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Revision 0

# Final Report Summary of DM1200 Operation at VSL

## VSL-06R6710-2, Rev. 0, 9/7/06

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

**Office of River Protection**

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

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

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

G. Diener
T. Bardakci
I. L. Pegg
Vitreous State Laboratory,
The Catholic University of America

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**Richland, Washington 99352**

J. D. Aardal
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# Final Report

# Summary of DM1200 Operation at VSL

*prepared by*

**Keith S. Matlack, Glenn Diener, Tevfik Bardakci, and Ian L. Pegg**

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

*for*

**Duratek, Inc.**

*and*

**Bechtel National, Inc.**

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for W. Tamosaitis
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**Test Specifications:** Various, as listed in the primary test reports referenced herein.
**Test Plans:** Various, as listed in the primary test reports referenced herein.
**R&T Focus Area(s):** HLW Vitrification, HLW Off-Gas, LAW Off-Gas
**Test Scoping Statement(s):** VH-4, VHO-3, VHO-1, VLO-5, VLO-1

**Completeness of Testing:**

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

**I.L. Pegg:** ______________________ **Date:** 9/7/06
**VSL Program Director/Principal Investigator**

**I. Joseph:** Innocent Joseph **Date:** 9/7/06
**Duratek Sub-Contract Manager**

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# List of Abbreviations

| | |
|---|---|
| ADS | Air Displacement Slurry |
| BSE | Back-Scattered Electron |
| CFR | Code of Federal Regulation |
| CUA | Catholic University of America |
| DCP | Direct Current Plasma Emission Spectroscopy |
| DF | Decontamination Factor |
| DM | DuraMelter® |
| DM1200 | DuraMelter 1200 |
| DOE | Department Of Energy |
| EDS | Energy Dispersive X-Ray Spectroscopy |
| HEME | High-Efficiency Mist Eliminator |
| HEPA | High-Efficiency Particulate Air Filter |
| HLW | High Level Waste |
| LAW | Low Activity Waste |
| NQA | Nuclear Quality Assurance |
| PBS | Packed Bed Scrubber |
| QAPjP | Quality Assurance Project Plan for Testing Programs Generating Environmental Regulatory Data |
| RPP | River Protection Project |
| SBS | Submerged Bed Scrubber |
| SCR | Selective Catalytic Reduction |
| SEM | Scanning Electron Microscopy |
| TCO | Thermal Catalytic Oxidizer |
| VSL | Vitreous State Laboratory |
| WESP | Wet Electrostatic Precipitator |
| WTP | Hanford Tank Waste Treatment and Immobilization Plant |

## SUMMARY OF TESTING

### A) Objectives

The principal objective of this report was to summarize the testing experience on the DuraMelter 1200 (DM1200), which is the High Level Waste (HLW) Pilot Melter located at the Vitreous State Laboratory (VSL). Further objectives were to provide descriptions of the history of all modifications and maintenance, methods of operation, problems and unit failures, and melter emissions and performance while processing a variety of simulated HLW and low activity waste (LAW) feeds for the Hanford Waste Treatment and Immobilization Plant (WTP) and employing a variety of operating methods. All of these objectives were met.

### B) Test Exceptions

This report is a summary of previously reported test results. While the source reports were subject to various Test Exceptions, there were no Test Exceptions specific to this report.

### C) R&T Testing Conditions

Several tests have been conducted with simulants of WTP HLW and LAW streams on the DM1200 melter and prototypical off-gas system since its installation in early 2001. Throughout these tests, the off-gas system components were operated under conditions intended to mimic WTP operating conditions, as known at the time, in order to permit the expected performance of each unit to be assessed. The melter and off-gas system were evaluated over the course of producing over 180 metric tons of glass from HLW feed simulants and 83 metric tons of glass from LAW feed simulants.

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

Specific testing conditions varied according to the specific Test Plans; these are listed in each of the referenced reports and are summarized in the body of this report.

## D) Results and Performance Against Objectives

The DM1200 melter at VSL has been operated for over five years, during which time, over a million and a half pounds of feed was processed to produce over half a million pounds of glass. A wide range of simulated HLW and LAW streams were treated under a variety of melter and off-gas system operating conditions. From these tests, a large body of data has been collected on melter performance, maintenance, post test inspections, and potential failure modes. This includes the operation of the film cooler as well as plugging and corrosion of both the film cooler and transition line.

Recent inspections show that, overall, the DM1200 melter is in excellent condition after five years of being at its operating temperature. The plenum bricks appear to be structurally sound with some surface cracking. All of the seams between the bricks are tight with no evidence of any significant gaps. The tuckstone is showing some minor wear and cracking on the brick faces nearest the glass pool. Some small areas of spalling were also noted, but overall the tuckstone is in good condition. The lid of the melter is in excellent condition; no spalling or cracking was noted. Finally, the discharge chamber is in excellent condition. No significant wear of the trough was noted.

One aspect of the present review was to determine the frequency that various melter components were replaced, including thermocouples, thermowells, level detectors, discharge air lances, and discharge heaters. Detailed information for these components is provided.

One of the primary objectives of DM1200 testing was to determine the maximum production rates feasible for various feeds containing simulated HLW. This objective was addressed, over time, as the production rate requirement was increased and the projected solids content of the waste was decreased. Initial tests showed that melt pool bubbling was required to produce glass at a rate of 400 $kg/m^2/day$. Subsequently, tests with two single outlet bubblers demonstrated that production rates of 800 $kg/m^2/day$ could be obtained for HLW with greater than 17 wt% undissolved solids. Significant further improvements in glass production rates (up to 1400 $kg/m^2/day$) were achieved with feeds corresponding to 15 wt% undissolved solids in the HLW from pretreatment by employing optimized bubbler configurations. These improvements appear to be sufficient to more than make up for the production rate short-fall brought about by the reduction in the solids content in the feed from pretreatment from 20 wt% to 15 wt% undissolved solids. However, attainment of the target rate was not possible for all HLW simulants after yet further reductions in solids content. Attempts to achieve the target rate with low solids content feed resulted in unstable melter conditions and frequent blockages of the film cooler. Further optimization, including adding more bubbling outlets and employing automated bubbler flow rate skewing, would result in additional production rate enhancements.

Throughout testing on the DM1200, plugging of the film cooler and transition line occurred, particularly in tests with higher bubbling rates. On several occasions, feeding was interrupted in order to manually rod out the film cooler and, less frequently, a portion of the transition line had to be disassembled for cleaning. A thorough review of operational data indicated that the film cooler occlusions were directly related to the higher bubbling rates used to maximize glass production rates. Analysis of the deposits removed from the film cooler indicate that their composition is very similar to the composition of particulate melter emissions in that they are close to the feed composition and enriched in volatile constituents. Film cooler plugging can be limited by reducing the bubbling rate, which has the undesirable effect of reducing the glass production rate, or by increasing the number of bubbling outlets, which permits the use of greater amounts of bubbler air without concentrating the air flow in a limited number of locations. However, a mechanical means to remove blockages needs to be developed and tested to ensure that it is reliable and will remove blockages without damaging the delicate film cooler louvers.

The three film coolers used over the five years of DM1200 operation experienced severe corrosion on the inlet, and glassy deposits occluded the air outlet holes on the leading edge. Much of the corrosion on the film cooler inlet may be due to exposure to higher temperatures during extended idling periods and therefore this may be less of an issue for a continuously operated melter.

Melter emissions were sampled throughout the DM1200 tests to provide data for off-gas system design, to determine the effect of feed composition and melter operation on melter emissions, and to provide data for system mass balance calculations. Analysis of the samples shows that melter emissions increase with increasing melt pool bubbling, feed water content, feed volatile content, and glass pool temperature. The effect of bubbling can be mitigated by distributing the bubbler flow through more bubbling outlets. The composition of the particulate emissions reflects the major feed components, indicating entrainment of feed components into the exhaust stream. In addition, the high concentrations of volatile components such as sulfur in the particulate indicate volatilization from the glass surface or cold cap. Particulate from LAW exhaust has a higher proportion of volatile and semi-volatile constituents, indicating a greater contribution from the glass surface or cold cap.

The major conclusions from this review are:

- Bubblers are needed to obtain glass production rates of 400 kg/m$^2$/day in WTP HLW melters with Hanford HLW feeds.
- Glass production rates as high as 1400 kg/m$^2$/day can be obtained in the DM1200 melter with two double outlet bubblers and HLW feeds prepared from waste simulants with 15% or higher undissolved solids.
- Feeds prepared from HLW with solids contents of less than 15% will require very high bubbling rates to achieve the contractually required glass production rate of 800 kg/m$^2$/day. These high bubbling rates are likely to cause film cooler clogging that may disrupt operations.
- Film cooler clogging can be minimized by increasing the number of bubbler outlets so that bubbling is more distributed in the melt pool, while maintaining the same total bubbler air flow. Skewing of bubbler air flow may also be beneficial in enhancing production rates.
- A mechanical film cooler cleaning device will likely be required at the WTP, and should be tested.
- Bubblers placed deeper in the melt pool are more effective in increasing processing rate.
- Addition of sugar and nitrates does not improve processing rates of Hanford HLW feeds.
- The rheology of the HLW melter feed does appear to affect processing rates, probably through its effect on feed distribution and cold cap formation. However, more viscous feeds processed somewhat faster.
- DM1200 glass production rates were obtained using visual monitoring of the cold cap, per Project direction. Visual observation is not planned for the WTP HLW melters, where instead, plenum temperature will be monitored to control feed rates. Since this could result in lower glass production rates, it would be beneficial to determine the impact of the planned WTP mode of operation on the DM1200.
- In bubbled melters, melter emissions consist mostly of entrained feed constituents with volatiles over represented.
- Melter emissions increase with bubbling rate, feed water content, feed volatile content, and temperature.
- After five years at the operating temperature, the DM1200 is in excellent condition.

## E) Quality Requirements

This work is a summary of previously reported test results, the quality assurance requirements for each of which are provided in the original reports. This work was conducted under a quality assurance program that is in place at the VSL that is based on Nuclear Quality Assurance (NQA)-1 (1989) and NQA-2a (1990) Part 2.7. This program is supplemented by a Quality Assurance Project Plan for RPP-WTP work that is conducted at VSL. Test and procedure requirements by which the testing activities are planned and controlled are also defined in this plan. The program is supported by VSL standard operating procedures that were used for this work. This work was not subject to DOE/RW-0333P or the requirements of the RPP-WTP Quality Assurance Project Plan for Testing Programs Generating Environmental Regulatory Data (QAPjP). However, several of the original tests were subject to the requirements of the RPP-WTP QAPjP, as noted in the original test reports.

## F) Simulant Use

This summary covers testing that employed a wide range of HLW and LAW simulants formulated based on various waste bases, as detailed in the respective original test reports. References for each waste simulant are provided in each source report. The HLW waste simulants processed were AZ-101 [3, 9, 17, 29, 30], AZ-102 [23, 35], C-106/AY-102 [26, 29, 35, 41], and C-104/AY-101 [28]. The LAW Sub-Envelope simulants processed were C1 [10], A1 [14], B1 [21], A2 [41], and A and C [31].

## G) Issues

These tests showed that significant improvements in HLW glass production rates could be achieved by refining the bubbler configurations, even when this refinement is subject to the significant constraints imposed by the existing melter lid design. These improvements appear to be sufficient to more than make up for the production rate short-fall brought about by the reduction in the solids content in the HLW feed from pretreatment from 20 wt% to 15 wt% undissolved solids. However, attainment of the target rate was not possible for all HLW simulants after yet further reduction in feed solids content. Attempts to achieve the target rate with low solids content HLW feed resulted in unstable melter conditions and frequent blockages of the film cooler. Overall, the success demonstrated to date suggests that there is considerable further scope for HLW production rate enhancement.

The observed differences in processing rates for different waste compositions for adjusted rheology feeds and lower solids content feeds underscores the need for pilot-scale production rate testing across the full range of feed compositions and likely solids contents.

Film cooler clogging events continued to be a significant operational problem; their frequency appeared to increase with bubbling rate and glass production rate. Feeds with low solids contents further exacerbate this issue because of the need for increased bubbling rates in order to maintain glass production rates. None of the film cooler washing procedures were effective for preventing clogging with HLW feeds. No mechanical cleaning device has been tested. Consequently, this would appear to be a significant issue with respect to the ability of the

WTP to meet HLW throughput requirements. These findings have been reported to the WTP Project and decisions regarding resolution are pending.

Per WTP Project direction, maintaining a cold cap limited feed rate during DM1200 tests was dependent on frequent visual monitoring of conditions in the melter. In contrast, operation of the WTP melters will be based only on non-visual data, such as plenum temperature. This could lead to either under feeding of the melter, resulting in under-achievement of otherwise attainable production rates, or over feeding of the melter, resulting in excessive cold-cap buildup as well as other operational difficulties. Testing under such conditions is therefore recommended to determine whether the required glass production rates can be achieved without employing the artificial visual data.

# SECTION 1.0
# INTRODUCTION

The River Protection Project – Hanford Waste Treatment and Immobilization Plant (RPP-WTP) Project has undertaken a "tiered" approach to vitrification development testing involving computer-based glass formulation, glass property-composition models, crucible melts, and continuous melter tests of increasing, more realistic scales. Melter systems ranging from 0.02 to 1.2 $m^2$ installed at 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 at Duratek, Inc., span more than two orders of magnitude in melt surface area. In this way, less-costly small-scale tests can be used to define the most appropriate tests to be conducted at the larger scales in order to extract maximum benefit from the large-scale tests. For high level waste (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 [1]. Both melters have similar melt surface areas (1.2 $m^2$), but the DM1200 is prototypical of the present RPP-WTP HLW melter design whereas the DM1000 was not. In particular, the DM1200 provides for testing on a vitrification system with the specific train of unit operations that has been selected for both HLW and LAW RPP-WTP off-gas treatment [2].

Over the course of testing on the DM1200 system, over one and a half million pounds of feed has been processed, producing almost 600,000 pounds of glass. A complete list of all the DM1200 melter tests performed is provided in Table 1.1 [3-42]; summaries of individual tests are provided in Tables 1.2-1.18. 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 tests conducted to address the performance of the DM1200 melter are summarized below:

- Initial tests to determine the need for melt pool bubbling to achieve the former project baseline of 0.4 $MT/m^2/d$ while processing HLW simulants [3, 9]. As a result of this testing, it was concluded that the current WTP HLW melter design is not capable of achieving the baseline production rate of 1.5 MT/d without the use of bubblers [43].

- Tests with two single outlet bubblers to demonstrate the “performance enhancement” necessary to achieve the then-future expanded capacity per melter of 3.0 MT/d (0.8 $MT/m^2/d$), which is the present requirement under the so-called "2+2" revised baseline [44]. These tests evaluated the effects of waste solids content, HLW composition (AZ-101, AZ-102, C-106/AY-102, C-104/AY-101), and melt pool bubbling rate on glass production [17, 23, 26, 28].

- Tests designed to optimize the bubbler configuration to increase glass production rates while processing HLW simulants [30]. Variables tested included bubbler depth, bubbler location, bubbler orientation, the number of bubbling outlets per bubbler, and systematic changes in bubbler flow rates between the bubblers. The production rate goal for the DM1200 was increased from 0.8 MT/m$^2$/d to 1.05 MT/m$^2$/d to account for scaling effects.

- Testing conducted to validate the optimized bubbler configuration with HLW AZ-101, AZ-102, and C-106/AY-102 simulants [30, 35, 41]. The solids content of the waste from pretreatment was reduced from the former baseline of 20 percent un-dissolved solids (UDS) to 11-15 percent to reflect the new projected solids content of waste delivered from the pretreatment facility.

- Testing conducted to evaluate variation in the HLW flow sheet with respect to feed rheology and feed nitrate and organic content [29, 35]. The bubbler configuration prior to optimization was used in order to provide comparisons with data collected in previous tests [3, 9, 17, 23, 26, 28].

- Tests conducted with LAW simulants to provide scaling data in between those obtained on the DM100 and DM3300 Pilot Melter [10, 14, 21, 31]. These tests were also the sole source of prototypical off-gas system performance data on an exhaust stream originating from the vitrification of LAW simulants.

- Tests conducted with LAW and HLW simulants to collect regulatory data [10, 14, 41].

This report summarizes melter operation, production rate testing, maintenance activities, and current status of the DM1200, which is the HLW Pilot Melter system at the Vitreous State Laboratory of The Catholic University of America (VSL-CUA).

# SECTION 2.0
# DM1200 SYSTEM DESCRIPTION AND MAINTENANCE

## 2.1 Melter System Description

The DuraMelter™ 1200 (DM1200), which is the HLW Pilot Melter, was used for all of the tests described in this report. Cross-sectional diagrams of the melter illustrating the discharge chamber and electrode configuration are provided in Figures 2.1 and 2.2. The DM1200 is a Joule-heated melter with Inconel 690 electrodes and thus has an upper operating temperature of about 1200°C. The melter shell is water-cooled and incorporates a jack-bolt thermal expansion system. The footprint of the melter is approximately 8 ft. by 6.5 ft. with a 4 ft. by 2.3 ft. air-lift discharge chamber appended to one end; the melter shell is almost 8 ft. tall. The melt surface area and the melt pool height are approximately 32 percent and 57 percent, respectively, of the corresponding values for the full-scale HLW melter. The discharge riser and trough are full-scale to verify pouring performance. Other aspects of the discharge system, such as the chamber ventilation scheme, are also prototypical. The glass contact refractory is Monofrax® K-3, while the plenum area walls are constructed of Monofrax® H refractory. The surface of the glass pool is 34" by 54" with a glass depth of nominally 25". The resultant melt volume is approximately 45,000 cubic inches (735 liters), which represents a glass tank capacity of more than 1.7 metric tons of glass. However, since the typical operating glass level is closer to 29 inches, the effective glass volume during testing is actually about 849 liters, giving an inventory of about 2.0 metric tons, which is larger than had been previously assumed [10]. The DM1200 is fitted with one pair of electrodes placed high on opposite walls of the melter as well as one bottom electrode; the bottom electrode is no longer prototypic of the WTP HLW melter since that feature was later removed from the design. 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; side-to-side operation was used (identical to the operation mode planned for the WTP HLW melter), except for some of the early tests without bubbling. Programmable process controllers are installed and can be used to control temperature or power. The melt temperature is controlled by configuring the process controller to maintain constant power and adjusting the power set-point as needed to maintain the desired operating temperature. Alarms can be set to detect out-of-range temperatures or power in the melter. Backup process controllers are installed to be used in case of failure of the main controllers. The entire system is supported by a back-up generator that is tripped on in the event of a power outage.

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

Testing on the DM1200 was episodic and therefore the melter was idled for long intervals during the last five years. During idling, the glass temperature is lowered to between 1050°C and 1075°C. The side-to-side powering of the electrodes was used exclusively during idling except for some of the idling periods within the first year of testing. In idling mode, flow through the main off-gas system is prevented by the insertion of a blind flange immediately downstream of the film cooler. A vacuum of 0.1 to 0.2 inches of water is maintained on the melter through the bypass line, which is fitted with high efficiency particulate air (HEPA) filtration. In July of 2003, air from the discharge dam cooling air flow, which goes to the bypass off-gas piping during testing, was routed to the film cooler inlet, where it mixes with and lowers the temperature of the air flowing from the melter plenum into the film cooler to cool and protect the film cooler during periods of extended idling, The cooling air flow rate is about 23 scfm at a temperature of about 135°C at the outlet of the dam. This mixes with the plenum air, which is typically around 1020°C during idling. As a result of this cooling system, the film cooler internal temperature is about 540°C during idling. Bubblers were often left in the melter and air flow adjusted to a very low rate during idling periods to generate data on corrosion from exposure to HLW glass compositions [45].

## 2.2 Lance Bubblers

Three types of lance bubblers, placed in a variety of locations and orientations, were evaluated during these tests for the effect on processing rate. The three types of bubblers used, single-outlet “J”, single-outlet “L”, and double-outlet “J”, are shown in Figures 2.3, 2.4, and 2.5, respectively. In initial tests with HLW simulants [3, 9, 17, 23, 26, 28, 29, 35], two single-outlet “J” bubblers were used, located in opposite corners, pointing towards the center, six inches from the melter floor. Tests evaluating bubbler air flow skewing, bubbler depth, and HLW flow sheet variations also used the “J” bubblers in these locations [30]. For the first test evaluating bubbler depth, the bubblers were rotated parallel to the electrodes to avoid current channeling and the height of the “J” bubblers from the floor was varied [30]. In tests with LAW simulants [10, 14, 21, 41], four single-outlet “L” bubblers were used, located in opposite corners, six inches from the melter floor pointing diagonally towards the center. Combinations of “J” and “L” bubblers were used in tests to simulate the locations of bubbling outlets of proposed double-ported bubblers, as illustrated in Figures 2.6 and 2.7 [30]. The Duratek design group provided the bubbler arrangement shown in Figure 2.6: bubblers on the melter floor, one bubbler outlet 11.3 inches from the feed tube (in the plane of the melt surface), and eight inches separation between bubbling outlets on each side of the melter. The WTP Project provided an alternate bubbler arrangement for testing, as shown in Figure 2.7: bubblers on the melter floor and fourteen inches separation between bubbling outlets on each side of the melter, placed at the maximum distance from the feed tube with a minimum distance from the wall of 8 inches. Figure 2.8 shows a schematic of the prototypical double-outlet bubbler design that was based on the combination of the results from these DM1200 tests and room-temperature tests that were performed in a transparent fluid simulating the properties of the glass melt [46]. 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 2.9, results in one of the bubbling outlets being 11.3 inches from the feed tube. These double outlet bubblers in the optimized orientation were evaluated for several waste compositions [30, 35, 41]. Bubblers were removed and replaced in the melter to achieve the required bubbling configurations; no replacements had to be made due to any lance bubbler failures. The original “J” bubblers and the prototypical double-outlet bubblers, although not currently installed in the melter, are fully functional and could be reinstalled for use at any time. The extent of corrosion of these lance bubblers from exposure to HLW glasses is detailed in a previous report [45].

## 2.3 DM1200 Maintenance History

Over the past five years, the VSL operations personnel have documented all of the maintenance activities performed on the DM1200 in maintenance logbooks. A detailed log summarizing all these entries is provided in Table 2.1. One aspect of the present review was to determine the frequency with which various melter components were replaced, including thermocouples, thermowells, level detectors, discharge air lances, and discharge heaters. The results of this review are discussed below.

The effect of radioactive exposure is outside of the scope of this summary and the referenced reports. However, the reported life expectancy of components is highly relevant to WTP operations unless presently unknown failure mechanisms due to radioactivity are identified. For example, film cooler clogging and corrosion should be unaffected (positively or negatively) by radioactivity. Thus, although radioactivity is not expected to affect failure rates, the radioactive environment is certainly taken into consideration with respect to conservatism in change out frequency for bubblers and other components.

### 2.3.1 Thermocouples

The thermocouples used in the DM1200 melter are Type K thermocouples and are used to measure the glass pool and plenum temperatures, electrode temperatures, and the discharge chamber temperatures. Nearly all of the thermocouples are installed into thermowells that provide protection and allow them to be easily replaced. The exposed plenum thermocouple is the only thermocouple that does not utilize a thermowell.

Table 2.2 provides a summary of the number of times that the DM1200 thermocouples were replaced as well as the minimum, maximum, and average lifetime of the thermocouples. The glass pool thermocouples were replaced anywhere between 8 and 14 times over the five years of operation. Although the duration between the minimum and maximum replacement frequency is extremely large, the average lifetime of all of the thermocouples is very similar, between three and four months. The plenum thermocouples have similar lifetime to the glass pool thermocouples (four months), except for the exposed thermocouple. Since this thermocouple is directly exposed to the harsh, corrosive environment generated during the vitrification process, it is not surprising that it lasts an average of only two months in the melter. Glass pool and plenum thermocouples were routinely replaced on a four- to six-month schedule as a preventative maintenance activity or when they had failed (typically as an open circuit). No drift in the thermocouple readings was noted between replacements. The thermocouples in the discharge chamber and electrodes have an average lifetime greater than eight months and have only been replaced a few times. This is primarily due to the fact that the thermocouples are located in areas that are not directly exposed to the corrosive environment generated during melter feeding. The only exception is the discharge riser thermocouple, which is located in the melter riser and is continuously exposed to the molten glass. As a result, this thermocouple was replaced more frequently and has a shorter average lifetime than the discharge chamber and electrode thermocouples.

### 2.3.2 Thermowells

The DM1200 typically has two thermowells installed in the melter to hold the glass pool and plenum thermocouples. The thermowells are fabricated from Inconel 690, ¾" schedule 160 pipe that is capped on the bottom. Table 2.3 provides the dates that the thermowells were installed in the melter, the number of days that the thermowells were exposed to feeding operations, and the number of times they were removed for inspection, as well as the type of feed that the thermowells were exposed to during operations (HLW or LAW feeds). The thermowells were exposed mostly to HLW feeds because HLW melter testing was the primary R&T mission for the DM1200 over the past five years. The replacement frequency of the thermowells varied between 105 and 784 days, with an average frequency of just under one year. The thermowells were removed periodically for inspection or installation of corrosion coupons. Most of the thermowells were removed due to wear. However, several of the thermowells were prematurely replaced in order to install thermowells with corrosion coupons [45].

### 2.3.3 Level Detector

The DM1200 has a level detector installed in the melter to determine the level and density of the glass during processing and to determine the melter vacuum. The level detector consists of two Inconel 690, ¾" schedule 160 pipes that extend to different depths within the glass pool. Argon is then bubbled through the pipes and the backpressure is monitored to determine the glass level and density. A third pipe, which is exposed to just the plenum, is used to monitor the melter vacuum. Table 2.3 provides the dates that the level detector was installed in the melter, the number of days that it was exposed to feeding operations, and the number of times it was removed for inspection, as well as the type of feed that the level detector was exposed to during operations (HLW or LAW feeds). Since the primary mission of the DM1200 was to determine the glass production rates for HLW feeds, the level detector was primarily exposed to HLW feeds. The replacement frequency of the level detector varied between 424 and 668 days, with an average frequency of 1.5 years. The level detector was removed periodically for inspection or installation of corrosion coupons. In all cases, the reason for replacement of the level detectors was wear of the level and density legs.

### 2.3.4 Discharge Air Lance

Glass is discharged from the DM1200 using an air lance installed in the riser through which air is bubbled to create an air lift that lifts the glass up the riser and out of the melter. The air lance is fabricated from Inconel 690, ¾" schedule 160 pipe and extends down to the bottom of the discharge riser. The location of the riser is shown in Figure 2.1. Table 2.3 provides the dates that the discharge air lance was installed in the melter, and the number of days that it was exposed to feeding operations, as well as the type of feed that the air lance was exposed to during operations (HLW or LAW feeds). Since the primary mission of the DM1200 was to determine the glass production rates for HLW feeds, the air lance was primarily exposed to HLW glass compositions. The replacement frequency of the air lance varied between 241 and 921 days with an average frequency of approximately 1.7 years.

### 2.3.5 Discharge Heaters

The temperature within the DM1200 discharge chamber is maintained at its operating temperature (typically greater than 1000°C) by fourteen heaters arranged horizontally around the discharge trough. The heaters are spiral-type silicon carbide heaters that are placed within heater sheaths to prevent corrosion of the heaters due to gaseous emissions from the discharging glass. Inside the heater sheaths, the heaters are placed within ceramic tubes to prevent the heaters from electrically shorting to the metal heater sheath. Figure 2.10 provides a schematic of the heater locations as well as heater numbering.

During the first year and a half of operation, the DM1200 had frequent failures of the heaters, with many failing within one to two months of operation. Since a ceramic isolator surrounds the heater element, it was surmised that the isolator was hindering the heat dissipation from the heater, which increased the average centerline temperature of the heater, resulting in premature aging and failure of the heater. To rectify this problem, the ceramic isolators were split lengthwise to allow a greater amount of radiant heat loss in order to reduce the centerline temperature. Figure 2.11 shows a discharge heater with the modified ceramic isolator. After this modification was implemented in August 2002, no heater failures occurred in over 3.4 years of operation. Table 2.4 shows the number of times heaters were replaced, and the minimum, maximum, and average lifetime of the heaters, both before and after the ceramic isolator modification.

## 2.4 Current State of the DM1200 Melter

This section discusses the results of an inspection of the interior of the DM1200 melter to assess its current condition after five years of operation. Prior to discussing the details of the inspection, it is useful to provide a more detailed description of the DM1200 construction in order to provide the appropriate background for the discussion of the inspection results.

### 2.4.1 DM1200 Construction Details

The basic refractory package of the DM1200 consists of two layers: a glass contact refractory and a back-up refractory. The glass contact refractory (melter walls and floor) consists of a 5-inch thick layer of Monofrax® K-3 brick. Figure 2.12 shows the K-3 refractory package for the DM1200. The large brick at the center of Figure 2.12 is the riser brick that is used to direct glass out of the melter and into the discharge chamber. The back-up refractory consists of two layers of 3-inch thick AZS brick. The plenum refractory package, which sits on top of the glass contact refractory, consists of 5-inch thick Monofrax® H brick, behind which is 6 inches of fiberboard. The plenum refractory sits on a layer of refractory called the tuckstone, which is also manufactured from Monofrax® H brick. The top edge of the tuckstone is chamfered toward the glass pool so that any glass or feed from the plenum walls will drain back into the melter. The tuckstone refractory is 11 inches wide and 5 inches thick. Figures 2.13 and 2.14 provide views of the plenum refractory for the DM1200.

The DM 1200 lid is constructed from castable refractory supported by a carbon steel framework and provides access into the melter through penetrations arranged in rows. The castable refractory consist of 6 inches of an insulating castable (Kaolite 2500-LI) followed by 6" of refractory castable (Narcon 60A). The refractory castable is directly exposed to the plenum environment of the melter.

The DM1200 discharge chamber is a carbon steel shell lined with fiberboard. Fourteen discharge heaters enter horizontally through the west side of the chamber to maintain the chamber at its operating temperature of approximately 1000°C. The discharge heaters are spiral-type resistance heaters manufactured from silicon carbide.

### 2.4.2 DM1200 Inspection

On May 30, 2006 an inspection of the DM1200 was performed to assess the condition of the melter plenum refractory, melter lid, and the discharge chamber trough. Due to the level of the glass in the melter (approximately 27 inches), inspection of the glass contact refractory (K-3 bricks) could not be performed. Discussed below are the details of the inspection.

DM1200 Refractory

Utilizing existing view ports on the west side of the melter, a visual inspection of the east wall was performed. Although the field of view was limited through the view ports, the east wall plenum refractory appeared to be in excellent condition with only minor surface cracking. All visible seams were tight and no rounding or spalling of the refractory edges was noted. In addition to the views through the view ports, a water-cooled video camera was inserted into the melter through the center port in the lid and through the film cooler port to record the condition of the melter refractory. Even though the camera was water cooled, the plenum temperature was high enough (>1000°C) that the camera could only be inserted into the melter for 5 – 10 seconds before it needed to be removed to prevent damage. Still frames from the video were obtained to document the results of the inspection.

Inspection of the south plenum refractory revealed some isolated cracking of the plenum wall refractory. These appear to be surface cracks in the refractory and probably do not penetrate very deep in the overall thickness of the brick (5 inches). The refractory seam that is visible in the video was in excellent condition with no evidence of deterioration or widening. Some slight spalling of the tuckstone (approximately 8 inches long by 1 inch wide) is evident, but it appears to be isolated. A picture of the south wall (taken from the video) is provided in Figure 2.15.

Figure 2.16 shows the condition of the plenum refractory on the east wall of the DM1200. Aside from various surface cracks in the plenum refractory, there appears to be an area near the northeast corner that is protruding slightly from the rest of the wall and may be in the early stages of spalling. This area is centered on a refractory seam and is approximately 12 inches in length and several inches high at its largest point. The tuckstone appears to be in good condition, but some cracking is evident from the videos. Unlike the south wall, no spalling of the tuckstone has occurred.

Video inspection of the north wall of the DM1200 again revealed surface cracking of the plenum refractory. The only viewable refractory seam appears to be slightly wider than the seams on the other walls (see Figure 2.17). It is unclear, however, if this widening occurred during melter operations or if it was present during the initial startup of the melter. As with the east wall, the tuckstone refractory shows signs of cracking, and slight spalling (<1 inch) is evident at the seams of the tuckstone.

The west wall is in similar condition to the other walls in the melter; surface cracking of the refractory was noted as well as cracking of the tuckstone (see Figure 2.18). Figure 2.19 shows the southwest corner of the melter, which is directly under the film cooler. This view provides a closer look at the general condition of the plenum refractory. Again, minor surface cracking can be seen on the walls and in the tuckstone. Some slight spalling can also be seen on the edges of the tuckstone. The plenum brick that is directly behind the discharge chamber is in excellent condition, with sharp edges and no spalling. This brick was purposely extended beyond the rest of the plenum wall during the design of the DM1200 melter to allow room for the riser assembly.

### Melter Lid

The visual inspection of the melter lid was performed through a port on the west side of the melter that allowed viewing approximately 40% of the lid. The visible portion of the lid was in excellent condition and was covered with a thin layer of a glassy material. No cracking or spalling of the castable was noted and all areas around the lid penetrations were intact. No pictures of the lid were taken due to the difficulty of obtaining clear pictures through the view port.

### Discharge Chamber

Inspection of the inside of the discharge chamber was performed through a view port on the south side of the chamber as well as up through the discharge port at the bottom of the chamber. Overall, the fiberboard insulation was in excellent condition with no evidence of deterioration, as shown in Figure 2.20. Figure 2.20 also shows the condition of the bottom portion of the Inconel 690 discharge trough. This portion of the trough had a thin coating of glass and was in excellent condition. No significant wear of the trough was observed, although a very slight rounding of the trough edges was noted on the bottom edge. Figure 2.21 provides another view of the bottom of the discharge trough through the port on the south wall of the chamber. The joint where the vertical portion of the trough connects to the sloped portion of the trough is shown in Figure 2.22. This section of the trough was in excellent condition, but some very slight rounding of the joint was evident.

### Inspection Conclusions

Overall, the DM1200 melter is in excellent condition after five years of being at its operating temperature. The plenum bricks appear to be structurally sound with some surface cracking. All of the seams between the bricks are tight, with no evidence of any significant gaps. The tuckstone is showing some minor wear and cracking on the brick faces nearest the glass pool. Some small areas of spalling were also noted, but overall the tuckstone is in good condition. The lid of the melter was in excellent condition; no spalling or cracking was noted. Finally, the discharge chamber is in excellent condition. No significant wear of the trough was noted.

# SECTION 3.0
# DM1200 GLASS PRODUCTION RATES

One of the primary objectives of DM1200 melter tests was to determine the achievable glass production rates while processing simulated HLW feeds. This information is critical for underpinning the performance of the WTP, for melter design, and for integration of the HLW melter with waste pretreatment and LAW vitrification facilities. However, it is important to recognize that the HLW melter throughput requirements have evolved significantly over the course of the DM1200 test program. The minimum production rate requirement for the DM1200 has more than doubled, while the potential solids content of the HLW feed from pretreatment has decreased by a factor of almost two, as depicted in Figure 3.1. The RPP-WTP HLW design basis of 400 kg/m$^2$/day (1.5 MT/d full scale WTP) was increased to 800 kg/m$^2$/day (3.0 MT/d full scale WTP) with the "2+2" revised baseline [44]. In addition, the DM1200 production rate target was subsequently increased to 1050 kg/m$^2$/day to reflect the scaling effects associated with the fact that there are two bubblers in the one-third-scale DM1200 but five bubblers in the full scale melter. Since, other things being equal, processing rates decrease with decreasing waste solids content, the continued drop in the projected solids content of the waste further increases the demands on melter production capacity. The DM1200 testing program had to evolve to address these challenges while also striving to define the effect that various waste characteristics have on HLW glass production rates.

For simulated LAW feeds, the definitive glass production rate data were collected on the DM3300 LAW Pilot Melter and therefore factors affecting LAW glass production rates are not discussed here. It is noted, however, that tests conducted on the DM1200 with LAW simulants matched the corresponding surface-area-normalized rates obtained on the LAW Pilot Melter and the information was used to produce scaling data with respect to bubbling rate [31, 46]. A further objective of the LAW tests on the DM1200 was to collect data on the performance of the prototypical off-gas system with simulated LAW feeds.

Initial tests that were conducted on the DM1200 melter with HLW simulants were intended to determine the feasibility of attaining the design basis glass production rate of 400 kg/m$^2$/day without bubblers [3, 9]. Previous testing on the DM1000 system [1] concluded that achievement of that rate with simulants of projected WTP melter feeds (AZ-101 and C-106/AY-102) was unlikely without the use of bubblers. As part of those tests, the same feed that was used during the cold-commissioning of the West Valley Demonstration Project (WVDP) HLW vitrification system was run on the DM1000 system. The DM1000 tests reproduced the rates that were obtained at the larger WVDP facility, lending confidence to the tests results [1]. Since the inclusion or exclusion of a bubbler has significant design implications, the Project commissioned further tests to address this issue. The results of these tests are depicted in Figure 3.2. All tests without bubbling resulted in production rates lower than 400 kg/m$^2$/day. None of the variables investigated, which included feed concentration, feed acidification, frit as the glass former additive, variable additions of reductant (sugar), continuous feeding (as opposed to pulsed), and increased glass temperature, resulted in production rates approaching the Project baseline. Conversely, all tests that used bubbling exceeded the production rate of 400 kg/m$^2$/day even though the feed solids content for many of the tests was significantly lower. As a result of these findings, it was concluded that the current WTP HLW melter design is not capable of achieving the baseline production rate of 1.5 MT/d without the use of bubblers and that bubblers should be installed [43].

After the decision to include bubblers in the design, a series of tests was conducted on the DM1200 to determine the effects of bubbling rate and feed solids content on glass production rate while processing a simulated HLW AZ-101 feed composition [17]. Three nine-day tests, each at different feed solids content (530, 400 and 300 g glass per liter), were conducted at three bubbling rates. These tests were preceded by tests designed to establish the bubbling rate values required to produce glass at ~400 and ~800 kg/m$^2$/day, as well as the maximum production rate. An additional test was added that featured no bubbling to determine the effect of bubbling on the retention of noble metals. Analogous tests were conducted at the highest solids content (20 wt% undissolved solids) with three other HLW compositions (AZ-102, C-106/AY-102, C-104/AY-101) to assess the effect of waste composition on production rate [23, 26, 28]. The bubbler configuration used for all the tests was two single-outlet "J" bubblers, located in opposite corners, pointing towards the center, six inches from the melter floor (see Section 2.2). Steady-state production rates were obtained in the preliminary test with AZ-101 simulants for production rates of 400, 600, 800, and 1000 kg/m$^2$/day, but not for higher production rates, as shown in Figure 3.3. Higher production rates at about 140 and 160 hours run time were not sustainable due to accumulating and poorly distributed amounts of feed on the melt surface. Based on these results, values of 8, 40, and 65 lpm were selected for subsequent tests. The cold-cap-limited, steady-state production rates from tests conducted at these bubbling rates with AZ-101 simulants at three solids contents are shown in Figure 3.4. As expected, glass production rates increased with bubbling and decreased with decreasing feed solids content. The steady-state production rates for four HLW compositions (20% undissolved solids in the waste simulant) are illustrated in Figure 3.5. The production rates for three of the four compositions are virtually identical to each other, whereas the production rate for the C-106/AY-102 composition was about 10% lower at lower bubbling rates and about 10% higher at the highest bubbling rate. Also of note is that production rates for all four compositions exceed the present WTP requirement of 800 kg/m$^2$/day with feed containing 20% undissolved solids in the simulant. The tests employing the highest bubbling rate and feed solids content on the DM1200 exceeded the required WTP glass production rate (800 kg/m$^2$/day, or 3 MT/d per HLW melter), whereas tests with lower bubbling rates or solids contents did not. Feed with waste solids contents of less than about 17% UDS could not be processed at a glass production rate of 800 kg/m$^2$/day at the highest bubbling rate feasible with that bubbler configuration. Upon the conclusion of these tests, the projection for the HLW waste solids content was reduced to 15% UDS and therefore testing was proposed to increase the effectiveness of the bubblers. In addition, since the full-scale WTP melter has slightly fewer bubblers per unit melt surface area than does the DM1200 (five bubblers in 3.75 m$^2$ vs. two bubblers in 1.2 m$^2$), a scaling factor was added which increases the required DM1200 production rate to 1050 kg/m$^2$/day.

Melter tests were also conducted on the DM1200 to determine the effects of flow sheet changes of feed rheology, nitrate content, and organic content on glass production rate while processing the HLW AZ-101 [29], AZ-102 [35], and C-106/AY-102 [29, 35] feed compositions. The bubbler configuration and maximum bubbling rate (65 lpm) used in previous tests [17, 23, 26, 28] were used in the flow sheet variation tests to allow the results from the tests to be compared. Tests with HLW AZ-102 and C-106/AY-102 simulants employed rheology-adjusted feeds that were intended to provide better representations of the rheological properties of some of the more viscous actual waste samples that have been characterized; the majority of the previous melter testing has been performed with HLW waste simulants that are of somewhat lower viscosity. The test results illustrated in Figure 3.6 show that the rheology-adjusted feeds processed at rates that were four to fifty percent higher than those in analogous tests with the less viscous feeds, indicating that the previous test results likely give an accurate to conservative estimate of processing rate. Significant differences in processing rate were observed as a function of simulant composition for rheology-adjusted feeds, suggesting that the previously held conclusion that the processing rates for different HLW simulants are virtually identical may only apply for limited compositions with lower feed viscosities. Tests conducted with AZ-101 simulants and variable amounts of sugar, C-106/AY-102 simulants and variable amounts of sugar, and C-106/AY-102 simulants with high concentrations of nitrates and variable amounts of sugar, demonstrated that additions of sugar and nitrate do not result in production rate increases and can result in poor cold cap characteristics, which result in lower production rates.

Melter tests with HLW AZ-101 simulants were conducted on the DM1200 to optimize bubbler operation and configuration with respect to glass production rates [30]. Tests of durations of between seven and nine days were conducted using a variety of bubbler configurations, operational strategies, and bubbling rates. An additional test was also conducted with sodium chloride and sulfate spikes to determine the effects of the addition of these salts on production rate. Each of the tests began with a day of feeding to establish the cold cap before determining the production rate during the two- to four-day test segments. The results depicted in Figure 3.7 show that of the test variables investigated, the number of bubbler outlets and their locations had the greatest impact on processing rate. Tests using four outlets either as four lances simulating two double-outlet bubblers, or two actual double-outlet bubblers, resulted in production rates of between 1200 and 1400 kg/m$^2$/day for feed containing 400 g glass per liter. This result was obtained with four lances simulating two double-outlet bubblers with either 8" or 14" separation between the outlets. Production rates dropped from 1300 to 1100 kg/m$^2$/day when the number of bubbler outlets was reduced from four to two. A 25°C increase in glass temperature did not produce a large rate increase, primarily because of power supply limitations; however, a production rate of 1450 kg/m$^2$/day was obtained in that test with 23% less bubbling than in the comparable test at 1150°C. Increasing bubbler depth increased production rate; however, the only test systematically evaluating that variable was complicated as a result of bubbler orientation (parallel to the electrode as opposed to diagonally pointing towards the melter center, which placed the bubble flow closer to the wall), which had a larger effect than did the depth. A smaller but discernable production rate increase was observed as a result of varying the flow between the two bubblers while keeping the total flow constant (skewing), as shown in Figure 3.8. The effect of the chemical additives sodium chloride and sodium sulfate on production rate was unclear in these tests. Sodium chloride and sodium sulfate alone appeared to decrease production rate, while the two combined appeared to increase production rate. However, it is believed that these decreases in production rate may be attributable to cold-cap ridges that built up in the first two test segments that were burned off prior to the last segment. Based on these tests, the optimum configuration selected for future tests was two bubblers, each with two outlets 8 inches apart, placed on the floor, one bubbler outlet 11.3" from feed tube, as shown in Figures 2.5, 2.8 and 2.9.

The limited number of tests conducted with the optimized bubbler configuration is listed in Table 3.1. The objective of the first four of these tests [30, 35] was to evaluate the optimized bubbler configuration with respect to production rate, whereas the production rates achieved during the MACT tests was a consequence of achieving other target test conditions, most notably plenum temperature. The target production rate of 1050 $kg/m^2/day$ was achieved or exceeded for feed containing HLW AZ-101 and C-106/AY-102 simulants but not with AZ-102 simulants. During most of the tests explicitly evaluating the optimum bubbler configuration [30, 35], the bubbling rate was adjusted to give the maximum cold cap limited steady state production rate. In the tests with the AZ-102 simulants, the target production rate of 1050 $kg/m^2/day$ was initially achieved; however, excessive mounding of the feed on the cold cap necessitated reducing the feed and bubbling rate. Prior to reducing the feed rate, total bubbling flow rates as high as 225 lpm were used in an unsuccessful attempt to break down the accumulations in the cold cap. A steady state rate greater than 1050 $kg/m^2/day$ was achieved in one of the MACT tests at the low bubbling rate of 43 lpm, suggesting that without the plenum temperature limitations, the production rates with this feed and the optimum bubbler configuration would be significantly higher. The comparisons that best illustrate the production rate enhancements are given in Table 3.2. Feed of similar composition and solids content were processed 40 to 64% faster with the optimized bubbler configuration.

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

In summary, tests showed that significant improvements in glass production rates could be achieved by employing optimized bubbler configurations. These improvements appear to be sufficient to more than make up for the production rate short-fall brought about by the reduction in the solids content in the HLW feed from pretreatment from 20 wt% to 15 wt% undissolved solids. However, attainment of the target rate was not possible for all HLW simulants after further reduction in solids content. Attempts to achieve the target rate with low solids content HLW feed resulted in unstable melter conditions and frequent blockages of the film cooler. Further optimization, including the addition of more bubbling outlets and employing automated bubbler flow rate skewing would result in additional production rate enhancements. All of these increases in production rate have been achieved while visually monitoring the cold cap; the increases may be lower if operators must rely exclusively on remotely collected data such as plenum temperature. However, overall, the success demonstrated to date suggests that there is considerable further scope for HLW production rate enhancement.

# SECTION 4.0
# DM1200 FILM COOLER AND TRANSITION LINE

This section provides data and analysis on the operation, maintenance, and post test inspections of the melter film cooler and the transition line in between the film cooler and the submerged bed scrubber (SBS). Similar reports reviewing the performance of the SBS and wet electrostatic precipitator (WESP) have been issued previously [47, 48].

## 4.1 Film Cooler Operation

The duct between a melter and its off-gas system has traditionally been a trouble spot for accumulation of deposits as a result of carryover in the melter exhaust, sometimes to the point of constriction or blockage. The film cooler was developed as a means of mitigating this problem. The film cooler injects a gas layer along the inside pipe wall to prevent collection of entrained solids and to cool the melter exhaust stream to a temperature below the softening point of the solids such that they are less adhesive and easier to remove.

The DM1200 has a louvered-type film cooler installed in the lid of the melter. The DM1200 film cooler is not fully prototypic of the WTP HLW melter film cooler, but many of its key features are similar. Figure 4.1 provides a representation of the DM1200 film cooler. An outer shell with a flanged air injection line and an intermediate diverter sleeve create a cylindrical passage that forces the air to the bottom of the film cooler. At the bottom, the air changes direction and is swept upward through the cylindrical passage between the middle shell and the louvered inner sleeve. Air exits the film cooler between these louvers. During normal DM1200 operations, the film cooler is kept clean by injecting water into the injection air supply line. One liter per minute of water is added to the line for five minutes every twelve hours. In the event that the water flushing is not sufficient to clean the film cooler, operations personnel manually clean the film cooler with a rod and/or brushes.

Since the LAW Pilot Melter (DM3300) had an entire program to assess the operation of the film cooler while processing LAW feeds, the results of which have been reported separately [49, 50], discussion of the operation of the film cooler on the DM1200 will focus mainly on HLW feeds. Initially, plugging of the film cooler was not an issue for the DM1200, especially when low glass bubbling rates were used to meet the design HLW glass production rate of 400 kg/m$^2$/day. However, as the WTP requirements have evolved over the last few years, the required HLW glass production rate has increased from 400 to 800 kg/m$^2$/day. In addition to this rate increase, the target glass production rate for the DM1200 was increased to 1050 kg/m$^2$/day to account for scale-up issues associated with the number of bubblers installed in the melter. In order to achieve these rates, a significant amount of testing was undertaken to optimize the bubbler configuration [30] and determine the impact of different feed chemistries [29] and rheology [35] on the glass production rate. During these tests, increased instances of film cooler plugging were observed. Figure 4.2 shows typical views of the film cooler with heavy particulate buildup that required manual cleaning by the operations personnel.

In order to determine the causes of the film cooler plugging, operating data from April 2003 through the HLW MACT test were reviewed [29, 30, 35, 41], as were the operations log books, to identify when manual cleaning of the film cooler was performed. Since it was believed that the increased bubbling rates used to achieve the high glass production rates were the main cause of film cooler plugging, plots of glass pool bubbling rate versus film cooler differential pressure (DP) were created. Typically, a high differential pressure measurement across the film cooler was the result of a plugged film cooler. Therefore, when the film cooler DP is overlaid against the glass pool bubbling rate, impacts of high bubbling rates in the melter can be easily observed.

Figure 4.3 shows the glass pool bubbling rate versus the film cooler DP for the HLW AZ-102 feed rheology test [35]. As can be seen in Figure 4.3, the initial part of the test was conducted at a bubbling rate of 65 liters per minute (lpm) while processing a high rheology feed at various solids contents (17 and 20 wt% solids). During this time, the film cooler was manually cleaned once, as can be seen from the high film cooler DP at the run time of 20 hours. At approximately 100 hours into the test, the feed was changed to a nominal rheology, dilute feed (340 g/l). Bubbling rate was increased significantly in an attempt to achieve the desired glass production rate of 1050 kg/m$^2$/day, which resulted in 12 manual cleanings of the film cooler over a period of approximately 24 hours. Since the conditions within the melter were not sustainable, the bubbling rate was reduced to approximately 65 lpm to achieve a sustainable rate of around 900 kg/m$^2$/day. During this period, the film cooler was cleaned twice. Specific production rate and processing information can be found in the referenced report [35].

Figure 4.4 shows the operating data from Test 9 of the configuration tests [30]. During this test, production rates were maintained at 1000 kg/m$^2$/day for the first 160 hours of the test, with a glass pool bubbling rate of between 55 and 70 lpm. No film cooler plugging was observed during this steady state run. The second part of the test was used to determine the maximum production rate that could be achieved with this HLW AZ-101 feed. Bubbling rates were increased to well over 100 lpm, which resulted in production rates as high as 1300 kg/m$^2$/day. However, during this 2.5-day portion of the test, the film cooler was manually cleaned 5 times. Similar film cooler plugging and bubbling rate correlations can be seen in Test 8 [30] operating data (Figure 4.5), where the maximum glass production rate was determined at 1150°C and 1175°C. In the first 36 hours of Test 8, where the bubbling rate was less than 75 lpm, no film cooler cleanings were required. However, for the rest of the tests, where the bubbling rate was greater than 80 lpm, 21 and 13 manual cleanings were performed during the 1150°C and 1175°C tests, respectively.

A summary of the manual film cooler cleanings for all of the HLW tests from April 2003 through the HLW MACT test is provided in Table 4.1. Table 4.1 provides test conditions and average production rates for each test, as well as the number of cleanings at various bubbling rate ranges. The bubbler flow is the total flow of air through all of the bubblers. The terms "fixed" and "variable" refer to how the air flow to the individual bubblers was controlled. Fixed flow rates are those in which all of the bubblers have the same flow, which totals to the overall flow rate (i.e., flow per bubbler is the total flow divided by the number of bubblers in the melter). Variable flow rates signify that the air flow to each bubbler can vary subject to the constraint that the air flow through all of the bubblers must total the overall flow rate. Figure 4.6 shows the difference between "fixed" and "variable" bubbling rates, where the first 70 hours of the test was run under a fixed condition (both bubblers were set at 32.5 lpm) and the remaining portion of the test was conducted under a variable condition (individual bubbler flows varied, but always totaled 65 lpm).

The frequency of manual cleaning of the film cooler increases significantly when the bubbling rate increases above approximately 65 lpm when processing HLW simulants. The instances of manual film cooler cleaning during tests with a bubbling rate of 65 lpm or less occurred primarily during the initial startup and establishment of the cold cap. During this period of time, melter emissions are at their highest as the melter feed is falling directly on a molten glass surface instead of an established cold cap. Test 1 [30] resulted in a large number of manual cleanings, which may be due to the high bubbling rates for individual bubblers, since the flow rates ranged from 17 to 48 lpm at any given time (see Figure 4.6).

A similar table was assembled for the DM1200 transition line blockages and this information is shown in Table 4.2. Although the correlation between line blockages and bubbling rate is not as obvious as with the film cooler data, it is apparent from the data that line blockages typically occurred at the higher bubbling rates. Many times the blockages were removed by simply tapping the line with a hammer. Another item of note is that the sensor lines clogged frequently even though the lines were purged with air to prevent solids buildup.

Although testing of the DM1200 was mainly focused on HLW feeds, five LAW feed campaigns were run on the DM1200. Four of the campaigns were run to collect off-gas emissions data (LAW Sub-Envelopes A1, B1, C1, and the LAW MACT test) and the remaining was bubbling rate and foaming tests utilizing Envelope A and C feeds. During these LAW campaigns, the film cooler was manually cleaned three times (twice while processing the Sub-Envelope A1 feed and once during the LAW MACT test). Plugging of the transition line only occurred during the bubbling rate and foaming test (four occurrences) and the blockages were cleared by tapping the transition line with a rubber mallet.

Based on the review of the operational data, it appears that plugging of the film cooler and transition line is strongly dependent on the melter bubbling rate. As the bubbling rate increases, larger holes are formed in the cold cap, which allows fresh feed more opportunity to make direct contact with molten glass, leading to higher particulate carryover. In addition, the higher bubbling rate makes the surface of the glass pool very active, which increases glass and feed spraying within the plenum area. This additional particulate matter is then swept out of the melter through the film cooler where it deposits and builds up, eventually clogging the film cooler and transition line. The formation of holes in the cold cap can be prevented by reducing bubbling, which has the undesirable effect of reducing the glass production rate, or by increasing the number of bubbling outlets, which permits the use of greater amounts of bubbler air without concentrating the air flow in a limited number of locations.

Although the diameter of the WTP HLW film cooler is approximately twice the size of the DM1200 film cooler, there is reason to believe that similar plugging will occur in the WTP HLW melter system. Therefore, it is recommended that routine washing/flushing of the WTP film cooler be performed to ensure that any buildup that does occur during processing is quickly removed before it impacts the facility operations. Redundancy of sensor lines and their design should be considered especially given the number of times the sensor lines plugged on the DM1200 system. While film cooler washing may slow the rate of clogging, in DM1200 tests with HLW feeds, it was found to be ultimately unsuccessful in removing the clogs that inevitably occurred. Therefore, a mechanical means to remove blockages needs to be developed and tested to ensure that it is reliable and will remove blockages without damaging the delicate film cooler louvers. Film cooler plugging can also be mitigated by the addition of more bubblers and bubbling outlets.

## 4.2 Film Cooler and Transition Line Inspections

The film cooler and transition line were inspected for solids accumulation and corrosion after several of the DM1200 tests [10, 14, 28, 30, 31, 41]. The general layout of the film cooler and transition line sections is shown in Figure 4.7. The film cooler is shown on the right hand side of the photograph. Transition line section #1 is located on the right, above the film cooler, and has a Y shape. Transition line section #2 is a long and slightly curved portion following transition line section #1. Transition line section #3 is a shorter straight part following section #2. The transition line bellows is a short section shown as the last section in Figure 4.7. The transition line section in between the bellows and SBS inlet, which is not shown in Figure 4.7, has a similar shape to transition line section #1 and connects the transition line bellows to the SBS. A complete list of deposits removed from the film cooler transition line is given in Table 4.3; chemical analyses of select deposits are given in Table 4.4

### 4.2.1 Inspection After LAW Sub-Envelope C1 Test [10]

At the end of the LAW Sub-Envelope C1 test, a large amount of dry solids was found at the thermocouple location (~1/2 of the pipe diameter occluded) in the film cooler and on the section right above the transition line connection to the film cooler. The film cooler was cleaned with a rod and brush. Accumulation in the film cooler appeared to be greater than was observed in the previous HLW tests [3, 9]. Only a slight coating was observed in the transition line inlet. Similarly, only a slight solids coating was observed inside the bellows. Analysis by Direct Current Plasma Atomic Emission Spectroscopy (DCP-AES) of material from the transition line bellows shows the same four major components as in the melter feed (i.e., $SiO_2$ ~47 wt%, $Na_2O$ ~14 %, $Al_2O_3$ ~6%, and $Fe_2O_3$ ~6%). The sample also contained a large amount of $SeO_2$, which was not present in the melter feed. $SeO_2$, $SO_3$, SrO, $TeO_2$, MnO and $Cs_2O$ are probably deposits from the AZ-101 post-commissioning tests [9] that were performed prior to the LAW Sub-Envelope C1 test.

### 4.2.2 Inspection After LAW Sub-Envelope A1 Test [14]

Film Cooler: At the end of the LAW Sub-Envelope A1 test series, the film cooler was removed and inspected in detail. Photographs of the solids deposits in various parts of the film cooler are provided in Figures 4.8 - 4.11. Although the mass of the deposits was not recorded, significant solids deposition can be observed in the photographs. In addition to the solids deposition, significant corrosion damage at the bottom of the film cooler was observed, as shown in Figures 4.12 - 4.19. DCP analysis of a sample of solids removed from the film cooler after washing indicated that the deposits consist mainly of sodium and silicon, with lesser amounts of aluminum, boron, chromium, iron, nickel, selenium, and zinc. Cleaning of the film cooler was only marginally successful, as shown in Figures 4.20 - 4.23.

A scanning electron microscope (SEM) image of a sample removed from the film cooler bottom ring is shown in Figure 4.24. Specific results from analysis using SEM coupled with energy dispersive x-ray spectroscopy (EDS) include:

- Glass has adhered to the corroded surface and is inundated with Cr-Fe-Ni spinel.
- A chromium chloride phase is found at the interfaces where the glass is observed in contact with the bulk metal, both at the corroded surfaces and in cracks.
- Platelets of chromium oxide are found throughout the cross section of the ring, except in the highly corroded/depleted regions.
- Metal near the corrosion areas is severely depleted in chromium.
- Sulfur attack is present, which extends into the bulk metal.
- Metal in the central areas of the ring is compositionally consistent with Inconel 690.
- Other phases observed in glassy/scale regions include aluminum oxide platelets, as well as chlorine- and sulfur-containing phases.

Based on the SEM/EDS analysis, the general trend observed is glass with significant spinel formation adhered to broad zones of chromium oxide that are hundreds of microns thick. Next, a chromium chloride phase is observed forming a non-uniform boundary between the chromium oxide and the chromium-depleted metal surface. Within the chromium depleted metal (which is typically a few hundred microns thick), significant grain boundary attack is observed, and formation of chromium oxide and sulfate phases is occurring at those boundaries. Finally, away from the highly depleted/corroded areas of the metal, a significant amount of an eskoalite platelet is observed. In general, these observations are consistent with high-temperature corrosion of Inconel in the presence of chlorides and sulfates.

Given the extent of the damage to the film cooler (which was the original unit installed in the DM1200), a replacement was installed prior to the next set of tests on the DM1200 system.

Transition Line: After 121.6 hours operation (in between the second and third test segments) and at the end of the test series, parts of the transition line were removed for inspection. The inside of the flexible bellows between the film cooler and the transition pipe and the inside of the transition pipe (SBS side) contained solids deposits after 121.6 hours operation, as shown in Figures 4.25 and 4.26. Similar, but not as extensive deposits were also observed at the end of the test series.

### 4.2.3 Inspection After HLW C-104/AY-101 Test [28]

Photographs of the solids deposits in the film cooler after the HLW C-104/AY-101 test are shown in Figures 4.27 and 4.28. Photographs of the solids deposits in various sections of the transition line are provided in Figures 4.29 - 4.34. The largest mass of solids (3.11 kg) was collected from transition line section #2. DCP analysis of solids taken from this section shows major component composition similar to that of AZ-101, AZ-102, C-106/AY-102 and C-104/AY-101 melter feeds, indicating entrainment of feed components into the exhaust stream. However, the concentrations of volatile components such as selenium were higher than those in the feed, indicating volatilization from the glass surface or cold cap. Other notable elements were zinc, zirconium, lithium, and manganese, which are also present in all of the four HLW feeds. Sulfur is present in the sample and is present only in the AZ-101 and AZ-102 feeds.

Contributing factors to the amount of solids deposition in the film cooler probably include feed composition, cooling of the off-gas, flow direction changes, and the film cooler washing process. The solids deposits are the accumulations since 6/21/2002 for the film cooler and the transition line sections #1, #2, and #3. The transition line bellows and the transition line on the SBS side were cleaned on 10/24/2002, hence the deposits on these two sections accumulated over a four-month period. The film cooler photographs (Figures 4.27 and 4.28) indicate that there is some corrosion of the film cooler leading surfaces and some plugging of the air holes. As noted above, this film cooler, which is constructed of Inconel 690, had been in service since 6/21/02. Corrosion of the film cooler is likely somewhat enhanced during idling since it is exposed to higher temperatures than during normal feeding as a result of the absence of a cold cap. This component is one that is expected to need occasional replacement. The film cooler and all sections of the transition line were cleaned before reassembly.

### 4.2.4 Inspection During and After HLW Configuration Tests [30]

#### Configuration Test 2

Solids deposits at the inlet of the film cooler are shown in Figure 4.35. Photographs of the solids deposits throughout the transition line are given in Figures 4.36 - 4.41. The film cooler and all sections of the transition line were cleaned before reassembly. The solids deposits in the film cooler, transition line sections #1, #2, #3, transition line bellows, and transition line section connecting to the SBS are the result of accumulations since 3/5/03, right after the C-104/AY-101 HLW simulant test [28]. The maximum solids deposition was in transition line section #2 in both cases. The masses of solids collected from this section were 3.11 kg on 3/5/03 and 2.28 kg on 6/11/03. The tests conducted between the two dates were Tests 5 and 6 of the HLW Reductant series [29] and Configuration Test 2 [30], during which approximately 26,000 kg of glass was poured. The transition line differential pressure increased during the latter half of Test 6 and was fairly steady during Test 2, suggesting that the bulk of the transition line deposits may have occurred during Test 6.

### Configuration Test 1

After the test, the film cooler, transition line sections #2, #3, and transition line bellows were inspected. Very little particulate was observed in the film cooler or transition line sections #2 and #3. A photograph of the solids deposits at the transition line bellows inlet is provided in Figure 4.42. About 10 grams of solids deposits was removed from the transition bellows. The film cooler and the above mentioned sections of the transition line were cleaned before reassembly.

