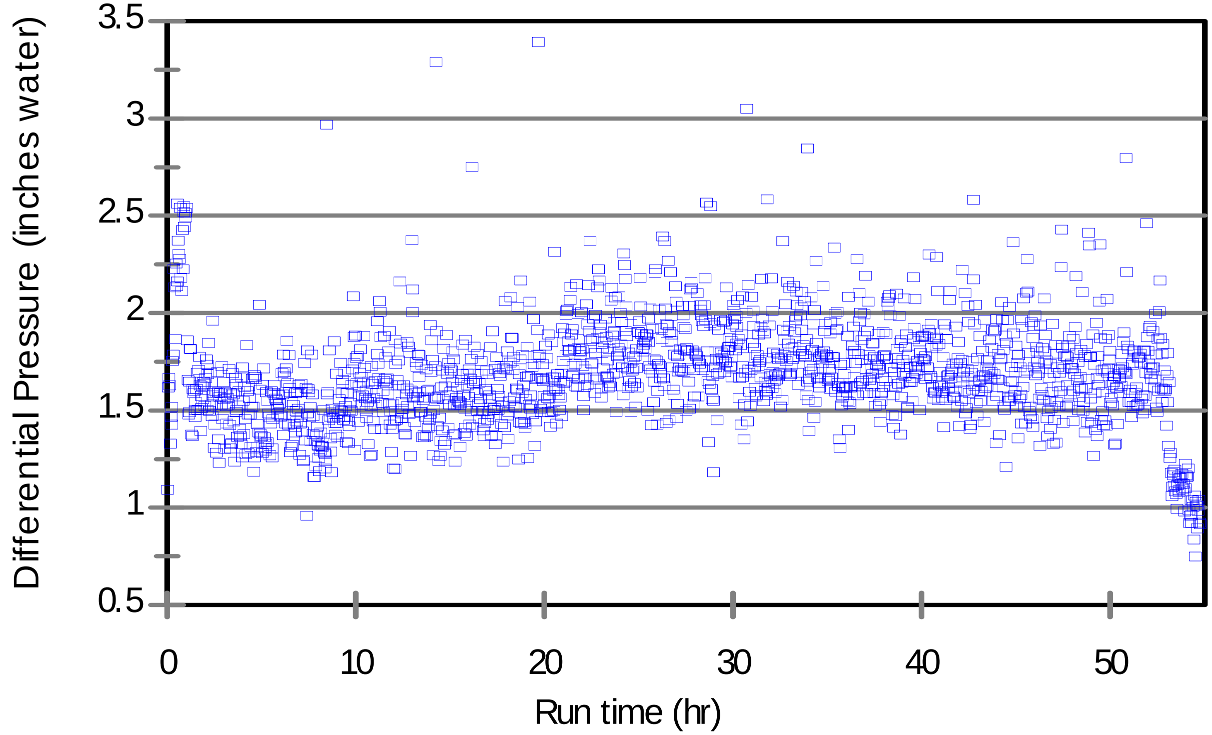



**Figure 4.16. Differential pressure across the film cooler while processing with two double-outlet and two single-outlet bubblers, Test 4.**

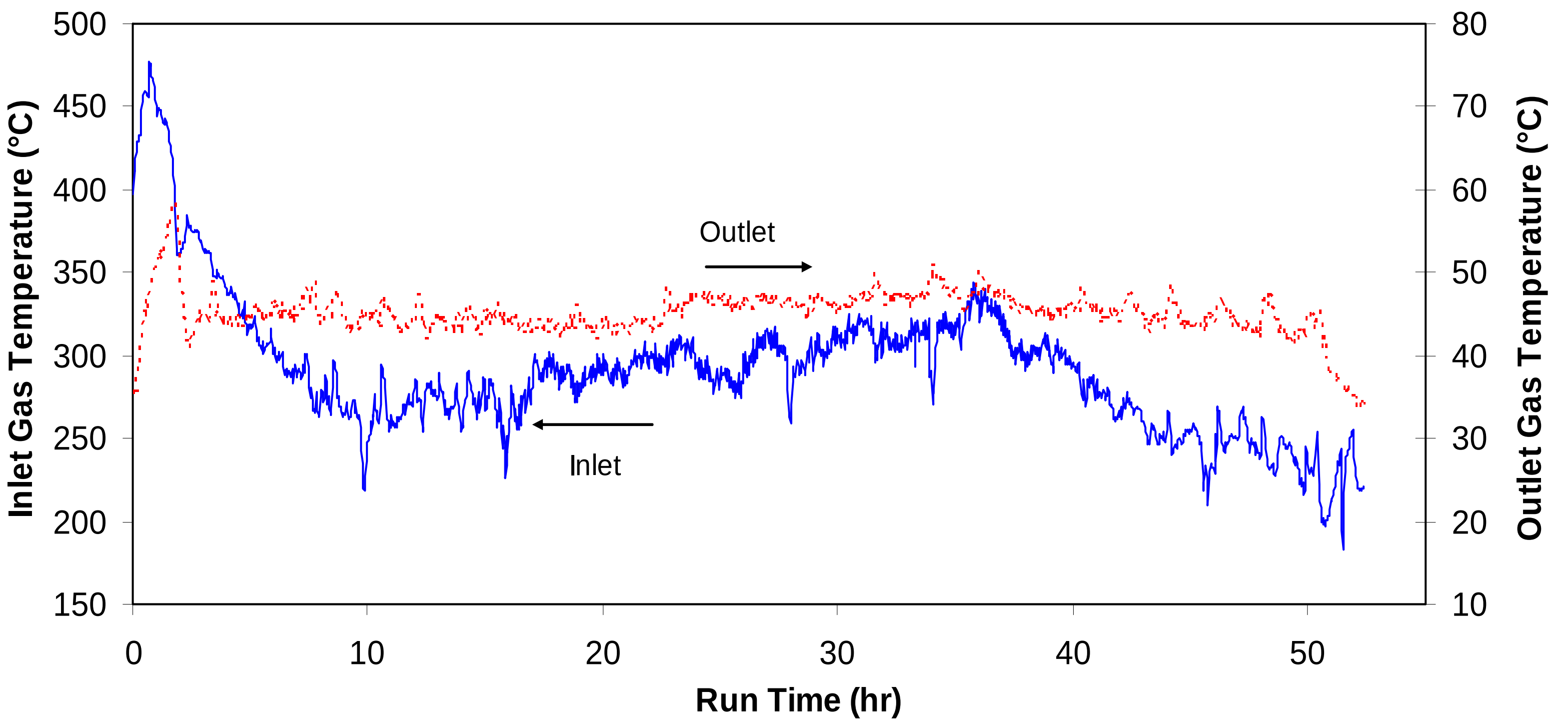



**Figure 4.17. SBS inlet and outlet gas temperatures while processing with two double-outlet bubblers, Test 1.**

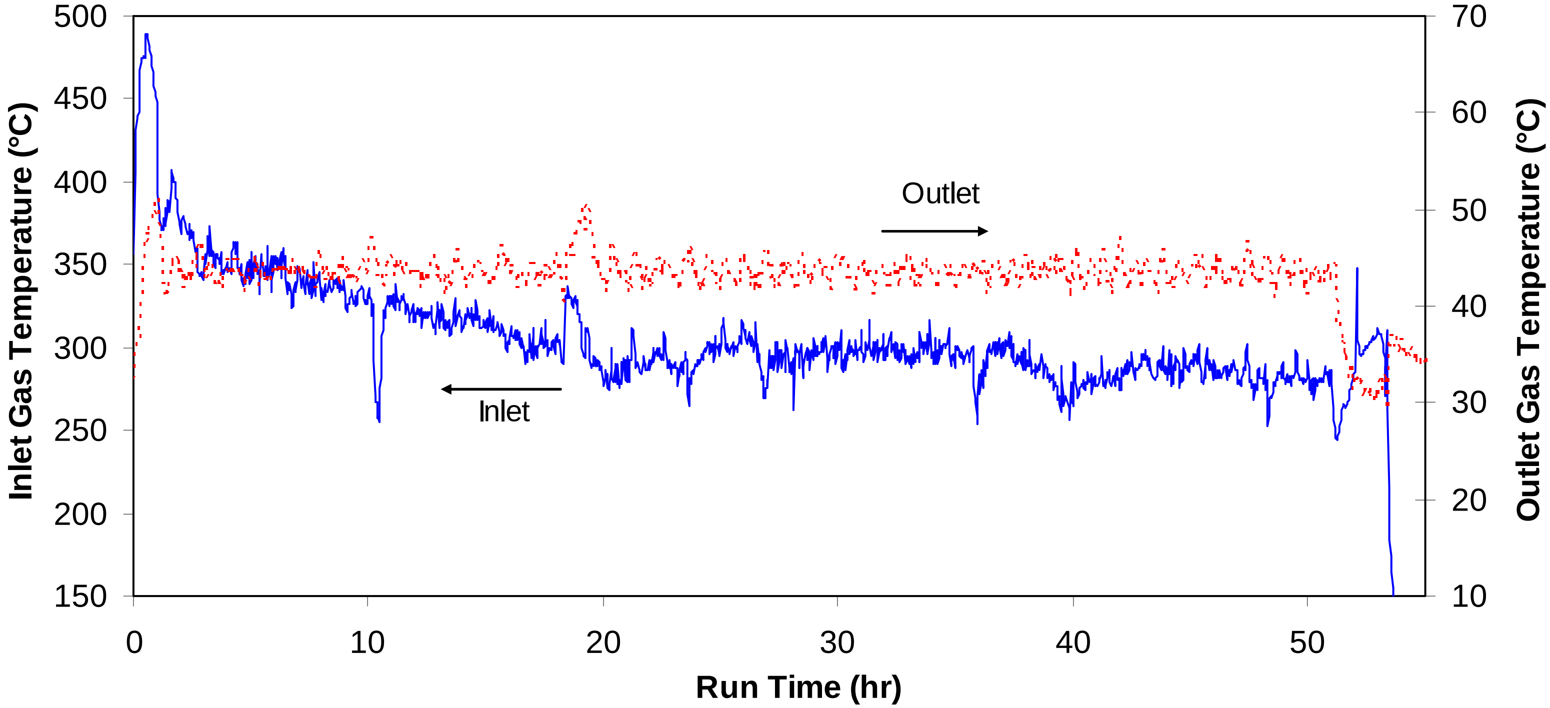



**Figure 4.18. SBS inlet and outlet gas temperatures while processing with two double-outlet and one single-outlet bubblers, Test 2.**

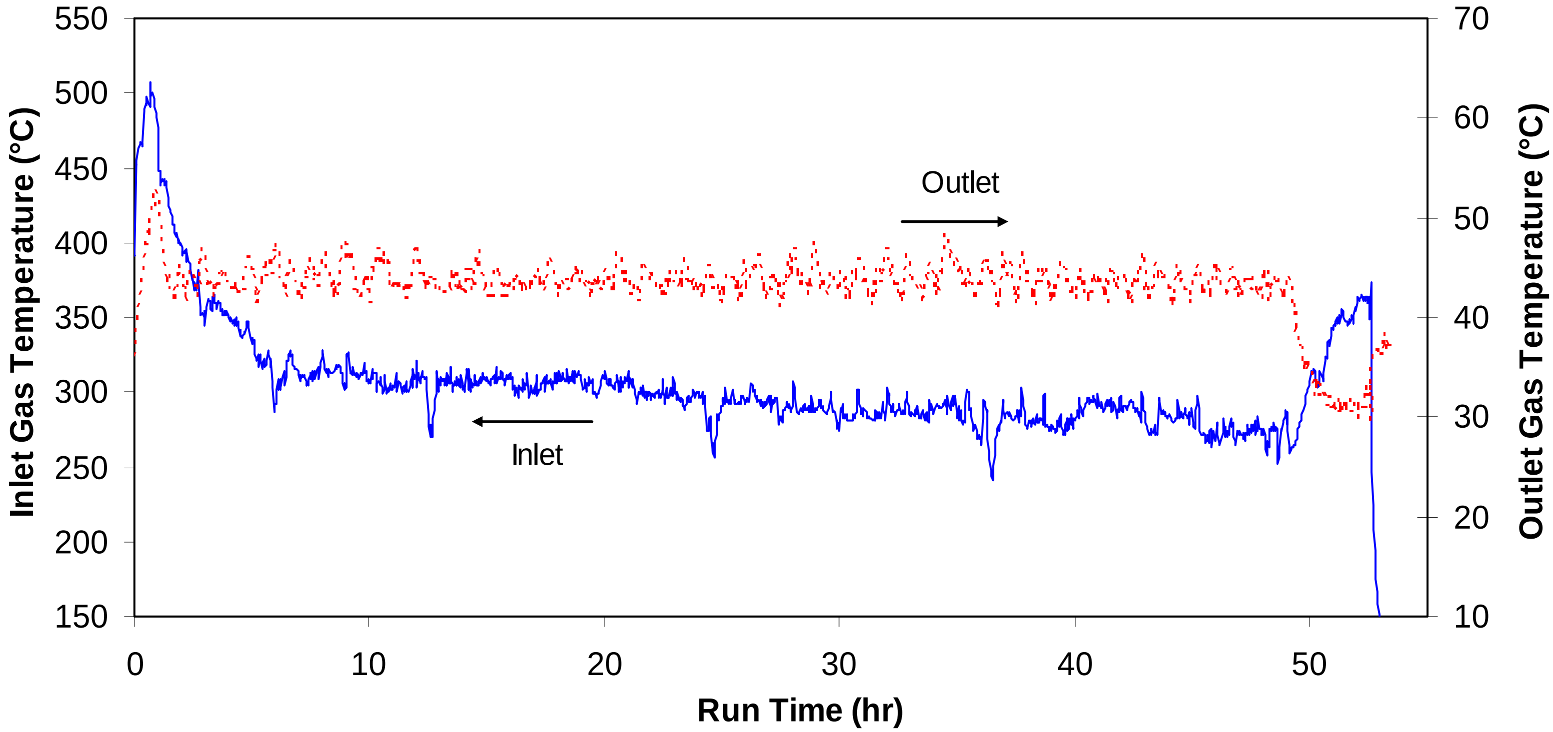



**Figure 4.19. SBS inlet and outlet gas temperatures while processing with two double-outlet and two single-outlet bubblers, Test 3.**

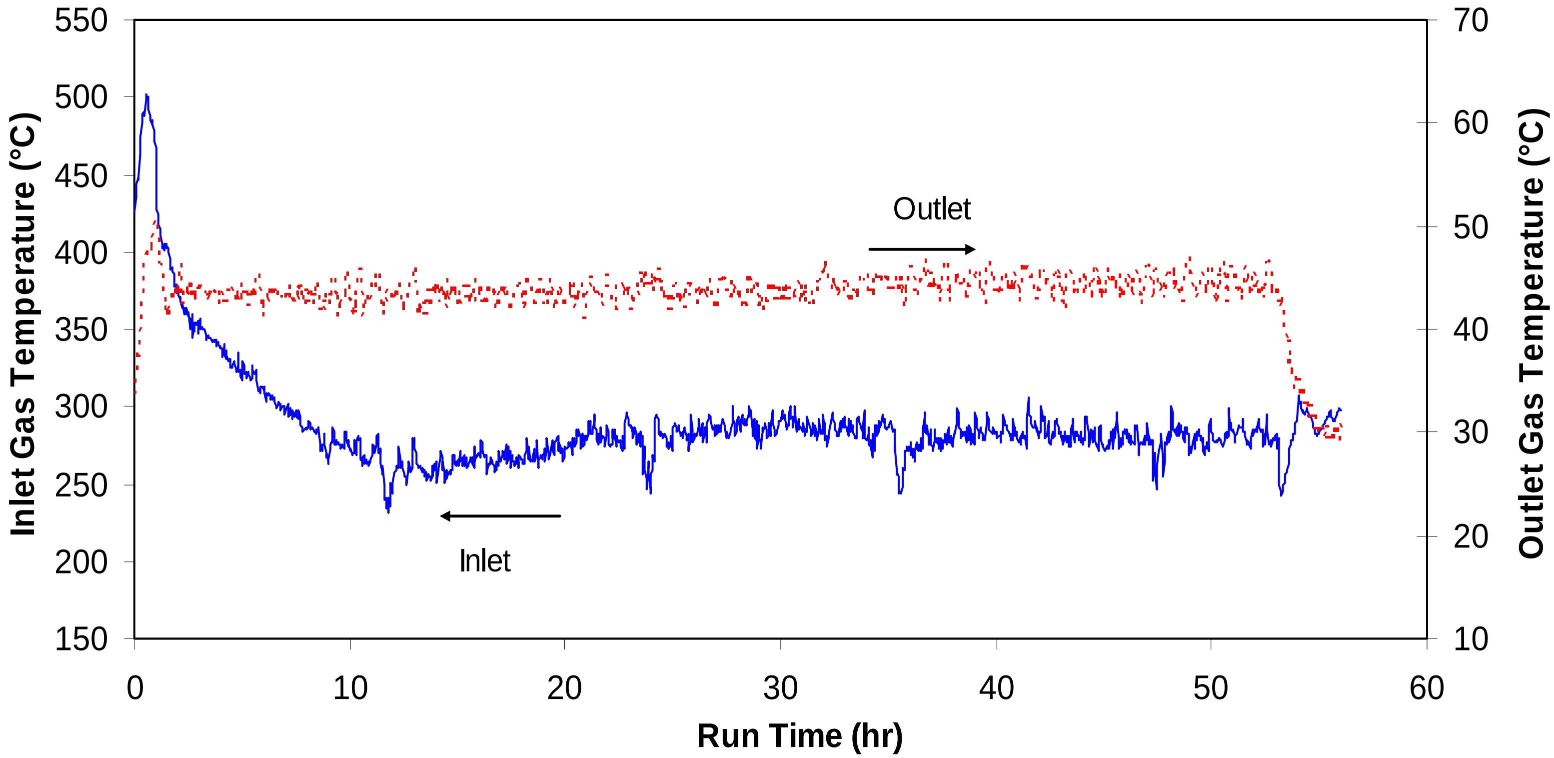



**Figure 4.20. SBS inlet and outlet gas temperatures while processing with two double-outlet and two single-outlet bubblers, Test 4.**

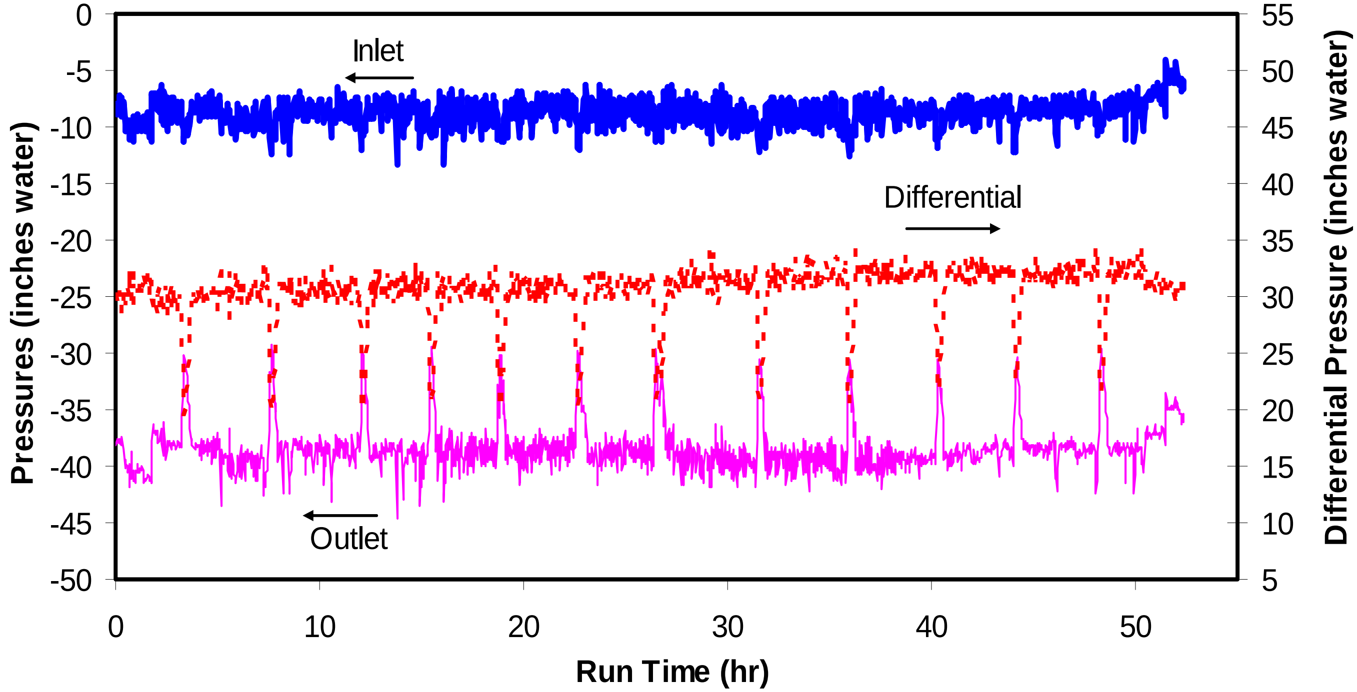



**Figure 4.21. SBS inlet, outlet and differential pressures while processing with two double-outlet bubblers, Test 1.**

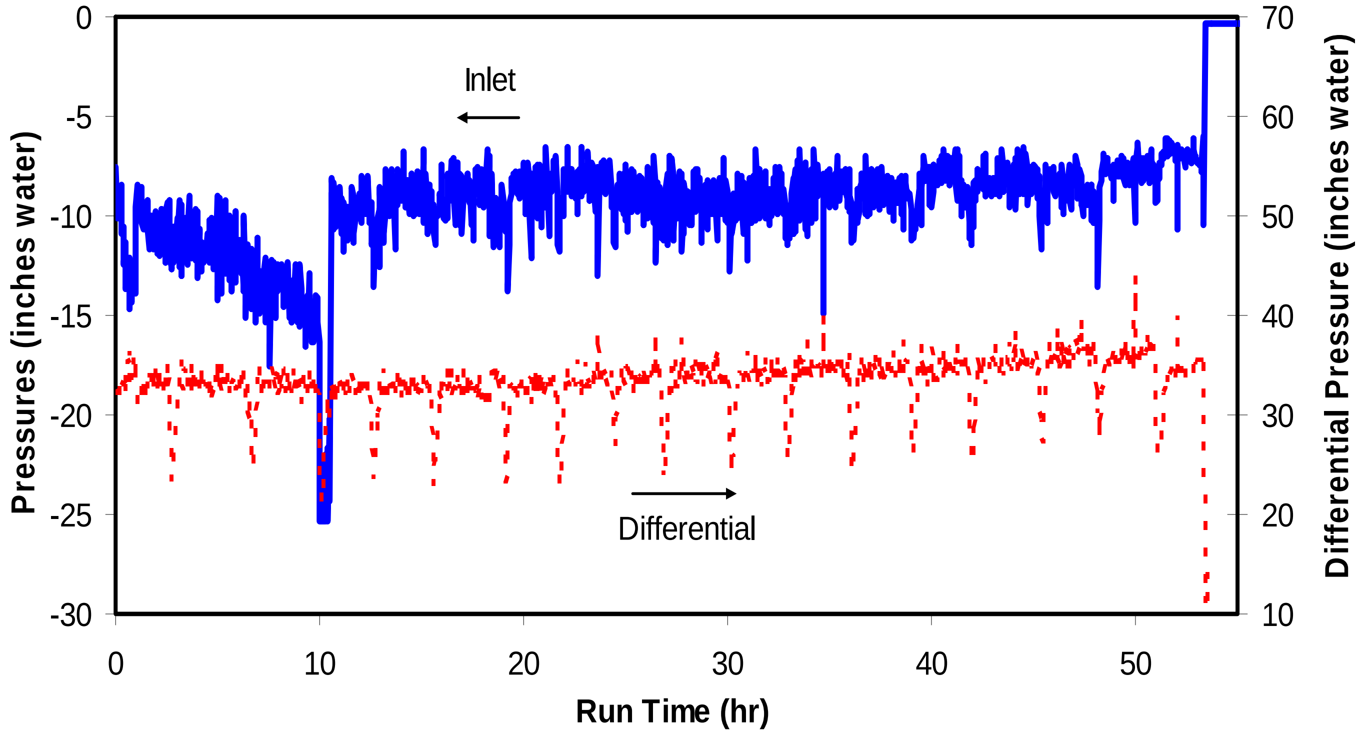



**Figure 4.22. SBS inlet and differential pressures while processing with two double-outlet and one single-outlet bubblers, Test 2.**

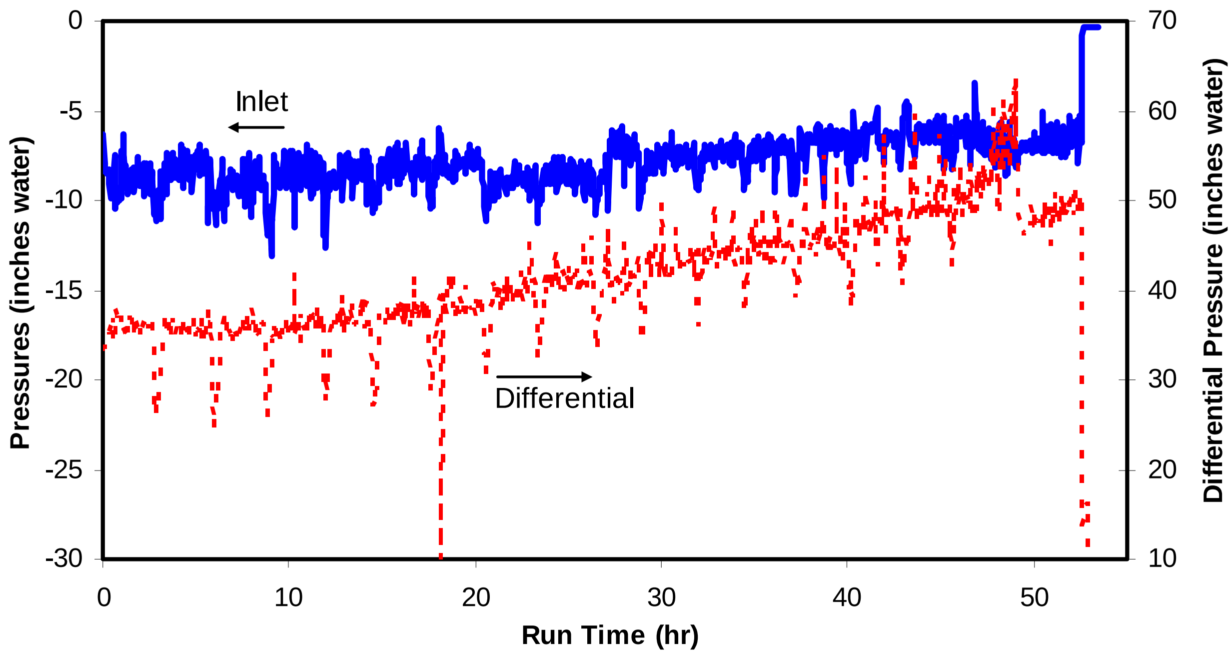



**Figure 4.23. SBS inlet and differential pressures while processing with two double-outlet and two single-outlet bubblers, Test 3.**

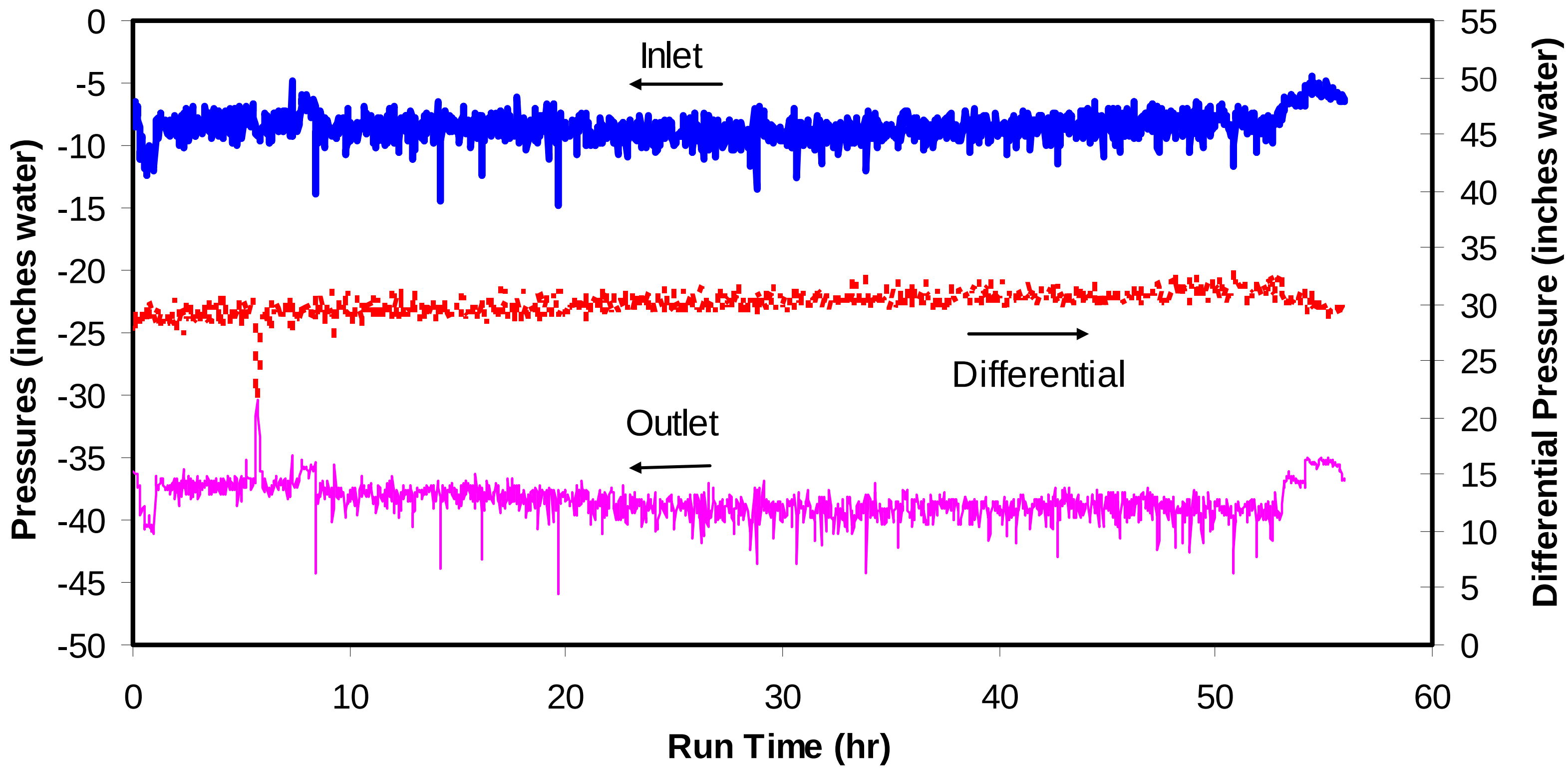



**Figure 4.24. SBS inlet, outlet and differential pressures while processing with two double-outlet and two single-outlet bubblers, Test 4.**

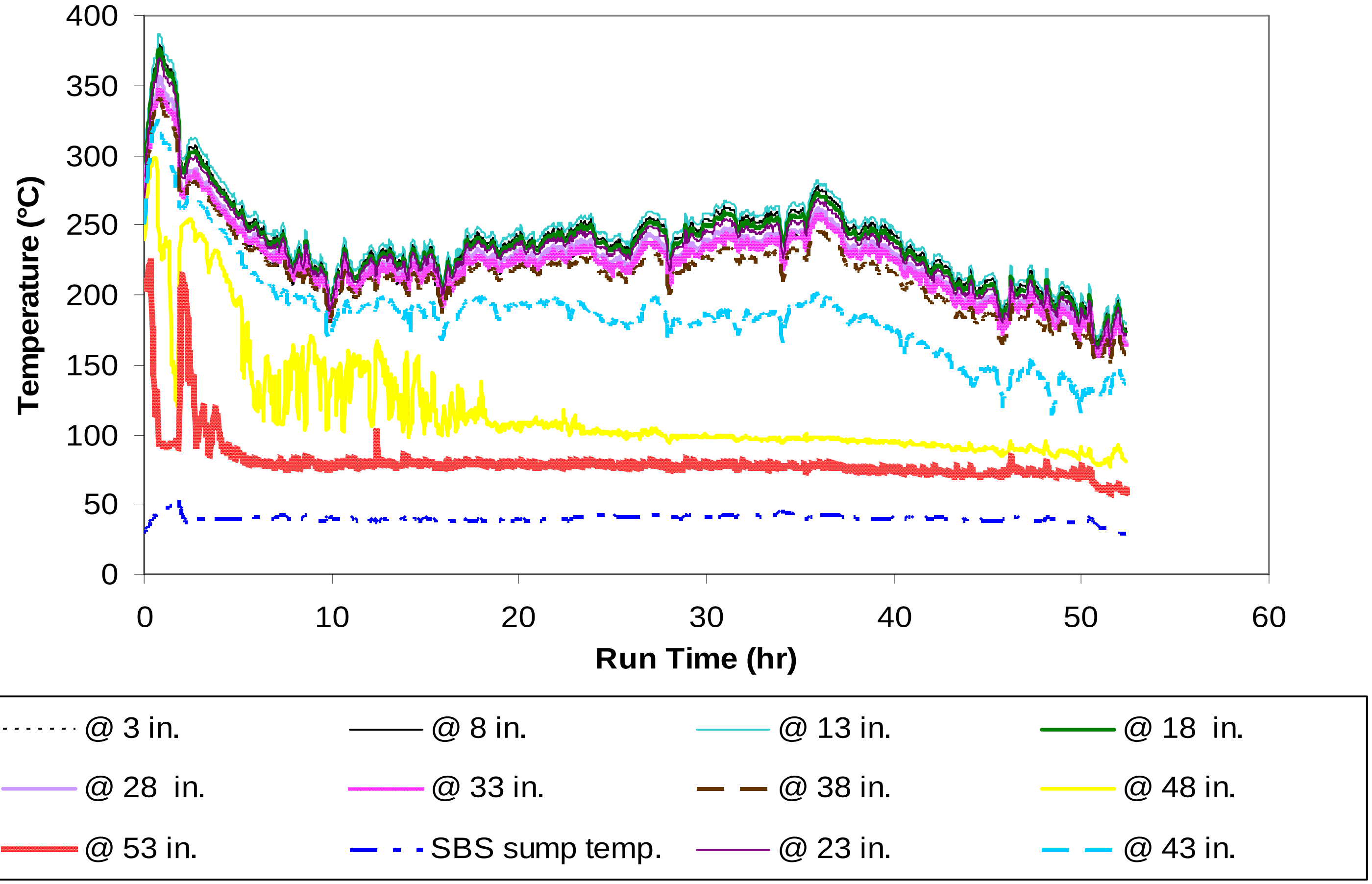



**Figure 4.25. Off-gas temperatures in the SBS down-comer and sump water temperatures while processing with two double-outlet bubblers, Test 1.**

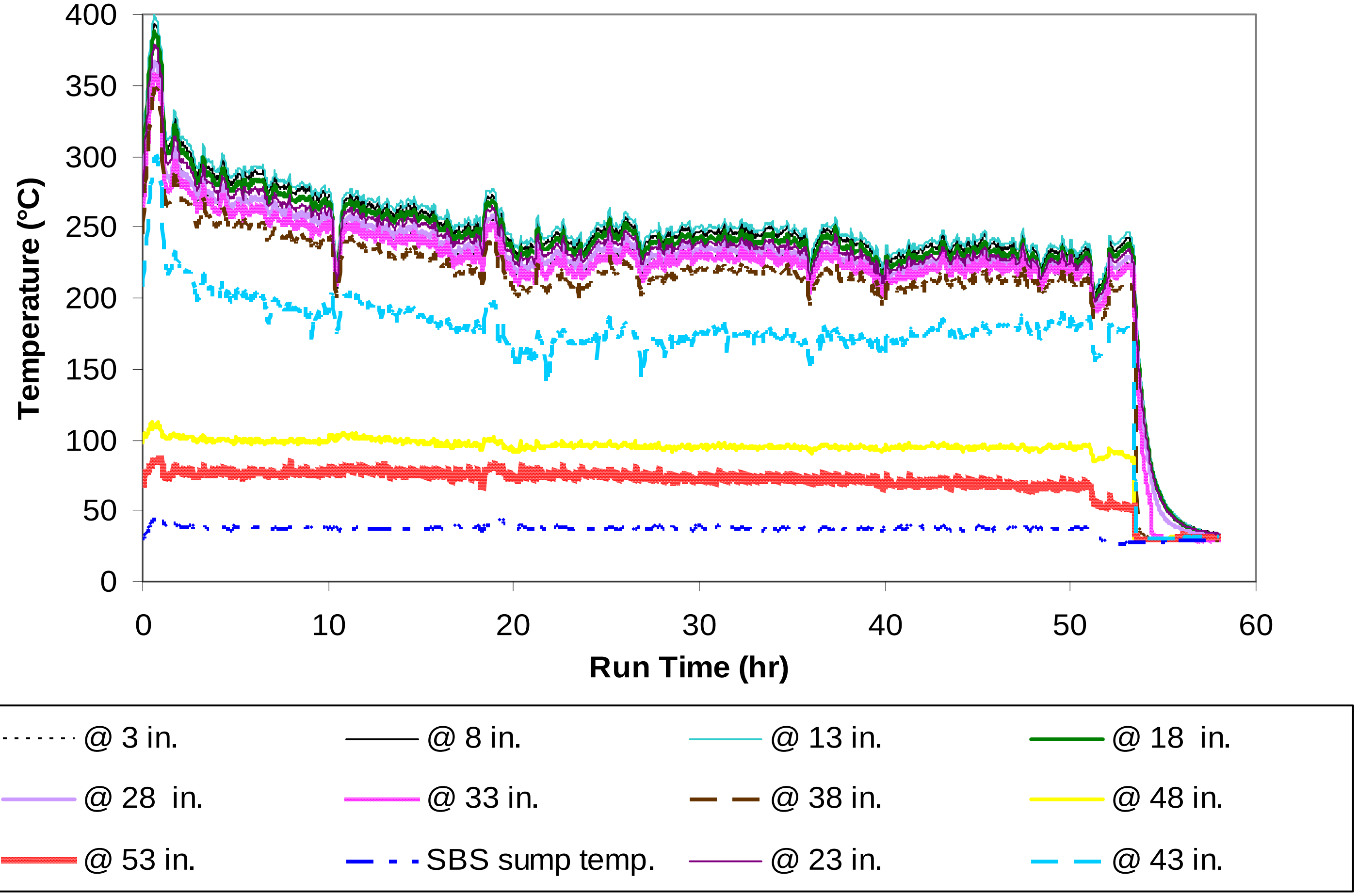



**Figure 4.26. Off-gas temperatures in the SBS down-comer and sump water temperatures while processing with two double-outlet and one single-outlet bubblers, Test 2.**

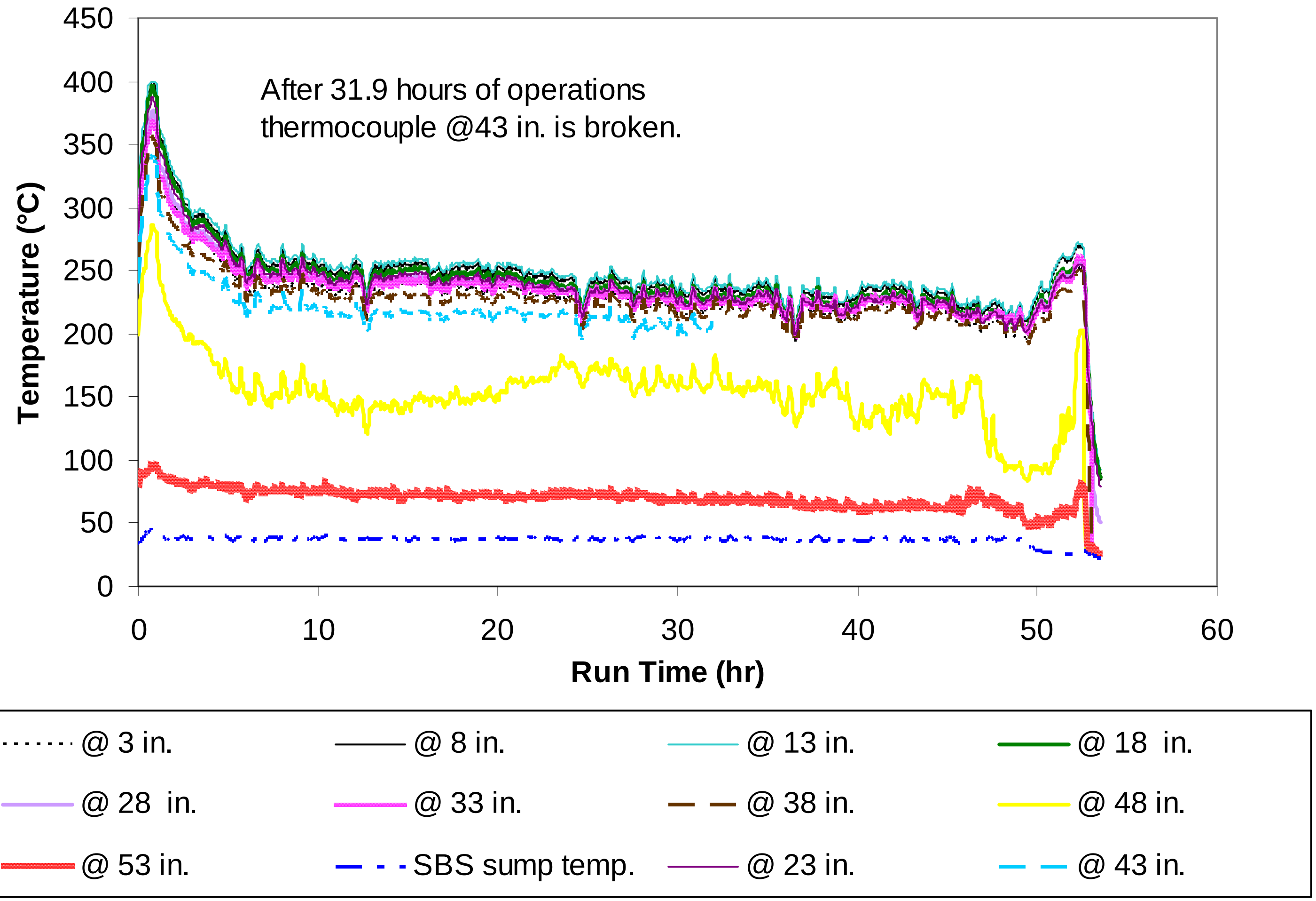



**Figure 4.27. Off-gas temperatures in the SBS down-comer and sump water temperatures while processing with two double-outlet and two single-outlet bubblers, Test 3.**

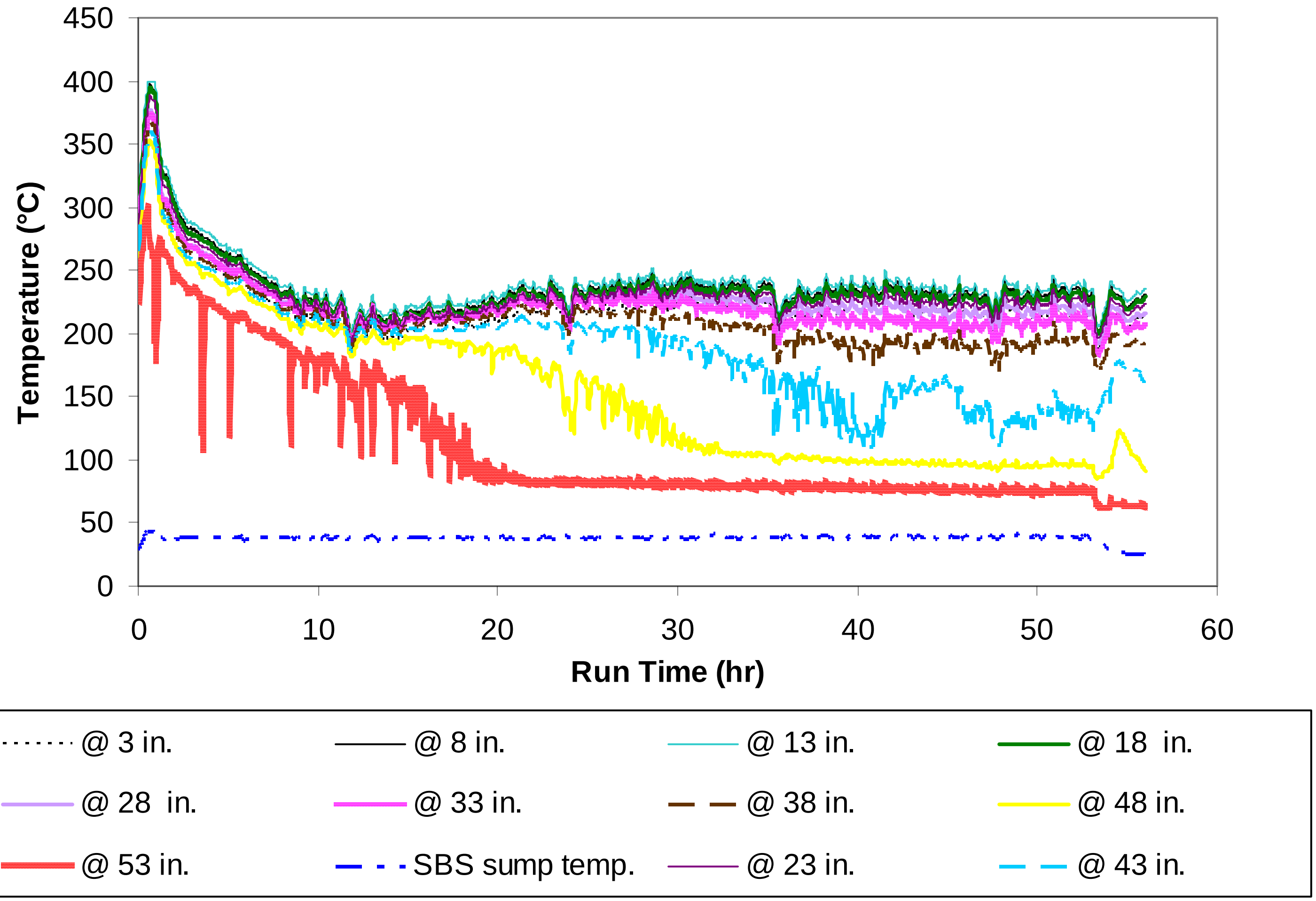



**Figure 4.28. Off-gas temperatures in the SBS down-comer and sump water temperatures while processing with two double-outlet and two single-outlet bubblers, Test 4.**

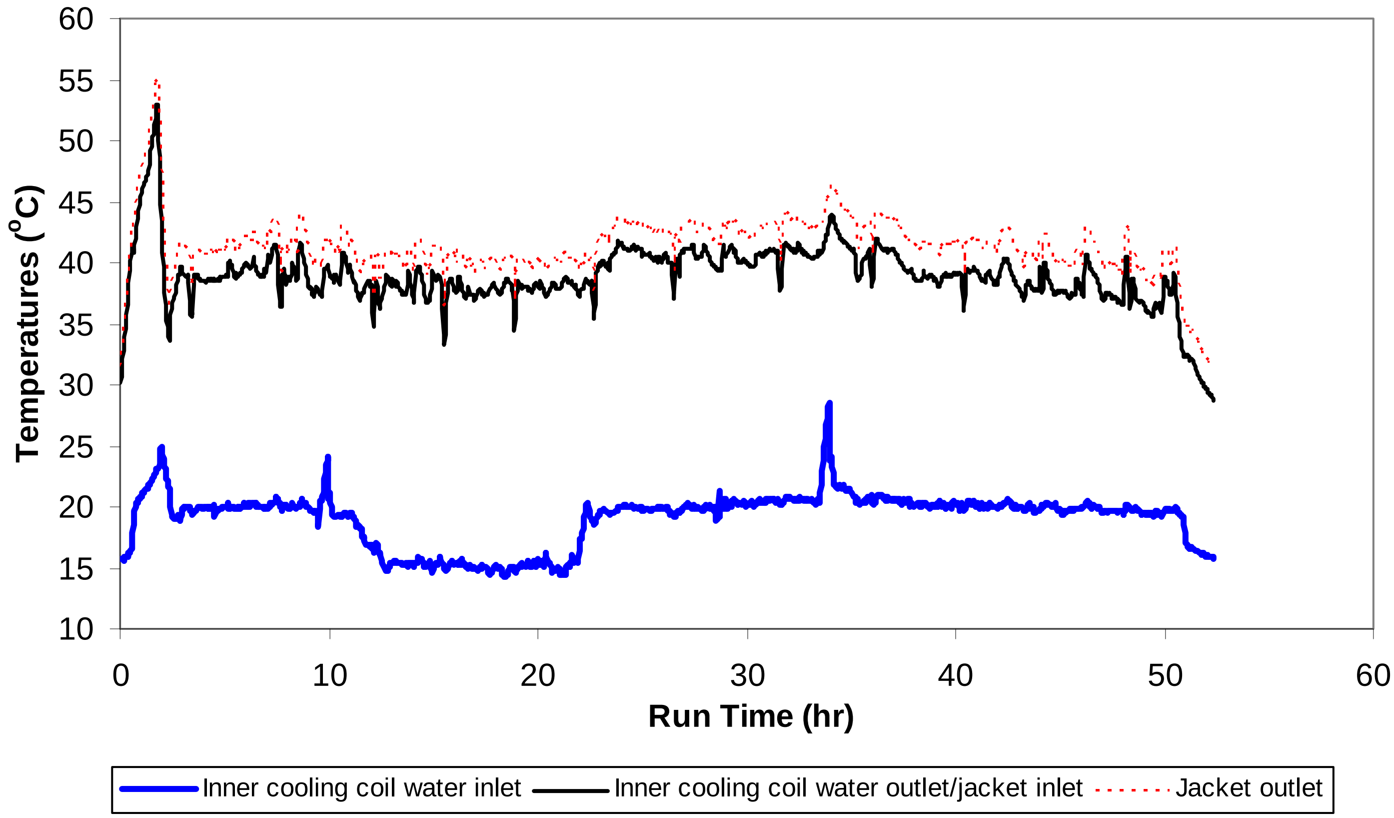



**Figure 4.29. SBS cooling coil inlet, cooling coil outlet/jacket inlet and jacket outlet water temperatures while processing with two double-outlet bubblers, Test 1.**

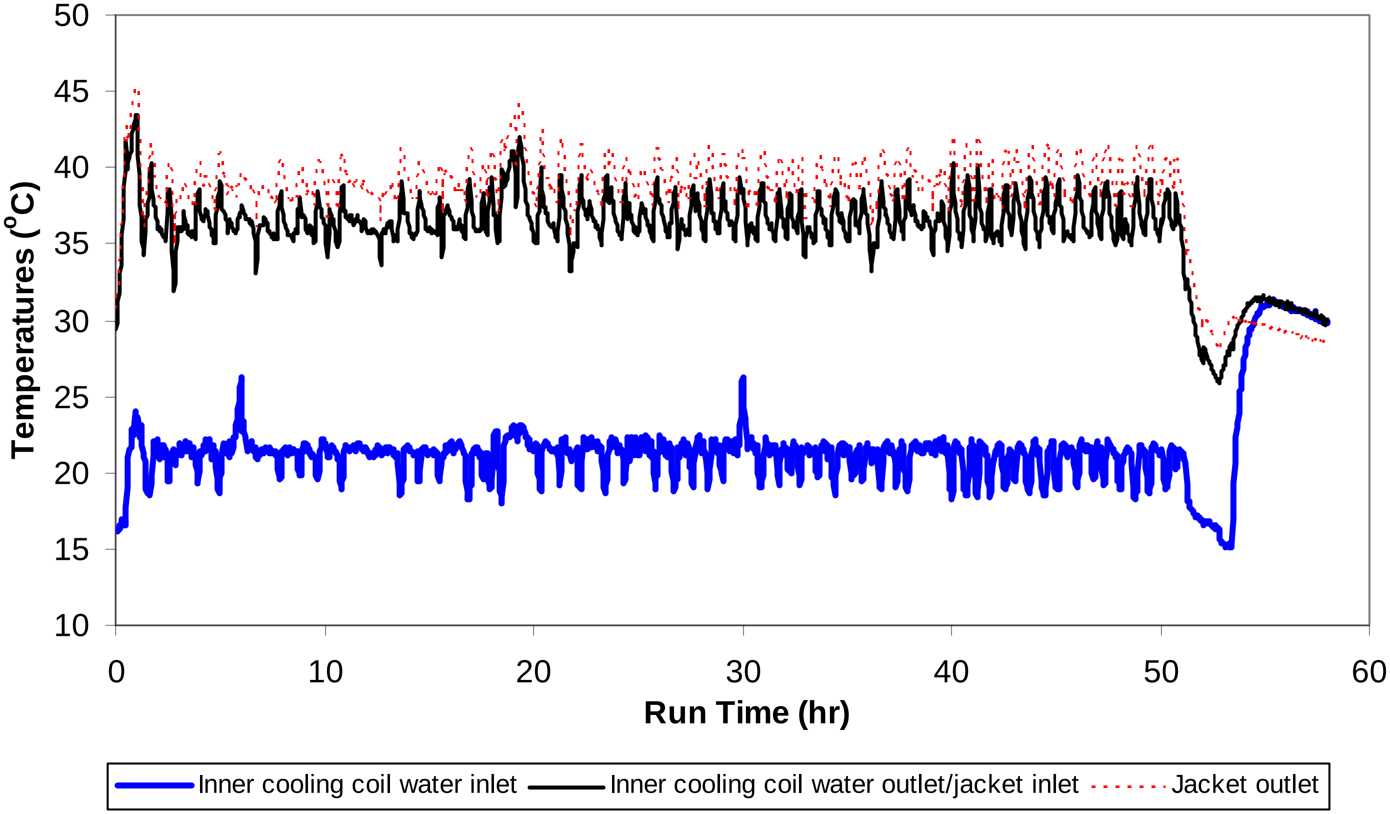



**Figure 4.30. SBS cooling coil inlet, cooling coil outlet/jacket inlet and jacket outlet water temperatures while processing with two double-outlet and one single-outlet bubblers, Test 2.**

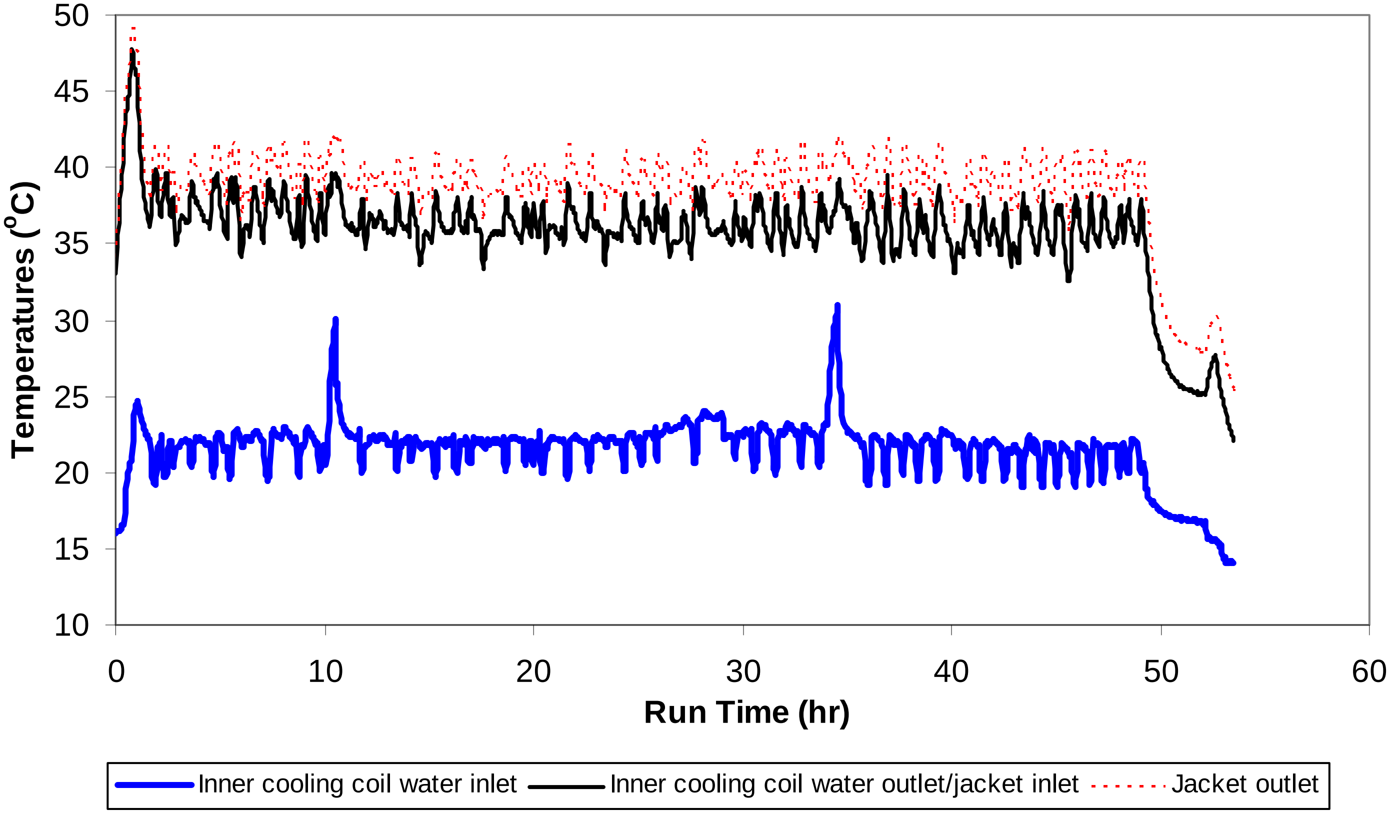



**Figure 4.31. SBS cooling coil inlet, cooling coil outlet/jacket inlet and jacket outlet water temperatures while processing with two double-outlet and two single-outlet bubblers, Test 3.**

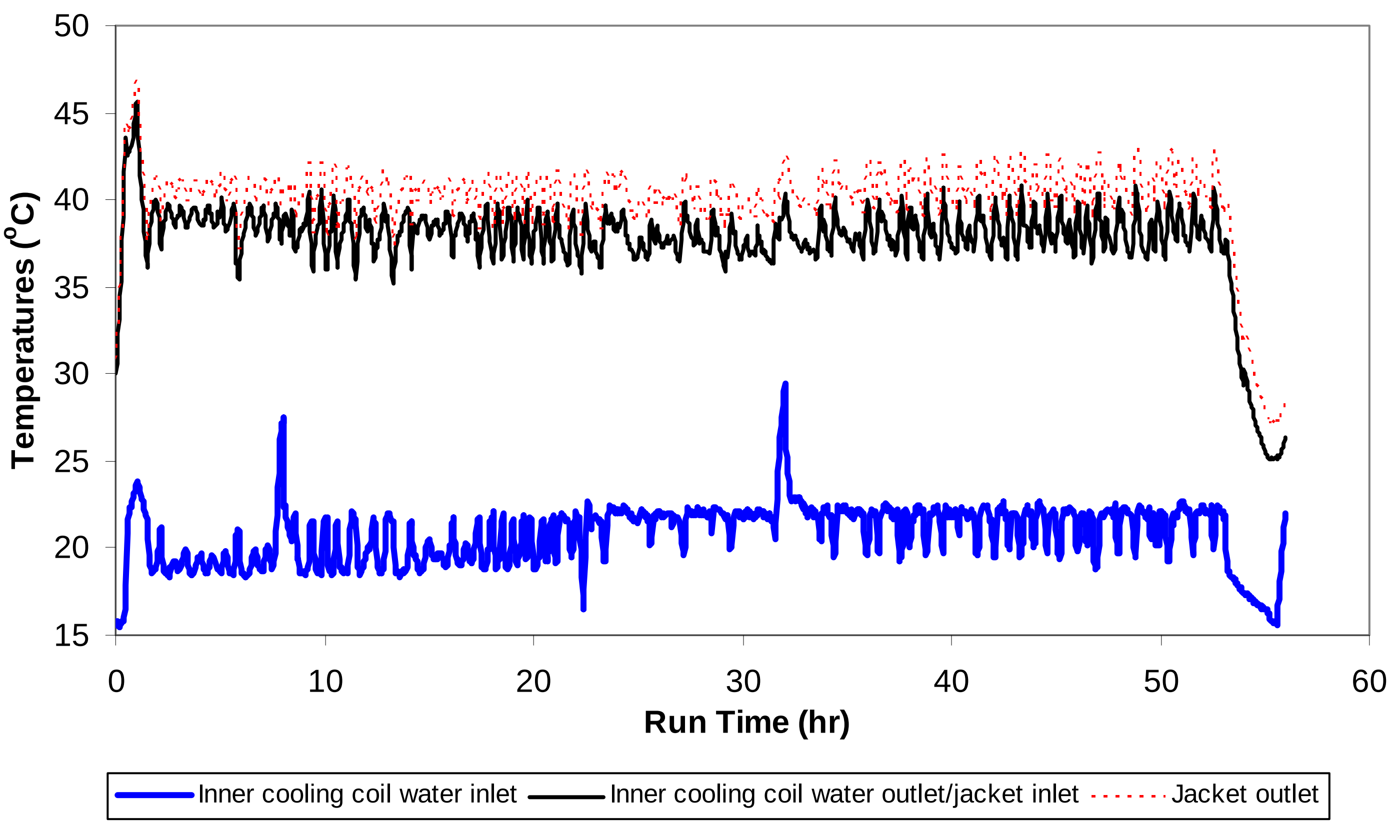



**Figure 4.32. SBS cooling coil inlet, cooling coil outlet/jacket inlet and jacket outlet water temperatures while processing with two double-outlet and two single-outlet bubblers, Test 4.**

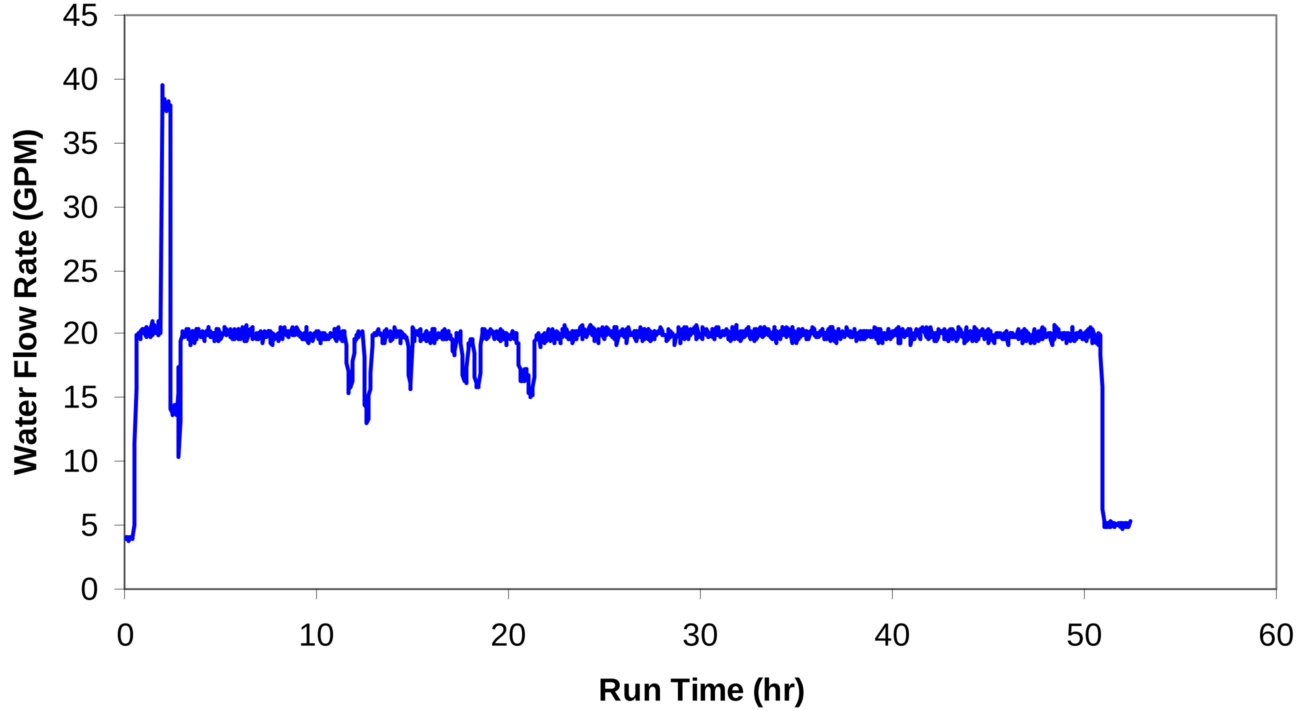



**Figure 4.33. SBS cooling coil/jacket water flow rate while processing with two double-outlet bubblers, Test 1.**

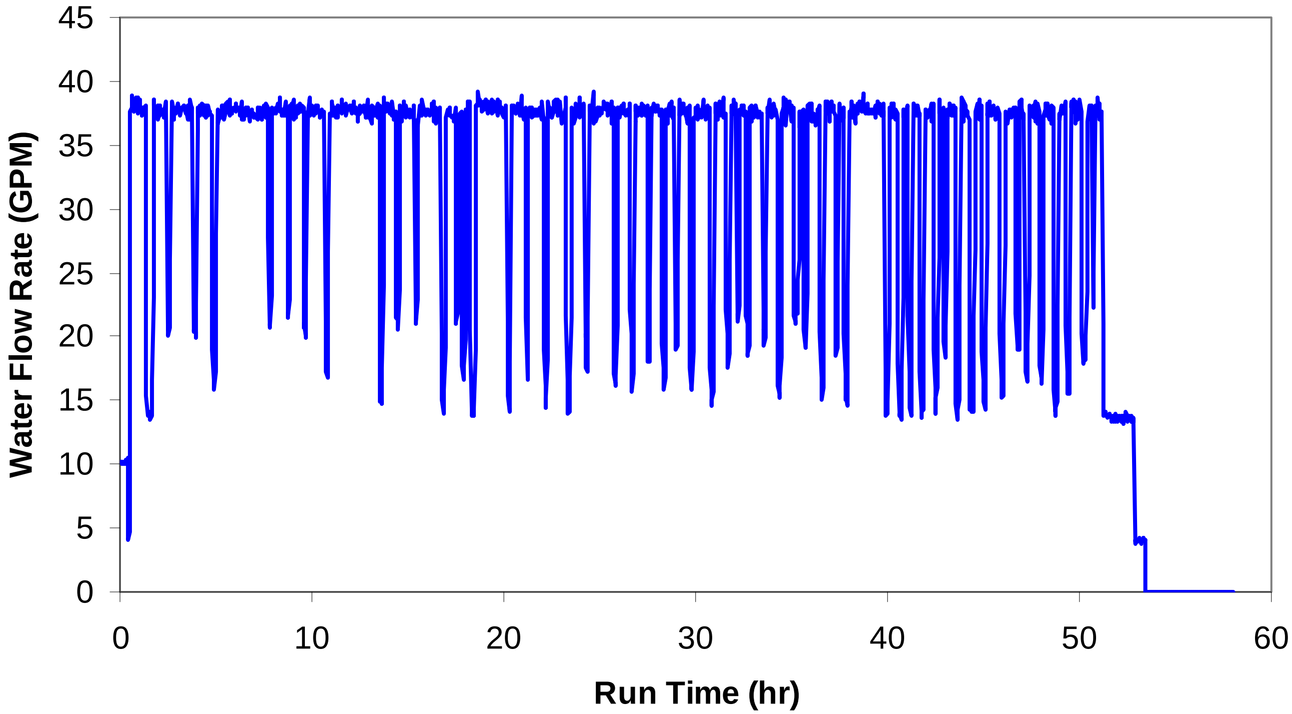



**Figure 4.34. SBS cooling coil/jacket water flow rate during while processing with two double-outlet and one single-outlet bubblers, Test 2.**