### Configuration Test 3

At around 162.3 hours into Test 3, melter feeding was interrupted and the transition line bellows was removed due to clogging; a 4”-diameter solid chunk (shown in Figure 4.43.a) and a small amount of debris totaling 0.254 kg were removed from the bellows. The film cooler was rodded out about one hour prior to the solids removal at the bellows. After the film cooler was cleaned, the transition line was tapped and the deposit moved down the transition line and lodged in the bellows. A macro image of the material, which is shown in Figure 4.43.b, indicates a reddish glassy admixture inundated with pores and periodically encrusted with a whitish substance. An SEM/EDS spectrum of this sample is presented in Figure 4.43.c. Observations with respect to this sample can be summarized as follows:

- An EDS spectrum taken in a region that showed a somewhat eroded appearance in SEM back-scattered electron (BSE) mode revealed that the mixture primarily contained Na, Al, Si, Fe, Zn, S, and Cl.
- In regions where whitish material was evident, high Na, S, and Cl concentrations were observed.
- Sodium sulfate was readily observed across the sample.
- In areas with surface cracks, various undissolved feed components were observed in the cross section. Most notable was a sodium zirconium silicate.

- The material contains the major feed components, indicating entrainment of feed components into the exhaust stream, as well as higher-than-feed concentrations of volatile components such as sulfur, indicating volatilization from the glass surface or cold cap.

At the end of the test, the film cooler was removed and inspected. Figure 4.44 shows some glazed build up of solids on air vent holes at the very bottom of the film cooler. There was also moderate particulate buildup on its louvers. The film cooler (2nd installed on the DM1200) was replaced on 7/23/03, before Test 8. The transition line segments were not inspected after the test.

To cool and protect the film cooler during periods of extended idling, air from the discharge dam cooling air flow, which goes to the bypass off-gas piping during testing, is routed to the film cooler inlet, where it mixes with and lowers the temperature of the air flowing from the melter plenum into the film cooler. The cooling air flow rate is about 23 scfm at a temperature of about 135°C at the outlet of the dam. This mixes with the plenum air, which is typically around 1020°C during idling. As a result of this cooling system, the film cooler internal temperature is about 540°C during idling.

**Test 10**

The mass of solids removed from the film cooler and transition line segments was 0.57 kg and 1.5 kg, respectively. Photographs of the film cooler inlet are shown in Figures 4.45 and 4.46. Photographs of the solids deposits throughout the transition line are given in Figures 4.47 - 4.53. The white deposits seen in the figures are presumed to be alkali halides (sodium chloride was spiked into the feed during Test 10). The film cooler and all sections of the transition line were cleaned before reassembly. The cleaned film cooler inlet is shown in Figure 4.54.

**Test 9**

Figure 4.55 shows some glazed buildup of solids on air vent holes at the very bottom of the film cooler. Only slight solids deposits were observed throughout the transition line except in the transition line section in between the bellows and the SBS inlet, as shown in Figure 4.56. The film cooler was partially cleaned, as shown in Figure 4.57, before the next test. The transition line sections were deliberately not cleaned before reassembly; however, some solids in the transition line section connected to the SBS inlet fell out.

### 4.2.5 Inspection After LAW Production Rate and Foaming Tests [31]

After both the Production Rate and Foaming Tests, the transition line bellows were removed. About 60 grams of small chunks and very fine white solids were removed from the transition line bellows. The results from this test were similar to the previous LAW Sub-Envelope C1 test [10] in that no blockages of the transition line occurred and only a small amount of material was deposited in the transition line bellows. Photographs of deposits observed in the transition line after the Foaming Tests are given in Figures 4.58 - 4.60. Sixteen grams of solids was removed from transition line section #3 and fourteen grams was removed from transition line section #2.

The film cooler was not inspected during or after the Production Rate or Foaming Tests.

### 4.2.6 Inspection After MACT Tests [41]

After the completion of regulatory tests with both LAW and HLW simulants as well as an HLW turnover period of about 62 hours in duration, the transition line sections and the film cooler were taken out and inspected. The film cooler was installed during the bubbler configuration test series (3rd installed on the DM1200) in July of 2003 [30]. Since that installation, the film cooler and transition line were removed and cleaned on several occasions, the most recent of which occurred in April 2004 [30]. The amount of material collected and documented at the inspection at the end of the MACT tests therefore reflects feed processing during the simulant verification tests [35], turn-over and scoping tests associated with the MACT tests, the MACT tests, and idling time in between these tests. One exception occurred after the MACT tests during the HLW turnover when a clog that began to severely limit the vacuum on the melter required cleaning and removal of the bellows and cleaning of the adjacent transition line segments in place. Corrosion observed on the film cooler can be attributed to about 440 days of idling and 87 days of feed processing, whereas the measured amounts of solids (more than 1.56 kg) collected are the result of about 41 days of feeding but do not include the material removed during the HLW Turnover Test. During the HLW Turnover Test, the transition line clogged and the transition line bellows were taken out. Views of transition line bellows and transition line section in between the bellows and SBS inlet at 26.9 hours into the HLW Turnover Test are provided in Figures 4.61 and 4.62, respectively. A view of the film cooler inlet after the HLW Turnover Test is provided in Figure 4.63. Glassy solids had deposited at the end of the film cooler. In Figure 4.64, damage to the tip of the film cooler is shown. Even though the film cooler was severely corroded, it functioned without incident throughout the tests. Close-up views of the film cooler louvers and the film cooler outlet are shown in Figures 4.65 and 4.66, respectively. The inlet of the film cooler after cleaning is shown in Figures 4.67 and 4.68. Included in Figure 4.67 for comparison is a picture of the film cooler after about half the exposure time. Deposits observed throughout the transition line are shown in Figures 4.69 - 4.76.

In summary, film cooler clogging events continued to be a significant operational problem during DM1200 tests. Their frequency appeared to increase with bubbling rate and glass production rate. Feeds with low solids contents further exacerbate this issue because of the need for increased bubbling rates in order to maintain glass production rates. None of the film cooler washing procedures were effective for clogging with HLW feeds. No mechanical cleaning device has been tested. Consequently, this would appear to be a significant issue with respect to the ability of the WTP to meet HLW throughput requirements. These findings have been reported to the WTP Project and decisions regarding resolution are pending.

# SECTION 5.0
# DM1200 EMISSIONS

Exhaust samples were taken in the transition line using 40-CFR-60 Methods 3, 5, and 29 to quantify and qualify emissions from the DM1200. Sampling durations were about one hour due to the high particle concentration. Teflon filters were used to allow for analysis of all feed components. The majority of the off-gas analyte concentrations were derived from laboratory data on solutions extracted from air samples (filters and various solutions) together with measurements of the volume of air sampled. The volume of air sampled and the rate at which it can be sampled are defined in 40-CFR-60 and SW-846. Isokinetic sampling, which entails removing gas from the exhaust at the same velocity that the air is flowing in the duct (40-CFR-60, Methods 1-5), was used. Total particulate loading was determined by gravimetric analysis of the standard particle filter and of probe-rinse solutions. Downstream of the particulate filter in the sampling train are iced impingers with acidic (5% concentrated nitric acid plus 10% hydrogen peroxide) and basic (2 N sodium hydroxide) solutions. The analysis of these solutions permits the determination of total gaseous emissions of several elements, notably halides and sulfur. An additional procedure was required for particulate samples containing ruthenium [17, 29]. Undissolved ruthenium particles were filtered from the nitric/hydrofluoric acid digestate, fused with sodium hydroxide, and dissolved with hydrochloric acid. Results from all inorganic isokinetic samples taken at the melter outlet are provided in Table 5.1, including test, feed type, melt pool bubbling rate, elemental emission rates, and melter decontamination factors (DFs). 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. Impinger solutions and filtered solids from off-gas sampling were analyzed for all of the elements in the feed, but only halides, boron, selenium, and sulfur were detected in the impinger solutions.

Melter emissions can be attributed to two distinct mechanisms: simple entrainment of feed or glass particles into the exhaust stream and volatilization of constituents from the glass surface or cold cap. The composition of the former is very similar to the feed and glass target composition, whereas the composition of the latter is skewed towards the more volatile elements such as selenium, sulfur, halides, boron, and alkali metals. Increases in glass pool bubbling rate have the potential to increase emissions generated by both mechanisms; entrainment due to glass or feed being lifted into the plenum space and volatilization due to creation of openings in the cold cap exposing the molten glass surface. The effect of feed composition on emissions is most evident in the concentrations of volatile species that are lost from the melt pool or cold cap. Extremely volatile components, such as water or nitrates, can also increase the activity in the surface on the cold cap through gas evolution, thereby aiding the entrainment of other feed components into the exhaust stream. In general, particulate melter emissions are composed of major feed components with higher-than-feed concentrations of volatile components. The C-106/AY-102 formulation is the only one of the four HLW compositions tested that contained the volatile element selenium and, therefore, emissions from this test are uniquely enriched in selenium. Likewise, the C-104/AY-101 formulation contained significant amounts of fluorine, resulting in emissions containing significant concentrations of fluorine. Particulate melter emissions during tests with LAW simulants have higher concentrations of alkali metals, sulfur, and halides due to their higher concentrations in the feed. The analyzed compositions of the particulate emissions are similar to the analysis of the deposits removed from the film cooler (see Section 4.2).

Figure 5.1 compares particulate carryover from the melter for several tests conducted with HLW AZ-101 simulants with and without melt pool bubbling [3, 9]. Solids carryover from the melter is relatively low in this test series and increases with increased melt pool bubbling. Exceptions to the bubbling trend are tests with minimal bubbling and feed that contains nitrates and sugar, which result in emissions rates comparable to tests with bubbling.

Emissions samples were taken from tests with HLW AZ-101 simulants to determine the effect of bubbling rate and feed water content on melter emissions [17]. The results are depicted in Figures 5.2 and 5.3 for percent carryover of total solids and many feed elements. No distinction was evident between emissions at the lowest bubbling rates when the data are normalized to feed rate; however, emissions did increase substantially at the highest bubbling rate. Bubbling at the intermediate rate of 40 lpm is probably insufficient to disrupt the cold cap enough to substantially increase glass production or emissions from the melter. Particulate carryover increases with increasing feed water content (decreasing feed solids content), in keeping with the expectation that increased steam generation in the cold cap region can lead to increased entrainment of feed particulates. These data also illustrate the relative volatility of the depicted feed components, with boron being most volatile, silicon being the least volatile, and total particulate emissions being in between these two extremes. Also of note is the common response of most feed elements and total solids to changes in feed water content and melter conditions. In Figure 5.4, the solids carryover from the tests conducted at 65 lpm (Figure 5.3) is compared to emissions collected while processing HLW AZ-101 feed in other tests at the same bubbling rate [29, 30]. Melter emissions were higher in tests with sugar as a feed additive due to less desirable cold cap conditions and the evolution of gases upon the breakdown of the sugar. While processing feed at a solids content of 400 g glass per liter, emissions were lowest when the 65 lpm of bubbling was spread out between four bubbling outlets instead of two.

Emissions data collected from melter tests with all HLW compositions are comparable to data from samples taken during tests processing HLW AZ-101 compositions [26, 28, 29, 35, 41]. Percent solids carryover from the melter during tests with HLW C-106/AY-102 increased with bubbling and was typically higher in tests with sugar and nitrates incorporated into the feed, as shown in Figure 5.5. Emissions from tests with four HLW compositions at the highest feed solids content (20% UDS) and a bubbling rate of 65 lpm are compared in Figure 5.6. The measured solids carryover from the melter was lower for the AZ-101 composition (0.55 percent of feed solids) than for any of the other compositions. This performance was not due to compositional differences, given the similarity between the feeds with lowest (AZ-101) and highest (AZ-102) melter emission rates, but more likely was due to changing conditions in the melter (e.g., deposits on the tip of the feed nozzle causing spraying of feed towards the off-gas outlet during the tests with HLW AZ-102 simulants, or ridges in the cold cap leaving sections of the melt surface exposed vs. a contiguous cold cap across the entire melt pool surface) as the samples are being taken. Measured carryover for tests with AZ-101, C-106/AY-102, and C-104/AY-101 were all very similar.

The bubbler configuration tests provide a good opportunity to examine the effect of changes in melter operation, particularly bubbler configuration and usage, on melter emissions since the same AZ-101 feed is used throughout the tests with little compositional change [30]. Percent solids carryover for some of these tests is illustrated in Figure 5.7. These data can also be compared to previous tests processing the same AZ-101 feed with two single outlet bubblers at a bubbling rate of 65 lpm, which had a solids carryover from the melter of 0.55% and 0.78% for feeds at 530 and 400 g solids per liter, respectively [17]. Another comparison can be made to tests with the same AZ-101 feed at 400 g solids per liter processed using double outlet bubblers at 64 and 134 lpm resulting in 0.62% and 1.11% solids carryover from the melter, respectively. The data illustrate the increase in melter emissions with bubbling, although the increases are all or partly mitigated when the bubbler air flow is distributed between four instead of two bubbler outlets. For example, a test conducted with four bubbling outlets and total bubbling rate of 117 lpm had lower solids carryover than an earlier test with the same feed conducted with two bubbling outlets and a total bubbling rate of 65 lpm (0.78% vs. 0.58%). Carryover from tests conducted at the same total bubbler flow rate but with the flow spread out over four outlets instead of two were lower (0.78% vs. 0.62%), suggesting that spreading bubbler flow over the surface not only enhances production rate, but also reduces solids carryover from the melter. Other conditions tested that showed increased emissions included increased melt temperature and the addition of chloride and sulfate to the feed. Solids carryover from the melter in the test with the sulfate-only spike was higher than expected, particularly considering that the test with the same amount of sulfate and chloride had about half the melter carryover. The high value is probably due to the inherent variability in melter emissions as a result of continuing changes in the cold cap and the difficulty in establishing an even cold cap during portions of tests with the added salts. Step bubbler skewing resulted in a small increase in emissions due to the higher air flow from one bubbler over an extended period of time.

Sampling of the melter exhaust while processing LAW simulants was done primarily to provide scaling data between the DM100 melter and the DM3300 LAW Pilot Melter [51]. A summary of the percent solids carryover for the DM1200 tests processing LAW simulants is given in Figure 5.8. Many of the general trends observed during tests with HLW simulants were observed; increased emissions with increased bubbling and higher emissions when volatile components such as halides are added to the feed. Solids carryover increased with increasing feed alkali and halogen content (A > C > B), as expected. Comparison of DM1200 melter emissions with those measured on other melter platforms is shown in Figures 5.9 and 5.10 while processing the same LAW Sub-Envelope A1 and B1 simulants, respectively. There is reasonable consistency across the three melters. Elemental carryover is highest for the most volatile elements: sulfur followed by alkali metals, chromium, and boron (it should be noted, however, that the chromium data are likely skewed high as a result of the prevalence of chromium sources in the melter materials of construction). This trend is apparent at all three melter scales and for all three Sub-Envelope compositions. Total emissions are therefore highest for the compositions with highest total volatile content (LAW A) and lowest for compositions with the lowest total volatile content (LAW B). The higher percentage of emissions for volatile constituents indicates that volatilization is more significant than simple entrainment as the mechanism for generating melter emissions during tests with LAW feeds. Simple entrainment would result in equal carryover for all elements, which is not observed. In view of the differences in geometry and air in-leakage rates, the similarity of emissions for melters spanning a range of a factor of 30 in melter surface suggests that the emissions are dominated by the gross chemical and physical process involved in the feed to glass conversion with an essentially complete cold cap rather than the details of the melter design. Comparison of these data also suggests that melter emissions data collected on smaller melters can be reliable predictors of melter emissions at much larger scales provided that the operating conditions are similar.

# SECTION 6.0
# SUMMARY AND CONCLUSIONS

The DM1200 at VSL has been operated for over five years, during which time over a million and a half pounds of feed has been processed to produce over half a million pounds of glass. A wide range of simulated HLW and LAW streams were treated under a variety of melter and off-gas system operating conditions. From these tests, a large body of data has been collected on melter performance, maintenance, post test inspections, and potential failure modes. This includes the operation of the film cooler as well as plugging and corrosion of both the film cooler and transition line.

Recent inspections show that, overall, the DM1200 is in excellent condition after five years of being at its operating temperature. The plenum bricks appear to be structurally sound with some surface cracking. All of the seams between the bricks are tight with no evidence of any significant gaps. The tuckstone is showing some minor wear and cracking on the brick faces nearest the glass pool. Some small areas of spalling were also noted, but overall the tuckstone is in good condition. The lid of the melter is in excellent condition; no spalling or cracking was noted. Finally, the discharge chamber is in excellent condition. No significant wear of the trough was noted.

One aspect of the present review was to determine the frequency that various melter components were replaced, including thermocouples, thermowells, level detectors, discharge air lances, and discharge heaters; detailed information for these components is provided in Section 2.0.

One of the primary objectives of DM1200 testing was to determine the maximum production rates feasible for various feeds containing HLW simulated wastes. This objective was addressed, over time, as the production rate requirement was increased and the projected solids content of the waste was decreased. Initial tests showed that melt pool bubbling was required to produce glass at a rate of 400 $kg/m^2/day$. Subsequently, tests with two single outlet bubblers demonstrated that production rates of 800 $kg/m^2/day$ could be obtained for HLW wastes with greater than 17 wt% undissolved solids. Significant further improvements in glass production rates (up to 1400 $kg/m^2/day$) were achieved with feeds corresponding to 15 wt% undissolved solids from pretreatment by employing optimized bubbler configurations. These improvements appear to be sufficient to more than make up for the production rate short-fall brought about by the reduction in the solids content in the feed from pretreatment from 20 wt% to 15 wt% undissolved solids. However, attainment of the target rate was not possible for all HLW simulants after yet further reductions in solids content. Attempts to achieve the target rate with low solids content feed resulted in unstable melter conditions and frequent blockages of the film cooler. Further optimization, including adding more bubbling outlets and employing automated bubbler flow rate skewing, would result in additional production rate enhancements.

Throughout testing on the DM1200, plugging of the film cooler and transition line occurred, particularly in tests with higher bubbling rates. On several occasions, feeding was interrupted in order to manually rod out the film cooler and, less frequently, a portion of the transition line had to be disassembled for cleaning. A thorough review of operational data indicated that the film cooler occlusions were directly related to the higher bubbling rates used to maximize glass production rates. Analysis of the deposits removed from the film cooler indicate that their composition is very similar to the composition of particulate melter emissions in that they are close to the feed composition and enriched in volatile constituents. Film cooler plugging can be limited by reducing the bubbling rate, which has the undesirable effect of reducing the glass production rate, or by increasing the number of bubbling outlets, which permits the use of greater amounts of bubbler air without concentrating the air flow in a limited number of locations. None of the film cooler washing procedures were effective for preventing clogging with HLW feeds. A mechanical means to remove blockages needs to be developed and tested to ensure that it is reliable and will remove blockages without damaging the delicate film cooler louvers. No mechanical cleaning device has been tested. Consequently, this would appear to be a significant issue with respect to the ability of the WTP to meet HLW throughput requirements. These findings have been reported to the WTP Project and decisions regarding resolution are pending.

The three film coolers used over the five years of DM1200 operation experienced severe corrosion on the inlet and glassy deposits occluded the air outlet holes on the leading edge. Much of the corrosion on the film cooler inlet may be due to exposure to higher temperatures during extended idling periods and therefore this may be less of an issue for a continuously operated melter.

Melter emissions were sampled throughout the DM1200 tests to provide data for off-gas system design, to determine the effect of feed composition and melter operation on melter emissions, and to provide data for system mass balance calculations. Analysis of the samples shows that melter emissions increase with increasing melt pool bubbling, feed water content, feed volatile content, and glass pool temperature. The effect of bubbling can be mitigated by distributing the bubbler flow through more bubbling outlets. The composition of the particulate emissions reflects the major feed components, indicating entrainment of feed components into the exhaust stream. In addition, the high concentrations of volatile components such as sulfur in the particulate indicate volatilization from the glass surface or cold cap. Particulate from LAW exhaust has a higher proportion of volatile and semi-volatile constituents, indicating a greater contribution from the glass surface or cold cap.

The major conclusions from this review are:

- Bubblers are needed to obtain glass production rates of 400 kg/m$^2$/day in WTP HLW melters with Hanford HLW feeds.

- Glass production rates as high as 1400 kg/m$^2$/day can be obtained in the DM1200 melter with two double outlet bubblers and HLW feeds prepared from waste simulants with 15% or higher undissolved solids.
- Feeds prepared from HLW with solids contents of less than 15% will require very high bubbling rates to achieve the contractually required glass production rate of 800 kg/m$^2$/day. These high bubbling rates are likely to cause film cooler clogging that may disrupt operations.
- Film cooler clogging can be minimized by increasing the number of bubbler outlets so that bubbling is more distributed in the melt pool, while maintaining the same total bubbler air flow. Skewing of bubbler air flow may also be beneficial in enhancing production rates.
- A mechanical film cooler cleaning device will likely be required at the WTP, and should be tested.
- Bubblers placed deeper in the melt pool are more effective in increasing processing rate.
- Addition of sugar and nitrates does not improve processing rates of Hanford HLW feeds.
- The rheology of the HLW melter feed does appear to affect processing rates, probably through its effect on feed distribution and cold cap formation. However, more viscous feeds processed somewhat faster.
- DM1200 glass production rates were obtained using visual monitoring of the cold cap, per Project direction. Visual observation is not planned for the WTP HLW melters, where instead, plenum temperature will be monitored to control feed rates. Since this could result in lower glass production rates, it would be beneficial to determine the impact of the planned WTP mode of operation on the DM1200.
- In bubbled melters, melter emissions consist mostly of entrained feed constituents with volatiles over represented.
- Melter emissions increase with bubbling rate, feed water content, feed volatile content, and temperature.
- After five years at the operating temperature, the DM1200 is in excellent condition.

# SECTION 7.0
# REFERENCES

[1] "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.

[2] "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.

[3] "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.

[4] "Tank Waste Remediation System Operation and Utilization Plan to Support Waste Feed Delivery," R.A. Kirkbride, G.K. Allen, R.M. Orme, R.S. Wittman, J.H. Baldwin, T.W. Crawford, J. Jo, L.J. Fergestrom, G.T. MacLean and D.L. Penwell, Volume I, HNF-SD-WM-SP-012, Revision 1 (Draft), February 1999.

[5] Hanford Tank Waste Best Basis Inventory, Tank Waste Information Network System 2 (http://twins.pnl.gov:8001).

[6] "Phase I High-Level Waste Pretreatment and Feed Staging Plan," A.F. Manuel, S.L. Lambert and G.E. Stegen, WHC-SD-WM-ES-370, Revision 1, September 1996.

[7] "Calculation of Lag Storage Requirements for Phase 1 Pretreatment Operations," BNFL, Inc. Memorandum #001753, E. Slaathaug to I. Papp, 2/17/99.

[8] "Using $MnO_4$ for TRU Separations," M. Johnson, E-mail message to I.L. Pegg, 5/17/99.

[9] "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.

[10] "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.

[11] "Tank Farm Contractor Operation and Utilization Plan," R.A. Kirkbride, et al., CH2M Hill Hanford Group Inc., Richland, WA, HNF-SD-SP-012, Rev. 2, 4/19/00.

[12] "Complex Concentrate Pretreatment FY 1986 Progress Report," R.O. Lokken, et al., PNL-7687, September 1986.

[13] "Basis of Design," BNFL report, DB-W375-EG00001, Rev. 0, 11/23/98.

[14] "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.

[15] "Tank Farm Contractor Operation and Utilization Plan," R.A. Kirkbride, et al., CH2M Hill Hanford Group Inc., Richland, WA, HNF-SD-SP-012, Rev. 3, 10/2/01.

[16] "Tank Waste Remediation System (TWRS) Privatization Contractor Samples – Waste Envelope B Material, 241-AN-105," R.A. Esch, HNF-SD-WM-DP-218, Rev. 1, 5/30/97.

[17] "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.

[18] "Tank Farm Contractor Operation and Utilization Plan," R.A. Kirkbride, et al., CH2M Hill Hanford Group Inc., Richland, WA, HNF-SD-SP-012, Rev. 3A, 12/12/01.

[19] "Small-Scale Ion Exchange Removal of Cesium and Technetium from Envelope B Hanford Tank 241-AZ-102," W.D. King, WSRC-TR-2000-00419 (SRT-RPP-2000-00036), 02/15/2001.

[20] "Integrated DM1200 Testing of HLW Compositions Using Bubblers," J.M. Perez, RPP-WTP Test Specification, 24590-HLW-TSP-RT-02-005, Rev 0, 4/1/02.

[21] "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.

[22] "Tank 241-AZ-101 Cores, 266 and 269 Analytical Results for the Final Report," F.H. Steen, Fluor Hanford, Richland, WA, HNF-1701, Rev. 0, 7/28/00.

[23] "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.

[24] "Phase I High-Level Waste Pretreatment and Feed Staging Plan," A.F. Manuel, S.L. Lambert and G.E. Stegen, WHC-SD-WM-ES-370, Rev. 1, Westinghouse Hanford Company, Richland, WA, September 1996.

[25] "Tank Characterization for Double-Shell Tank 241-AZ-102," R.D. Schreiber, WHC-SD-WM-ER-411, Rev. 0, Westinghouse Hanford Company, Richland, WA, July 1995.

[26] "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.

[27] "Small-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-102, N.M. Hassan, R. Hayden, W.D. King, D.J. McCabe and M.L. Crowder, BNF-003-98-0219, Rev. 0, 03/29/00.

[28] "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.

[29] "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.

[30] "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.

[31] "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.

[32] "Tank Characterization Report for Double-Shell Tank 241-AN107," J. Jo, J.D. Franklin, D.J. Morris and L.C. Amato, WHC-SD-WM-ER600, Rev. 0, Westinghouse Hanford Company, WA, 1996.

[33] "LAW Pilot Melter and DM-100 Sub-Envelope Changeover Testing," E.V. Morrey, WTP Test Specification, Rev. 0, 24590-LAW-TSP-RT-02-012, 8/13/02.

[34] "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.

[35] "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.

[36] (a) "RE: CCN:082426 Direction for Test Planning of HLW Simulant Validation Tests," E-Mail from E.V. Morrey to I.L. Pegg, 2/25/04. (b) "Authorization to Procure Feed for Upcoming 102-AZ DM1200," E-Mail from E.V. Morrey to I.L. Pegg, 4/28/04.

[37] "CCN:082426 Direction for Test Planning of HLW Simulant Validation Test," E-Mail from E.V. Morrey to I.L. Pegg, 2/18/04.

[38] "Test Exception to Define the High Waste Loading C-106/AY-102 Composition and Test Operating Conditions," 24590-WTP-TEF-RT-04-00028, 8/10/04.

[39] "AY-102/C-106 Actual Waste Sample Glass Formulation Guidance," CCN 067620, RPP-WTP Memorandum, C. Musick to I.L. Pegg, 3/23/04.

[40] "Multiple Ion Exchange Column Runs for Cesium and Technetium Removal from AW-101 Waste Sample (U)," N. M. Hassan, K. Adu-Wusu and C.A. Nash, WSRC-TR-2003-00098, Rev. 0 (SRT-RPP-2003-00026, Rev. 0), Westinghouse Savannah River Company, Aiken, SC, July 2003.

[41] "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.

[42] "HLW/LAW Regulatory Off-Gas Emission Testing," S. Kelly, RPP-WTP Test Specification, 24590-WTP-TSP-RT-04-0001, Rev. 1, 7/13/04.

[43] "Research & Technology Recommendation on the Requirement of Bubblers in the HLW Melter," Perez, J.M. 24590-HLW-RPT-RT-01-003, River Protection Project, Waste Treatment Plant, 3000 George Washington Way, Richland, WA 99352, 2002.

[44] "Flowsheet and Process Variability Vitrification Testing of Nonradioactive HLW Simulants," J.M Perez and D.K. Peeler, Test Specification, 24590-HLW-TSP-RT-02-015, Rev. 0, 3/8/03.

[45] "High-Level Waste Melter System Materials of Construction Testing," R.K Mohr, I. Vidensky, C. T. F. Mooers, A. C. Buechele, R. A. Callow, K. S. Matlack, and I.L. Pegg, Final Report, VSL-04R5730-1, Rev. 1, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 6/5/06.

[46] "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.

[47] "Summary of DM1200 SBS History and Performance," K.S. Matlack, W. Gong, G. Diener, T. Bardakci, M. Brandys, and I.L. Pegg, Final Report, VSL-06R6410-2, Rev. A, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 8/2/06.

[48] "Summary of DM1200 WESP History and Performance," K.S. Matlack, W. Gong, Glenn Diener, T. Bardakci, N. M. Brandys, and I.L. Pegg, Final Report, VSL-06R6710-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 7/17/06.

[49] "RPP-WTP Pilot Melter Film Cooler Cleaning Test Results Report," TRR-PLT-051, Rev. 0, 10/13/00.

[50] "RPP-WTP Pilot Melter Film Cooler Performance and Cleaning Protocols Test Results Report," TRR-PLT-034, Rev. 0, 2/3/04.

[51] "Comparison of Off-Gas Emissions from Tests with LAW Simulants on the DM100, DM1200, and DM3300 Melters," R.A. Callow, K.S. Matlack, and I.L. Pegg, Summary Report, VSL-04S4850-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 4/19/04.

# Table 1.1. Summary of Melter Tests Conducted on the DM1200 at VSL.

| Report | Testing Date | Objective | Feed Type | Amount Fed (kg) | Glass Produced (kg) |
|---|---|---|---|---|---|
| VSL-01R0100-2 [3] | 5/7/01-5/23/01 | Initial Testing of DM1200 systems | HLW AZ-101 with variable amounts of water [4-8] | 15549 | 5457 |
| VSL-02R0100-2 [9] | 6/25/01 - 11/10/1 | Verification of the need to use bubblers to achieve required glass production rates | HLW AZ-101 with variable amounts of water, nitrate and sugar. Additives as chemicals or frit [4-8] | 77668 | 26726 |
| VSL-02R8800-1 [10] | 1/7/02 - 1/15/02 | Regulatory Emissions Testing | LAW Sub-Envelope C1 with iodine [11-13] | 29245 | 14820 |
| VSL-02R8800-2 [14] | 2/27/02 - 3/20/02 | Regulatory Emissions Testing | LAW Sub-Envelope A1 with iodine [11, 13, 15, 16] | 28783 | 14661 |
| VSL-03R3800-4 [17] | 7/23/02 - 10/24/02 | Determination of glass production as a function of feed solids content and bubbling rate, two single outlet bubblers | HLW AZ-101 with iodine, variable amounts of water and noble metals (select tests) [4, 6, 18-20] | 79870 | 25109 |
| VSL-03R3851-1 [21] | 11/4/02 - 11/8/02 | Comparison of production rates with LAW Pilot Melter | LAW Sub-Envelope B1 with iodine [11, 13, 22] | 30857 | 16281 |
| VSL-03R3800-2 [23] | 11/18/02 - 11/27/02 | Determination of glass production rate as a function of bubbling rate, two single outlet bubblers | HLW AZ-102 with iodine [5, 19, 20, 24, 25] | 17348 | 6748 |
| VSL-03R3800-1 [26] | 1/22/03 - 1/31/03 | Determination of glass production rate as a function of bubbling rate, two single outlet bubblers | HLW C-106/AY-102 with cesium and iodine [6, 18, 20, 27] | 16574 | 6316 |
| VSL-03R3800-3 [28] | 2/19/03 - 2/28/03 | Determination of glass production rate as a function of bubbling rate, two single outlet bubblers | HLW C-104/AY-101 with cesium and iodine [18, 20] | 18530 | 6983 |
| VSL-04R4800-1 [29] | 4/30/03 - 5/23/03 | Determination of glass production rate as a function of feed nitrate and sugar content, two single outlet bubblers | HLW C-106/AY-102 with variable amounts of cesium, iodine, sugar and nitrates. [6, 18, 20, 27] | 43617 | 19281 |
| VSL-04R4800-4 [30] | 5/28/03 – 4/01/04 | Optimization of bubbler configuration (orientation, number of outlets, location) to maximize production rate | HLW AZ-101 with iodine, variable amounts of water and noble metals (select tests) [4, 6, 18-20] | 168319 | 56010 |
| VSL-04R4800-1 [29] | 8/19/03 - 8/28/03 | Determination of glass production rate as a function of feed sugar content, two single outlet bubblers | HLW AZ-101 with variable amounts of iodine and sugar [4, 6, 18-20] | 28095 | 8956 |
| VSL-04R4851-1 [31] | 9/25/03 - 10/20/03 | Comparison of production rates with LAW Pilot Melter | LAW Sub-Envelope C1[11-13, 32] | 42645 | 21340 |
|  | 10/20/03-10/21/03 | Study of melt pool foaming | LAW Envelope A [33] | 4521 | 1404 |

# Table 1.1. Summary of Melter Tests Conducted on the DM1200 at VSL (continued).

| Report | Testing Date | Objective | Feed Type | Amount Fed (kg) | Glass Produced (kg) |
|---|---|---|---|---|---|
| VSL-03L4850-1 [34] | 11/3/03 – 11/8/03 | Change glass pool composition, development of allyl alcohol monitoring method | LAW Envelopes A+C, various HLW | 17149 | 7817 |
| VSL-05R5800-1 [35] | 6/21/04-6/25/04 | Determination of the effect of feed rheology on production rate | HLW AZ-102 adjusted to provide different rheological properties [5, 19, 20, 24, 25, 36, 37] | 14713 | 5397 |
| VSL-05R5800-1 [35] | 6/25/04-6/30/04 | Test optimum bubbler configuration | HLW AZ-102 [5, 19, 20, 24, 25] | 20002 | 10769 |
| VSL-05R5800-1 [35] | 8/02/04-8/07/04 | Determination of the effect of feed rheology on production rate | HLW C-106/AY-102 adjusted to provide different rheological properties [6, 18, 20, 27, 36, 37] | 14300 | 5193 |
| VSL-05R5800-1 [35] | 11/08/04-11/12/04 | Test optimum bubbler configuration | HLW C-106/AY-102 [6, 18, 20, 27, 36-40] | 20100 | 5168 |
| VSL-05R5830-1 [41] | 11/15/04-12/12/04 | Regulatory Emissions Testing | HLW C-106/AY-102 with projected maximum concentrations of toxic metals, halides and nitrates [6, 18, 20, 27, 42] | 23969 | 7525 |
| VSL-05R5830-1 [41] | 3/7/05 - 3/23/05 | Regulatory Emissions Testing | LAW Sub-Envelope A2 with projected maximum concentrations of toxic metals, halides and nitrates [13, 33, 42] | 28750 | 15201 |
| Total | | | | 725055 | 287161 |

## Table 1.2. Test Summary for DuraMelter 1200 HLW AZ-101 Commissioning Tests (VSL-01R0100-2) [3].

| Test # | | 1 | 2 | 3 |
|---|---|---|---|---|
| Time | Feed Start | 5/7/01 10:00 | 5/14/01 09:29 | 5/21/01 08:51 |
| | Feed End | 5/12/01 13:10 | 5/16/01 13:39 | 5/23/01 13:28 |
| | Interval | 123.2 hr | 52.2 hr | 52.7 hr |
| Water Feeding for Cold Cap | | 3.2 hr | 2.6 hr | 2.5 hr |
| Slurry Feeding | | 120.0 hr | 49.6 hr | 50.2 hr |
| Cold cap burn off | | 10.0 hr | 1.2 hr | 1.6 hr |
| Total | | 133.2 hr | 53.4 hr | 53.2 hr |
| Bubbling Rate | | < 8 scfh | 100 scfh | 100 scfh |
| Feed | Characteristics | Nominal | Nominal | High Water |
| | Used | 4178 kg | 4948 kg | 6423 kg |
| | Glass yield[#] | 570 g/l | 570 g/l | 350 g/l |
| | | 0.380 kg/kg | 0.380 kg/kg | 0.275 kg/kg |
| | Average Feed Rate | 34.8 kg/hr | 99.8 kg/hr | 127.9 kg/hr |
| Glass Produced | Poured | 1587 kg | 1948 kg | 1922 kg |
| | Average Rate[$] | 265 kg/m$^2$/day | 785 kg/m$^2$/day | 766 kg/m$^2$/day |
| | Average Rate[*] | 265 kg/m$^2$/day | 759 kg/m$^2$/day | 705 kg/m$^2$/day |
| | Steady State Rate[*] | 155 kg/m$^2$/day | 750 kg/m$^2$/day | 700 kg/m$^2$/day |
| | Average Power Use | 9.8 kW.hr/kg glass | 3.6 kW.hr/kg glass | 4.5 kW.hr/kg glass |

# - Target values.
$ - Rates calculates from amount of glass poured.
*- Rates calculated from amount of feed consumed and conversion ratio.
Note: Rates do not take into account the time for water feeding and cold-cap burn-off.

### Table 1.3. Summary of Test Conditions and Results for HLW AZ-101 Tests 1-9 (VSL-02R0100-2) [9].

| Test # | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Time | Feed Start | 6/25/01 10:45 | 7/23/01 17:47 | 8/6/01 16:59 | 8/20/01 13:08 |
| | Feed End | 7/2/01 10:50 | 8/1/01 11:47 | 8/11/01 11:47 | 8/25/01 1444 |
| | Interval | 168.1 hr | 216 hr | 114.8 hr | 121.6 hr |
| Water Feeding for Cold Cap | | 2.25 hr | 1.6 hr | 0.8 hr | 1.9 hr |
| Slurry Feeding | | 165.8 hr | 214.4 hr | 114.0 hr | 119.7 hr |
| Cold cap burn | | 5.0 hr | 10.0 hr | 3.3 hr | 3.3 hr |
| Total | | 173.1 hr | 226.0 hr | 118.1 hr | 124.9 hr |
| Bubbling Rate | | <4 lpm | < 4 lpm | Deep: 62 lpm | Shallow: 50 lpm |
| Electrode Firing | | Side to Bottom | Side to Bottom | Side to Side | Side to Bottom |
| Feed | Characteristics | High Solids | High Solids +<br>10 g sugar/l | High Water | High Water |
| | Used | 5927 kg | 6816 kg | 19184 kg | 11573 kg |
| | Glass yield# | 570 g/l | 570 g/l | 400 g/l | 400 g/l |
| | | 0.38 kg/kg | 0.38 kg/kg | 0.29 kg/kg | 0.29 kg/kg |
| | Average Rate | 35.7 kg/hr | 31.8 kg/hr | 168.3 kg/hr | 96.7 kg/hr |
| Glass Produced | Poured | 2301 kg | 2594 kg | 6180 kg | 3465 kg |
| | Average Rate$ | 278 kg/m$^2$/day | 242 kg/m$^2$/day | 1084 kg/m$^2$/day | 579 kg/m$^2$/day |
| | Average Rate* | 272 kg/m$^2$/day | 242 kg/m$^2$/day | 976 kg/m$^2$/day | 561 kg/m$^2$/day |
| | Steady State Rate* | 255 kg/m$^2$/day | 205 kg/m$^2$/day | 980 kg/m$^2$/day | 540 kg/m$^2$/day |
| | Average Power Use | 6.1 kW.hr/ Kg glass | 5.7 kW.hr/ kg glass | 3.9 kW.hr/ kg glass | 4.7 kW.hr/ kg glass |

# - Target Values.
$ - Rates calculates from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.

## Table 1.3. Summary of Test Conditions and Results for HLW AZ-101 Tests 1-9 (VSL-02R0100-2) [9] (continued).

| | Test # | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|
| Time | Feed Start | 9/25/01 13:17 | 10/11/01 08:21 | 10/22/01 14:12 | 10/29/01 13:45 |
| | Feed End | 10/1/01 13:37 | 10/17/01 19:24 | 10/27/01 14:12 | 11/2/01 17:45 |
| | Interval | 144.5 hr | 155.0 hr | 120.0 hr | 100.0 hr |
| | Water Feeding for Cold Cap | 2.0 hr | 2.2 hr | 1.5 hr | 1.1 hr |
| | Slurry Feeding | 142.5 hr | 152.8 hr | 118.5 hr | 98.9 hr |
| | Cold cap burn | 6.4 hr | 14.5 hr | 4.3 hr | 10.3 hr |
| | Total | 150.9 hr | 169.5 hr | 124.3 hr | 110.3 hr |
| | Bubbling Rate | < 4 lpm | < 4 lpm | 60 lpm deep | < 4 lpm |
| | Electrode Firing | Side to Bottom | Side to Bottom | Side to Side | Side to Bottom |
| Feed | Characteristics | Nitrated + sugar (sugar ratio=0.5) | Frit + 7.5 g sugar/l | Frit + 7.5 g sugar/l | Nitrated + sugar (sugar ratio=0.7) |
| | Used | 4932 kg | 5417 kg | 16240 kg | 3426 kg |
| | Glass yield (target) | 420 g/l feed | 480 g/l feed | 480 g/l feed | 420 g/l feed |
| | | 0.31 kg/kg feed | 0.35 kg/kg feed | 0.35 kg/kg feed | 0.31 kg/kg feed |
| | Average Rate | 34.6 kg/hr | 35.5 kg/hr | 137.0 kg/hr | 34.6 kg/hr |
| Glass Produced | Poured | 1659 kg | 1901 kg | 5976 kg | 944 kg |
| | Average Rate[$] | 233 kg/m$^2$/day | 249 kg/m$^2$/day | 1009 kg/m$^2$/day | 191 kg/m$^2$/day |
| | Average Rate[*] | 215 kg/m$^2$/day | 248 kg/m$^2$/day | 959 kg/m$^2$/day | 215 kg/m$^2$/day |
| | Steady State Rate[*] | 220 kg/m$^2$/day | 210 kg/m$^2$/day | 1100 kg/m$^2$/day | 200 kg/m$^2$/day |
| | Average Power Use | 6.5 kW.hr/kg glass | 6.0 kW.hr/kg glass | 3.3 kW.hr/kg glass | 6.3 kW.hr/kg glass |

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.

**Table 1.3. Summary of Test Conditions and Results for HLW AZ-101 Tests 1-9 (in Test 9 both feed tubes used continuous instead of pulsed feed) (VSL-02R0100-2) [9] (continued).**

| Test # | | 9a | 9b |
|---|---|---|---|
| Time | Feed Start | 11/5/1 14:20 | 11/8/1 11:00 |
| | Feed End | 11/8/1 11:00 | 11/10/1 17:00 |
| | Interval | 68.6 hr | 54.0 hr |
| Water Feeding for Cold Cap | | 1.1 hr | NA |
| Slurry Feeding | | 67.5 hr | 54.0 hr |
| Cold cap burn | | NA | 6.9 hr |
| Total | | 68.6 hr | 60.9 hr |
| Glass Temperature | | 1150°C | 1200°C |
| Bubbling Rate | | < 4 lpm | |
| Electrode Firing | | Side to Side | |
| Feed | Characteristics | Nominal + 10 g sugar / l | |
| | Glass yield | 570 g/l | |
| | | 0.38 kg/kg | |
| | Used | 2028 kg | 2125 kg |
| | Average Rate | 30.0 kg/hr | 39.4 kg/hr |
| Glass Produced | Poured | 859 kg | 847 kg |
| | Average Rate[$] | 255 kg/m$^2$/day | 313 kg/m$^2$/day |
| | Average Rate[*] | 228 kg/m$^2$/day | 299 kg/m$^2$/day |
| | Steady State Rate[*] | 230 kg/m$^2$/day | 310 kg/m$^2$/day |
| | Average Power Use | 6.3 kW.hr/kg glass | 5.4 kW.hr/kg glass |

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn

## Table 1.4. Summary of Test Conditions and Results using LAW Sub-Envelope C1 Feed with Iodine (VSL-02R8800-1) [10]. (Process Engineering Data)

| | | |
|---|---|---|
| Time | Feed Start | 1/7/02 14:36 |
| | Feed End | 1/15/02 07:20 |
| | Duration | 184.8 hr |
| Water Feeding for Start-up | | 2.5 hr |
| Slurry Feeding | | 182.3 hr |
| Cold cap burn-off | | 1.5 hr |
| Total | | 186.3 hr |
| Electrode Firing | | Side to Side |
| Organic Spike | Start | 1/12/02 11:20 |
| | End | 1/14/02 21:25 |
| | Duration | 58.1 hr |
| Feed | Used | 29245 kg |
| | Glass yield (target) | 851 g/l feed |
| | | 0.511 kg/kg feed |
| | Average Rate | 160.4 kg/hr |
| Glass Produced | Poured | 14820 kg |
| | Average Rate$^{\$}$ | 1626 kg/m$^2$/day |
| | Average Rate$^{*}$ | 1639 kg/m$^2$/day |
| | Steady State Rate$^{*}$ | 1800 kg/m$^2$/day |
| | Average Power Use | 1.9 kW hr/kg glass |

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.

## Table 1.5. Summary of Test Conditions and Results using LAW Sub-Envelope A1 with Iodine (VSL-02R8800-2) [14]. (Process Engineering Data)

| | | | | |
|---|---|---|---|---|
| Time | Feed Start | 2/27/02, 16:41 | 3/3/02, 07:26 | 3/18/02, 08:45 |
| | Feed End | 3/1/02, 13:18 | 3/6/02, 06:33 | 3/20/02, 09:35 |
| | Duration | 44.4 hr | 71.1 hr | 48.8 hr |
| Water Feeding for Start-up | | 2.15 hr | 2.1 hr | 2.0 hr |
| Slurry Feeding | | 42.2 hr | 68.9 hr | 46.8 hr |
| Cold cap burn-off | | 3.45 hr | 2.6 hr | 1.7 hr |
| Total | | 47.9 hr | 73.7 hr | 50.5 hr |
| Feed Reductant | | Sugar | Sugar | Sugar |
| Organic Spike | Start | NA | 3/4/02, 13:42 | 3/19/02, 00:38 |
| | End | NA | 3/6/02, 06:31 | 3/19/02, 23:59 |
| | Duration | NA | 40.8 hr | 23.35 hr |
| Feed | Used | 6850 kg | 13195 kg | 8738 kg |
| | Glass yield (target) | 860 g/l feed | 860 g/l feed | 860 g/l feed |
| | | 0.516 kg/kg feed | 0.516 kg/kg feed | 0.516 kg/kg feed |
| | Average Rate | 162 kg/h | 192 kg/hr | 186 kg/hr |
| Glass Produced | Poured | 3452.6 kg | 6584.5 kg | 4623.8 kg |
| | Average Rate[$] | 1636 kg/$m^2$/day | 1907 kg/$m^2$/day | 1976 kg/$m^2$/day |
| | Average Rate[*] | 1664 kg/$m^2$/day | 1976 kg/$m^2$/day | 1920 kg/$m^2$/day |
| | Steady State Rate[*] | 1900 kg/$m^2$/day | 2000 kg/$m^2$/day | 1950 kg/$m^2$/day |
| | Average Power Use | 1.6 kW.hr/kg glass | 1.6 kW.hr/kg glass | 1.6 kW.hr/kg glass |

# - On 3/2/02 and 3/15/02, the melter was fed slurry for 6.2 hr and 4 hr, respectively. Tests were stopped due to WESP maintenance and blower failure. No organic spike was fed on 3/2/02 and the spike was fed for 1.25 hr on 3/15/02.

$ - Rates calculated from glass poured.

*- Rates calculated from feed data.

NA – Not applicable.

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

## Table 1.6. Summary of Test Conditions and Results Using HLW AZ-101 Feed with Iodine, Variable Amounts of Water and Noble Metals (VSL-03R3800-4) [17].

| Test | | 1 | | | | | 2 |
|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | |
| Time | Feed Start | 7/23/02<br>13:12 | 7/25/02<br>14:25 | 7/26/02<br>14:26 | 7/27/02<br>14:27 | 7/28/02<br>16:16 | 7/31/02<br>01:39 |
| | Feed End | 7/25/02<br>14:25 | 7/26/02<br>14:26 | 7/27/02<br>14:27 | 7/28/02<br>14:26 | 7/31/02<br>00:59 | 8/01/02<br>15:25 |
| | Interval | 49.2 hr | 24 hr | 24 hr | 24 hr | 56.7 hr | 36.2 hr |
| Water Feeding for Cold Cap | | 1.2 hr | NA | NA | NA | NA | NA |
| Slurry Feeding | | 48 hr | 24 hr | 24 hr | 24 hr | 56.7 hr | 33.8 hr |
| Cold Cap Burn | | NA | NA | NA | NA | NA | 2.4 hr |
| Bubbling Rate (lpm) | Average | 7.5 | 26 | 43 | 65 | 73 | 69 |
| | Range | 6.0 - 11 | 10 - 33 | 29 - 54 | 49 - 74 | 11- 107 | 23 - 99 |
| Feed | Used | 2634 kg | 2032 kg | 2586 kg | 3199 kg | 7209 kg | 3506 kg |
| | Glass Yield# | 504 g/l | 504 g/l | 504 g/l | 504 g/l | 504 g/l | 281 g/l |
| | | 0.37 kg/kg | 0.37 kg/kg | 0.37 kg/kg | 0.37 kg/kg | 0.37 kg/kg | 0.23 kg/kg |
| | Average Rate | 54.9 kg/hr | 86.4 kg/hr | 116.7 kg/hr | 43.0 kg/hr | 127.1 kg/hr | 103.7 kg/hr |
| Glass Produced | Poured | 879.4 kg | 688.9 kg | 1055.4 kg | 1198.4 kg | 2732.0 kg | 863.5 kg |
| | Average Rate$ | 366 kg/m$^2$/day | 574 kg/m$^2$/day | 880 kg/m$^2$/day | 999 kg/m$^2$/day | 964 kg/m$^2$/day | 510 kg/m$^2$/day |
| | Average Rate* | 406 kg/m$^2$/day | 627 kg/m$^2$/day | 797 kg/m$^2$/day | 986 kg/m$^2$/day | 941 kg/m$^2$/day | 477 kg/m$^2$/day |
| | Steady State Rate* | 400 kg/m$^2$/day | 630 kg/m$^2$/day | 800 kg/m$^2$/day | 1000 kg/m$^2$/day | Not Achieved | 500 kg/m$^2$/day |

# - Average measured values.
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

**Table 1.6. Summary of Test Conditions and Results Using HLW AZ-101 Feed with Iodine, Variable Amounts of Water and Noble Metals (VSL-03R3800-4) [17] (continued).**

| Test | | 3 | | | 4 | | |
|---|---|---|---|---|---|---|---|
| | | A | B | C | A | B | C |
| Time | Feed Start | 9/09/02<br>19:46 | 9/12/02<br>20:59 | 9/15/02<br>21:00 | 9/23/02<br>16:02 | 9/26/02<br>19:01 | 9/29/02<br>19:02 |
| | Feed End | 9/12/02<br>20:58 | 9/15/02<br>20:59 | 9/18/02<br>21:01 | 9/26/02<br>19:00 | 9/29/02<br>19:01 | 10/02/02<br>21:30 |
| | Interval | 73.2 hr | 72 hr | 74.9 hr | 75 hr | 72 hr | 74.5 hr |
| Water Feeding for Cold Cap | | 1.2 hr | NA | NA | 3.0 hr | NA | NA |
| Slurry Feeding | | 72 hr | 72 hr | 72 hr | 72 hr | 72 hr | 72 hr |
| Cold Cap Burn | | NA | NA | 2.9 hr | NA | NA | 2.5 hr |
| Bubbling Rate | | 8 lpm | 40 lpm | 65 lpm | 8 lpm | 40 lpm | 65 lpm |
| Feed | Used | 3955 kg | 6220 kg | 8399 kg | 3099 kg | 5506 kg | 8120 kg |
| | Glass Yield# | 530 g/l | 530 g/l | 530 g/l | 400 g/l | 400 g/l | 400 g/l |
| | | 0.375 kg/kg | 0.375 kg/kg | 0.375 kg/kg | 0.315 kg/kg | 0.315 kg/kg | 0.315 kg/kg |
| | Average Rate | 54.9 kg/hr | 86.4 kg/hr | 116.7 kg/hr | 43.0 kg/hr | 76.5 kg/hr | 112.8 kg/hr |
| Glass Produced | Poured | 1502.6 kg | 2356.5 kg | 3116.1 kg | 1032.6 kg | 1710.4 kg | 2491.8 kg |
| | Average Rate$ | 417 $kg/m^2/day$ | 655 $kg/m^2/day$ | 866 $kg/m^2/day$ | 287 $kg/m^2/day$ | 475 $kg/m^2/day$ | 692 $kg/m^2/day$ |
| | Average Rate* | 412 $kg/m^2/day$ | 648 $kg/m^2/day$ | 875 $kg/m^2/day$ | 271 $kg/m^2/day$ | 481 $kg/m^2/day$ | 709 $kg/m^2/day$ |
| | Steady State Rate* | 400 $kg/m^2/day$ | 655 $kg/m^2/day$ | 900 $kg/m^2/day$ | 270 $kg/m^2/day$ | 500 $kg/m^2/day$ | 750 $kg/m^2/day$ |
| | Average Power Use | 4.8 kW.hr/ kg glass | 3.9 kW.hr/ kg glass | 3.4 kW.hr/ kg glass | 7.0 kW.hr/ kg glass | 5.2 kW.hr/ kg glass | 4.3 kW.hr/ kg glass |

# - Target values.
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

**Table 1.6. Summary of Test Conditions and Results Using HLW AZ-101 Feed with Iodine, Variable Amounts of Water and Noble Metals (VSL-03R3800-4) [17] (continued).**

| Test | | 5 | | | 6 |
|---|---|---|---|---|---|
| | | A | B | C | |
| Time | Feed Start | 10/15/02 13:30 | 10/18/02 14:31 | 10/21/02 14:32 | 10/07/02 12:49 |
| | Feed End | 10/18/02 14:30 | 10/21/02 14:31 | 10/24/02 17:30 | 10/12/02 20:30 |
| | Interval | 73 hr | 72 hr | 75 hr | 127.7 hr |
| Water Feeding for Cold Cap | | 1 hr | NA | NA | 1.5 hr |
| Slurry Feeding | | 72 hr | 72 hr | 72 hr | 122.7 hr |
| Cold Cap Burn | | NA | NA | 3 hr | 3.5 hr |
| Bubbling Rate | | 8 lpm | 40 lpm | 65 lpm | < lpm |
| Feed | Used | 3410 kg | 6816 kg | 9726 kg | 3453 kg |
| | Glass Yield[#] | 300 g/l | 300 g/l | 300 g/l | 400 g/l |
| | | 0.249 kg/kg | 0. 249 kg/kg | 0. 249 kg/kg | 0.315 kg/kg |
| | Average Rate | 47.4 kg/hr | 94.7 kg/hr | 135.1 kg/hr | 28.1 kg/hr |
| Glass Produced | Poured | 825.6 kg | 1508.0 kg | 2098.9 kg | 1049.2 kg |
| | Average Rate[$] | 229 kg/m$^2$/day | 419 kg/m$^2$/day | 583 kg/m$^2$/day | 171 kg/m$^2$/day |
| | Average Rate[*] | 235 kg/m$^2$/day | 471 kg/m$^2$/day | 672kg/m$^2$/day | 177 kg/m$^2$/day |
| | Steady State Rate[*] | 250 kg/m$^2$/day | 450 kg/m$^2$/day | 550 kg/m$^2$/day | 190 kg/m$^2$/day |
| | Average Power Use | 8.5 kW.hr/ kg glass | 5.5 kW.hr/ kg glass | 4.4 kW.hr/ kg glass | 14.3 kW.hr/ kg glass |

# - Target Values.
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

## Table 1.7. Summary of Test Conditions and Results Using LAW Sub-Envelope B1 Feed with Iodine (VSL-03R3851-1) [21].

| - | | First Steady State Period | Second Steady State Period | Entire Feeding Period |
|---|---|---|---|---|
| Time | Feed Start | 11/4/02, 18:03 | 11/6/02, 21:30 | 11/4/02, 12:44 |
| | Feed End | 11/5/02, 16:46 | 11/8/02, 17:24 | 11/8/02, 17:24 |
| | Duration | 22.7 hr | 43.9 hr | 100.7 hr |
| | Run Time hours | 5.3 – 28.0 | 56.8 – 100.7 | 0 – 100.7 |
| Water Feeding for Start-up | | NA | NA | 1.0 hr |
| Slurry Feeding | | 22.7 hr | 43.9 hr | 99.7 hr |
| Organic Spike | Start | NA | NA | 11/6/02, 10:28 |
| | End | NA | NA | 11/6/02, 14:04 |
| | Duration | NA | NA | 3.6 hr |
| Cold cap burn-off | | NA | NA | 1.7 hr |
| Feed Reductant | | Sugar | Sugar | Sugar |
| Feed | Used | 3186 kg | 9489 kg | 18182 kg |
| | Glass Yield (target) | 957 g/l feed | 957 g/l feed | 957 g/l feed |
| | | 0.557 kg/kg feed | 0.557 kg/kg feed | 0.557 kg/kg feed |
| | Average Rate | 140 kg/h | 216 kg/hr | 182 kg/hr |
| Glass Produced | Poured | 1548 kg | 5106 kg | 9627 kg |
| | Average Rate[$] | 1364 kg/m$^2$/day | 2326 kg/m$^2$/day | 1931 kg/m$^2$/day |
| | Average Rate[*] | 1563 kg/m$^2$/day | 2408 kg/m$^2$/day | 2032 kg/m$^2$/day |
| | Average Power Use | 2.0 kW.hr/ kg glass | 1.6 kW.hr/ kg glass | 1.8 kW.hr/ kg glass |

"-"- Empty data field
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
NA – Not applicable.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.

## Table 1.8. Summary of DM1200 Test Conditions and Results Using HLW AZ-102 Feed with Iodine (VSL-03R3800-2) [23].

| Test Segment | | A | B | C |
|---|---|---|---|---|
| Time | Feed Start | 11/18/02<br>12:00 | 11/21/02<br>13:00 | 11/24/02<br>13:02 |
| | Feed End | 11/21/02<br>13:00 | 11/24/02<br>13:01 | 11/27/02<br>13:03 |
| | Interval | 73 hr | 72 hr | 72 hr |
| Water Feeding for Cold Cap | | 1.0 hr | NA | NA |
| Slurry Feeding | | 72 hr | 72 hr | 72 hr |
| Cold Cap Burn-Off | | NA | NA | 2.4 hr |
| Bubbling Rate | | 8 lpm | 40 lpm | 65 lpm |
| Feed | Used | 3526 kg | 5780 kg | 8042 kg |
| | Glass Yield# | 550 g/l | 550 g/l | 550 g/l |
| | | 0.385 kg/kg | 0.385 kg/kg | 0.385 kg/kg |
| | Average Rate | 49.0 kg/hr | 80.3 kg/hr | 111.7 kg/hr |
| Glass Produced | Poured | 1277 kg | 2249 kg | 3222 kg |
| | Average Rate$ | 355 $kg/m^2/day$ | 625 $kg/m^2/day$ | 895 $kg/m^2/day$ |
| | Average Rate* | 377 $kg/m^2/day$ | 618 $kg/m^2/day$ | 860 $kg/m^2/day$ |
| | Steady State Rate* | 380 $kg/m^2/day$ | 650 $kg/m^2/day$ | 900 $kg/m^2/day$ |
| | Average Power Use | 5.1 kW.hr/ kg glass | 4.2 kW.hr/ kg glass | 3.5 kW.hr/ kg glass |

# - Target values.
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

## Table 1.9. Summary of Test Conditions and Results Using HLW C-106/AY-102 Feed with Cesium and Iodine (VSL-03R3800-1) [26].