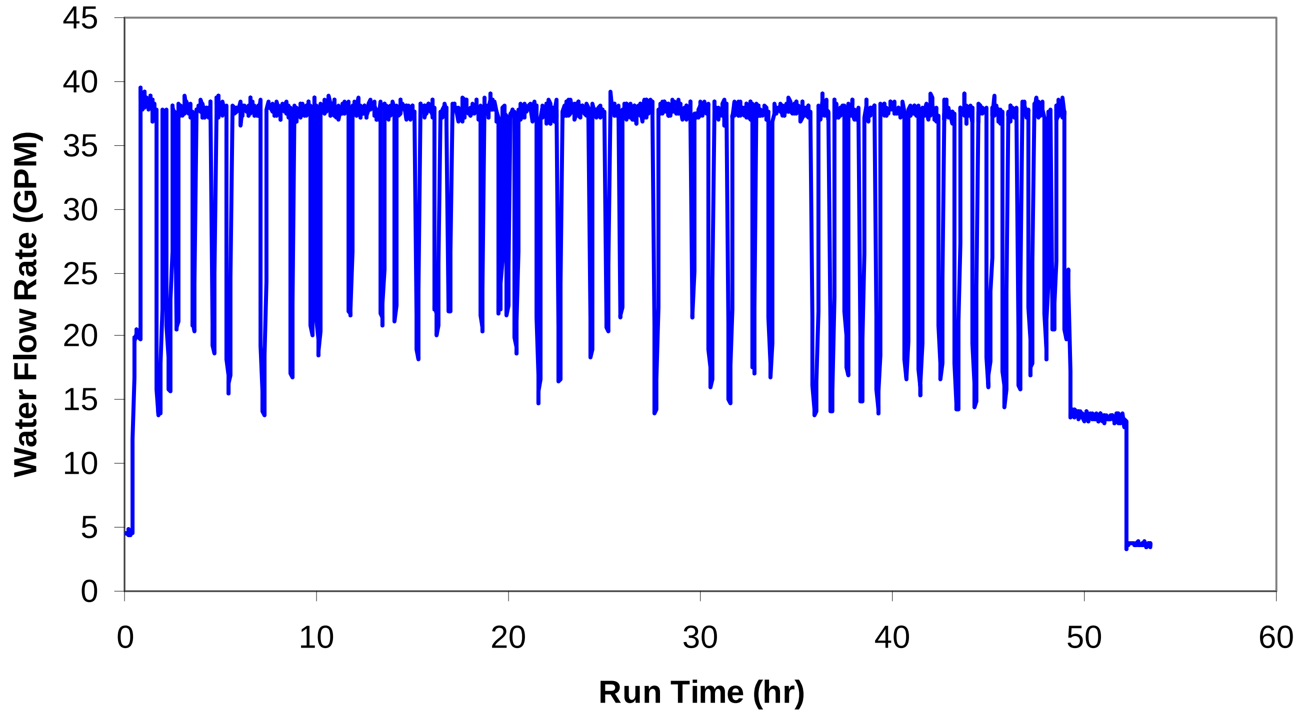



**Figure 4.35. SBS cooling coil/jacket water flow rate while processing with two double-outlet and two single-outlet bubblers, Test 3.**

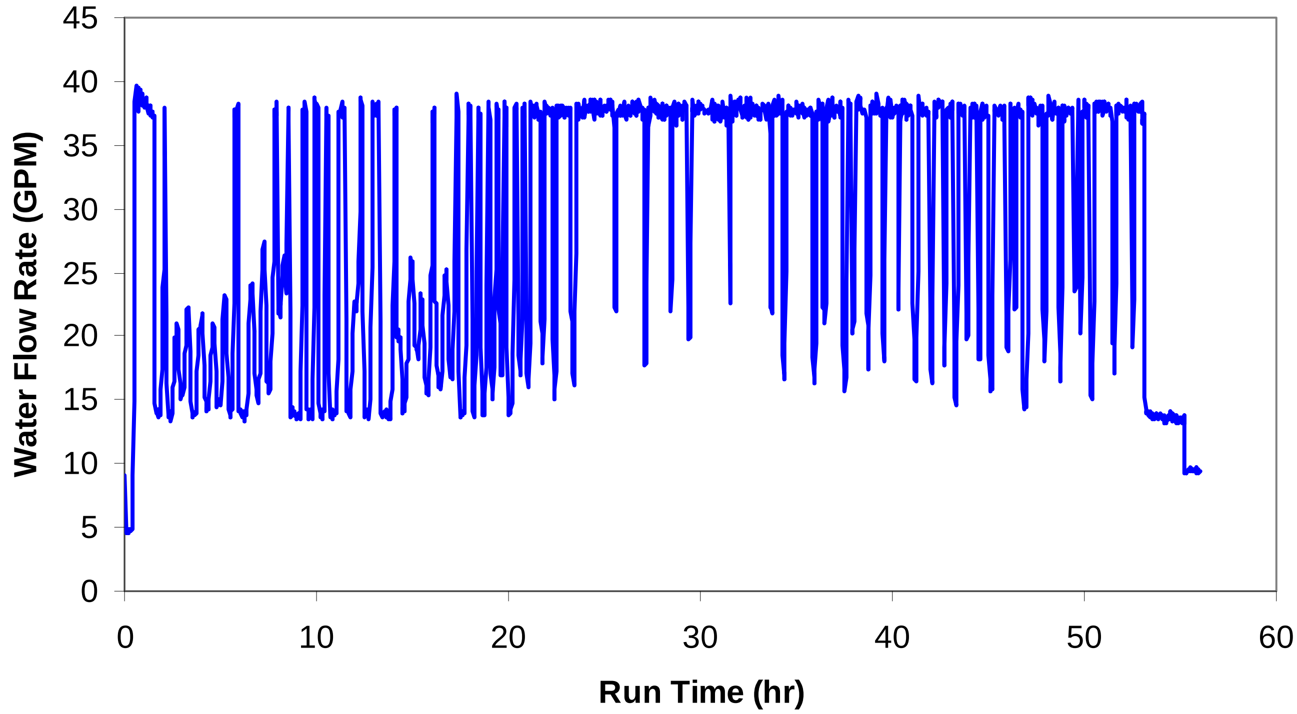



**Figure 4.36. SBS cooling coil/jacket water flow rate while processing with two double-outlet and two single-outlet bubblers, Test 4.**

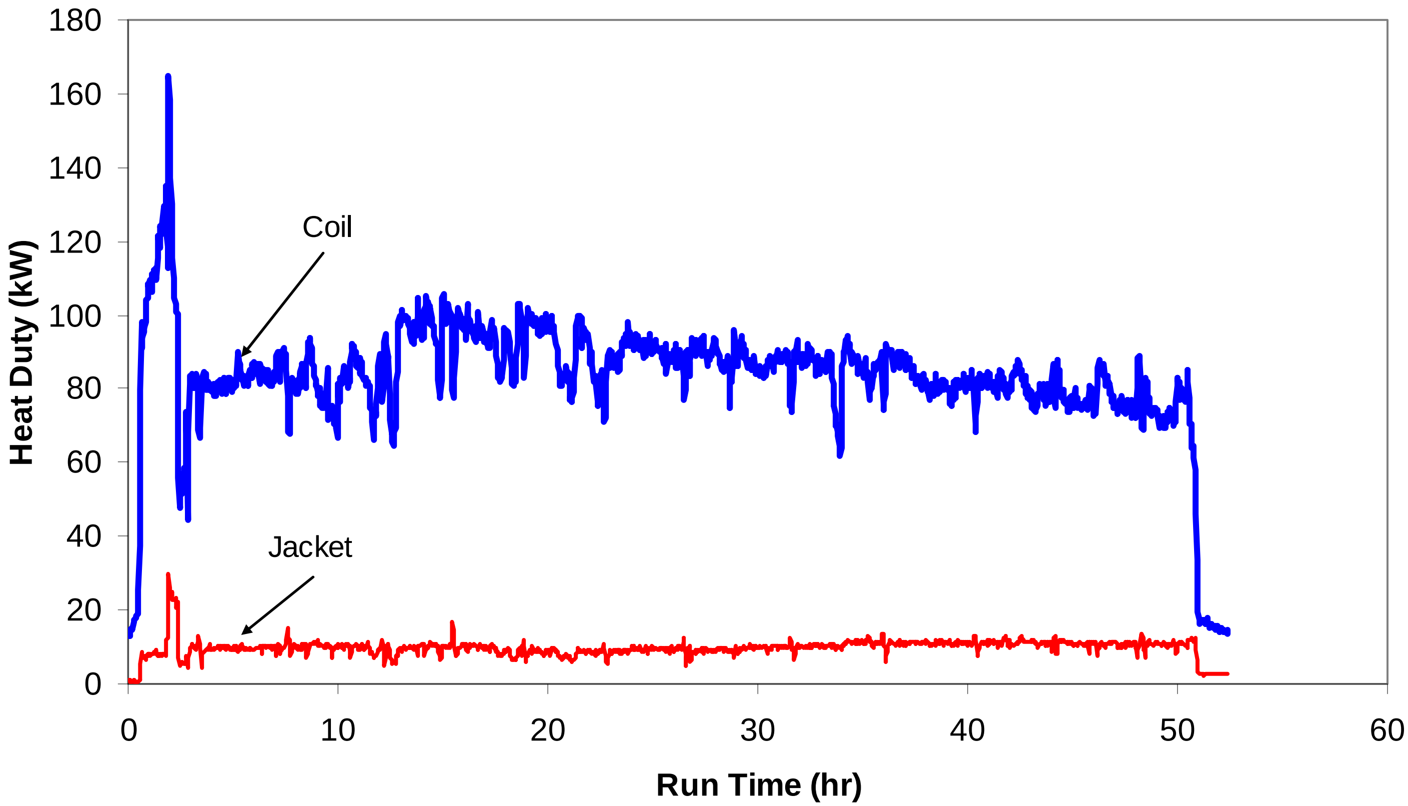



**Figure 4.37. Calculated heat loads on the inner coil and jacket while processing with two double-outlet bubblers, Test 1.**

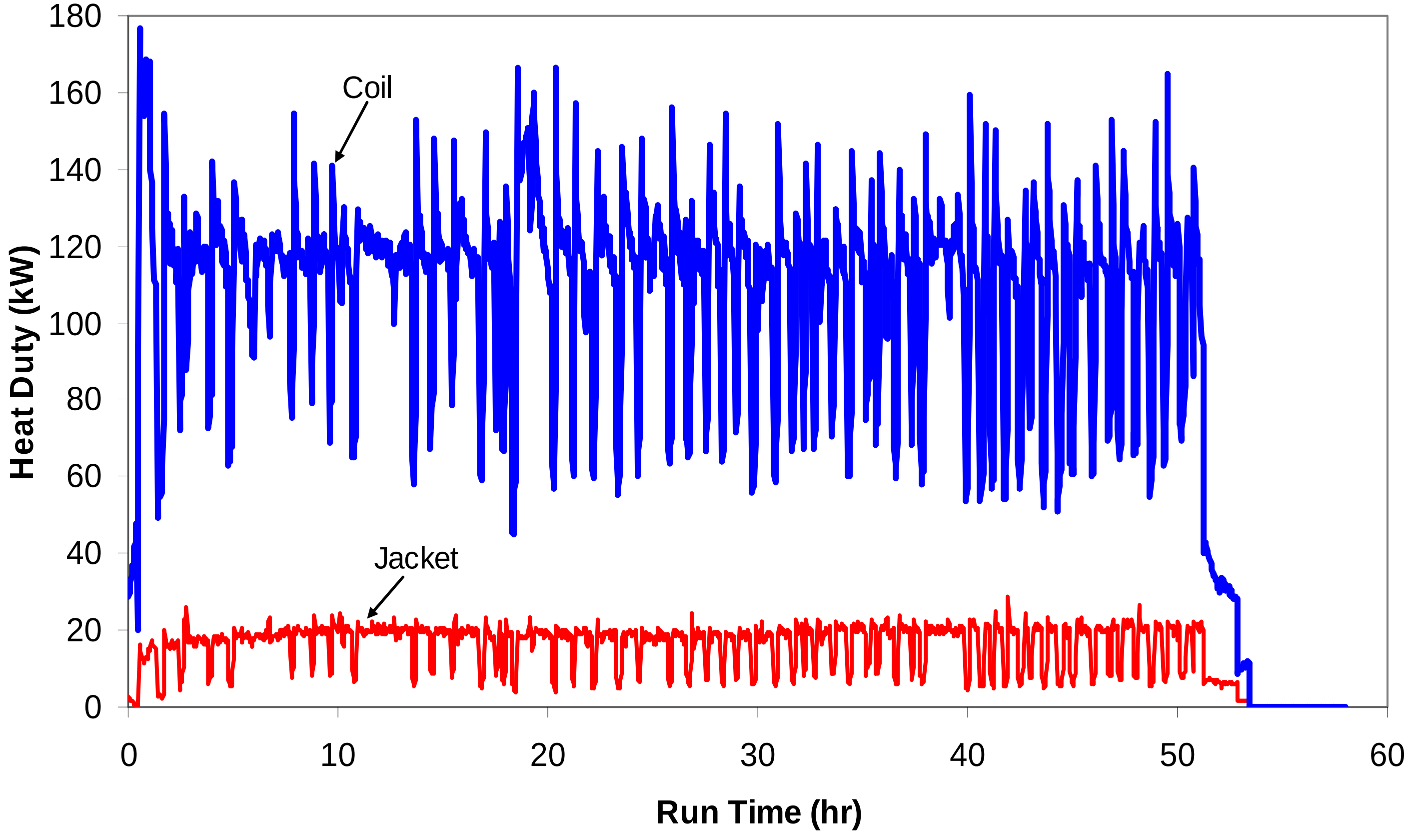



**Figure 4.38. Calculated heat loads on the inner coil and jacket while processing with two double-outlet and one single-outlet bubblers, Test 2.**

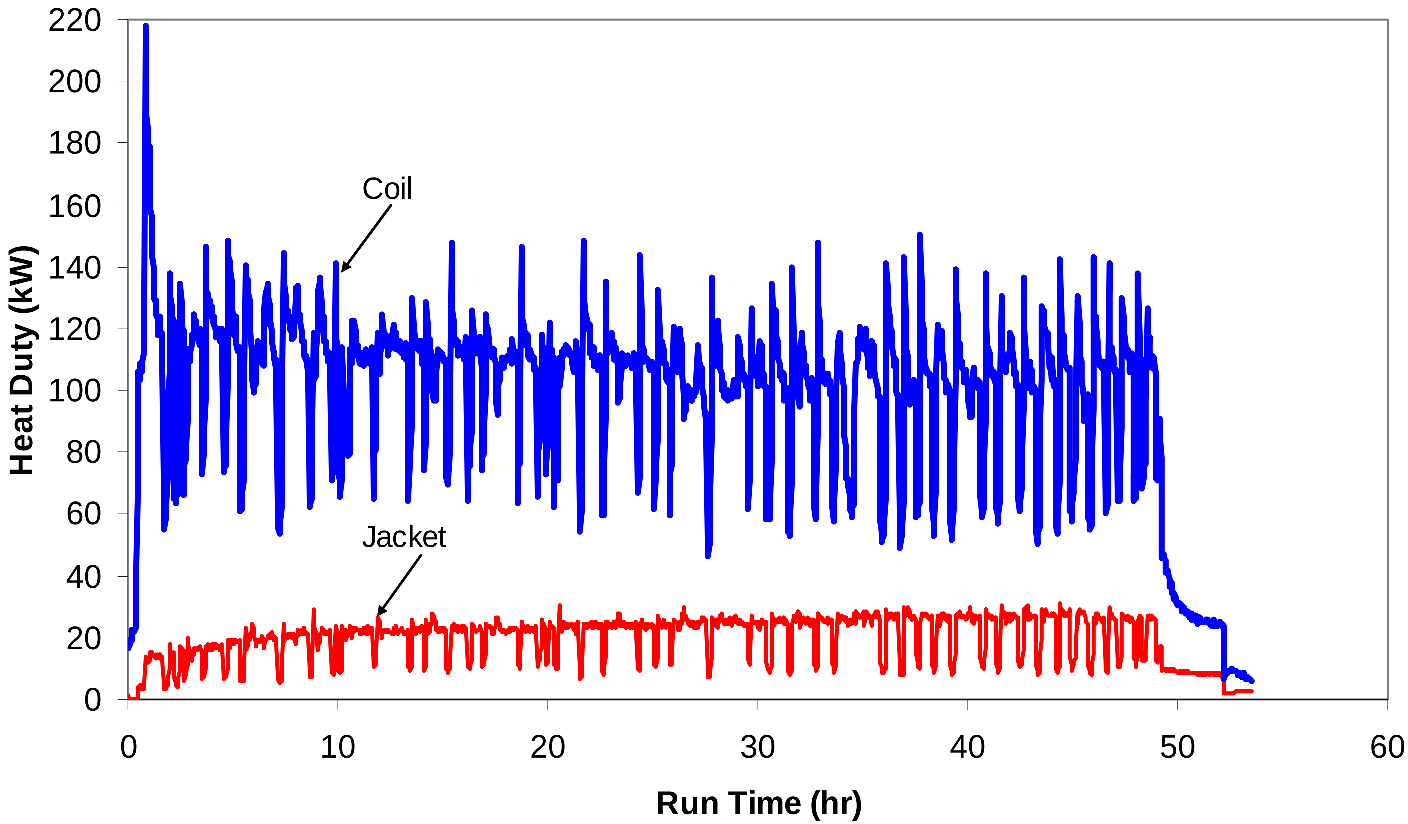



**Figure 4.39. Calculated heat loads on the inner coil and while processing with two double-outlet and two single-outlet bubblers, Test 3.**

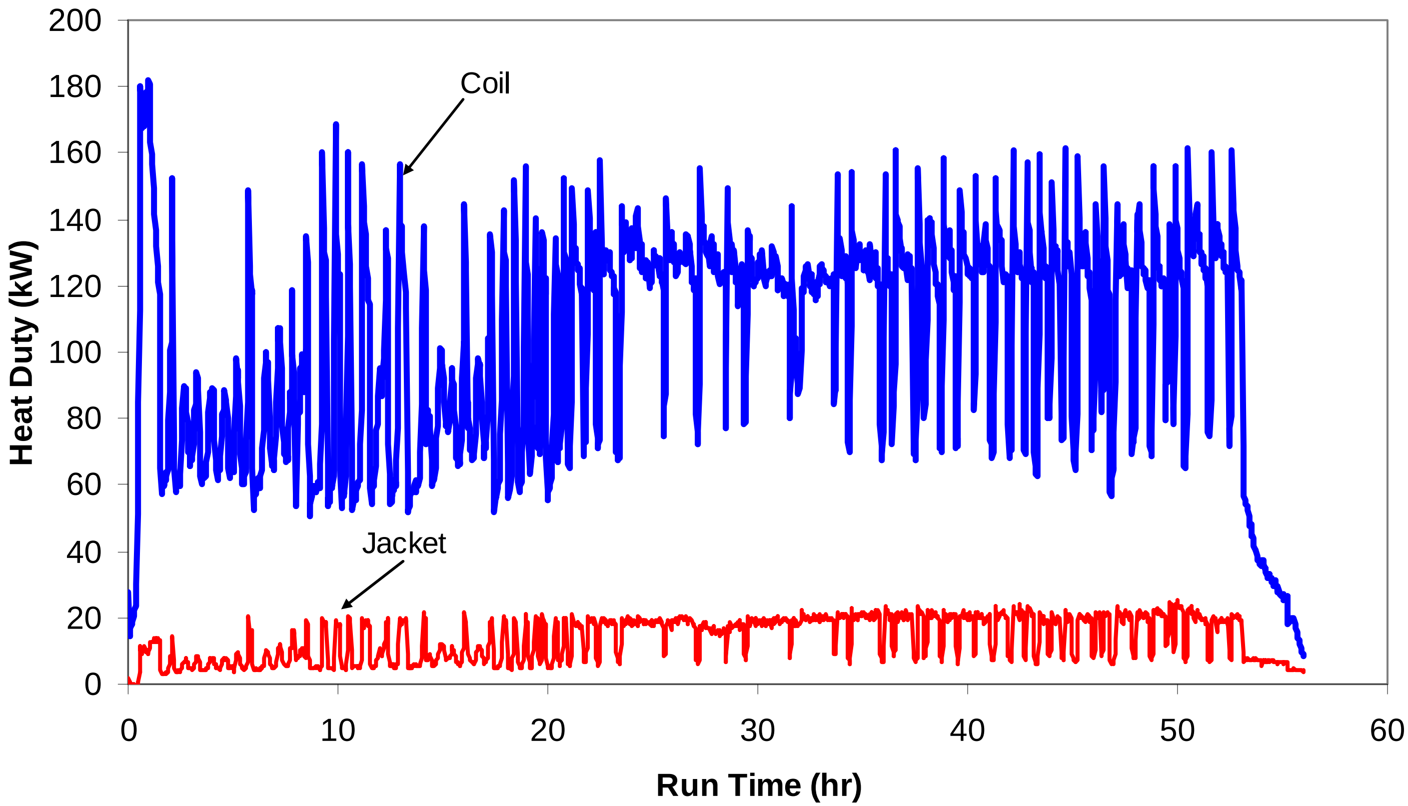



**Figure 4.40. Calculated heat loads on the inner coil and jacket while processing with two double-outlet and two single-outlet bubblers, Test 4.**

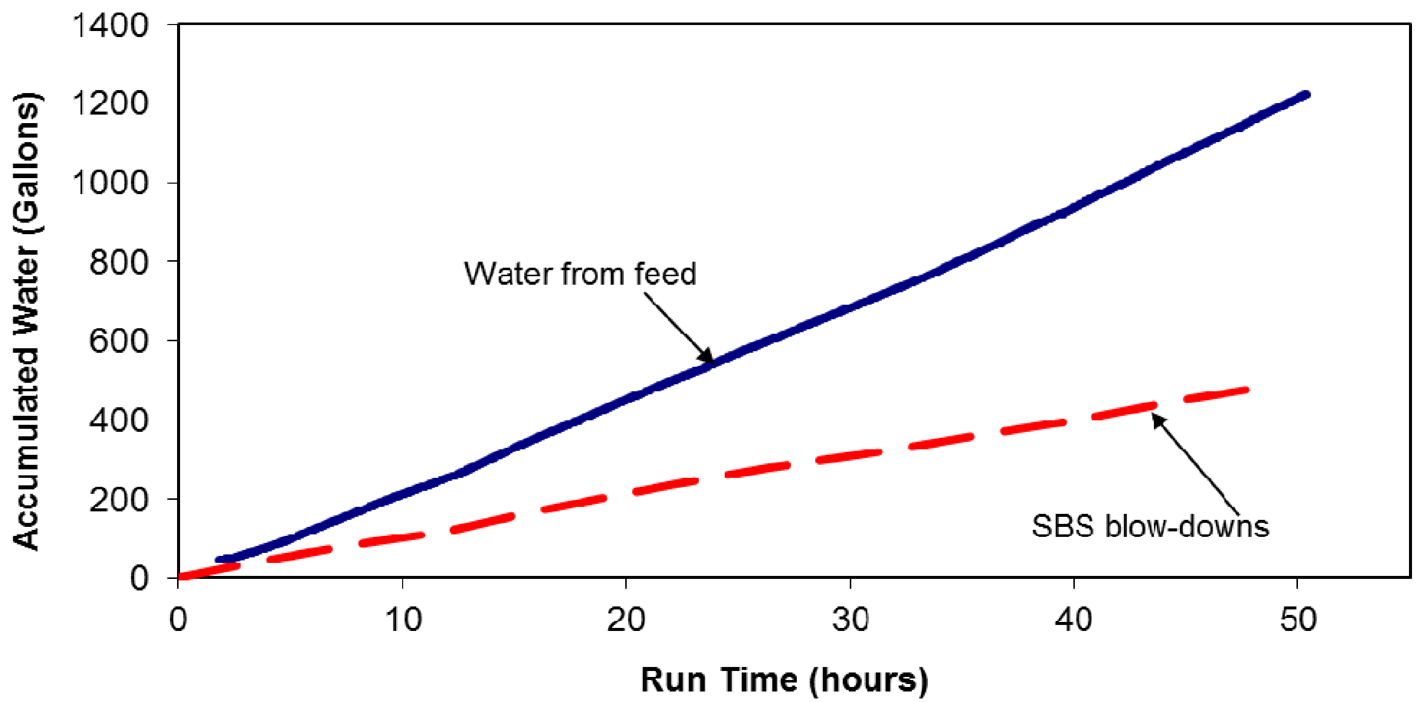



**Figure 4.41. Accumulated SBS blow-down volume and accumulated feed water while processing with two double-outlet bubblers, Test 1.**

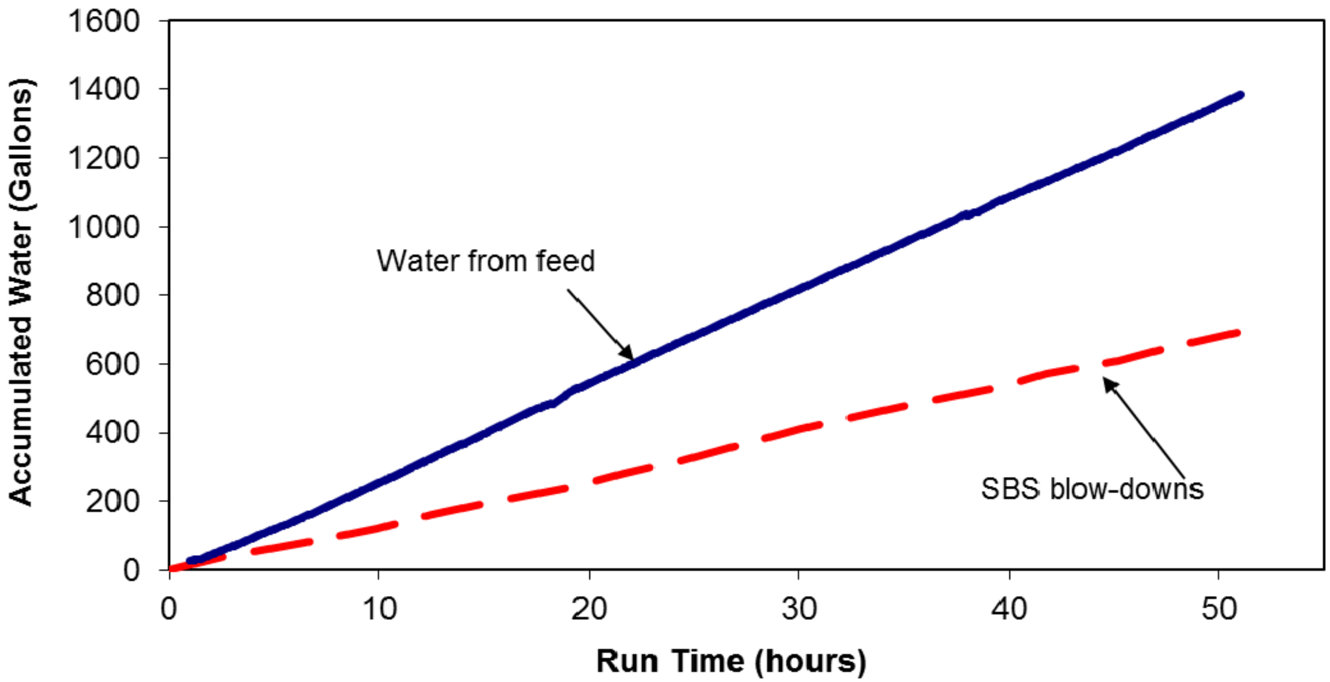



**Figure 4.42. Accumulated SBS blow-down volume and accumulated feed water while processing with two double-outlet and one single-outlet bubblers, Test 2.**

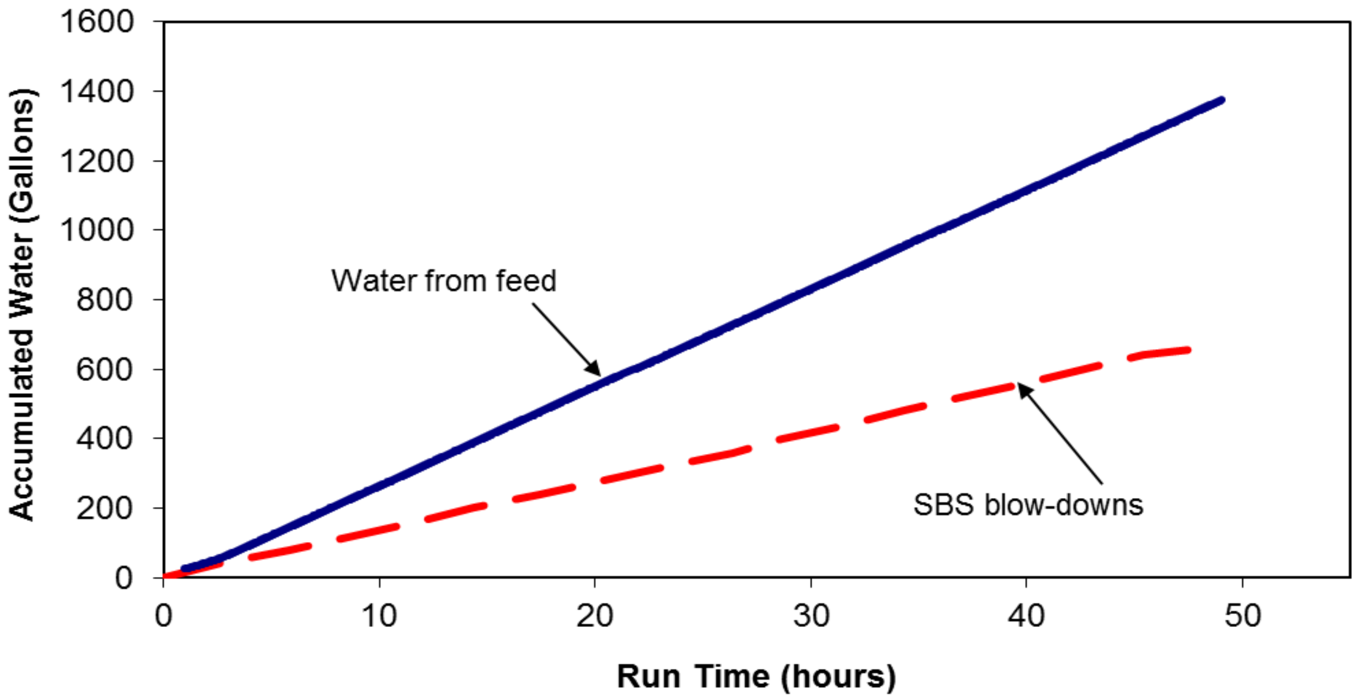



**Figure 4.43. Accumulated SBS blow-down volume and accumulated feed water while processing with two double-outlet and two single-outlet bubblers, Test 3.**

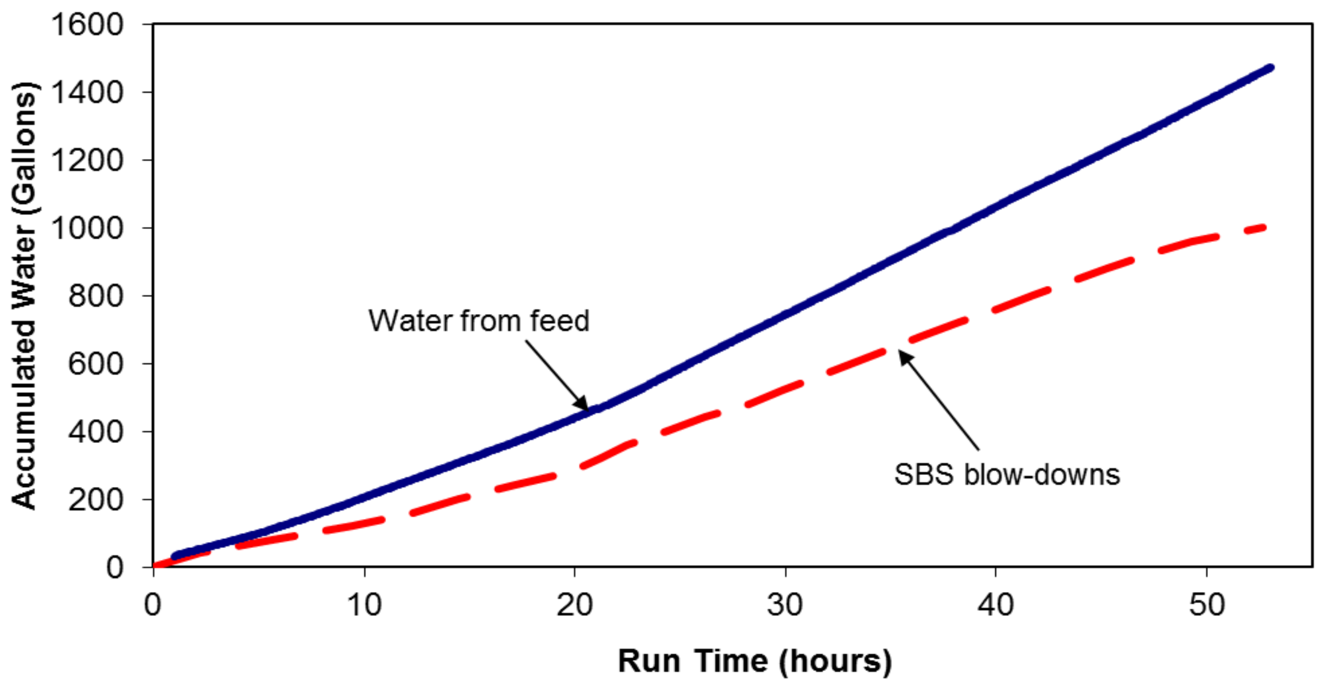



**Figure 4.44. Accumulated SBS blow-down volume and accumulated feed water while processing with two double-outlet and two single-outlet bubblers, Test 4.**

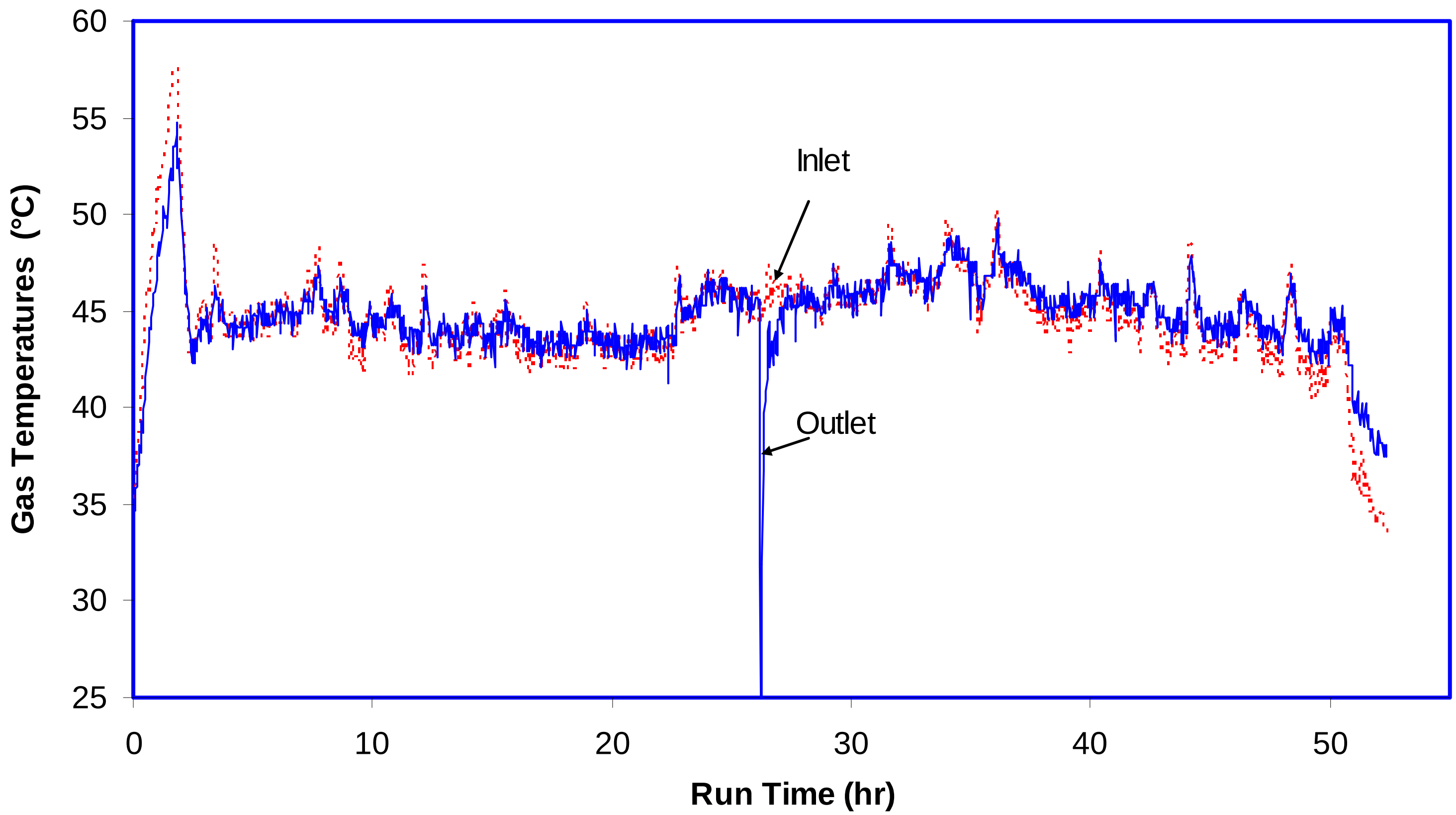



**Figure 4.45. WESP inlet and outlet gas temperatures while processing with two double-outlet bubblers, Test 1.**
**(Note: Downward outlet temperature spikes are the result of WESP deluges.)**

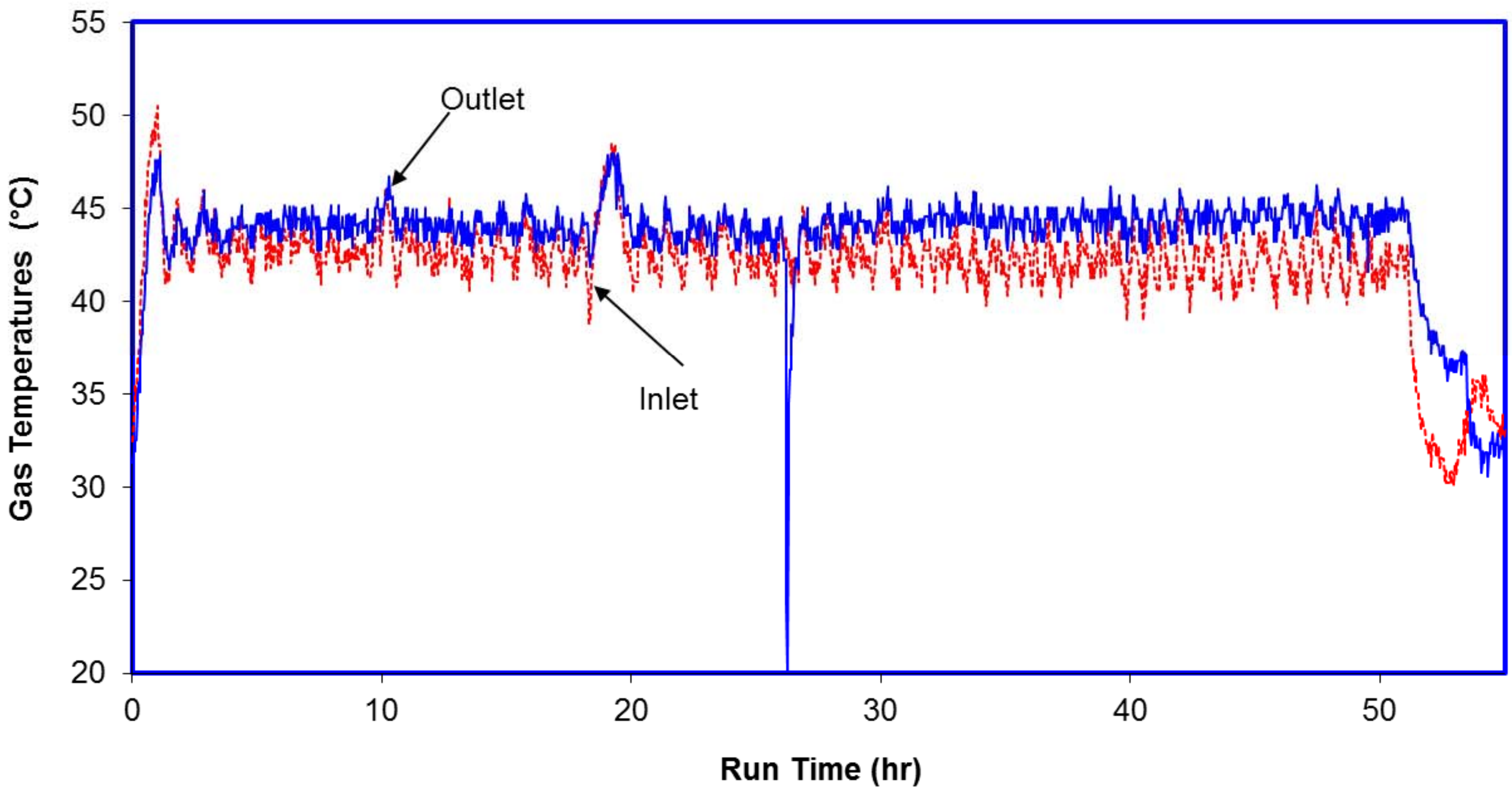



**Figure 4.46. WESP inlet and outlet gas temperatures during while processing with two double-outlet and one single-outlet bubblers, Test 2.**
**(Note: Downward outlet temperature spikes are the result of WESP deluges.)**

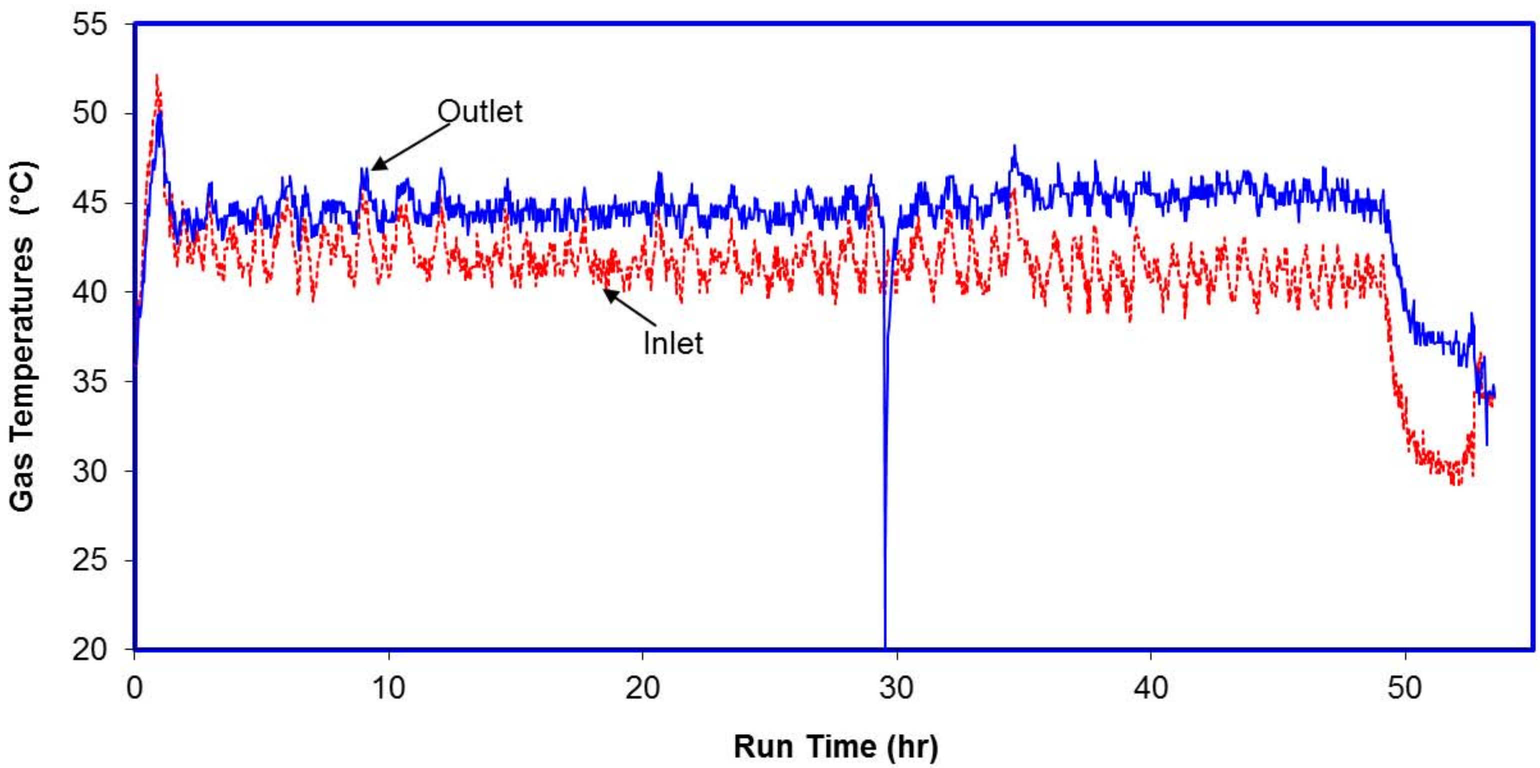



**Figure 4.47. WESP inlet and outlet gas temperatures while processing with two double-outlet and two single-outlet bubblers, Test 3.**
**(Note: Downward outlet temperature spikes are the result of WESP deluges.)**

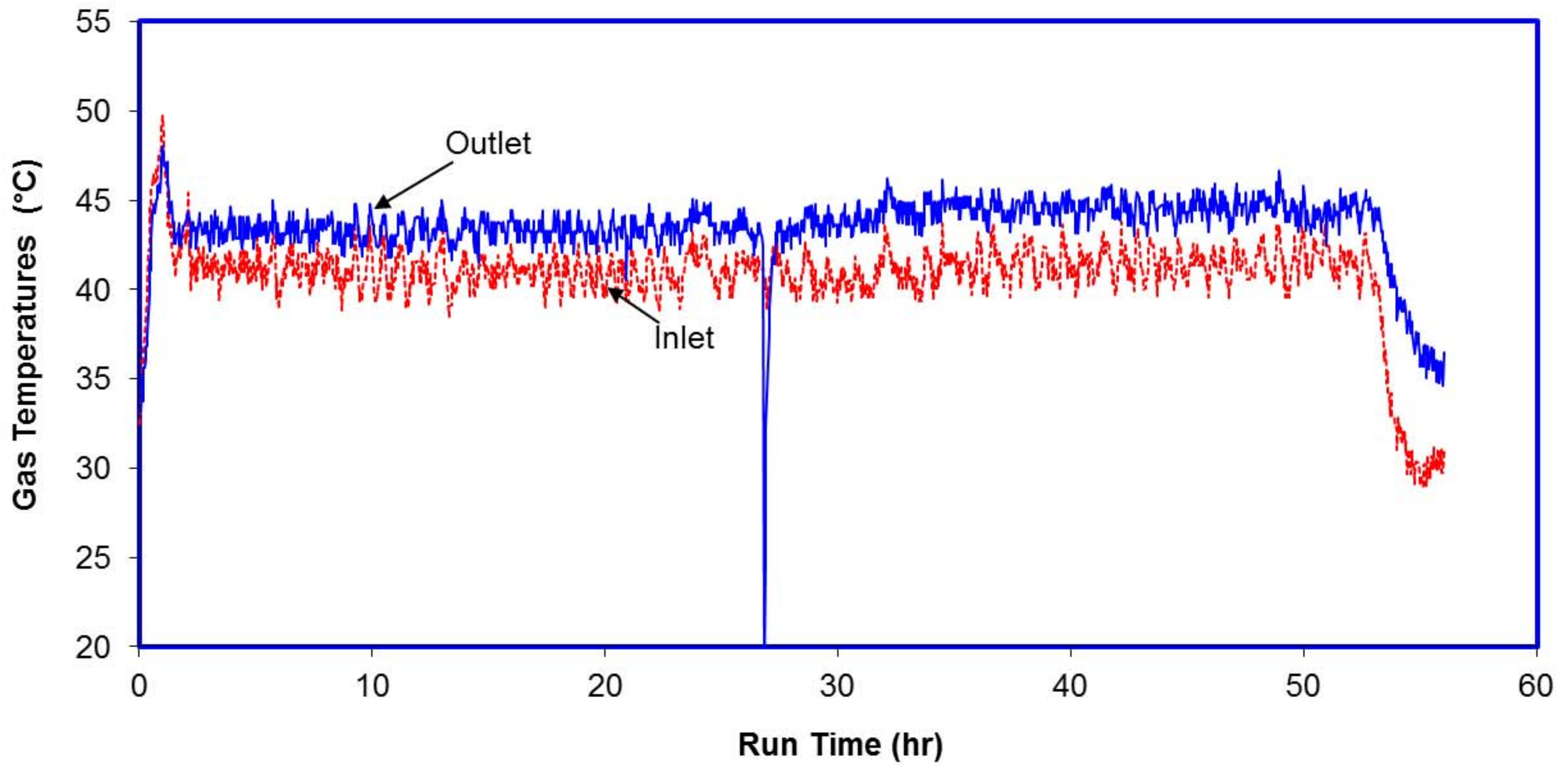



**Figure 4.48. WESP inlet and outlet gas temperatures while processing with two double-outlet and two single-outlet bubblers, Test 4.**
**(Note: Downward outlet temperature spikes are the result of WESP deluges.)**

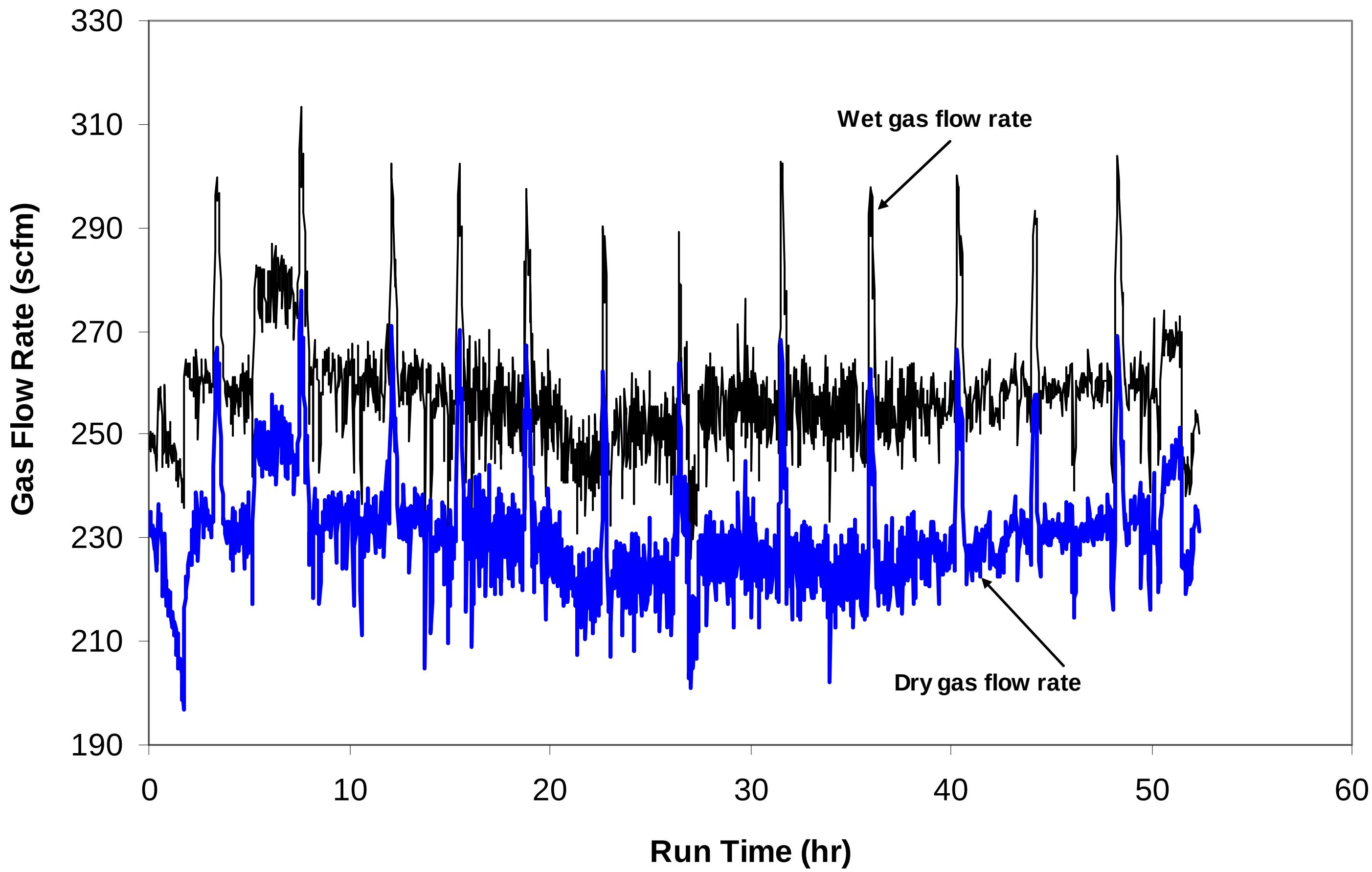



**Figure 4.49. WESP outlet gas flow rate while processing with two double-outlet bubblers, Test 1.**

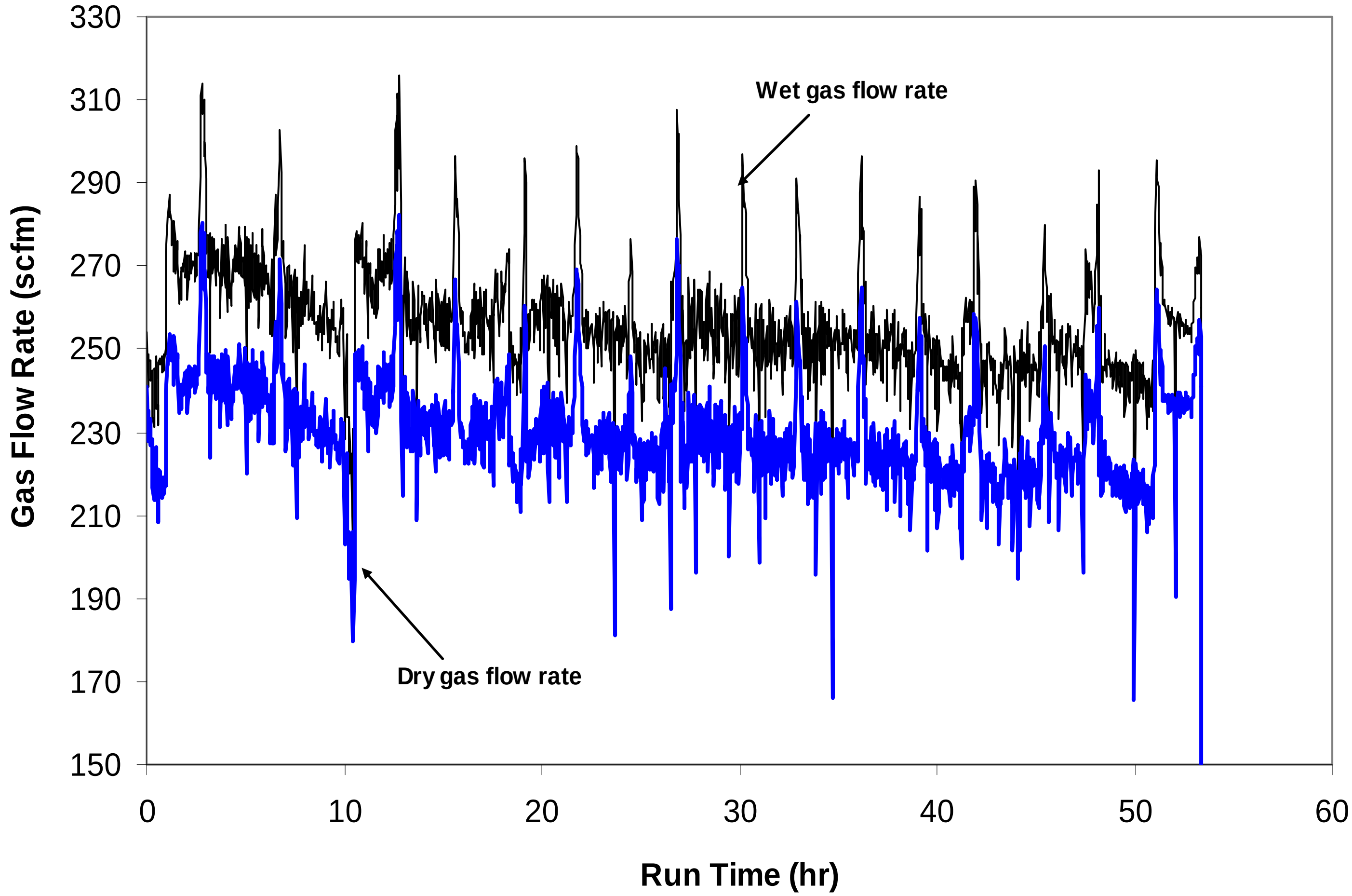



**Figure 4.50. WESP outlet gas flow rate while processing with two double-outlet and one single-outlet bubblers, Test 2.**

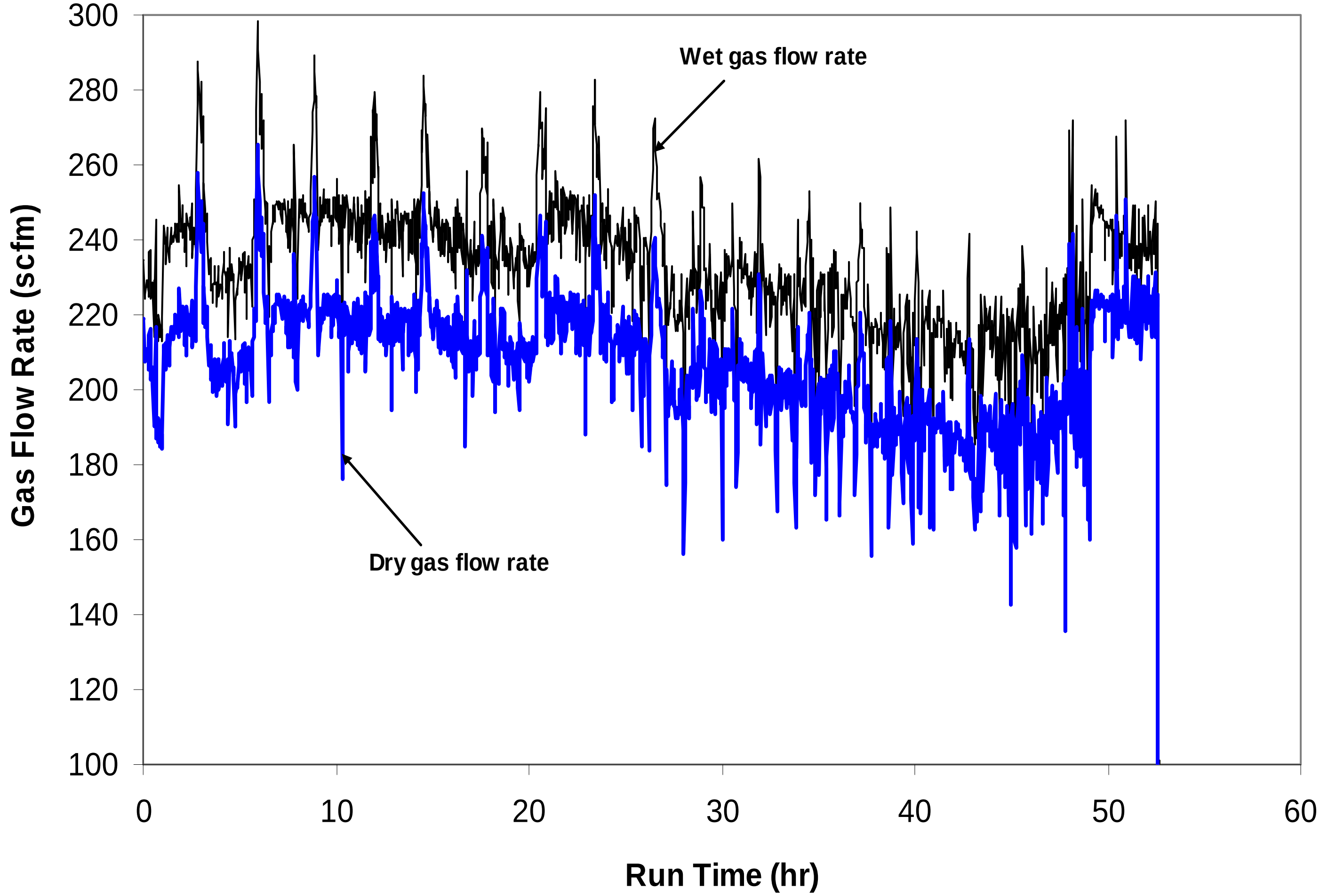



**Figure 4.51. WESP outlet gas flow rate while processing with two double-outlet and two single-outlet bubblers, Test 3.**