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

@ - Measured values.
# - Target values.
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

## Table 1.10. Summary of DM1200 Test Conditions and Results Using HLW C-104/AY-101 Feed with Cesium and Iodine (VSL-03R3800-3) [28].

| Test Segment | | A | B | C |
|---|---|---|---|---|
| Time | Feed Start | 02/19/03<br>18:37 | 02/22/03<br>20:14 | 02/25/03<br>20:14 |
| | Feed End | 02/22/03<br>20:13 | 02/25/03<br>20:14 | 02/28/03<br>20:14 |
| | Interval | 73.7 hr | 72 hr | 72 hr |
| Water Feeding for Cold Cap | | 1.7 hr | NA | NA |
| Slurry Feeding | | 72 hr | 72 hr | 72 hr |
| Cold Cap Burn-Off | | NA | NA | 4.7 hr |
| Bubbling Rate | | 8 lpm | 40 lpm | 65 lpm |
| Feed | Used | 3875 kg | 5934 kg | 8721 kg |
| | Glass Yield | 528$^{@}$ g/l | 528$^{@}$ g/l | 528$^{@}$ g/l |
| | | 0.357$^{\#}$ kg/kg | 0.357$^{\#}$ kg/kg | 0.357$^{\#}$ kg/g |
| | Average Rate | 53.8 kg/hr | 82.4 kg/hr | 121.1 kg/hr |
| Glass Produced | Poured | 1487 kg | 2245 kg | 3251 kg |
| | Average Rate$^{\$}$ | 413 kg/m$^2$/day | 624 kg/m$^2$/day | 903 kg/m$^2$/day |
| | Average Rate$^{*}$ | 384 kg/m$^2$/day | 588 kg/m$^2$/day | 865 kg/m$^2$/day |
| | Steady State Rate$^{*}$ | 400 kg/m$^2$/day | 660 kg/m$^2$/day | 900 kg/m$^2$/day |
| | Average Power Use | 5.0 kW.hr/ kg glass | 4.3 kW.hr/ kg glass | 3.6 kW.hr/ kg glass |

@ - Measured values.
# - Target values.
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

# Table 1.11. Summary of DM1200 Test Conditions and Results Using HLW C-106/AY-102 Feed (VSL-04R3800-1) [29].

| C-106/AY-102 (Target Glass Yield = 0.372 kg/kg or 550 g/l) with Variable Amounts of Sugar, Bubbling = 65 lpm | | | | | | |
|---|---|---|---|---|---|---|
| - | | A | B | C | D | E |
| Time | Feed Start | 4/30/03<br>11:32 | 5/01/03<br>14:34 | 5/03/03<br>14:49 | 5/05/03<br>14:59 | 5/07/03<br>15:12 |
| | Feed End | 5/01/03<br>14:34 | 5/03/03<br>14:49 | 5/05/03<br>14:59 | 5/07/03<br>15:12 | 5/09/03<br>15:45 |
| | Interval | 27 hr | 48.3 hr | 48.2 hr | 48 hr | 48.6 hr |
| Water Feeding for Cold Cap | | 2.6 hr | NA | NA | NA | NA |
| Slurry Feeding | | 24.4 hr | 48.25 hr | 48.2 hr | 48 hr | 48.6 hr |
| Cold cap burn | | NA | NA | NA | NA | 3.6 hr |
| Feed | Sugar Concentration | 0 | 10 g/l | 15 g/l | 17.5 - 20 g/l | 25 g/l |
| | Used | 3035 kg | 4714 kg | 5630 kg | 4334 kg | 4253 kg |
| | Average Rate | 124.4 kg/hr | 97.6 kg/hr | 116.8 kg/hr | 90.3 kg/hr | 87.5 kg/hr |
| Glass Produced | Poured | 1093 kg | 2020 kg | 2001 kg | 1720 kg | 1836 kg |
| | Average Rate$ | 896 kg/m$^2$/day | 836 kg/m$^2$/day | 830 kg/m$^2$/day | 717 kg/m$^2$/day | 756 kg/m$^2$/day |
| | Average Rate* | 926 kg/m$^2$/day | 726 kg/m$^2$/day | 869 kg/m$^2$/day | 672 kg/m$^2$/day | 651 kg/m$^2$/day |
| | Steady State Rate* | Not Attained | Not Attained | 870 kg/m$^2$/day | 700 kg/m$^2$/day | 650 kg/m$^2$/day |
| | Average Power Use | 3.3 kW.hr/ kg glass | 3.8 kW.hr/ kg glass | 3.3 kW.hr/ kg glass | 3.7 kW.hr/ kg glass | 3.8 kW.hr/ kg glass |

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.
"-" Empty data field

**Table 1.11. Summary of DM1200 Test Conditions and Results Using HLW C-106/AY-102 Feed (VSL-04R3800-1) [29] (continued).**

| C-106/AY-102 (Target Glass Yield = 0.372 kg/kg or 550 g/l) with Additional Nitrate and Variable Amounts of Sugar, Bubbling = 65 lpm | | | | | | |
|---|---|---|---|---|---|---|
| - | | A | B | C | D | E |
| Time | Feed Start | 5/14/03<br>12:05 | 5/15/03<br>14:00 | 5/17/03<br>15:03 | 5/19/03<br>16:00 | 5/21/03<br>16:20 |
| | Feed End | 5/15/03<br>14:00 | 5/17/03<br>15:03 | 5/19/03<br>16:00 | 5/21/03<br>16:20 | 5/23/03<br>16:30 |
| | Interval | 25.9 hr | 49 hr | 49 hr | 48.3 hr | 48.2 hr |
| Water Feeding for Cold Cap | | 0.7 hr | NA | NA | NA | NA |
| Slurry Feeding | | 25.3 hr | 49 hr | 49 hr | 48.3 hr | 48.2 hr |
| Cold cap burn | | NA | NA | NA | NA | 3.5 hr |
| Feed | Sugar Concentration | 0 | 10 g/l | 15 g/l | 20 g/l | 25 g/l |
| | Used | 2643 kg | 5885 kg | 6738 kg | 6385 kg | 6502 kg |
| | Average Rate | 104.5 kg/hr | 120.1 kg/hr | 137.5 kg/hr | 132.2 kg/hr | 134.9 kg/hr |
| Glass Produced | Poured | 1022 kg | 2244 kg | 2437 kg | 2395 kg | 2513 kg |
| | Average Rate$ | 808 kg/$m^2$/day | 916 kg/$m^2$/day | 995 kg/$m^2$/day | 992 kg/$m^2$/day | 1043 kg/$m^2$/day |
| | Average Rate* | 777 kg/$m^2$/day | 894 kg/$m^2$/day | 1023 kg/$m^2$/day | 984 kg/$m^2$/day | 1004 kg/$m^2$/day |
| | Steady State Rate* | Not Attained | 1000 kg/$m^2$/day | 1000 kg/$m^2$/day | 1000 kg/$m^2$/day | 1000 kg/$m^2$/day |
| | Average Power Use | 3.6 kW.hr/ kg glass | 3.4 kW.hr/ kg glass | 3.0 kW.hr/ kg glass | 3.0 kW.hr/ kg glass | 3.0 kW.hr/ kg glass |

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.
"-" Empty data field

## Table 1.11. Summary of DM1200 Test Conditions and Results Using HLW AZ-101 Feed (VSL-04R3800-1) [29] (continued).

| AZ-101 (Target Glass Yield = 0.3145 kg/kg or 400 g/l) with Variable Amounts of Sugar and Ruthenium, Bubbling = 65 lpm | | | | | | |
|---|---|---|---|---|---|---|
| - | | A | B$^{\#}$ | C$^{\#}$ | D$^{\#}$ | E$^{\#}$ |
| Time | Feed Start | 8/19/03 11:15 | 8/20/03 12:43 | 8/22/03 13:07 | 8/24/03 13:27 | 8/26/03 13:31 |
| | Feed End | 8/20/03 12:43 | 8/22/03 13:07 | 8/24/03 13:27 | 8/26/03 13:31 | 8/28/03 13:31 |
| | Interval | 25.5 hr | 48.4 hr | 48.3 hr | 48.1 hr | 48 hr |
| Water Feeding for Cold Cap | | 1.5 hr | NA | NA | NA | NA |
| Slurry Feeding | | 24 hr | 48.4 hr | 48.3 hr | 48.1 hr | 48 hr |
| Cold cap burn | | NA | NA | NA | NA | 3.3 hr |
| Feed | Sugar Concentration | 0 | 13.3 – 7.6 g/l | 10 g/l | 12.5 g/l | 16 g/l |
| | Used | 2266 kg | 6026 kg | 6332 kg | 6624 kg | 6847 kg |
| | Average Rate | 94.4 kg/hr | 124.5 kg/hr | 131.1 kg/hr | 137.7 kg/hr | 142.6 kg/hr |
| Glass Produced | Poured | 708 kg | 1841 kg | 2055 kg | 2039 kg | 2313 kg |
| | Average Rate$^{\$}$ | 590 kg/m$^2$/day | 761 kg/m$^2$/day | 851 kg/m$^2$/day | 848 kg/m$^2$/day | 964 kg/m$^2$/day |
| | Average Rate$^{*}$ | 594 kg/m$^2$/day | 783 kg/m$^2$/day | 825 kg/m$^2$/day | 866 kg/m$^2$/day | 897 kg/m$^2$/day |
| | Steady State Rate$^{*}$ | Not Attained | 850 kg/m$^2$/day | 850 kg/m$^2$/day | 900 kg/m$^2$/day | 930 kg/m$^2$/day |
| | Average Power Use | 4.3 kW.hr/ kg glass | 3.9 kW.hr/ kg glass | 3.8 kW.hr/ kg glass | 3.8 kW.hr/ kg glass | 3.7 kW.hr/ kg glass |

# - Test segments B-E included ruthenium and yttrium spiked into the feed.
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.
"-" Empty data field

## Table 1.12. Summary of DM1200 AZ-101 Feed Test Conditions and Results (VSL-04R4800-4) [30].

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

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

## Table 1.12. Summary of DM1200 AZ-101 Feed Test Conditions and Results (VSL-04R4800-4) [30] (continued).

<table>
<tr><td colspan="6">AZ-101 (Target Glass Yield = 0.375 kg/kg or 530 g/l), Bubbling = 65 lpm with Two J Bubblers 6” from floor pointed towards the melt pool center</td></tr>
<tr><td colspan="2">-</td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td rowspan="3">Time</td><td>Feed Start</td><td>6/25/03<br>12:00</td><td>6/26/03<br>13:00</td><td>6/28/03<br>13:02</td><td>6/30/03<br>13:02</td></tr>
<tr><td>Feed End</td><td>6/26/03<br>13:00</td><td>6/28/03<br>13:02</td><td>6/30/03<br>13:02</td><td>7/02/03<br>13:01</td></tr>
<tr><td>Interval</td><td>25 hr</td><td>48 hr</td><td>48 hr</td><td>48 hr</td></tr>
<tr><td colspan="2">Water Feeding for Cold Cap</td><td>1 hr</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td colspan="2">Slurry Feeding</td><td>24 hr</td><td>48 hr</td><td>48 hr</td><td>48 hr</td></tr>
<tr><td colspan="2">Cold cap burn</td><td>NA</td><td>NA</td><td>NA</td><td>1.7 hr</td></tr>
<tr><td colspan="2">Bubbler Skewing</td><td>None</td><td>None</td><td>16 lpm, step</td><td>16 lpm, gradual</td></tr>
<tr><td rowspan="2">Feed</td><td>Used</td><td>2344 kg</td><td>6643 kg</td><td>6907 kg</td><td>7034 g</td></tr>
<tr><td>Average Rate</td><td>97.7 kg/hr</td><td>138.4 kg/hr</td><td>143.9 kg/hr</td><td>146.5 kg/hr</td></tr>
<tr><td rowspan="4">Glass Produced</td><td>Poured</td><td>795 kg</td><td>2484 kg</td><td>2619 kg</td><td>2757 kg</td></tr>
<tr><td>Average Rate$^{\$}$</td><td>663 kg/m$^2$/day</td><td>1035 kg/m$^2$/day</td><td>1091 kg/m$^2$/day</td><td>1148 kg/m$^2$/day</td></tr>
<tr><td>Average Rate$^*$</td><td>733 kg/m$^2$/day</td><td>1038 kg/m$^2$/day</td><td>1079 kg/m$^2$/day</td><td>1099 kg/m$^2$/day</td></tr>
<tr><td>Steady State Rate$^*$</td><td>Not Attained</td><td>1050 kg/m$^2$/day</td><td>1100 kg/m$^2$/day</td><td>1100 kg/m$^2$/day</td></tr>
</table>

"-" Empty data field
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

## Table 1.12. Summary of DM1200 AZ-101 Feed Test Conditions and Results (VSL-04R4800-4) [30] (continued).

AZ-101 (Target Glass Yield = 0.315 kg/kg or 400 g/l), Bubblers on floor, 8" apart on East and West side, one bubbler outlet 11.3" from feed tube. Refer to Figure 2.6 for Segments 3A & 3B bubbler placement. Segment 3C used only the L bubblers in Figure 2.6.

| - | | A | B | C |
|---|---|---|---|---|
| Time | Feed Start | 7/15/03 12:15 | 7/16/03 12:53 | 7/20/03 10:02 |
| | Feed End | 7/16/03 12:53 | 7/20/03 10:02 | 7/22/03 20:20 |
| | Interval | 24.6 hr | 93.2 hr | 58.3 hr |
| Water Feeding for Cold Cap | | 0.6 hr | NA | NA |
| Slurry Feeding | | 24 hr | 93.2 hr | 58.3 hr |
| Cold cap burn | | NA | NA | 1.1 hr |
| Bubblers | Outlets | 4 | 4 | 2 |
| | Steady State Bubbling Rate | NA | 135 lpm | 80 lpm |
| Feed | Used | 2289 kg | 17252 kg | 9532 kg |
| | Average Rate | 95.4 kg/hr | 185.1 kg/hr | 163.5 kg/hr |
| Glass Produced | Poured | 658 kg | 5358 kg | 3173 kg |
| | Average Rate$ | 548 $kg/m^2/day$ | 1150 $kg/m^2/day$ | 1089 $kg/m^2/day$ |
| | Average Rate* | 600 $kg/m^2/day$ | 1164 $kg/m^2/day$ | 1028 $kg/m^2/day$ |
| | Steady State Rate* | Not Attained | 1300 $kg/m^2/day$ | 1100 $kg/m^2/day$ |

"-" Empty data field
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

**Table 1.12. Summary of DM1200 AZ-101 Feed Test Conditions and Results (VSL-04R4800-4) [30] (continued).**

| AZ-101 (Target Glass Yield = 0.315 kg/kg or 400 g/l), four bubblers on floor, one in each corner, 14" apart on East and West side. Refer to Figure 2.7 for bubbler placement. | | | | |
|---|---|---|---|---|
| - | | A | B | C |
| Time | Feed Start | 8/05/03 12:16 | 8/06/03 12:00 | 8/10/03 15:00 |
| | Feed End | 8/06/03 12:00 | 8/10/03 15:00 | 8/13/03 15:01 |
| | Interval | 23.7 hr | 99 hr | 72 hr |
| Water Feeding for Cold Cap | | 1.7 hr | NA | NA |
| Slurry Feeding | | 22 hr | 99 hr | 72 hr |
| Cold cap burn | | NA | NA | 1.1 hr |
| Glass Temperature | | 1150°C | 1150°C | 1175°C |
| Steady State Bubbling Rate | | NA | 117 lpm | 90 lpm |
| Steady State Power Use | | NA | 238 kW | 243 kW |
| Feed | Used | 2596 kg | 19079 kg | 16515 kg |
| | Average Rate | 118.0 kg/hr | 192.7 kg/hr | 229.4 kg/hr |
| Glass Produced | Poured | 780 kg | 5931 kg | 5351 kg |
| | Average Rate$^{\$}$ | 709 kg/m$^2$/day | 1198 kg/m$^2$/day | 1486 kg/m$^2$/day |
| | Average Rate$^{*}$ | 742 kg/m$^2$/day | 1212 kg/m$^2$/day | 1443 kg/m$^2$/day |
| | Steady State Rate$^{*}$ | Not Attained | 1400 kg/m$^2$/day | 1450 kg/m$^2$/day |

"-" Empty data field
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

# Table 1.12. Summary of DM1200 AZ-101 Feed Test Conditions and Results (VSL-04R4800-4) [30] (continued).

| AZ-101 (Target Glass Yield = 0.315 kg/kg or 400 g/l), Two L Bubblers on floor, Bubbler on East side 11.3" from feed tube as shown for the two L bubblers in Figure 1.6, Bubbling rate = 80 lpm. | | | | | |
|---|---|---|---|---|---|
| - | | A | B | C | D |
| Time | Feed Start | 9/03/03 12:46 | 9/04/03 13:51 | 9/06/03 14:30 | 9/08/03 15:29 |
| | Feed End | 9/04/03 13:51 | 9/06/03 14:30 | 9/08/03 15:29 | 9/10/03 15:30 |
| | Interval | 25.1 hr | 48.7 hr | 49 hr | 48 hr |
| Water Feeding for Cold Cap | | 1 hr | NA | NA | NA |
| Slurry Feeding | | 24.1 hr | 48.7 hr | 49 hr | 48 hr |
| Cold cap burn | | NA | NA | 1.1 hr | 2.7 hr |
| Spike Solution Used | | None | NaCl | $Na_2SO_4$ | NaCl + $Na_2SO_4$ |
| Feed | Used | 2789 kg | 6604 kg | 5804 kg | 7029 kg |
| | Average Rate | 115.7 kg/hr | 135.6 kg/hr | 118.4 kg/hr | 146.4 kg/hr |
| Glass Produced | Poured | 770 kg | 1958 kg | 1920 kg | 2516 kg |
| | Average Rate$ | 639 $kg/m^2/day$ | 804 $kg/m^2/day$ | 784 $kg/m^2/day$ | 1048 $kg/m^2/day$ |
| | Average Rate* | 730 $kg/m^2/day$ | 853 $kg/m^2/day$ | 745 $kg/m^2/day$ | 921 $kg/m^2/day$ |
| | Steady State Rate* | Not Attained | Not Attained | Not Attained | 930 $kg/m^2/day$ |

"-" Empty data field
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

## Table 1.12. Summary of DM1200 AZ-101 Feed Test Conditions and Results (VSL-04R4800-4) [30] (continued).

| AZ-101 (Target Glass Yield = 0.315 kg/kg or 400 g/l), Two bubblers, each with two outlets 8 inches apart, placed on the floor, one bubbler outlet 11.3” from feed tube. Refer to Figure 2.9 for bubbler placement. | | | |
|---|---|---|---|
| - | | A | B |
| Time | Feed Start | 3/23/04 19:21 | 3/29/04 20:35 |
| | Feed End | 3/29/04 20:35 | 4/1/04 20:35 |
| | Interval | 145.2 hr | 72.0 hr |
| Water Feeding for Cold Cap | | 1.2 hr | NA |
| Slurry Feeding | | 144.0 hr | 72.0 hr |
| Cold cap burn | | NA | 5.7 hr |
| Sugar concentration | | 3.8 g/l | 3.8 g/l |
| Bubblers | Outlets | 4 | 4 |
| | Steady State Bubbling Rate | 64 lpm | 134 lpm |
| Feed | Used | 23248 kg | 15206 kg |
| | Average Rate | 161 kg/hr | 211 kg/hr |
| Glass Produced | Poured | 7240 kg | 4920 kg |
| | Average Rate$^{\$}$ | 1006 kg/m$^2$/day | 1366 kg/m$^2$/day |
| | Average Rate$^*$ | 1017 kg/m$^2$/day | 1330 kg/m$^2$/day |
| | Steady State Rate$^*$ | 1050 kg/m$^2$/day | 1400 kg/m$^2$/day |

"-" Empty data field
$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.

**Table 1.13. Summary of Test Conditions and Results for Turnover Tests using LAW Sub-Envelope C1 and LAW Envelope A (VSL-04R4851-1) [31].**

| - | | A | B |
|---|---|---|---|
| Time | Feed Start | 9/25/03 06:40 | 9/26/03 12:05 |
| | Feed End | 9/26/03 10:00 | 9/26/03 20:47 |
| | Interval | 27.3 hr | 8.7 hr |
| Water Feeding for Cold Cap | | 1.0 hr | NA |
| Slurry Feeding | | 26.3 hr | 8.7 hr |
| Average Bubbling Rate | | 100 lpm | 96 lpm |
| Feed | Type | Mixed LAW, LAWC | LAWC |
| | Used | 5545 kg | 1895 kg |
| | Average Rate | 210.8 kg/hr | 217.8 kg/hr |
| Glass | Poured | 2831 kg | 834 kg |
| | Average Rate$ | 2153 kg/m$^2$/day | 1917 kg/m$^2$/day |
| | Average Rate* | 2159 kg/m$^2$/day | 2230 kg/m$^2$/day |
| Cold cap burn-off | Conditions | Power Off,<br>Bubbling = 63 lpm | Power Off,<br>Bubbling = 9.4 lpm |
| | Duration | 1 hour, 2 minutes | 2 hour, 49 minutes |
| | Consumed | 100 % | 50 % |
| | Average Glass Temperature when power restored | 1031°C | 950°C |
| | Additional time required after power restoration to complete cold cap burn-off | NA | 2.0 hr |

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.
"-" Empty data field

## Table 1.14. Summary of Test Conditions and Results for LAW Envelope C Rate Test (VSL-04R4851-1) [31].

| - | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| Time | Feed Start | 9/30/03 07:06 | 10/01/03 11:00 | 10/03/03 11:00 | 10/05/03 11:00 | 10/07/03 11:30 |
| | Feed End | 10/01/03 11:00 | 10/03/03 11:00 | 10/05/03 11:00 | 10/07/03 11:30 | 10/09/03 17:02 |
| | Interval | 27.9 hr | 48.0 hr | 48.0 hr | 48.5 hr | 53.5 hr |
| Water Feeding for Cold Cap Creation or Maintenance | | 1.0 hr | NA | NA | NA | 4.0 hr |
| Slurry Feeding | | 26.9 hr | 48.0 hr | 48.0 hr | 48.5 hr | 49.5 hr |
| Average Bubbling Rate | | 91.3 lpm | 20.6 lpm | 41.1 lpm | 62.1 lpm | 103.4 lpm |
| Cold cap burn-off | | NA | NA | NA | NA | 3.2 hr[#] |
| Feed | Used | 5509 kg | 3530 kg | 5402 kg | 7359 kg | 11232 kg |
| | Average Rate | 204.8 kg/hr | 73.5 kg/hr | 112.5 kg/hr | 151.7 kg/hr | 226.9 kg/hr |
| Glass Produced | Poured | 2593 kg | 2046 kg | 2449 kg | 3689 kg | 5855 kg |
| | Average Rate[$] | 1928 kg/m$^2$/day | 853 kg/m$^2$/day | 1020 kg/m$^2$/day | 1521 kg/m$^2$/day | 2365 kg/m$^2$/day |
| | Average Rate[*] | 2097 kg/m$^2$/day | 753 kg/m$^2$/day | 1152 kg/m$^2$/day | 1554 kg/m$^2$/day | 2323 kg/m$^2$/day |
| | Steady State Rate[*] | Not Attained | 750 kg/m$^2$/day | 1200 kg/m$^2$/day | 1600 kg/m$^2$/day | 2500 kg/m$^2$/day |
| | Average Power Use | 1.8 kW.hr/ kg glass | 2.4 kW.hr/ kg glass | 2.1 kW.hr/ kg glass | 1.9 kW.hr/ kg glass | 1.8 kW.hr/ kg glass |

$ - Rates calculated from glass poured.

*- Rates calculated from feed data.

# - Average glass temperature dropped to 1045°C during water feeding, lengthening time for cold cap burn-off.

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

NA: Not applicable.

"-" Empty data field

### Table 1.15. Summary of DM1200 Test Conditions and Results Using LAW Envelopes A and C and Various HLW Feeds (VSL-03L4850-1) [34].

| - | | | LAW Test | HLW Test |
|---|---|---|---|---|
| Time | Feed Start | | 11/03/03 13:30 | 11/06/03 01:30 |
| | Feed End | | 11/06/03 01:30 | 11/07/03 20:01 |
| | Duration | | 60 hr | 42.5 hr |
| Water Feeding for Start-up | | | 1 hr | NA |
| Slurry Feeding | | | 59 hr | Hr |
| Cold cap burn-off | | | NA | 4 hr |
| Feed Reductant | | | Sugar | None |
| Feed | Type | | LAWA + LAWC [5] | AZ-101 with and without sugar [6], AZ-102 [7], C104/AY-101 [8] |
| | Used | | 9610 kg | 7620 kg |
| | Glass yield (estimated) | | 0.516 kg/kg feed | 0.375 kg/kg feed |
| | Average Rate | | 163 kg/hr | 179 kg/hr |
| | Average Rate During Alcohol Feeding | | 168 kg/hr | 166 kg/hr |
| Alcohol Feeding | 1 | Start | 11/05/03, 07:10 | 11/06/03, 09:07 |
| | | End | 11/05/03, 08:58 | 11/06/03, 10:54 |
| | 2 | Start | 11/05/03, 09:28 | 11/06/03, 11:17 |
| | | End | 11/05/03, 11:28 | 11/06/03, 12:57 |
| | 3 | Start | 11/05/03, 13:45 | 11/06/03, 13:22 |
| | | End | 11/05/03, 15:41 | 11/06/03, 15:29 |
| | Run Time Interval | | 41.7 – 50.2 hours | 67.6 – 74.0 hours |
| Glass Production Rate | Average Rate$^*$ | | 1682 kg/m$^2$/day | 1345 kg/m$^2$/day |
| | Average Rate$^*$ During Alcohol Feeding | | 1734 kg/m$^2$/day | 1245 kg/m$^2$/day |

*- Rates calculated from feed data.
NA – Not applicable.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
"-" Empty data field

## Table 1.16. Summary of DM1200 AZ-102 and C-106/AY-102 Test Conditions and Results (VSL-05R5800-1) [35].

| - | | 1A1 | 1A2 | 1B | 2A | 2B |
|---|---|---|---|---|---|---|
| Time | Feed Start | 6/21/04<br>13:36 | 6/23/04<br>18:40 | 6/25/04<br>16:15 | 8/02/04<br>15:15 | 11/08/04<br>09:30 |
| | Feed End | 6/23/04<br>17:46 | 6/25/04<br>12:33 | 6/30/04<br>11:30 | 8/07/04<br>17:33 | 11/12/04<br>19:18 |
| | Interval | 52.2 hr | 41.9 hr | 115.3 hr | 110.3 hr | 105.8 hr |
| Water Feeding for Cold Cap | | 2.0 hr | NA | 1.3 hr | 3.0 hr | 1.0 hr |
| Slurry Feeding | | 50.2 hr | 41.9 hr | 114 hr | 107.3 hr | 104.8 hr |
| Cold cap burn | | NA | 1.2 hr | 1.5 hr | 2 hr | 2.2 hr |
| Bubbling | Bubblers | “J” , single outlet | “J” , single outlet | Prototypic, Double Outlet | “J” , single outlet | Prototypic, Double Outlet |
| | Location | 6” above floor | 6” above floor | On floor | 6” above floor | On floor |
| | Control | Constant | Constant | Optimized | Constant | Optimized |
| | Average Total | 60 lpm | 64 lpm | 100 lpm | 63 lpm | 87 lpm |
| | Steady State | 65 lpm | 65 lpm | 65 lpm | 65 lpm | 90 lpm |
| Feed | Simulant | AZ-102 | AZ-102 | AZ-102 | C-106/AY-102 | High waste loading C- |
| | Rheology | Adjusted | Adjusted | Nominal | Adjusted | Nominal |
| | Glass Yield | 0.384 kg/kg | 0.347 kg/kg | 0.27 kg/kg | 0.372 kg/kg | 0.263 kg/kg |
| | | 560 g/l | 480 g/l | 340 g/l | 540 g/l | 340 g/l |
| | Used | 7877 kg | 6836 kg | 20002 kg | 14300 kg | 20100 kg |
| | Average Rate | 156.9 kg/hr | 163.2 kg/hr | 175.5 kg/hr | 130.8 kg/hr | 191.8 kg/hr |
| Glass Produced | Poured | 2932 kg | 2465 kg | 5576 kg | 5193 kg | 5168 kg |
| | Average Rate$ | 1168 $kg/m^2/day$ | 1177 $kg/m^2/day$ | 978 $kg/m^2/day$ | 968 $kg/m^2/day$ | 986 $kg/m^2/day$ |
| | Average Rate* | 1204 $kg/m^2/day$ | 1133 $kg/m^2/day$ | 948 $kg/m^2/day$ | 982 $kg/m^2/day$ | 1008 $kg/m^2/day$ |
| | Steady State Rate* | 1350 $kg/m^2/day$ | 1150 $kg/m^2/day$ | 900 $kg/m^2/day$ | 1010 $kg/m^2/day$ | 1050 $kg/m^2/day$ |

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
NA: Not applicable.
"-" Empty data field

## Table 1.17. Summary of HLW MACT Test Conditions and Results (VSL-05R5830-1) [41].

| C-106/AY-102 Simulant + MACT spikes, Target Glass Yield = 0.312 kg/kg | | | | | |
|---|---|---|---|---|---|
| Test | | 1 | 2A | 1-continued | 2B |
| Target Plenum Temp. (C°) | | 400 | 300 | 400 | 500 |
| Average$^{\#}$ Measured Plenum Temp. (C°) | 8” below ceiling | 400 | 353 | 410 | 488 |
| | 17”below ceiling | 392 | 338 | 387 | 484 |
| | Exposed TC | 405 | 345 | 407 | 593 |
| | Overall | 399 | 345 | 401 | 522 |
| Time | Feed Start | 11/15/04 13:45 | 12/6/04 10:12 | 12/9/04 13:24 | 12/10/04 09:40 |
| | Feed End | 11/17/04 18:00 | 12/9/04 13:24 | 12/10/04 09:40 | 12/12/04 15:35 |
| | Duration | 52.3 hr | 75.2 hr | 19.1 hr | 54.0 hr |
| Water Feeding for Start-up | | 1.0 hr | 1.0 hr | NA | NA |
| Slurry Feeding | | 51.3 hr | 74.2 hr | 19.1 hr | 54.0 hr |
| Cold Cap Burn-Off | | 2.0 hr | NA | NA | 2.0 hr |
| Average Bubbling Rate (lpm) | | 23.9 | 9.2 | 28.1 | 42.7 |
| Organic Spikes | Type | Allyl Alcohol | Allyl Alcohol | Naphthalene/ MeOH | NA |
| | Rate | 40 g/min | 40 g/min | 13 g/min | |
| | Start | 11/16/04 11:36 | 12/07/04 11:29 | 12/09/04 13:38 | |
| | End | 11/16/04 17:42 | 12/07/04 17:58 | 12/09/04 21:00 | |
| | Duration | 6.1 hr | 6.5 hr | 7.4 hr | |
| | Type | Naphthalene/ MeOH | Naphthalene/ MeOH | NA | |
| | Rate | 13 g/min | 13 g/min | NA | |
| | Start | 11/17/04 12:15 | 12/08/04 10:44 | NA | |
| | End | 11/17/04 17:36 | 12/08/04 21:38 | NA | |
| | Duration | 5.4 hr | 10.9 hr | NA | |
| | Type | NA | Allyl Alcohol/ Naphthalene | NA | |
| | Rate | NA | 40 g/min | NA | |
| | Start | NA | 12/09/04 10:28 | NA | |
| | End | NA | 12/09/04 13:22 | NA | |
| | Duration | NA | 2.9 hr | NA | |
| Feed | Used | 5751 kg | 6656 kg | 2268 kg | 9294 kg |
| | Average Rate | 112 kg/h | 88 kg/hr | 119 kg/hr | 172 kg/hr |
| Glass Produced | Poured | 1833 kg | 1933 kg | 724 kg | 3035 kg |
| | Average Rate$^{\$}$ | 715 kg/m$^2$/day | 521 kg/m$^2$/day | 758 kg/m$^2$/day | 1122 kg/m$^2$/day |
| | Average Rate$^{*}$ | 699 kg/m$^2$/day | 550 kg/m$^2$/day | 742 kg/m$^2$/day | 1072 kg/m$^2$/day |

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
NA – Not applicable.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.

## Table 1.18. Summary of LAW MACT Test Conditions and Results (VSL-05R5830-1) [41].

| Test | | 1 | 2B | 2A |
|---|---|---|---|---|
| Target Plenum Temp. (C°) | | 400 | 500 | 300 |
| Average$^{\#}$ Measured Plenum Temp. (C°) | 8" below ceiling | 397 | 490 | 321 |
| | 17"below ceiling | 414 | 504 | 333 |
| | Exposed TC | 416 | 503 | 326 |
| | Overall | 409 | 499 | 327 |
| Time | Feed Start | 3/7/05 09:03 | 3/17/05 9:30 | 3/20/05 06:01 |
| | Feed End | 3/10/05 12:01 | 3/20/05 06:00 | 3/23/05 03:01 |
| | Duration | 75 hr | 68.5 hr | 69 hr |
| Water Feeding for Start-up | | 1.0 hr | 1.0 hr | NA |
| Slurry Feeding | | 74 hr | 67.5 hr | 69 hr |
| Cold Cap Burn-Off | | 1.3 hr | NA | 1.2 hr |
| Average Bubbling Rate (lpm) | | 26 | 43 | 9.3 |
| Organic Spikes | Type | Allyl Alcohol | - | Allyl Alcohol/ Naphthalene |
| | Rate | 10 g/min | | 11 g/min |
| | Start | 3/8/05 10:06 | | 3/21/05 09:00 |
| | End | 3/8/05 16:50 | | 3/21/05 20:16 |
| | Duration | 6.7 hr | | 11.3 hr |
| | Type | Naphthalene/ MeOH | | Naphthalene/ MeOH |
| | Rate | 13 g/min | | 13 g/min |
| | Start | 3/9/05 10:02 | | 3/22/05 09:05 |
| | End | 3/9/05 21:12 | | 3/22/05 19:58 |
| | Duration | 11.2 hr | | 10.9 hr |
| Feed | Used | 9036 kg | 11000 kg | 8714 kg |
| | Average Rate | 122 kg/h | 163 kg/hr | 126 kg/hr |
| Glass Produced | Poured | 4774 kg | 5779 kg | 4648 kg |
| | Average Rate$^{\$}$ | 1290 kg/m$^2$/day | 1712 kg/m$^2$/day | 1347 kg/m$^2$/day |
| | Average Rate$^{*}$ | 1287 kg/m$^2$/day | 1718 kg/m$^2$/day | 1331 kg/m$^2$/day |
| | Steady State Rate | 1400 kg/m$^2$/day | 1850 kg/m$^2$/day | 1300 kg/m$^2$/day |

$ - Rates calculated from glass poured.
*- Rates calculated from feed data.
NA – Not applicable.
Note: Rates do not take into account the time for water feeding and cold cap burn-off.
"-" Empty data field

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections.

| Report | Feed | Date | Melter performance, observations, and maintenance activities. |
|---|---|---|---|
| VSL-01R0100-2 | HLW AZ-101 (5/07/01-5/23/01, 5/14/01-5/16/01, 5/21/01-5/23/01) | | Completed construction and installation of the DM1200 system during Part B1.<br>Note: Anytime during the insertion of anything to or removal of anything from the melter glass pool, power was secured. |
| | | 8/1/2000 | Approximately 37 gallons of ethylene glycol were added to the system. The system was tested to have a freezing point of ~ 20°F. This corresponds to 17% ethylene glycol concentration in the cooling system. Therefore, the estimated cooling system volume is ~ 217 gallons. |
| | | 8/22/2000 | Started leak test of DM1200 melter to determine the actual melter air inleakage. The calibrated thermocouples used for the bake out were MM-XXX-TR-01, -02, -03, -04, -05 and -06. |
| | | 8/23-25/2000 | DM1200 Melter bake out. (Note: The melter bake out period lasted for longer than normal due to contractor changes at the WTP, and time taken to make decisions about the future of the DM1200 test program.) |
| | | 9/6/2000 | DM1200 Melter bake out. |
| | | 10/4/2000 | To size a regenerative air blower to supply air to the dam cooler, pressure drop across the dam cooler pipe was determined. |
| | | 10/10/2000 | Replaced electrode VI power transducer. |
| | | 11/02-06/2000 | Continued and finished installation of the transition line.<br>Changed the location of the EOG vent line. Replaced the main EOG valve, MM-EOG-V-401. Installed EOG dilution air valve, MM-EOG-V-402. |
| | | 11/10-20/2000 | Worked on cooling system modification so that during melter idling conditions we would be able to maintain the cooling panel temperatures warm enough to prevent moisture condensation. |
| | | 12/29/2000 | CUA power outage between 7:15 and 12:00. Melter powered by VSL backup diesel generator. |
| | | 1/17/2001 | Continued DM1200 Melter bake out. Melter Emergency off-gas was operational only in the manual mode. Back up city water was operational. However, the primary side of the building chilled water supply was not functional. The secondary cooling water was operating in the closed loop. Back up compressed air bubblers were tested. One out of six pressure regulators was leaking air slightly and was marked for replacement. Bottom electrode was isolated. Air was supplied to the electrode bubblers. Melter electrode power supply was locked-out/tagged out. |
| | | 1/21/2001 | Procedures were set up for dealing with circuit breaker tripping and fire in the control panel. |
| | | 1/21-23/2001 | Cooling system temperature testing was completed. Heat removal capacity of the back-up heat exchanger, MCL-CW-HX-401 in which the city water was used as the cooling medium, was tested with the primary system chilled water pump, MCL-CW-P-401 secured. |
| | | 1/22/2001 | Heat loss through the emergency off-gas line was determined as a function of the off-gas exit temperature. |
| | | 2/13-14/2001 | Reducing air in-leakage into the melter was explored. Air in-leakage was determined as a function of the melter vacuum.<br>Pitot tube on the transition line was clogged. |
| | | February 2001 | Discharge chamber heater elements were placed in service. |
| | | 2/14/2001 | Silicon caulking was applied around electrodes and other locations to reduce air in-leakage. |
| | | 2/26/2001 | Obtained dip measurements of glass pool depth, which was found to be 23". |
| | | 3/09/2001 | An automotive type antifreeze tester was used to find the freezing point of the cooling system fluid. The measured freezing point was between +10 and +20 °F. Added ~ 2gallons of Betz NT402 corrosion inhibitor to the system. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-01R0100-2 | HLW AZ-101 (5/07/01-5/23/01, 5/14/01-5/16/01, 5/21/01-5/23/01) | 3/15-23/2001 | Started water feed to test the performance of the DM1200 melter and off-gas system. |
| | | 3/19/2001 | Performed a three-point accuracy check of cooling system thermocouples (readings were within ½%). |
| | | 3/20/2001 | Between 7:25 and 10:05 the auxiliary diesel generator was tested. |
| | | 3/26-27/01 | Performance of the DM1200 melter was tested with water feed. |
| | | 3/28/2001 | First start-up test with about 2000 kg of HLW AZ-101 feed was performed to assess the performance of the new melter, identify and correct problems, train operators, and finalize procedures. |
| | | 3/29/2001 | Between 10:30 and 11:04, turned melter power off to insulate under melter around heat exchanger. |
| | | 3/292001 | The thermocouples (TCs) of MM-XXX-TR-12, -01, -06 were calibrated. |
| | | 4/18/2001 | Discharge chamber silicon controlled rectifier, SCR, was set to full output. |
| | | 5/17/2001 | Replaced EOG HEPA train (MM-EOG-F-401) local differential pressure gauge (MM-EOG-DPI-400) with a 0-5" W.C. scale gauge to improve sensitivity. |
| | | 5/18/2001 | Removed circuit 6 heaters (two heaters) from the discharge chamber for inspection. |
| | | 5/25/2001 | Work began on chilled water system to monitor cooling panel temperatures. All temperature readings were satisfactory. Six hours later, the chilled water system was returned to normal operation. |
| | | 5/30/2001 | Cooling system controls were tested. |
| VSL-02R0100-2 | HLW AZ-101 (6/25/01-7/2/01, 7/23/01-8/1/01, 8/6/01-8/11/01, 8/20/01-8/25/01, 9/25/01-10/1/01, 10/11/01-10/17/01, 10/22/01-10/27/01, 10/29/01-11/2/01, 11/5/01-11/10/01) | 6/7/2001 | Power to the electrodes was shut off to reconfigure for side-to-bottom firing. |
| | | 6/16/2001 | Removed the power fuse for the affected discharge heater circuit (see above). |
| | | 6/19/2001 | Electrode bubbler #1 was partially clogged; highest attainable flow rate was 1.0 SCFH |
| | | 6/20/2001 | Electrode bubbler #5 flow rate was <3.5 SCFH with backpressure of 37 psi. Adjusted flow rate to 1.0 SCFH, backpressure was 32 psi. Electrode bubblers 1 and 5 are now at a flow rate of 1.0 SCFH, bubblers 2, 3 and 4 are at a flow rate of 3.5 SCFH. |
| | | 6/21/2001 | Found that electrode bubbler 5 flow rate can be increased to 3.5 SCFH at a backpressure of 40 psi. Electrode bubbler 1 flow rate is 1.0 SCFH, bubblers 2, 3, 4 and 5 are at 3.5 SCFH flow rate. |
| | | 6/23/2001 | Checked the melter operating parameters every two hours and everything is within acceptable limits. |
| | | 6/25/2001 | Replaced heating elements of discharge chamber heaters 1B and 3A. |
| | | 7/10/2001 | A selector switch was installed so that the melter can be operated based on power or glass temperature feedback control. |
| | | 7/19/2001 | Removed thermowell for inspection.<br>Observed a 2" long and 1" wide high temperature/arc coloration on thermowell (TW) #2 at 9"-11" from the bottom, and another spot on opposite side of pipe at 8" from the bottom. Also observed signs of arcing at the very bottom of the pipe.<br>The immersed section of thermowell in the glass had become thinner. Signs of metal erosion near the tip also were observed. The melter-air interface section looked relatively intact. Installed new thermowell #2 on the west side. All thermowell thermocouples of MM-XXX-TR-01, -02, -03, -04 and -05 were replaced. |
| | | 7/21/2001 | Secured discharge chamber for maintenance and later energized the discharge chamber heaters. Calibrated melter pressure sensor at instrument port (MM-XXX-PR-200). |
| | | 7/22/2001 | The melter pressure sensor at level detector port was labeled as MM-AR-PR-202. |
| | | 7/23/2001 | The power transducer for DM1200 melter electrodes was modified to improve response. |
| | | 7/23/2001 | Emergency diesel generator (new 300 kW generator) was installed. Verified that MM-XXX-TR-01, -02, -03, -12 and -13 TCs were used to determine the average glass temperatures. Cleaned emergency off-gas port. The pipe was ~75% clogged. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-02R0100-2 | HLW AZ-101<br>(6/25/01-7/2/01,<br>7/23/01-8/1/01,<br>8/6/01-8/11/01,<br>8/20/01-8/25/01,<br>9/25/01-10/1/01,<br>10/11/01-10/17/01,<br>10/22/01-10/27/01,<br>10/29/01-11/2/01,<br>11/5/01-11/10/01) | 7/25/2001 | Replaced 0-10 SCFH airlift flowmeter with a 2-20 SCFH flowmeter due to airlift requiring >10 SCFH flow rate to lift glass at desired rate. |
| | | 8/2/2001 | Removed TW #1 for inspection. Turned power off during removal.<br>Feed tube "B" was removed to allow bubbler testing to occur utilizing this port.<br>Visual inspection of TW #1 showed multiple "arc" spots with slight metal degradation. No obvious failure points. Decided to remove 60" of old TW pipe and weld on a new 60" section.<br>Reinstalled TW #1 with the same TC's that were in use. Power was turned off during this evolution.<br>Reconfigured electrode firing side to side. Torqued connecting fasteners to 105 lb-ft. Removed TW #2 for inspection. No signs of arcing. Reinstalled TW #2 and reconnected TCs. |
| | | 8/3/2001 | Melter lid components were re-configured. Electrode bubbler back pressures were going up, which was an indication that these bubblers were clogging.<br>A new thermocouple was installed in lance bubbler #2.<br>Lance bubbler #1 was installed in port A-3,<br>Lance bubbler #2 was installed in port D-1,<br>Level detector was installed in port B-1,<br>TW #1 was installed in port A-2,<br>TW #2 was installed in port D-2.<br>Feed tube A was installed in port C-2,<br>Feed tube B was installed in port B-2. |
| | | 8/6/2001 | Secured electrode power. Lowered lance bubbler #2 to 6" from floor. Also installed lance bubbler #1 in the southeast port. Power was restored. Checked glass level and glass density transmitter's calibration. Removed MM-CA-MFCR-001and -002 to recalibrate. Calibration of MM-CA-MFCR-003 and -005 were performed. Bubbler outlets were installed at depths of ~62.8" and ~68.8" from the lid of the melter. Bottom of bubblers were 6" below bottom of side electrode. |
| | | 8/8/2001 | Replaced mass flow controller for lance bubbler #2. Controller was very hot. Installed a temporary fan to cool the controller. Mass flowmeter was removed and shipped to factory for repair/calibration/evaluation. |
| | | 8/11/2001 | Changed melter voltage taps from 168 V to 112 V to reduce harmonic frequency in SCR (silicon controlled rectifier) and maximize power transfer. Control power output was 70 kW. |
| | | 8/13/2001 | Melter pressure increased to +0.6" W.C. Replaced all EOG filters. Melter pressure decreased to -0.4" W.C. |
| | | 8/14/2001 | Re-configured electrodes to fire side to bottom. Torqued connecting hardware to105 ft-lbs. Raised both lance bubblers to 11 ½". This puts bottom of lance bubblers even with the middle of the side electrode. |
| | | 8/15/2001 | Removed TW #1 (east side) for inspection. Found one small heat mark on the end of TW #1. Reinstalled TW #1 and reconnected TCs. |
| | | 8/17/2001 | Lance bubbler #1 flow is low with mass flow meter controller (MM-CA-MFCR-001). Switched the flow control to MM-CA-MFCR-004 in order to repair the other mass flow controller. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-02R0100-2 | HLW AZ-101 (6/25/01-7/2/01, 7/23/01-8/1/01, 8/6/01-8/11/01, 8/20/01-8/25/01, 9/25/01-10/1/01, 10/11/01-10/17/01, 10/22/01-10/27/01, 10/29/01-11/2/01, 11/5/01-11/10/01) | 8/20/2001 | Lowered both lance bubblers 4" and installed both feed tubes. MM-XXX-TR-17 TC was installed as plenum exposed TC at an insertion depth of 17" below the ceiling through EOG clean-out flange.<br>MM-CA-MFCR-003 and -005 readings were compared with NIST traceable flow meter readings.<br>Verified temperature averaging for the TCs of MM-XXX-TR-02, -03, -12, and -13. MM-XXX-TR-19 TC was replaced.<br>Back-up mass flow controller comparison check was performed with a NIST traceable calibrated flowmeter.<br>Adjusted electrode power input range; changed from 218 kW to 250 kW.<br>Replaced MM-XXX-TR15 TC. |
| | | 8/21/2001 | Failure of the mass flowmeter was identified by AALBORG Engineering to a design flaw in the 4-20 mA input, and corrected. |
| | | 8/24/2001 | Replaced TC of emergency HEPA inlet temperature indicator, MM-EOG-TR-11 TC.<br>Calibrated electrode voltage and TCs of MM-XXX-TR-04, -09 and -11. |
| | | 8/28/2001 | Turned off power to the melter, removed TW #2 for inspection, and turned on the melter power and set it to 69 kW. |
| | | 8/29/2001 | Removed mass flow controllers for lance bubblers #1 and #2 for recalibration and replaced them with mass flow controllers with current calibrations. |
| | | 8/30/2001 | MM-AR-PR-202 and MM-XXX-PR-200 transmitters were replaced with fast response Ashcraft transmitters. Loop calibration verified. |
| | | 9/16/2001 | Toshiba UPS for generator power for room 10 was tested. Power failure was simulated, and UPS picked up the load. UPS seems to be compatible with the generator, and the system worked as required. |
| | | 9/7/2001 | Visual inspection of electrodes to make sure that the silicone was still holding in between the electrodes and the melter shell. |
| | | 9/19/2001 | Removed lance bubbler #1 and #2 for inspection. Removed TW #1 for inspection and reinstalled TW #1 in melter. Bubblers and TW photographs were taken. |
| | | 9/24/2001 | Inspected film cooler. Slight build-up on walls. Inspected the Teflon lining of all feed tubes and found them to be in good condition. |
| | | 9/25/2001 | Removed plug A-3, and relocated level detector from port B-1 to port A-3.<br>Feed tubes A and B reinstalled with verification of cooling water flow to each prior to installation. Replaced TCs of MM-XXX-TR-23 and -17. |
| | | 10/10/2001 | Removed TW #2 for inspection. Digital photographs of TW #2 were taken. Observed slight crystallization, but no sign of high temperature or arcing. Reinstalled TW #2. MM-XXX-TR-14 TC failed and was scheduled for replacement. Observed that MM-XXX-TR-14 and TR-15 connections were reversed; error was corrected. |
| | | 10/13/2001 | Replaced TCs of MM-XXX-TR-16 and TR-06. |
| | | 10/18/2001 | Removed TW #1. It did appear that the ceramic insulator or liner in the thermowell around the TC was starting to crack. Relocated the level detector to port B-1. Photographs of TW #1 were taken. |
| | | 10/22/2001 | Removed MM-XXX-TR-17 and -19 TCs for inspection.<br>Secured power to reconfigure electrode firing from side to bottom to side to side, and installed lance bubblers in ports A-3 and D-1. MM-XXX-TR-19 TC was inspected, cleaned and reinstalled. MM-XXX-TR-17 TC was replaced.<br>Tightened all bolts around bubblers, feed tube, TWs and plugs on top of the melter. Bottom of bubbler was 6" below bottom of side electrode. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-02R0100-2 | HLW AZ-101 (6/25/01-7/2/01, 7/23/01-8/1/01, 8/6/01-8/11/01, 8/20/01-8/25/01, 9/25/01-10/1/01, 10/11/01-10/17/01, 10/22/01-10/27/01, 10/29/01-11/2/01, 11/5/01-11/10/01) | 10/23/2001 | Replaced lance bubbler #2 mass flow controller. The unit was sent to AALBORG for repair and failure analysis. |
| | | 10/25/2001 | Replaced MM-XXX-TR-01 TC due to suspected failure. During inspection, found that the entire bundle was stuck together. Replaced TW #1 thermocouples as a group with a multi-TC unit. MM-XXX-TR-01, -02, -03, -04 and -05 TCs were replaced. |
| | | 10/28/2001 | Photographs of TW #1 and TW #2 were taken. TW #1 had about a 6" arcing spot about 2.3 inches from the bottom. TW #2 had 6 arcing spots up about 10 inches from bottom. |
| | | 10/29/2001 | Secured power to reconfigure electrodes for side to bottom firing. Repositioned melter level detector from port B-1 to port A-3 and installed feed tubes. Wired electrodes to fire side to bottom. Replaced all lock washers, torqued bolts to 105 ft-lbf. Tightened all flanges on the melter. Added a new TC in TW #2 to 1" from bottom of melter using the existing TC wire connection for readout on LabVIEW. |
| | | 10/30/2001 | Replaced discharge heaters 1A and 1B. Found heater 1A had failed.<br>Tested the back-up chilled water cooling pump(s) switching by simulating low water pressures. |
| | | 11/3/2001 | Removed TW #1 for inspection. TW #1 showed about a 10-12" stretch of arcing about 2' up from the bottom. Photographs were taken. |
| | | 11/3/2001 | Removed MM-XXX-TR-17 TC (exposed plenum) to minimize damage. |
| | | 11/5/2001 | Used silicone to minimize the air inleakage around the west electrode.<br>Replaced the damaged MM-XXX-TR-17 TC (exposed plenum). |
| | | 11/5/2001 | Inspected film cooler. Observed ~ ½" of build-up below TC on south west side of pipe. Rest of the pipe was very clean up to transition pipe. Above transition pipe there was a dry powdery build-up. |
| | | 11/6/2001 | Ran back-up dam wall regenerative blower and back-up chilled water cooling pumps for 15 minutes. |
| | | 11/7/2001 | Film cooler regenerative blower, MM-RGB-B-102 bearings may have burned up. |
| | | 11/15/2001 | Removed plenum exposed TC MM-XXX-TR-17. Also secured power to remove TW #1 for inspection. TW #2 was removed, and power was restored to 61 kW. Visual inspection of TW #2 showed significant crystallization with ~3-4" wide high temperature indications centered at 10" from end, wrapping full circumference of pipe. Digital photographs were taken. |
| | | 11/20/2001 | Installed new TW #2. Power restored to 61 kW. Also removed TW #1 which showed some signs of crystallization. Took digital photographs. Also, TW #2 had signs of arcing about 12" from bottom. Replaced TW #1 with a new TW. The removed TW had high temperature/burn marks starting approximately 12" from the bottom of the TW and extending to 24" from the bottom of TW. Restored power to 61 kW. |
| | | 11/21/2001 | Automatic transfer switch ATS-10 was installed in the back-up generator system. |
| | | 11/26/2001 | Discharge circuit 4 was not functioning. Total of 2 discharge heaters were affected. |
| | | 11/29/2001 | Removed MM-XXX-TR-12 TC for inspection. It was found defective and was replaced. Replaced thermocouples for MM-XXX-TR-03, -16, -05, -15, -01, -04, -14, -02, -13. |
| | | 12/3/2001 | Relocated the level detector from port A-3 to port B-1. |
| | | 12/8/2001 | Isolated power to the discharge chamber to remove and replace heating elements connected to circuits 2 and 4. Replaced heaters 2A, 2B, 4A and 4B with new elements.<br>Power was restored and set to a maximum of 15 kW. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-02R0100-2 | HLW AZ-101 (6/25/01-7/2/01, 7/23/01-8/1/01, 8/6/01-8/11/01, 8/20/01-8/25/01, 9/25/01-10/1/01, 10/11/01-10/17/01, 10/22/01-10/27/01, 10/29/01-11/2/01, 11/5/01-11/10/01) | 12/10/2001 | Replaced TR-17 (exposed plenum) TC. Replaced bubbler #1 TC.<br>Two new bubblers, bubbler #3 and bubbler #4, were made and new TC installed in them.<br>Secured power to electrodes to reconfigure firing pattern. Restored power to electrodes (firing side by side).<br>Raised electrode power first to 90W then 100 kW.<br>Installed four lance bubblers between 11:23 and 12:00 while power was secured to reconfigure firing pattern.<br>Bubbler #1 was installed in port A-1.<br>Bubbler #2 was installed in port A-3<br>Bubbler #3 was installed in port D-1<br>Bubbler #4 was installed in port D-3<br>Bottoms of the bubblers were 6" below bottom of the side electrodes.<br>Repaired west electrode silicone gasket by applying ¼" bead of RTV (room temperature vulcanizing silicon).<br>Feed tube B gasket was missing; installed silicone gasket, which caused a gain of approximately 1.2" W.C. in melter vacuum. |
| | | 12/11/2001 | Relocated the melter pressure measurement port from D-3 to emergency off-gas line; connections were made for melter pressure sensor and exposed plenum TC.<br>Replaced film cooler regenerative blower, MM-RGB-B-102 with new blower due to the damaged bearing.<br>Installed melter pressure control air (i.e. dilution air) system. System included the following.<br>a. PAXTON blower (OG-DA-B-301) with variable frequency drive.<br>b. Air flow indicator/transmitter.<br>c. Fast acting diverter valve, driven by compressed air and controlled based on melter pressure. |
| | | 12/15/2001 | Placed electrode bubbler air flow through rotameters and turned off power to electrode bubbler mass flow meters.<br>Installed a new TC in melter pressure dilution air pipe and installed a pitot tube upstream of TC. |
| | | 12/17/2001 | Removed lance bubblers #1, #2, #3, and #4. |
| | | 12/18/2001 | Reconfigured electrodes to fire from side to bottom. |
| | | 12/19/2001 | Disconnected power to discharge chamber, replaced two heating elements and two heating sleeves, and restored power. |
| | | 1/4/2002 | Replaced discharge chamber heating elements 1A and 1B. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-02R8800-1 | LAW Envelope C1 with cesium and hazardous organic compounds (1/7/02-1/15/02) | 1/7/2002 | Installed lance bubblers #1, #2, #3, and #4. Bottom of bubblers were 6" below bottom of side electrode. A new TC was installed for the exposed plenum temperature measurement, MM-XXX-TR-17. Replaced the riser TC (MM-XXX-TR-08). |
| | | 1/16-17/2002 | Removed transition line bellows. Only slight coating of material was observed in transition line bellows. Transition line bellows were reinstalled after cleaning. Inspected film cooler. Found large amounts of dry feed build-up on TC (~ ½ pipe diameter) and also in section of pipe above transition line into dilution air port. TC was removed and cleaned.<br>Removed TW #2. Observed what appeared to be a few more arcing marks on the lower end of the tube. Took photographs and reinstalled TW # 2.<br>Secured power to remove lance bubblers and reconfigure electrode firing pattern.<br>Lance bubblers #1 and #2 showed significant signs of crystallization/pitting and slight bow at bottom 6 to 12". Lances bubblers #3 and #4 were in good condition. Photographs were taken. |
| VSL-02R8800-2 | LAW Envelope A1 with cesium, cadmium, selenium and hazardous organic compounds (2/27/02-3/1/02, 3/3/02-3/6/02, 3/18/02 -3/20/02) | 2/20/2002 | Started preparations to install new lance bubblers and change electrode power configuration/tap. Lance bubblers #1 and #2 were replaced with new lance bubblers. New TCs were also installed with the new lance bubblers.<br>All four lance bubblers were installed.<br>Installed plenum exposed TC of MM-XXX-TR-17. |
| | | 2/25/2002 | Inspection of TW #1 showed a slight bow approximately 14" from the bottom. Photographs were taken; TW # 1 was reinstalled. |
| | | 2/26/2002 | Replaced TC of MM-XXX-TR-17. Since the TC was not of the correct length, it was removed and installed at a later date.<br>Added a switch to off-gas and melter labVIEW systems to change the save location of the data file to the local hard drive should network server be down.<br>Added control air flow calculation to labVIEW.<br>Changed many of the instrument cabling to shielded cable in order to reduce the noise in the signal for the following instruments:<br>MM-AR-PR-202 (melter pressure – off-gas labVIEW), MM-XXX-PR-200 (melter pressure - melter labVIEW).<br>The melter pressure measurement (MM-AR-PR-202) output values were averaged over ~ 0 s intervals p in the off gas labVIEW program and the average value signal was transmitted to a CN 7600 series Omega PID process controller to control melter pressure. The melter pressure control range was set to 0-15 inches W.C.<br>The controller was set to maintain melter pressure based on the set point value entered into the controller. The initial amount of control air flowing into the melter was 40-50 SCFM; this amount was varied to maintain melter pressure. |
| | | 2/27/2002 | Installed a new TC for MM-XXX-TR-17.<br>Cooling jacket for Paxton blower failed because it was not made of corrosion resistant material. Based on recommendations from the manufacturer, modifications were made to the blower so that it could be operated at a higher temperature without coolant. |
| | | 3/3/2002 | Replaced plenum exposed TC of MM-XXX-TR-17. Inspected and verified that the film cooler (FC) had only minor build-up on walls. |

### Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-02R8800-2 | LAW Envelope A1 with cesium, cadmium, selenium and hazardous organic compounds (2/27/02-3/1/02, 3/3/02-3/6/02, 3/18/02 -3/20/02) | 3/7/2002 | Secured power to reconfigure electrode firing to side to bottom. Removed lance bubblers and TW #2. Secured power to lance bubbler mass flow controllers based on vendor recommendation to secure power to the mass flow controllers when air is not flowing through them. Restored power. Digital photographs were taken of lance bubbler #2.<br>Removed the level detector and stopped argon flow.<br>Reinstalled TW #2.<br>Removed TW #1 for inspection.<br>Secured power to replace discharge heaters 2A and 2B with new elements.<br>Power was restored. |
| | | 3/8/2002 | Replaced fuse on discharge heater circuit 2, which controls heaters 2A and 2B.<br>Replaced the heating elements of the discharge chamber heaters 2A and 2B.<br>Visual inspection of level detector showed damage to the ends of both glass submerged pipes. On the longest pipe ½" of half the diameter of the pipe was missing, and there was a split in the pipe ~2" up the pipe. On the second longest pipe about the same amount of metal was missing, but no splitting. Also, there was significant crystallization and pitting. Overall lengths of the pipes were still as specified in the drawing. Digital photographs were taken. Inspection of TW #1 showed slightly more crystallization than during the previous inspection. No significant crystallization or heat damage was noticed. Photographs were taken. |
| | | 3/11/2002 | Replaced TW #1 and TCs. Secured electrode power to install new TW #1. Power was restored.<br>Cooling liquid was added to the secondary cooling system to raise the inlet water pressure of the chilled water pumps MCL-CW-P-402A/B from 1 psi to 20 psi. The system was not working properly, and ~ 2 gallons of liquid was removed to bring the inlet water pressure down to ~10 psi. Cooling system was a closed loop system with an expansion tank; adjustments were made on an as-needed basis.<br>After replacing EOG pre-filters, melter vacuum was about -0.3 “WC.<br>Removed transition line bellows for inspection. |
| | | 3/12/2002 | Took digital photographs of transition line from melter to SBS before and after cleaning. No significant solids build-up was observed. Small amount of solids were seen in the bellows, which was typical. Bellows was reinstalled.<br>Secured power and reinstalled level detector. Power was restored.<br>Found erratic melter level and density readings. Investigation showed that argon supply was off. Restored argon flow and readings returned to normal.<br>Film cooler and transition line were cleaned.<br>A second EOG HEPA housing was installed. |
| | | 3/15/2002 | A pressure regulating valve was installed at the inlet of the ammonia system regenerative blowers to control air flow. |
| | | 3/18/2002 | Investigated unusual melter pressure and film cooler DP readings and found damage to the EOG vent line (~20" of pipe missing from EOG vent pipe insertion into the melter), and extensive corrosion of pressure sensor line that was connected to the EOG vent line. Temporarily plugged port while new sensor pipe was fabricated. The EOG went line was replaced.<br>TC of MM-XXX-TR-17 was also replaced. |
| | | 3/21/2002 | Secured electrode power to remove lance bubblers and change electrode firing pattern to side to bottom.<br>Re-energized the electrodes. Lance bubblers #1- #4 were removed, and photographed |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-02R8800-2 | LAW Envelope A1 with cesium, cadmium, selenium and hazardous organic compounds (2/27/02-3/1/02, 3/3/02-3/6/02, 3/18/02 -3/20/02) | 3/22/2002 | Removed MM-XXX-TR-17 and MM-XXX-PR-200 from EOG port. Large amount of solids build-up was observed in vertical and horizontal sections of EOG piping. Solids from the vertical section were cleaned and put in the melter. Horizontal was still blocked at the 45° bend and was cleaned by vacuuming. |
| | | 3/26/2002 | Secured melter electrode power to facilitate cleaning of EOG piping.<br>Removed solids in EOG line with a vacuum cleaner with stainless steel flex hose. Sample of the removed material were taken.<br>Opened manual EOG vent valve, MM-EOG-V-403 and found piping packed with material resembling concrete. Cleared valve and removed piping at upstream flange. Material found packed solid past next "T" fitting. Removed and cleaned the EOG vent line.<br>Re-energized electrodes. |
| | | 3/27/2002 | Continued EOG vent cleaning. Main EOG valve, MM-EOG-V-401 had large amount of solids build-up on damper and pipe downstream, ~ ¾" build-up at the bottom of the pipe. Upstream pipe was coated with a thin layer of material. Digital photographs were taken.<br>Finished cleaning MM-EOG-V-401 valve and piping. Changed EOG filters. |
| | | 4/3/2002 | Removed and replaced EOG HEPA filters on MM-EOG-F-402 EOG HEPA train. |
| | | 4/5/2002 | Replaced pre-filters and HEPA filters in both MM-EOG-F401 and MM-EOG-F-402 EOG HEPA trains.<br>Transition line and film cooler were removed; digital photographs were taken. Observed solids build-up on the film cooler. There was significant corrosion damage to the bottom of the film cooler. The transition line piping had ~1/16" - 1/8" build up on pipe wall uniformly along entire piping.<br>Small sections of film cooler bottom were collected for analysis by microscopy. |
| | | 4/6/2002 | Cleaned film cooler with water. This was only marginally successful. Majority of solids remained. Tried to remove materials by chipping with hammer/chisel with marginal success. Collected sample of removed solids for analysis. Digital photographs were taken. |
| | | 4/8/2002 | Melter pressure became positive; switched to EOG HEPA train MM-EOG-F-401. |
| | | 4/11/2002 | Secured power to change TCs of MCL-CW-TR-410, TR-411, TR-406, TR-409, TR-413, TR-415, TR-416 and TR-418, all used to measure temperature of chilled water supply to the melter. |
| | | 4/29/2002 | Removed air-lift for inspection. Inspected the airlift and noticed some arcing on the bottom end of the lance. Photographs were taken. |
| | | 5/1/20002 | Cooling panel back-up pumps and dam wall regenerative blowers were tested. They were all working properly. |
| | | 5/2/2002 | Installed power switch ATS-10A (Automatic Transfer Switch).<br>(In the event of a power failure, ATS-10A switches to the first source of electrical power available. When both sources of power are available, it uses the normal power source. If normal power fails, ATS-10A switches to emergency power.) |
| | | 5/3/2002 | Restored dam cooling to normal RGB supply and disconnected temporary B-301 air supply connection.<br>Replaced HEPA and pre-filters on both EOG HEPA trains. |
| | | 5/3/2002 | ATS wiring was completed. Secured power to melter electrodes and discharge heaters and placed diesel generator in "OFF" position to complete wiring modifications.<br>Operation of ATS-10A was performed.<br>Power was restored to melter and the discharge heaters. Diesel generator was placed back in "Auto" control. |
| | | 5/14 and 5/16/2002 | Effect of a bulb on air flow through the bubbler was tested. |
| | | 5/15/2002 | Changed EOG HEPA train MM-EOG-F-401filter and pre-filter. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-02R8800-2 | | 5/17/2002 | Changed EOG HEPA train MM-EOG-F-402 filter and pre-filter. |
| | | 5/21/2002 | Noticed that heater #5 in discharge chamber had burned out. |
| | | 6/13/2002 | Switched the EOG exhaust trains. Replaced pre-filter on MM-EOG-F-401 EOG HEPA train. |
| VSL-03R3800-4 | HLW AZ-101 (7/23/02-8/1/02, 9/9/02-9/18/02, 9/23/02-10/02/02, 10/7/02-10/12/02, 10/15/02-10/24/02, | 6/21/2002 | Installed new film cooler and re-piped the dam wall outlet air into the film cooler. Installed a new film cooler TC. |
| | | 6/22/2002 | Replaced EOG train MM-EOG-F-402 HEPA with a high temperature stainless steel filter.<br>Noticed that melter pressure was at 0.00" W.C. Piping dam wall outlet air to film cooler may be the cause of lack of melter vacuum. Momentarily switched dam wall outlet air valve through EOG, and vacuum went to -0.24" W.C. Switched the valve back so that dam wall outlet air flow was through film cooler. |
| | | 7/2/2002 | Installed HEPA filter and pre-filter in EOG HEPA train.<br>Performed instrument calibration and loop calibration on:<br>MM-OG-DPR-002, MM-AR-DTR-201, MM-AR-PR-201, MM-AR-LTR-201, MM-OG-DPR-001, MM-XX-PR-200, OG-B-FIR-301, MM-AR-PR-202, MM-OG-DPR-002, glass density and glass level.<br>Removed the pancake flange from the transition line. |
| | | 7/8/2002 | Reduced power from 65 to 60 kW for core drilling of melter lid. |
| | | 7/10/2002 | Secured power to electrodes to begin core drill evolution, utilizing rented air compressor.<br>Core drilling complete. Restored power. Shut down off-gas system.<br>Switched electrode power to “Auto”. |
| | | 7/12/2002 | Placed both EOG HEPA trains in service.<br>Inspected EOG port. Vertical section was clean, horizontal pipe was ~ ½ blocked. Rodded as much as possible of the solids into the melter.<br>Inspection of EOG TC showed no visible damage.<br>Removed MM-EOG-V-403 valve (Manual EOG vent/dilution air valve). No clog was observed downstream of EOG valve MM-EOG-V-401, emergency vent valve. Replaced valve, MM-EOG-V-403 due to corroded ball and seat. |
| | | 7/13/2002 | Replaced the elements of discharge chamber heaters 5A and 5B with new elements. Heater 5B failed due to fracture.<br>Made a modification to EOG control circuit. During automatic system operation the dilution valve would open with a time delay. Replaced MM-XXX-TR-10 TC. |
| | | 7/15/2002 | Secured power. Removed TW #2 for inspection. Minor arc spots and minor crystallization were observed. Photographs were taken.<br>Power was restored.<br>Secured power to reinstall TW #2. Restored power.<br>Installed a 100 – 3000 CCM flow meter for the film cooler water wash line.<br>Installed film cooler water wash line nozzle at 40 psi.<br>Transition line was cut on the bend with pipe support added down to the melter so the film cooler could be removed without taking down the entire transition line.<br>Cut hole in the lid, welded flange in the center of the melter lid and core drilled for ADS feed tube.<br>Installed new instrumentation and exposed plenum TC in melter port B-3 and reconnected all instrumentation.<br>Installed a manual 4" blast gate valve (with an in/out sliding piece of metal) on the end of the emergency dilution air pipe. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-03R3800-4 | HLW AZ-101<br>(7/23/02-8/1/02,<br>9/9/02-9/18/02,<br>9/23/02-10/02/02,<br>10/7/02-10/12/02,<br>10/15/02-10/24/02 | 7/16/2002 | Installed new thermocouple in riser air lance MM-XXX-TR-08. TC was inserted to a depth of ½" above the bottom of the air Lance. |
| | | 7/17/2002 | Replaced filters and pre-filters of both MM-EOG-F-401 and -402 EOG HEPA trains. |
| | | 7/20/2002 | Inspected EOG lines. Horizontal section of the EOG line was clear. The vertical section was partially clogged up to the "T" section. Air flow still had about 90% open flow path. The material was removed. Took sample of solids found blocking EOG dilution air valve. |
| | | 7/22/2002 | Secured power to replace lance bubblers with "J" type bubblers. Thermocouples were installed in lance bubblers #1 and #2.<br>Removed TW #1 for inspection.<br>Lance bubblers #1 and #2 were replaced with "J" bubblers to the same depth. After TW #1was removed, power was restored.<br>Inspection of TW #1 showed significant crystallization and signs of conduction of electric current. Caliper measurements were taken. Inspection of removed bubblers showed some crystallization with arcing spots on lance bubbler #2. Photographs were taken.<br>Secured power to install TW #1. Power was restored after installing TW #1. |
| | | 7/24/2002 | Repaired discharge chamber heater circuit 4A and 4B. Replaced the heating elements of heaters 4A and 4B with new elements. Heating element of heater 4A had failed. Also repaired several overheated heater connections. An external fan was added to help remove radiant heat. A different type of material ring terminals ordered to replace all connection ends.<br>Ran back-up generator for 30 minutes. |
| | | 7/31/2002 | Replaced MM-XXX-TR-13 TC. |
| | | 8/5/2002 | TW #1and #2 were removed for inspection. Initial inspection TW #1 (before glass coating shattered) showed unusually large deposits, which have not been observed previously, on electrode side of TC.<br>Closer observation of deposits on TW #1 showed a metallic appearance and was collected for analysis.<br>Visual inspection of both TW #1 and #2 showed significant degree of crystallization in the section exposed to the electrode. TW #2 appears more degraded than TW #1. TW #1 had an unusual shiny coating on the bottom 3" of the TW. Significant signs of arcing were observed on the bottom end of both TWs. Photographs and dial caliper readings were taken of both.<br>Decision was made to replace both TW #1 and #2. Fabrication was started. |
| | | 8/8/2002 | Since the new TW #1 was shortened, TC of MM-XXX-TR-04 was replaced with a shorter TC. Existing TC for MM-XXX-TR-13 is now MM-XXX-TR-15. Both TW #1 and #2 were reduced in length from 76 ½" to 67 ½". Also TC for MM-XXX-TR-18 was removed. Glass pool temperature average now uses MM-XXX-TR-01, -02, -03, -12, -13 and -14.<br>In the new configuration:<br>TCs of MM-XXX-TR-01 and MM-XXX-TR-12 are 13" from melter floor.<br>TCs of MM-XXX-TR-02 and MM-XXX-TR-13 are 15 ½" from melter floor.<br>TCs of MM-XXX-TR-03 and MM-XXX-TR-14 are 18" from melter floor.<br>TCs of MM-XXX-TR-04 and MM-XXX-TR-15 are 27" from melter floor.<br>Plenum TCs are unchanged.<br>In addition to shortening the TW, a 16" quartz sleeve was inserted to insulate TCs of MM-XXX-TR-01,-02, -03, -12,-13, -14 from TW wall.<br>Removed pancake flange from the transition line. Reinstalled gasket and secured the bolts. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-03R3800-4 | HLW AZ-101<br>(7/23/02-8/1/02,<br>9/9/02-9/18/02,<br>9/23/02-10/02/02,<br>10/7/02-10/12/02,<br>10/15/02-10/24/02 | 8/9/2002 | Switched to MM-EOG-F-401 EOG HEPA train. Decided to replace EOG HEPA pre-filter on the other train. |
| | | 8/12/2002 | Replaced MM-EOG-F-402 EOG HEPA train pre-filter. Observed build-up before pre-filter. |
| | | 8/12/2002 | Verified the TW #2 TC readings. |
| | | 8/13/2002 | Discharge chamber heaters 3A and 3B failed. |
| | | 8/16/2002 | Heating elements of discharge chamber heaters 1A, 1B, 7A and 7B were replaced with new elements. Modified heating element sleeve by splitting it in half. Removed top half of the alumina insulation inside the Kanthal protection tube covering each heater element. The reason for removing the upper half of the alumina sleeve was to reduce failure due to high temperature caused by the excessive insulation<br>Switched from EOG HEPA train MM-EOG-F-401 to EOG HEPA train MM-EOG-F-402. |
| | | 8/17/2002 | Replaced pre-filters and HEPA filters on both EOG HEPA trains. |
| | | 8/20/2002 | Bubbler in port D-1 and TW in port D-2 were removed. Lance bubbler #2 showed some high temperature (arcing) at the tip, on the bend, and just above the bend. No crystallization was observed. Photographs were taken.<br>TW #2 showed no physical damage but did show an indentation on the pipe (full circumference) at the glass surface interface. Photographs were taken.<br>Coupons were installed on both the lance bubbler and TW #2. Photographs were taken.<br>TW #2 and lance bubbler #2 were installed.<br>Secured power to discharge chamber for repairs.<br>Replaced the heating elements of discharge chamber heaters 3A, 4A, 4B and 5A with used elements.<br>All of the heater elements were removed for inspection and resistance measurements were taken at room temperature of the elements that were reinstalled. A Tektronix model TX1 True RMS Multimeter was used for this purpose. The ceramic (alumina) isolator was split lengthwise to allow for a greater amount of radiative heat loss to lower the average temperature in the heating zone of the heating elements. This was implemented to try and prevent the failure mode observed with some of the past heater element failures. Metal sheaths of the following heating elements were significantly warped: 1A, 2A, 2B, 3A, 4A, 7A and 7B. The ceramic insulators for these heating elements were again cut in half lengthwise to allow better fit inside the warped metal sheaths. Two cylindrical tube sections were placed around all of the heating elements to prevent the elements from melting the ceramic insulators and to prevent the heating element from touching the metal sheaths at the top. This tube, which was ~3/8" wide at the connection end and ~1" wide at the heating zone tip had a high alumina content. This material had good insolating properties. All heater power leads showed various degrees of overheating at the conductor - terminal connection. So all of the heater power lead connections were redone using 1200 F nickel-plated steel crimp on ring terminals. These replaced the 195 F aluminum set screw ring terminal connectors.<br>Restored power to the discharge chamber. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-03R3800-4 | HLW AZ-101 (7/23/02-8/1/02, 9/9/02-9/18/02, 9/23/02-10/02/02, 10/7/02-10/12/02, 10/15/02-10/24/02 | 8/21/2002 | Removed level detector and replaced with new level detector with coupons attached.<br>Outside diameter caliper readings were taken of the old level detector.<br>Removed level detector showed significant crystallization and loss of pipe outside diameter. Radial cracks were observed on both level detector pipe (7" from end) and density pipe (1 ½" from end). Photograph and caliper readings were taken. |
| | | 8/22-23/2002 | While attempting to open MM-EOG-F-401, EOG HEPA filter outlet isolation valve-damper (MM-EOG-V-405), the damper stem fell into the ductwork. (Damper stem was broken). MM-EOG-F-401 was opened.<br>Removed EOG damper (MM—EOG-V-405) from the ductwork. In MM-EOG-V-401, no clogging was found. MM-EOG-F-402 filters were marked for replacement. |
| | | 8/26/2002 | Installed a new level detector with coupons.<br>LabVIEW calculations for glass level were modified for new detector pipe dimensions. Level detector was placed in service. |
| | | 8/27/2002 | Performed functional/operational test of cooling water system and diesel generator. |
| | | 9/3/2002 | Completed high temperature switch testing for the cooling system. Chilled water return high temperature switch TSH-105 and supply city water high temperature switch TSH-107 were tested for their functionality. |
| | | 9/4/2002 | Removed airlift lance. Maintained air flow in an attempt to remove and replace TC. Air flow was maintained for glass to flow out and to keep the lance open.<br>Air lance outside diameter caliper readings were taken. |
| | | 9/5/2002 | Performed loop calibration of MM-BB-TR-01 and TCs of MM-XXX-TR- -19, -10, -05, -01, -02, -03, -04, -06, -16, -11, -08, -12, -14, -15, -07, -23, -21, -22, -09 and -13. |
| | | 9/6/2002 | Removed TW #1and lance bubbler #1. Coupon closest to bottom of bubbler had broken off during cooling.<br>Outside diameter caliper readings were taken of lance bubblers #1 and TW #1.<br>Bubbler #1was reinstalled without re-attaching coupon. TW #1 was inspected and reinstalled. Photos of both were taken.<br>Coupons were installed on air lift lance.<br>Replaced air lift TC MM-XXX-TR-08 with a new one. |
| | | 9/9/2002 | Reinstalled MM-XXX-TR-17, plenum exposed TC.<br>Installed corrosion coupons in the film cooler and transition pipe<br>Lance bubbler #1 and #2 backpressure transmitters were added (0 -15 psi). |
| | | 9/11/2002 | Completed control air control upgrades. Input to controller is MM-AR-PR-201 (melter pressure for the EOG system). |
| | | 9/16/2002 | Diesel generator weekly test run was completed. |
| | | 9/20/2002 | Removed TW #2 and lance bubbler #2. Nothing unusual noted. Outside diameter caliper readings of lance bubbler #2 were taken.<br>Outside diameter caliper readings of TW #2 were taken. |
| | | 9/23/2002 | Weekly test of diesel generator was completed. Completed test of MCL-CW-P-402 B and -403B chilled water pumps.<br>Missing coupons of lance bubbler #2 were remounted.<br>TW #2 and lance bubbler #2 were reinstalled.<br>Checked exposed plenum TC. It was functional.<br>Replaced TC of MM-XXX-TR-15 due to erratic readings. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-03R3800-4 | HLW AZ-101 (7/23/02-8/1/02, 9/9/02-9/18/02, 9/23/02-10/02/02, 10/7/02-10/12/02, 10/15/02-10/24/02 | 10/3/2002 | Removed TW #1 and lance bubbler #1. Lance bubbler #1 showed pitting after the bend (the corner) at the end about 4" long and farther up at 13" from the bottom. There were two hot spots close together plus some crystallization from 8" to 22" from the bottom. Photographs were taken.<br>There was Joule heating signs at 0 to ½" from the bottom of TW #1. No other spots or crystallization were noticed on TW #1.<br>Outside diameter caliper readings of lance bubblers #1 were taken.<br>Outside diameter caliper readings of TW #1 were taken.<br>Lance bubbler #1 and TW #1 were reinstalled. |
| | | 10/7/2002 | Installed manual rotameter flow meters for lance bubblers #1 and #2. (MM-CA-FIC-012, -013).<br>Replaced RGB/film cooler domestic water totalizer (RGB-DW-FIT-215).<br>Performed back-up chilled water pump and back-up dam wall regenerative blower tests. |
| | | 10/9/2002 | Removed manual bubbler mass flow controllers MM-CA-MFR-001, -004, -005, -010, -011, -012, and -013 for offsite calibration. |
| | | 10/12/2002 | Removed lance bubbler #2 and TW #2. |
| | | 10/13/2002 | While trying to measure dimensions of lance bubbler #2 and TW #2, found too much residual feed on both.<br>Reinstalled both into the melter to melt residual feed.<br>Removed lance bubbler #2 and TW #2 again. After bubbler was removed, one of the lower coupons came off.<br>Photographs were taken.<br>Outside diameter caliper readings of TW #2 were taken. |
| | | 10/14/2002 | Installed lance bubbler #2 and TW #2.<br>Installed a new TC in lance bubbler #2. |
| | | 10/15/2002 | MM-XXX-TR-17 exposed plenum TC was inspected and reinstalled. |
| | | 10/15/2002 | Back-up chilled water pumps & diesel generator tests were completed. |
| | | 10/16/2002 | After troubleshooting melter pressure indication, found that 24 volt DC power supply needed to operate the pressure transmitter was overloaded. Added another power supply.<br>Replaced RGB/film cooler water totalizer with a model of 0-3 lpm capacity (RGB-DW-FIT-215). |
| | | 10/17/2002 | During glass discharge operator noticed that knife gate valve was closed; immediately secured discharge and attempted to open knife gate valve. Since the valve had warped, it was necessary to loosen the nuts around the valve body before it could be opened. Removed glass from the valve body, verified that glass discharge path was clear, and replaced discharge can. This happened because the interlock that should have prevented glass discharge, while the gate was closed, did not work.<br>Repaired limit switch for discharge chamber knife switch.<br>Replaced MM-XXX-TR-02 TC. |
| | | 10/22/2002 | A start up test was performed on all cooling panel motors including backups. |
| | | 10/24/2002 | Photographs were taken of coupons inside the transition piping. Transition line itself appeared mostly clean. Some debris around the bellows was removed. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

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|---|---|---|---|
| VSL-03R3800-4 | HLW AZ-101 (7/23/02-8/1/02, 9/9/02-9/18/02, 9/23/02-10/02/02, 10/7/02-10/12/02, 10/15/02-10/24/02 | 10/28/2002 | TW #2, air lift and level detector were removed for inspection and coupon removal. Removed coupons from discharge chamber.<br>Took photographs of air lift from bottom to 31" up. The metal appeared somewhat pitted. Also, there was a greenish color to the pipe up to ~31" (it has greenish tint to it). A small amount of crystallization also was observed in this region. Between 27" – 31" there was heavy pitting and between 18" - 23" there was a bend in it. Air lift outside diameter caliper readings were taken.<br>Outside diameter caliper readings of lance bubblers #1, #2, #3 and #4 were taken.<br>Inspection of TW #2 showed slight crystallization. No sign of arcing. Photographs were taken.<br>Outside diameter caliper readings of TW #1 and TW #2 were taken.<br>Inspection of level detector showed no signs of degradation. Photographs were taken.<br>Inspection of airlift showed no sign of degradation. Photographs were taken.<br>TW #2, airlift, and level detector were reinstalled. |
| | | 10/29/2002 | Removed lance bubbler #1, lance bubbler #2 and TW #1.<br>Inspection of lance bubbler #1 showed slight narrowing at tip with minor crystallization. Photographs were taken.<br>Lance bubbler #2 had similar appearance as lance bubbler #1. Photographs were taken.<br>TW #1 showed slight crystallization with only minor indication of arcing. Photographs were taken.<br>Installed lance bubblers #1, #2, #3, #4 and TW #1.<br>Installed TCs of MM-XXX-TR-01, -02, -03, -04 and -05 in TW #1.<br>Replaced HEPA and pre-filter in EOG HEPA train MM-EOG-F-402. |
| | | 11/1/2002 | Installed a new TC in lance bubbler #2, MM-BB-TR-02.<br>Removed discharge chamber knife gate valve; replaced the gate with a piece of 1/8" TK 601 inconel plate and reinstalled the valve. |
| | | 11/3/2002 | Replaced plenum exposed MM-XXX-TR-17 TC with a new one. Inserted the MM-XXX-TR-17 TC 17" below the lid. |
| VSL-03R3851-1 | LAW Envelope B1 with hazardous organic compounds (11/4/02-11/8/02) | 11/4/2002 | Replaced 2 "J" type lance bubblers with 4 "L" type lance bubblers.<br>Removed all glass corrosion coupons.<br>Replaced exposed plenum TC.<br>Installed 2 more (total 4) back pressure transmitters for 4 lance bubblers.<br>Melter LabVIEW software was changed to revision VI.<br>Removed transition line pancake flange and tightened film cooler flange bolts.<br>Repaired damaged TC wire of MM-XXX-TR-17.<br>Zeroed all blow-down and water addition totalizers.<br>Reinstalled all mass flow controllers previously removed for calibration. Added lance bubblers #3 and #4 back pressure transmitters to melter labVIEW. |
| | | 11/8/2002 | Outside diameter caliper readings of the "J" type lance bubblers #1, and #2 were taken. They appeared the same as during the inspection on 10/19/2002. Glass was adhering to the bubblers, making it difficult to get good dimension measurements. Readings near the tip were taken to determine the severity of loss there.<br>Removed lance bubblers #2 and #3 for inspection and caliper measurements ("L" type). |
| | | 11/9/2002 | Photographs of lance bubblers #2 and #3 were taken. Inspection showed various spots on both bubblers, and some minor pitting on lower 20" of bubblers. Took caliper readings on lance bubblers #2 and #3. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

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|---|---|---|---|
| VSL-03R3851-1 | LAW Envelope B1 with hazardous organic compounds (11/4/02-11/8/02) | 11/11/2002 | Increased power from 75 to 80 kW in preparation for bubbler installation and transformer tap change from 224 V to 168 V.<br>Tested RGB electronic valve for film cooler washing. Verified timer and flow were correct for 5-liter water flow. Since the existing nozzle could not be cleaned, installed a new spray nozzle for film cooler wash line.<br>Tested (electric valve with timer) flow rate and adjusted rotameter to flow 1 liter of water per minute.<br>Installed “J” bubblers in ports A-3 and D-1. Increased discharge heater power from 12 to 14 kW.<br>Replaced upstream film cooler inlet air temperature (MM-RGB-TR-201) TC.<br>Replaced exposed plenum TC (MM-XXX-TR-17). Note: ~ 6" was missing from the “OLD” TC.<br>Film cooler was inspected.<br>Replaced “L” type lance bubblers in ports A-3 and D-4 with “J” type lance bubblers.<br>Added upstream film cooler inlet air temperature, MM-RGB-TR-201 to the melter data file. |
| | | 11/13/2002 | Changed voltage connections from 224 V tap to 168 V tap. |
| | | 11/15/2002 | Removed lance bubblers #1, #2, #3, #4 and TW #2.<br>Installed “J” type lance bubblers #2 and #3 with new TCs.<br>Inspected and took photographs of lance bubblers #1, #2, #3, #4 and TW #1 and #2. Only visible damage was an arc spot on lance bubbler #4 at about 12"-14" from the bottom. |
| | | 11/16/2002 | Installed coupons on both sides of the transition line. |
| VSL-3R3800-2 | HLW AZ-102 (11/18/02-11/27/02) | 11/18/2002 | Installed new TCs MM-XXX-TR-12, -TR-13, -TR-14, -TR-15 and -TR-16 in TW #2.<br>Caliper readings of TW #2 were taken<br>Outside diameter caliper readings of lance bubbler #1 (L type), lance bubbler #2 (J type), lance bubbler #3 (J type) and lance bubbler #4 (L type) were taken.<br>TW #2 was installed.<br>Exposed plenum TC was inspected and reinstalled.<br>Discharge coupons were reinstalled.<br>Replaced TCs of MM-XXX-TR-12, -13 and -14 with multi TC set. |
| | | 11/27/2002 | Removed lance bubbler #1 and TW #1 for inspection.<br>Inspected film cooler. It appeared clean and smooth with no-build-up. Photographs were taken.<br>Inspection of TW #1 did not reveal any new damage or bends. Photographs taken.<br>Outside diameter caliper readings of TW #1 and TW2 were taken.<br>“J” type lance bubbler #1 lost two coupons due to removing adhering glass with hammer. Other than that the bubbler looked good with no apparent damage. Photographs were taken. Outside diameter caliper readings of “J” type lance bubbler #1 were taken. Decided to leave bubblers out until coupons were reattached.<br>TW #1 was reinstalled. |
| | | 11/28/2002 | Removed the pancake flange from film cooler outlet. Replaced two damaged bolts.<br>Due to unusual noise from chilled water (CW) pump, MCL-CW-P-402A, switched from CW pump MCL-CW-P-402A to CW pump MCL-CW-P-402B. |
| | | 12/3/2002 | Lance bubbler #2 was removed for coupon inspection. All 6 coupons were still attached. Some of the coupons became detached during removal of glass adhering to the outside of the bubbler. The bubbler appeared to be in good condition, except for minor signs of high temperature at bend (bottom side) of “J”. Outside diameter caliper readings of the bubbler were taken.<br>Performed operational test on the chilled water pump MCL-CW-P-402A. Did not observe any noise. Pump outlet pressure gauge removed and tested. Chilled water pump MCL-CW-P-402B was placed in operation with MCL-CW–P-402A CW pump in back-up. |

### Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

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|---|---|---|---|
| VSL-3R3800-2 | HLW AZ-102 (11/18/02-11/27/02) | 12/4/2002 | Temporary EOG installation was completed in preparation to remove the existing off-gas duct pipes.<br>Replaced both EOG HEPA filters and pre-filters.<br>Installed temporary "W.C. differential pressure indication (0-10") on both EOG HEPAs. |
| | | 12/11/2002 | Installed lance bubblers #1 and #2 with attached corrosion coupons. |
| | | 12/16/2002 | Since building compressed air supply was not functioning properly, dilution air could not be supplied prior to EOG HEPA. Therefore, a hole was cut in the line prior to EOG HEPA to reduce exhaust gas temperature to about 180 °C.<br>EOG dilution air valve became functional. Temporary hole to supply dilution air at the EOG HEPA inlet sealed. |
| | | 12/17/2002 | DM1200 off-gas duct pipes were removed. |
| | | 12/18/2002 | Temporarily closed EOG to modify ductwork for gas sample ports to be installed.<br>EOG returned to service. |
| | | 12/19/2002 | Level detector and airlift were removed, and coupons were installed.<br>EOG sampling/testing was performed.<br>Reinstalled level detector and airlift.<br>Back-up air compressor was placed in service because main air compressor could not be started.<br>Adjusted EOG dilution air valve-damper to gain more melter vacuum. |
| | | 1/6/2003 | Tied-in EOG duct work to permanent piping.<br>Replaced temporary EOG HEPA pre-filters.<br>Replaced EOG HEPA filters. |
| | | 1/9/2003 | Installed pre-filter and filter in both new EOG HEPA housings. |
| | | 1/13/2003 | Installed pancake flange in the transition line. |
| | | 1/16/2003 | An automatic switching panel was installed for the roof blowers, including an upgraded damper mechanism.<br>Panel had alarm interlocks and received power through automatic transfer switch, ATS-10A system. |
| | | 1/21/2002 | Weekly test of diesel generator and cooling pumps was completed. |
| VSL-03R3800-1 | HLW C-106/AY-102 (1/22/03-1/31/03) | 1/28/2003 | ~ 30 minutes since the main compressor was switched off for maintenance and the back-up compressor did not come on line. |
| | | 2/1/2003 | Installed pancake flange on the transition line.<br>Lance bubblers #1 and #2 and TW #2 were removed. One of the coupons on lance bubbler #1 became detached after removal. |
| VSL-03R3800-3 | HLW C-104/AY-101 (2/19/03-2/28/03) | 2/4/2003 | Outside caliper readings of lance bubbler #1 ("J" type) and #2 ("J" type), and TW #2 were taken.<br>Inspection of TW #2 showed moderate pitting and crystallization. Photographs were taken. Inspection of lance bubblers #1 and #2 showed no signs of arcing or crystallization. Photographs were taken.<br>Performed a test to simulate a broken belt on the roof blower for the DM 1200 off-gas system. Responses of 5 pressure indicators were used to evaluate the response of the system to roof blower PLC (programmable logic controller) control program. The system response was acceptable. |
| | | 2/10/2003 | Airlift and level detector were removed. Discharge chamber exhaust pipe was removed for inspection for build-up.<br>Inspection of discharge chamber exhaust pipe showed a lot of dry solids in the flange opening, coming off the top of the chamber where there was an inner reduced flange with a ¼" opening. There were some solids in the opening by the EOG piping. Pipe itself appeared to be clear. Photographs were taken. Pipe was reinstalled.<br>Completed diesel performance test. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

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|---|---|---|---|
| VSL-03R3800-3 | HLW C-104/AY-101 (2/19/03-2/28/03) | 2/11/2003 | Replaced pre-filter and HEPA filter in EOG HEPA train, MM-EOG-F-401. |
| | | 2/12/2003 | Inspection of airlift showed ½ circumference crack in pipe just above the larger pipe at the bottom. While moving residual glass for further inspection with needle gun, tip broke off completely. Tip had visible arc spots. Photographs were taken. All coupons were still attached to the airlift.<br>Level detector outside diameter caliper readings and air lance outside caliper readings were taken. |
| | | 2/19/2003 | Raised airlift lance 3" from previous insertion depth. |
| | | 2/24/2003 | Replaced existing Omega Controller Model CN7600 used with control air system to a series 8600 Love Model 8600 controller that is a newer PID (proportional integral derivative) controller. |
| | | 2/25/2003 | Performed test on back-up dam wall regenerative blower and back-up chilled water cooling pumps. |
| | | 2/27/2002 | Replaced TC of MM-XXX-TR-21. |
| | | 3/3/2002 | Installed the pancake flange in the transition line.<br>Lance bubblers #1 and #2 and airlift air lance were removed. |
| | | 3/4/2003 | Visual inspections of lance bubblers and airlift air lance were made.<br>Lance bubbler #1 had all corrosion coupons still attached. Metal loss was visible on "J" section (O.D. significantly less than remainder of pipe). No sign of crystallization was noted. Tip was very rounded.<br>Lance bubbler 2 appeared similar to lance bubbler #1.<br>Airlift showed signs of some arcing on bottom tip. No metal degradation was observed. Caliper readings and photographs were taken. |
| | | 3/5-6/2003 | Film cooler and sections of transition line were removed for inspection.<br>Total of ~4.5 kg of solids were removed from the film cooler, 4 sections of the transition line and transition line bellows. Light coating of solids was seen in the film cooler pipe walls. Inlet of the film cooler showed large amount of glass collected at the bottom side of pipe, blocking most of the air holes. Fin area had only light coating of material. Parts of transition line section 2 were 50% blocked with solids. Photographs were taken.<br>Film cooler and transition line sections were cleaned by chipping, hammering, soaking and washing.<br>Took photographs of cleaned film cooler and sections of the transition line and bellows.<br>Photograph illustrating the configuration (lay-out) of the film cooler and transition line also were taken. |
| | | 3/10/2003 | Changed filter and pre-filter of EOG HEPA in train #2 (MM-EOG-F-402).<br>Performed automatic switching test on the chilled water pumps MCL-CW-P-402A to -402B and MM-CW-P-403A to -403B respectively. Two pumps, one pump from either MCL-CW-P-402A or -402B and one pump from either MM-CW-P-403A or -403B were operational at any time. Ran the dam wall regenerative blower MCA-RGB-B-101 for 30 minutes. All of the systems functioned satisfactorily |
| | | 3/24/2003 | Diesel generator test was completed. |
| | | 3/27/2003 | Removed and replaced TW #2, thermocouple wires of MM-XXX-TR-12, -13, -14 and -15.<br>Removed dam wall flow indicator (local) MCA-RGB-FI-201 pitot tube to check blockages. It was clean. |
| | | 3/28/2003 | TC for MM-XXX-TR-16 was giving erratic readings. |
| | | 3/31/2003 | Switched from MM-EOG-F-401 EOG HEPA train to -402 EOG HEPA train. Replaced HEPA pre-filter in MM-EOG-F-401 EOG HEPA train. |
| | | 4/7/2003 | CUA maintenance confirmed primary system chilled water pump, MCL-CW-P-401, seal failure. Repair required primary CW outage. Scheduled repair and ordered new pump as replacement.<br>Performed chilled water back-up pumps test for 0.5 hour. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

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|---|---|---|---|
| VSL-03R3800-3 | HLW C-104/AY-101 (2/19/03-2/28/03) | 4/8/2003 | Reinstallation of film cooler and transition line was started.<br>Installed a new TC in film cooler for film cooler air temperature, MM-XXX-TR-09.<br>Initiated city water flow to cooling panel. Secured primary chilled water pump, MCL-CW-P-401, for repair/replacement.<br>Finished installation of film cooler and transition line sections. Replaced EOG HEPA filter and pre-filter on both trains.<br>Upgraded melter labVIEW.<br>CUA maintenance notified that repair/replacement of MCL-CW-P-401 was complete. The system was placed in normal operation. City water was secured. |
| | | 4/10/2003 | Installed coupons in the film cooler outlet and SBS inlet.<br>Installed discharge chamber exhaust flow manometer (MM-XXX-FI-205), tubing and pitot tube. |
| | | 4/14/2003 | Reconfigured electrode firing pattern form side to bottom to side to side.<br>Installed "J" type lance bubblers #1 and #2, in ports A-3 and D-1 respectively.<br>Installed airlift.<br>Performed weekly chilled water back-up pump test. |
| | | 4/16/2003 | Installed coupons in discharge chamber. |
| Post C104/AZ101 Turnover | HLW AZ-101 (4/22/03-4/25/03) | 4/22/2003 | Installed ("L" type) lance bubblers #3 and #4 in ports A-1 and D-3 respectively. Also mass flow controllers MM-CA-MFCR-008 and 009 were installed to operate these lances.<br>• Wire in "J" type lance bubbler #1 pressure transmitter line that was broken was repaired.<br>• Installed parallel 20 HP blowers for melter pressure control with associated piping and controls to run "independently" or in parallel<br>• Installed additional alarms for stack vacuum to indicate belt failures, fire damper closure or blower failures.<br>• Added film cooler and dam cooler inlet flow indications.<br>• Replaced exposed plenum TC, MM-XXX-TR-17.<br>(1) Installed rebuilt ammonia supply regulator with new inlet and outlet pressure gauges. |
| | | 4/25/2003 | Removed lance bubblers #3 and #4, TW #1 and TW #2. Secured bubbling and flow to lances bubblers #3 and #4.<br>Installed the pancake flange in the transition line.<br>TW #1 and TW #2 were inspected. Both showed a green tint from the bottom up to about 18". Also pitting was observed throughout on both TWs. Photographs were taken. Coupons were still attached to TW #2 (4 total).<br>TW #1and #2 were reinstalled.<br>TW #1 and TW #2 outside diameter caliper readings were taken. |
| | | 4/26/2003 | Inspection of lance bubbler #3 showed an arc spot at about 25" from the bottom. Joule heating signs are present on lance bubbler #4 at the bend and on lance bubbler #3 at about 26" from the bottom. Digital photographs were taken.<br>Outside diameter measurements were taken. |
| VSL-04R4800-1 | HLW C-106/AY-102 with sugar (4/30/03-5/09/03) | 4/28/2003 | Removed the pancake flange from the transition line.<br>Power was lost temporarily to all 4 computers screens, EOG, electrode temperatures, alarms, and power controller. Power was restored to all components. |
| | | 4/30/2003 | The solenoid that controls main EOG valve, MM-EOG-V-401 failed. Parts were ordered for repair.<br>Removed "L" type lance bubblers #3 and #4. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

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|---|---|---|---|
| VSL-04R4800-1 | HLW C-106/AY-102 with sugar (4/30/03-5/09/03) | 5/1/2003 | Replaced TW #1 TCs MM-XXX-TR-01, -02, -03 with multi-TC.<br>Replaced TW #2 TCs MM-XXX-TR-12, -13, -14 with multi-TC.<br>TW #1 TCs were replaced due to erratic TC MM-XXX-TR-01 reading.<br>TCs for MM-XXX-TR-12, -13 and –14 also were replaced.<br>MM-XXX-TR-05, -16, -15, -04 TCs were replaced.<br>Experienced an indication problem with MM-XXX-TR-01 indicator. Found a problem with channel input and corrected.<br>Main EOG valve, MM-EOG-V-401 actuator solenoid was repaired and tested for auto control function. |
| | | 5/5/2003 | Performed weekly cooling pump maintenance test. Completed diesel generator test. |
| | | 5/8/2003 | Replaced compressed air bottles #1 and #2 for bubbler back-up air supply. |
| | | 5/12/2003 | De-fragmented both off-gas and melter labVIEW hard drives. Re-started system. All systems are working properly. |
| | HLW C-106/AY-102 with sugar and nitrates (5/14/03-5/23/03) | 5/13/2003 | Installed the pancake flange into the transition line.<br>Cleaned both melter and off-gas labVIEW computers.<br>Found that electrode seals were damaged. Applied additional ¼" bead of RTV (room temperature vulcanizer) around electrodes to seal. Performed a two-point verification of all cooling system temperatures.<br>Applied additional ¼" bead of RTV around dam cooler flow inlet and outlet piping. |
| | | 5/14/2003 | Switched all cooling pumps to secondary pumps.<br>Completed monthly diesel generator test.<br>Completed functional test of MM-XXX-TR-01. |
| | | 5/15/2003 | Switched from CW pump, MCL-CW-402A to MCL-CW-402B due to leakage.<br>Repaired seal on chilled water pump MCL-CW-P-402A. Melter cooling panels were placed in closed loop recirculation with city water during repair. Secondary system was isolated from the cooling panels.<br>Pump MCL-CW-P-402A was reinstalled, leak tested, and vented. System was restored to normal operation. |
| | | 5/16/2003 | Chilled water pressure alarm MCL-CW-PAL-1006 indicated low differential pressure for chilled water pump MCL-CW-P-403B. The pressure alarm sensor was found to be leaking and was isolated. |
| | | 5/19/2003 | Verified that MM-XXX-PR-200 and MM-AR-PR-202 (melter pressure at the level detector) sensors responded over their full range. |
| | | 5/20/2003 | Switched from chilled water pump MCL-CW-P-402B to 402A and switched chilled water pump MCL-CW-P-403B to 403A. |
| | | 5/23/2003 | Removed airlift and lance bubblers and shut off mass flow controllers. Electrode firing pattern was reconfigured to side to bottom. |
| | | 5/24/2003 | Glass coating was removed from lance bubblers and airlift and digital photographs were taken. Several corrosion coupons had fallen off.<br>Installed pancake flange in transition line. There was some solids build-up on the inside of the pipe. It had to be removed from both sides of the pipe before the gasket could be pulled out. |
| | | 5/27/2003 | Took caliper readings of lance bubbler #1, lance bubbler #2 (both J type) and airlift. Photographs were taken. Airlift had a bend at about 24" from the bottom.<br>Replaced 0-2" W.C., primary system chilled water flow indicator, MCL-CW-FI-401 gauge with a 0-3" gauge. The larger range was needed to match the system flow characteristics.<br>Performed pump and blower weekly maintenance.<br>Electrode firing pattern was changed from side to bottom to side to side.<br>Lance bubblers #1 and #2 were reinstalled with new TCs. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

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|---|---|---|---|
| VSL-04R4800-4 | HLW AZ-101 (5/28/03-6/6/03, 6/25/03-7/2/03, 7/15/03-722/03, 8/5/03-8/13/03) | 5/28/2003 | Removed the pancake flange from the transition line. |
| | | 5/29/2003 | Replaced MCL-CW-PAL-1006, chilled water pressure alarm, with a new alarm.<br>Replaced airlift TC.<br>Switched CW pumps from MCL-CW-P-403A to -403B.<br>Bubbler configuration was changed for the melter test. Direction of air flow now parallel to electrode with varying elevation during test (i.e. 6" above normal and 6" below normal). |
| | | 6/2/2003 | Performed weekly maintenance of cooling water pumps and blowers. |
| | | 6/6/2003 | Electrode firing pattern was changed from side to side to side to bottom. Removed lance bubblers #1 and #2. |
| | | 6/9/2003 | Installed pancake flange in the transition line.<br>Performed monthly test on diesel generator and weekly test on chilled water pumps. Switched from chilled water pump MCL-CW-P-402A to -402B pump. Switched from dam wall regenerative blower MCA-RGB-B-102 to -101.<br>Cleaned bubblers J3 and J4 with needle gun. Bubbler J3 was inspected. There were signs of Joule heating at about 10.5", 15.5" and 17" on J3. The rest of bubbler J3 was in very good shape. Photographs were taken.<br>Inspection of bubbler J4 showed a total of 19 joule heating spots ranging in size from 0.25" to 3.5" wrapping halfway around the bubbler. The joule heating spots were seen from 10.5"to 29.5" from the bottom. The rest of bubbler J4 was in good shape. Photographs were taken. Caliper readings were taken of bubblers J3 and J4. |
| | | 6/10-13/2003 | Installed pancake flange in the transition line. Removed transition line sections and the film cooler for inspection.Photographs of film cooler and transition line sections were taken.<br>Total of about 4 kg solid deposits were removed from the film cooler and all of the transition line sections including the bellows. About 25% of the holes were clogged in the film cooler. |
| | | 6/11/2003 | Switched to city water on cooling panels due to loss of chilled water.<br>Switched back to chilled water. |
| | | 6/17/2003 | Roof blowers fault alarms were observed. Found that alarm tubing was disconnected. The tubing was reconnected. |
| | | 6/18/2003 | TW #1 and #2 were removed.<br>Inspection of TW #1 showed joule heating spot at about 17-18" from end, some pitting in the glass area, and some discoloration to about 20" from the tip. No significant bends or twists were observed.<br>TW #2 showed no joule heating spots. Discoloration was observed at 11 to 17" from the tip. There was some pitting in the glass area. Photographs were taken.<br>Caliper readings of both TWs were taken.<br>Reconnected all computers inside new control console in room 10.<br>Reinstalled TW #1. |
| | | 6/19/2003 | Added 55 gallons of antifreeze to closed loop cooling system. Also added 2.5 liters of corrosion inhibitor.<br>TW #2 was reinstalled. |
| | | 6/20/2003 | Transition line differential pressure sensor, MM-OG-DPR-001, high and low side tubing and the film cooler differential pressure sensor, MM-OG-DPR-002, low side tubing were cleaned with compressed air. All three lines showed small amounts of dust when airflow was initiated.<br>Installed revised labVIEW software for melter system.<br>Tested lance bubbler skewing function for manual and auto control and was found to be satisfactory. Secured mass flow controllers for the lance bubblers. |
| | | 6/23/2003 | Reinstalled transition line sections and the film cooler. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

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| VSL-04R4800-4 | HLW AZ-101 (5/28/03-6/6/03, 6/25/03-7/2/03, 7/15/03-722/03, 8/5/03-8/13/03) | 6/24/2003 | Replaced TC in lance bubbler #1.<br>Observed that electrode bubbler #2 flow is now at 7 scfh<br>Swapped on-line chilled water pumps from MCL-CW-P-402B and -403B to -402A and 403A, respectively.<br>Delayed dam wall regenerative blower weekly test until feed preparation completed.<br>Modified labVIEW VI to support automatic lance bubbler flow variance in either “step” or “ramp” mode.<br>Reinstalled lance bubblers #1 and #2.<br>Electrode firing was reconfigured from side to bottom to side to side. |
| | | 6/25/2003 | Switched dam wall blower MCA-RGB-B-101 to MCA-RGB-B-102.<br>Switched control air flow to manual due to removal of TCs in the SBS down-comer. A number of new TCs were installed in the SBS. |
| | | 6/26/2003 | Noticed some noise from MCL-CW-P-402A chilled water pump. Switched to MCL-CW-P-402B chilled water pump. Suspect that the chilled water pump MCL-CW-P-402A has a broken seal. |
| | | 7/3/2003 | Removed section #3 of the transition pipe. There was little or no clogging. Photographs were taken from bellows toward the SBS inlet. There was a small amount of very hard dry particulate at the bottom of the bellows inlet. Photographs of section #3 were taken. Inspection of section #2 of the transition line showed only very slight build-up.<br>Photographs of airlift were taken. There were 3 sets of 2 coupons attached at the bottom, 16", and 40" up.<br>Removed the pancake flange from the transition line.<br>Partially closed chilled water isolation valve MCL-CW-V-494 to raise cooling panel temperatures. This valve is located at outlet of main chilled water heat exchanger MCL-CW-HX-402 and at the inlet of the four chilled water pumps. |
| | | 7/7/2003 | Roof blower panel showed a broken belt warning for blower #1; system automatically switched to blower #2. This fault was caused by severe weather.<br>Blower #1 was reset.<br>Replaced pre-filter on EOG HEPA, MM-EOG-F-402. Switched from EOG HEPA train MM-EOG-F-402 to -403. |
| | | 7/8/2003 | Shifted lance bubbler air supply from mass flow meters to rotameters to implement LabVIEW VI changes. |
| | | 7/9/2003 | Roof blower #2 tripped due to heavy rain. |
| | | 7/10/2003 | Experienced a total of 3 power outages in 60 seconds. Momentarily lost compressed air and connection to all computers.<br>All power was restored. Computer connection to network was not functional. System was left in local drive until network connection could be reestablished.<br>Noticed that chilled water system was not working.<br>Placed domestic water supply in parallel to cooling water system by opening, city water bypass valve, MCL-DW-V-404.<br>Reset labVIEW melter, O/G, feed) from local drive to network data log. Also closed MCL-DW-V-404 valve.<br>Installed new melter labVIEW VI Rev. 1763 software. |

### Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-04R4800-4 | HLW AZ-101 (5/28/03-6/6/03, 6/25/03-7/2/03, 7/15/03-722/03, 8/5/03-8/13/03) | 7/10/2003 | Removed lance bubblers #1 and #2. Installed new lance bubblers #1, #2, #3, and #4 as given below.<br>• “J” type lance bubbler (J3) was installed in port A3<br>• “L” type lance bubbler (L1) was installed in port B3<br>• “J” type lance bubbler (J4) was installed in port C1<br>• “L” type lance bubbler (L2) was installed in port C2<br>LabVIEW was modified to support the “banked” bubbler flow control. Lance bubblers #1 and #2 to be controlled together, and lance bubblers #3 and #4 to be controlled together.<br>Lance bubbler #4 was installed with a new TC. |
| | | 7/11/2003 | Lost roof blower #1 due to severe weather.<br>Observed fluctuations and had to reset some alarms and systems due to weather.<br>Lance bubbler #3 controller was indicating flow with no corresponding glass agitation. Found loose tubing in bubbler control panel. The connections were tightened in order to restore flow.<br>Adjusted EOG damper from ¾ to ½ open.<br>Replaced chilled water pump MCL-CW-P-402A for repair.<br>Cleaned, measured the dimensions, and stored bubblers J5 and J6. Photographs were taken. No damage was observed. |
| | | 7/14/2003 | Airlift was reinstalled.<br>Conducted monthly diesel generator test. |
| | | 7/15/2003 | Shut off city water and returned melter cooling to chilled water system.<br>Lost all power to Hannan Hall.<br>Cooling system was switched to work on city water.<br>Heaters were turned off.<br>About 44 minutes later power was restored. Off-gas system was restarted. |
| | | 7/22/2003 | Transition line bellows was removed due to clogging. A 4" diameter chunk of solids, plus small amount of debris, was removed. Photographs were taken. |
| | | 7/23/2003 | Removed all 4 lance bubblers from melter.<br>Lance bubbler #3 installed in Port C1 (J type) showed small indication of arcing at 19" from bottom. No indication of any bowing or metal loss was seen. Photograph was taken.<br>Lance bubbler #4 installed in Port C2 (L type) showed slight bow at 24" from bottom and indication of joule heating at 22". Photographs were taken.<br>Lance bubbler #2 installed in port B3 (L type) had slight bow and indication of joule heating at 28" from bottom. Photographs were taken.<br>Lance bubbler #1installed in port A3 (J type) showed no bowing, but had indication of joule heating at 28" from bottom. Photographs were taken.<br>Caliper readings of all 4 bubblers were taken.<br>Nylon bushing for lance bubbler #3 back pressure sensor was broken.<br>Switched from city water to chilled water.<br>Installed the pancake between film cooler and transition line.<br>Installed “J” bubblers, J3 in port A-3 and J4 in port D-1. Replaced MM-XXX-TR-09 TC. |
| | | 7/28/2003 | Noticed that air compressor breaker had shut off. The compressor was reset. labVIEW was in local mode.<br>Both labVIEWs were switched back to network mode.<br>Secured city water. Adjusted CW supply valve. |

### Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-04R4800-4 | HLW AZ-101 (5/28/03-6/6/03, 6/25/03-7/2/03, 7/15/03-722/03, 8/5/03-8/13/03) | 7/29/2003 | Reduced chilled water flow.<br>Replaced the film cooler. Photographs of old film cooler were taken. Moderate particulate buildup was observed on louvers and glazed buildup on air vent holes on very bottom of film cooler.<br>Increased chilled water flow by adjusting valve MCL-CW-V-494 to reduce cooling panel temperatures. Switched chilled water pumps and dam wall regenerative blowers. |
| | | 7/31/2003 | Installed lance bubblers #2 (L1) and #4(L3) into ports A-1 and D-3 respectively. Mass flow controllers were set to 1.5 lpm air flow rate.<br>Connection wire on plug for TC of MM-XXX-TR-17, which was loose, was tightened.<br>Investigated compressor air low-pressure alarm and found that compressed air bottle #2 was leaking. The leak was stopped; compressed air was turned back on. |
| | | 8/4/2003 | Switched chilled water cooling pumps and dam wall regenerative blowers.<br>Temporarily transferred lance bubblers #1- #4 air flow control from mass flow controllers (MFCRs) to manual rotameters, MM-CA-FIC-012 thru 00015. Flow was set to 1.0 SCFH each while checking labVIEW program.<br>Transferred lance bubblers #1- #4 air flow control back to mass flow meters. Secured manual rotameters MM-CA-FIC-012 thru -015. No problem was found with melter labVIEW VI. |
| | | 8/5/2003 | Replaced PID (proportional integral derivative) control air controller due to output failure. Configured lance bubblers with one in each corner (i.e. ports A1, A3, D1 and D3) controlled by MFCRs in banked mode with lance bubblers #1 and #2 together, and lance bubblers #3 and #4 together.<br>Utilized city water to supplement CW system on cooling panel temperature control. |
| | | 8/7/2003 | Replaced the thermocouples of MM-XXX-TR-15, -05, -04 and -16.<br>Replaced pitot tube of MM-RGB-FI-201. |
| | | 8/13/2003 | Removed horizontal blank flange on EOG port on the melter lid. Visual inspection showed ~ ½ pipe diameter of solids restricting flow of air. Vacuumed EOG line to remove solids from the pipe all the way to the 90° bend on the east wall. |
| | | 8/14/2003 | All bubblers and airlift were removed.<br>Lance bubbler #1 and #3 showed no evidence of any abnormalities on either "J" bubbler, except for bubbler #3 castable section which showed some damage. Photographs were taken.<br>Lance bubbler #2 showed significant bend at 28" from the bottom. Also, slight joule heating marks were seen at the same location. Castable section also showed damage. Photographs were taken.<br>Lance bubbler #4 was bent at ~28" from the bottom. No signs of joule heating were observed. Photographs were taken.<br>TW #1 showed minor pitting, but no bend. Photograph was taken.<br>TW #2 showed damage to the castable section. Photograph was taken.<br>Airlift showed small bend in middle section, with no other noticeable damage. Photograph was taken.<br>Replaced multi-junction TC in each TW:<br>TCs of MM-XXX-TR-01, -02 and –03 were replaced in TW #1.<br>TCs of MM-XXX-TR-12, -13, -14 were replaced in TW #2<br>Caliper readings of all 4 lance bubblers, both TWs, and air lift were taken.<br>"J" bubblers #1 and #2 were reinstalled. Reconnected TCs for lance bubblers #1 and #2. |
| | | 8/17/2003 | Closed MM-EOG-V-403, manual EOG vent/dilution valve to increase the melter vacuum from -0.1 to -0.2" W.C. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-04R4800-1 | HLW AZ-101 with Sugar (8/19/03-8/28/03) | 8/18/2003 | Switched chilled water pumps and dam wall regenerative blowers.<br>EOG HEPA train #2 in service. |
| | | 8/19/2003 | Utilized two "J" type lance bubblers in ports A3 and D1, respectively controlled in individual mode.<br>Installed air lift.. |
| | | 8/22/2003 | Replaced TW #2 thermocouples MM-XXX-TR-12, -13, and -14. |
| | | 8/26/2003 | Switched chilled water pumps and dam wall regenerative blowers. |
| | | 8/28/2003 | Installed pancake flange in the transition line. |
| | | 8/29/2003 | Main EOG valve, MM-EOG-V-401 failed. Due to failure of the main EOG valve, regular off gas system was started.<br>TW #1 and #2 both were cleaned, inspected and measured for the dimensions. Upon inspection found no significant abnormality on either except damage to the castable on TW #2. Photographs were taken. In addition to caliper measurement of dimensions, and photographs, both TWs were turned over and metallic dust was removed from both. TW #2 had considerably more metallic dust.<br>Removed pre-filters from both EOG HEPA trains.<br>Lance bubbler J1 was installed in port A-3 and J2 in port D-1. Both were cleaned and inspected prior to installation. No significant abnormalities were noted on J2. Lance bubbler J1 located in port A-3 had an arc spot adjacent to a corrosion coupon. Photographs of both lance bubblers were taken.<br>Cleaned and inspected airlift lance. No abnormalities noted, other than a slight bend in the lance located at the location of the lower corrosion coupon.<br>Caliper readings of J1 and J2 lance bubblers, TW #1 and #2, and airlift were taken.<br>Removed MM-EOG-V-401 emergency vent valve and found valve shaft sheared. Replaced shaft and valve with old parts. Photographs were taken. Electrode TCs were calibrated. |
| VSL-04R4800-4 | HLW AZ-101 with chloride and sulfate (9/3/03-9/10/03) | 9/2/2003 | Switched chilled water pumps and dam wall regenerative blowers.<br>Reconfigured electrodes to fire from side to side.<br>Lances bubblers L1 and L2 (in ports B-3 and C-2), TW #2 and airlift were installed. Lance bubbler in C-2 port was configured to be 11.3" from feed tube center line.<br>Film cooler inspected, and was found to be clean. |
| | | 9/5/2003 | Replaced city water filter due to low flow rate. |
| | | 9/6/2003 | Cleaned film cooler rinse spray nozzle. Hole was partially clogged. |
| | | 9/8/2003 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 9/10/2003 | Bubblers, airlift, TW #2 and level detector were removed.<br>Secured air flow through mass flow controllers to bubblers.<br>Removed transition line sections and film cooler.<br>Inspection of film cooler showed 50% blockage at the bottom with light coating on louvers. Photographs were taken.<br>Transition line showed some solids build-up, but no large accumulations. Heavier build-up was seen on bottom of pipe as expected. Photographs were taken. |

### Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-04R4800-4 | HLW AZ-101 with chloride and sulfate (9/3/03-9/10/03) | 9/11/2003 | Replaced EOG HEPA filters and installed pre-filters.<br>Inspection showed vertical section of EOG clear, but horizontal section was ~50% blocked due to hard solid deposits. Solids were chipped as far as possible (i.e. up to 45° bend). Collected sample of material for analysis.<br>Installed pancake flange in the transition line.<br>Due to shared sensor port, melter vacuum reading on EOG panel was in error.<br>Cleaned and inspected air lift. Normal pitting was noted. Five corrosion coupons were still attached. Slight bend in pipe was noticed at lower coupon holder.<br>Cleaned and inspected TW #1. Normal pitting was noted. Three corrosion coupons were still attached. Slight bend was seen ~13" from bottom. Approximately 4-5" of castable was missing from bottom of plug. Photographs were taken.<br>Cleaned and inspected lance bubbler L2. Normal pitting was noted. Arc spots were seen on back side of bubbler, between 27-30". Slight bend was noticed at 28-29". Photographs were taken. Cleaned and inspected level detector. Two coupons were attached. Normal pitting was noted. The level detector tube had a slight bend at 12" and an eroded area next to the outlet of the density tube. The air outlet on both tubes showed signs of erosion. Photographs were taken.<br>Dimensions of the air lift, TW #2, lance bubblers L1 and L2, and level detector were measured using calipers.<br>Reconfigured electrodes to fire from side to bottom.<br>Reinstalled level detector, air lift and TW #2.<br>Replaced MM-XXX-TR-09 TC because the old one broke in half partway through installation. |
| | | 9/12/2003 | Film cooler and transition line were cleaned and reinstalled. Samples and photographs were taken.<br>Positioned the dam wall cooling outlet valve to direct air into film cooler.<br>Removed coupons from discharge chamber. |
| | | 9/15/2003 | Removed all coupons from the transition line.<br>Switched chilled water pumps and dam wall regenerative blowers.<br>Corrected discharge chamber knife gate closed alarm problem by adjusting switch. |
| | | 9/22/2003 | Switched chilled water pumps and dam wall regenerative blowers. |
| | | 9/23/2003 | Replaced TCs in lance bubblers #1 and #3.<br>Reconfigured electrodes to fire from side to side.<br>Installed lance bubblers L1, L2, L3 and L4 in ports A-1, A-3, D-1 and D-4, respectively.<br>Replaced damaged TC wires in lance bubblers #3 and #4. |
| | | 9/24/2003 | Erratic CW temperature indications. Reboot of operating system corrected the problem.<br>Installed 4 "L" bubblers at normal elevations in ports A-1, A-3, D-1and D-3.<br>Added cooling panel flow display on labVIEW. |
| VSL-04R4851-1 | Mixed LAW (9/25/03-9/27/03) | 9/25/2003 | Installed a new exposed plenum TC.<br>Replaced airlift TC. |
| | | 9/27/2003 | Removed level detector. |
| | | 9/29/2003 | Found that melter cooling panel system flow rate indicator, MCL-CW-FR-401 pitot tube had failed. A spare was calibrated and installed.<br>Inspection of level detector showed that bottom 12-15" of pipe was heavily pitted, and that bottom of pipe had started to break and fall part. Density pipe was in similar condition though the damage was not that severe. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

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|---|---|---|---|
| VSL-04R4851-1 | LAW Envelope C (9/30/03-10/9/03) | 9/30/2003 | Installed level/density detector in normal position in port B-1and additional detector in port C-1.<br>Swapped CW pumps and RGB blowers.<br>Replaced film cooler outlet TC. |
| | | 10/3/2003 | Replaced butterfly type dampers on EOG HEPA trains with slide gate style dampers.<br>Replaced compressed air bottle #1. |
| | | 10/7/2003 | Swapped CW pumps and RGB blowers. |
| | | 10/8/2003 | Replaced exposed plenum temperature TC. |
| | | 10/10/2003 | Removed transition line bellows. Inspection showed only some small chunks of solids and some very fine white particulate, samples of which were collected. The rest of the transition line showed only a thin coating of particulate.<br>Secured mass flow controllers (MFCRs) for bubblers, and bubbler air flow control was switched to manual rotameters while updating some of the software.<br>Computer updates were completed. Air flow control was returned to MFCRs. |
| | | 10/15/2003 | Replaced pre-filter in EOG HEPA train MM-EOG-F-402<br>Swapped chilled water pumps and dam wall regenerative blowers.<br>Adjusted control air set point for melter pressure from 3.75 to 3.0" W.C. |
| | | 10/16/2003 | Replaced HEPA filter in EOG HEPA train MM-EOG-F-401. |
| | | 10/17/2003 | Replaced pre-filter and filter in EOG HEPA train MM-EOG-F-402. |
| | LAW Envelopes A and C (10/20/03-10/23/03) | 10/20/2003 | Replaced TW #2, thermocouples MM-XXX-TR-15 and -16.<br>Replaced TW #1, thermocouples MM-XXX-TR-04 and -05.<br>Switched chilled water pumps. |
| | | 10/24/2003 | Removed transition line section #3 and bellows, and took solids samples. Photographs were taken.<br>Removed transition line section #2, and collected samples. Photographs were taken.<br>Transition line sections were reinstalled. Installed a pancake flange on bellows outlet to allow draining and inspection of SBS. |
| | | 10/28/2003 | Replaced level detector.<br>Replaced pre-filters in both EOG HEPA trains.<br>Replaced main city water filter.<br>Lance bubblers #1 and #4 MFCRs were removed to do a check. Lance bubblers #1 and #4 were connected to manual rotameter circuit at 1.0 SCFH air flow rate.<br>Lance bubblers #1 and #4 were connected back to mass flow controllers. |
| | | 10/30/2003 | Temporarily tested new melter labVIEW software.<br>If labVIEW VI fails, the system will be restarted using the new Rev 17c. |
| | | 10/31/2003 | Performed calibrations of back pressure transmitters for lance bubblers #1 - #4, and the inlet gas, outlet gas, and differential pressure transmitters.<br>Completed calibration of density probe. |
| VSL-03L4850-1 | LAW + HLW (11/03/03-11/08/03) | 11/3/2003 | Replaced plenum exposed TC.Switched CW pumps and RGB blowers.<br>Repaired tubing for melter pressure indicator (MM-XXX-PR-200). Near the EOG line, tubing appeared to be brittle.<br>Replaced 2 part level detector with single unit per new design.<br>In-house comparison checks of flow rates were made against a calibrated NIST traceable manual rotameter. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-03L4850-1 | LAW + HLW (11/03/03-11/08/03) | 11/4/2003 | Replaced control air flow pitot tube, OG-DA-FR-301. Replace the control air valve.<br>Bled air from the cooling system flow transmitter to restore normal system readings. |
| | | 11/8/2003 | Pancake flange was installed in transition line inlet.<br>Lance bubblers were removed from the melter.<br>Lance bubbler #1 had heavy pitting up to 24" from bottom and a substantial bow at about 16-24". Photographs were taken.<br>Lance bubbler #2 had a slight bow and showed minor pitting. Photograph was taken.<br>Lance bubbler #4 showed minor pitting. Photograph was taken.<br>Lance bubbler #3 showed only minor pitting.<br>Caliper readings of all lance bubblers were taken.<br>Installed lance bubbler #1 in port B-3 and lance bubbler #2 in port C-2. |
| | | 11/10/2003 | Observed lance bubbler #2 flow to be 0 SCFH; and on investigation found that MFCR air supply was not connected. Reconnected air supply to the bubbler.<br>Due to lack of spare MFCRs, utilized lance bubbler #3 MFCR for lance bubbler #2.<br>Switched the chilled water pumps.<br>Switched melter electrode control power fuses from 1 amp to 5 amps. One amp was too close to the normal load for the circuit. 5 amps fuse allows circuit to operate while maintaining necessary protection. Fuses were switched to allow for changeover to VSL emergency generator power.<br>Diesel generator test was performed.<br>Bubbler configuration modified from 4 lance bubblers to 2 bubblers.<br>Installed lance bubbler #2 (L2) in port C-2 at 11.3" from feed tube center. Installed lance bubbler #1 (L1) in B-3 port. |
| VSL-04R4800-4 | HLW AZ-101 (3/23/04-4/02/2004) | 11/11/2003 | Swapped dam wall regenerative blowers. |
| | | 11/12/2003 | Replaced electrode TCs of MM-XXX-TR-22 and -23. |
| | | 11/15/2003 | Removed lance bubblers #1 and #2. Changed electrode firing pattern to side to bottom.<br>Bubblers were cleaned, inspected photographed, and measured for dimensions.<br>Lance bubbler #1 was bowed and had pitting in the lowest 12" section of the bubbler.<br>Lance bubbler #2 had a large bend in the top 40" of bubbler and heavy pitting on lower section of bubbler. |
| | | 11/17/2003 | Air compressor alarm activated. Investigation showed that air compressor main breaker had failed. No spare was in stock. Lowered all electrode bubbler flow rates.<br>Removed both TWs.<br>Cleaned and inspected TW #1 and #2. Both are bent about 9-11" from bottom. Normal pitting also was observed.<br>Photographs of both TWs were taken. Caliper readings of both TWs were taken.<br>Replaced multi-function TC in TW #1. |
| | | 12/2/2003 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Diesel generator testing was performed.<br>Removed TW #2. |
| | | 12/3/2003 | Moved control air controller location.<br>Installed TW #2 with 3 corrosion coupons. |
| | | 12/4/2003 | Removed transition line pancake flange.<br>Fitting for L2 bubbler, which was slightly loose was tightened. |
| | | 12/5/2003 | Main EOG valve, MM-EOG-V-401 was replaced with a knife gate valve. Its functional test was satisfactory. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-04R4800-4 | HLW AZ-101 (3/23/04-4/02/2004) | 12/6/2003 | City water low pressure alarm sounded. Found city water valve on west wall in the open position. Valve was closed.<br>Due to low city water pressure, removed camera from feed tube port and replaced blank plug. |
| | | 12/9/2003 | Swapped chilled water pumps. |
| | | 12/12/2003 | Removed the mass flow controller, MFCR-004 for testing.<br>Replaced the thermocouples for MM-XXX-TR-01, -02, -03, -04, -12, -13, -14 and -15.<br>Removed feed tube from "feed port" and installed a blank flange in its place.<br>Replaced the mass flow controller, MFCR-004 in the system. |
| | | 12/15/2003 | Installed 2 "J" bubblers in ports A-3 and D-1. The video camera was also installed in the feed tube port to record the bubbler configuration testing.<br>Bubbler depth was adjusted twice.<br>Installed the pancake flange in transition line. |
| | | 12/16/2003 | Switched electrode firing from side to bottom to side to side. Installed "L" bubblers in ports A-1 and D-3. "J" bubblers are still installed in ports D-1 and A-3. The bubblers were rotated so that there is 14" separation from tips of bubblers in A-1 and A-3 and D-1 and D-3 per project direction.<br>Depths of bubblers were changed.<br>Removed bubblers to reinstall in a new configuration.<br>Installed bubblers for bubbler configuration test. |
| | | 12/17/2003 | Bubbler depths were adjusted.<br>Adjusted east electrode high temperature alarm set point from 1100 °C to 1110 °C to complete tests per the test plan. |
| | | 12/18/2003 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Removed lance bubblers #1, #2, #3, and # 4.<br>Electrode firing configuration was changed from side to side to side to bottom. |
| | | 12/19/2003 | Changed electrode high temperature alarm set point from 1110 °C to 1100 °C. |
| | | 12/20/2003 | Switched EOG HEPA train MM-EOG-F-401 to -402. |
| | | 12/21/2003 | Compressor low pressure alarmed. Restored compressor pressure. |
| | | 1/6/2004 | Swapped CW pumps and dam wall blowers.<br>Removed transition line sections and bellows. Dam wall cooling outlet valve was positioned to direct air to EOG line. |
| | | 1/7/2004 | Removed film cooler. Photographs of the transition line sections including bellows and film cooler were taken. Film cooler seems to be clean and inspection found no sign of abnormalities. |
| | | 1/8/2004 | Removed total of ~1.4 kg solids from the transition line sections. Inspection of the film cooler showed no particulate to sample. |
| | | 1/12/2004 | Determined that air compressor failure was due to power supply failure inside the unit. Parts will not be available until 1/13/2004.<br>Opened manual EOG vent/dilution air valve, EOG-V-403 to reduce vacuum in the melter from 0.28" W.C. to 0.15" W.C. |
| | | 1/21/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 1/27/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 1/28/2004 | Placed new air compressor in service and old air compressor in stand by. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