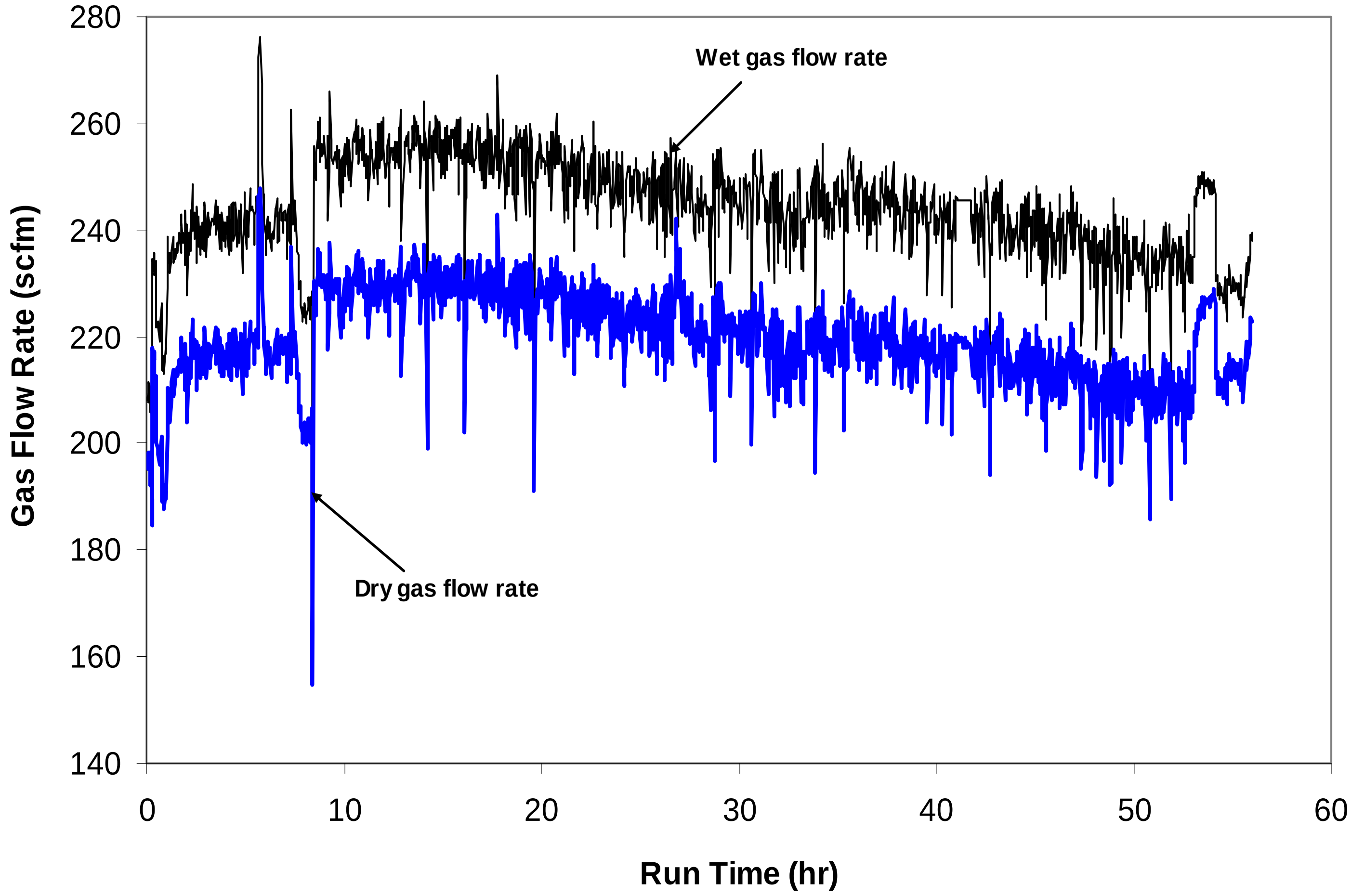



**Figure 4.52. WESP outlet gas flow rate while processing with two double-outlet and two single-outlet bubblers, Test 4.**

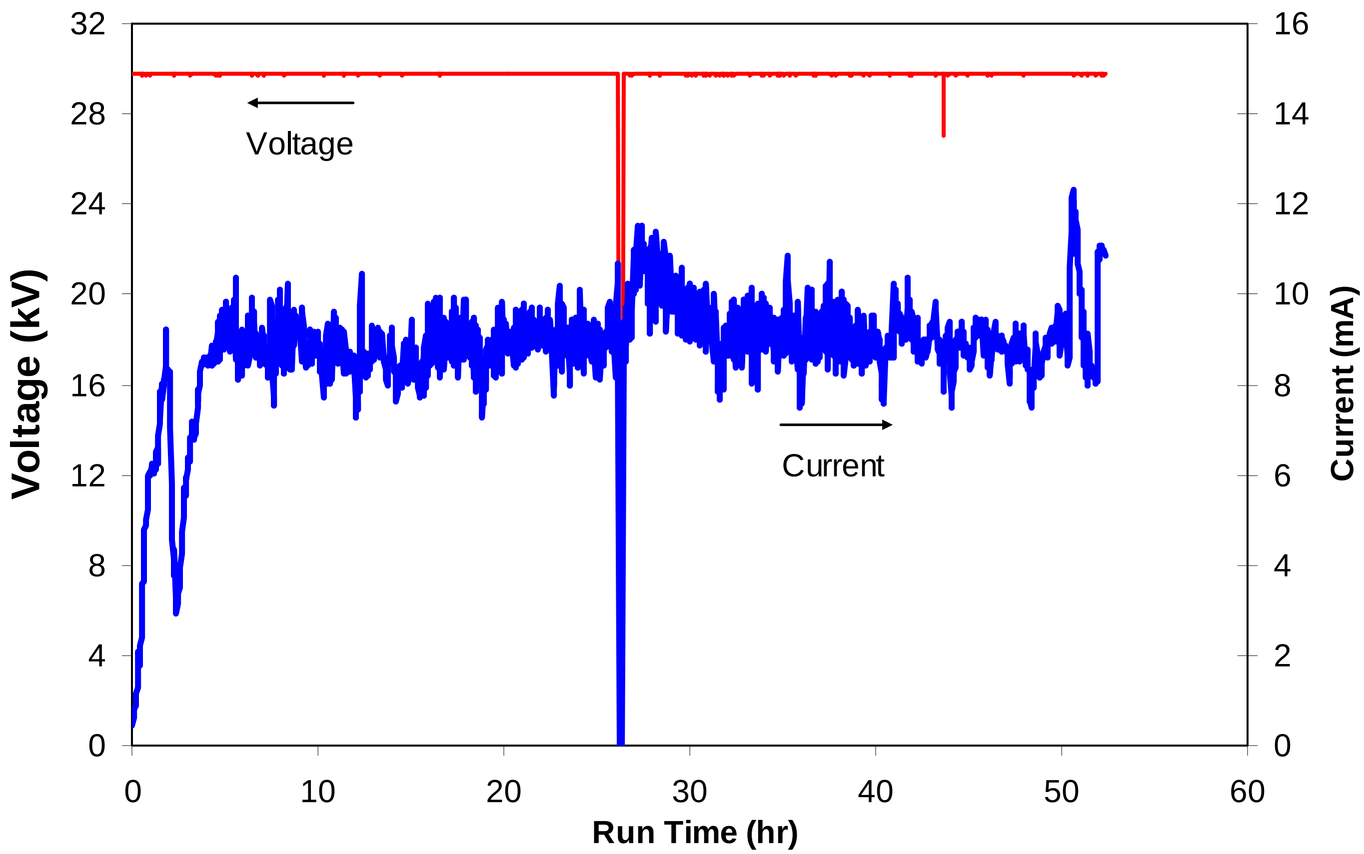



**Figure 4.53. Voltage and current across the WESP while processing with two double-outlet bubblers, Test 1.**

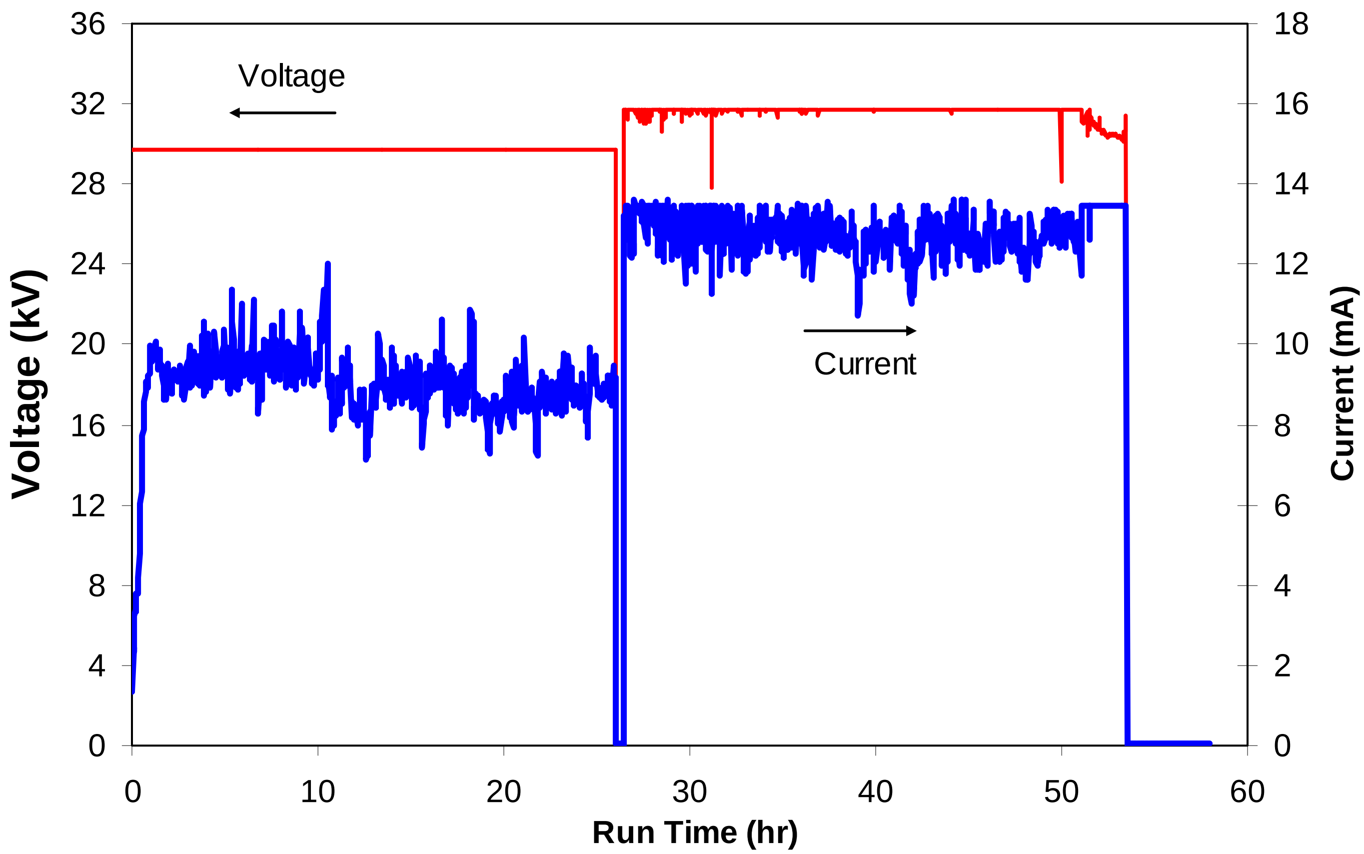



**Figure 4.54. Voltage and current across the WESP while processing with two double-outlet and one single-outlet bubblers, Test 2.**

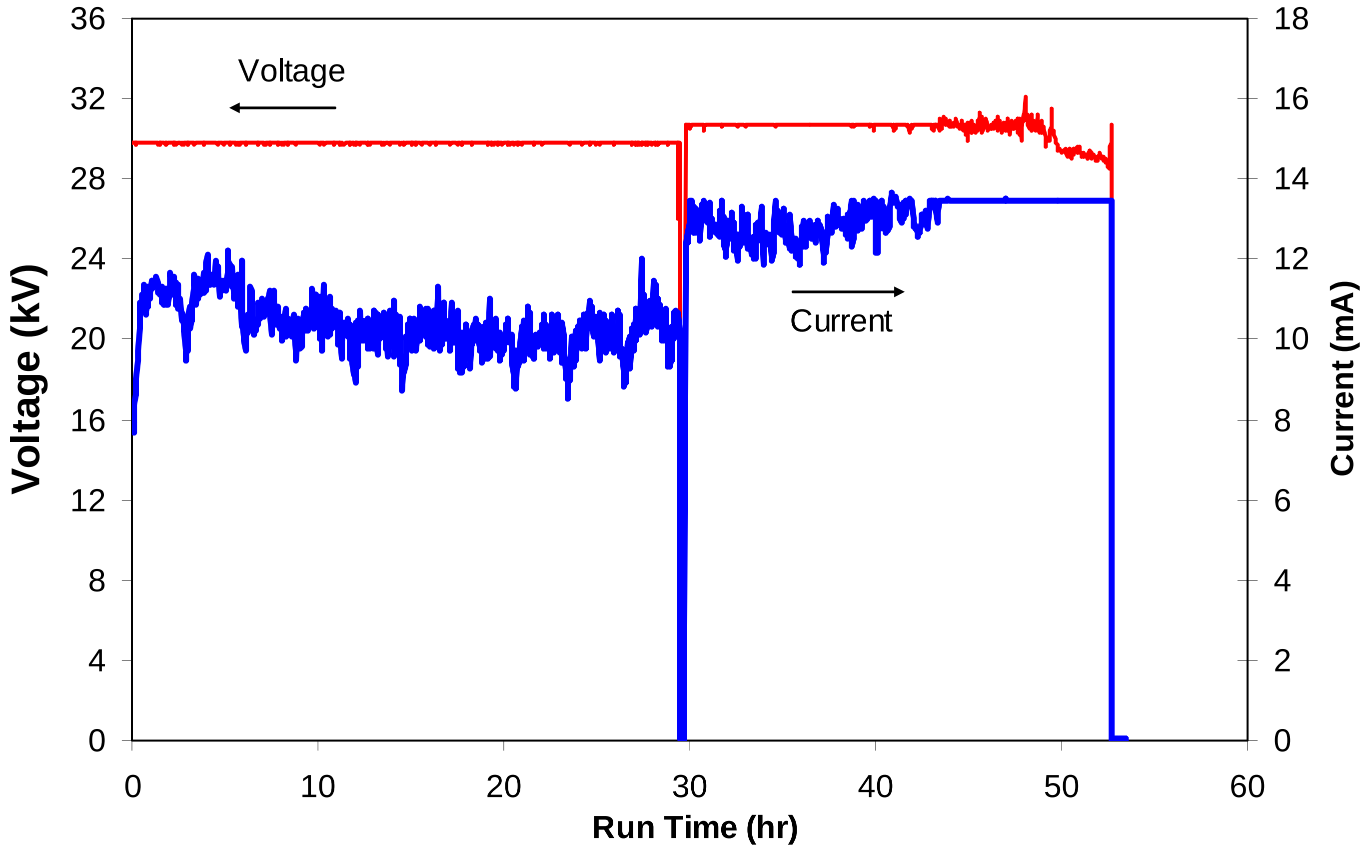



**Figure 4.55. Voltage and current across the WESP while processing with two double-outlet and two single-outlet bubblers, Test 3.**

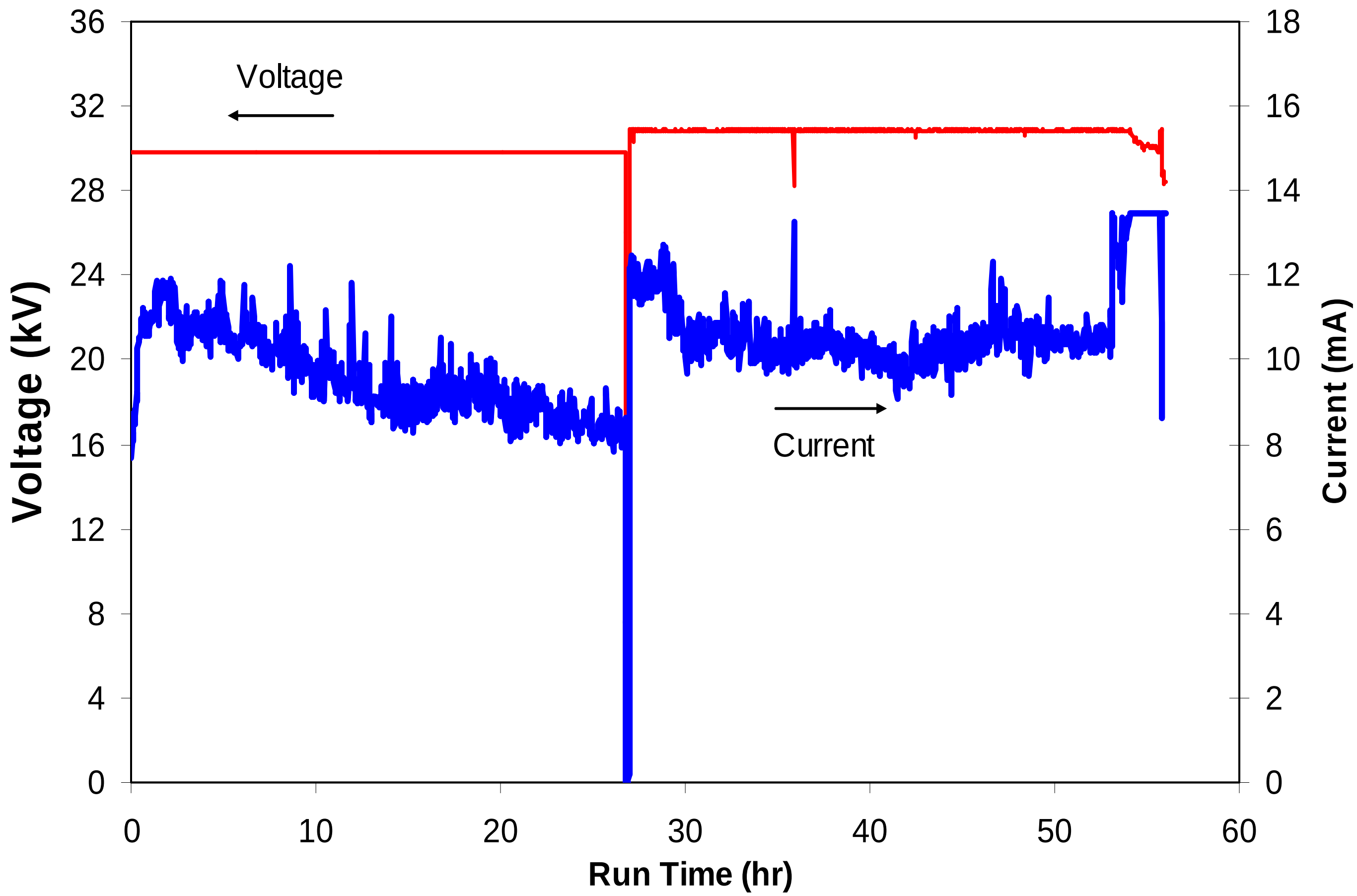



**Figure 4.56. Voltage and current across the WESP while processing with two double-outlet and two single-outlet bubblers, Test 4.**

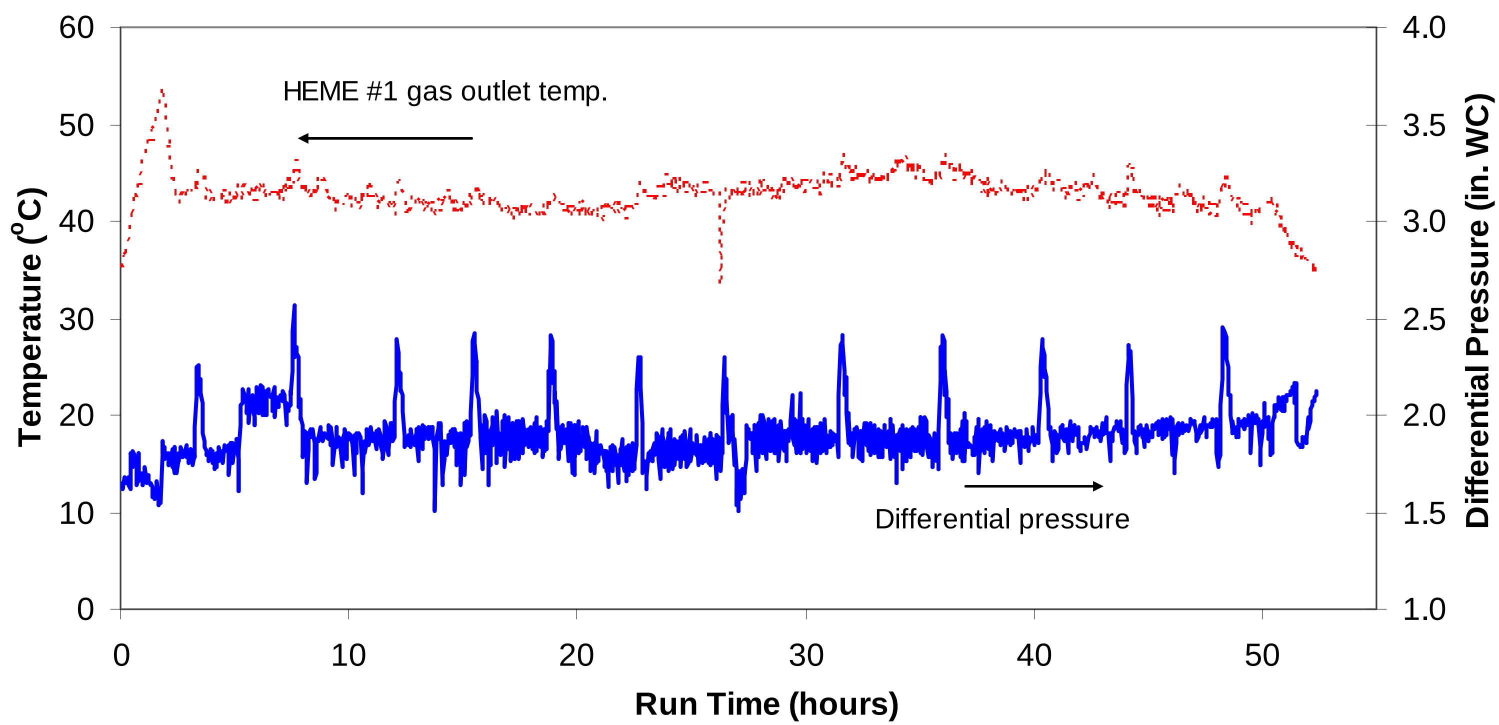



**Figure 4.57. Outlet temperature and differential pressure for HEME #1 while processing with two double-outlet bubblers, Test 1.**

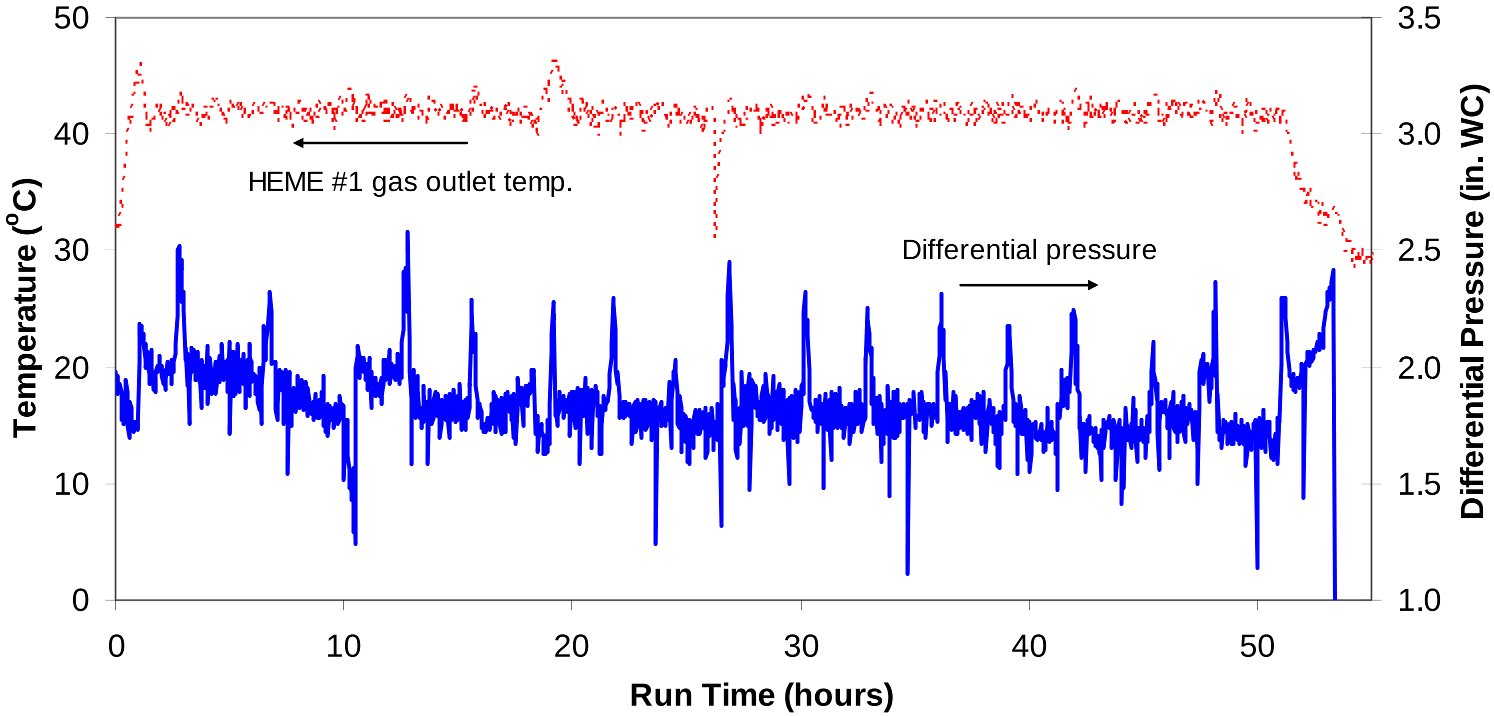



**Figure 4.58. Outlet temperature and differential pressure for HEME #1 while processing with two double-outlet and one single-outlet bubblers, Test 2.**

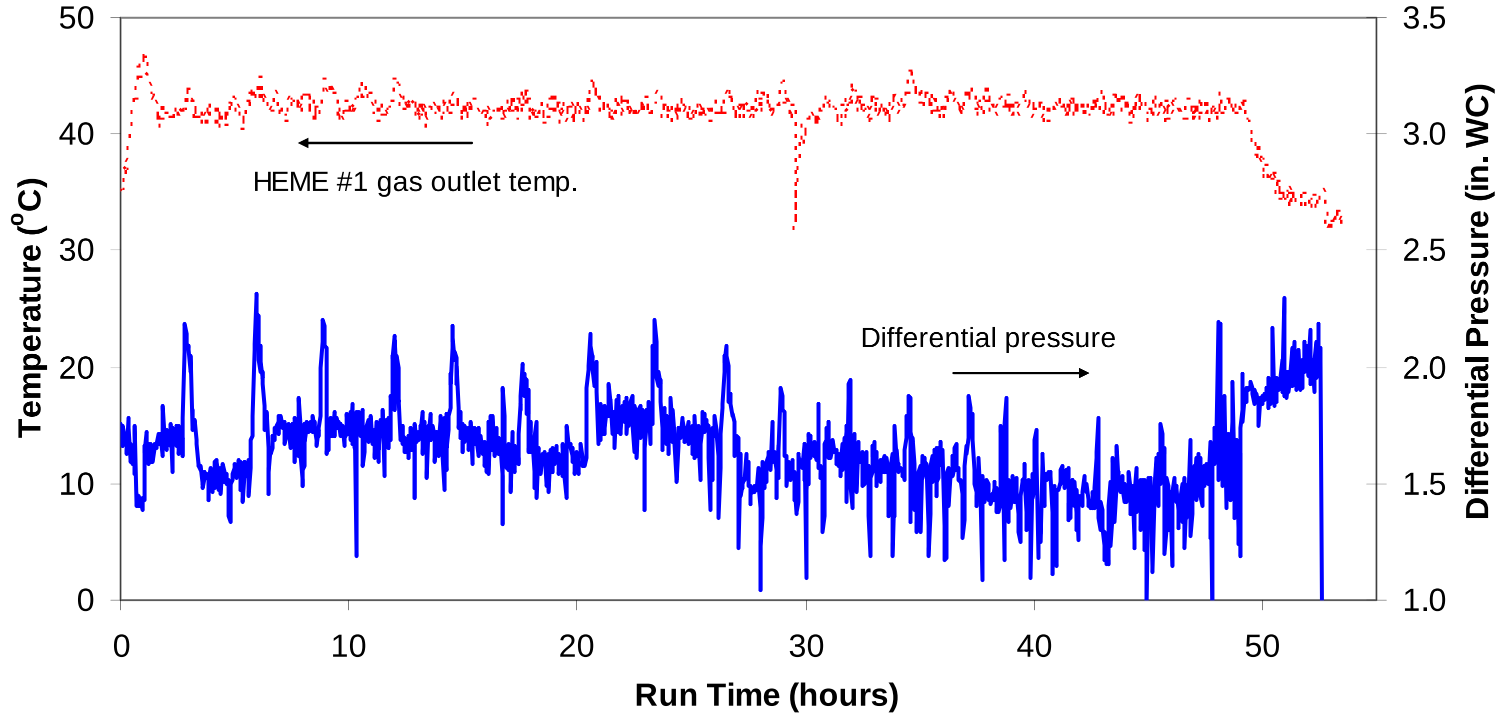



**Figure 4.59. Outlet temperature and differential pressure for HEME #1 while processing with two double-outlet and two single-outlet bubblers, Test 3.**

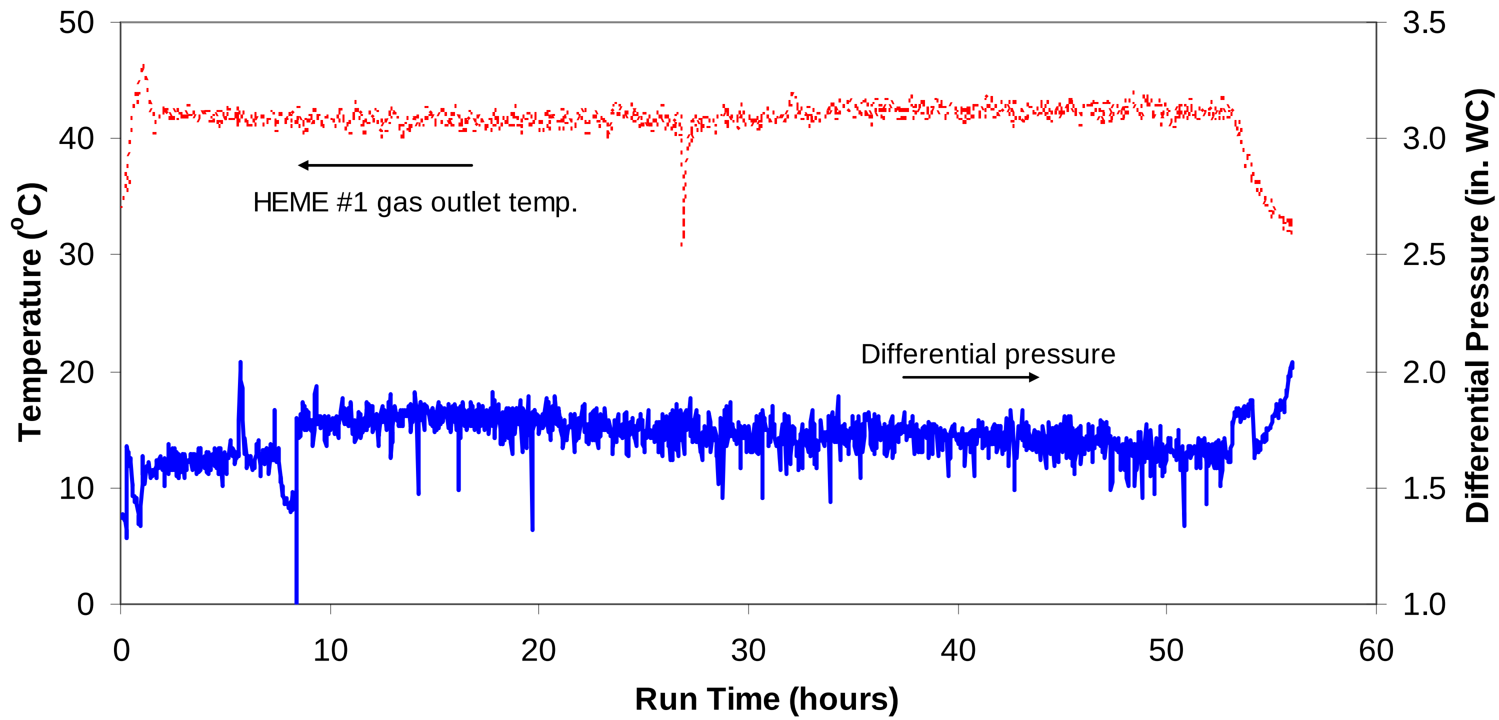



**Figure 4.60. Outlet temperature and differential pressure for HEME #1 while processing with two double-outlet and two single-outlet bubblers, Test 4.**