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|---|---|---|---|
| VSL-04R4800-4 | HLW AZ-101 (3/23/04-4/02/2004) | 2/2/2004 | Swapped CW pumps and dam wall regenerative blowers.<br>Simulated loss of power and tested the diesel generator. |
| | | 2/4/2004 | Electrode firing pattern was changed from side to bottom to side to side. |
| | | 2/5/2004 | Secured cooling water to camera cooling plug. Plug had been removed form the melter. |
| | | 2/6/2004 | Disconnected air flow to lance bubblers to allow glass migration to occur. |
| | | 2/11/2004 | Transition line inlet pressure transmitter taken out of service for testing. Cooling water flow transmitter, MCL-CW-FR-401 placed in service to monitor system flow rate.<br>Transition line inlet pressure transmitter returned to service.<br>Mass flow controllers for bubblers L1A, L4A, spare 6, electrode bubblers # 2, #3, and #4 were placed back in service. |
| | | 2/12/2004 | Melter cooling panel system flow rate transmitter, MCL-CW-FR-401 was isolated to check the problem with the transmitter. |
| | | 2/17/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Switched EOG HEPA train MM-EOG-F-402 to F-401. |
| | | 2/23/2004 | Replaced the thermocouples of thermowells #1 and #2, MM-XXX-TR-04, -15, -05 and -16. |
| | | 2/24/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 3/1/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Performed simulated loss of power diesel generator test. |
| | | 3/5/2004 | Replaced the thermocouples of chilled water return and supply MCL-CW-TR-417 and 418, respectively. City water low-pressure alarm sounded. No knowledge of any broken mains or any other problems. |
| | | 3/6/2004 | City water low-pressure alarm was cleared. |
| | | 3/8/2004 | Swapped CW pumps and dam wall blowers.<br>Installed a new TC on film cooler internal temperature, MM-XXX-TR-09.<br>Repositioned dam wall exhaust diverter three-way valve MCA-RGB-V-220 to exhaust via the film cooler. |
| | | 3/9/2004 | Replaced filter and pre-filter of MM-EOG-F-401 EOG HEPA train. |
| | | 3/10/2004 | Completed installation of film cooler and transition line assembly from melter to SBS.<br>Installed two coupons in the transit line closest to the film cooler.<br>Straightened transition line piping and installed metal gasket on the bellows flange upstream of the SBS. |
| | | 3/11/2004 | Replaced the three-way control valve (which maintains the chilled water temperature during idling) MCL-CW-V-496 positioner, and restored automatic temperature control of chilled water at 80 °F.<br>Melter air pressure indication was connected to control air circuit. |
| | | 3/12/2004 | Replaced air pressure transmitter. Replaced 0-100 psi pressure transmitter, which displays "compressed air pressure" indicator on the annunciator sub-panel. The new transmitter, which measures 0-200 psi, was placed in service.<br>Raised compressor air low-pressure indicator set value from 100 psi to 105 psi. |
| | | 3/14/2004 | Placed both EOG HEPA trains online. |
| | | 3/16/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Installed corrosion coupons in discharge chamber. |
| | | 3/17/2004 | Leak found on CPVC coupling to lance bubbler #2 hose. Investigated and found that fitting had cracked.<br>Replacement of CPVC header is required.<br>Replaced TW #2 multi-thermocouples, (TCs of MM-XXX-TR-12, -13 and -14).<br>Replaced TC for MM-XXX-TR-08. |

### Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-04R4800-4 | HLW AZ-101 (3/23/04-4/02/2004) | 3/18/2004 | Modified lance bubbler tubing to combine outputs from mass flow controller MM-CA-MFCR-003, MM-CA-MFCR-008, MM-CA-MFCR-004, and MM-CA-MFCR-009 as a single source to lance bubbler #2 (port D-1) since the test plan called for more air flow than that one mass flow controller alone could provide.<br>Replaced TCs of MM-XXX-TR-06 and -10.<br>Modified tubing connections for lance bubbler #1 to combine outputs from mass flow controller MM-CA-MFCR-001, MM-CA-MFCR-006, MM-CA-MFCR-002, and MM-CA-MFCR-007 as a single source to lance bubbler #1. Reconfigured mass flow meters to conduct the test according to the test plan. |
| | | 3/19/2004 | Replaced filter and pre-filter of EOG HEPA lower train (MM-EOF-F-401).<br>Removed pancake from the transition line.<br>Replaced filter and pre-filter in EOG HEPA train of MM-EOG-F-401. All the studs that hold the door shut have stripped.<br>Opened the chilled water isolation valve, MM-EOG-V-494, and closed city water valve.<br>Removed both TWs, level detector, and airlift. TW #1 is to be inspected and reinstalled. |
| | | 3/20/2004 | Alarms sounded twice when air compressors pressure reached 100 psi.<br>TW #1 and #2 caliper readings of dimensions were taken. Photographs were taken. Inspection showed no damage or abnormalities. |
| | | 3/22/2004 | Placed melter cooling panel system flow rate transmitter MCL-CW-FR-401 in service.<br>TW #2 was cleaned, inspected and measured. No damaged spots were found. Photograph was taken.<br>Similar observations were for the level detector. Photographs were taken.<br>Performed inspection of air lift. Observed a slight bend at approximately 21" from the bottom (at the 2$^{nd}$ corrosion coupon tab), which possibly happened during removal. No other damages were observed. Digital photographs were taken.<br>Swapped chilled water pumps and dam wall regenerative blowers.<br>Isolated MCL-CW-FR-401 so that maintenance could be performed on the cooling system.<br>Changed melter thermocouple connections to module 1120 for labVIEW; MM-XXX-TR-01 to MM-XXX-TR-04 and MM-XXX-TR-12 to MM-XXX-TR-15.<br>Completed caliper readings for the airlift and level detector.<br>Installed TW #2, airlift, level detector and lance bubbler #1.<br>DM1200 melter lid temperature survey was done. |
| VSL-04R4800-4 | HLW AZ-101 (3/23/04-4/02/04) | 3/23/2004 | Replaced multi-thermocouple in TW #1 for MM-XXX-TR-01, -02 and -03.<br>Completed 1st functional check of melter labVIEW VI rev 17e for bubbler control. The check failed because the MFCR flow readings were erratic.<br>Retested melter labVIEW VI Rev 17e again for functionality. The test was satisfactory, and the new software was accepted for operations.<br>Lance bubblers were modified to be two deep bubblers with 2 outlets each. Bubblers were set on melter floor through ports A-3 and D-1. |
| | | 3/27/2004 | Drained control air receiver tank in mechanical room; ~ 10 gallons of water was removed. |
| | | 3/31/2004 | Replaced MM-XXX-TR-04 TC in TW #1. |
| | | 4/2/2004 | Cleared blockage of EOG vertical line on top of the melter. The 4" line was ~ 50% blocked. |
| | | 4/5/2004 | Secured power to mass flow controllers for lance bubblers L1A and L3A. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-04R4800-4 | HLW AZ-101 (3/23/04-4/02/04) | 4/6/2003 | Removed film cooler and transition line sections.<br>Video and digital photographs of the film cooler and the transition line assembly were taken. Visual inspection showed that most of the transition line was clear of solids build-up. No solids were removed. Film cooler showed some glass and dry feed mostly on the bottom section covering the air holes. Film cooler was cleaned (gently) due to minor metal corrosion.<br>Swapped CW pumps and dam wall regenerative blowers. |
| VSL-05R5800-1 | HLW AZ-102 (6/21/04-6/30/04, 8/2/04-8/7/04) | 4/13/2004 | Swapped CW pumps and dam wall regenerative blowers |
| | | 4/15/2004 | Photographs were taken of film cooler and transition line bellows. |
| | | 4/16/2004 | Removed discharge chamber coupons and transition line coupons. |
| | | 4/19/2004 | Swapped CW pumps and dam wall regenerative blowers.<br>Removed TW #2, airlift, level detector and lance bubbler #1 for inspection and coupon removal. |
| | | 4/20/2004 | Level detector showed only very minor pitting on submerged section of level and density pipes. Two corrosion coupons in plenum area were still attached. Photographs were taken.<br>Airlift showed some crystallization from 8-15" with minor bend at coupon tab (21" elevation). Photographs were taken.<br>Inspection of DB-2 lance bubbler (DB stands for deep bubbling double outlet bubbler) showed ~1/2 of bottom support tab missing with a shiny (silver) look to bottom of pipe (melter floor side). Significant arc spots were observed at 1st coupon tab (~15" from floor) with shiny metal surface. Remainder of the bubbler was in good condition with no visible damage. Photographs were taken.<br>Bubbler did have a slight bend near 1st tab (possibly may have occurred during removal). Seven corrosion coupons were still attached.<br>Inspection of TW #2 showed no damage or arc spots. Photographs were taken. Three corrosion coupons were attached.<br>Caliper readings of level detector, air lance, lance bubblerDB-2 (in port A-3), TW #1 and TW #2 were taken. |
| | | 4/21/2004 | Removed lance bubbler #2 (DB-1) (deep bubbling double outlet bubbler -1) and installed TW2, level detector, smaller "J" bubblers, lance bubbler #1 in port A-3 and lance bubbler #2 in port D-1 (lance bubbler ID in port A-3 is J3 and in port D-1 is J5).<br>Visual inspection of lance bubbler from port D-1 (DB-1) showed that bottom support tab was completely missing and tip end of the bubbler lance had bent away from horizontal to vertical (pointing down towards the floor). Slight "rounding" of tip and other minor heat spots were noted on the vertical portion of the submerged section. Photographs were taken. Caliper readings of bubbler #2 (DB-1) were taken.<br>Installed air lift. |
| | | 4/25/2004 | Adjusted manual set point for electrode(s) and discharge chamber power. |
| | | 4/26/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Comparison check was performed between NIST traceable calibrated flowmeter and mass flow meter, MM-CA-MFR-009 (used to supply air to lance bubbler L4B). |
| | | 4/27/2004 | About 3 gallons of water was blown down from the compressor.<br>Installed film cooler and associated transition line piping. Diverted dam wall air flow via film cooler.<br>Checked EOG cleaning port for solids build-up. Very little debris was found. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-05R5800-1 | HLW AZ-102<br>(6/21/04-6/30/04,<br>8/2/04-8/7/04) | 4/28/2004 | About 1 gallon of water was blown down from the compressor.<br>Checked EOG port. No solids build-up was found in the vertical section, but very minor build-up was found up to 45 ° bend in the horizontal section.<br>MM-XXX-TR-15 TC was found damaged due to arcing. MM-XXX-TR-15 TC was fused to MM-XXX-TR-16 TC. MM-XXX-TR-09 TC was also out of service, but not due to the arcing. Replaced TC of MM-XXX-TR-15. |
| | | 4/29/2004 | Repositioned external section of TC of MM-XXX-TR-16 to eliminate the chance of arcing to ground. |
| | | 5/2/2004 | Electrode power control was switched to ordinary potentiometer because of automatic circuit failure (Dimension controller). |
| | | 5/3/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Performed loss of power simulation, diesel generator test.<br>About 5-6 gallons of water was blown down from the compressor.<br>Switched discharge chamber heater control to manual setting at 33.3%.<br>Replaced dimension controller with spare unit.<br>Replaced TC of MCL-CW-TR-418. |
| | | 5/7/2004 | Adjusted control air damper for EOG to increase vacuum to -0.16" W.C. |
| | | 5/10/2004 | Electrode bubbler #5 pressure transmitter was removed and tested. The unit passed the functional tests successfully and was returned to service. |
| | | 5/11/2004 | Removed airlift. TC out of lance bubbler #2 was removed.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 5/17/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Replaced the cooling fan on top of the melter. |
| | | 5/20/2004 | Refer to DB-1 and DB-2 damaged or missing support tabs on 4/20/2004 and 4/21/2004 entries.<br>Analysis of tab material determined that tabs were not Inconel 690, but stainless steel. New supports were made of ½" thick I-690 and welded in place. Tabs are ½" thick, 1½" wide and 1¾" long. |
| | | 5/21/2004 | Dimension controller was replaced with two Love Model 8600 controllers. |
| | | 5/24/2004 | Switched the discharge chamber power and electrode controls from the Dimension controller to Love Model 8600 controller in order to perform functional testing.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 5/25/2004 | Electrode temperature loop calibrations were completed.<br>Completed various temperature loop checks throughout the melter system.<br>Opened city water bypass valve, MCL-DW-V-404, due to chillers being down.<br>CUA maintenance indicated that chilled water was functioning, but there appeared to be a damper problem. |
| | | 5/27/2004 | Removed vertical and horizontal flanges on the EOG and rodded out piping beyond the initial bend. Minor blockage was observed after the flanges. |
| | | 6/1/2004 | Swapped CW pumps and dam wall regenerative blowers,<br>Performed loss of power simulation testing of diesel generator.<br>Removed film cooler to install TC. Installed TC for MM-XXX-TR-09, film cooler internal temperature.<br>Reinstalled film cooler in melter system. Redirected dam wall air flow back into film cooler.<br>Replaced filter and pre-filter of EOG HEPA train MM-EOG-F-402. Both filters appeared black. Repaired threads for door bolts and installed new wing nuts. |
| | | 6/2/2004 | Removed blockage in EOG piping using a drain snake. Build-up appeared to be in the first 90° elbow closest to melter. |

# Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-05R5800-1 | HLW AZ-102 (6/21/04-6/30/04, 8/2/04-8/7/04) | 6/3/2004 | Melter pressure sensor, MM-XXX-PR-200 tubing, which became disconnected, was reconnected. |
| | | 6/4/2004 | Completed riser TC temperature evaluation. |
| | | 6/7/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 6/10/2004 | Adjusted dilution air damper. |
| | | 6/14/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Secured bypass rotameters for lance bubblers #1 and #3 and reconnected to mass flow meters MM-CA-MFCR-001 and 003. Set flow rate for both at 1.5 lpm each. |
| | | 6/15/2004 | Air lift was installed.<br>Rebooted melter labVIEW VI.<br>Switched instrument port (for melter pressure) from B-2 to B-3 due to camera being installed.<br>Switched to Dimension controller; unable to switch back to Love 8600 controller.<br>Secured power to the Love 8600 melter and discharge chamber controllers. Replaced the Love 8600 melter controller. Restored power to the Love 8600 melter and discharge chamber controllers.<br>Removed lance bubbler #3 for inspection. |
| | | 6/16/2004 | Inspected and took photographs of lance bubbler #3. Inspection showed bubbler pipe to be in good condition. Glass blockage was seen at air inlet. Somehow glass had migrated up the entire length of the bubbler and frozen at air inlet. Caliper readings of the bubbler dimensions were also taken. |
| | | 6/17/2004 | Cleared the glass blockage that was observed in lance bubbler #3.<br>Installed lance bubbler #3 in port D-1.<br>Disconnected labVIEW power indicator in order to perform a functional test of the loop.<br>Reconnected labVIEW power indicator. Loop calibration test was completed successfully.<br>Replaced plenum exposed TC of MM-XXX-TR-17.<br>Completed water separator filter maintenance for air dryer system.<br>Switched lance bubbler #3A to the manual rotameter in order to perform mass flow controller maintenance.<br>Replaced riser TC of MM-XXX-TR-08.<br>Compressor air dryer alarm sounded and was investigated.<br>Returned lance bubbler #3A connection to the mass flow controller. |
| | | 6/18/2004 | Compressed air system functioned satisfactorily after the alarm was reset.<br>Functional testing of electrode voltage and electrode power current loops was completed. No problems were found. All testing was completed successfully.<br>Thermocouples of MM-XXX-TR-21, -22, and -23 were replaced. |
| | | 6/21/2004 | Added 2nd set of power controllers for melter electrodes and discharge heaters.<br>Switched from Dimension controller to Love controller.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 6/25/2004 | Removed nominal depth "J" bubbler. Installed extended bubbler that rests on the melter floor.<br>Installed extended bubbler #1 (DB-2) in port A-3 and extended bubbler #2 (DB-1) in port D-1. |
| | | 6/26/2004 | Inspections and caliper readings of lance bubblers J3 and J5 were performed. No signs of damage were found. Photographs were taken. |
| | | 6/28/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 6/29/2004 | Photographs were taken of cold cap formation and stalactites in the melter plenum. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-05R5800-1 | HLW AZ-102 (6/21/04-6/30/04, 8/2/04-8/7/04) | 6/30/2004 | Lance bubbler #2 was raised to cool prior to removal.<br>Removed lance bubbler #2 from the melter.<br>Lance #1 was raised to cool and then removed.<br>Lance bubblers J3 and J5 were installed in ports A-3 and D-1, respectively. |
| | | 7/1/2004 | Switched off all but mass flow meters L1A and L3A a 1.5 lpm each.<br>Opened MM-EOG-V-403 (EOG-HEPA-401 outlet damper) about half way. Melter vacuum decreased from -0.25"W.C. to -0.20" W.C.<br>Lance bubblers DB-1 and DB-2 were cleaned and inspected. Lance bubbler DB-1 appeared to be in good condition with only minor pitting. Lance bubbler DB-2 was in similar condition with minor pitting and no arcing spots. Photographs were taken. Caliper readings of the dimensions were taken. |
| | | 7/6/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 7/7/2004 | Switched dam wall regenerative blower from MCA-RGB-B-102 to B101. MCA-RGB-B-101was slated to remain in use for 2 weeks to make up for not being switched in proper sequence to balance run time. |
| | | 7/9/2004 | Switched from EOG HEPA train MM-EOG-F-401 to -402. |
| VSL-05R5800-1 | HLW AZ-102 | 7/13/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 7/15/2004 | TW #1 and TW #2 were removed. Visual inspection of TW #1 and TW #2 showed no damage. Caliper readings of dimensions, and photographs were taken.<br>TW #1 and TW #2 were reinstalled.<br>Changed air dryer inlet filter. Removed desiccant for inspection and refilled with same material. The dryer was turned back on. |
| | | 7/17/2004 | Adjusted dilution air to bring vacuum to about -0.20" W.C. Observed readings of MM-AR-PR-201, MCA-RGB-FR-201, MM-XXX-TR-11 and HF-EOG-DPI-403 (differential pressure across MM-EOG-F-402 EOG HEPA train). |
| | | 7/19/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Both EOG HEPA trains were placed online. |
| | | 7/26/2004 | Swapped CW pumps and dam wall regenerative blowers. |
| | | 7/29/2004 | DM1200 high electrode temperature alarm sounded. Started actions to correct the situation. |
| | | 7/30/2004 | Switched lance bubblers #1 and #2 to manual rotameters MM-CA-FIC-012 and MM-CA-FIC-013, respectively. Manual rotameters were set to 1 SCFH. Bubbling was verified inside the melter before and after the flow controllers were switched.<br>Adjusted EOG dilution air valve.<br>Returned lance bubblers #1 and #2 inputs to mass flow controller MM-CA-MFCR-001 and MM-CA-MFCR-003, respectively. Mass flow controller MM-CA-MFCR-006 was removed for testing. Mass flow controller MM-CA-MFCR-010 was used to replace mass flow controllerMM-CA-MFCR-006. Mass flow controllers MM-CA-MFCR-001 and MM-CA-MFCR-003 were set to 1.5 lpm. Bubbling was verified inside the melter. |
| | | 7/31/2004 | Added water to CW secondary system.<br>Replaced thermocouples in TW #2. New multi-thermocouple consists of MM-XXX-TR-12, -13, -14, -15 and -16. TCs of MM-XXX-TR-04 and MM-XXX-TR-05 in TW #1 were also replaced.<br>Changed filter and pre-filter of MM-EOG-F-401 EOG HEPA train. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-05R5800-1 | HLW AZ-102 | 8/1/2004 | Replaced HEPA filter and pre-filter of MM-EOG-F-402 EOG HEPA train. There was a leak in the bottom left corner due to inability to tighten the wing nut. A longer bolt was used to correct this problem.<br>Switched EOG HEPA train MM-EOG-F-401 to -F-402. It was not possible to seal the door of EOG HEPA train MM-EOG-F-401 due to studs, which were fixed or replaced as needed. |
| | | 8/2/2004 | Swapped chilled water pumps and dam wall regenerative blowers. Simulated loss of power and tested diesel generator.<br>Modified film cooler spray to utilize a wand inserted through top view-port to the bottom of film cooler. Spray volume was still set at 5 liters. Previous film wash method was discontinued.<br>Inserted melter camera in port C-2.<br>Electrode power control was switched back to Love controller.<br>Replaced transducers for electrode voltage and electrode power with newly calibrated units (or units with unexpired calibration dates) as part of instrumentation calibration maintenance. |
| | | 8/3/2004 | Replaced TW #1 multi-TC due to suspect readings. |
| | | 8/10/2004 | Airlift was removed. |
| | | 8/12/2004 | Cleaned airlift for inspection. There were 3 bends in the pipe; one at 9" from the bottom, second at 16" from bottom, and the third at 22" from the bottom. Photographs were taken. The most significant damage was that a piece of the pipe had flaked off at 48" from the bottom. Caliper readings of the airlift were taken. It was decided to replace the airlift. |
| | | 8/12/2004 | Removed bubblers J3 and J5 from the melter. Bubblers DB-2 and DB-1 were installed in ports A-3 and D-1, respectively.<br>Slightly closed EOG damper slide gate. |
| | | 8/13/2004 | Completed cleaning and inspection of bubblers J3 and J5. Inspection showed no damage on either bubbler, except for heat marks at about 22" from the bottom on lance bubbler J5. Caliper measurements of the dimensions and photographs were taken. |
| | | 8/14/2004 | City water low pressure light was lit on the annunciation panel. However, water pressure throughout the room appeared normal. |
| | | 8/15/2004 | City water alarm was investigated. It was found that the supply valve to the pressure transmitter was closed.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 8/17/2004 | Repaired door on EOG HEPA MM-EOG-F-401 housing and put that train on line. EOG HEPA train MM-EOG-402 was taken off line and filter and pre-filter were replaced.<br>Placed EOG HEPA train MM-EOG-F-402 train back in service and took MM-EOG-F-401 off line. |
| | | 8/19/2004 | Photographs were taken of plenum camera fixture, camera, and light.<br>Switched EOG HEPA train from MM-EOG-F-402 to -401. |
| | | 8/23/2004 | Replaced EOG HEPA filter and pre-filter on MM-EOG-F-402.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 8/24/2004 | Cooling panel temperature indicator (MCL-CW-TR-408) appeared to be out of service; monitoring continued. |
| | | 8/25/2004 | Rebooted Melter labVIEW. MCL-CW-TR-408 functioned properly. |
| | | 8/25/2004 | Annunciator panel alarm was noticed, but no lights were illuminated. No operational problems were identified. |
| | | 8/30/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Installed lance bubbler L1B. Moved mass flow controller MM-CA-MFCR-010 to stand by. |
| | | 8/31/2004 | Switched EOG HEPA train from MM-EOG-F-401 to MM-EOG-F-402. |
| | | 9/1/2004 | Performed simulated loss of power, diesel generator test. |
| | | 9/5/2004 | Adjusted dilution air damper. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-05R5800-1 | HLW AZ-102 | 9/7/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Opened EOG HEPA train MM-EOG-F-402 due to low melter vacuum and high HEPA temperature. |
| | | 9/8/2004 | City water low pressure alarmed due to testing by CUA maintenance.<br>Replaced pre-filter on EOG HEPA train MM-EOG-F-401. Closed EOG HEPA train MM-EOG-F-402. Replaced pre-filter on EOG HEPA train MM-EOG-F-402. |
| | | 9/12/2004 | Opened flow to EOG HEPA train MM-EOG-F-402. Both trains were placed on line. |
| | | 9/13/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 9/14/2004 | Inspection of EOG piping showed plenty of solid material throughout. Photographs were taken. About 160 grams of solids sample was removed from the EOG piping. Including the solids removed earlier, total mass of solids removed from the EOG piping was about 6.1 kg. Photographs were taken.<br>1.7 kg more solids were removed from the EOG pipe after the EOG valve. The new total solids mass was about 7.8 kg plus the sample mass of ~160 grams.<br>Closed EOG HEPA train MM-EOG-F-401.<br>Opened EOG manual vent/dilution valve, MM-EOG-V-403 about ¾ way. |
| | | 9/15/2004 | Adjusted MM-EOG-V-403 to be open ~½ way. |
| | | 9/16/2004 | Closed MM-EOG-V-403. Partially closed EOG dilution air slide gate to increase vacuum.<br>Obtained caliper measurements of new air lift.<br>Installed new air lift.<br>Removed air lift due to a bad TC fitting. TC that was damaged during earlier air lift removal was replaced. |
| | | 9/17/2004 | Lance bubbler #2 was pointing closer to TW #2 than preferred. Adjusted lance bubbler #2 orientation more towards port C-2.<br>Opened city water bypass valve, MCL-DW-V-404, to provide additional cooling to the panels.<br>Closed MCL-DW-V-404 valve because chilled water was back on line.<br>Adjusted main EOG valve to be ~ ½ closed.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 9/23/2004 | Adjusted main EOG valve slightly. |
| | | 9/24/2004 | Collected dip samples. |
| | | 9/27/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 10/1/2004 | Collected dip samples |
| | | 10/4/2004 | Swapped chilled water pumps and dam wall regenerative blowers. Performed simulated power loss diesel generator test. |
| | | 10/8/2004 | Dip samples were collected. |
| | | 10/9/2004 | Opened main EOG valve slightly. |
| | | 10/12/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Slightly closed main EOG valve slide gate. |
| | | 10/18/5004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 10/16/2004 | Adjusted EOG damper open slightly. |
| | | 10/29/2004 | TC of MM-XXX-TR-04 failed and was removed. Repaired connection plug of TC of MM-XXX-TR-04 that had heat damage. TC of MM-XXX-TR-04 was scheduled to be replaced within the week with TCs of MM-XXX-TR-05, -15 and -16.<br>Completed functional testing of the lance bubbler back pressure transmitters. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-05R5800-1 | HLW C-106/AY-102 (11/08/04-11/12/04) | 11/1/2004 | Film cooler wash lance was tested. The timer was set for a 230 second cycle with the air pulse set for 10 seconds on and 10 seconds off. One cycle was set to provide 5 liters of wash water.<br>Swapped CW pumps and dam wall regenerative blowers. |
| | | 11/3/2004 | TW #1 and TW #2 were removed. During removal hot glass dripped on the level detector tubing causing erratic reading on labVIEW. Level detector tubing was repaired. Caliper readings of both TWs were taken. Digital photographs of TWs were taken. |
| | | 11/4/2004 | Replaced the following thermocouples: MM-XXX-TR-04, -05, -06, -10, -15, -16 and -17. Thermowells were cleared of debris before reinstallation of thermocouples. Noticeable reduction in diameter measurements on both TW at 18" from the bottom.<br>Replaced the following thermocouples: MM-XXX-TR-01, -02, -03, -12, -13 and -14.<br>TW #1 and TW #2 were reinstalled. |
| | | 11/5/2004 | Found that TCs of MM-XXX-TR-14 and MM-XXX-TR-15 were reversed. During the swap of connections, TC wire of MM-XXX-TR-14 broke inside the connector. Repaired connection.<br>Removed mass flow controllers MM-CA-MFCR-002 and MM-CA-MFCR-005 for testing. Moved mass flow controller MM-CA-MFCR-010 into the mass flow controller MM-CA-MFCR-002 position.<br>Collected dip sample. |
| | | 11/8/2004 | Rebooted both melter and off-gas labVIEWs.<br>Observed difficulty in achieving normal discharge temperatures. Investigated and found that the weld connecting mounting flange to the bottom of the discharge chamber was partially cracked causing air inleakage.<br>Modified film cooler rinse mechanism to combine water and compressed air purge during wash cycle. Cycle time was set to 120 seconds for a 5-liter flush. |
| | | 11/13/2004 | Removal and inspection of feed tube, plenum camera and airlift were completed. Airlift outside diameter caliper readings were taken. There was no visible damage to the air lift lance, except for minor arcing on tip and slight metal discoloration. |
| VSL-05R5830-1 | HLW C-106/AY-102 with envelope maximum concentrations of RCRA metals and hazardous organic compounds (11/15/04-11/17/04, 12/06/04-12/12/04) | 11/15/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Rebooted both melter and off-gas labVIEW VI.<br>Airlift was reinstalled. |
| | | 11/18/2004 | Removed deep lance bubblers DB-1 and DB-2 for inspection.<br>Inspection of DB-2 and DB-1 showed no damage, except for some pitting and arcing that were noticed during the last inspection. Photographs were taken. Bubblers were tipped over to remove any metallic debris (total of about 20 g of debris; DB-1 had slightly more debris than DB-2). Caliper readings of the bubbler dimensions were taken.<br>DB-1 and DB-2 were reinstalled in ports A-3 and D-1, respectively. |
| | | 11/22/2004 | Adjusted dilution air supply.<br>Swapped chilled water pumps and dam wall regenerative blowers.<br>Lifted lance bubbler #2 to check gasket. The gasket appeared cut in half.<br>Removed bubbler and replaced gasket. |
| | | 11/23/2004 | Opened flanges to the 90 ° and horizontal pipe of the EOG line to DM1200 melter for inspection. Investigation showed minimal build up of solids that was cleared. |
| | | 11/26/2004 | Replaced pre-filter in EOG HEPA train MM-EOG-F-402. The other EOG HEPA train was on line. |
| | | 11/28/2004 | Adjusted main EOG valve to bring DM1200 melter vacuum from -0.10" W.C. to -0.15"W.C. |
| | | 11/29/2004 | Replaced HEPA filter in EOG train MM-EOG-F-401.<br>Swapped chilled water pumps and dam wall regenerative blowers.<br>Switched from EOG HEPA train MM-EOG-F-401 to -402. Filter and pre-filter of EOG HEPA train MM-EOG-F-402 were replaced. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-05R5830-1 | HLW C-106/AY-102 with envelope maximum concentrations of RCRA metals and hazardous organic compounds (11/15/04-11/17/04, 12/06/04-12/12/04) | 12/1/2004 | Performed monthly diesel generator test. |
| | | 12/2/2004 | It appeared that particles were being emitted from the glass pool due to bubbling. This was seen by a rise in EOG HEPA differential pressure and debris within EOG piping.<br>Rodded the EOG piping up to the first 90° elbow, and removed minor build up. Lots of fine dust was seen.<br>Melter vacuum increased from -014" W.C. to -0.17" W.C.<br>Rodded the EOG piping for the second time, including past the 90 ° elbow.<br>EOG HEPA filter and pre-filter were replaced in MM-EOG-F-401 train. |
| | | 12/6/2004 | Installed plenum camera. |
| | | 12/12/2004 | The EOG control circuit had a limit switch that needed adjusting. |
| | | 12/13/2004 | Removed both thermowells. Completed inspection and caliper measurements of both TW #1 and TW #2. TW #1 showed some discoloration. Both TWs showed significant metal loss on submerged sections with moderate pitting and minor crystallization. Photographs were taken.<br>Replaced TW #2 with a new TW and the old TC bundle. During the holiday idle period, only TW #2 scheduled to be installed.<br>Swapped chilled water pumps and dam wall regenerative blowers.<br>Lance bubblers 1and 2 and airlift were removed for inspection. TW #2 (new TW) was installed. Lance bubblers not scheduled to be reinstalled at this time. Changed electrode firing pattern from side to side to side to bottom.<br>Level detector was disconnected during DB-2 removal and then reconnected.<br>Visual inspections of lance bubbler #1 showed numerous arcing spots and a slight bend ~37" down from the ceramic insulator. Photographs were taken. Lance bubbler #2 also showed numerous arcing spots and a slight bend ~32" down from the ceramic insulator. Photographs were taken. Air lance looked good, with no significant damage. Caliper readings of lance bubblers #1 (DB-2) and #2 (DB-1) and the air lift were taken. |
| | | 12/14/2004 | Reduced supply air pressure to electrode bubblers #3 and #5 due to back pressure being too high.<br>Installed jumpers on TC connectors MM-XXX-TR-01 thru -05. |
| | | 12/22/2004 | On, 12/22, 12/24, and 12/29, tapped on EOG piping to dislodge solids build up to improve system airflow and to reduce the melter vacuum. |
| | | 12/23/2004 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 12/30/2004 | Due to scheduled power outage, melter was powered by diesel generator for about six hours. |
| | | 12/31/2004 | All systems functioned satisfactorily. City water bypass valve, MCL-DW-V-404, to cooling panels left open until 1/3/2005 to supply city water to the back-up heat exchanger. |
| | | 1/3/2005 | Closed cooling panel, city water bypass MCL-DW-V-404.<br>No monthly testing of the diesel generator was done due to the scheduled outage on 12/30/2004.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 1/4/2005 | Airlift was reinstalled. |
| | | 1/10/2005 | Swapped chilled water pumps and dam wall regenerative blowers.. |
| | | 1/18/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 1/24/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Opened EOG port at melter for inspection and found no blockage in vertical section and very little on horizontal section. Cleaned all visible solids build up. |
| | | 1/25/2005 | Found TC of MCL-CW-TR-418, removed from thermo well on chilled water pipe. Reinstalled the TC, and the reading changed by ~6 °C to 32.5 °C. |
| | | 1/26/2005 | Performed loop testing of various melter thermocouples. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-05R5830-1 | HLW C-106/AY-102 with envelope maximum concentrations of RCRA metals and hazardous organic compounds (11/15/04-11/17/04, 12/06/04-12/12/04) | 1/27/2005 | Removed mass flow controllers for the bubblers L1A, L4A and L spare 6 from the system for testing,<br>Placed mass flow controllers for bubbler L spare 5 and L2A back in operation after testing. |
| | | 1/28/2005 | Removed air lift for inspection. No damage was noticed. Caliper readings and photographs were taken. Air lift left out for now. |
| | | 1/29/2005 | Switched form EOG HEPA train MM-EOG-F-402 to -401. |
| | | 1/31/2005 | Found that both melter and off gas labVIEW VI were recording to “local” drive. Reestablished network connection, and system appeared to be working satisfactorily.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 2/2/2005 | Electrode firing was from side to bottom. |
| | | 2/7/2004 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Started and completed calibration of various melter and off gas thermocouples. |
| | | 2/8/2004 | EOG piping was cleaned.<br>Started and completed calibration of various melter and off-gas loops. |
| | | 2/9/2005 | Started and completed calibration of various melter and off-gas loops. |
| | | 2/10/2005 | Completed updates to melter, off-gas, and feed data programs including spyware detection and removal.<br>Started and completed calibration of various melter and off-gas loops. |
| | | 2/11/2005 | Reinstalled air lift. |
| | | 2/14/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 2/17/2005 | Reconfigured lance bubbler air supply tubing from MFCRs to allow for individual air flow control.<br>Found dam wall air flow (MCA-RGB-FR-201) reading 0 SCFM. Investigation of blower status, outlet pressure, and local differential pressure did not show any problems. Cleaned both dam wall RGB inlet filters.<br>Electrode firing pattern was changed from side to bottom to side to side.<br>Reinstalled lance bubblers J4 in port A-3, L3 in port A-1, L4 in port D-3 and L2 in port D-1.<br>Power was set to 69 kW.<br>Adjusted dam wall regenerative blower, MCA-RGB-B-102 outlet pressure from 28 to 25 psig. Dam wall flow was unchanged at 26 SCFM. Lower pressure may trip low pressure alarm. |
| | | 2/18/2005 | Reinstalled TW #1 with a new multi-TC assembly and TW #2.<br>Replaced EOG filter and pre-filter of EOG HEPA train MM-EOG- F-402. Debris had accumulated on the housing floor. |
| | | 2/21/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Functional test of mass flow meters for lance bubblers 1B, 2A, 2B, 3A, 3B and 4B with labVIEW VI was unsuccessful. |
| | | 2/22/2005 | Increased discharge chamber power from 12 to 15 kW. Discharge chamber was heated to discharge glass to obtain grab sample of riser glass, and lower melt pool level in preparation for glass turnover to LAW composition.<br>Replaced TC of MM-XXX-TR-08 for airlift. |

### Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| VSL-05R5830-1 | HLW C-106/AY-102 with envelope maximum concentrations of RCRA metals and hazardous organic compounds (11/15/04-11/17/04, 12/06/04-12/12/04) | 2/23/2005 | Turned on MM-CA-MFR-013 (electrode bubbler #3) at 1 lpm. No flow was observed through MM-CA-MFCR-013 after 8 minutes. Unplugged power to MFCR.<br>Swapped lance bubbler air supply from rotameter to MFCR and verified flow in melt pool. Lance bubblers were installed with L1 in port A-1, L2 in port A-3, L3 in port D-1 and L4 in port D-3. MFCRs in use were set to 1.5 lpm air flow rate. Secured power to electrode MFCRs.<br>Swapped EOG HEPA line from MM-EOG-F-401 to MM-EOG-F-402 train. MM-EOG-F-401 EOG HEPA differential pressure was 3.5" W.C. Melter vacuum was -0.11" W.C. with dilution air valve (from manual EOG went/dilution valve, MM-EOG-V-403) almost fully closed. Tapping EOG pipe had no effect on melter pressure.<br>Reduced air supply pressure to electrode bubbler #2 due to back pressure being >42 psi.<br>Found MM-XXX-PR-200 (melter pressure at instrument port) melter pressure tubing disconnected. When the tubing was reconnected, melter vacuum reading changed from +0.1" W.C. to -0.1" W.C., as expected.<br>Primary chilled water system pump MCL-CW-P-401 tripped for unknown reason, was reset, and continued to operate without any other problems. The pump will be monitored.<br>Completed testing of several of gas and melter pressure transmitters.<br>Melter pressure at -0.1" W.C., This may be due to partial blockage in the vertical section of the EOG piping.<br>Minor build up was removed from the bottom part of the vertical section of the EOG pipe.<br>Chillers appeared to be down. CUA maintenance was notified that chillers were off line.<br>Removed mass flow controller, MM-CA-MFCR-013 from the system for testing.<br>Chilled water supply temperature, MCL-CW-TR-402 was at 46 °C. |
| | | 2/25/2005 | Replaced EOG HEPA train MM-EOG-F-401 filter and pre-filter. |
| LAW Scoping test | LAW Envelope A with envelope maximum concentrations of RCRA metals and hazardous organic compounds (2/28/04-3/04/04) | 2/26/2005 | Installed lance bubblers 1A, 2B and 4A in the melter. The units were powered and set to 1.5 lpm flow rate. |
| | | 2/27/2005 | Turned on mass flow controller MM-CA-MFCR-002 of lance bubbler L2A at 1.5 lpm, and secured mass flow controller MM-CA-MFCR-007 of lance bubbler L2B. |
| | | 2/28/2005 | Installed 4 lance bubblers (3 L type bubblers and one J type bubbler) in 4 corners pointed to the center of the melter. |
| | | 3/1/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| VSL-05R5830-1 | LAW Envelope A with envelope maximum concentrations of RCRA metals, halides, and hazardous organic compounds (3/07/05-3/10/05, 3/17/05-3/23/05) | 3/7/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 3/11/2005 | Both EOG HEPA trains were placed on line. |
| | | 3/12/2005 | Replaced MM-EOG-F-401 EOG HEPA filter and pre-filter. High amounts of sulfate dust were found inside the HEPA housing. Both EOG HEPA trains were placed on line. |
| | | 3/13/2005 | Tapped on the EOG pipe, which raised melter vacuum from 0.09 to 0.18" W.C. |
| | | 3/14/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Replaced EOG HEPA, MM-EOG-F-401 pre-filter. |
| | | 3/15/2005 | Replaced MM-EOG-F-402 HEPA train pre-filter and filter. Left both trains on line. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-05R5830-1 | LAW Envelope A with envelope maximum concentrations of RCRA metals, halides, and hazardous organic compounds (3/07/05-3/10/05, 3/17/05-3/23/05) | 3/16/2005 | Replaced electrode TCs TR-22, TR-21 and TR-23.<br>Film cooler was inspected visually. No build up was found.<br>Reinstalled plenum exposed TC.<br>Installed a remote melter pressure indicator (MM-AR-PR-201) by the chemical room door, tested for functionality, and was found to be satisfactory. |
| | | 3/18/2005 | Found clog in one of the MM-OG-DPR-002 sensing lines. |
| | | 3/21/2005 | Observed discharge chamber drum flange to be "looser" than previously noted. It was difficult to maintain chamber temperature.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 3/23/2005 | EOG pipe got clogged causing loss of melter vacuum. Used drain snake to clear clog.<br>Melter vacuum returned to -0.32" W.C. Opened dilution air valve with both HEPA trains open.<br>One EOG HEPA train was taken off line to allow for swapping trains to replace filters.<br>Reduced electrode bubblers 1, 2, 4 and 5 flow rates from 0.5 to 0.2 SCFH to help minimize carryover to EOG piping/HEPA.<br>Removed TC of MM-XXX-TR-17.<br>Both EOG HEPA trains were placed on line. Checked all melter ports for leakage.<br>Started modified off-gas operation to clean EOG piping. During this time PBS was in line and HCU was off line. Switched back to EOG.<br>~ 5 kg of solids build up was removed. This was in the EOG pipe after the 90° and up to valve 401. Was not able to remove much of the build up before the 90° on top of the melter. There is only about 2" opening through the pipe. Cleaning scheduled for a later time.<br>Placed cooling panels on city water. |
| | | 3/24/2005 | Primary system chilled water pump, MCL-CW-P-401, tripped and was reset, The pump worked satisfactorily afterwards. Water pressures appeared to be normal, but monitoring of pump continued.<br>HEPA filter and pre-filter of MM-EOG-F-401 EOG HEPA train were replaced. |
| | | 3/26/2005 | Tapped on the first 90° of EOG line and was able to bring vacuum to -0.07" W.C.<br>Both HEPA trains were in operation. |
| | | 3/27/2005 | Both EOG HEPA filters and pre-filters were replaced.<br>Tapped on EOG line to try to remove blockage due to solids deposits. Tried rodding out EOG line with a drain snake. Neither was effective in removing the blockage. Due to the condition of the EOG line, a modified off-gas system was implemented bypassing HCU. Melter vacuum was at -0.09" W.C.<br>Changed EOG alarm set point from 0.5" to 0.00" W.C. |
| | | 3/28/2005 | EOG alarm sounded and was reset. |
| | | 3/29/2005 | Primary system chilled water pump, MCL-CW-P-401 alarm sounded on the annunciator and cooling panels. Alarms reset.<br>Removed the first section of the EOG line for modification and cleaning.<br>Cut the first section of EOG line, 90% packed with solids. Photographs were taken.<br>First section of the EOG line on top of the melter was cleaned, modified and put back together. Photographs were taken. EOG was put back on line. |
| | | 3/31/2005 | Placed lance bubblers #1, #2, #3, and #4 on the bypass rotameters, and set them at 0.5 SCFH flow rate to reduce carry over to the HEPA system. |
| | | 4/1/2005 | Switched EOG HEPA trains from MM-EOG-F-402 to -401. Replaced EOG HEPA train MM-EOG-F-402 filter and pre-filter. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| VSL-05R5830-1 | LAW Envelope A with envelope maximum concentrations of RCRA metals, halides, and hazardous organic compounds (3/07/05-3/10/05, 3/17/05-3/23/05) | 4/4/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Completed simulated loss of power diesel generator test. Primary cooling pump MCL-CW-P-401 tripped, was reset, and worked satisfactorily afterwards.<br>Dam wall regenerative blower, MCA-RGB-B-102, tripped due to low air flow rate. Flow rate was increased to 23 SCFM and the system functioned satisfactorily. |
| | | 4/6/2005 | Lost dam wall regenerative blower, MCA-RGB-FR-202. Was able to reset and adjust flow to dam wall using blower MCA-RGB-FR-201 at 20 SCFM.<br>Switched EOG line from EOG HEPA train MM-EOG-F-401 to -402. |
| | | 4/7/2005 | Added particulate removed from EOG piping into melter.<br>Replaced EOG HEPA train MM-EOG-F-401 pre-filter. |
| | | 4/9/2005 | Replaced EOG HEPA train MM-EOG-F-402 pre-filter. |
| | | 4/11/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 4/12/2005 | Removed mass flow controllers for lance bubblers L1A, L4A and L spare 6 (MM-CA-MFCR-001, -004, and -010) for testing. Moved mass flow controllers for lance bubblers L1B and L4A (MM-CA-MFCR-006 and -009) into positions for MM-CA-MFCR-001 and -004.<br>Per CUA maintenance, primary CW system was fully functional. |
| HLW Turnover VSL-05R5830-1 | HLW mixed (4/13/05-4/15/05) | 4/13/2005 | Reinstalled MM-XXX-TR-17, exposed plenum TC.<br>Secured city water to melter panel heat exchanger.<br>TR-17 TC failed again. Replaced TR-17 TC. |
| | | 4/14/2005 | Stopped test to remove transition line bellows. Differential pressure across transition line was very high at 7-10″ W.C. Inspection showed only minor build up at the bellows. Photographs were taken. Clog was found at the end of the curvature from the melter, prior to sample port. Rodded with slight success. About 333 grams of solids were removed. |
| | | 4/18/2005 | Removed lance bubblers #1, #2, #3 and #4, TW #1 and TW #2.<br>Changed electrode firing pattern from side to side to side to bottom.<br>Swapped chilled water pumps and dam wall regenerative blowers.<br>Inspection of TW #1 showed heavy pitting at the lower 15″ section. Above the 15″ mark, the TW seemed OK. Joule heating was observed at about 3″ and 10″ from the bottom.<br>Inspection of TW #2 showed two joule heating spots at 1″ and 20″marks. The rest of the pipe was in very good shape. Photographs and caliper readings of both thermowells were taken.<br>Both TWs were reinstalled. Removed TC of MM-XXX-TR-17. |
| | | 4/19/2005 | Lance bubblers were inspected:<br>Lance bubbler # 1 (L3) showed crystallization in the pipe below glass level. Pitting was observed above the glass level. Three joule heating spots were seen at 9.5″, 17.5″ and 23″, and a bend at 23″.<br>Lance bubbler #2 (J4) showed crystallization in the bottom 20″ and pitting above that. Joule heating spots were seen from 12″ to 18″.<br>Lance bubbler #4 (L4A) showed crystallization in the bottom 20″ and slight pitting above. Joule heating spots were seen in the bottom 15″ and the pipe had a bend at 26.5″.<br>Lance bubbler #3 (L2) showed crystallization in the bottom 17″ and heavy pitting above that. Joule heating spots were seen in the bottom 24.5″ and the pipe had bends at 14″, 21″, and 28″.<br>Photographs and caliper readings of all 4 lance bubblers were taken. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| HLW Turnover VSL-05R5830-1 | HLW mixed (4/13/05-4/15/05) | 4/20/2005 | More than 1560 grams of solids were removed from the transition line assembly and the film cooler. Transition line section #1 was clean. Film cooler end was damaged. Photographs of the solid deposits and the film cooler were taken. |
| | | 4/21/2005 | Cleaned glass build-up from the bottom of film cooler. Photographs were taken. Louvered section of the film cooler had separated from the main body. Photographs of the Louvered section were taken. |
| | | 4/22/2005 | Reduced electrode bubblers #1, #2, #4 and #5 air flow rate from 0.8 to 0.5 SCFH.<br>Removed MM-XXX-TR-04 TC from the melter.<br>Swapped chilled water pumps and dam wall regenerative blowers.<br>Opened MCL-DW-V-404 valve (city water bypass valve) in preparation for cooling tower outage. |
| | | 4/29/2005 | Closed MCL-DW-V-404 valve and returned to chilled water for cooling panels. |
| - | Maintenance | 5/2/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Simulated loss of power and successfully completed diesel generator test. |
| | | 5/9/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 5/12/2005 | Switched from EOG HEPA train MM-EOG-F-401 to -402. Melter pressure was -0.20″ W.C. EOG HEPA inlet temperature (MM-XXX-TR-11) was reading 81°C. Differential pressure across MM-EOG-F-401 EOG HEPA train was ~5.6″ W.C., which had not changed for several days. After switching to MM-EOG-F-402 train, melter vacuum increased to -0.66″ W.C. All dilution air valves were opened.<br>Partially closed MM-EOG-F-401 EOG HEPA inlet valve, which dropped melter vacuum to -0.14″ W.C, then closed the suction valve after the HEPA outlets. Melter vacuum at 0.21″ W.C.<br>Replaced MM-EOG-F-401 EOG HEPA train filter and pre-filter. This HEPA housing had a large amount of particulate (possibly sulfate) prior to pre-filter. Underneath particulate there was a build-up of glass-like material. The housing was scraped and vacuumed, and new gasket material was placed on the door. |
| | | 5/13/2005 | Removed lance bubbler #4. |
| | | 5/15/2005 | Alarm sounded because cooling system, chilled water pump MCL-CW-P-401 was not running. The pump was restarted.<br>Partially closed the main EOG valve to raise the melter vacuum to about -0.17″ W.C.<br>Partially opened MCL-DW-V-404 valve to allow some city water flow to the back-up heat exchanger. |
| | | 5/16/2006 | Swapped chilled water pumps and dam wall regenerative blowers. Dam wall regenerative blower MCA-RGB-B-102 outlet pressure was adjusted to 2.5 psi. Flow was 25 SCFM.<br>CUA maintenance informed that chilled water was back in service. |
| | | 5/17/2005 | Primary chilled water system was functioning satisfactorily. Closed city water to MCL-DW-V-404 valve.<br>Adjusted EOG HEPA train MM-EOG-F-402 inlet valve to fully open. Melter vacuum was at -0.14″ W.C.<br>Closed manual EOG vent/dilution valve completely and opened the dilution air damper to about 70% open.<br>Melter vacuum was at -0.20″ W.C. |
| | | 5/20/2005 | City water low pressure alarm sounded due to city water outage for Hannan Hall.<br>City water restored to Hannan Hall.<br>Turned on city water to the back-up heat exchanger because chilled water supply temperature was 80°F and return 82°F. Cooling panel temperatures at 39-43 °C. |
| | | 5/22/2005 | Switched from MM-EOG-F-402 EOG HEPA train to -401 train. |
| | | 5/23/2005 | Closed MCL-DW-V-404 city water bypass valve.<br>Swapped chilled water pumps and dam wall regenerative blowers. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

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|---|---|---|---|
| | Maintenance | 5/26/2005 | Partially closed MM-EOG-V-403 valve, ¼ of the way. Melter vacuum increased from -0.13″ to -0.18″ W.C.<br>Replaced the filter and pre-filter of MM-EOG-F-402 EOG HEPA train.<br>Closed MM-EOG-V-403 valve to increase the melter vacuum from -0.16″ to -0.19″ W.C.<br>Removed lance Bubbler #3 back pressure transmitter from the system. Unit was removed for use in the DM100 system. |
| | | 5/30/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 5/31/2005 | Performed simulated loss of power diesel generator test. |
| | | 6/3/2005 | Closed MM-EOG-V-403 valve fully, and partially (½) closed dilution air valve (MM-EOG-V-402). Melter vacuum changed from -0.14″ to -0.17″ W.C. |
| | | 6/6/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Hannan Hall experienced loss of power. Automatic transfer switch (ATS) for building powered by back-up diesel generator did not activate. Normal power was restored. Diesel generator was generating only ~220 volts on all 3 phases, which might be insufficient to power ATS.<br>Switched dam wall regenerative blower from MCA-RGB-B-101 to –102. Blower MCA-RGB-B-101 was making unusual noises and not maintaining proper flow. |
| | | 6/7/2005 | Air compressor dryer switching alarm activated. The compressor was back to normal operation after the solenoid valve was reset.<br>Found that diesel generator speed (motor) switch was set for low speed. Switched to high speed and tested generator. Output was back to ~480 volts on all phases. |
| | | 6/9/2005 | Swapped chilled water pumps. Did not switch dam wall regenerative blowers. |
| | | 6/18/2005 | Inspected EOG inlet port at the melter and found horizontal section almost 90% blocked; cleared blockage and melter vacuum increased from -0.14″ to -0.35″ W.C.<br>Completely opened dilution air damper and MM-EOG-V-403 valve. Melter vacuum changed to -0.18″ W.C.<br>Slightly closed MM-EOG-V-403 valve. Melter vacuum changed to -0.21″ W.C. |
| | | 6/20/2005 | Swapped chilled water pumps. Checked the MCA-RGB-B-101 blower for operation. Noticed a grinding noise from the blower housing. Maintained flow using MCA-RGB-B-102 dam wall regenerative blower.<br>Inspected internals of MCA-RGB-B-101 blower along with outlet check valve. No problems were identified.<br>Observed noise during operation of MCA-RGB-B-101 that occurred only when it warmed up, indicating probable bearing failure. The blower maintained as emergency back-up.<br>Closed valve MM-EOG-V-403 entirely. Opened dilution air damper completely. Melter vacuum at -0.20″ W.C. |
| | | 6/25/2005 | Partially closed (~2/3) EOG dilution air damper. Melter vacuum was changed from -0.12″ to -0.16″ W.C. |
| | | 6/26/2005 | Switched EOG line from EOG HEPA train MM-EOG-F-401 to -402.<br>Adjusted electrode bubbler #3 supply pressure to target of ~40 psi (found at 32 psi and no flow) |
| | | 6/27/2005 | Swapped chilled water pumps. |
| | | 6/28/2005 | Replaced filter and pre-filter of EOG HEPA train MM-EOG-F-401. |
| | | 7/5/2005 | Swapped chilled water pumps. |
| | | 7/11/2005 | Swapped chilled water pumps.<br>Started removal/replacement of MCA-RGB-B-101 dam wall regenerative blower. New blower was a single stage regenerative blower. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| | Maintenance | 7/12/2005 | Melter vacuum had decreased to -0.09″ W.C. Removed horizontal flange and vertical plug at melter outlet. Rodded out blockage in both sections. Replaced flange and plug. Melter vacuum increased to -0.42″ W.C.<br>Opened dilution air damper and MM-EOG-V-403 completely. Melter vacuum changed to -0.22″ W.C.<br>Temporarily secured power to MCA-RGB-B-102 dam wall regenerative blower to replace temperature overload relays inside disconnect box. Replacement was to downgrade relay temperature limit due to replacement of MCA-RGB-B-101 with a smaller unit. Performed replacement in 2 stages to prevent excessive heating of dam wall panel.<br>Restarted air to dam wall. Outlet air temperature at 160 °C.<br>1st stage of overload replacement was completed, allowed temperatures to decrease before completing second stage.<br>Secured dam wall regenerative blower to complete temperature overload replacement. Outlet temperature at 139 °C.<br>Power restored to RCA-RGB-B-102. Dam wall outlet temperature at 173 °C. |
| | | 7/13/2005 | MCA-RGB-B-101, new dam wall regenerative blower was returned to service in standby mode. |
| | | 7/14/2005 | Performed monthly simulated loss of power diesel generator test. |
| | | 7/18/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 7/19/2005 | Switched EOG line from EOG HEPA train MM-EOG-F-402 to -401.<br>Replaced filter and pre-filter of EOG HEPA train MM-EOG-F-402. |
| | | 7/25/2005 | Swapped chilled water pumps and dam wall regenerative blowers.. |
| | | 7/27/2005 | City water low pressure alarm activated due to maintenance work being performed.<br>Found dam wall inlet flow at 29 SCFM, adjusted back to 28 SCFM.<br>CUA maintenance experienced some problems with one of the chillers. Opened city water bypass valve MCL-DW-V-404 until problem was resolved.<br>Dam wall regenerative blower inlet flow was at 30 SCFM with outlet pressure at 2.10 psi. Switched blower to MCA-RGB-B-102. Adjusted outlet pressure to 2.50 psi.<br>Dam wall outlet flow from -B-102 at 21 SCFM. |
| | | 7/28/2005 | Closed city water bypass valve MCL-DW-V-404 about ½ way. Flow was adjusted from 32 gpm to 27 gpm.<br>MM-XXX-TR-16 temperature was 32.3°C and -17 temperature 36.3°C.<br>Partially closed (~80%) city water bypass valve MCL-DW-V-404. CW supply temperature at 32.3°C and panels at 35-39 °C. |
| | | 8/1/2005 | Swapped chilled water pumps. Until alarm set point could be lowered for MCA-RGB-B-102, dam wall regenerative blowers would not be switched.<br>Simulated loss of power and tested diesel generator.<br>Found electrode bubbler #3 back pressure at 35.8 psi; adjusted regulator to 40.5 psi pressure. |
| | | 8/2/2005 | Closed city water bypass valve MCL-DW-V-404 completely. Chiller returned to service. Panel temperatures at 37-43°C. |
| | | 8/5/2005 | Found labVIEW data logged in local position and reset to network.<br>Tested dam wall regenerative blower -B-102 for flow with outlet relief pressure at 2.5 psi; flow at 20 SCFM.<br>No problems were observed with either blower operation. Switched back to -B-101 dam wall regenerative blower. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| | Maintenance | 8/8/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Found some blockages in the EOG vertical and horizontal sections. Once blockages were cleared, melter vacuum increased from -0.10″ to -0.30″ W.C. Partially opened (½ way ) dilution valve. Melter pressure at -0.21″ W.C.<br>Switched dam wall regenerative blower (RGB), MCA-RGB-B-102 to -B-101. Found inlet flow at 31 SCFM and blower outlet at 2.5 psi pressure. When the blower was switched pressure was still at 2.5 psi, but inlet flow dropped to 20 SCFM. Also noticed no melter pressure change after switching blowers. |
| | | 8/9/2005 | Switched dam wall regenerative blower (RGB), MCA-RGB-B-101 to -B-102 and lowered outlet pressure to 2.2 psi; corresponding flow rate was 19 SCFM. In order to increase dam wall air flow rate to 31 SCFM, blower outlet pressure was increased to 2.5 psi. |
| | | 8/10/2005 | Performed flow versus outlet pressure testing of MCA-RGB-B-101 and –B-102.<br>-B-101 at 2.5 psi outlet pressure flow is 21 SCFM.<br>-B-102 at 1.6 – 2.5 psi outlet pressure flow is 20 SCFM (after 45 minutes).<br>–B-102 has at times shown flow rates as high as 31 SCFM.<br>Outlet pressure for both blowers will be maintained at 2.5 psi. |
| | | 8/13/2005 | Switched EOG line from EOG HEPA train MM-EOG-F-401 to –F-402. |
| | | 8/15/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower outlet pressure to 2.5 psi. |
| | | 8/18/2005 | Replaced filter and pre-filter of EOG HEPA train MM-EOG-F-401. |
| | | 8/21/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower outlet pressure to 2.5 psi |
| | | 8/23/2005 | MM-EOG-V-403 valve was fully closed. Ammonia duct valve was closed, and EOG damper valve was closed. Melter vacuum at -0.15″ W.C. Tapping on the EOG pipe at the melter outlet raised the melter vacuum to -0.30″ W.C.<br>MCL-CW-TR-408 TC failed. It was taken out of service. |
| | | 8/27/2005 | Rodded out build up of particulate at EOG horizontal and vertical sections. Vacuum increased from -0.15″ to -0.18″ W.C. |
| | | 8/28/2005 | Used the manual drain snake device to clear EOG horizontal piping and was successful in cleaning the 45 degree elbow. Melter vacuum increased from -0.14″ W.C to -0.79″ W.C. Opened dilution damper to full open position, and fully opened MM-EOG-V-403 valve; vacuum at -0.34″ W.C.<br>Opened ammonia exhaust valve fully. Vacuum now at -0..24 ″ W.C. |
| | | 8/29/2005 | Swapped chilled water pumps and dam wall regenerative blowers |
| | | 8/31/2005 | Replaced TC of MCL-CW-TR-408. |
| | | 9/1/2005 | Removed level detector from melter.<br>Inspection of level detector showed significant damage and metal loss. Both level and density pipes had lost ½″ or more of the pipe due to corrosion extending upward at a 45° angle. Pipes also showed significant crystallization and arcing. Photographs and outside diameter caliper readings were taken. |
| | Maintenance | 9/2/2005 | Installed temporary jumper from MM-XXX-PR-200 (melter pressure measurement at instrument port) to MM-AR-PR-202 (melter pressure measurement at level detector port) tubing to provide melter pressure indication on EOG panel and labVIEW for MM-XXX-PR-201 (melter pressure indication at EOG).<br>Removed TW #1 for inspection. Also removed TC of MM-XXX-TR-15 from service.<br>Visual inspection of TW #1 showed significant damage. It will not be reinstalled. Only one TW (TW #2) will be installed in the melter. Photographs and caliper readings of TW #1 were taken. |
| | | 9/5/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| | Maintenance | 9/6/2005 | Found compressor alarm fault illuminated. Reset the fault switch on dryer in the mechanical room. Found large amounts of moisture build up in dryer. Will continue to monitor.<br>Removed TW #2 for inspection.<br>There were some pittings and metal flaking on lower 12-15″ of TW #2. Overall, the condition of TW#2 was satisfactory.<br>Caliper readings and photographs of TW #2 were taken.<br>TC of MM-XXX-TR-16 failed. Replaced this TC with the TC from TW#1 that had been removed from service.<br>Simulated loss of power, diesel generator test was performed. |
| | | 9/9/2005 | Switched from EOG HEPA train MM-EOG-F-402 to -F-401. |
| | | 9/12/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower pressure to 2.5 psi. |
| | | 9/14/2005 | Increased melter vacuum from -0.17" to -0.21" W.C. by slightly opening EOG HEPA inlet valve. |
| | | 9/19/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower pressure from 2.2 to 2.5 psi. |
| | | 9/24/2005 | Replaced filter and pre-filter of HEPA train MM-EOG-F-402. |
| | | 9/26/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower pressure to 2.5 psi. |
| | | 9/27/2005 | Found city water pressure alarm on. Pressure was at 3.5 psi. The alarm was silenced. Primary CW supply temperature was 87°F and return temperature was 90°F.<br>The city water pressure at 46 psi and rising. Alarm was reset. |
| | | 10/3/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower pressure to 2.5 psi. |
| | | 10/6/2005 | Rebooted melter labVIEW VI to reset the readout from TC of MM-XXX-TR-408. |
| | | 10/7/2005 | Switched from EOG HEPA train MM-EOG-F-401 to -F-402 |
| | | 10/10/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower pressure from 2.9 to 2.5 psi. |
| | | 10/12/2005 | Performed simulated loss of power, diesel generator test. |
| | | 10/13/2005 | Adjusted electrode bubbler #3 back pressure from 35.6 to ~41 psi. Air flow rate at <1.0 SCFH. |
| | | 10/17/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower pressure to 2.5 psi. |
| | | 10/22/2005 | Replaced filter and pre-filter of MM-EOG-F-401 EOG HEPA train. |
| | | 10/24/200 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower pressure to 2.5 psi. |
| | | 10/31/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower pressure to 2.5 psi. |
| | | 11/3/2005 | Performed simulated loss of power diesel generator test.<br>The city water pressure alarm was on. The city water pressure was at 36 psi. Alarm was reset.<br>The water pressure now at 79 psi. |
| | | 11/7/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower pressure to 2.5 psi. |
| | | 11/8/2005 | Switched from EOG HEPA train MM-EOG-F-402 to -F-401. |
| | | 11/14/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Replaced filter and pre-filter of MM-EOG-F-402 EOG HEPA train. |
| | | 11/22/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 11/28/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 12/5/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Performed simulated loss of power-diesel generator test. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| | Maintenance | 12/8/2005 | Annunciator panel alarm sounded. No lights were illuminated. However primary chilled water supply and return temperatures as shown on MCL-CW-TI-402 and 421 were at 120°F while on the labVIEW corresponding chilled water supply and return temperatures were 45.6 and 54.2°C, respectively. All cooling panel temperatures were 53-55°C.<br>Found chiller stopped. CUA maintenance was alerted.<br>Opened the city water bypass valve MCL-DW-V-404 half way.<br>Later found the secondary chilled water temperatures to be normal and pressures and temperatures within normal parameters. Closed the city water bypass valve MCL-DW-V-404 |
| | | 12/12/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 12/15/2005 | Due to chiller being off line city water bypass valve was opened half way.<br>Chiller back in service; city water bypass valve was closed. |
| | | 12/18/2005 | Cooling panel temperatures exceeded 40°C. Opened city water bypass valve partially.<br>Chilled water back on line. Closed city water bypass valve. |
| | | 12/19/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 12/20/2005 | Opened city water bypass valve in preparation for chiller outage.<br>Switched from EOG HEPA train MM-EOG-F-401 to -F-402.<br>Differential pressure across the MM-EOG-F-402 EOG HEPA train was 5.2″ W.C. Fully opened the air dilution valve and MM-EOG-V-403 valve. MM-EOG-F-402 EOG HEPA inlet valve was about half way open and melter vacuum as at -0.17″ W.C. |
| | | 12/21/2005 | Closed the city water bypass valve, chiller back on line.<br>Replaced filter and pre-filter of EOG HEPA train MM-EOG-F-401. |
| | | 11/22/2005 | In anticipation of power outages throughout the day, opened the city water bypass valve to provide water for the back-up heat exchanger. |
| | | 12/23/2005 | Closed the city water bypass valve. |
| | | 12/26/2005 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 12/29/2005 | Chiller out of service. City water bypass valve was opened.<br>Chiller back in service. Closed city water bypass valve. |
| | | 12/30/2005 | Opened slightly MCL-DW-V-404 city water bypass valve in preparation for power outage later in the day.<br>Power outage in progress, melter powered by the diesel generator. |
| | | 12/31/2005 | Closed MCL-DW-V-404 city water bypass valve. Cooling panels on normal chilled water. |
| | | 1/2/2006 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower outlet pressure to 2.5 psi. |
| | | 1/4/2006 | Partially opened the city water bypass valve for replacement of the chilled water 3-way valve. |
| | | 1/5/2005 | Primary system chilled water pump fault alarm.<br>Notified by CUA maintenance that primary chilled water system was back in service.<br>Restarted primary system chilled water pump. Primary chilled water temperatures still high. City water bypass valve to be left on until temperatures return to normal.<br>Rebooted melter labVIEW VI due to reset erroneous display of MCL-CW-TR-408 temperatures.<br>The temperature readings returned to normal, |
| | | 1/6/2006 | Closed city water bypass valve. |
| | | 1/8/2006 | Primary chilled water return temperature rose from 79 to 100°F during the last 2 hours, and cooling panel temperatures increased several degrees at over 40 °C. City water bypass valve was opened due to the suspected chiller problems. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| | Maintenance | 1/9/2006 | Primary chilled water system appears to be functioning properly. Secured the city water bypass valve.<br>Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 1/17/2005 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower outlet to 2.5 psi. |
| | | 1/23/2005 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Secured power to discharge chamber to replace a bad cooling fan on SCR. Heaters to be left off to facilitate repairs to isolation valve and bad heating elements. |
| | | 1/30/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 2/4/2006 | Switched from EOG HEPA train MM-EOG-F-402 to -F-401. |
| | | 2/6/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 2/13/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 2/14/2006 | MM-RGB-B-101 regenerative blower fault alarm sounded. Switched to alternate blower MM-RGB-B-102. The dam wall cooler inlet air flow rate now at 26 SCFM. Attempted to restart dam wall regenerative blower MM-RGB-B-101. As soon as the blower was turned on, the outlet pressure dropped.<br>Inspection of the blower for mode of failure indicated bearing failure.<br>Swapped chilled water pumps. |
| | | 2/22/2006 | Replaced filter and pre-filter of EOG HEPA train MM-EOG-F-402. |
| | | 2/23/2006 | Adjusted MCA-RGB-B-102 outlet pressure from 2.3 to 1.3 psig and dam wall flow rate from 27 to 25 SCFM. |
| | | 2/27/2006 | Swapped chilled water pumps.<br>Removed TW #2 for inspection. Inspection showed extensive pitting 18″ from the bottom upward. No bends were seen. Photographs and caliper readings of TW #2 were taken. |
| | | 3/2/2006 | Replaced dam wall regenerative blower MCA-RGB-B-101. The blower needs to be wired and checked for proper operation before being placed in service. |
| | | 3/6/2006 | Swapped chilled water pumps. |
| | | 3/7/2006 | Performed simulated loss of power-diesel generator test.<br>Tested dam wall regenerative blower MCA-RGB-B-101. |
| | | 3/8/2006 | Switched from dam wall blower MCA-RGB-B-102 to blower -B-101. Initially the outlet pressure was 3.75 psig; adjusted pressure to 2.5 psig with a flow rate of 22 SCFM.<br>Regenerative blower -B-101 outlet pressure dropped from 2.5 to 2.25 psig, adjusted back to 2.5 psig; flow rate at 21 SCFM. |
| | | 3/13/2006 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted blower outlet pressure to 2.5 psi.<br>Switched from EOG HEPA train MM-EOG-F-401 to -F-402. |
| | | 3/17/2006 | Replaced filter and pre-filter of EOG HEPA train MM-EOG-F-401. |
| | | 3/20/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 3/27/2006 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted dam wall regenerative blower outlet pressure to 2.5 psig. |
| | | 3/28/2006 | Melter pressure was at -0.14″ W.C. Tapped on EOG pipe in an attempt to increase melter vacuum. This resulted in melter pressure of -0.09″ W.C. Attempted to remove blockage using drain snake down the EOG pipe. This also was not effective in increasing melter vacuum. |

## Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).

| | | | |
|---|---|---|---|
| | Maintenance | 3/29-30/2006 | Attempted again to clear any blockage in the EOG pipe using a drain snake. Measurement of the length of the snake in the EOG pipe showed it to have passed up to the main EOG valve. Also cleared a blockage above the MM-EOG-V-403 (manual EOG vent/dilution) valve. During this attempt to clear the EOG pipe, no obstructions were felt and melter pressure stayed at -0.09″ W.C.<br>Switched from EOG HEPA train MM-EOG-F-402 to –F-401. The differential pressure of EOG HEPA train MM-EOG-F-401 was 4.2″ W.C.<br>Used MM-AR-PR-202 for melter pressure indication.<br>Switched back to EOG HEPA train MM-EOG-F-402 to increase vacuum on the melter.<br>Troubleshooting of melter vacuum measurement identified that melter pressure indication on the MM-AR-PR-201 and -202 were inaccurate since the sensor line was disconnected during the level detector removal. Reconnected sensor line to high pressure port on the instrument plug for the film cooler differential pressure measurement. (Film cooler differential pressure, high pressure line was left disconnected). Since argon was no longer available to purge, modified purge supply to compressed air on 3/30/2006.<br>Melter vacuum now between -0.10 to -0.20″ W.C. |
| | | 4/3/2006 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Performed simulated loss of power-diesel generator test.<br>Switched from EOG HEPA train MM-EOG-F-402 to –F-401. |
| | | 4/10/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 4/11/2006 | Replaced the filter and pre-filter of EOG HEPA train MM-EOG-F-402. |
| | | 4/17/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 4/23/2006 | Noticed that chilled water return line from Room 15 had a leak. |
| | | 4/24/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 4/27/2006 | Switched from EOG HEPA train MM-EOG-F-401 to –F-402. |
| | | 5/1/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 5/2/2006 | Performed simulated loss of power-diesel generator test. Noticed some corrosion on the battery terminals. |
| | | 5/8/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 5/9/2006 | City water low pressure alarm. Water pressure at 3.2 psig. |
| | | 5/12/2006 | Turned on the Room 10 air conditioning unit to cool the computers. |
| | | 5/15/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 5/16/2006 | Secured Room 10 air conditioning unit. |
| | | 5/22/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 5/26/2006 | Replaced the filter and pre-filter of EOG HEPA train MM-EOG-F-401. |
| | | 5/29/2006 | Swapped chilled water pumps and dam wall regenerative blowers. |
| | | 5/30/2006 | Took digital photographs of discharge chamber trough, melter plenum interior walls, and ceiling. |
| | | 6/1/2006 | Performed simulated loss of power-diesel generator test. Noticed some corrosion on the battery terminals. |
| | | 6/5/2006 | Switched from EOG HEPA train MM-EOG-F-402 to –F-401. |
| | | 6/5/2006 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted dam wall regenerative blower outlet pressure to 2.5 psig. |
| | | 6/6/2006 | City water low pressure alarm. The pressure reading at 30.5 psig. |
| | | 6/7/2006 | The primary system chilled water pump MCL-CW-P-401 fault alarm illuminated. Attempted to reset without success.<br>Opened the city water bypass valve to the back-up heat exchanger. |

**Table 2.1. Chronology of the DM1200 Melter Maintenance and Inspections (continued).**

| | | | |
|---|---|---|---|
| | Maintenance | 6/8/2006 | Low pressure alarm on primary system chilled water pump, MCL-CW-P-401. Pump was reset and restarted.<br>Low pressure alarm on primary system chilled water pump, MCL-CW-P-401. Secured -P-401 pump to allow CUA chilled water to circulate and vent potential air bubbles out of the system. |
| | | 6/9/2006 | Restarted primary system chilled water pump, MCL-CW-P-401. Monitored for low pressure alarms.<br>Completely closed the city water bypass valve, MCL-DW-V-404. |
| | | 6/12/2006 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted dam wall regenerative blower outlet pressure to 2.5 psig. |
| | | 6/15/2006 | Removed discharge chamber heater and ceramic sheath for digital photographs. Reinstalled after photographs were taken. |
| | | 6/16/2006 | Diesel generator was temporarily disconnected to relocate the unit to allow inspection and repair of underground storage tanks. |
| | | 6/19/2006 | Swapped chilled water pumps and dam wall regenerative blowers.<br>Performed simulated loss of power diesel generator test after it was relocated. The system worked satisfactorily.<br>Diesel generator was placed in the standby mode. |
| | | 6/26/2006 | Swapped chilled water pumps and dam wall regenerative blowers. Adjusted dam wall regenerative blower outlet pressure to 2.5 psig. |

## Table 2.2. Summary of Thermocouple Replacements on the DM1200.

| Thermocouple Location | Thermocouple Description | # Times Replaced | Minimum Time Installed, days | Maximum Time Installed, days | Average Time Installed, days |
|---|---|---|---|---|---|
| Glass Pool | 1" from floor (W) | 13 | 25 | 225 | 111 |
| | 13" from floor (W) | 14 | 2 | 223 | 104 |
| | 18" from floor (W) | 13 | 25 | 225 | 111 |
| | 27" from floor (W) | 14 | 35 | 312 | 108 |
| | 9" from floor (E) * | 8 | 8 | 354 | 134 |
| | 18" from floor (E) * | 9 | 8 | 244 | 119 |
| | 24" from floor (E) * | 8 | 8 | 354 | 134 |
| | 30" from floor (E) | 12 | 53 | 302 | 123 |
| Plenum | 8" below ceiling * | 10 | 35 | 225 | 120 |
| | 17" below ceiling | 9 | 47 | 354 | 158 |
| | Exposed | 20 | 1 | 227 | 56 |
| Discharge | TC 1 * | 2 | 231 | 887 | 559 |
| | TC 2 * | 2 | 231 | 614 | 423 |
| | Riser * | 6 | 52 | 384 | 190 |
| Electrode | East * | 2 | 271 | 842 | 557 |
| | West * | 2 | 219 | 271 | 245 |
| | Bottom * | 2 | 490 | 778 | 634 |

* Thermocouple still installed in melter; therefore, lifetime data for that thermocouple is not included.
Note: Replacement data does not include the first thermocouples installed.

## Table 2.3. Summary of Thermowell, Level Detector and Discharge Air Lance Replacements on the DM1200.

| - | Dates in Melter | Duration in Melter, days | Total Days Exposed to Feeding | Days Exposed to LAW Feeding | Days Exposed to HLW Feeding | # Times Removed for Inspection |
|---|---|---|---|---|---|---|
| Thermowell #1 | 08/22/00 – 08/02/01 | 345 | 25.5 | 0.0 | 25.5 | 2 |
| | 08/02/01 – 11/15/01 | 105 | 36.6 | 0.0 | 36.6 | 5 |
| | 11/20/01 – 08/05/02 | 258 | 23.5 | 14.6 | 8.9 | 4 |
| | 08/08/02 – 05/01/03 | 266 | 65.4 | 4.2 | 61.2 | 5 |
| | 05/01/03 – 09/02/05 | 784 | 124.1 | 22.2 | 101.9 | 9 |
| | Average | 352 | 55.0 | 8.2 | 46.8 | - |
| Thermowell #2 | 07/19/01 – 11/15/01 | 119 | 45.6 | 0.0 | 45.6 | 3 |
| | 11/20/01 – 08/05/02 | 258 | 23.5 | 14.6 | 8.9 | 4 |
| | 08/08/02 – 05/01/03 | 266 | 65.4 | 4.2 | 61.2 | 7 |
| | 05/01/03 – 12/13/04 | 592 | 115.3 | 13.4 | 101.9 | 11 |
| | 12/13/04 – 05/31/06 * | 534 | 8.9 | 8.9 | 0.0 | 1 |
| | Average | 354 | 51.7 | 8.2 | 43.5 | - |
| Level Detector | 02/01/01 – 08/21/02 | 561 | 85.6 | 14.6 | 71.0 | 5 |
| | 08/26/02 – 10/28/03 | 424 | 142.2 | 15.1 | 127.1 | 6 |
| | 10/28/03 – 09/01/05 | 668 | 48.3 | 11.4 | 36.9 | 2 |
| | Average | 551 | 92.0 | 13.7 | 78.3 | - |
| Discharge Air Lance | 02/01/01 – 10/28/03 | 921 | 226.8 | 25.4 | 201.4 | 11 |
| | 11/03/03 – 08/10/04 | 241 | 26.6 | 2.4 | 24.2 | 3 |
| | 09/16/04 – 05/13/06 * | 584 | 21.6 | 8.8 | 12.8 | 3 |
| | Average | 608 | 91.7 | 12.3 | 79.4 | - |

* Component still installed in melter.
"-" Empty data field

### Table 2.4. Summary of Discharge Heater Replacements on the DM1200.

| Heater # | Before Modification | | | | After Modification | |
|---|---|---|---|---|---|---|
| | # Times Replaced | Min. Time Installed, days | Max. Time Installed, days | Ave. Time Installed, days | # Times Replaced | Time Installed, days |
| 1A | 3 | 66 | 271 | 187 | 0 | 1256 |
| 1B | 4 | 66 | 224 | 140 | 0 | 1256 |
| 2A | 4 | 26 | 310 | 141 | 0 | 1252 |
| 2B | 4 | 26 | 310 | 141 | 0 | 1252 |
| 3A | 2 | 144 | 421 | 283 | 0 | 1252 |
| 3B | 1 | 565 | 565 | 565 | 0 | 1252 |
| 4A | 3 | 27 | 310 | 188 | 0 | 1252 |
| 4B | 3 | 27 | 310 | 188 | 0 | 1252 |
| 5A | 2 | 38 | 527 | 283 | 0 | 1252 |
| 5B | 3 | 12 | 527 | 188 | 0 | 1252 |
| 6A | 1 | 565 | 565 | 565 | 0 | 1252 |
| 6B | 1 | 565 | 565 | 565 | 0 | 1252 |
| 7A | 1 | 561 | 561 | 561 | 0 | 1256 |
| 7B | 1 | 561 | 561 | 561 | 0 | 1256 |

## Table 3.1. Tests Performed with Final HLW Bubbler Configuration.

| Test | Feed | Glass Yield | Duration | Bubbling Rate | Glass Production Rate |
|---|---|---|---|---|---|
| Configuration Test 9A VSL-04R4800-4 [30] | AZ-101 | 400 g/l | 145 hrs | 64 lpm | 1050 kg/m$^2$/d |
| Configuration Test 9B VSL-04R4800-4 [30] | AZ-101 | 400 g/l | 72 hrs | 134 lpm | 1400 kg/m$^2$/d |
| Test 1B VSL-05R5800-1 [35] | AZ-102 | 340 g/l | 114 hrs | 65 lpm | 900 kg/m$^2$/d |
| Test 2B VSL-05R5800-1 [35] | C-106/AY-102, High Waste Loading | 340 g/l | 105 hrs | 90 lpm | 1050 kg/m$^2$/d |
| MACT HLW 1 (400°C plenum) VSL-05R5830-1 [41] | C-106/AY-102, spiked | 430 g/l | 52 hrs | 24 lpm | 700 kg/m$^2$/d |
| MACT HLW 2A (345°C plenum) VSL-05R5830-1 [41] | C-106/AY-102, spiked | 430 g/l | 75 hrs | 9 lpm | 550 kg/m$^2$/d |
| MACT HLW 1-cont (400°C plenum) VSL-05R5830-1 [41] | C-106/AY-102, spiked | 430 g/l | 19 hrs | 28 lpm | 742 kg/m$^2$/d |
| MACT HLW 2B (500°C plenum) VSL-05R5830-1 [41] | C-106/AY-102, spiked | 430 g/l | 54 hrs | 43 lpm | 1072 kg/m$^2$/d |

## Table 3.2. Rate Increase from Improved Bubbler Configuration.

| Test | Bubbler Configuration | Feed | Glass Yield | Duration | Bubbling Rate | Glass Production Rate |
|---|---|---|---|---|---|---|
| Test 1B VSL-05R5800-1 [35] | New (2 – Double Outlet bubblers on floor) | AZ-102 | 340 g/l | 114 hrs | 65 lpm | 900 kg/m$^2$/d |
| Test 5C VSL-03R3800-4 [17] | Old (2 - Single Outlet bubblers in corners facing center, 6” from floor) | AZ-101 | 300 g/l | 75 hrs | 65 lpm | 550 kg/m$^2$/d |
| **Rate Increase** | | | | | | **64%** |
| Configuration Test 9A VSL-04R4800-4 [30] | New (2 – Double Outlet bubblers on floor) | AZ-101 | 400 g/l | 145 hrs | 64 lpm | 1050 kg/m$^2$/d |
| Test 4C VSL-03R3800-4 [17] | Old (2 - Single Outlet bubblers in corners facing center, 6” from floor) | AZ-101 | 400 g/l | 72 hrs | 65 lpm | 750 kg/m$^2$/d |
| **Rate Increase** | | | | | | **40%** |

**Table 4.1. Summary of Manual Cleanings of the DM1200 Film Cooler.**

| Test | Feed Type and Test Conditions | Ave. Glass Production Rate, kg/m$^2$/day | Bubbler Flow Rate, lpm * | Number of Cleanings vs. Bubbling Rate | | |
|---|---|---|---|---|---|---|
| | | | | 0 – 65 lpm | 65 – 100 lpm | >100 lpm |
| 5 | C-106/AY-102, variable sugar, 550 g/l [29] | 650 – 925 | 65 (variable) | 0 | - | - |
| 6 | C-106/AY-102, variable sugar with nitrates, 550 g/l [29] | 895 – 1025 | 65 (variable) | 1 | - | - |
| 2 | AZ-101, variable bubbling depth (parallel to electrodes, 530 g/l [30] | 550 – 650 | 65 (variable) | 0 | - | - |
| 1 | AZ-101, bubbler skewing, 530 g/l [30] | 730 – 1100 | 65 (skewed) | 10 | - | - |
| 3 | AZ-101, prototypical bubbling, 2 and 4 outlet bubblers, 400 g/l [30] | 600 – 1165 | Adjusted for max rate (fixed) | 2 | 10 | 5 |
| 8 | AZ-101, 4 outlet bubbling and 1175°C, 400 g/l [ 30] | 740 – 1450 | Adjusted for max rate (fixed) | 0 | 12 | 22 |
| 4 | AZ-101, variable sugar with Ru, 400 g/l [29] | 600 – 900 | 65 (variable) | 0 | - | - |
| 10 | AZ-101, variable Cl/SO$_4$, 400 g/l [30] | 730 – 920 | 80 (variable) | 1 | - | - |
| 9 | AZ-101, best bubbler configuration, 400 g/l [30] | 1000 – 1275 | Adjusted for max rate (fixed) | 0 | 0 | 5 |
| - | AZ-102, rheology test, 2 and 4 bubbling outlets, 500 – 340 g/l [35] | 1000 – 1300 | 65 and adjusted for max rate (fixed) | 3 | 0 | 12 |
| - | C-106/AY-102, rheology test, 2 and 4 bubbling outlets, 540 – 340 g/l [35] | 1010 – 1050 | 65, adjusted for 1050 kg/m$^2$/day (fixed) | 1 | 1 | - |
| HLW MACT | C-106/AY-102, 4 outlet bubblers, 420 g/l [41] | 500 – 1100 | <65 (adjusted to achieve rate) | 0 | - | - |

"-" Empty data field

* Fixed – all bubblers have equal flow rates and total to the target overall flow rate.
Variable – bubbler flow rates are independent of one another, but total to the target overall flow rate.

**Table 4.2. Summary of DM1200 Transition Line Blockages.**

| Test | Feed Type and Test Conditions | Ave. Glass Production Rate, kg/m$^2$/day | Bubbler Flow Rate, lpm * | # of Blockages | Comments |
|---|---|---|---|---|---|
| 5 | C-106/AY-102, variable sugar, 550 g/l [29] | 650 – 925 | 65 (variable) | 0 | Sensor line clogging, line not cleaned after test. |
| 6 | C-106/AY-102, variable sugar with nitrates, 550 g/L [29] | 895 – 1025 | 65 (variable) | 0 | Line not cleaned after test. |
| 2 | AZ-101, variable bubbling depth (parallel to electrodes, 530 g/l [30] | 550 – 650 | 65 (variable) | 4 | Line cleaned after test. |
| 1 | AZ-101, bubbler skewing, 530 g/l [30] | 730 – 1100 | 65 (skewed) | 1 | Blockage cleaned by tapping line with hammer, sensor line clogged. |
| 3 | AZ-101, prototypical bubbling, 2 and 4 outlet bubblers, 400 g/l [30] | 600 – 1165 | Adjusted for max rate (fixed) | 5 | Blockages rodded out, line not cleaned at end of test. |
| 8 | AZ-101, 4 bubbling outlets and 1175°C, 400 g/l [ 30] | 740 – 1450 | Adjusted for max rate (fixed) | 0 | Line not cleaned at end of test. |
| 4 | AZ-101, variable sugar with Ru, 400 g/l [29] | 600 – 900 | 65 (variable) | 0 | Line not cleaned at end of test. |
| 10 | AZ-101, variable Cl/SO$_4$, 400 g/l [30] | 730 – 920 | 80 (variable) | 2 | Blockage cleared by tapping with hammer, line cleaned after test. |
| 9 | AZ-101, optimum bubbler configuration, 400 g/l [30] | 1000 – 1275 | Adjusted for max rate (fixed) | 0 | Line not cleaned after test. |
| - | AZ-102, rheology test, 2 and 4 bubbling outlets, 500 – 340 g/l [35] | 1000 – 1300 | 65 and adjusted for max rate (fixed) | 0 | Line tapped with hammer prior to start, sensor tubing clogged. |
| - | C-106/AY-102, rheology test, 2 and 4 bubbling outlets, 540 – 340 g/l [35] | 1010 – 1050 | 65, adjusted for 1050 kg/m$^2$/day (fixed) | 0 | - |
| HLW MACT | C-106/AY-102, 4 bubbling outlets, 420 g/L [41] | 500 – 1100 | <65 (adjusted to achieve rate) | 0 | - |
| LAW MACT | LAW Sub-Envelope A2, 4 bubblers, 8M Na [41] | 1300 – 1850 | 20 - 35 | 0 | Sensor tubing clogged several times. |

"-" Empty data field

* Fixed – all bubblers have equal flow rates and total to the target overall flow rate.
Variable – bubbler flow rates are independent of one another, but total to the target overall flow rate.

# Table 4.3. Solid Deposits Removed During DM1200 Tests.

| Report Number | Sampling Date | Location | Mass (g) |
|---|---|---|---|
| VSL-02R8800-1 [10] | 1/15/2002 | Transition line bellows | 130 |
| VSL-02R8800-2 [14] | 3/6/2002 | Solids in the transition bellows and transition line section 4 | Mass not recorded. |
| | 4/5/2002 | Small sections of film cooler bottom for microscopy analysis | Digital pictures taken. Mass not recorded. |
| | 4/6/2002 | Solids removed from film cooler with chisel and hammer. | Digital pictures taken. Mass not recorded. |
| VSL-03R3800-4 [17] | 10/24/2002 | Transition line section #4 - transition line section #1 | Masses are not recorded. |
| VSL-03R3800-3 [28] | 3/6/2003 | Film cooler | 62 |
| | 3/6/2003 | Transition line (section) #1 | 116 |
| | 3/6/2003 | Transition line section #2 | 3110 |
| | 3/6/2003 | Transition line section #3 | 842 |
| | 3/6/2003 | Transition line bellows | 236 |
| | 3/6/2003 | Transition line #4<br>(SBS inlet transition line pipe) | 136 |
| VSL-04R4800-4 [30] | 6/11/2003 | Transition line section #1 | 740 |
| | 6/11/2003 | Transition line section #3 | 410 |
| | 6/11/2003 | Transition line section #4 | 260 |
| | 6/11/2003 | Transition line section #2 | 2280 |
| | 6/11/2003 | Transition line bellows | 270 |
| | 6/11/2003 | Film cooler | 80 |
| | 7/2/2003 | Transition line bellows | 10 |
| | 7/22/2003 | Transition line bellows | 254 |
| VSL-04R4800-4 [30] | 9/12/2003 | Transition line and bellows | 1500 |
| | 9/12/2003 | Film cooler | 570 |
| VSL-04R4851-1 [31] | 10/10/2003 | Transition line bellows | 60 |
| | 10/23/2003 | Transition line section #3 and bellows | 16 |
| | 10/23/2003 | Transition line section #2 | 12 |
| VSL-03L4850-1 [34] | 1/8/2004 | Transition line bellows | 150 |
| | 1/8/2004 | Transition line section #3 | 270 |
| | 1/8/2004 | Transition line section #1 | 4 |
| | 1/8/2004 | Transition line section #4 | 87 |
| | 1/8/2004 | Transition line section #2 | 890 |
| | 1/8/2004 | Film cooler | Found no particulate to sample. |
| VSL-05R5800-1 [35] | 4/14/2005 | Transition line section #2 | 333 |
| | 4/20/2005 | Transition line section #2 | 834 |
| | 4/20/2005 | Transition line section #3 and bellows | 360 |
| | 4/20/2005 | Transition line section #4, | 370 |

## Table 4.4. DCP Analyzed Composition of Solid Deposits Collected During DM1200 Tests (wt%).

| Report | VSL-02R8800-1 [10] | VSL-02R8800-2 [14] | VSL-03R3800-3 [28] | VSL-04R4800-4 [30] | VSL-05R5800-1 [35] | | |
|---|---|---|---|---|---|---|---|
| Date | 1/16/2002 | 4/06/2002 | 3/6/2003 | 7/22/2003 | 4/20/2005 | | |
| Sample Description | Transition line bellows | Residual solids removed from film cooler after washing. | Transition line section #2 | Transition line bellows | Transition line Section #2 | Transition line section #3 & bellows | Transition line section #4 |
| $Al_2O_3$ | 7.47 | 4.19 | 4.14 | Main constituents determined by SEM/EDS were Na, Al, Si, Fe, Zn, S and Cl. In regions where whitish material was evident, high Na, S, and Cl peaks in EDS spectra were observed. Sodium sulfate was readily observed across the sample. | 2.13 | 2.05 | 3.65 |
| $As_2O_3$ | 0.10 | 0.01 | 0.08 | | <0.01 | <0.01 | <0.01 |
| $B_2O_3$ | 3.22 | 9.97 | 6.93 | | 7.49 | 8.06 | 10.35 |
| BaO | 0.03 | 0.01 | 0.01 | | 0.01 | 0.01 | 0.05 |
| CaO | 0.96 | 1.33 | 0.63 | | 0.73 | 0.60 | 0.50 |
| CdO | 0.43 | 0.13 | 0.03 | | 0.12 | 0.13 | 0.04 |
| $Cr_2O_3$ | 0.31 | 2.81 | 0.04 | | 5.01 | 2.75 | 0.14 |
| $Cs_2O$* | 0.55 | NA | 0.11 | | NA | NA | NA |
| CuO | 0.03 | 0.01 | 0.03 | | 0.01 | 0.01 | 0.02 |
| $Fe_2O_3$ | 14.39 | 6.95 | 11.68 | | 7.66 | 6.60 | 11.88 |
| I** | <0.01 | NA | NA | | NA | NA | NA |
| $K_2O$ | 0.39 | 1.37 | 0.06 | | 5.57 | 5.37 | 0.27 |
| $Li_2O$ | 2.06 | 1.37 | 1.03 | | 0.75 | 1.15 | 2.04 |
| MgO | 0.70 | 0.30 | 0.60 | | 0.46 | 0.42 | 0.60 |
| MnO | 0.61 | 0.28 | 1.11 | | 0.35 | 0.30 | 2.71 |
| $Na_2O$ | 6.99 | 17.78 | 6.61 | | 22.55 | 22.71 | 11.90 |
| NiO | 0.74 | 4.02 | 0.37 | | 0.17 | 0.17 | 0.34 |
| $P_2O_5$ | 0.25 | 0.14 | 0.08 | | 0.10 | 0.19 | 0.34 |
| PbO | 0.15 | 0.04 | 0.08 | | 0.08 | 0.09 | 0.53 |
| $Sb_2O_3$ | 0.16 | <0.01 | 0.13 | | NA | NA | NA |
| $SeO_2$ | 14.01 | 1.99 | 5.06 | | NA | NA | NA |
| $SiO_2$ | 20.68 | 14.73 | 26.42 | | 13.42 | 13.70 | 35.05 |
| $SO_3$** | 6.06 | <0.01 | 1.99 | | 12.07 | 6.89 | 2.28 |
| SrO | 1.70 | 0.39 | 0.38 | | 0.22 | 0.26 | 0.36 |
| $TeO_2$ | 1.44 | 0.25 | NA | | NA | NA | NA |
| $TiO_2$ | 0.24 | 1.53 | 0.19 | | 0.45 | 0.49 | 0.16 |
| ZnO | 2.01 | 2.15 | 2.07 | | 1.35 | 1.47 | 1.20 |
| $ZrO_2$ | 0.73 | 0.70 | 3.48 | | 0.61 | 0.40 | 1.47 |
| Total | 86.43 | 72.49 | 73.36 | | 81.31 | 73.82 | 85.88 |

* Analyzed by AA; **Analyzed by IC; NA Not analyzed

**Table 5.1. Melter Emission Rates.**

| Report | | VSL-01R0100-2 [3] | | | | | VSL-01R0100-2 [3] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 570 g/l | | | | | HLW AZ-101, 570 g/l | | | | | |
| Dates | | 5/10/01 | | | 5/10/01 | | 5/15/01 | | | 5/15/01 | | |
| Bubbler Configuration | | Bubbling from the bottom electrode bubblers | | | | | Bubbling from the bottom electrode bubblers | | | | | |
| Bubbling Rate | | < 4 lpm | | | | | 47 lpm | | | | | |
| - | | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total$ | 9655 | 78.0 | 2063 | 60.0 | 2682 | 42045 | 1879 | 373 | 46717 | 1951 | 399 |
| | Al | 303.6 | 1.7 | 2976 | 1.8 | 2811 | 1322.2 | 40.3 | 547 | 1469.1 | 46.1 | 531 |
| | As | 2.4 | 0.1 | 400 | 0.1 | 400 | 10.2 | 1.7 | 100 | 11.4 | 1.5 | 127 |
| | B | 120.3 | 0.8 | 2506 | 2.1 | 955 | 523.7 | 32.7 | 267 | 581.9 | 27.4 | 354 |
| | Ba | 2.8 | <0.1 | >470 | <0.1 | >470 | 12.1 | 0.5 | 403 | 13.4 | 0.5 | 447 |
| | Ca | 13.9 | 0.9 | 257 | 1.0 | 232 | 60.3 | 5.4 | 186 | 67.0 | 4.9 | 228 |
| | Cd | 25.7 | 0.1 | 4283 | 0.3 | 1428 | 111.8 | 6.3 | 296 | 124.2 | 5.4 | 383 |
| | Cr | 1.1 | <0.1 | >180 | 0.1 | 183 | 4.6 | 1.0 | 77 | 5.1 | 0.7 | 121 |
| | Cs | 6.2 | 0.1 | 1033 | 0.4 | 258 | 27.0 | 9.5 | 47 | 30.0 | 6.9 | 72 |
| | Cu | 1.9 | <0.1 | >320 | <0.1 | >320 | 8.1 | 0.4 | 338 | 9.0 | 0.4 | 375 |
| | Fe | 563.1 | 4.0 | 2346 | 4.2 | 2235 | 2452.0 | 97.7 | 418 | 2724.5 | 96.7 | 470 |
| | I | 7.8 | <0.1 | >1300 | <0.1 | >1300 | 33.8 | <0.1 | >5630 | 37.5 | <0.1 | >6250 |
| | K | 10.9 | 0.3 | 606 | 0.4 | 454 | 47.6 | 7.3 | 109 | 52.9 | 6.0 | 147 |
| | Li | 216.0 | 0.6 | 6000 | 1.2 | 3000 | 940.7 | 21.7 | 723 | 1045.2 | 19.7 | 884 |
| | Mg | 2.8 | 0.2 | 233 | 0.1 | 467 | 12.2 | 0.9 | 226 | 13.6 | 0.9 | 252 |
| | Mn | 181.9 | 0.3 | 10106 | 0.4 | 7579 | 792.0 | 8.2 | 1610 | 880.0 | 7.1 | 2066 |
| | Na | 378.9 | 4.4 | 1435 | 6.2 | 1019 | 1650.2 | 91.4 | 301 | 1833.5 | 78.0 | 392 |
| | Ni | 32.9 | 0.2 | 2742 | 0.3 | 1828 | 143.2 | 6.2 | 385 | 159.1 | 6.3 | 421 |
| | P | 113.7 | 0.1 | 18950 | <0.1 | >18950 | 495.0 | 0.3 | 27500 | 550.0 | <0.1 | >91660 |
| | Pb | 10.8 | 0.1 | 1800 | 0.1 | 1800 | 47.0 | 3.1 | 253 | 52.2 | 2.7 | 322 |
| | S | 7.8 | 2.6 | 50 | 1.8 | 72 | 33.8 | 35.7 | 16 | 37.6 | 30.3 | 21 |
| | Sb | 12.3 | 0.1 | 2050 | <0.1 | >2050 | 53.4 | 1.1 | 809 | 59.3 | 0.6 | 1647 |
| | Se | 8.3 | 8.3 | 17 | 21.2 | 7 | 36.0 | 345.9 | 2 | 40.0 | 323.1 | 2 |
| | Si | 1649.5 | 5.1 | 5391 | 2.2 | 12496 | 7183.2 | 114.0 | 1050 | 7981.4 | 111.0 | 1198 |
| | Sr | 152.0 | 0.8 | 3167 | 1.2 | 2111 | 662.1 | 21.8 | 506 | 735.7 | 20.5 | 598 |
| | Te | 8.7 | 0.5 | 290 | 1.9 | 76 | 37.8 | 43.1 | 15 | 42.0 | 34.3 | 20 |
| | Ti | 2.8 | <0.1 | >470 | 0.1 | 467 | 12.1 | 0.5 | 403 | 13.5 | 0.7 | 321 |
| | Zn | 124.5 | 0.8 | 2594 | 1.3 | 1596 | 542.3 | 20.7 | 437 | 602.5 | 20.6 | 487 |
| | Zr | 204.3 | 0.3 | 11350 | 0.1 | 34050 | 889.5 | 10.5 | 1412 | 988.3 | 9.4 | 1752 |
| Gas | B | 120.3 | 17.2 | 117 | 4.9 | 409 | 523.7 | 141.5 | 62 | 581.9 | 197.9 | 49 |
| | Cl | 0.8 | 8.7 | 2 | 2.9 | 5 | 3.4 | 65.5 | 1 | 3.8 | 78.7 | 1 |
| | F | 3.1 | 4.4 | 12 | 4.3 | 12 | 13.5 | 72.8 | 3 | 15.0 | 103.3 | 2 |
| | I | 7.8 | 47.2 | 3 | 122.3 | 1 | 33.8 | 475.9 | 1 | 37.5 | 584.6 | 1 |
| | S | 7.8 | 5.2 | 25 | 1.8 | 72 | 33.8 | 95.0 | 6 | 37.6 | 119.1 | 5 |
| | Se | 8.3 | 17.4 | 8 | 12.7 | 11 | 36.0 | 38.0 | 16 | 40.0 | 63.1 | 11 |

NC – Not calculated.
"-" Empty data filed.
$ - From gravimetric analysis of filters and rinse dry downs

**Table 5.1. Melter Emission Rates (continued).**

| Report | | VSL-01R0100-2 [3] | | | VSL-02R0100-2 [9] | | | VSL-02R0100-2 [9] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 350 g/l | | | HLW AZ-101, 570 g/l | | | HLW AZ-101, 570 g/l with 10 g/l sugar | | |
| Dates | | 5/22/01 | | | 6/29-30/01 | | | 7/29-30/01 | | |
| Bubbler Configuration | | Bubbling from the bottom electrode bubblers | | | No bubbling | | | No bubbling | | |
| Bubbling Rate | | 47 lpm | | | < 4 lpm | | | < 4 lpm | | |
| - | | Feed Flux (g/hr) | Average Melter Emissions* Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 41746 | 1704 | 408 | 317167 | 155.3 | 2042 | 232167 | 202 | 1149 |
| | Al | 1371.2 | 47.7 | 479 | 12425 | 3.04 | 4090 | 9095 | 5.82 | 1563 |
| | As | 10.6 | 2.5 | 71 | 96 | < 0.41 | > 234 | 70 | 1.58 | 45 |
| | B | 543.1 | 276.4 | 33 | 9843 | 30.20 | 326 | 7205 | 6.07 | 1187 |
| | Ba | 12.5 | 0.5 | 417 | 114 | < 0.10 | > 1140 | 83 | < 0.10 | > 830 |
| | Ca | 62.5 | 24.9 | 42 | 567 | < 4.46 | >127 | 415 | 0.72 | 573 |
| | Cd | 116.0 | 8.6 | 225 | 1051 | 0.67 | 1572 | 769 | 13.45 | 57 |
| | Cl | 3.5 | 41.6[$] | 1 | NA | NA | NC | NA | NA | NC |
| | Cr | 4.8 | 2.0 | 40 | 87 | < 0.13 | > 669 | 64 | 0.13 | 503 |
| | Cs | 28.0 | 9.9 | 47 | 239 | 0.40 | 599 | 175 | 0.46 | 380 |
| | Cu | 8.4 | 0.4 | 350 | 76 | 0.29 | 258 | 56 | 0.24 | 232 |
| | F | 14.0 | 0.5[$] | 467 | NA | NA | NC | NA | NA | NC |
| | Fe | 2542.8 | 90.8 | 467 | 23043 | 6.38 | 3609 | 16867 | 10.27 | 1643 |
| | I | 35.0 | 181.8 | 3 | 317 | < 0.09 | > 5286 | 232 | < 0.06 | > 3869 |
| | K | 49.4 | 8.8 | 94 | 448 | 0.48 | 925 | 328 | 0.57 | 578 |
| | Li | 975.5 | 28.4 | 572 | 8840 | 1.49 | 5932 | 6471 | 2.35 | 2755 |
| | Mg | 12.7 | 4.6 | 46 | 2208[#] | 1.18 | 1871 | 1613[#] | 1.69 | 954 |
| | Mn | 821.3 | 8.7 | 1573 | 7443 | 0.78 | 9587 | 5448 | 1.72 | 3159 |
| | Na | 1711.3 | 661.8 | 43 | 15507 | 7.71 | 2012 | 11351 | 7.50 | 1514 |
| | Ni | 148.5 | 6.0 | 413 | 1346 | < 0.30 | > 4487 | 985 | 0.50 | 1976 |
| | P | 513.3 | 0.7 | 12221 | 180 | < 1.52 | > 118 | 132 | 0.32 | 412 |
| | Pb | 48.7 | 3.9 | 208 | 442 | 0.38 | 1156 | 323 | 1.71 | 189 |
| | S | 35.1 | 190.2 | 3 | 318 | 12.56 | 25 | 233 | 0.88 | 265 |
| | Sb | 55.3 | 2.6 | 354 | 501 | < 0.30 | > 1670 | 367 | 0.55 | 665 |
| | Se | 37.4 | 400.4 | 2 | 339 | 104.25 | 3 | 248 | 29.64 | 8 |
| | Si | 7449.3 | 97.3 | 1276 | 67505 | 9.78 | 6906 | 49414 | 15.38 | 3213 |
| | Sr | 686.6 | 24.1 | 475 | 6222 | 2.37 | 2624 | 4555 | 3.64 | 1250 |
| | Te | 39.2 | 64.4 | 10 | 355 | 2.56 | 138 | 260 | 37.66 | 7 |
| | Ti | 12.6 | 0.4 | 525 | 114 | < 0.09 | > 1901 | 84 | < 0.08 | > 1050 |
| | Zn | 562.4 | 20.9 | 448 | 5096 | 3.55 | 1434 | 3730 | 3.88 | 961 |
| | Zr | 922.4 | 7.7 | 1997 | 8359 | < 0.67 | > 12476 | 6119 | 0.86 | 7074 |
| Gas | B | 543.10 | NA | NC | 9843 | 18.99 | 518 | 7205 | 24.53 | 294 |
| | Cl | 3.50 | NA | NC | 32 | < 4.05 | > 8 | 23 | 5.31 | 4 |
| | F | 14.00 | NA | NC | 127 | < 4.33 | > 29 | 93 | 5.21 | 18 |
| | I | 35.00 | NA | NC | 317 | 216.03 | 1 | 232 | 63.66 | 4 |
| | S | 35.07 | NA | NC | 318 | < 10.49 | > 30 | 233 | 22.99 | 10 |
| | Se | 37.36 | NA | NC | 339 | 16.73 | 20 | 248 | 22.27 | 11 |

NC – Not calculated..

[$] - From gravimetric analysis of filters and rinse dry-downs.

* - Melter emissions include gas and particle fractions combined due to filter breach.

\# - The analyzed MgO concentration of 1.15 wt% instead of the target value of 0.06 wt% was used to calculate the feed flux

NA –Not analyzed; "-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-02R0100-2 [9] | | | VSL-02R0100-2 [9] | | | VSL-02R0100-2 [9] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 400 g/l | | | HLW AZ-101, 400 g/l | | | HLW AZ-101, 420g/l with nitrated + sugar (sugar ratio=0.5) | | |
| Dates | | 8/08-10/01 | | | 8/22-24/01 | | | 9/28-30/01 | | |
| Bubbler Configuration | | Bubbling: Deep | | | Bubbling: Shallow | | | No bubbling | | |
| Bubbling Rate | | 62 lpm | | | 50 lpm | | | < 4 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total$^{\$}$ | 1036333 | 4520 | 229 | 536667 | 1748 | 307.4 | 275333 | 949.7 | 290 |
| | Al | 40600 | 169.48 | 240 | 21025 | 76.37 | 275 | 10787 | 15.11 | 714 |
| | As | 314 | 5.83 | 54 | 163 | 1.56 | 104 | 83 | 0.38 | 221 |
| | B | 32162 | 140.49 | 229 | 16655 | 49.26 | 338 | 8545 | 26.19 | 326 |
| | Ba | 371 | 1.46 | 255 | 192 | 0.64 | 300 | 99 | 0.19 | 514 |
| | Ca | 1852 | 9.08 | 204 | 959 | 3.68 | 261 | 492 | 1.37 | 359 |
| | Cd | 3433 | 21.27 | 161 | 1778 | 8.53 | 209 | 912 | 2.30 | 397 |
| | Cr | 284 | 4.75 | 60 | 147 | 2.10 | 70 | 75 | 0.26 | 289 |
| | Cs | 782 | 16.61 | 47 | 405 | 8.32 | 49 | 208 | 1.46 | 142 |
| | Cu | 248 | 0.97 | 257 | 129 | 0.49 | 263 | 66 | 0.18 | 361 |
| | Fe | 75292 | 312.81 | 241 | 38990 | 119.84 | 325 | 20003 | 28.15 | 711 |
| | I | 1036 | < 0.06 | > 17272 | 537 | < 0.06 | > 8944 | 275 | < 0.06 | > 4589 |
| | K | 1463 | 11.55 | 127 | 757 | 5.46 | 139 | 389 | 2.80 | 139 |
| | Li | 28884 | 71.23 | 405 | 14958 | 32.85 | 455 | 7674 | 18.20 | 422 |
| | Mg# | 7200 | 36.84 | 195 | 3725 | 15.68 | 238 | 1920 | 3.97 | 105 |
| | Mn | 24319 | 32.71 | 743 | 12593 | 14.10 | 893 | 6461 | 3.43 | 1886 |
| | Na | 50670 | 223.13 | 227 | 26240 | 93.11 | 282 | 13462 | 51.26 | 263 |
| | Ni | 4398 | 18.81 | 234 | 2277 | 7.54 | 302 | 1168 | 1.70 | 689 |
| | P | 588 | 6.21 | 95 | 305 | 1.54 | 197 | 156 | 0.64 | 245 |
| | Pb | 1443 | 7.23 | 200 | 747 | 3.06 | 244 | 383 | 0.60 | 634 |
| | S | 1038 | 102.47 | 10 | 538 | 34.34 | 16 | 276 | 1.49 | 185 |
| | Sb | 1638 | 6.11 | 268 | 848 | 1.96 | 433 | 435 | 0.11 | 3892 |
| | Se | 1106 | 485.26 | 2 | 573 | 278.12 | 2 | 294 | 38.76 | 8 |
| | Si | 220570 | 459.30 | 480 | 114223 | 171.89 | 664 | 58601 | 38.38 | 1527 |
| | Sr | 20330 | 70.73 | 287 | 10528 | 31.30 | 336 | 5401 | 7.90 | 684 |
| | Te | 1160 | 81.88 | 14 | 601 | 42.07 | 14 | 308 | 1.16 | 266 |
| | Ti | 373 | 1.17 | 319 | 193 | 1.35 | 143 | 99 | 0.29 | 346 |
| | Zn | 16652 | 67.92 | 245 | 8623 | 30.26 | 285 | 4424 | 5.53 | 801 |
| | Zr | 27312 | 37.59 | 727 | 14144 | 12.65 | 1118 | 7256 | 7.30 | 993 |
| Gas | B | 32162 | 333.09 | 97 | 16655 | 146.58 | 114 | 8545 | 65.35 | 131 |
| | Cl | 104 | 73.78 | 1 | 54 | 66.71 | 1 | 28 | < 0.07 | > 459 |
| | F | 415 | 131.53 | 3 | 215 | 61.61 | 3 | 110 | 139.60 | 1 |
| | I | 1036 | 508.80 | 2 | 537 | 448.56 | 1 | 275 | 12.95 | 21 |
| | S | 1038 | 164.92 | 6 | 538 | 94.75 | 6 | 276 | 7.31 | 38 |
| | Se | 1106 | 49.64 | 22 | 573 | 37.22 | 15 | 294 | 0.52 | 562 |

NC – Not Calculated

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

\# - The analyzed MgO concentration of 1.15 wt% instead of the target value of 0.06 wt% was used to calculate the feed flux.

"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-02R0100-2 [9] | | | VSL-02R0100-2 [9] | | | VSL-02R0100-2 [9] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 480 g/l with frit and 7.5 g/l sugar | | | HLW AZ-101, 480 g/l with frit and 7.5 g/l sugar | | | HLW AZ-101, 420g/l with nitrated + sugar (sugar ratio=0.7) | | |
| Dates | | 10/15-17/01 | | | 10/23-25/01 | | | 10/30-11/1/01 | | |
| Bubbler Configuration | | No bubbling | | | Bubbling: Deep | | | No bubbling | | |
| Bubbling Rate | | < 4 lpm | | | 60 lpm | | | < 4 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total$ | 160333 | 206.4 | 797 | 957667 | 2212 | 433 | 285167 | 1291 | 221 |
| | Al | 6281 | 4.60 | 1364 | 37518 | 25.32 | 1482 | 11172 | 5.58 | 2004 |
| | As | 49 | 0.57 | 85 | 290 | 10.65 | 27 | 86 | 1.41 | 61 |
| | B | 4976 | 1.48 | 3367 | 29721 | 30.75 | 967 | 8850 | 61.33 | 144 |
| | Ba | 57 | < 0.06 | > 957 | 343 | 0.14 | 2381 | 102 | 0.31 | 328 |
| | Ca | 287 | 1.98 | 145 | 1711 | 3.36 | 509 | 510 | 2.14 | 238 |
| | Cd | 531 | 1.97 | 269 | 3173 | 35.09 | 90 | 945 | 5.31 | 178 |
| | Cr | 44 | 0.15 | 302 | 262 | 1.08 | 244 | 78 | 0.23 | 340 |
| | Cs | 121 | 0.43 | 282 | 723 | 9.53 | 76 | 215 | 6.24 | 34 |
| | Cu | 38 | < 0.07 | > 543 | 230 | 0.25 | 904 | 68 | 0.12 | 581 |
| | Fe | 11649 | 6.49 | 1795 | 69576 | 53.95 | 1290 | 20718 | 12.54 | 1652 |
| | I | 160 | < 0.06 | > 2672 | 958 | < 0.06 | > 15961 | 285 | < 0.06 | > 4753 |
| | K | 226 | 0.36 | 632 | 1352 | 6.17 | 219 | 402 | 9.45 | 43 |
| | Li | 4469 | 1.42 | 3149 | 26692 | 18.63 | 1432 | 7948 | 26.30 | 302 |
| | Mg# | 1114 | 0.66 | 1687 | 6643 | 3.26 | 2038 | 1978 | 2.75 | 719 |
| | Mn | 3762 | 0.36 | 10536 | 22473 | 3.44 | 6528 | 6692 | 1.53 | 4384 |
| | Na | 7839 | 3.74 | 2096 | 46824 | 55.92 | 837 | 13943 | 139.66 | 100 |
| | Ni | 680 | 0.36 | 1884 | 4064 | 3.08 | 1319 | 1210 | 0.74 | 1628 |
| | P | 91 | < 0.08 | > 1240 | 544 | 1.02 | 531 | 162 | 0.68 | 239 |
| | Pb | 223 | 0.25 | 896 | 1334 | 4.40 | 303 | 397 | 1.10 | 361 |
| | S | 161 | 1.17 | 137 | 959 | 41.72 | 23 | 286 | 3.65 | 78 |
| | Sb | 253 | < 0.13 | > 1946 | 1514 | 3.31 | 457 | 451 | 0.96 | 468 |
| | Se | 171 | 28.39 | 6 | 1022 | 562.05 | 2 | 304 | 29.28 | 10 |
| | Si | 34125 | 12.45 | 2742 | 203827 | 62.82 | 3245 | 60694 | 364.85 | 166 |
| | Sr | 3145 | 1.04 | 3026 | 18787 | 7.30 | 2573 | 5594 | 6.25 | 896 |
| | Te | 179 | 7.19 | 25 | 1072 | 122.25 | 9 | 319 | 3.02 | 106 |
| | Ti | 58 | 0.60 | 96 | 344 | 0.59 | 582 | 103 | 0.21 | 491 |
| | Zn | 2576 | 0.76 | 3397 | 15388 | 7.32 | 2102 | 4582 | 2.90 | 1582 |
| | Zr | 4226 | 0.56 | 7501 | 25239 | 4.62 | 5466 | 7515 | 2.48 | 3034 |
| Gas | B | 4976 | 14.36 | 347 | 29721 | 292.79 | 102 | 8850 | 55.23 | 160 |
| | Cl | 16 | 8.27 | 2 | 96 | 94.59 | 1 | 29 | < 0.07 | > 475 |
| | F | 64 | 20.73 | 3 | 383 | 265.73 | 1 | 114 | < 0.07 | > 1901 |
| | I | 160 | 27.86 | 6 | 958 | 222.54 | 4 | 285 | 15.19 | 19 |
| | S | 161 | 19.52 | 8 | 959 | 481.31 | 2 | 286 | 17.09 | 17 |
| | Se | 171 | 10.08 | 17 | 1022 | 30.35 | 34 | 304 | 0.59 | 513 |

NC – Not Calculated

$ - From gravimetric analysis of filters and rinse dry-downs

# - The analyzed MgO concentration of 1.15 wt% instead of the target value of 0.06 wt% was used to calculate the feed flux.

"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-02R0100-2 [9] | | | VSL-02R8800-1 [10] | | | VSL-02R8800-2 [14] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 570 g/l with 10 g/l sugar. | | | LAW Envelope C1, 851 g/l | | | LAW Envelope A1, 860 g/l | | |
| Dates | | 11/07-08/01 | | | 1/9-10/02 | | | 3/03- 04/02 and 3/18/02 | | |
| Bubbler Configuration | | No bubbling | | | Four top-entering bubblers (one in each corner) together with three of the bottom-electrode bubblers. | | | Four top-entering bubblers (one in each corner) together with three of the bottom-electrode bubblers. | | |
| Bubbling Rate | | < 4 lpm | | | 71 lpm | | | 90 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 281833 | 536 | 526 | 1126150 | 2767 | 407 | 2041667 | 8239.9 | 248 |
| | Al | 11041 | 2.25 | 4902 | 46417 | 6.39 | 7260 | 51717 | 56.65 | 912.9 |
| | As | 85 | 4.10 | 21 | NA | NA | NC | NA | NA | NC |
| | B | 8747 | 4.15 | 2108 | 44903 | 60.25 | 745 | 44048 | 75.06 | 586.8 |
| | Ba | 101 | < 0.06 | > 1683 | NA | NA | NC | NA | NA | NC |
| | Ca | 504 | 0.59 | 859 | 52482 | 4.72 | 11119 | 22444 | 13.23 | 1696.4 |
| | Cd | 934 | 32.12 | 29 | NA | NA | NC | 1704 | 14.57 | 117.0 |
| | Cl | NA | NA | NC | 1152[*] | 820.59[*] | 1.40 | 8881 | 3044.66 | 2.9 |
| | Cr | 77 | 0.09 | 824 | 197 | 3.14 | 63 | 217 | 5.15 | 42.1 |
| | Cs | 213 | 1.50 | 141 | 2173 | 119.73 | 18 | 2094 | 248.11 | 8.4 |
| | Cu | 68 | < 0.12 | > 567 | NA | NA | NC | NA | NA | NC |
| | F | NA | NA | NC | 2016[*] | 126.72[*] | 16 | 317 | 58.42 | 5.4 |
| | Fe | 20476 | 4.95 | 4140 | 56072 | 22.95 | 2443 | 76957 | 53.67 | 1433.9 |
| | I | 282 | < 0.06 | > 4697 | 1440[*] | < 0.01[*] | > 144000 | 1586 | < 0.10 | > 15860 |
| | K | 398 | 0.76 | 526 | 956 | 14.53 | 66 | 5793 | 141.70 | 40.9 |
| | Li | 7855 | 1.86 | 4227 | 16719 | 14.80 | 1129 | NA | NA | NC |
| | Mg# | 1958 | 0.60 | 3264 | 13108 | 0.32 | 41394 | 18933 | 0.43 | 44030.2 |
| | Mn | 6614 | 0.24 | 27815 | NA | NA | NC | NA | NA | NC |
| | Na | 13780 | 8.24 | 1673 | 154346 | 388.30 | 397 | 234847 | 1766.24 | 133.0 |
| | Ni | 1196 | 0.29 | 4081 | 339 | 0.04 | 8475 | NA | NA | NC |
| | P | 160 | < 0.18 | > 889 | 754 | 3.67 | 205 | 485 | 3.05 | 158.8 |
| | Pb | 392 | 2.49 | 157 | 267 | 1.64 | 163 | NA | NA | NC |
| | S | 282 | 3.26 | 87 | 2192[*] | 195.60[*] | 11 | 1525 | 61.05 | 25.0 |
| | Sb | 446 | 0.42 | 1060 | NA | NA | NC | NA | NA | NC |
| | Se | 301 | 168.09 | 2 | NA | NA | NC | 1128 | 333.21 | 3.4 |
| | Si | 59985 | 8.07 | 7434 | 312808 | 46.59 | 6715 | 328554 | 85.59 | 3838.5 |
| | Sr | 5529 | 1.00 | 5540 | NA | NA | NC | NA | NA | NC |
| | Te | 315 | 96.59 | 3 | NA | NA | NC | NA | NA | NC |
| | Ti | 101 | < 0.06 | > 1690 | 9839 | 5.38 | 1829 | 21011 | 27.47 | 764.8 |
| | Zn | 4528 | 1.25 | 3620 | 35392 | 18.70 | 1893 | 37584 | 67.56 | 556.3 |
| | Zr | 7428 | 0.40 | 18529 | 32080 | 0.47 | 67775 | 34868 | 1.67 | 348680 |
| Gas | B | 8747 | 32.25 | 271 | 44903 | 87.37 | 514 | 44048 | 163.03 | 270.2 |
| | Cl | 28 | 14.58 | 2 | 1152 | 4.25 | 271 | 8881 | 131.21 | 67.7 |
| | F | 113 | 30.04 | 4 | 2016 | 50.54 | 40 | 317 | 9.96 | 31.8 |
| | I | 282 | 98.60 | 3 | 1440 | 698.31 | 2 | 1586 | 633.29 | 2.5 |
| | S | 282 | 119.22 | 2 | 2192 | 6.03 | 364 | 1525 | 0.55 | 2500 |
| | Se | 301 | 10.18 | 30 | NA | NA | NC | 1128 | 1.63 | 667 |
| | $NH_4$ | NA | NA | NC | 0 | 2058 | NC | 2427 | 1516 | 1.6 |

"-" Empty data field; NC – Not calculated, NA – Not analyzed.

[$] - From gravimetric analysis of filters and rinse dry-downs

[*] - Calculation based on water dissolution of filter particulate

# - The analyzed MgO concentration of 1.15 wt% instead of the target value of 0.06 wt% was used to calculate the feed flux

**Table 5.1. Melter Emission Rates (continued).**

| Report | | VSL-03R3800-4 [17] | | | VSL-03R3800-4 [17] | | | VSL-03R3800-4 [17] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 530 g/l | | | HLW AZ-101, 530 g/l | | | HLW AZ-101, 530 g/l | | |
| Dates | | 9/12/02 | | | 9/14/02 | | | 9/17/02 | | |
| Bubbler Configuration | | Two top-entering "J" bubbling lances located six inches from the melter bottom in corners diagonally. | | | Two top-entering "J" bubbling lances located six inches from the melter bottom in corners diagonally. | | | Two top-entering "J" bubbling lances located six inches from the melter bottom in corners diagonally. | | |
| Bubbling Rate | | 40 lpm | | | 40 lpm | | | 62 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total$^{\$}$ | 396400 | 1634 | 243 | 625700 | 1116 | 561 | 903300 | 4987 | 181 |
| | Al | 8847 | 21.6 | 410 | 13965 | 26.0 | 537 | 20159 | 127 | 159 |
| | B | 11900 | 59.3 | 201 | 18784 | 65.1 | 288 | 27116 | 264 | 103 |
| | Ba | 58 | 0.18 | 322 | 91 | 0.51 | 178 | 132 | 1.45 | 91 |
| | Ca | 645 | 3.67 | 176 | 1018 | 3.17 | 321 | 1470 | 12.8 | 115 |
| | Cd | 173 | 0.59 | 293 | 273 | 1.04 | 263 | 394 | 3.38 | 117 |
| | Cl* | 0 | 40.4 | NC | 0 | 27.2 | NC | 0 | 95.3 | NC |
| | Cu | 77 | 0.28 | 275 | 122 | 0.28 | 436 | 176 | 0.97 | 181 |
| | F* | 129 | 12.6 | 10.3 | 203 | 17.9 | 11.4 | 294 | 261 | 1.1 |
| | Fe | 27510 | 71.89 | 383 | 43425 | 121 | 360 | 62688 | 492 | 127 |
| | I* | 322 | < 0.10 | > 3220 | 509 | < 0.10 | > 5090 | 734 | < 0.10 | > 7340 |
| | K | 80 | 1.00 | 80.0 | 127 | 1.17 | 109 | 183 | 5.37 | 34 |
| | Li | 5269 | 9.62 | 548 | 8317 | 11.6 | 720 | 12006 | 43.9 | 273 |
| | Mg | 214 | 1.53 | 140 | 337 | 1.73 | 195 | 487 | 6.89 | 71 |
| | Mn | 424 | 0.84 | 505 | 670 | 1.12 | 598 | 967 | 4.28 | 226 |
| | Na | 27851 | 115 | 243 | 43963 | 133 | 332 | 63464 | 476 | 133 |
| | Ni | 1545 | 3.94 | 392 | 2438 | 5.77 | 423 | 3520 | 27.35 | 129 |
| | Pb | 90 | 0.20 | 450 | 142 | 0.46 | 309 | 204 | 2.54 | 80 |
| | S* | 90 | 18.3* | 4.9 | 143 | 27.9 | 5.1 | 206 | 116 | 1.8 |
| | Si | 71396 | 87.7 | 814 | 112699 | 142 | 792 | 162690 | 463 | 351 |
| | Sr | 82 | 0.21 | 391 | 129 | 0.22 | 586 | 186 | 1.38 | 135 |
| | Zn | 5203 | 29.9 | 174 | 8213 | 25.0 | 329 | 11857 | 87.86 | 135 |
| | Zr | 9064 | 13.7 | 662 | 14308 | 21.7 | 661 | 20655 | 76.78 | 269 |
| Gas | B | 11900 | 46.2 | 258 | 18784 | 92.8 | 203 | 27116 | 193.07 | 140 |
| | Cl | 0 | < 0.10 | NC | 0 | < 0.10 | NC | 0 | < 0.10 | NC |
| | F | 129 | 16.9 | 7.6 | 203 | 43.4 | 4.7 | 294 | 60.57 | 4.9 |
| | I | 322 | 302 | 1.1 | 509 | 417 | 1.2 | 734 | 748 | 1.0 |
| | S | 90 | 8.15 | 11.0 | 143 | 28.6 | 5.0 | 206 | 33.3 | 6.2 |

$ - From gravimetric analysis of filters and front-half rinse dry-down

* - From water dissolution of filter particulate.