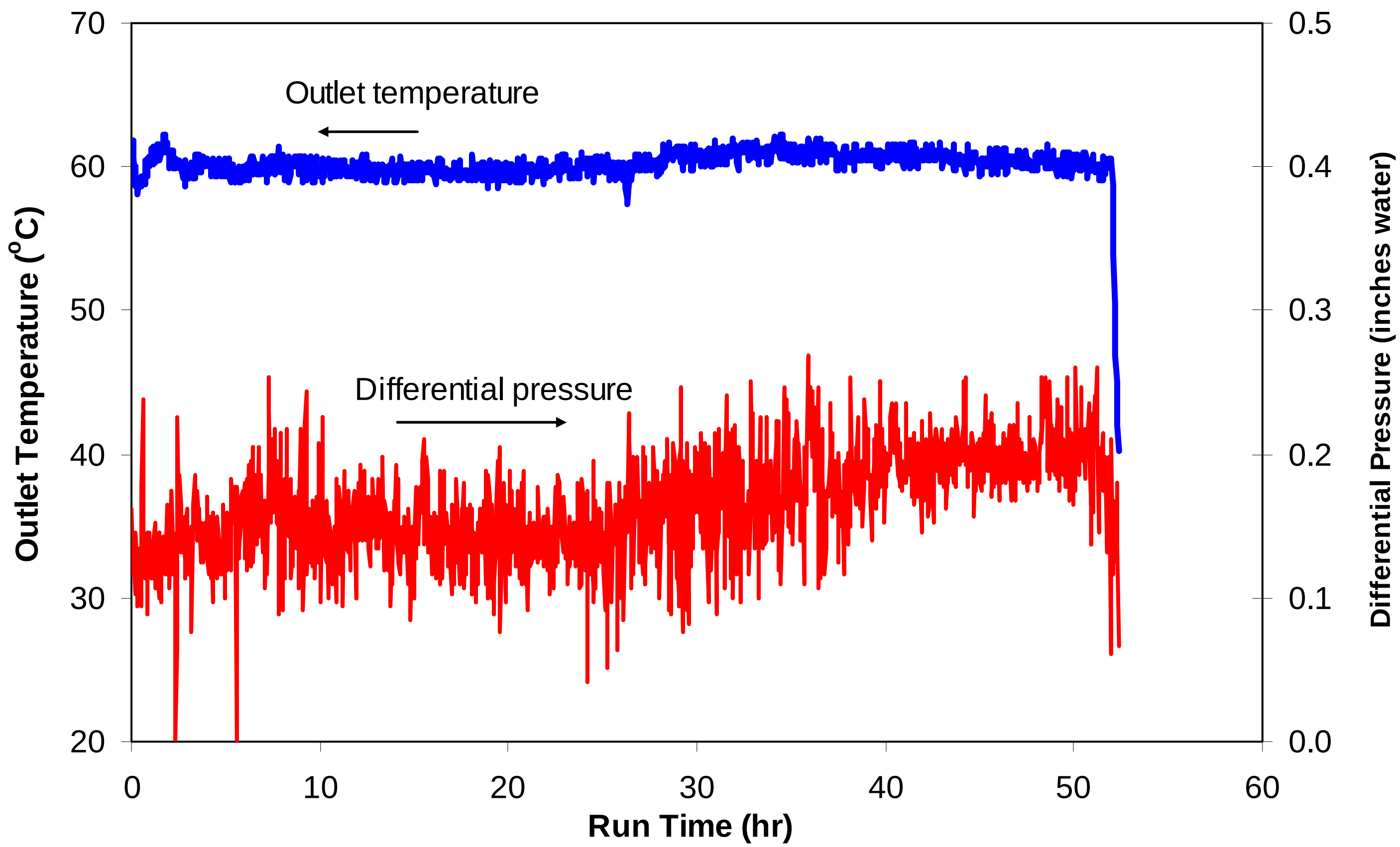



**Figure 4.61. Outlet temperature and differential pressure for HEPA #1 while processing with two double-outlet bubblers, Test 1.**

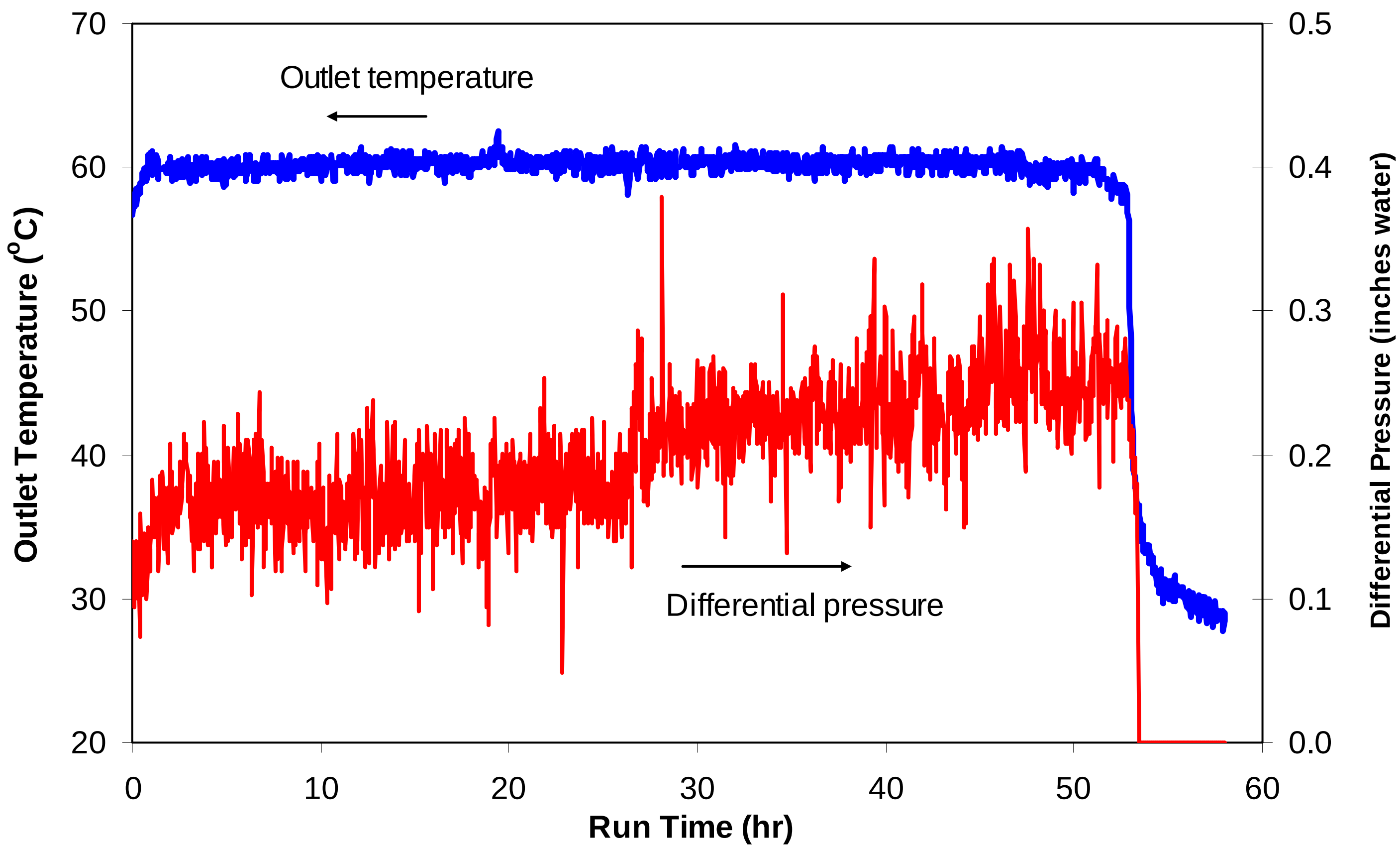



**Figure 4.62. Outlet temperature and differential pressure for HEPA #1 while processing with two double-outlet and one single-outlet bubblers, Test 2.**

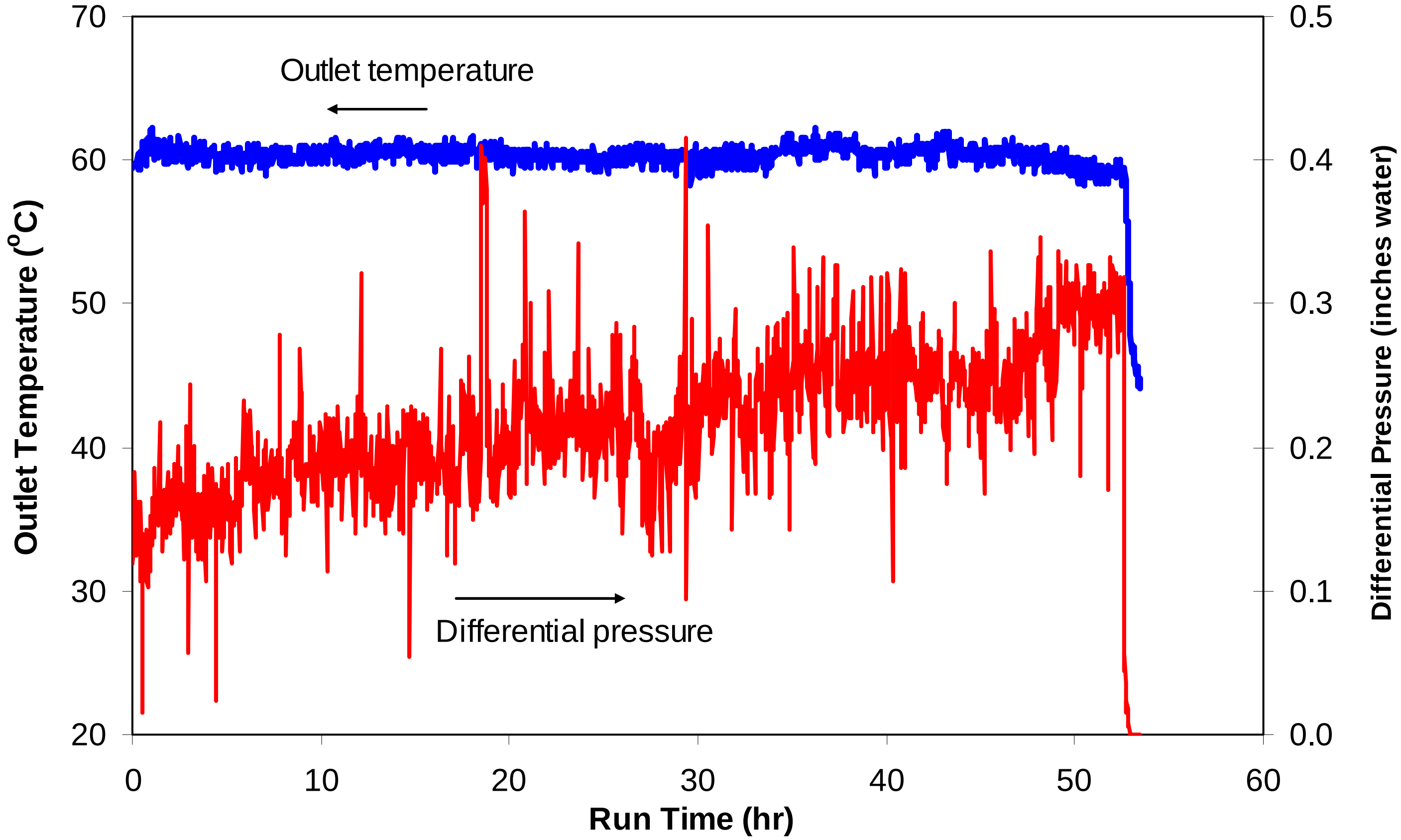



**Figure 4.63. Outlet temperature and differential pressure for HEPA #1 while processing with two double-outlet and two single-outlet bubblers, Test 3.**

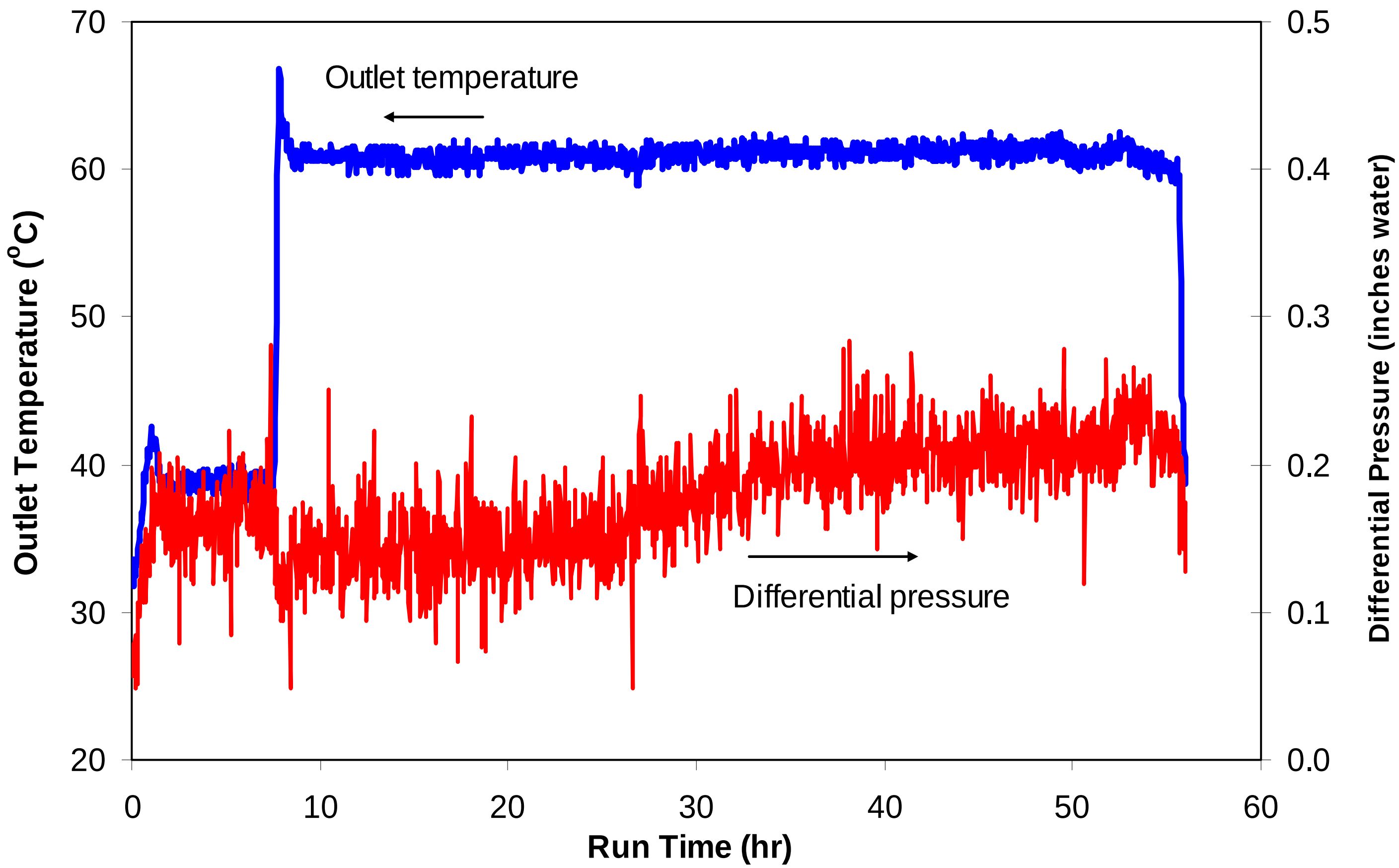



**Figure 4.64. Outlet temperature and differential pressure for HEPA #1 while processing with two double-outlet and two single-outlet bubblers, Test 4.**

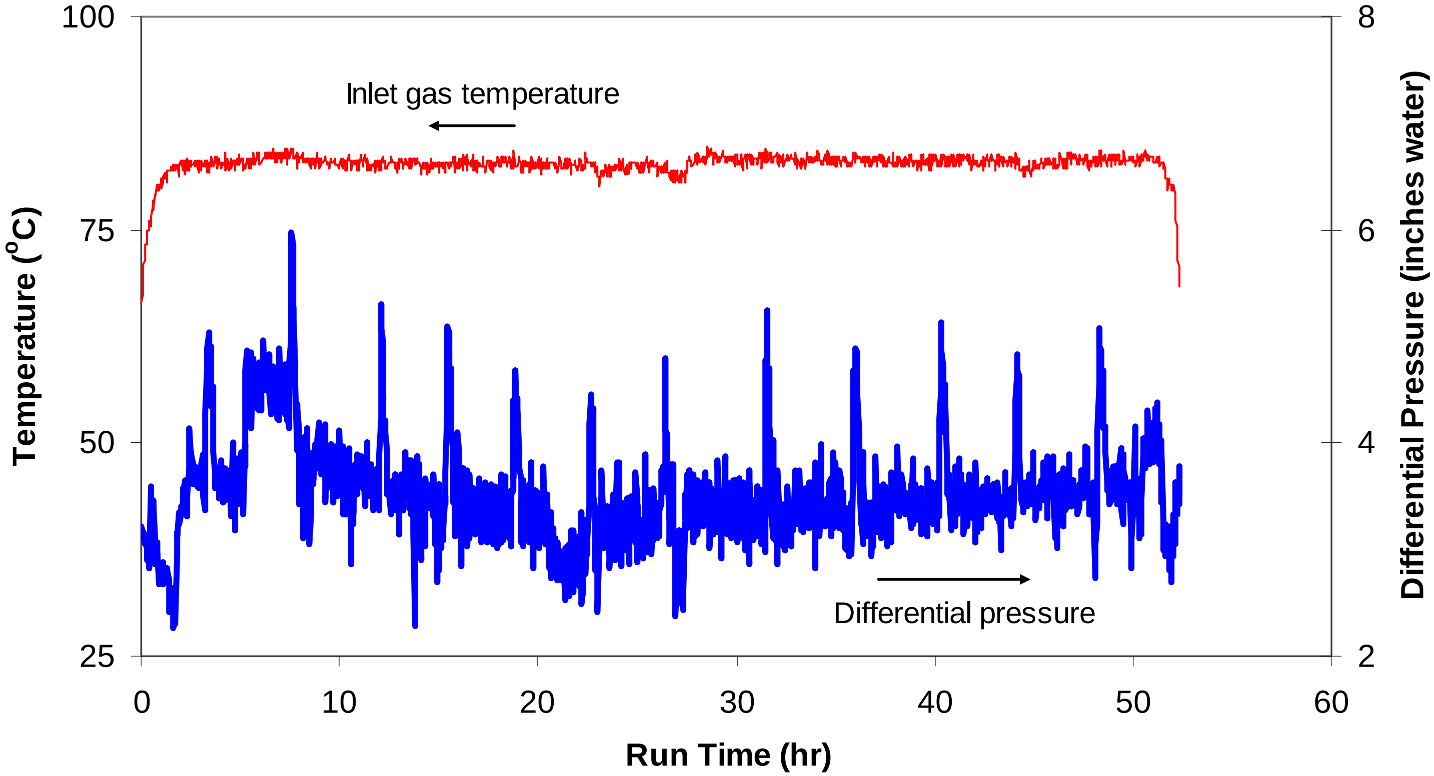



**Figure 4.65. Inlet gas temperature and differential pressure for PBS while processing with two double-outlet bubblers, Test 1.**

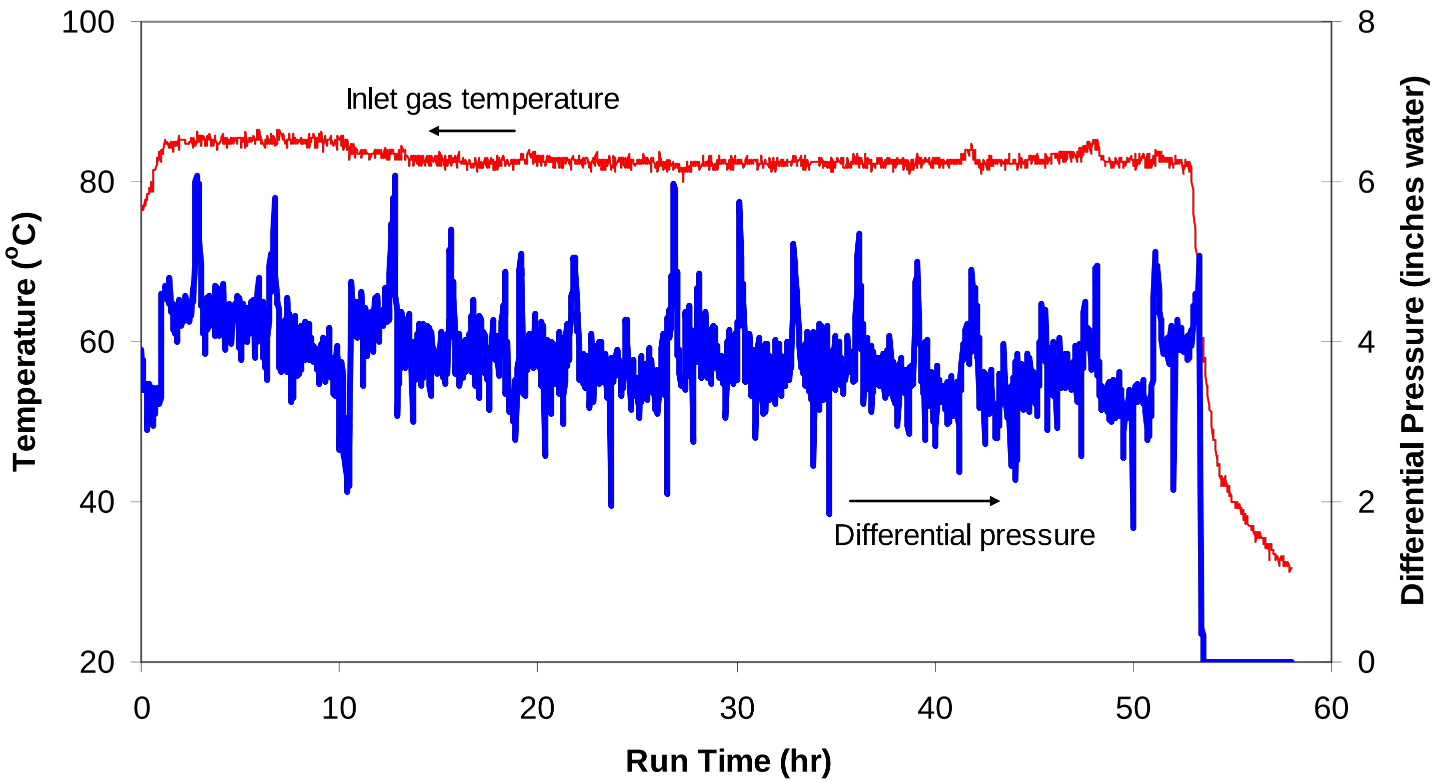



**Figure 4.66. Inlet gas temperature and differential pressure for PBS for while processing with two double-outlet and one single-outlet bubblers, Test 2.**

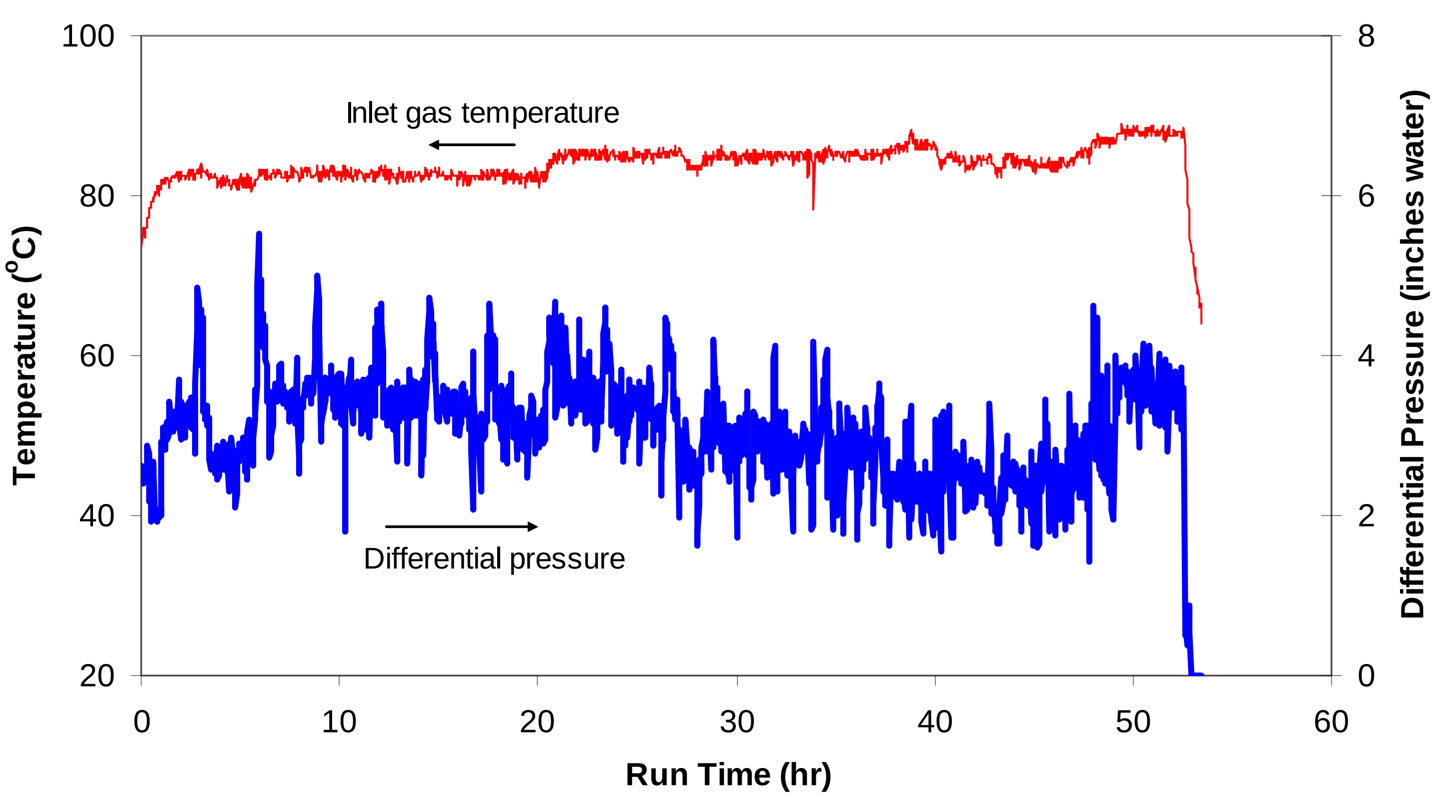



**Figure 4.67. Inlet gas temperature and differential pressure for PBS while processing with two double-outlet and two single-outlet bubblers, Test 3.**

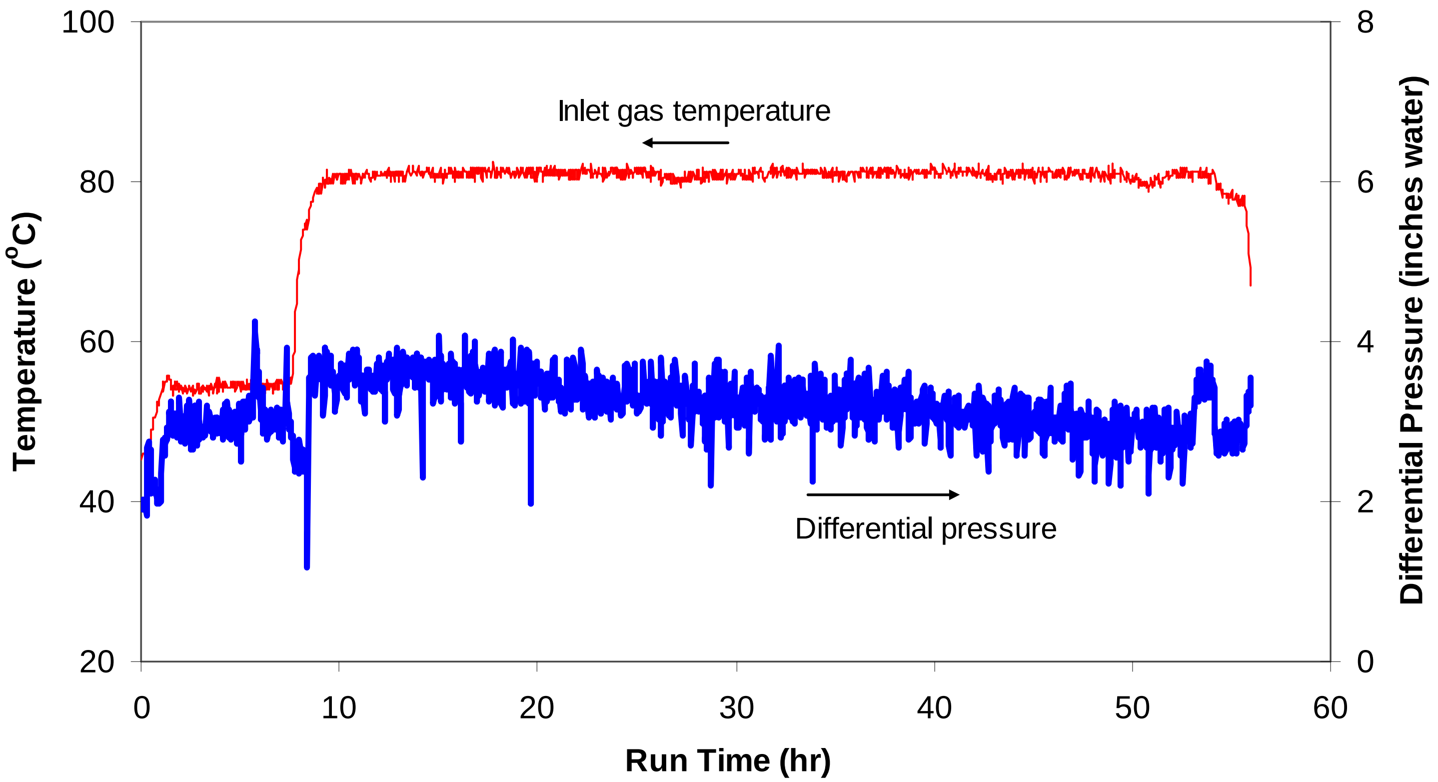



**Figure 4.68. Inlet gas temperature and differential pressure for PBS while processing with two double-outlet and two single-outlet bubblers, Test 4.**