NC –Not calculated

"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-03R3800-4 [17] | | | VSL-03R3800-4 [17] | | | VSL-03R3800-4 [17] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 400 g/l with noble metals. | | | HLW AZ-101, 315 g/l | | | HLW AZ-101, 300 g/l | | |
| Dates | | 10/01- 02/02 | | | 10/11/02 | | | 10/23-24/02 | | |
| Bubbler Configuration | | Two top-entering "J" bubbling lances located six inches from the melter bottom in corners diagonally. | | | Two top-entering "J" bubbling lances located six inches from the melter bottom in corners diagonally | | | Two top-entering "J" bubbling lances located six inches from the melter bottom in corners diagonally. | | |
| Bubbling Rate | | 63 | | | < 1 lpm | | | 62 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 703600 | 5462 | 129 | 185392 | 2196 | 84 | 509541 | 6176 | 82.5 |
| | Al | 17092 | 172 | 99 | 4431 | 44.9 | 99 | 12378 | 216 | 57.4 |
| | B | 22991 | 293 | 78 | 5961 | 86.9 | 69 | 16650 | 311 | 53.6 |
| | Ba | 112 | 1.49 | 75 | 29 | 0.44 | 66 | 81 | 2.30 | 35.3 |
| | Ca | 1246 | 14.8 | 84 | 323 | 4.97 | 65 | 902 | 16.8 | 53.9 |
| | Cd | 334 | 3.51 | 95 | 87 | 0.96 | 91 | 242 | 3.75 | 64.5 |
| | Cl* | 0 | 94.4 | NC | < 1 | 5.2 | NC | 0 | 108 | NC |
| | Cu | 149 | 1.01 | 147 | 39 | 0.40 | 98 | 108 | 1.39 | 77.5 |
| | F* | 249 | 182 | 1.4 | 65 | 41.6 | 1.6 | 180 | 131 | 1.4 |
| | Fe | 53151 | 582 | 91 | 13780 | 159 | 87 | 38491 | 495 | 77.8 |
| | I* | 623 | < 0.10 | > 6230 | 161 | < 0.10 | > 1610 | 451 | < 0.10 | > 4510 |
| | K | 155 | 4.76 | 33 | 40 | 0.95 | 42 | 112 | 4.31 | 26.0 |
| | Li | 10179 | 54.2 | 188 | 2639 | 16.1 | 160 | 7372 | 76.3 | 96.7 |
| | Mg | 413 | 7.98 | 52 | 107 | 2.34 | 46 | 299 | 7.38 | 40.5 |
| | Mn | 820 | 3.61 | 227 | 212 | 1.02 | 210 | 594 | 6.24 | 95.2 |
| | Na | 53809 | 534 | 101 | 13951 | 180 | 78 | 38968 | 502 | 77.6 |
| | Ni | 2984 | 31.7 | 94 | 774 | 8.22 | 94 | 2161 | 27.2 | 79.5 |
| | Pb | 173 | 2.83 | 61 | 45 | 0.86 | 52 | 126 | 2.90 | 43.5 |
| | Pd | 0 | < 0.10[##] | NC | 66 | 0.84 | 79 | 0 | < 0.12[#] | NC |
| | Rh | 0 | 0.56[#] | NC | 37 | 0.99 | 37 | 0 | 0.27[#] | NC |
| | Ru | 0 | 24.3[#] | NC | 104 | 3.22 | 32 | 0 | 3.64[#] | NC |
| | S* | 175 | 77.3 | 2 | 45 | 6.2 | 7.3 | 126 | 124 | 1 |
| | Si | 137940 | 509 | 271 | 35763 | 173 | 207 | 99895 | 504 | 198 |
| | Sr | 158 | 1.87 | 84 | 41 | 0.54 | 76 | 114 | 2.31 | 49.4 |
| | Zn | 10053 | 98.2 | 102 | 2606 | 37.7 | 69 | 7280 | 94.0 | 77.5 |
| | Zr | 17513 | 76.8 | 228 | 4540 | 32.7 | 139 | 12683 | 99.5 | 128 |
| Gas | B | 22991 | 177 | 130 | 5961 | 10.2 | 584 | 16650 | 122 | 137 |
| | Cl | < 1 | 11.0 | NC | < 1 | 14.2 | NC | 0 | < 7.8 | NC |
| | F | 249 | 45.2 | 6 | 65 | < 0.10 | > 650 | 180 | 19.2 | 9.4 |
| | I | 623 | 518 | 1 | 161 | 93.5 | 2.8 | 451 | 262 | 1.7 |
| | S | 175 | 14.1 | 12 | 45 | 2.44 | 18 | 126 | 11.8 | 10.6 |

$ - From gravimetric analysis of filters and front-half rinse dry-down
* - From water dissolution of filter particulate
# - From combination of standard $HF:HNO_3$ digestion and NaOH:Ru fusion in HCl.
NC – Not calculated.
"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-03R3851-1 [21] | | | VSL-03R3800-2 [23] | | | VSL-03R3800-1 [26] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | LAW Envelope B1, 957 g/l | | | HLW AZ-102, 550 g/l | | | HLW C-106/AY-102, 557.5 g/l | | |
| Dates | | 11/07- 08/02 | | | 11/26 - 27/02 | | | 1/29-30/03 | | |
| Bubbler Configuration | | Four top-entering bubblers (one in each corner) together with three of the bottom electrode bubblers. | | | Two top-entering bubblers located in diagonally opposite corners. | | | Two top entering bubblers located in diagonally opposite corners. | | |
| Bubbling Rate | | 54 lpm. | | | 65 lpm | | | 65 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 2259000 | 2888 | 782.2 | 845000 | 10688 | 49.3 | 954700 | 6458 | 148 |
| | Al | 65402 | 40.32 | 1622 | 20984 | 290.74 | 72.2 | 22690 | 105.30 | 215.5 |
| | As | NA | NA | NC | NA | NA | NC | 1167 | 19.66 | 59.4 |
| | B | 62246 | 52.54 | 1185 | 27598 | 469.51 | 58.8 | 23628 | 190.96 | 123.7 |
| | Ca | 96963 | 80.79 | 1200 | 1169 | 25.52 | 45.8 | 1739 | 21.13 | 82.3 |
| | Cd | NA | NA | NC | 700 | 11.10 | 63.1 | NA | NA | NC |
| | Cl | NA | NA | NC | NA | NA | NC | 892 | 237 | 3.76 |
| | Cr | 548 | 2.76 | 199 | NA | NA | NC | 444 | 5.24 | 84.7 |
| | Cs | 2835 | 29.87 | 95 | 335 | 12.59 | 26.6 | 382 | 10.46 | 36.5 |
| | Cu | NA | NA | NC | NA | NA | NC | 259 | 1.28 | 202.3 |
| | Fe | 73978 | 102.05 | 725 | 62182 | 792.18 | 78.5 | 71322 | 505.13 | 141.2 |
| | I | 2004 | < 0.10 | > 20040 | 711 | < 0.10 | > 7110 | 811 | < 0.10 | > 8110 |
| | K | 3160 | 14.55 | 217 | 177 | 6.19 | 28.6 | NA | NA | NC |
| | Li | 40023 | 42.40 | 944 | 10765 | 80.69 | 133.4 | 11337 | 47.45 | 238.9 |
| | Mg | 35883 | 7.25 | 4952 | 300 | 12.68 | 23.7 | 5720 | 38.31 | 149.3 |
| | Mn | NA | NA | NC | 1982 | 12.24 | 162.0 | 25117 | 52.46 | 478.8 |
| | Na | 81319 | 162.56 | 500 | 63394 | 849.95 | 74.6 | 71165 | 498.18 | 142.8 |
| | Ni | NA | NA | NC | 2514 | 32.97 | 76.2 | 1083 | 6.34 | 170.9 |
| | P | 350 | 0.40 | 882 | 93 | 3.25 | 28.6 | 319 | 1.89 | 168.8 |
| | Pb | NA | NA | NC | 462 | 8.33 | 55.4 | 1054 | 7.33 | 143.8 |
| | S | 5219 | 173.77 | 30 | 114 | 64.68 | 1.8 | NA | NA | NC |
| | Sb | NA | NA | NC | NA | NA | NC | 1694 | 12.20 | 138.9 |
| | Se | NA | NA | NC | NA | NA | NC | 2135 | 959.77 | 2.2 |
| | Si | 454471 | 320.31 | 1419 | 160367 | 1627.95 | 98.5 | 178291 | 481.36 | 370.4 |
| | Sr | NA | NA | NC | NA | NA | NC | 6308 | 40.24 | 156.8 |
| | Ti | 16697 | 23.66 | 706 | NA | NA | NC | 681 | 8.71 | 78.2 |
| | Zn | 77752 | 105.43 | 737 | 11479 | 157.02 | 73.1 | 13484 | 105.52 | 127.8 |
| | Zr | 46726 | 8.83 | 5292 | 9315 | 114.99 | 81.0 | 1561 | 5.83 | 267.6 |
| Gas | B | 62246 | 231.39 | 269 | 27598 | 162.47 | 169.9 | 23628 | 183.41 | 128.8 |
| | Cl | 200 | 15.34 | 13 | NA | NA | NC | 892 | 196.36 | 4.5 |
| | F | 1202 | 117.86 | 10 | NA | NA | NC | NA | NA | NC |
| | I | 2004 | 798.20 | 3 | 711 | 713.72 | 1.0 | 811 | 689.57 | 1.2 |
| | S | 5219 | 303.72 | 17 | 114 | 23.50 | 4.9 | NA | NA | NC |
| | Se | NA | NA | NC | NA | NA | NC | 2135 | 49.75 | 42.9 |

[$] - From gravimetric analysis of filters and rinse dry downs.
NA – Not analyzed.
NC – Not calculated.
"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-03R3800-3 [28] | | | VSL-04R4800-1 [29] | | | VSL-04R4800-1 [29] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW<br>C-104/AY-101, 528 g/l | | | HLW<br>C-106/AY-102, 550 g/l,<br>with 10 g/l sugar | | | HLW<br>C-106/AY-102, 550 g/l,<br>with 15 g/l sugar | | |
| Dates | | 2/26-27/03 | | | 05/02/03 | | | 5/4/2003 | | |
| Bubbler Configuration | | Two top entering bubblers located in diagonally opposite corners. | | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | |
| Bubbling Rate | | 65 lpm | | | 65 lpm | | | 65 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux+ (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux+ (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total$ | 924000 | 6689 | 138 | 508300 | 9268 | 54.8 | 609300 | 5750 | 106.0 |
| | Al | 14200 | 147.49 | 96.5 | 16931 | 177.60 | 95.3 | 20289 | 75.06 | 270.3 |
| | As | NA | NA | NC | 871 | 74.77 | 11.6 | 1043 | 83.86 | 12.4 |
| | B | 25200 | 296.79 | 84.9 | 17631 | 326.94 | 53.9 | 21128 | 97.47 | 216.8 |
| | Ca | 2580 | 16.19 | 159 | 1297 | 28.50 | 45.5 | 1555 | 8.94 | 173.9 |
| | Cd | NA | NA | NC | 0 | 15.57 | NC | 0 | 12.26 | NC |
| | Cl | < 1* | 131.87* | NC | 666 | NA | NA | 798 | NA | NA |
| | Cr | 308 | 5.54 | 55.6 | 331 | 0.63 | 525.4 | 397 | 0.39 | 1018 |
| | Cs | 354 | 10.43 | 34.0 | 285 | 21.28 | 13.4 | 342 | 8.86 | 38.6 |
| | Cu | 180 | 1.22 | 148 | 193 | 2.40 | 80.4 | 232 | 1.41 | 164.5 |
| | F | 902* | 690.04* | 1.31 | NA | NA | NC | NA | NA | NC |
| | Fe | 50100 | 645.56 | 77.7 | 53219 | 779.54 | 68.3 | 63775 | 289.77 | 220.1 |
| | I | 751* | 15.47* | 48.6 | 605 | < 0.10 | > 6050 | 725 | < 0.10 | > 7250 |
| | La | 961 | NA | NA | NA | NA | NC | NA | NA | NC |
| | Li | 11600 | 64.06 | 180 | 8459 | 70.93 | 119.3 | 10137 | 28.39 | 357.1 |
| | Mg | NA | NA | NC | 4268 | 60.25 | 70.8 | 5115 | 29.48 | 173.5 |
| | Mn | 8850 | 29.73 | 297 | 18742 | 69.14 | 271.1 | 22459 | 57.50 | 390.6 |
| | Na | 64100 | 659.88 | 97.1 | 53101 | 729.29 | 72.8 | 63634 | 331.38 | 192.0 |
| | Nd | 709 | NA | NA | NA | NA | NC | NA | NA | NC |
| | Ni | 2780 | 25.58 | 108 | 808 | 7.67 | 105.3 | 969 | 4.54 | 213.4 |
| | P | 131 | 1.66 | 78.9 | 238 | 9.57 | 24.9 | 285 | 2.50 | 114.0 |
| | Pb | 837 | 8.80 | 95.1 | 786 | 18.72 | 42.0 | 942 | 33.87 | 27.8 |
| | S | < 1* | 92.16* | NC | 0 | 86.66 | NC | 0 | 39.68 | NC |
| | Sb | NA | NA | NC | 1264 | 24.27 | 52.1 | 1515 | 16.37 | 92.5 |
| | Se | NA | NA | NC | 1593 | 915.61 | 1.7 | 1909 | 1277.55 | 1.5 |
| | Si | 163000 | 784.49 | 207.7 | 133037 | 793.55 | 167.6 | 159424 | 419.93 | 379.6 |
| | Sr | NA | NA | NC | 4707 | 66.53 | 70.8 | 5640 | 28.51 | 197.8 |
| | Ti | 90 | 6.68 | 13.5 | 508 | 14.39 | 35.3 | 608 | 5.46 | 111.4 |
| | Zn | 13000 | 131.33 | 99.3 | 10061 | 152.48 | 66.0 | 12057 | 63.60 | 189.6 |
| | Zr | 52500 | 251.82 | 208 | 1164 | 9.18 | 126.8 | 1395 | 5.08 | 274.6 |
| Gas | B | 25200 | 224.77 | 112 | 17631 | 129.34 | 136.3 | 21128 | 101.84 | 207.5 |
| | Cl | < 1 | 3.06 | NC | 666 | 86.56 | 7.7 | 798 | 241.55 | 3.3 |
| | F | 902 | 84.26 | 10.7 | 0 | 54.44 | NC | 0 | 16.69 | NC |
| | I | 751 | 586.72 | 1.28 | 605 | 319.54 | 1.9 | 725 | 419.76 | 1.7 |
| | S | < 1 | 10.89 | NC | 0 | 66.99 | NC | 0 | 100.06 | NC |
| | Se | NA | NA | NC | 1593 | 35.97 | 44.3 | 1909 | 64.25 | 29.7 |

$ - From gravimetric analysis of filters and rinse dry downs
* - From water dissolution
\+ - Calculated from target concentrations and steady state production rates
# - Amount of iodine in residual feed not rigorously known.
"- " Empty data field, NA – Not analyzed. NC – Not calculated.

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4800-1 [29] | | | VSL-04R4800-1 [29] | | | VSL-04R4800-1 [29] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW C-106/AY-102, 550 g/l, with 17.5-20 g/l sugar | | | HLW C-106/AY-102, 550 g/l, with 20 g/l sugar | | | HLW C-106/AY-102, 550 g/l, with 10 g/l sugar and nitrates | | |
| Dates | | 5/6/2003 | | | 5/8/2003 | | | 5/16/2003 | | |
| Bubbler Configuration | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | |
| Bubbling Rate | | 65 lpm | | | 65 lpm | | | 59 lpm | | |
| - | | Feed Flux$^+$ (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux$^+$ (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux$^+$ (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total$^{\$}$ | 490200 | 2633 | 186.2 | 455200 | 4542 | 100.2 | 688000 | 8853 | 77.7 |
| | Al | 16325 | 27.00 | 604.6 | 15159 | 55.10 | 275.1 | 23321 | 91.63 | 254.5 |
| | As | 839 | 54.13 | 15.5 | 779 | 79.28 | 9.8 | 1199 | 35.20 | 34.1 |
| | B | 16999 | 46.12 | 368.6 | 15785 | 100.15 | 157.6 | 24284 | 202.75 | 119.8 |
| | Ca | 1251 | 1.24 | 1009 | 1162 | 4.10 | 283.4 | 1787 | 14.14 | 126.4 |
| | Cd | 0 | 3.24 | NC | 0 | 2.98 | NC | 0 | 2.85 | NC |
| | Cl | 642 | NA | NA | 596 | NA | NA | 917 | 250.2 | 3.7 |
| | Cr | 319 | 0.42 | 759.5 | 296 | 0.31 | 954.8 | 456 | 6.54 | 69.7 |
| | Cs | 275 | 8.00 | 34.4 | 255 | 9.44 | 27.0 | 393 | 12.16 | 32.3 |
| | Cu | 186 | 0.56 | 332.1 | 173 | 1.10 | 157.3 | 266 | 2.13 | 124.9 |
| | F* | NA | NA | NC | NA | NA | NC | 0 | 471.7 | NC |
| | Fe | 51313 | 133.39 | 384.7 | 47648 | 253.96 | 187.6 | 73305 | 568.27 | 129.0 |
| | I | 583 | < 0.10 | > 5830 | 542 | < 0.10 | > 5420 | 0 | < 0.10 | NC |
| | Li | 8156 | 16.50 | 494.3 | 7574 | 26.87 | 281.9 | 11652 | 69.00 | 168.9 |
| | Mg | 4115 | 10.19 | 403.8 | 3821 | 21.65 | 176.5 | 5879 | 56.25 | 104.5 |
| | Mn | 18071 | 10.00 | 1807 | 16780 | 23.09 | 726.7 | 25815 | 70.51 | 366.1 |
| | Na | 51200 | 201.85 | 253.7 | 47543 | 345.78 | 137.5 | 73142 | 638.03 | 114.6 |
| | Ni | 779 | 1.91 | 407.9 | 724 | 2.88 | 251.4 | 1113 | 7.99 | 139.3 |
| | P | 229 | < 0.10 | > 2290 | 213 | < 0.10 | > 2130 | 327 | 3.19 | 102.5 |
| | Pb | 758 | 14.97 | 50.6 | 704 | 13.96 | 50.4 | 1083 | 4.19 | 258.5 |
| | S | 0 | 36.48 | NC | 0 | 42.23 | NC | 0 | 83.90 | NC |
| | Sb | 1219 | 4.73 | 257.7 | 1132 | 4.83 | 234.4 | 1741 | 8.71 | 199.9 |
| | Se | 1536 | 560.58 | 2.7 | 1426 | 862.81 | 1.7 | 2194 | 1356.12 | 1.6 |
| | Si | 128273 | 118.57 | 1082 | 119110 | 250.35 | 475.8 | 183246 | 643.24 | 284.9 |
| | Sr | 4538 | 10.74 | 422.5 | 4214 | 22.15 | 190.2 | 6483 | 51.21 | 126.6 |
| | Ti | 490 | 2.49 | 196.8 | 455 | 4.46 | 102.0 | 699 | 10.26 | 68.1 |
| | Zn | 9701 | 26.70 | 363.3 | 9008 | 51.02 | 176.6 | 13859 | 114.57 | 121.0 |
| | Zr | 1123 | 1.02 | 1101 | 1043 | 2.34 | 445.7 | 1604 | 8.15 | 196.8 |
| Gas | B | 16999 | 67.94 | 250.2 | 15785 | 86.57 | 182.3 | 24284 | 231.04 | 105.1 |
| | Cl | 642 | 200.68 | 3.2 | 596 | 83.49 | 7.1 | 917 | 120.50 | 7.6 |
| | F | 0 | 6.97 | NC | 0 | 11.08 | NC | 0 | 34.43 | NC |
| | I | 583 | 294.45 | 2.0 | 542 | 370.23 | 1.5 | 0 | < 0.10 | NC |
| | S | 0 | 52.21 | NC | 0 | 46.92 | NC | 0 | 17.94 | NC |
| | Se | 1536 | 117.94 | 13.0 | 1426 | 30.92 | 46.1 | 2194 | 36.31 | 60.4 |

$^{\$}$ - From gravimetric analysis of filters and rinse dry downs
\+ - Calculated from target concentrations and steady state production rates
NC – Not calculated
NA – Not available due to insufficient particulate loading for separate anion analysis
"-" Empty data field; *- From water dissolution of filter particulate

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4800-1 [29] | | | VSL-04R4800-1 [29] | | | VSL-04R4800-1 [29] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW<br>C-106/AY-102, 550 g/l with 15 g/l sugar and nitrates | | | HLW<br>C-106/AY-102, 550 g/l with 20 g/l sugar and nitrates | | | HLW<br>C-106/AY-102, 550 g/l with 25 g/l sugar and nitrates | | |
| Dates | | 5/18/203 | | | 5/20/03 | | | 5/22/03 | | |
| Bubbler Configuration | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | |
| Bubbling Rate | | 65 lpm | | | 63 lpm | | | 65 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 688000 | 8491 | 81.0 | 688000 | 9903 | 69.5 | 688000 | 7028 | 97.9 |
| | Al | 23321 | 91.46 | 255.0 | 23321 | 106.43 | 219.1 | 23321 | 53.12 | 439.0 |
| | As | 1199 | 116.62 | 10.3 | 1199 | 191.00 | 6.3 | 1199 | 304.85 | 3.9 |
| | B | 24284 | 195.42 | 124.3 | 24284 | 208.15 | 116.7 | 24284 | 180.61 | 134.5 |
| | Ca | 1787 | 5.24 | 341.0 | 1787 | 17.05 | 104.8 | 1787 | 11.74 | 152.2 |
| | Cd | 0 | 4.94 | NC | 0 | 3.69 | NC | 0 | 2.14 | NC |
| | Cl | 917 | NA | NA | 917 | NA | NA | 917 | NA | NA |
| | Cr | 456 | 2.45 | 186.1 | 456 | 1.54 | 296.1 | 456 | 0.45 | 1013 |
| | Cs | 393 | 6.48 | 60.6 | 393 | 15.59 | 25.2 | 393 | 12.90 | 30.5 |
| | Cu | 266 | 2.03 | 131.0 | 266 | 2.74 | 97.1 | 266 | 1.66 | 160.2 |
| | Fe | 73305 | 653.79 | 112.1 | 73305 | 615.27 | 119.1 | 73305 | 378.95 | 193.4 |
| | I | 0 | < 0.10 | NC | 0 | < 0.10 | NC | 0 | < 0.10 | NC |
| | Li | 11652 | 67.81 | 171.8 | 11652 | 73.65 | 158.2 | 11652 | 53.21 | 219.0 |
| | Mg | 5879 | 56.01 | 105.0 | 5879 | 62.04 | 94.8 | 5879 | 39.78 | 147.8 |
| | Mn | 25815 | 72.59 | 355.6 | 25815 | 82.33 | 313.6 | 25815 | 34.94 | 738.8 |
| | Na | 73142 | 653.28 | 112.0 | 73142 | 668.59 | 109.4 | 73142 | 571.88 | 127.9 |
| | Ni | 1113 | 8.97 | 124.1 | 1113 | 10.02 | 111.1 | 1113 | 7.92 | 140.5 |
| | P | 327 | 8.83 | 37.0 | 327 | 5.90 | 55.4 | 327 | 5.69 | 57.5 |
| | Pb | 1083 | 6.88 | 157.4 | 1083 | 42.23 | 25.6 | 1083 | 58.71 | 18.4 |
| | S | 0 | 42.86 | NC | 0 | 57.97 | NC | 0 | 34.08 | NC |
| | Sb | 1741 | 6.91 | 252.0 | 1741 | 29.29 | 59.4 | 1741 | 22.30 | 78.1 |
| | Se | 2194 | 1609.78 | 1.4 | 2194 | 1937.62 | 1.1 | 2194 | 1282.06 | 1.7 |
| | Si | 183246 | 691.18 | 265.1 | 183246 | 731.84 | 250.4 | 183246 | 299.98 | 610.9 |
| | Sr | 6483 | 49.57 | 130.8 | 6483 | 55.37 | 117.1 | 6483 | 34.35 | 188.7 |
| | Ti | 699 | 11.52 | 60.7 | 699 | 10.99 | 63.6 | 699 | 6.37 | 109.7 |
| | Zn | 13859 | 120.56 | 115.0 | 13859 | 119.75 | 115.7 | 13859 | 77.00 | 180.0 |
| | Zr | 1604 | 8.40 | 191.0 | 1604 | 9.32 | 172.1 | 1604 | 3.08 | 520.8 |
| | B | 24284 | 242.23 | 100.3 | 24284 | 217.50 | 111.7 | 24284 | 210.62 | 115.3 |
| | Cl | 917 | 31.88 | 28.8 | 917 | 22.79 | 40.2 | 917 | 40.31 | 22.7 |
| Gas | F | 0 | < 0.10 | NC | 0 | < 0.10 | NC | 0 | < 0.10 | NC |
| | I | 0 | < 0.10 | NC | 0 | < 0.10 | NC | 0 | < 0.10 | NC |
| | S | 0 | 62.07 | NC | 0 | 106.70 | NC | 0 | 127.77 | NC |
| | Se | 2194 | 5.35 | 410.1 | 2194 | 7.26 | 302.2 | 2194 | 7.14 | 307.3 |

[$] - From gravimetric analysis of filters and rinse dry downs
\+ - Calculated from target concentrations and steady state production rates
NC – Not calculated
NA – Not available due to insufficient particulate loading for separate anion analysis
"-" Empty data field.

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4800-1 [29] | | | VSL-04R4800-1 [29] | | | VSL-04R4800-1 [29] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 400 g/l with 13.3-7.6 g/l sugar and ruthenium | | | HLW AZ-101, 400 g/l with 10 g/l sugar and ruthenium | | | HLW AZ-101, 400 g/l with 12.5 g/l sugar and ruthenium | | |
| Dates | | 8/22/03 | | | 8/24/03 | | | 8/26/03 | | |
| Bubbler Configuration | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | |
| Bubbling Rate | | 65 lpm | | | 65 lpm | | | 65 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total$ | 476300 | 10308 | 46.2 | 476300 | 9108 | 52.3 | 504300 | 7030 | 71.7 |
| | Al | 19448 | 221.67 | 87.7 | 19448 | 190.33 | 102.2 | 20592 | 138.77 | 148.4 |
| | B | 26159 | 506.44 | 51.7 | 26159 | 373.20 | 70.1 | 27698 | 324.80 | 85.3 |
| | Ba | 127 | 1.65 | 77.0 | 127 | 1.51 | 84.1 | 134 | 1.14 | 117.5 |
| | Ca | 1418 | 30.15 | 47.0 | 1418 | 24.56 | 57.7 | 1501 | 19.85 | 75.6 |
| | Cd | 381 | 85.97 | 4.4 | 381 | 80.52 | 4.7 | 403 | 124.27 | 3.2 |
| | Cl* | 0 | 278.69 | NC | 0 | 239.64 | NC | 0 | 231.53 | NC |
| | Cs | 0 | 0.17 | NC | 0 | 0.16 | 0.0 | 0 | 0.18 | NC |
| | Cu | 170 | 1.77 | 96.0 | 170 | 2.58 | 65.9 | 180 | 1.75 | 102.9 |
| | F* | 283 | 335.43 | NC | 283 | 329.25 | NC | 300 | 216.45 | 1.4 |
| | Fe | 60476 | 881.92 | 68.6 | 60476 | 763.01 | 79.3 | 64034 | 650.75 | 98.4 |
| | K | 176 | 8.19 | 21.5 | 176 | 7.46 | 23.6 | 187 | 6.18 | 30.3 |
| | Li | 11582 | 86.22 | 134.3 | 11582 | 66.35 | 174.6 | 12263 | 52.47 | 233.7 |
| | Mg | 470 | 14.50 | 32.4 | 470 | 12.04 | 39.0 | 497 | 9.56 | 52.0 |
| | Mn | 933 | 7.87 | 118.6 | 933 | 7.62 | 122.4 | 987 | 5.79 | 170.5 |
| | Na | 61225 | 925.56 | 66.1 | 61225 | 783.65 | 78.1 | 64827 | 661.54 | 98.0 |
| | Ni | 3395 | 39.71 | 85.5 | 3395 | 41.82 | 81.2 | 3595 | 29.22 | 123.0 |
| | Pb | 197 | 4.64 | 42.5 | 197 | 4.44 | 44.4 | 209 | 3.84 | 54.4 |
| | S* | 199 | 96.43 | 2.1 | 199 | 59.50 | 3.3 | 210 | 84.53 | 2.5 |
| | Si | 156952 | 1209.72 | 129.7 | 156952 | 1329.04 | 118.1 | 166184 | 898.33 | 185.0 |
| | Sr | 180 | 3.24 | 55.6 | 180 | 2.76 | 65.2 | 190 | 2.15 | 88.4 |
| | Zn | 11438 | 163.05 | 70.2 | 11438 | 141.97 | 80.6 | 12111 | 118.08 | 102.6 |
| | Zr | 19926 | 254.32 | 78.4 | 19926 | 287.51 | 69.3 | 21099 | 172.80 | 122.1 |
| Gas | B | 26159 | 180.83 | 144.7 | 26159 | 196.60 | 133.1 | 27698 | 182.15 | 152.1 |
| | Cl | 0 | 0.51 | 0.0 | 0 | 1.51 | NC | 0 | 0.83 | NC |
| | F | 283 | 1.58 | 179.1 | 283 | 1.43 | 197.9 | 300 | 4.14 | 72.5 |
| | S | 199 | 134.62 | 1.5 | 199 | 123.28 | 1.6 | 210 | 105.45 | 2.0 |

$ - From gravimetric analysis of filters and rinse dry downs
+ - Calculated from target concentrations and steady state production rates
* - From water dissolution of filter particulate
NC – Not calculated
NA – Not available due to insufficient particulate loading for separate anion analysis
"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4800-1 [29] | | | VSL-04R4800-4 [30] | | | VSL-04R4800-4 [30] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 400 g/l with 16 g/l sugar and ruthenium | | | HLW AZ-101, 530 g/l | | | HLW AZ-101, 530 g/l | | |
| Dates | | 8/27/03 | | | 6/01/03 | | | 6/03/03 | | |
| Bubbler Configuration | | Two top entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Two bubblers oriented parallel to electrodes. Bubbler depth: shallow, 12” from floor. | | | Two bubblers oriented parallel to electrodes. Bubbler depth: nominal, 6” from floor | | |
| Bubbling Rate | | 65 lpm | | | 65 lpm | | | 65 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 520000 | 6669 | 78.0 | 505800 | 2848 | 177.6 | 645100 | 3271 | 197.2 |
| | Al | 21278 | 119.43 | 178.2 | 11852 | 54.19 | 218.7 | 15113 | 60.10 | 251.5 |
| | B | 28622 | 308.89 | 92.7 | 15894 | 151.88 | 104.6 | 20268 | 165.42 | 122.5 |
| | Ba | 139 | 1.00 | 139.0 | 77 | 0.35 | 218.4 | 98 | 0.46 | 212.3 |
| | Ca | 1551 | 17.44 | 88.9 | 861 | 8.59 | 100.2 | 1097 | 9.89 | 111.0 |
| | Cd | 416 | 147.78 | 2.8 | 231 | 1.05 | 220.8 | 295 | 1.07 | 276.4 |
| | Cl* | 0 | 217.44 | NC | NA | NA | NC | NA | NA | NC |
| | Cs | 0 | 0.25 | NC | NA | NA | NC | NA | NA | NC |
| | Cu | 186 | 1.61 | 115.5 | 103 | 0.48 | 215.2 | 131 | 0.53 | 247.1 |
| | F* | 310 | 396.94 | NC | 172 | 7.03 | 24.5 | 219 | 12.38 | 17.7 |
| | Fe | 66168 | 609.93 | 108.5 | 36863 | 285.66 | 129.0 | 47007 | 336.02 | 139.9 |
| | K | 193 | 5.83 | 33.1 | 107 | 4.15 | 25.8 | 137 | 3.58 | 38.1 |
| | Li | 12672 | 52.48 | 241.5 | 7031 | 28.73 | 244.7 | 8966 | 31.19 | 287.5 |
| | Mg | 514 | 9.11 | 56.4 | 285 | 5.18 | 55.0 | 364 | 5.68 | 64.0 |
| | Mn | 1020 | 5.31 | 192.1 | 566 | 7.44 | 76.1 | 722 | 3.04 | 237.8 |
| | Na | 66988 | 600.67 | 111.5 | 37167 | 274.33 | 135.5 | 47395 | 306.61 | 154.6 |
| | Ni | 3715 | 25.80 | 144.0 | 2095 | 12.58 | 166.5 | 2671 | 14.43 | 185.1 |
| | Pb | 216 | 3.68 | 58.7 | 120 | 0.88 | 136.3 | 153 | 1.62 | 94.3 |
| | S | 217 | 78.50* | 2.8 | 138 | 21.27 | 6.5 | 176 | 18.56 | 9.5 |
| | Si | 171723 | 757.67 | 226.6 | 95279 | 356.56 | 267.2 | 121499 | 370.81 | 327.7 |
| | Sr | 197 | 2.12 | 92.9 | 109 | 1.70 | 64.1 | 139 | 1.90 | 73.2 |
| | Zn | 12515 | 108.14 | 115.7 | 6978 | 81.95 | 85.1 | 8899 | 70.42 | 126.4 |
| | Zr | 21802 | 142.34 | 153.2 | 12160 | 62.29 | 195.2 | 15507 | 57.19 | 271.1 |
| Gas | B | 28622 | 208.30 | 137.4 | 15894 | 92.23 | 172.3 | 20268 | 110.10 | 184.1 |
| | Cl | 0 | 1.50 | NC | NA | NA | NC | NA | NA | NC |
| | F | 310 | 4.33 | 71.6 | 172 | < 0.10 | > 1720 | 219 | < 0.10 | > 2190 |
| | I | NA | NA | NC | < 430[#] | 95.74 | NC | < 548[#] | 26.89 | NC |
| | S | 217 | 101.31 | 2.1 | 138 | < 0.10 | > 1380 | 176 | 0.69 | 253.1 |

[$] - From gravimetric analysis of filters and rinse dry downs
+ - Calculated from target concentrations and steady state production rates
NC – Not calculated
* - From water dissolution of filter particulate
[#] - Amount of iodine in residual feed not rigorously known.
NA – Not available due to insufficient particulate loading for separate anion analysis
-" Empty data field.

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4800-4 [30] | | | VSL-04R4800-4 [30] | | | VSL-04R4800-4 [30] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 530 g/l | | | HLW AZ-101, 530 g/l | | | HLW AZ-101, 530 g/l | | |
| Dates | | 6/05/03 | | | 6/28/03 | | | 6/30/03 | | |
| Bubbler Configuration | | Two bubblers oriented parallel to electrodes. Bubbler depth: deep on melter floor | | | Two bubblers 6" from floor pointed towards melt pool center, bubbler skewing: none | | | Two bubblers 6" from floor pointed towards melt pool center, bubbler skewing: 16 lpm step | | |
| Bubbling Rate | | 65 lpm | | | 65 lpm | | | 65 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 658800 | 4336 | 151.9 | 1060700 | 5568 | 190.5 | 1121500 | 8935 | 125.5 |
| | Al | 15435 | 86.54 | 178.4 | 24852 | 90.01 | 276.1 | 26276 | 115.90 | 226.7 |
| | B | 20699 | 219.32 | 94.4 | 33327 | 328.96 | 101.3 | 35237 | 497.40 | 70.8 |
| | Ba | 100 | 0.60 | 168.3 | 162 | 0.72 | 224.3 | 171 | 1.31 | 130.8 |
| | Ca | 1121 | 10.92 | 102.6 | 1805 | 16.56 | 109.0 | 1908 | 24.91 | 76.6 |
| | Cd | 301 | 1.64 | 183.2 | 484 | 4.02 | 120.6 | 512 | 5.86 | 87.5 |
| | Cu | 134 | 0.81 | 166.1 | 216 | 0.71 | 303.1 | 228 | 1.40 | 163.8 |
| | F | 224* | 16.77* | 13.4 | 361 | NA | NA | 381* | 357.17* | 1.1 |
| | Fe | 48008 | 442.80 | 108.4 | 77298 | 603.81 | 128.0 | 81727 | 790.61 | 103.4 |
| | K | 139 | 3.12 | 44.7 | 225 | 7.99 | 28.1 | 237 | 9.84 | 24.1 |
| | Li | 9157 | 36.26 | 252.5 | 14743 | 59.47 | 247.9 | 15588 | 68.47 | 227.7 |
| | Mg | 371 | 5.88 | 63.2 | 598 | 8.39 | 71.3 | 632 | 12.15 | 52.0 |
| | Mn | 737 | 3.93 | 187.8 | 1187 | 4.11 | 288.9 | 1255 | 5.89 | 213.2 |
| | Na | 48404 | 406.59 | 119.0 | 77936 | 583.60 | 133.5 | 82402 | 849.29 | 97.0 |
| | Ni | 2728 | 19.18 | 142.2 | 4393 | 20.76 | 211.6 | 4645 | 33.71 | 137.8 |
| | Pb | 156 | 0.83 | 187.6 | 251 | 2.57 | 97.6 | 265 | 4.64 | 57.2 |
| | S | 180 | 28.36 | 6.3 | 289 | 43.07 | 6.7 | 306 | 57.46 | 5.3 |
| | Si | 124084 | 546.56 | 227.0 | 199790 | 525.48 | 380.2 | 211238 | 675.56 | 312.7 |
| | Sr | 142 | 1.27 | 111.7 | 229 | 1.54 | 148.3 | 242 | 2.71 | 89.2 |
| | Zn | 9088 | 82.31 | 110.4 | 14633 | 100.83 | 145.1 | 15471 | 157.50 | 98.2 |
| | Zr | 15837 | 97.23 | 162.9 | 25499 | 48.33 | 527.6 | 26960 | 65.50 | 411.6 |
| Gas | B | 20699 | 118.68 | 174.4 | 33327 | 208.33 | 160.0 | 35237 | 242.83 | 145.1 |
| | F | 224 | < 0.10 | > 2240 | 361 | < 0.10 | > 3610 | 381 | < 0.10 | > 3810 |
| | I | < 560[#] | 6.40 | NC | NA | NA | NC | NA | NA | NC |
| | S | 180 | 44.43 | 4.0 | 289 | 97.00 | 3.0 | 306 | 95.37 | 3.2 |

[$] - From gravimetric analysis of filters and rinse dry downs
* - From water dissolution of filter particulate
\# - Amount of iodine in residual feed not rigorously known.
NC – Not calculated
NA – Not available due to insufficient particulate loading for separate anion analysis

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4800-4 [30] | | | VSL-04R4800-4 [30] | | | VSL-04R4800-4 [30] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 530 g/l | | | HLW AZ-101, 400 g/l | | | HLW AZ-101, 400 g/l | | |
| Dates | | 7/02/03 | | | 7/19/03 | | | 7/22/03 | | |
| Bubbler Configuration | | Two bubblers 6" from floor pointed towards melt pool center, bubbler skewing: 16 lpm gradual. | | | Bubblers on floor, 8" apart on East and West side, one bubbler outlet 11.3" from feed tube. | | | Bubblers on floor, 8" apart on East and West side, one bubbler outlet 11.3" from feed tube. | | |
| Bubbling Rate | | 65 lpm | | | 135 lpm | | | 80 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total$ | 1081300 | 7128 | 151.7 | 1344400 | 16838 | 79.8 | 1085500 | 11776 | 92.2 |
| | Al | 25334 | 141.14 | 179.5 | 31205 | 349.50 | 89.3 | 25196 | 278.71 | 90.4 |
| | B | 33974 | 438.46 | 77.5 | 41847 | 855.80 | 48.9 | 33789 | 604.33 | 55.9 |
| | Ba | 165 | 1.13 | 145.5 | 203 | 2.18 | 92.9 | 164 | 1.73 | 94.6 |
| | Ca | 1840 | 24.61 | 74.8 | 2266 | 40.03 | 56.6 | 1830 | 31.11 | 58.8 |
| | Cd | 494 | 5.31 | 93.0 | 608 | 8.87 | 68.6 | 491 | 6.71 | 73.2 |
| | Cu | 220 | 1.16 | 189.4 | 271 | 3.70 | 73.4 | 219 | 2.93 | 74.9 |
| | F* | 368 | 208.68 | 1.8 | 453 | 244.29 | 1.9 | 366 | 486.75 | 0.8 |
| | Fe | 78798 | 742.77 | 106.1 | 97058 | 1565.19 | 62.0 | 78370 | 1024.18 | 76.5 |
| | K | 229 | 9.38 | 24.4 | 282 | 15.46 | 18.2 | 228 | 10.80 | 21.1 |
| | Li | 15030 | 81.67 | 184.0 | 18512 | 172.17 | 107.5 | 14948 | 122.28 | 122.2 |
| | Mg | 610 | 12.16 | 50.1 | 751 | 20.64 | 36.4 | 606 | 15.47 | 39.2 |
| | Mn | 1210 | 7.65 | 158.3 | 1491 | 12.80 | 116.4 | 1204 | 10.93 | 110.1 |
| | Na | 79449 | 761.44 | 104.3 | 97859 | 1519.70 | 64.4 | 79016 | 999.11 | 79.1 |
| | Ni | 4478 | 28.36 | 157.9 | 5516 | 69.42 | 79.5 | 4454 | 52.18 | 85.3 |
| | Pb | 256 | 3.85 | 66.5 | 315 | 7.81 | 40.4 | 255 | 6.42 | 39.6 |
| | S | 295 | 39.21 | 7.5 | 363 | 83.82 | 4.3 | 293 | 54.21 | 5.4 |
| | Si | 203668 | 657.20 | 309.9 | 250864 | 1977.69 | 126.8 | 202560 | 1301.11 | 155.7 |
| | Sr | 233 | 2.10 | 111.2 | 287 | 3.92 | 73.2 | 232 | 3.03 | 76.6 |
| | Zn | 14917 | 140.75 | 106.0 | 18373 | 268.69 | 68.4 | 14836 | 199.87 | 74.2 |
| | Zr | 25994 | 85.99 | 302.3 | 32017 | 371.53 | 86.2 | 25852 | 328.48 | 78.7 |
| Gas | B | 33974 | 205.22 | 165.6 | 41847 | 390.30 | 107.2 | 33789 | 232.33 | 145.4 |
| | F | 368 | < 0.10 | > 3680 | 453 | < 0.10 | > 4530 | 366 | < 0.10 | > 3660 |
| | S | 295 | 91.80 | 3.2 | 363 | 147.91 | 2.5 | 293 | 117.44 | 2.5 |

$ - From gravimetric analysis of filters and rinse dry downs
* - From water dissolution of filter particulate
NC – Not calculated
NA – Not available due to insufficient particulate loading for separate anion analysis
"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4800-4 [30] | | | VSL-04R4800-4 [30] | | | VSL-04R4800-4 [30] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 400 g/l | | | HLW AZ-101, 400 g/l | | | HLW AZ-101, 400 g/l with NaCl spike | | |
| Dates | | 8/10/03 | | | 8/12/03 | | | 9/06/03 | | |
| Bubbler Configuration | | Four bubblers on floor, one in each corner, 14” apart on East and West side. | | | Four bubblers on floor, one in each corner, 14” apart on East and West side. | | | Two bubblers on floor, bubbler on East side 11.3” from feed tube. | | |
| Bubbling Rate | | 117 lpm | | | 90 lpm (1175°C) | | | 80 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 1412700 | 8215 | 172.0 | 1439800 | 20444 | 70.4 | 861900 | 7987 | 107.9 |
| | Al | 32789 | 134.46 | 243.9 | 33419 | 424.61 | 78.7 | 20005 | 120.66 | 165.8 |
| | B | 43973 | 365.00 | 120.5 | 44817 | 1123.25 | 39.9 | 26828 | 291.18 | 92.1 |
| | Ba | 213 | 1.28 | 167.1 | 217 | 3.56 | 61.0 | 130 | 1.22 | 106.7 |
| | Ca | 2381 | 22.54 | 105.6 | 2427 | 59.84 | 40.6 | 1453 | 24.05 | 60.4 |
| | Cd | 639 | 5.69 | 112.4 | 651 | 14.18 | 45.9 | 390 | 6.16 | 63.4 |
| | Cl* | NA | NA | NC | NA | NA | NC | 3629 | 608.36 | 6.0 |
| | Cu | 285 | 1.40 | 203.9 | 291 | 4.39 | 66.2 | 174 | 2.17 | 80.3 |
| | F | 476* | 425.77* | 1.1 | 485 | 708.36 | < 1 | 290* | 192.81* | 1.5 |
| | Fe | 101988 | 759.44 | 134.3 | 103945 | 1857.40 | 56.0 | 62224 | 752.00 | 82.7 |
| | K | 296 | 9.47 | 31.3 | 302 | 15.40 | 19.6 | 181 | 10.12 | 17.9 |
| | Li | 19453 | 71.61 | 271.7 | 19826 | 168.25 | 117.8 | 11868 | 74.98 | 158.3 |
| | Mg | 789 | 10.36 | 76.1 | 804 | 27.34 | 29.4 | 481 | 12.00 | 40.1 |
| | Mn | 1566 | 6.14 | 255.1 | 1596 | 16.37 | 97.5 | 956 | 5.17 | 184.8 |
| | Na | 102829 | 739.32 | 139.1 | 104803 | 1897.88 | 55.2 | 65107 | 966.75 | 67.3 |
| | Ni | 5796 | 26.90 | 215.5 | 5907 | 84.41 | 70.0 | 3536 | 26.96 | 131.2 |
| | Pb | 331 | 4.15 | 79.8 | 338 | 11.90 | 28.4 | 202 | 4.82 | 41.9 |
| | S | 381 | 50.29 | 7.6 | 389 | 72.61 | 5.4 | 233 | 50.27 | 4.6 |
| | Si | 263605 | 831.56 | 317.0 | 268664 | 2543.73 | 105.6 | 160829 | 546.15 | 294.5 |
| | Sr | 302 | 2.61 | 115.7 | 308 | 6.81 | 45.2 | 184 | 2.81 | 65.5 |
| | Zn | 19307 | 130.82 | 147.6 | 19677 | 337.47 | 58.3 | 11779 | 133.64 | 88.1 |
| | Zr | 33643 | 112.98 | 297.8 | 34289 | 508.36 | 67.5 | 20526 | 53.97 | 380.3 |
| Gas | B | 43973 | 488.65 | 90.0 | 44817 | 413.98 | 108.3 | 26828 | 259.34 | 103.4 |
| | Cl | NA | NA | NC | NA | NA | NC | 3629 | 569.05 | 6.4 |
| | F | 476 | 3.27 | 145.5 | 485 | 1.44 | 337.1 | 290 | 85.09 | 3.4 |
| | S | 381 | 115.63 | 3.3 | 389 | 155.72 | 2.5 | 233 | 66.43 | 3.5 |

[$] - From gravimetric analysis of filters and rinse dry downs

* - From water dissolution of filter particulate

NC – Not calculated

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

"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4800-4 [30] | | | VSL-04R4800-4 [30] | | | VSL-04R4800-4 [30] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 400 g/l with $NaSO_4$ spike | | | HLW AZ-101, 400 g/l with NaCl +$NaSO_4$ spike | | | HLW AZ-101, 400g/l with 3.8 g/l sugar. | | |
| Dates | | 9/08/03 | | | 9/09/03 | | | 3/29/04 | | |
| Bubbler Configuration | | Two bubblers on floor, bubbler on East side 11.3” from feed tube. | | | Two bubblers on floor, bubbler on East side 11.3” from feed tube. | | | Two bubblers, each with two outlets 8 inches apart, placed on the floor, one bubbler outlet 11.3” from feed tube. | | |
| Bubbling Rate | | 80 lpm | | | 80 lpm. | | | 64 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (g/hr) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total$ | 734200 | 14588 | 50.3 | 910400 | 8111 | 112.2 | 1059610 | 6595 | 160.7 |
| | Al | 17042 | 314.91 | 54.1 | 21131 | 145.02 | 145.7 | 24594 | 107.98 | 227.8 |
| | B | 22855 | 607.82 | 37.6 | 28338 | 288.68 | 98.2 | 32982 | 295.96 | 111.4 |
| | Ba | 111 | 2.49 | 44.5 | 137 | 1.24 | 110.4 | 160 | 1.02 | 156.4 |
| | Ca | 1238 | 44.79 | 27.6 | 1534 | 21.18 | 72.4 | 1786 | 19.34 | 92.3 |
| | Cd | 332 | 7.33 | 45.3 | 412 | 4.92 | 83.8 | 479 | 11.13 | 43.0 |
| | Cl* | 0 | 274.57 | NC | 3833 | 694.96 | 5.5 | NA | NA | NC |
| | Cu | 148 | 3.66 | 40.5 | 184 | 2.24 | 82.0 | 214 | 1.29 | 166.3 |
| | F* | 247 | 139.74 | 1.77 | 307 | 83.90 | 3.6 | 357 | 291.24 | 1.2 |
| | Fe | 53008 | 1320.97 | 40.1 | 65725 | 754.25 | 87.1 | 76498 | 710.47 | 107.7 |
| | K | 154 | 10.86 | 14.2 | 191 | 8.51 | 22.4 | 222 | 11.57 | 19.2 |
| | Li | 10111 | 118.57 | 85.3 | 12536 | 77.69 | 161.4 | 14591 | 64.91 | 224.8 |
| | Mg | 410 | 21.23 | 19.3 | 509 | 10.48 | 48.5 | 592 | 11.13 | 53.2 |
| | Mn | 814 | 13.35 | 61.0 | 1009 | 7.08 | 142.5 | 1175 | 3.81 | 308.1 |
| | Na | 54868 | 1365.96 | 40.2 | 70533 | 988.44 | 71.4 | 77129 | 784.29 | 98.3 |
| | Ni | 3013 | 65.09 | 46.3 | 3735 | 29.27 | 127.6 | 4347 | 25.15 | 172.9 |
| | Pb | 172 | 7.48 | 23.0 | 214 | 5.27 | 40.5 | 249 | 2.73 | 91.2 |
| | Ru | NA | NA | NC | NA | NA | NC | 610 | 24.86 | 24.5 |
| | S | 1023 | 134.21 | 7.6 | 1269 | 114.00 | 11.1 | 286 | 115.51 | 2.5 |
| | Si | 137009 | 1704.91 | 80.4 | 169877 | 1140.41 | 149.0 | 197722 | 689.70 | 286.7 |
| | Sr | 157 | 4.93 | 31.8 | 194 | 2.56 | 76.0 | 226 | 2.33 | 96.9 |
| | Y | NA | NA | NC | NA | NA | NC | 527 | < 0.39 | > 1351.9 |
| | Zn | 10035 | 245.10 | 40.9 | 12442 | 136.76 | 91.0 | 14481 | 134.69 | 107.5 |
| | Zr | 17486 | 348.23 | 50.2 | 21681 | 117.23 | 184.9 | 25235 | 91.00 | 277.3 |
| Gas | B | 22855 | 195.44 | 116.9 | 28338 | 234.53 | 120.8 | 32982 | 373.91 | 88.2 |
| | Cl | 0 | 27.48 | NC | 3833 | 479.77 | 8.0 | NA | NA | NC |
| | F | 247 | 68.15 | 3.6 | 307 | 89.83 | 3.4 | 357 | < 3.15 | > 113.3 |
| | S | 1023 | 213.89 | 4.8 | 1269 | 238.44 | 5.3 | 286 | 77.45 | 3.7 |

$ - From gravimetric analysis of filters and rinse dry downs
* - From water dissolution of filter particulate
NC – Not calculated
NA – Not available due to insufficient particulate loading for separate anion analysis
"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4800-4 [30] | | |
|---|---|---|---|---|
| Feed Type | | HLW AZ-101, 400 g/l with 3.8 g/l sugar | | |
| Dates | | 3/31/04 | | |
| Bubbler Configuration | | Two bubblers, each with two outlets 8 inches apart, placed on the floor, one bubbler outlet 11.3" from feed tube. | | |
| Bubbling Rate | | 134 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 1324800 | 14761 | 89.8 |
| | Al | 30750 | 248.07 | 124.0 |
| | B | 41237 | 837.36 | 49.2 |
| | Ba | 200 | 2.76 | 72.5 |
| | Ca | 2233 | 35.49 | 62.9 |
| | Cd | 599 | 16.05 | 37.3 |
| | Cu | 267 | 2.77 | 96.3 |
| | F* | 446 | 158.33 | 2.8 |
| | Fe | 95644 | 1822.74 | 52.5 |
| | K | 278 | 15.79 | 17.6 |
| | Li | 18243 | 137.06 | 133.1 |
| | Mg | 740 | 23.90 | 31.0 |
| | Mn | 1469 | 9.70 | 151.5 |
| | Na | 96433 | 1811.81 | 53.2 |
| | Ni | 5436 | 58.90 | 92.3 |
| | Pb | 311 | 6.23 | 49.9 |
| | Ru | 763 | 47.12 | 16.2 |
| | S | 358 | 165.86 | 2.2 |
| | Si | 247208 | 1287.73 | 192.0 |
| | Sr | 283 | 6.48 | 43.7 |
| | Y | 659 | 1.32 | 498.9 |
| | Zn | 18106 | 293.23 | 61.7 |
| Gas | Zr | 31551 | 202.81 | 155.6 |
| | B | 41237 | 475.80 | 86.7 |
| | F | 446 | 6.63 | 67.2 |
| | S | 358 | 88.18 | 4.1 |

[$] - From gravimetric analysis of filters and rinse dry downs
* - From water dissolution of filter particulate
NC – Not calculated
NA – Not available due to insufficient particulate loading for separate anion analysis
"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4851-1 [31] | | | VSL-04R4851-1 [31] | | |
|---|---|---|---|---|---|---|---|
| Feed Type | | LAW Envelope C | | | LAW Envelope C | | |
| Dates | | 10/02/03 | | | 10/04/03 | | |
| Bubbler Configuration | | Four top-entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Four top-entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | |
| Bubbling Rate | | 20.6 lpm | | | 41.1 lpm | | |
| - | | Feed Flux[+] (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux[+] (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 553000 | 362 | 1528 | 885000 | 869 | 1018 |
| | Al | 14005 | 1.47 | 9552 | 22412 | 3.39 | 6602 |
| | B | 13563 | 1.20 | 11317 | 21704 | 2.32 | 9350 |
| | Ca | 15852 | 3.25 | 4877 | 25367 | 6.04 | 4199 |
| | Cl[#] | 739 | NA | NA | 1184 | 169* | 7.0 |
| | Cr | 59 | 0.53 | 113 | 95 | 1.30 | 72.9 |
| | F[#] | 1563 | NA | NA | 2498 | 45.5* | 54.9 |
| | Fe | 16934 | 2.20 | 7691 | 27098 | 4.44 | 6108 |
| | I | 434 | < 0.10 | > 4340 | 695 | < 0.10 | > 6950 |
| | K[#] | 936 | 5.34 | 175 | 1498 | 10.7 | 139 |
| | Li | 5040 | 2.90 | 1738 | 8065 | 5.84 | 1381 |
| | Mg | 3952 | 0.24 | 16553 | 6323 | 0.35 | 17869 |
| | Na | 46529 | 82.4 | 565 | 74457 | 37.6 | 1982 |
| | Ni | 102 | 0.20 | 516 | 164 | 0.24 | 686 |
| | P | 227 | < 0.10 | > 2270 | 364 | < 0.10 | > 3640 |
| | Pb | 81 | < 0.10 | > 810 | 129 | 0.20 | 638 |
| | S | 661 | 9.26 | 71.3 | 1058 | 44.49* | 23.9 |
| | Si | 94481 | 8.98 | 10516 | 151192 | 20.2 | 7477 |
| | Ti | 2966 | 1.33 | 2235 | 4746 | 2.94 | 1616 |
| | Zn | 10669 | 3.65 | 2926 | 17073 | 8.35 | 2046 |
| | Zr | 9703 | 0.27 | 35534 | 15527 | 0.56 | 27757 |
| Gas | B | 13563 | 13.9 | 973 | 21704 | 34.8 | 623 |
| | Cl[#] | 739 | 5.86 | 126 | 1184 | 18.1 | 65.6 |
| | F[#] | 1563 | 12.8 | 122 | 2498 | 57.4 | 43.4 |
| | I | 434 | 280 | 1.6 | 695 | 419 | 1.7 |
| | S | 661 | 7.14 | 92.6 | 1058 | 15.5 | 68.0 |

[$] - From gravimetric analysis of filters and rinse dry downs.
\+ - Calculated from target concentrations and steady-state production rates.
# - Calculated elemental feed rates from analyzed concentrations and steady-state production rates
NA – Not available due to insufficient particulate loading for separate anion analysis
* - Calculated from water dissolution of filter particulate.
"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-04R4851-1 [31] | | | VSL-04R4851-1 [31] | | |
|---|---|---|---|---|---|---|---|
| Feed Type | | LAW Envelope C | | | LAW Envelope C | | |
| Dates | | 10/7/03 | | | 10/8/03 | | |
| Bubbler Configuration | | Four top-entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | | Four top-entering bubblers located in diagonally opposite corners, six inches from the melter floor. | | |
| Bubbling Rate | | 62.1 lpm | | | 103.4 lpm. | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 1180000 | 1423 | 829 | 1843000 | 4513 | 408 |
| | Al | 29882 | 4.84 | 6174 | 46690 | 24.3 | 1923 |
| | B | 28939 | 7.43 | 3896 | 45216 | 50.3 | 898 |
| | Ca | 33823 | 7.95 | 4254 | 52847 | 39.9 | 1325 |
| | Cl[#] | 741 | 295 | 2.5 | 1157 | 841 | 1.4 |
| | Cr | 127 | 2.36 | 53.8 | 198 | 6.78 | 29.2 |
| | F[#] | 1296 | 36.5 | 35.5 | 2026 | 138 | 14.7 |
| | Fe | 36131 | 7.37 | 4900 | 56453 | 38.1 | 1481 |
| | I | 926 | < 0.10 | > 9260 | 1447 | < 0.10 | > 14470 |
| | K[#] | 615 | 21.6 | 28.5 | 961 | 56.5 | 17.0 |
| | Li | 10754 | 11.8 | 914 | 16802 | 39.5 | 425 |
| | Mg | 8431 | 0.69 | 12285 | 13173 | 2.77 | 4763 |
| | Na | 99276 | 92.5 | 1073 | 155115 | 286 | 543 |
| | Ni | 218 | 0.37 | 592 | 341 | 1.06 | 322 |
| | P | 485 | 0.92 | 526 | 758 | 1.32 | 573 |
| | Pb | 172 | 0.32 | 543 | 269 | 1.06 | 254 |
| | S | 1410 | 87.10* | 19.0 | 2203* | 216 | 10.2 |
| | Si | 201589 | 29.1 | 6935 | 314974 | 140 | 2255 |
| | Ti | 6329 | 3.68 | 1719 | 9888 | 18.1 | 548 |
| | Zn | 22765 | 12.0 | 1892 | 35569 | 52.2 | 682 |
| | Zr | 20703 | 1.73 | 11937 | 32347 | 4.31 | 7504 |
| Gas | B | 28939 | 75.7 | 382 | 45216 | 244 | 185 |
| | Cl[#] | 741 | 86.1 | 8.6 | 1157 | 220 | 5.3 |
| | F[#] | 1296 | 142 | 9.1 | 2026 | 351 | 5.8 |
| | I | 926 | 708 | 1.3 | 1447 | 1378 | 1.0 |
| | S | 1410 | 19.8 | 71.2 | 2203 | 46.4 | 47.5 |

[$] - From gravimetric analysis of filters and rinse dry downs
\+ - Calculated elemental feed rates from target concentrations and steady-state production rates
\# - Calculated elemental feed rates from analyzed concentrations and steady-state production rates
* - Calculated from water dissolution of filter particulate.
"-" Empty data field

## Table 5.1. Melter Emission Rates (continued).

| Report | | VSL-05R5800-1 [35] | | | VSL-05R5800-1 [35] | | |
|---|---|---|---|---|---|---|---|
| Feed Type | | HLW AZ-102, 560 g/l | | | HLW C-106/AY-102, 540 g/l | | |
| Dates | | 06/23/04 | | | 08/05-06/04 | | |
| Bubbler Configuration | | Top-entering bubbler. "J" single outlet, 6" above melter floor | | | Top-entering bubbler. "J" single outlet, 6" above melter floor | | |
| Bubbling Rate | | 65 lpm | | | 65 lpm | | |
| - | | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter | Feed Flux (mg/min) | Average Melter Emissions Flux (mg/min) | DF Across Melter |
| Particulate | Total[$] | 1187988 | 9206 | 129 | 992352 | 7477 | 133 |
| | Al | 33328 | 195.02 | 170.9 | 23643 | 90.81 | 260.4 |
| | As | NA | NA | NC | 1211 | 24.40 | 49.6 |
| | B | 43712 | 614.61 | 71.1 | 24527 | 227.15 | 108.0 |
| | Ca | 1850 | 27.45 | 67.4 | 1805 | 20.80 | 86.8 |
| | Cd | 1108 | 10.92 | 101.5 | NA | NA | NC |
| | Cl | NA | NA | NC | 926 | 183.2 | 5.1 |
| | Cr | NA | NA | NC | 461 | 5.09 | 90.6 |
| | Cs | 531 | 16.14 | 32.9 | 397 | 22.77 | 17.4 |
| | Cu | NA | NA | NC | 269 | 2.08 | 129.5 |
| | Fe | 98804 | 988.70 | 99.9 | 74332 | 562.84 | 132.1 |
| | K | 280 | 10.29 | 27.2 | NA | NA | NC |
| | Li | 17036 | 87.88 | 193.9 | 11768 | 48.16 | 244.4 |
| | Mg | 475 | 14.96 | 31.8 | 5938 | 44.13 | 134.6 |
| | Mn | 3137 | 12.71 | 246.7 | 26139 | 60.49 | 432.1 |
| | Na | 100328 | 1026.21 | 97.8 | 73936 | 607.68 | 121.7 |
| | Ni | 3978 | 26.41 | 150.6 | 1124 | 9.02 | 124.6 |
| | P | 147 | 1.42 | 103.5 | 331 | 5.95 | 55.6 |
| | Pb | 731 | 8.23 | 88.8 | 1094 | 7.24 | 151.1 |
| | S | 180 | 89.37 | 2.0 | 0 | 37.52 | NC |
| | Sb | NA | NA | NC | 1829 | 15.88 | 115.2 |
| | Se | NA | NA | NC | 2216 | 1078.06 | 2.1 |
| | Si | 253799 | 1043.34 | 243.3 | 185118 | 647.08 | 286.1 |
| | Sr | NA | NA | NC | 6548 | 50.11 | 130.7 |
| | Ti | NA | NA | NC | 706 | 8.83 | 79.9 |
| | Zn | 18167 | 167.30 | 108.6 | 13997 | 105.17 | 133.1 |
| | Zr | 14825 | 77.76 | 190.7 | 1620 | 9.01 | 179.8 |
| Gas | B | 43712 | 272.96 | 160.1 | 24527 | 179.25 | 136.8 |
| | Cl | NA | NA | NC | 926 | 114.45 | 8.1 |
| | F | NA | NA | NC | 0 | 1.03 | NC |
| | I | NA | NA | NC | 842 | 634.87 | 1.3 |
| | S | 180 | 70.15 | 2.6 | 0 | 17.54 | NC |
| | Se | NA | NA | NC | 2216 | 26.00 | 85.2 |

[$] - From gravimetric analysis of filters and rinse dry downs for the first set of data and
From gravimetric analysis of filters and front-half nitric acid analytical results for the second set of data.