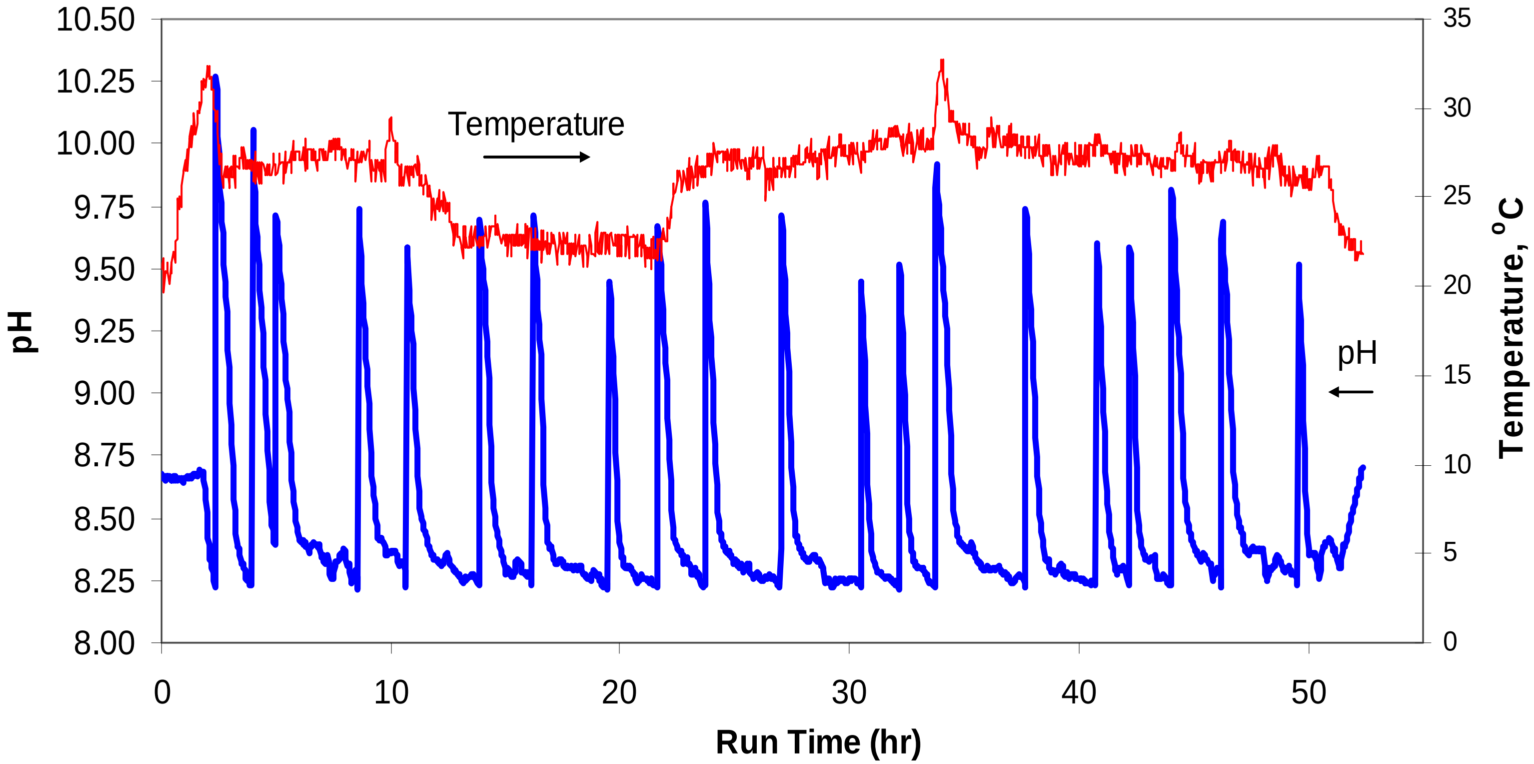



**Figure 4.69. pH for PBS while processing with two double-outlet bubblers, Test 1.**

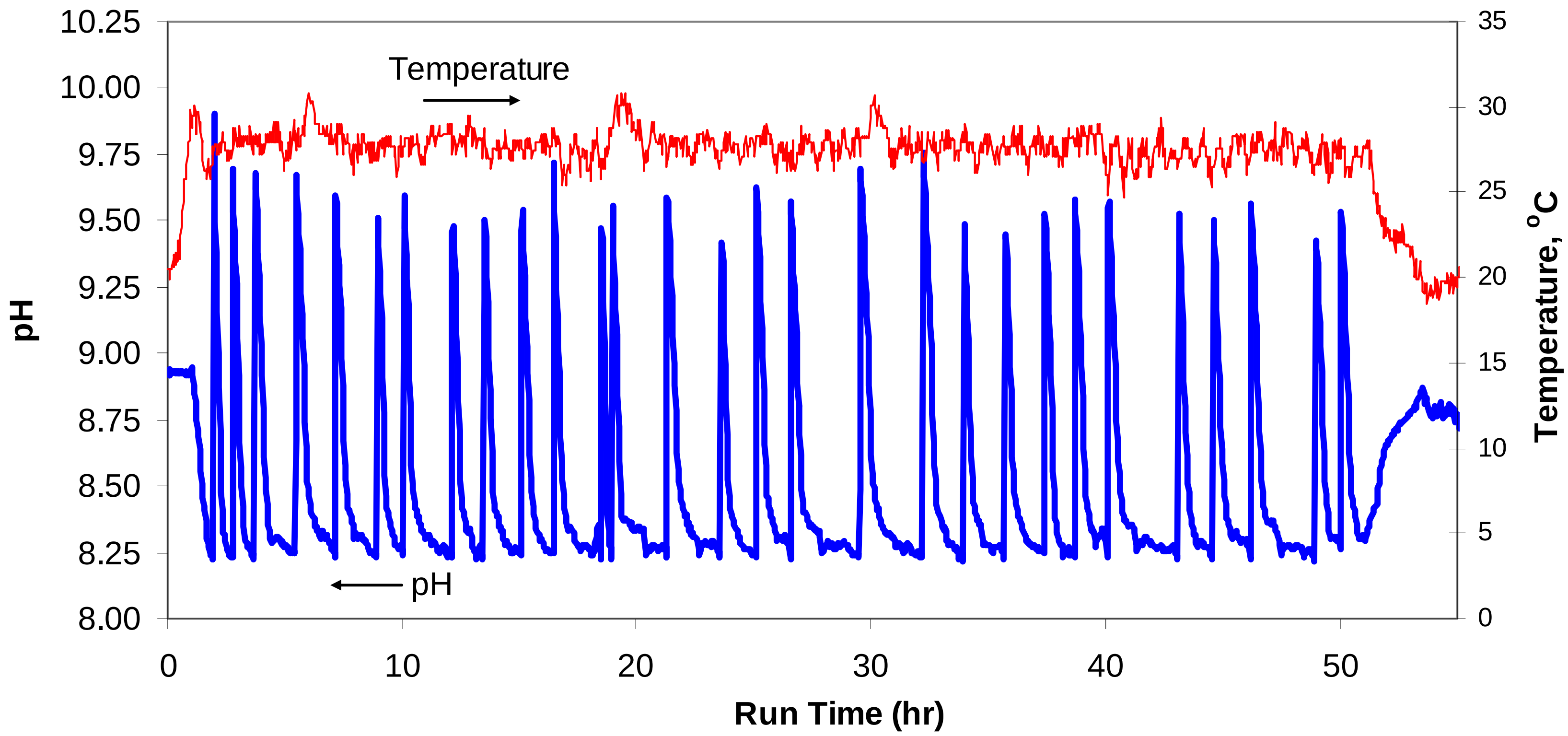



**Figure 4.70. pH for PBS while processing with two double-outlet and one single-outlet bubblers, Test 2.**

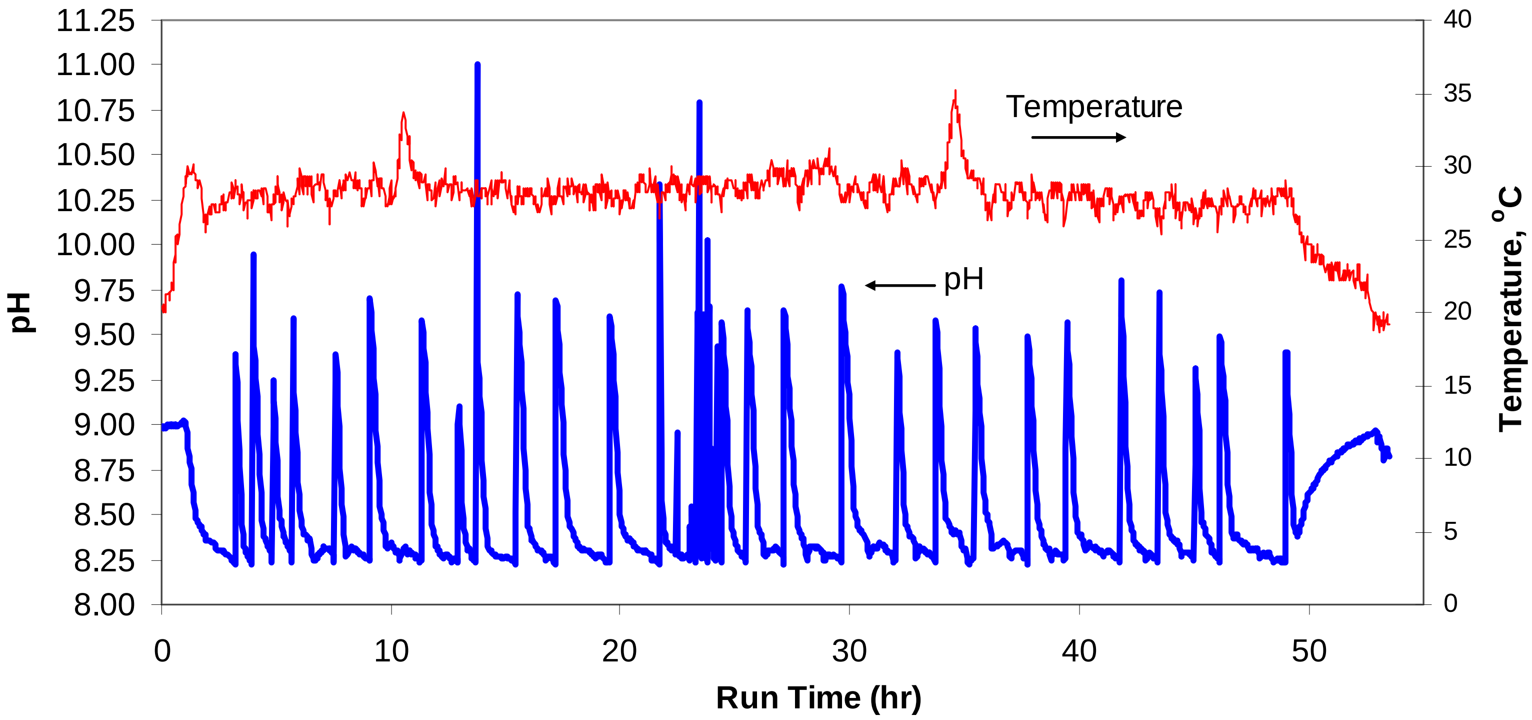



**Figure 4.71. pH for PBS while processing with two double-outlet and two single-outlet bubblers, Test 3.**

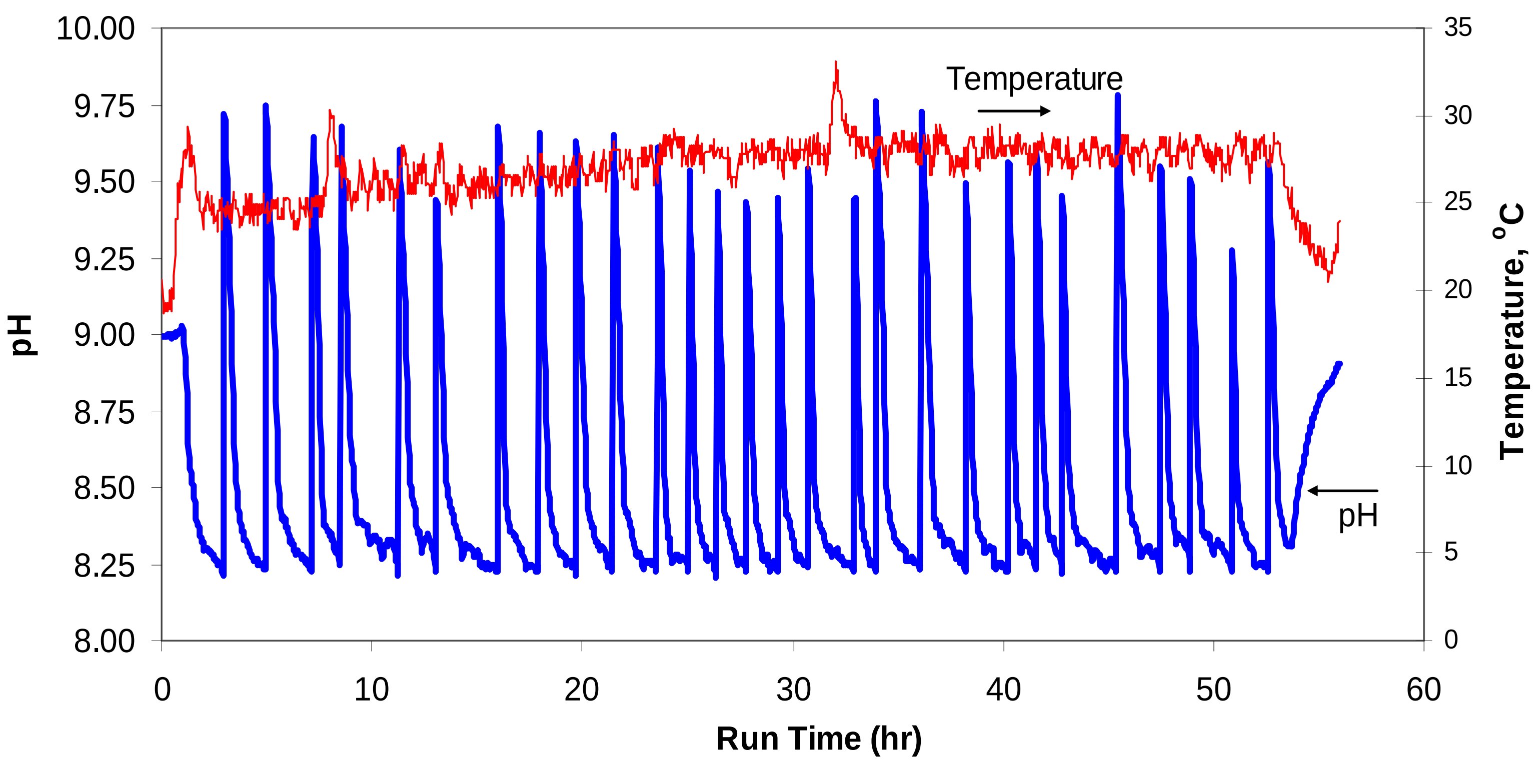



**Figure 4.72. pH for PBS while processing with two double-outlet and two single-outlet bubblers, Test 4.**

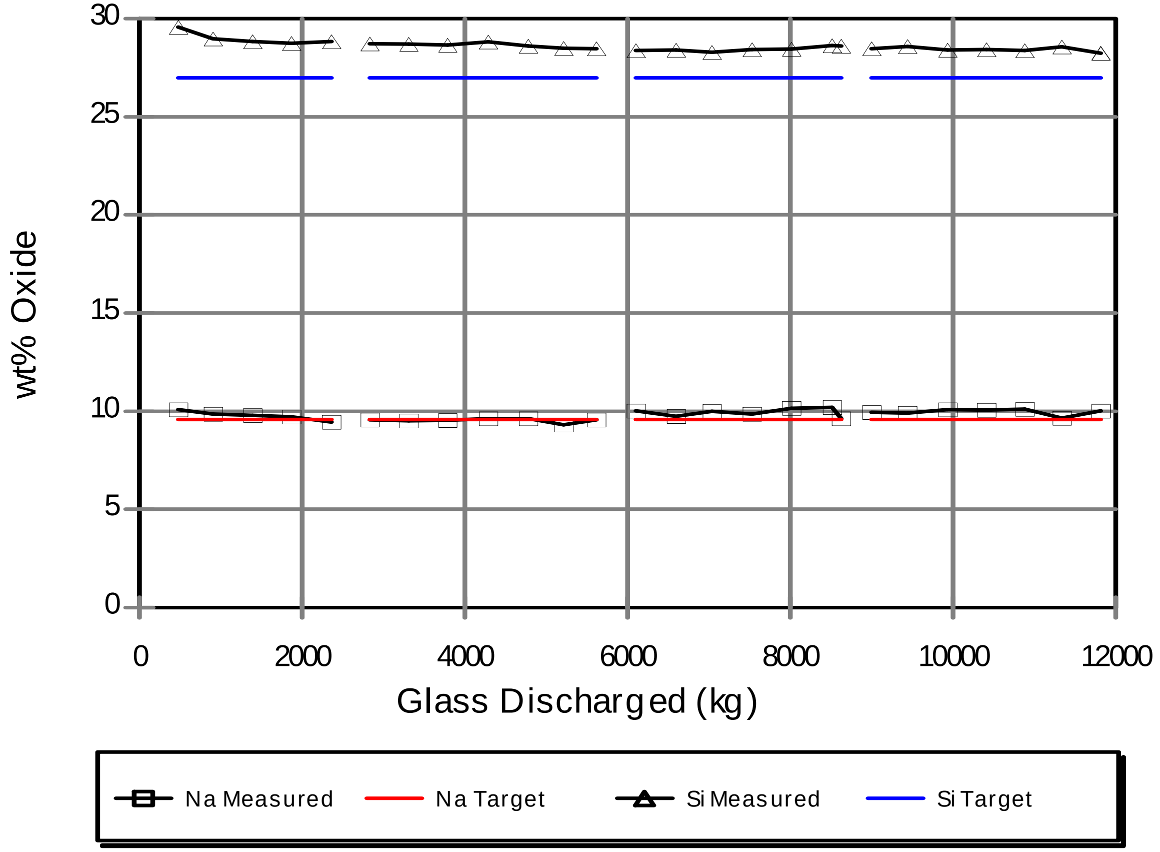



**Figure 5.1.a. DM1200 product and target glass compositions determined by XRF.**

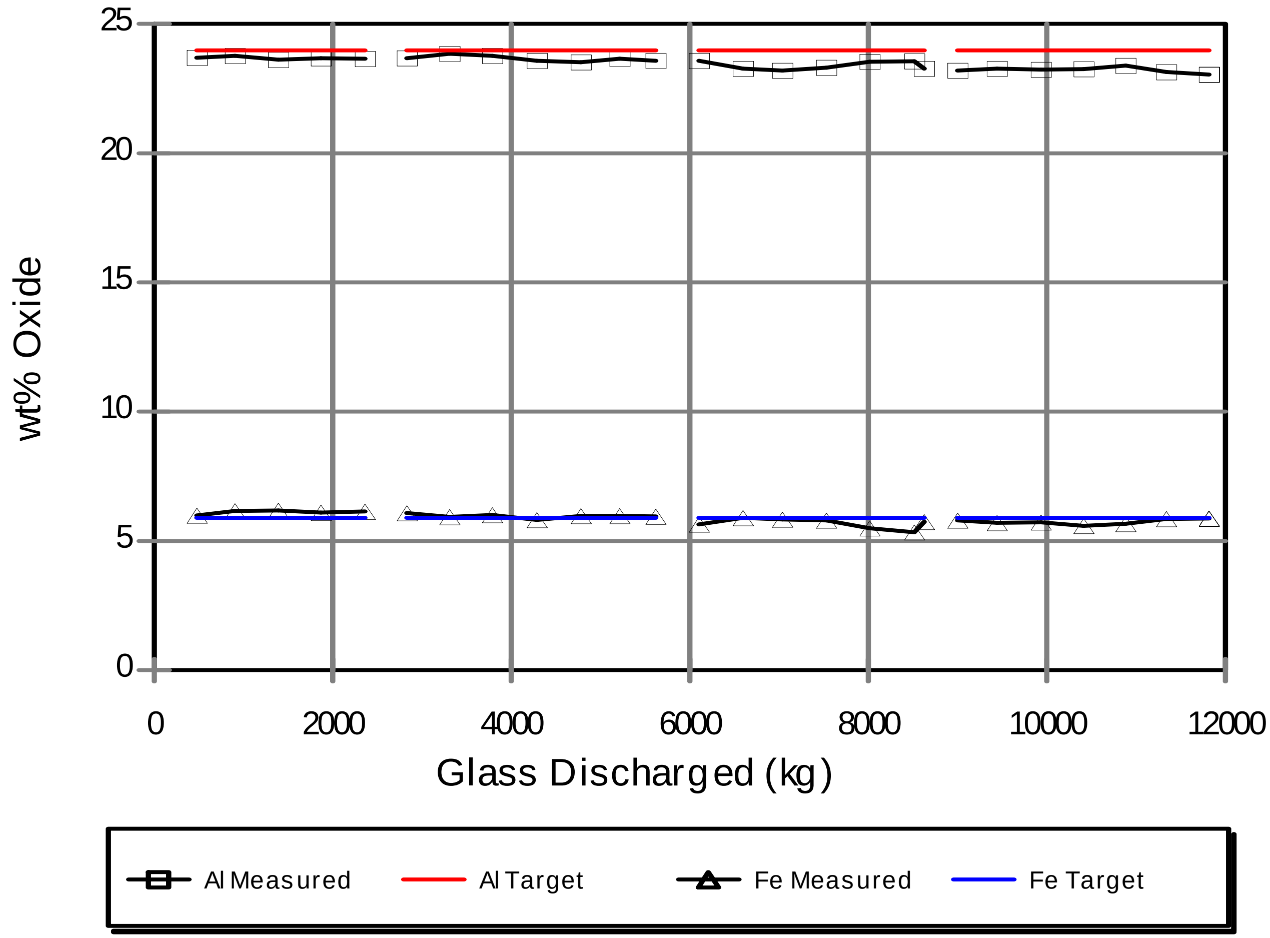



**Figure 5.1.b. DM1200 product and target glass compositions determined by XRF.**

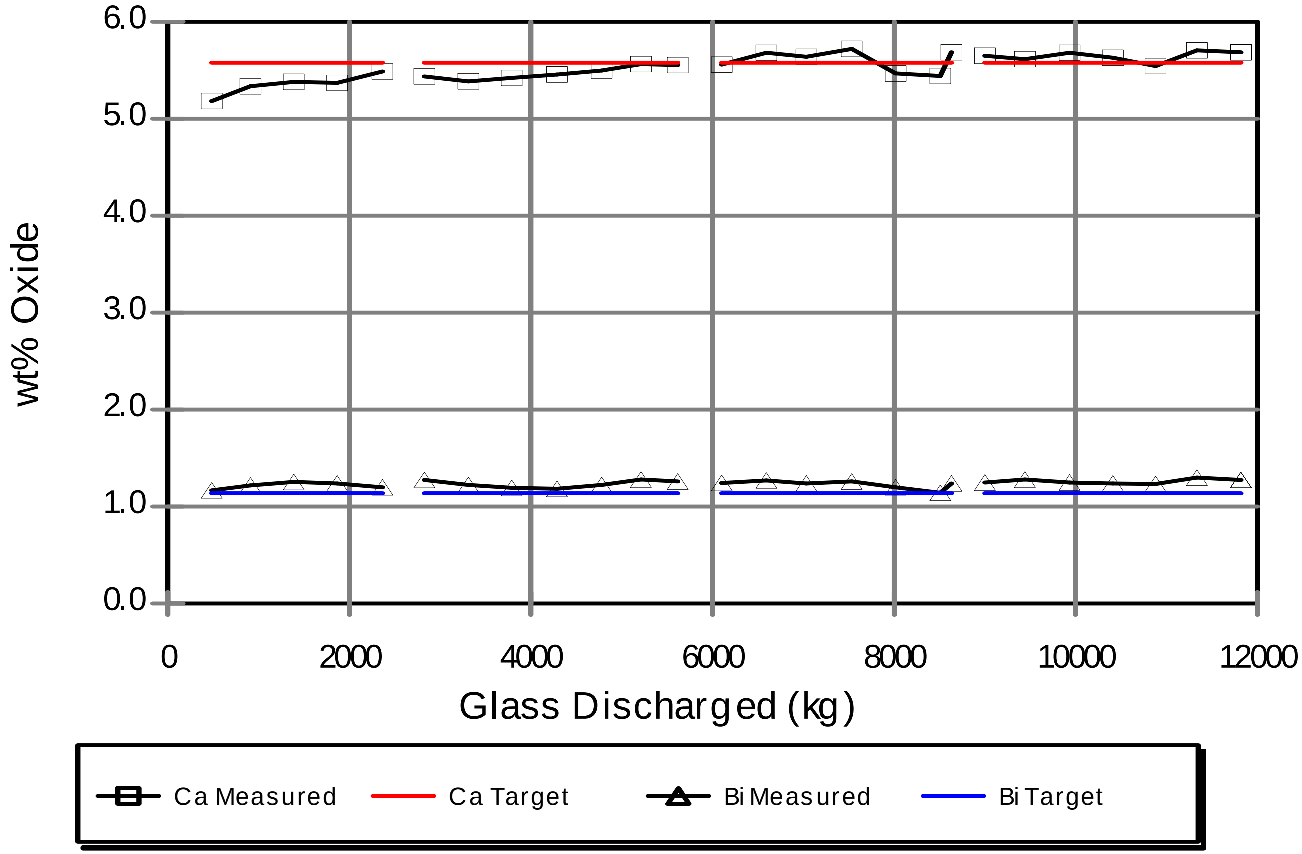



**Figure 5.1.c. DM1200 product and target glass compositions determined by XRF.**

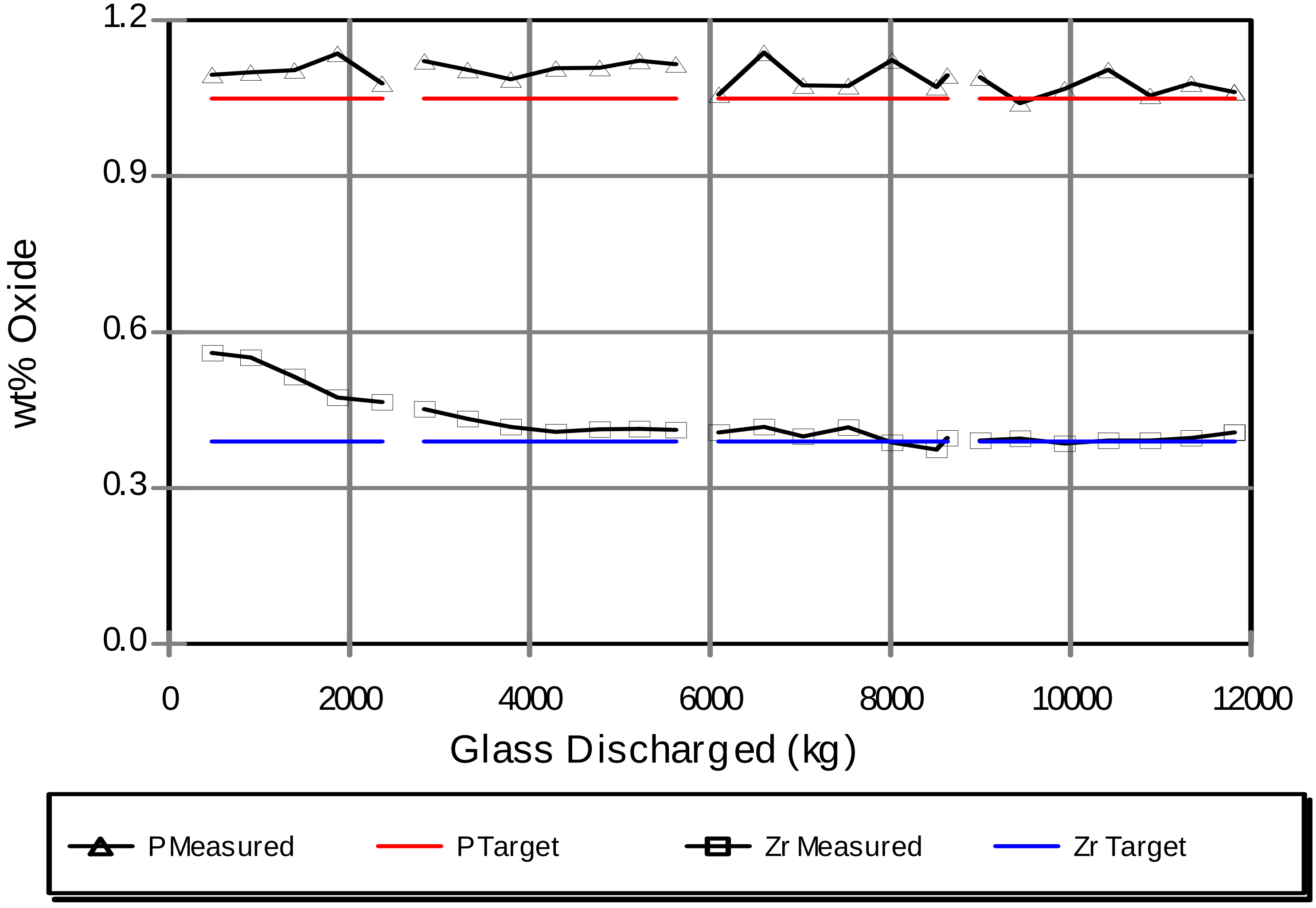



**Figure 5.1.d. DM1200 product and target glass compositions determined by XRF.**

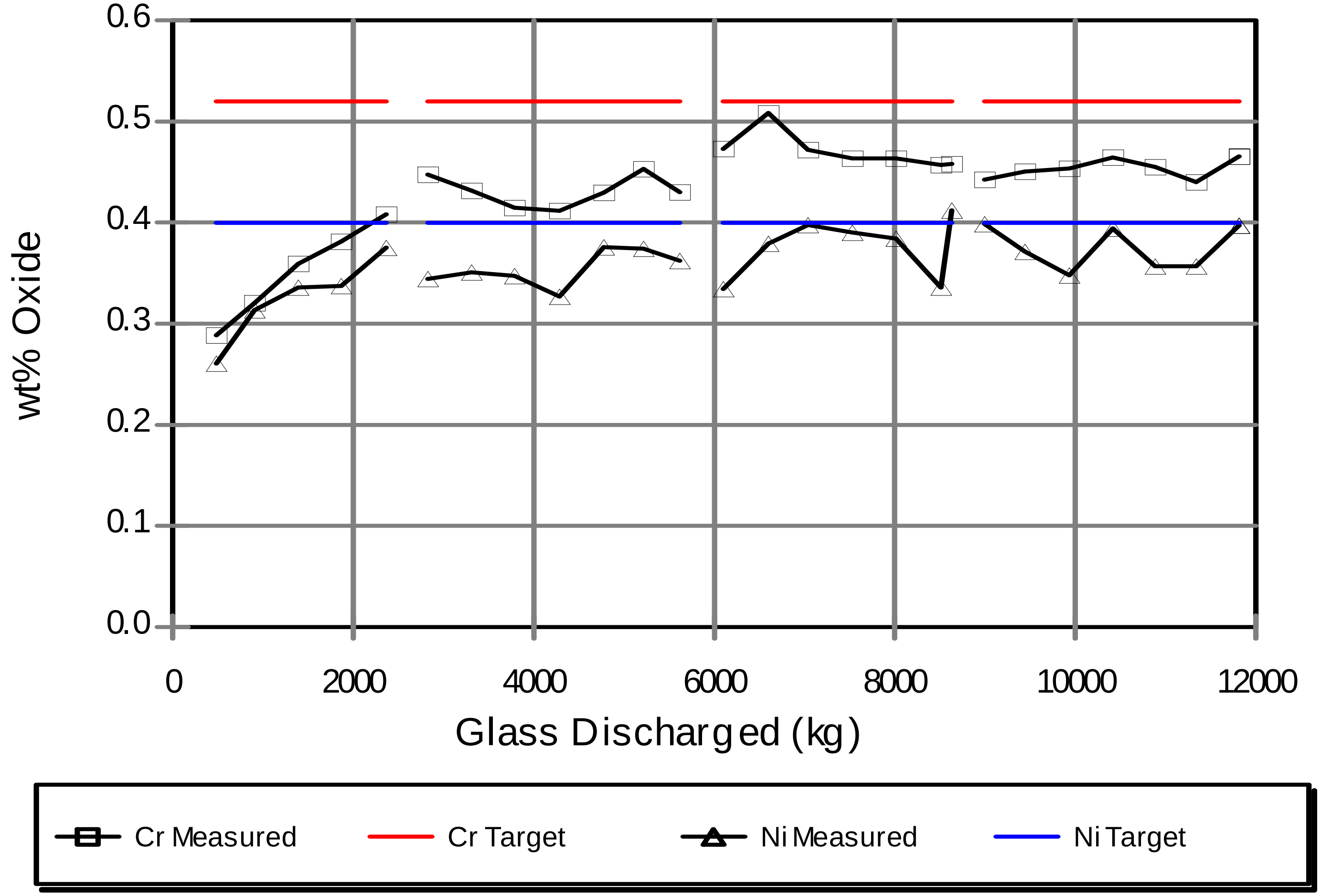



**Figure 5.1.e. DM1200 product and target glass compositions determined by XRF.**

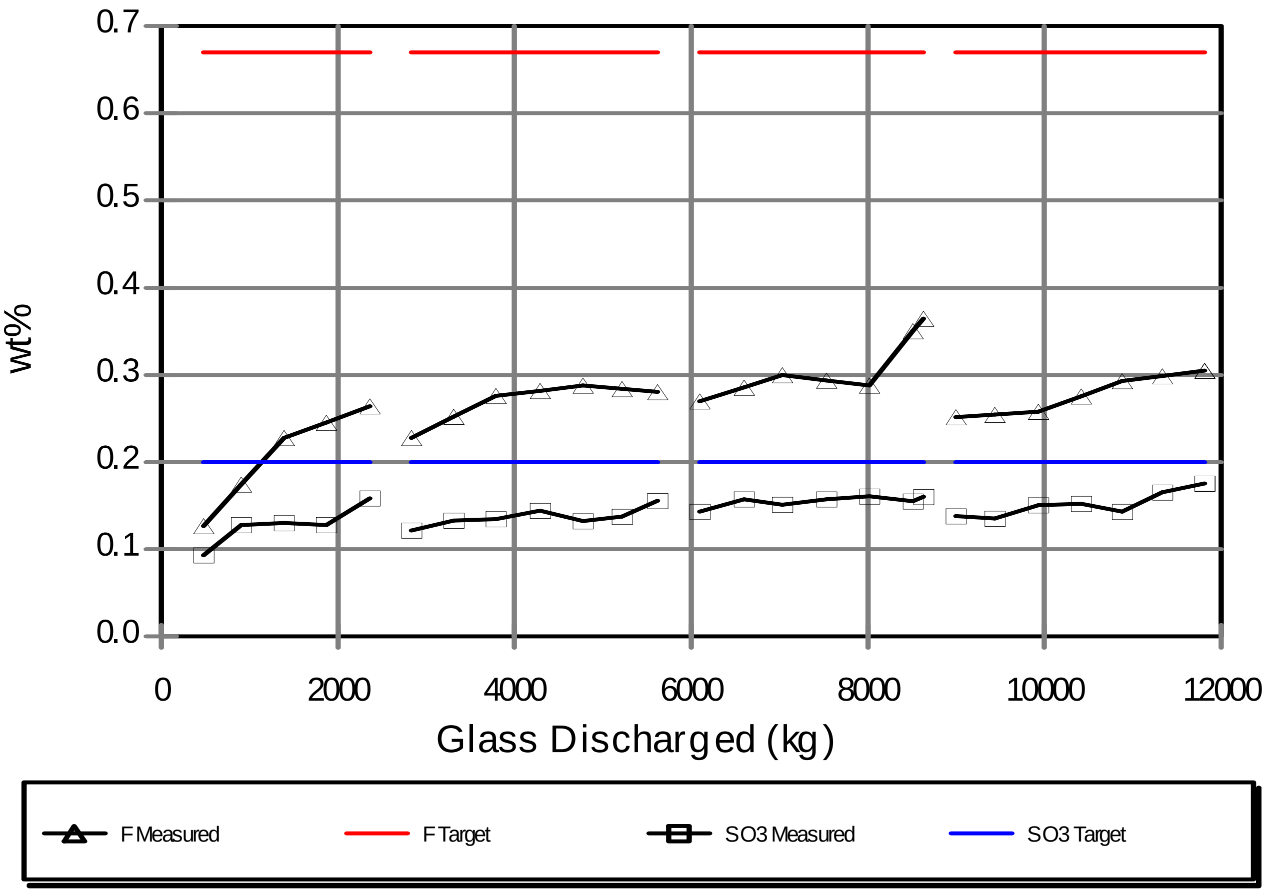



**Figure 5.1.f. DM1200 product and target glass compositions determined by XRF.**

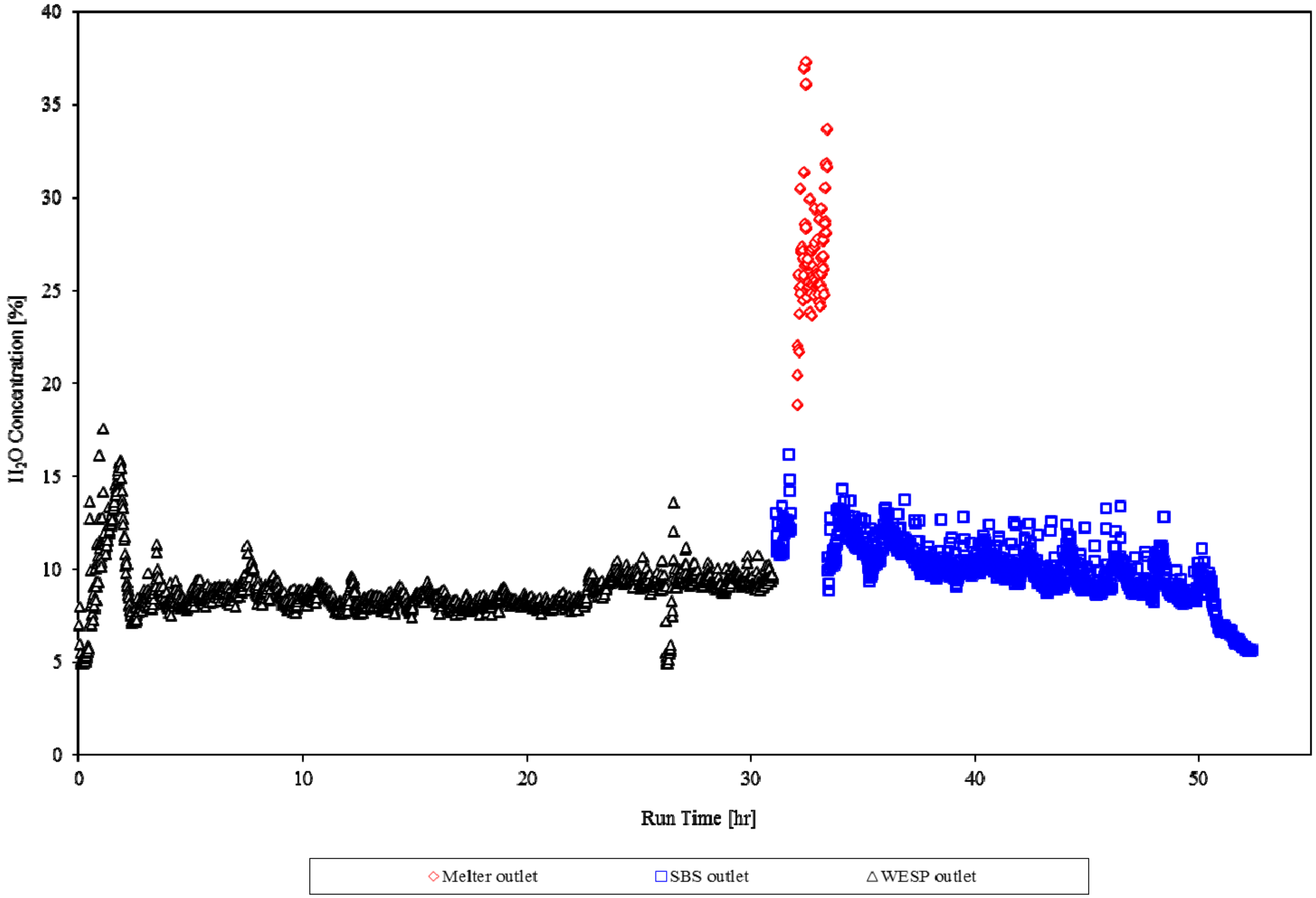



**Figure 6.1.a. FTIR Monitored water emissions during Test 1.**

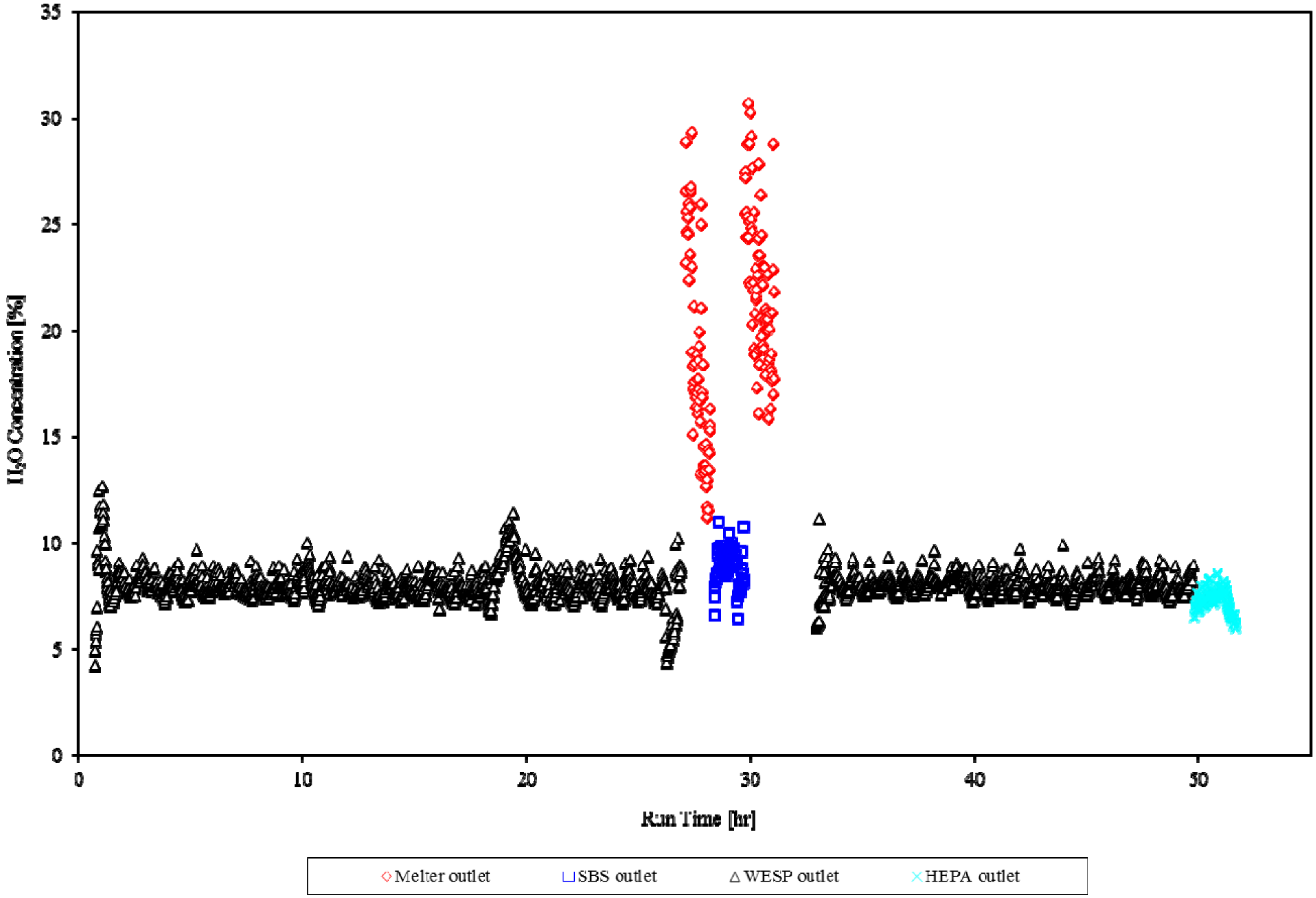



**Figure 6.1.b. FTIR Monitored water emissions during Test 2.**

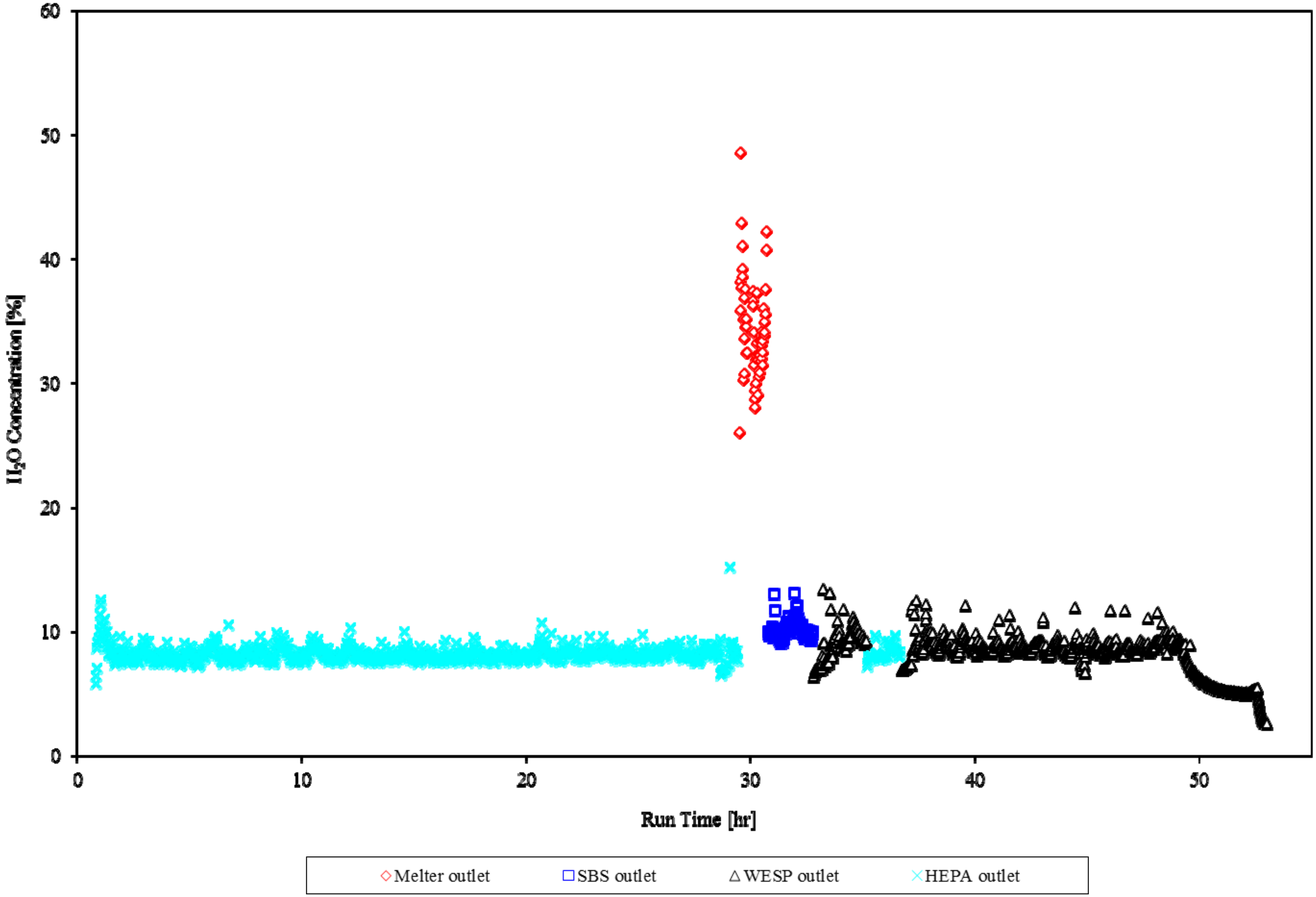



**Figure 6.1.c. FTIR Monitored water emissions during Test 3.**

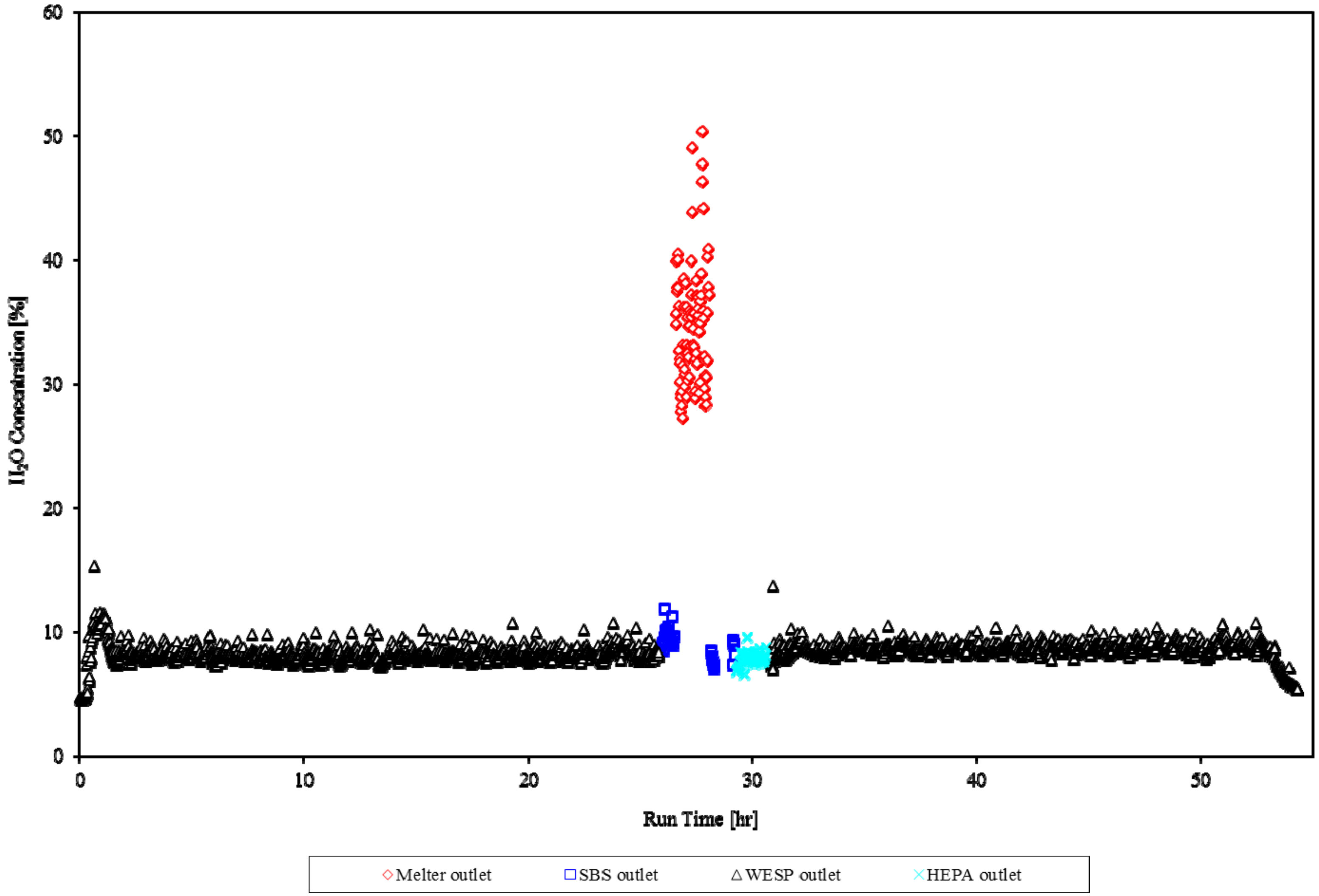



**Figure 6.1.d FTIR Monitored water emissions during Test 4.**

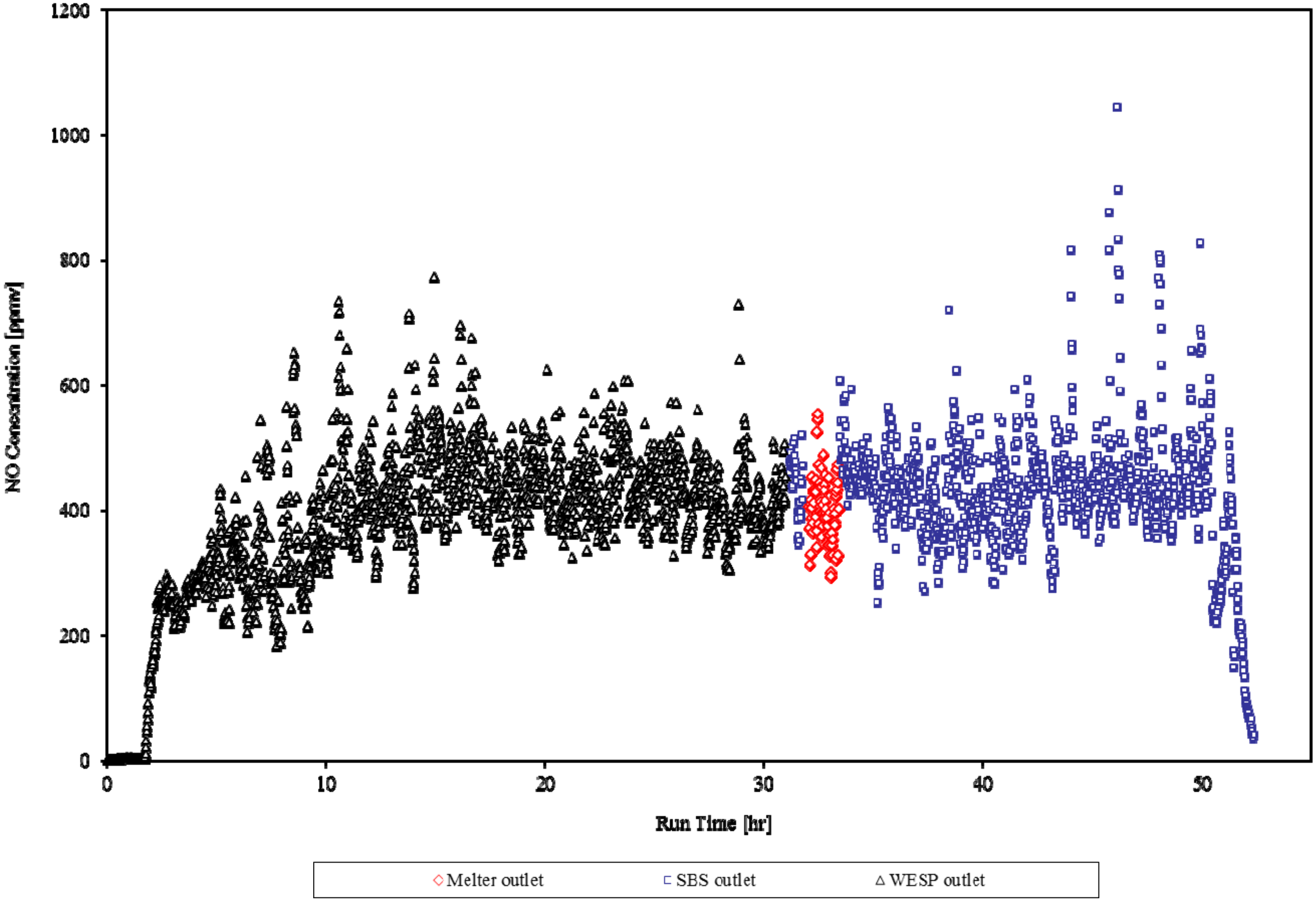



**Figure 6.2.a. FTIR Monitored NO emissions during Test 1.**

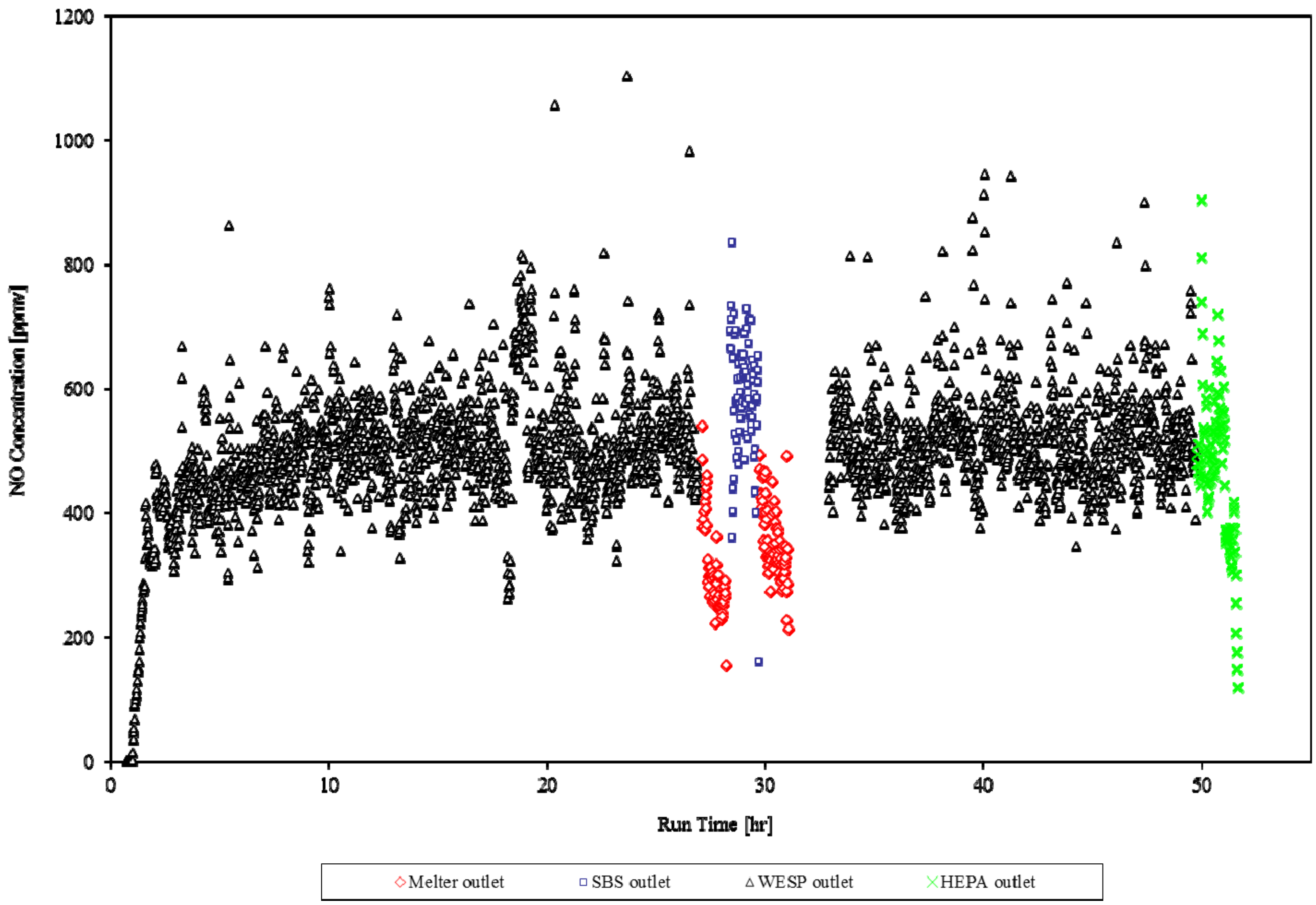



**Figure 6.2.b. FTIR Monitored NO emissions during Test 2.**

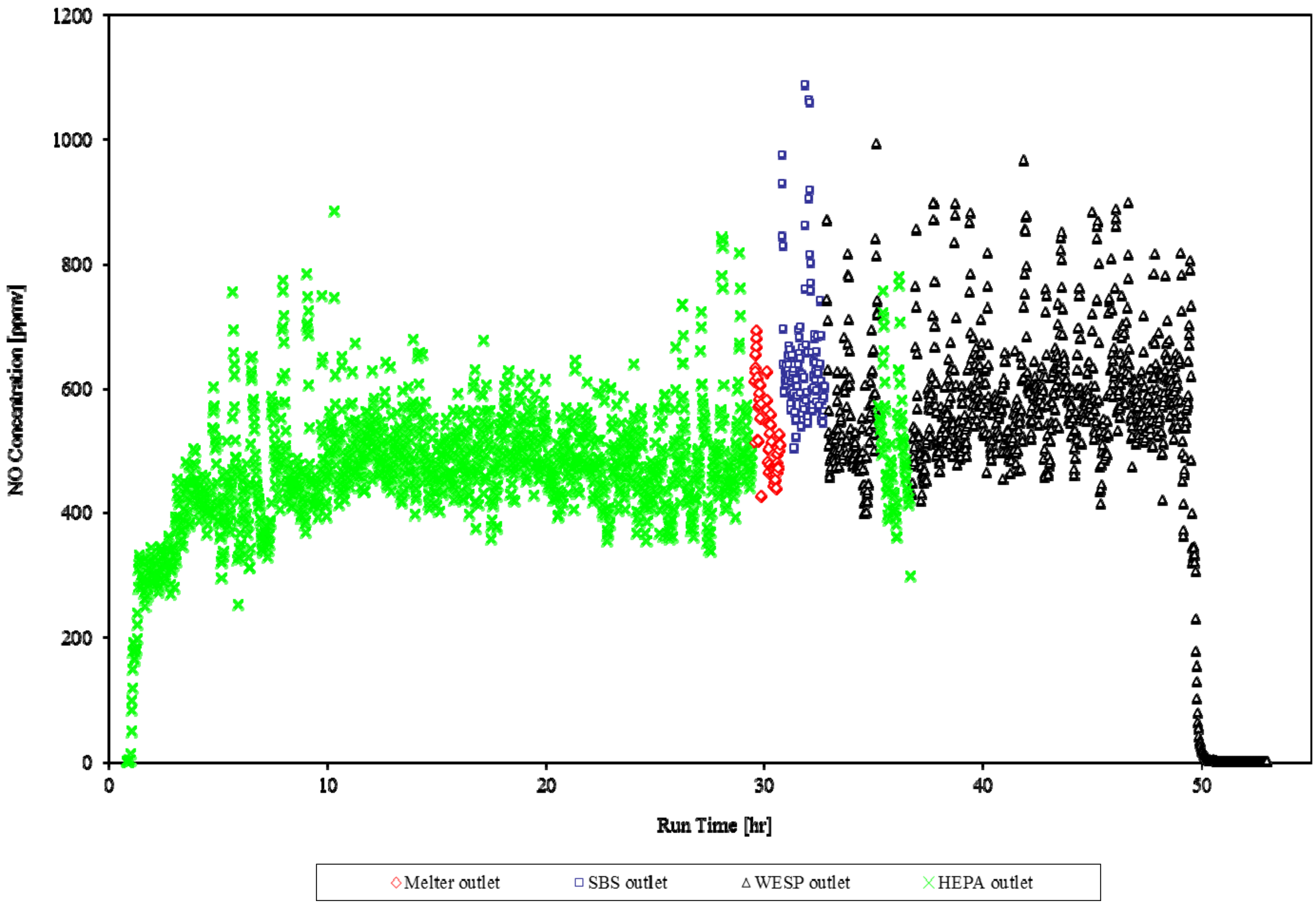



**Figure 6.2.c. FTIR Monitored NO emissions during DM1200 Test 3.**

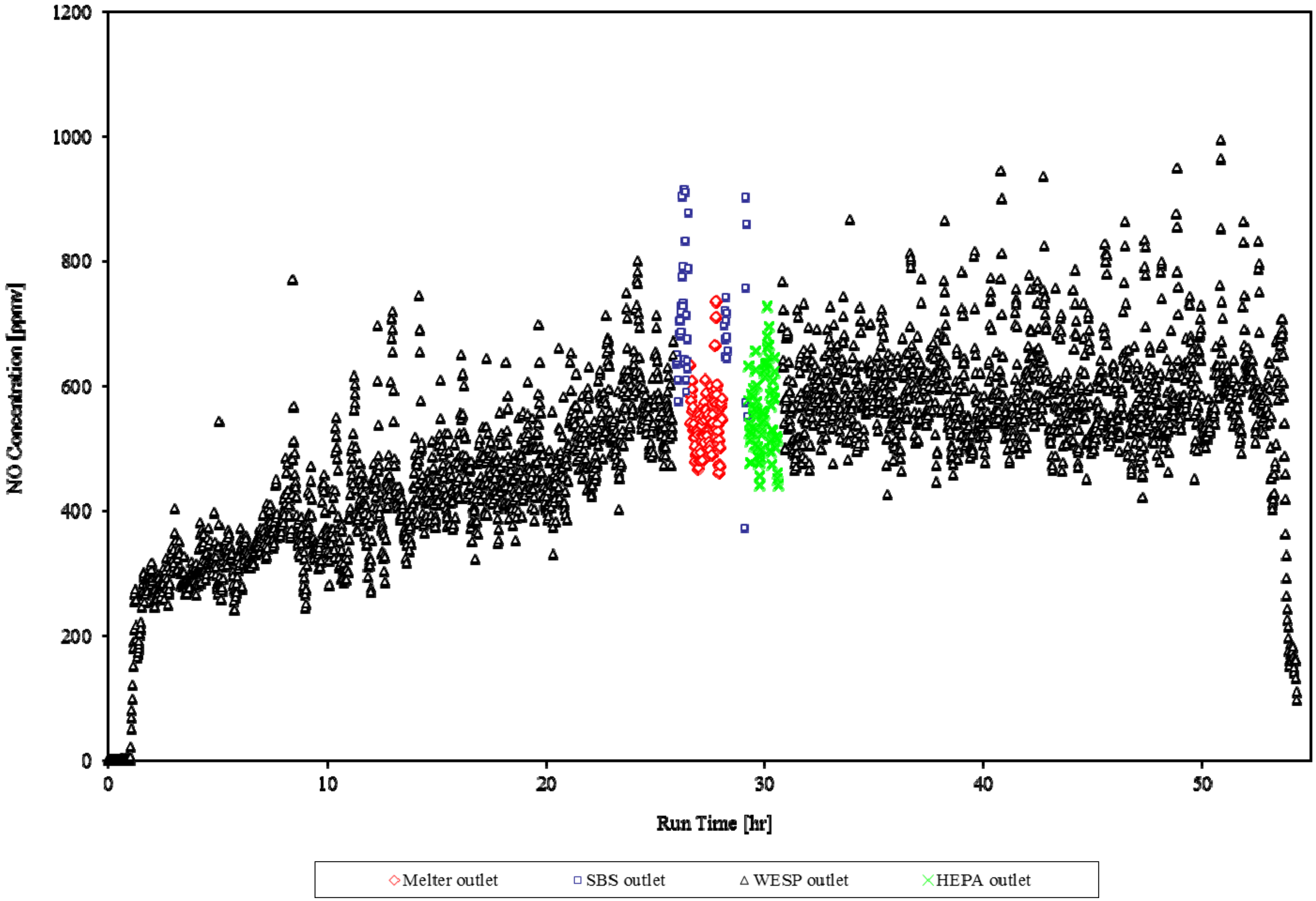



**Figure 6.2.d. FTIR Monitored NO emissions during DM1200 Test 4.**