NA – Not Analyzed

NC – Not Calculated.

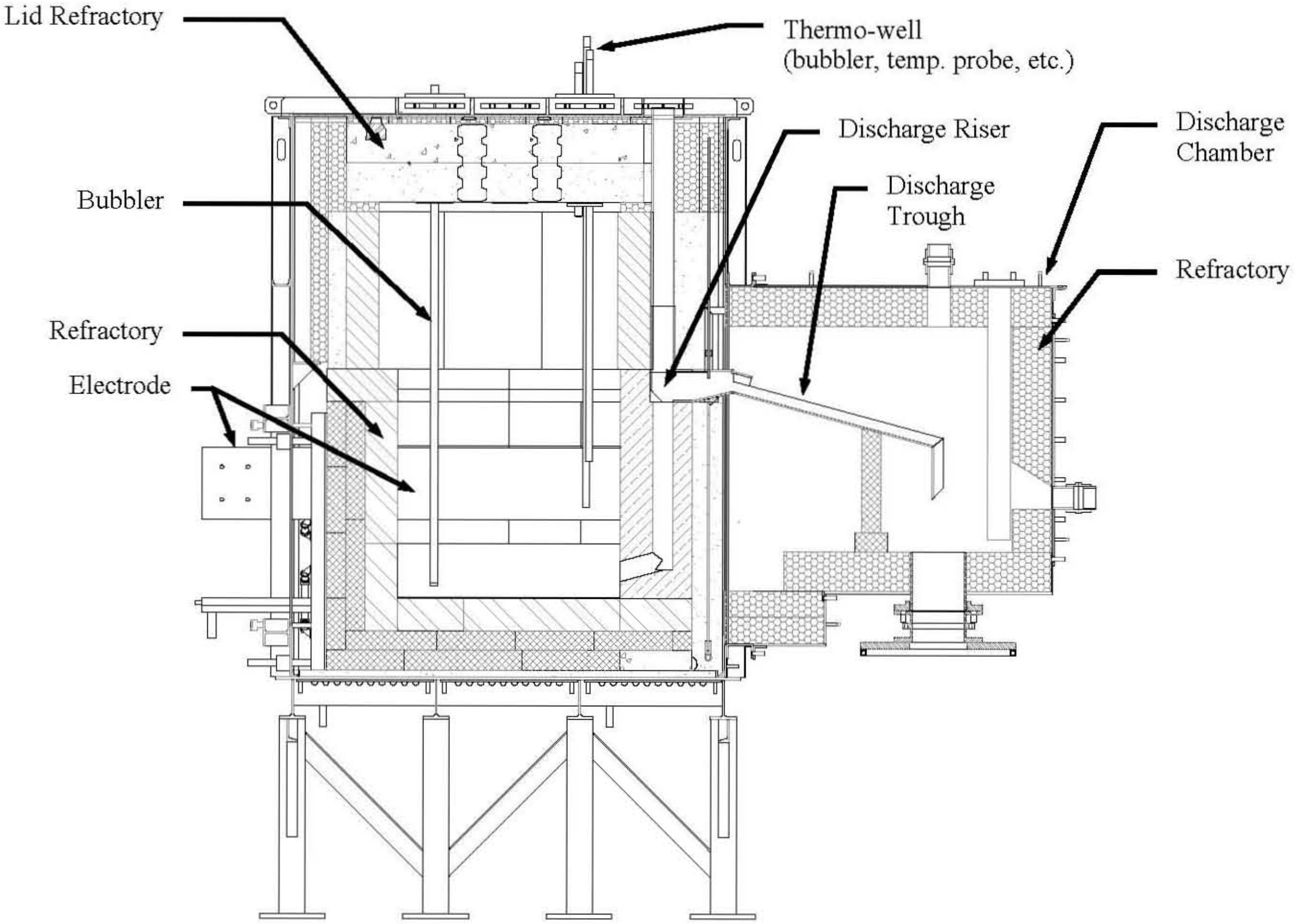


**Figure 2.1. Cross-section of the DM1200 melter through the discharge chamber.**

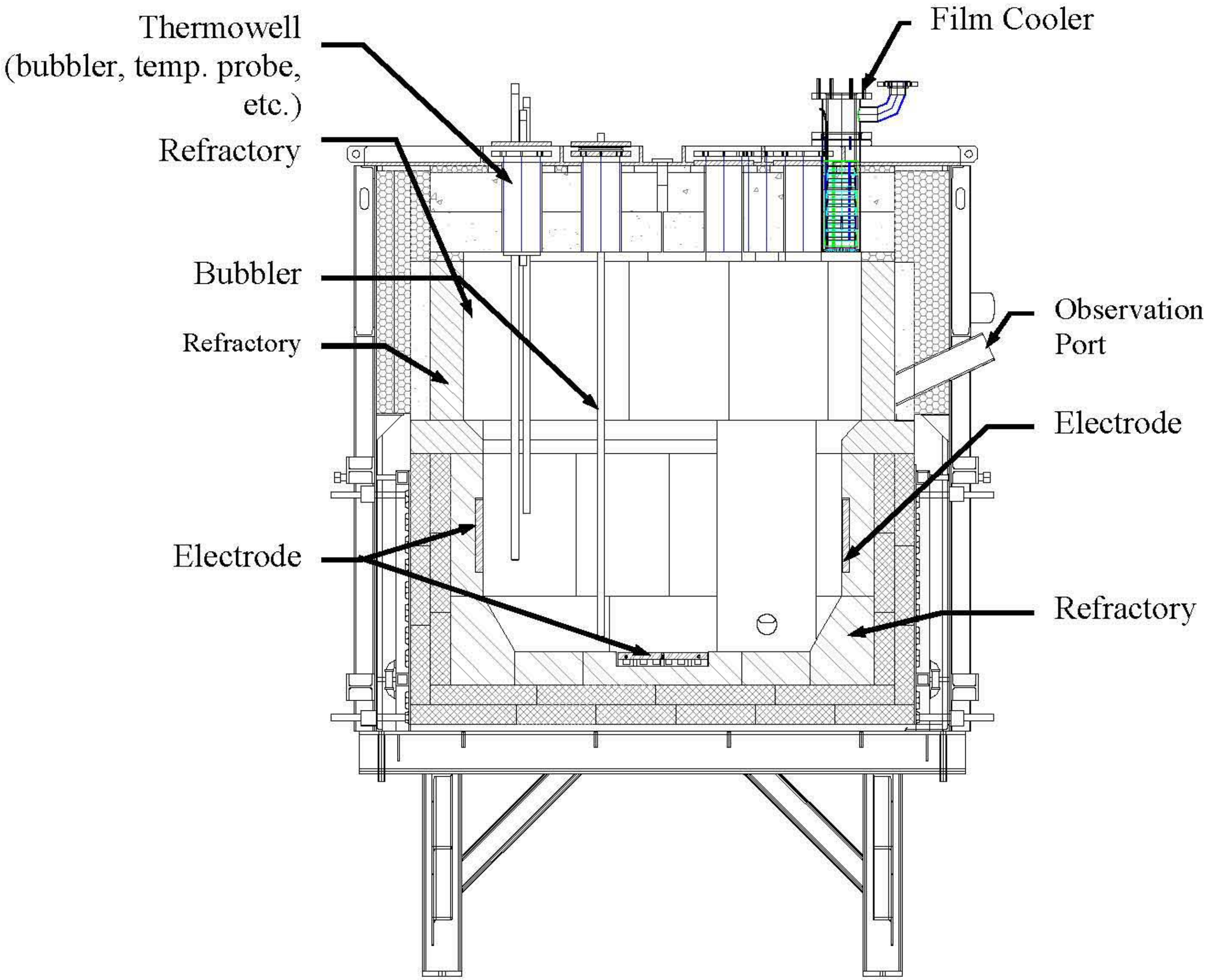
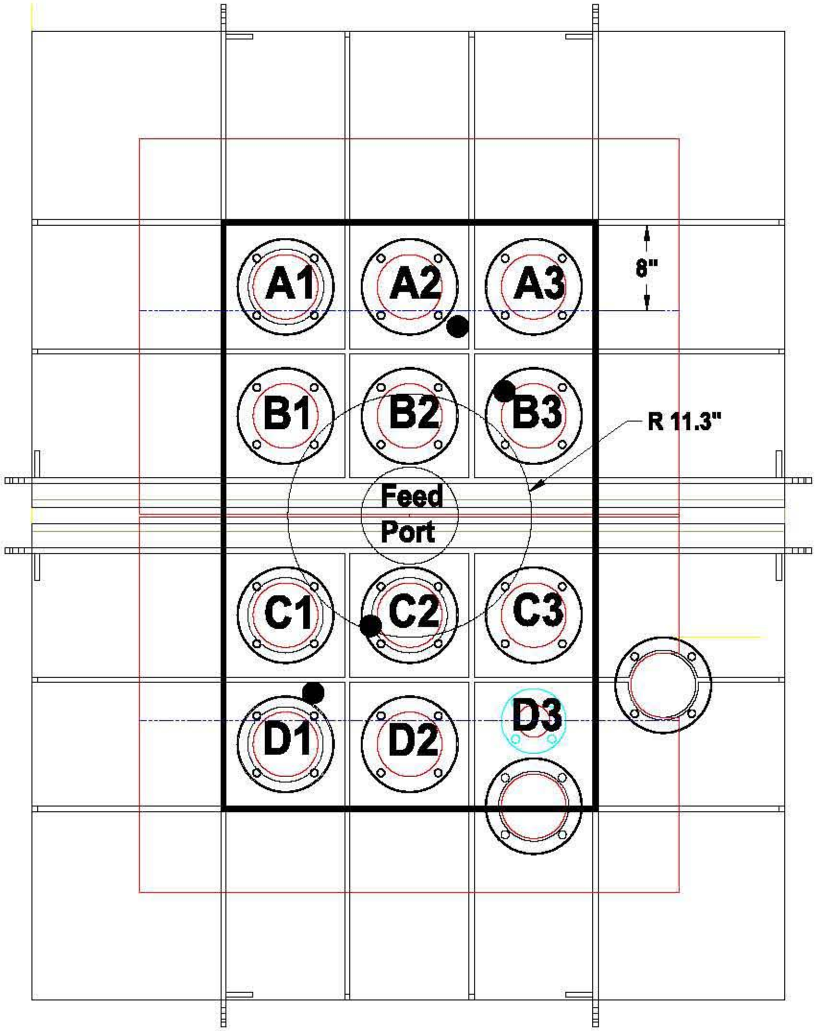


**Figure 2.2. Cross-section through the DM1200 melter showing electrodes.**

**Figure 2.3. Single Outlet "J" Bubbler.**

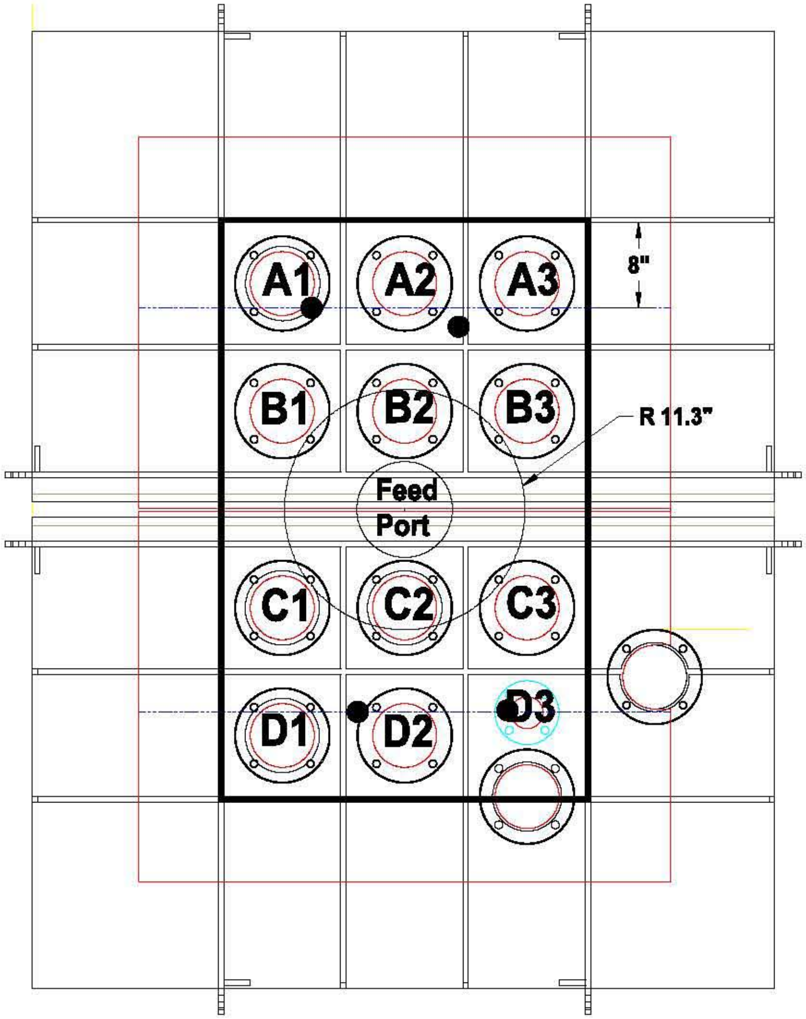
**Figure 2.4. Single Outlet "L" Bubbler.**

**Figure 2.5. Double Outlet "J" Bubbler.**



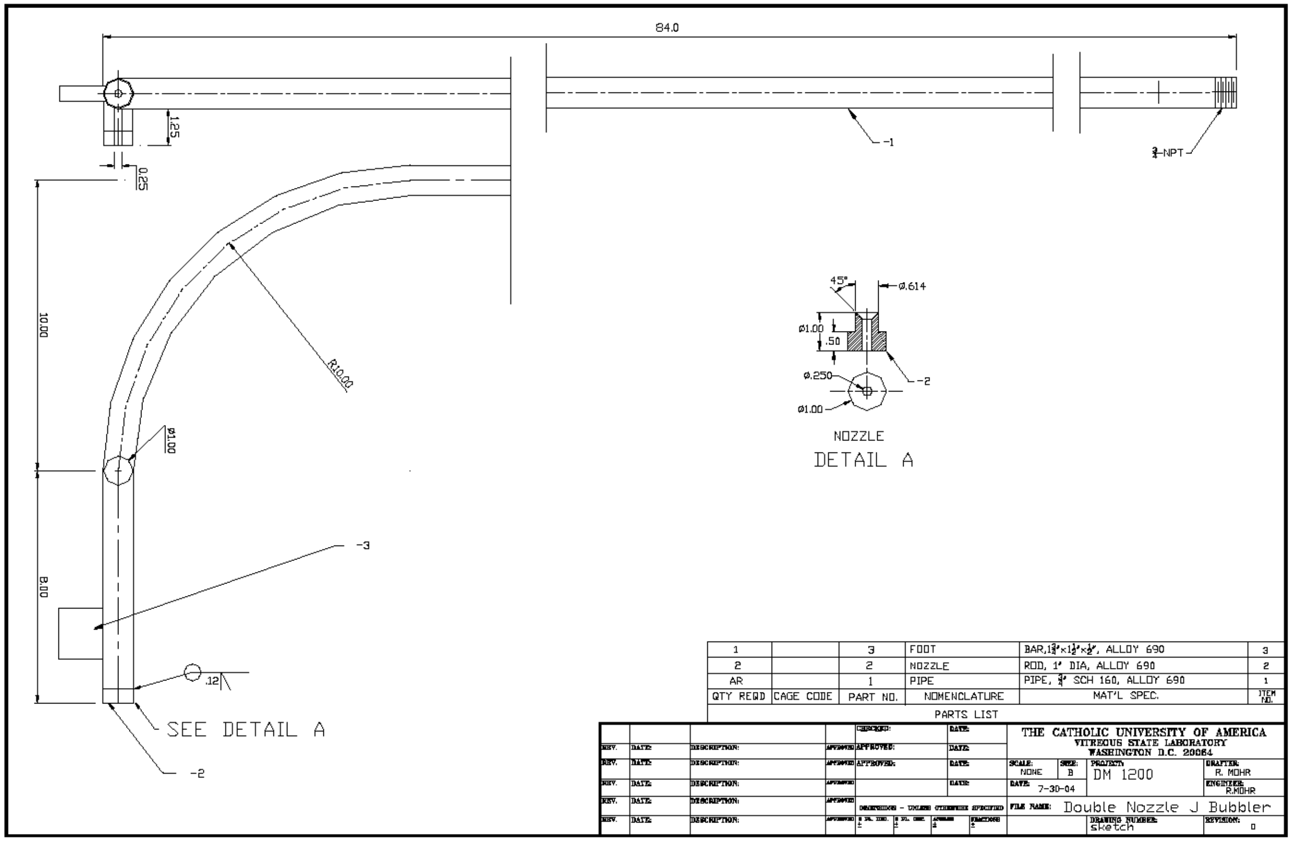
**L's in C2 and B3**
**J's in C1 and A3**

**Figure 2.6. Placement of 4 single outlet bubblers simulating 2 double outlet bubblers; 8" separation between outlets on each side of the melter. Note: solid circles represent locations of bubbler outlets.**



**L's in A1 and D3**
**J's in D1 and A3**

**Figure 2.7. Placement of 4 single outlet bubblers simulating 2 double outlet bubblers; 14" separation between outlets on each side of the melter. Note: solid circles represent locations of bubbler outlets.**



| | | | | | |
|---|---|---|---|---|---|
| 1 | | 3 | FOOT | BAR, $1\frac{3}{4}$"×$1\frac{1}{2}$"×$\frac{1}{2}$", ALLOY 690 | 3 |
| 2 | | 2 | NOZZLE | ROD, 1" DIA, ALLOY 690 | 2 |
| AR | | 1 | PIPE | PIPE, $\frac{3}{4}$" SCH 160, ALLOY 690 | 1 |
| QTY REQD | CAGE CODE | PART NO. | NOMENCLATURE | MAT'L SPEC. | ITEM NO. |
| PARTS LIST | | | | | |

THE CATHOLIC UNIVERSITY OF AMERICA
VITREOUS STATE LABORATORY
WASHINGTON D.C. 20064

SCALE: NONE
SIZE: B
PROJECT: DM 1200
DRAFTER: R. MOHR
DATE: 7-30-04
ENGINEER: R.MOHR
FILE NAME: Double Nozzle J Bubbler
DRAWING NUMBER: sketch
REVISION: 0

CHECKED: DATE:
APPROVED: DATE:
APPROVED: DATE:
DATE:
DIMENSIONS - UNLESS OTHERWISE SPECIFIED
REV. DATE: DESCRIPTION: APPROVED
REV. DATE: DESCRIPTION: APPROVED
REV. DATE: DESCRIPTION: APPROVED
REV. DATE: DESCRIPTION: APPROVED
REV. DATE: DESCRIPTION: APPROVED

Figure 2.8. Double Outlet "J" Bubbler.

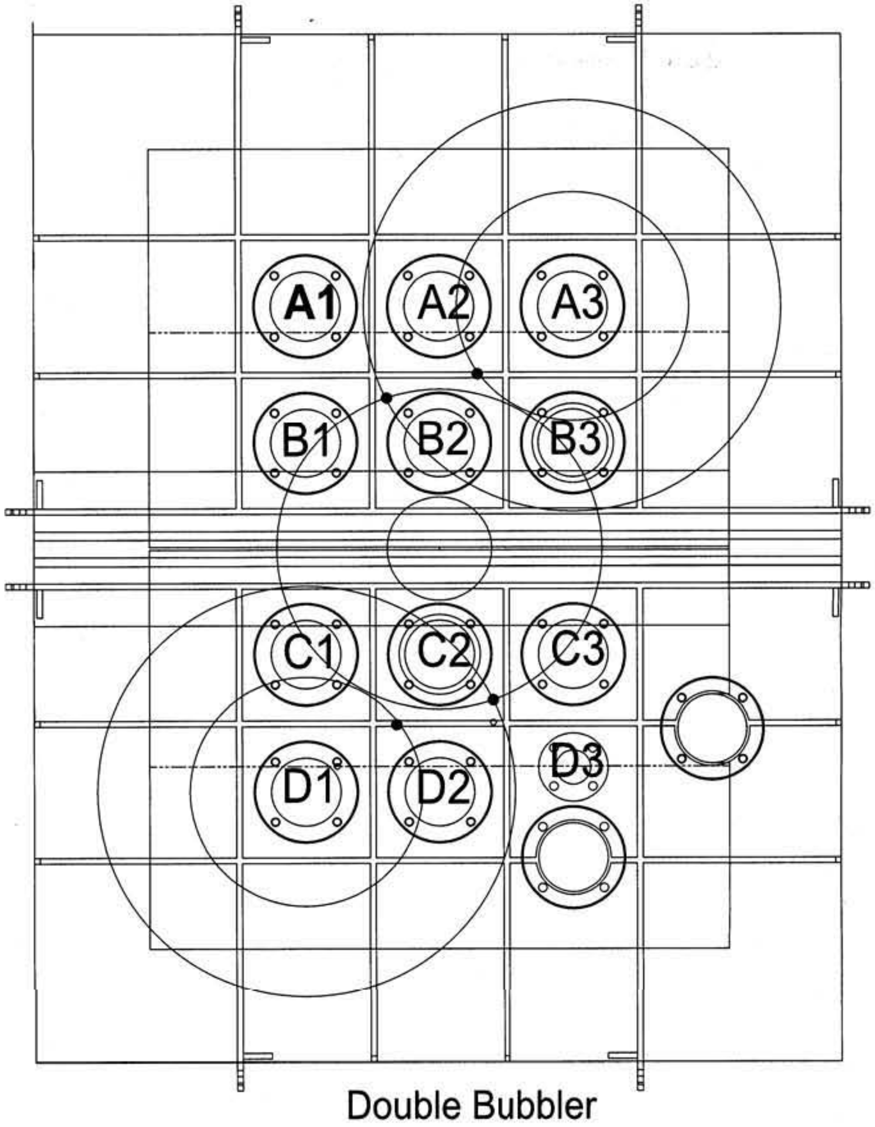


**Figure 2.9. Placement of double outlet bubblers. Note: solid circles represent location of bubbler outlet.**

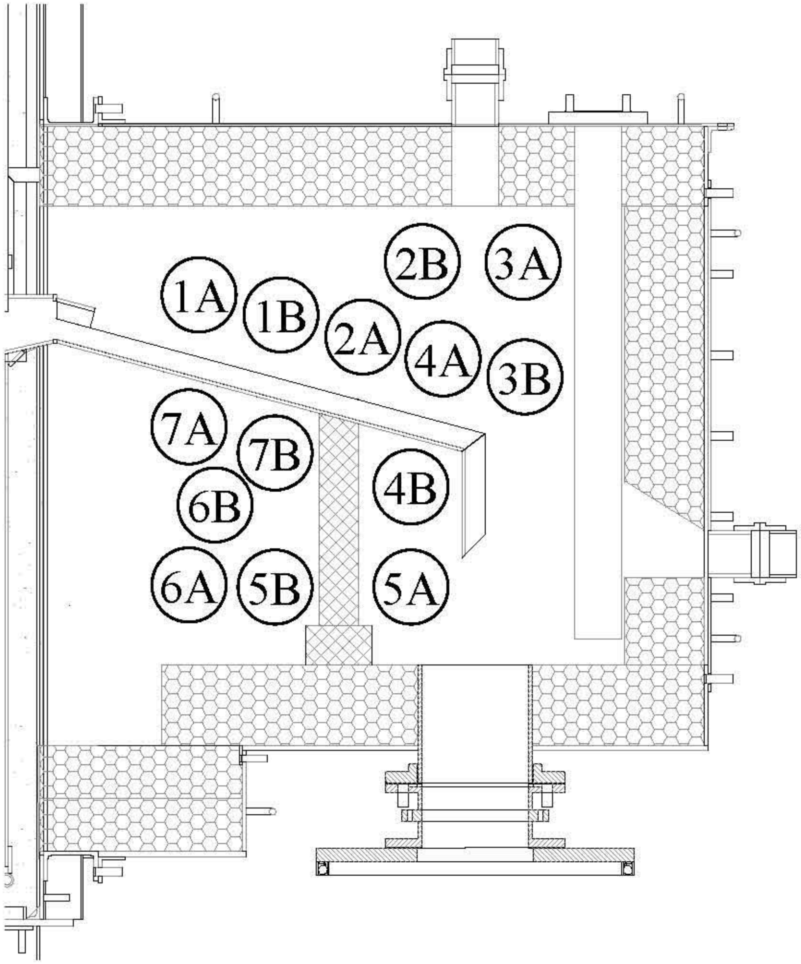


**Figure 2.10. Schematic of the DM1200 discharge chamber showing the location and numbering of heaters.**

**Figure 2.11. Typical discharge heater in the modified ceramic isolator. This assembly was installed in metal sheaths located in the discharge chamber.**

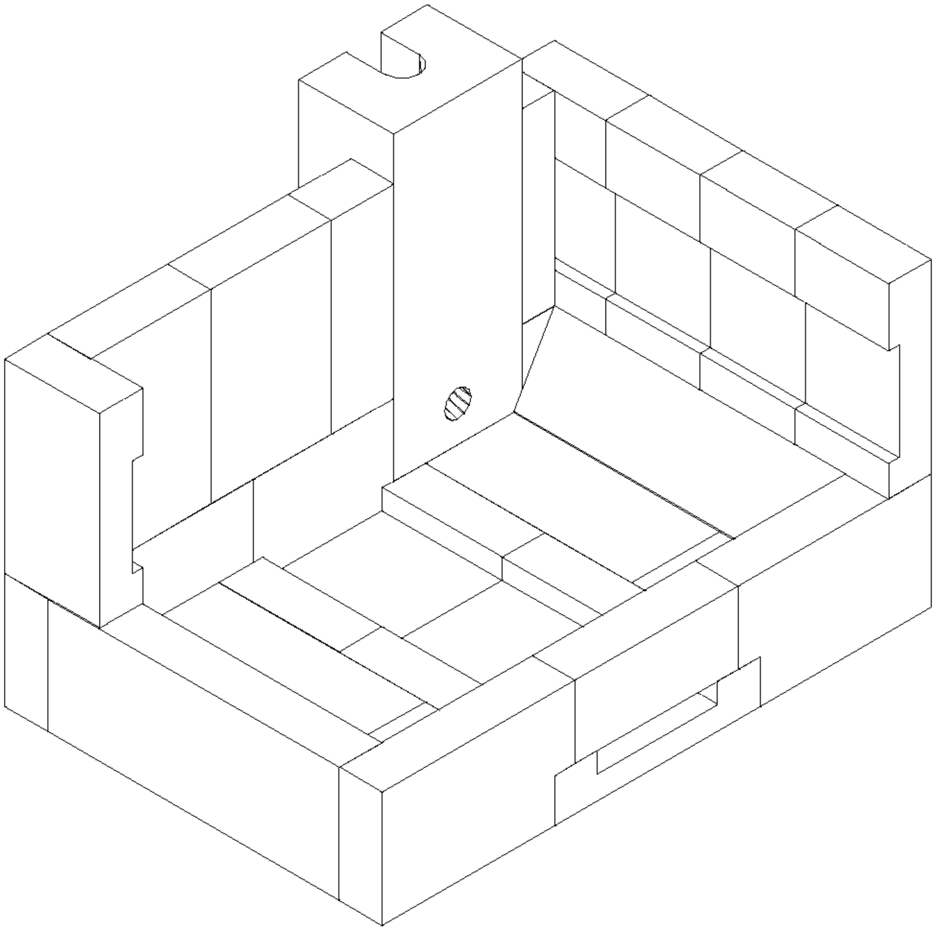


**Figure 2.12. View of the south and west DM1200 K-3 refractory (north and east walls removed for clarity)**

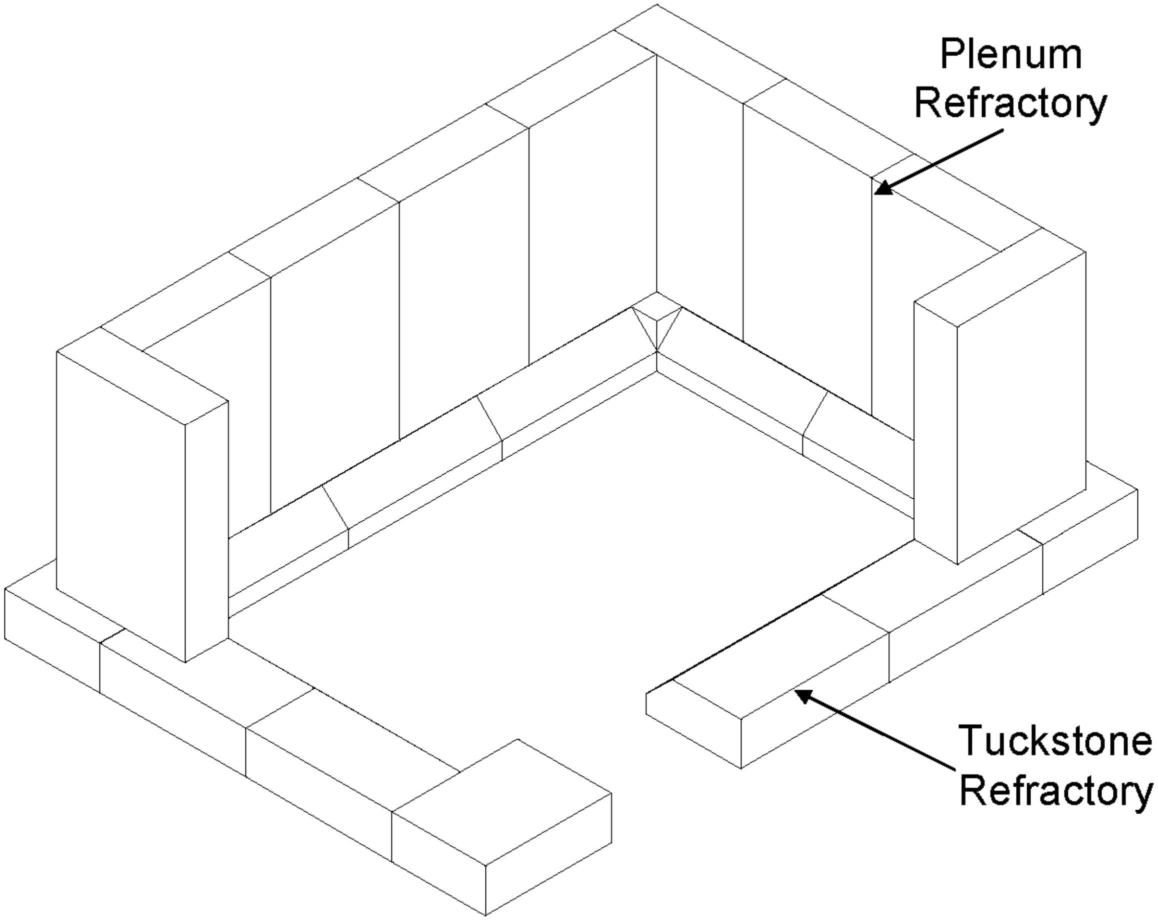


**Figure 2.13. View of the north and east walls of the DM1200 plenum refractory (south and west walls removed for clarity).**

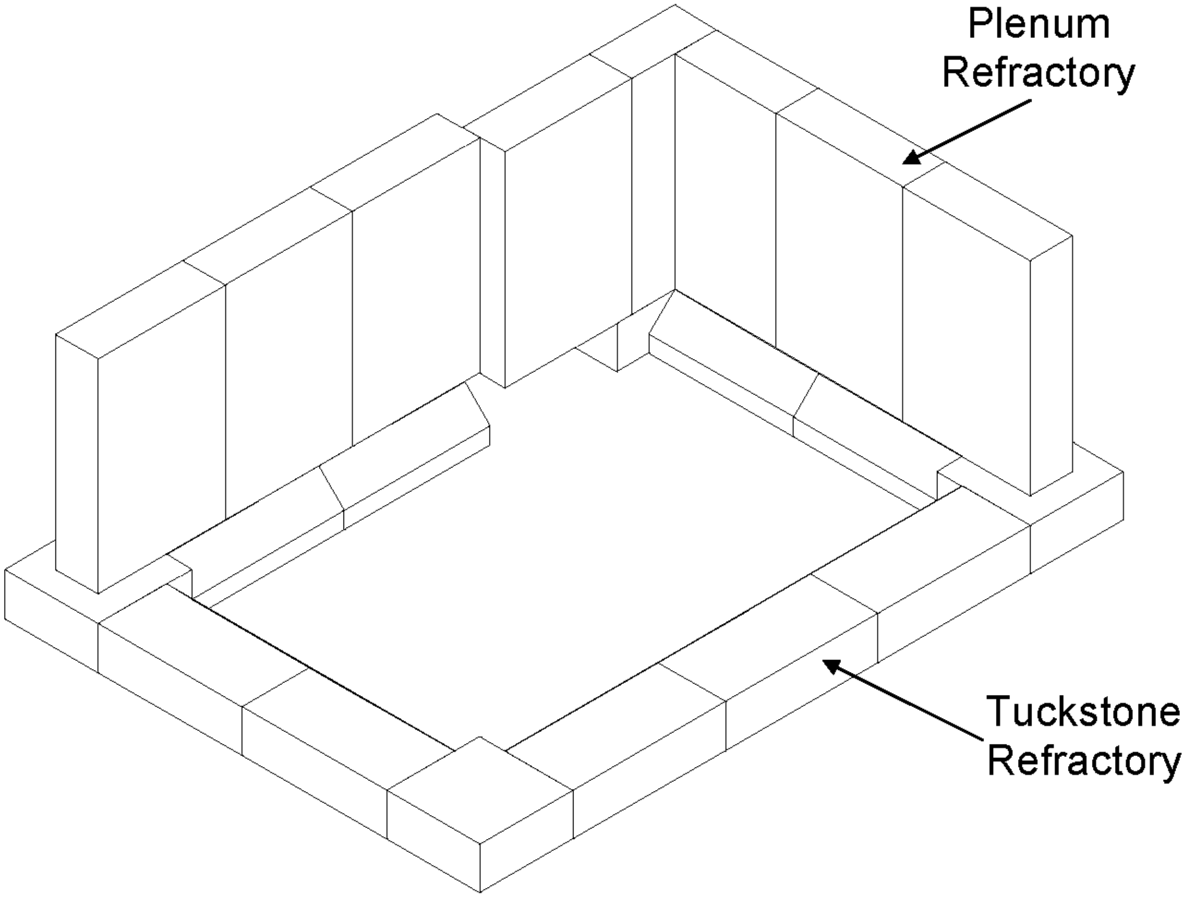


**Figure 2.14. View of the south and west walls of the DM1200 plenum refractory (north and east walls removed for clarity).**

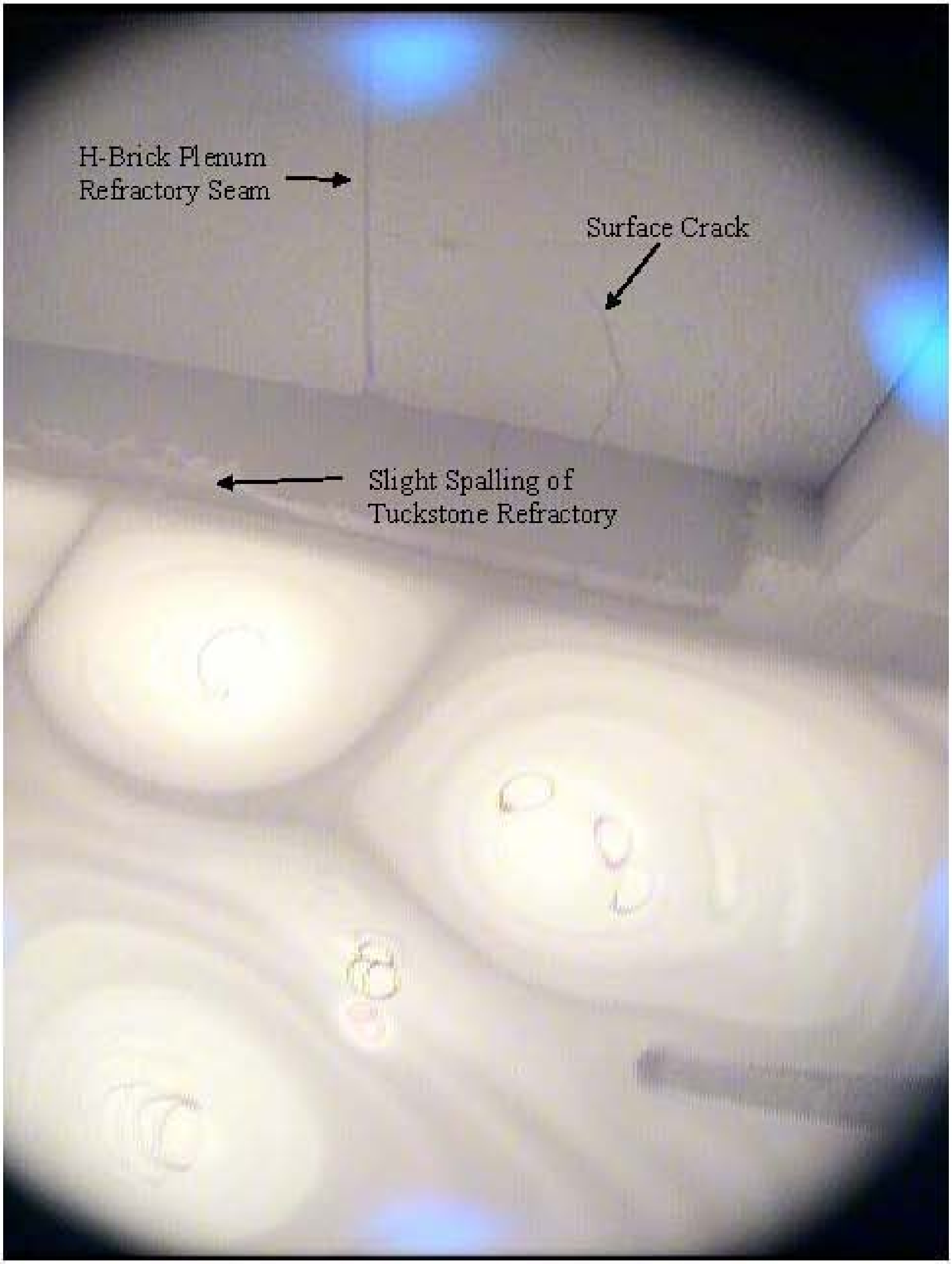


**Figure 2.15. View of the south wall plenum refractory in the DM1200.**

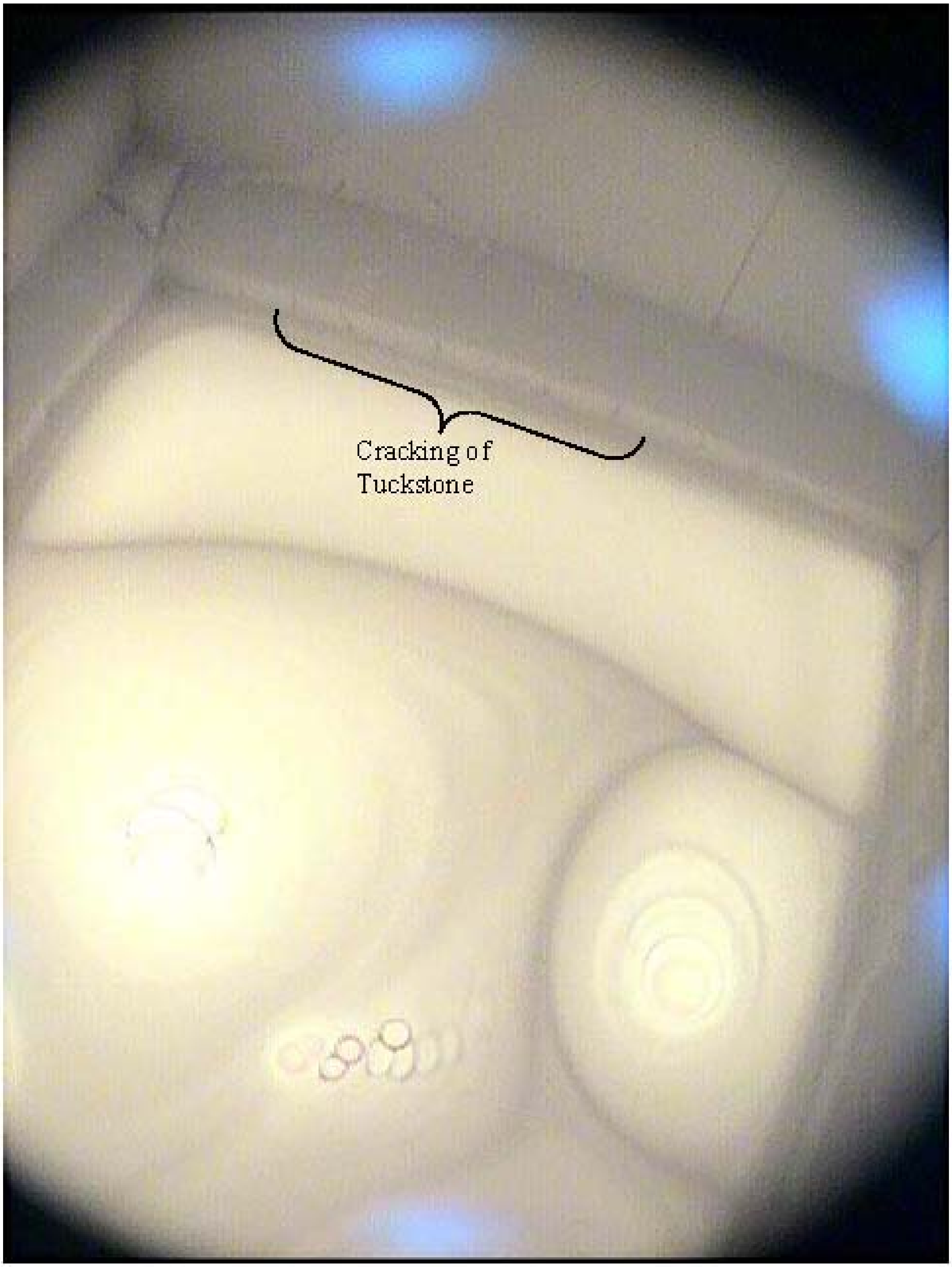


**Figure 2.16. View of the plenum refractory on the east wall of the DM1200.**

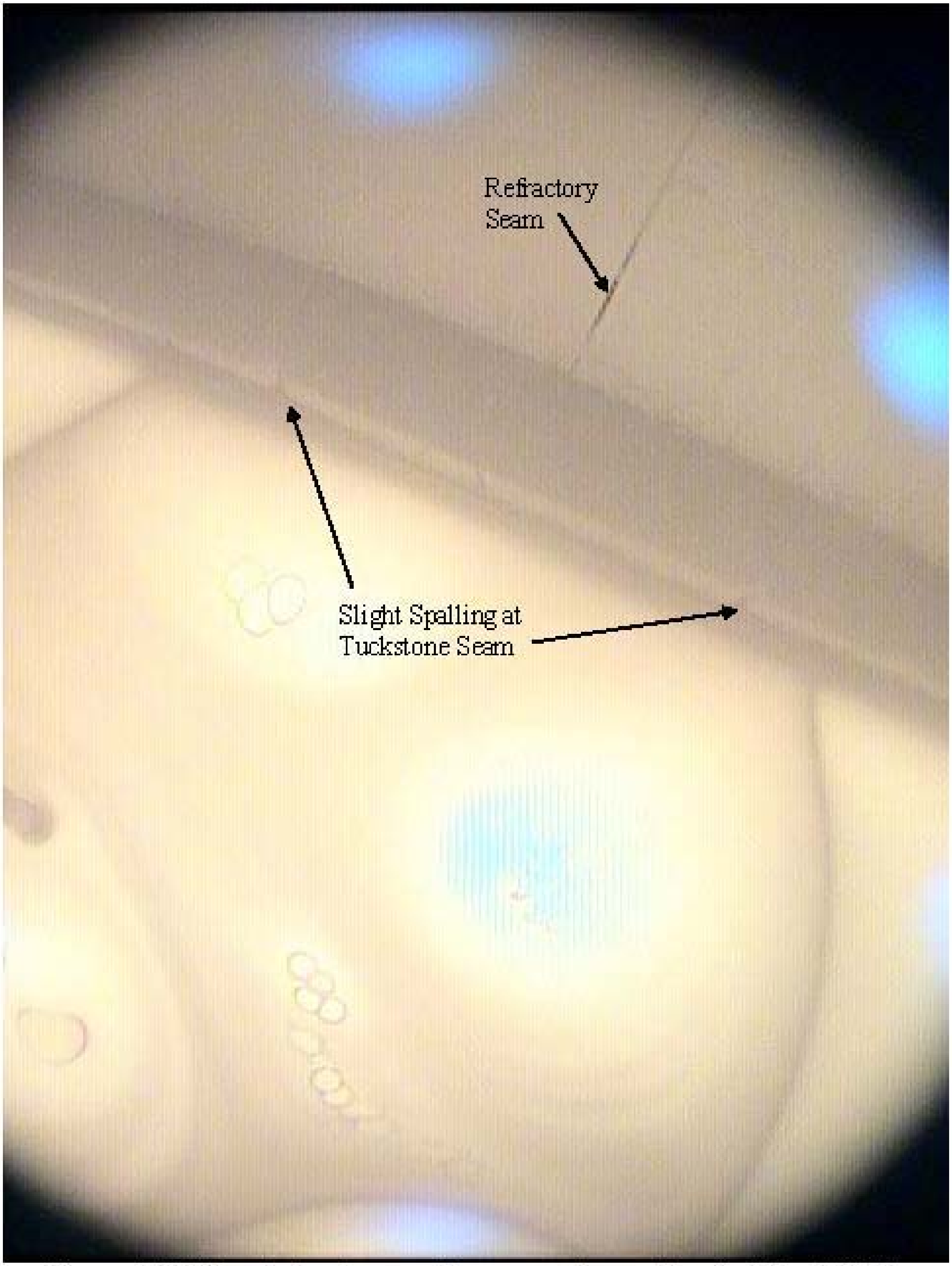


**Figure 2.17. View of the plenum refractory on the north wall of the DM1200.**

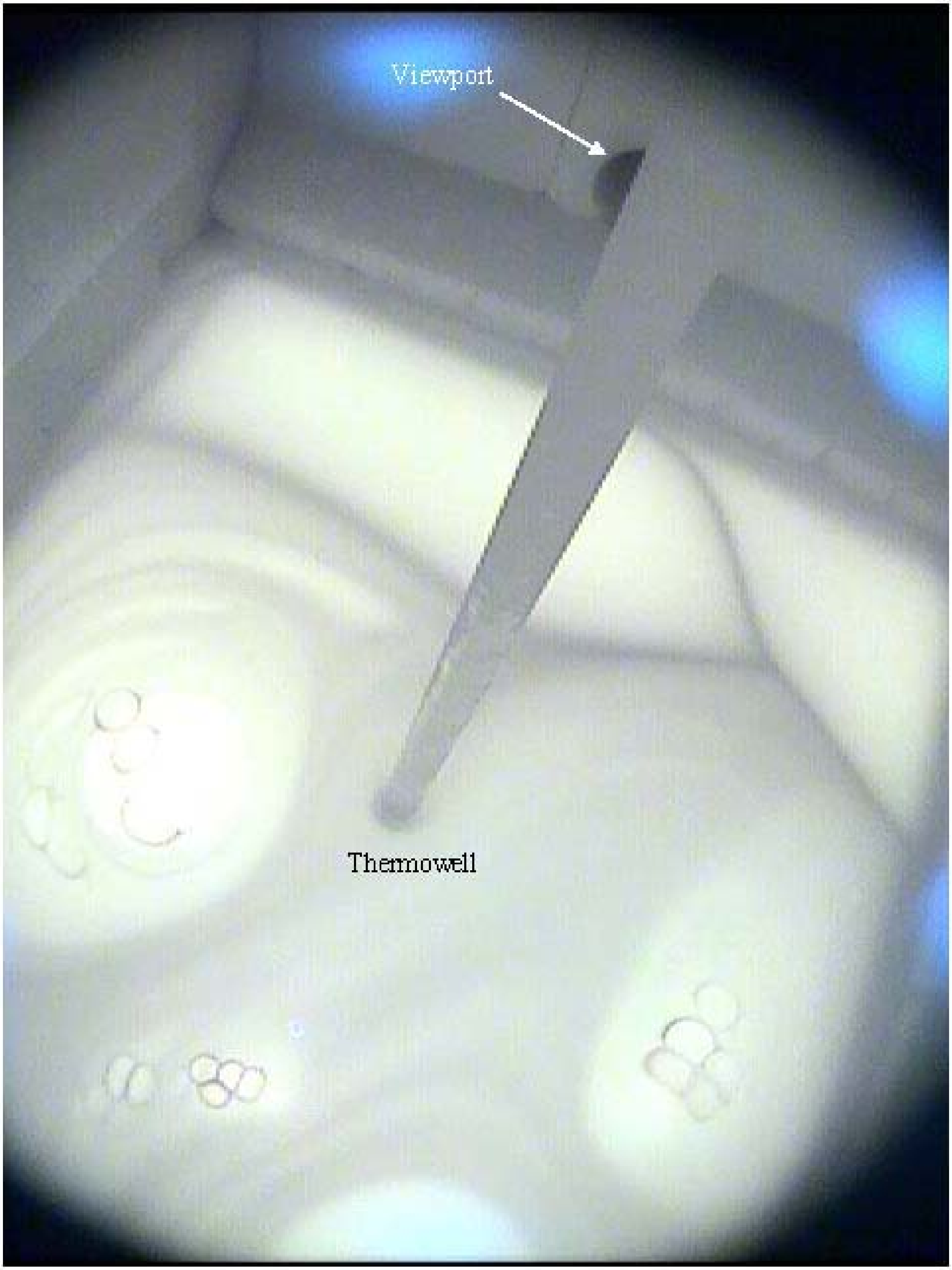


**Figure 2.18. View of the plenum refractory on the west wall of the DM1200.**

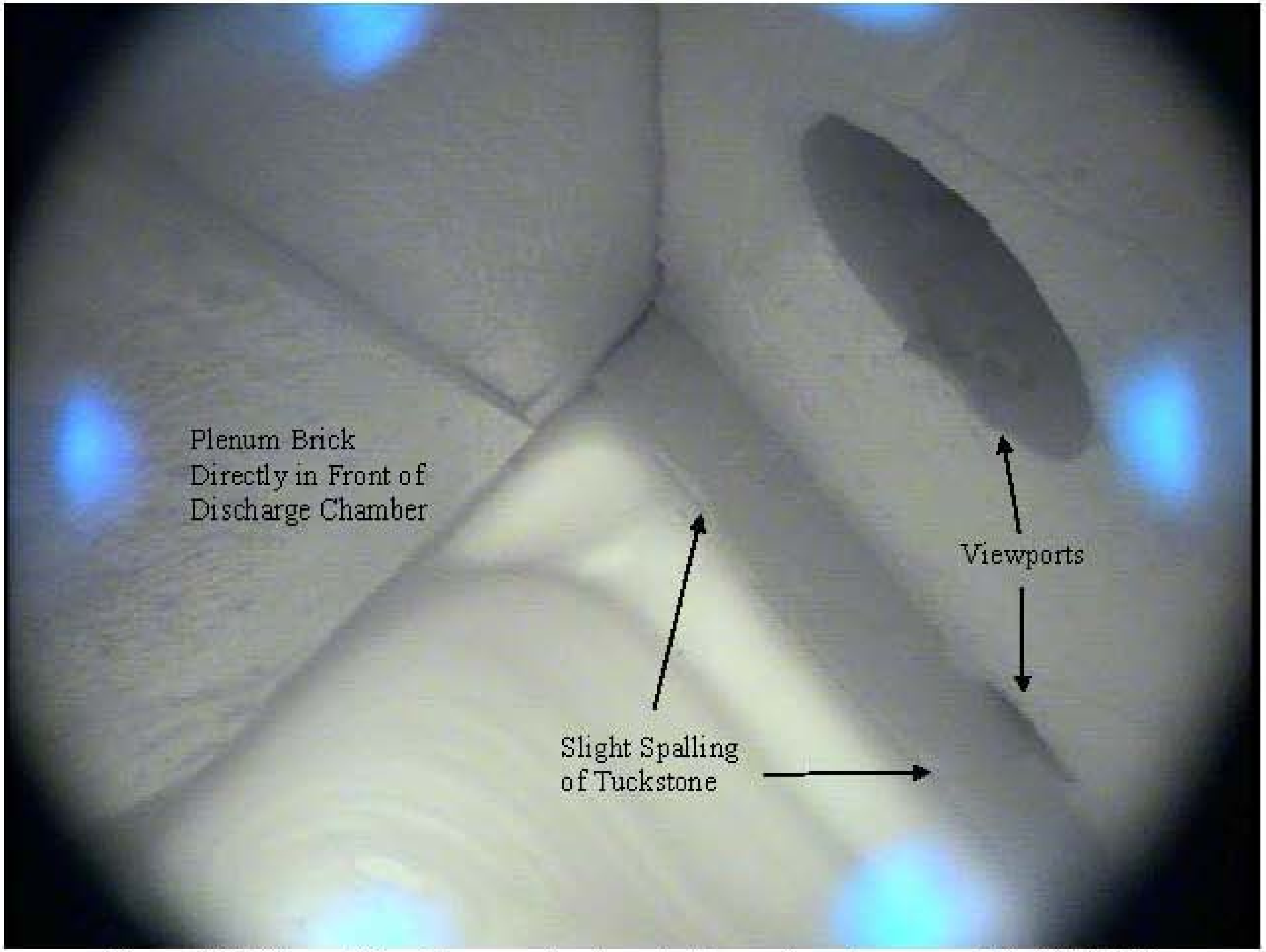


**Figure 2.19. View of the plenum refractory in the southwest corner of the DM1200.**

**Figure 2.20. View of the inside of the DM1200 discharge chamber showing the fiberboard walls and the end of the discharge trough. View up through the discharge port on the bottom of the chamber.**

**Figure 2.21. View of the bottom of the discharge trough through the view port on the south wall of the discharge chamber.**

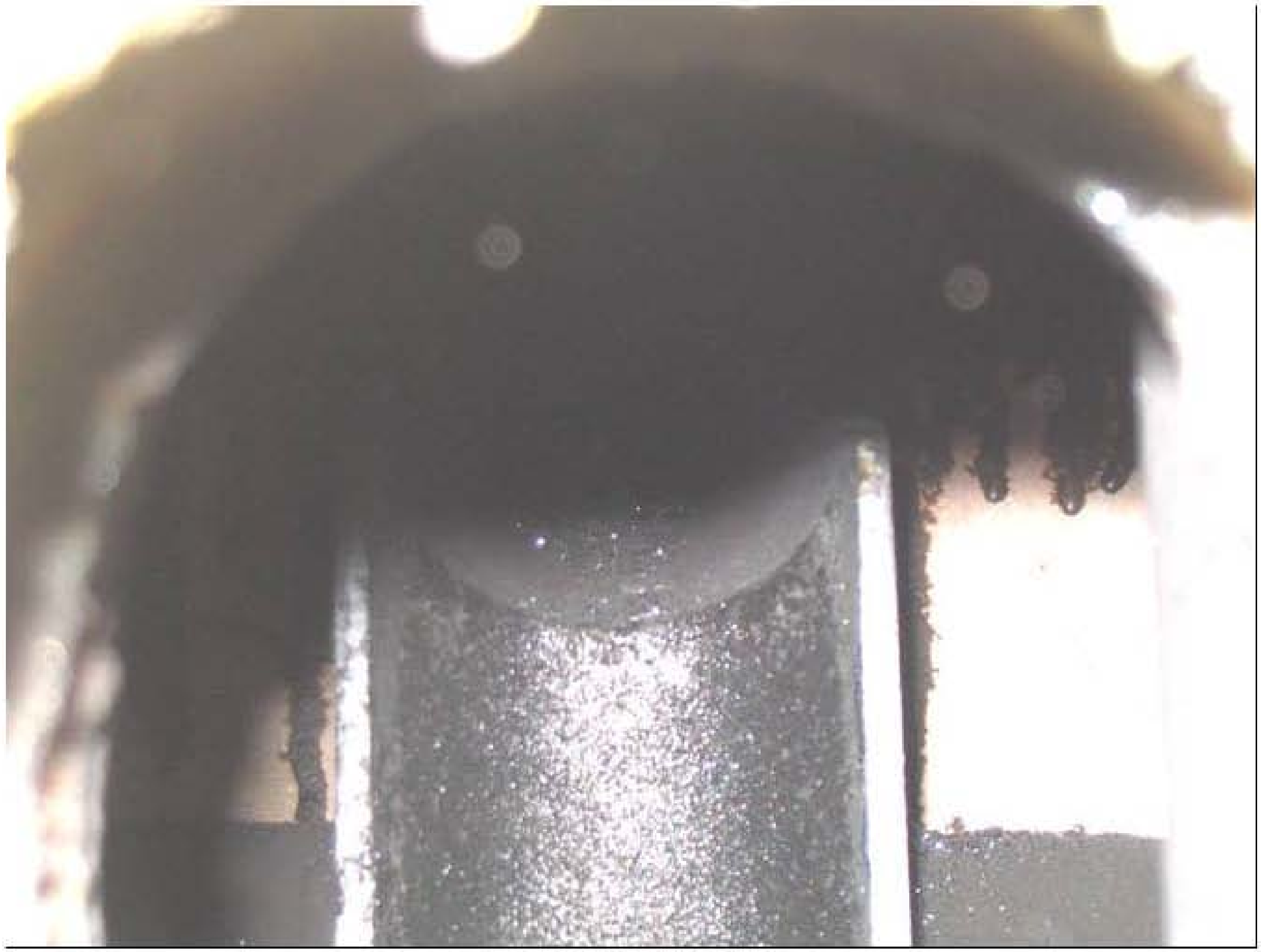


**Figure 2.22. View up the discharge trough showing the top edge of trough.**

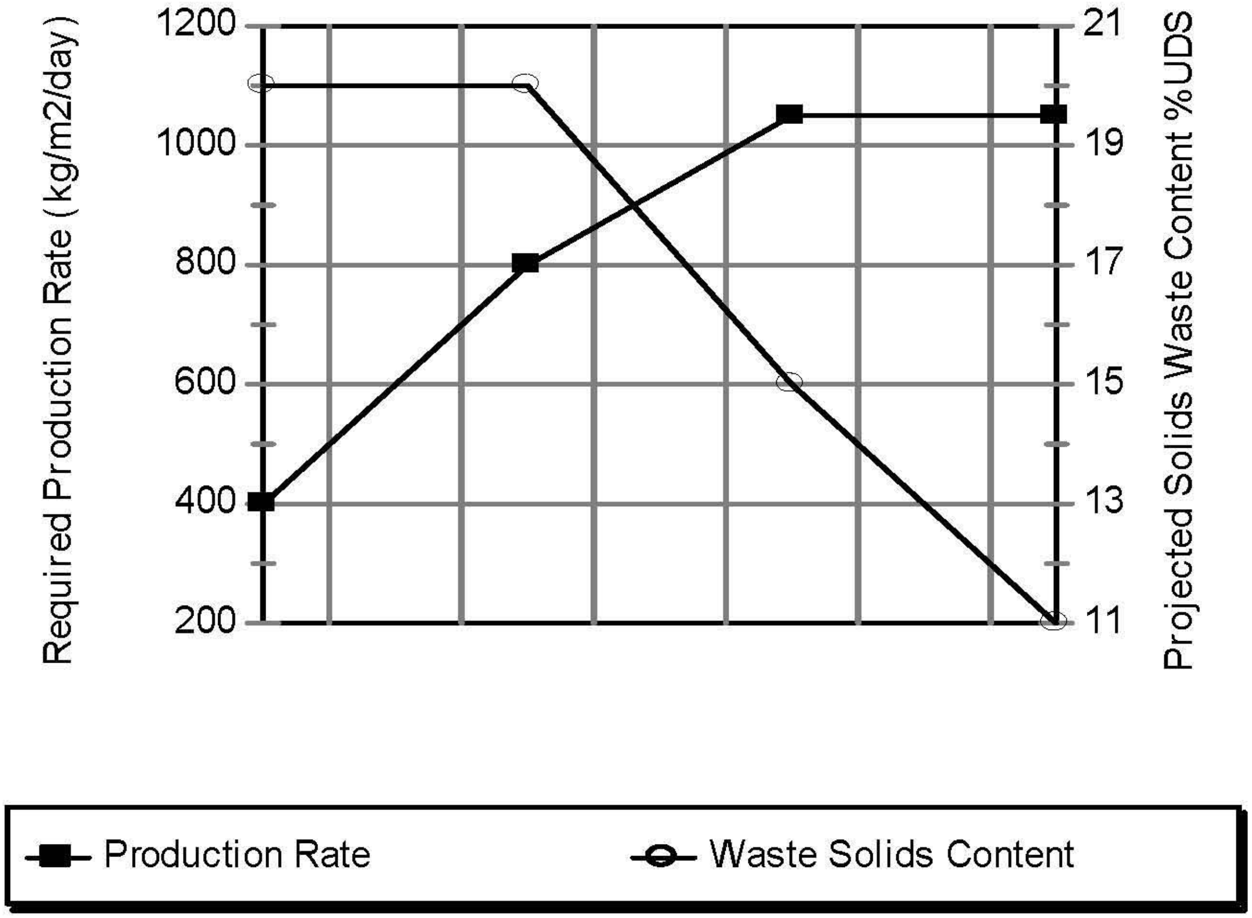


**Figure 3.1. Schematic representation of the variation over time of the required HLW glass production rates for the DM1200 and the projected solids content of the HLW feed from pretreatment.**

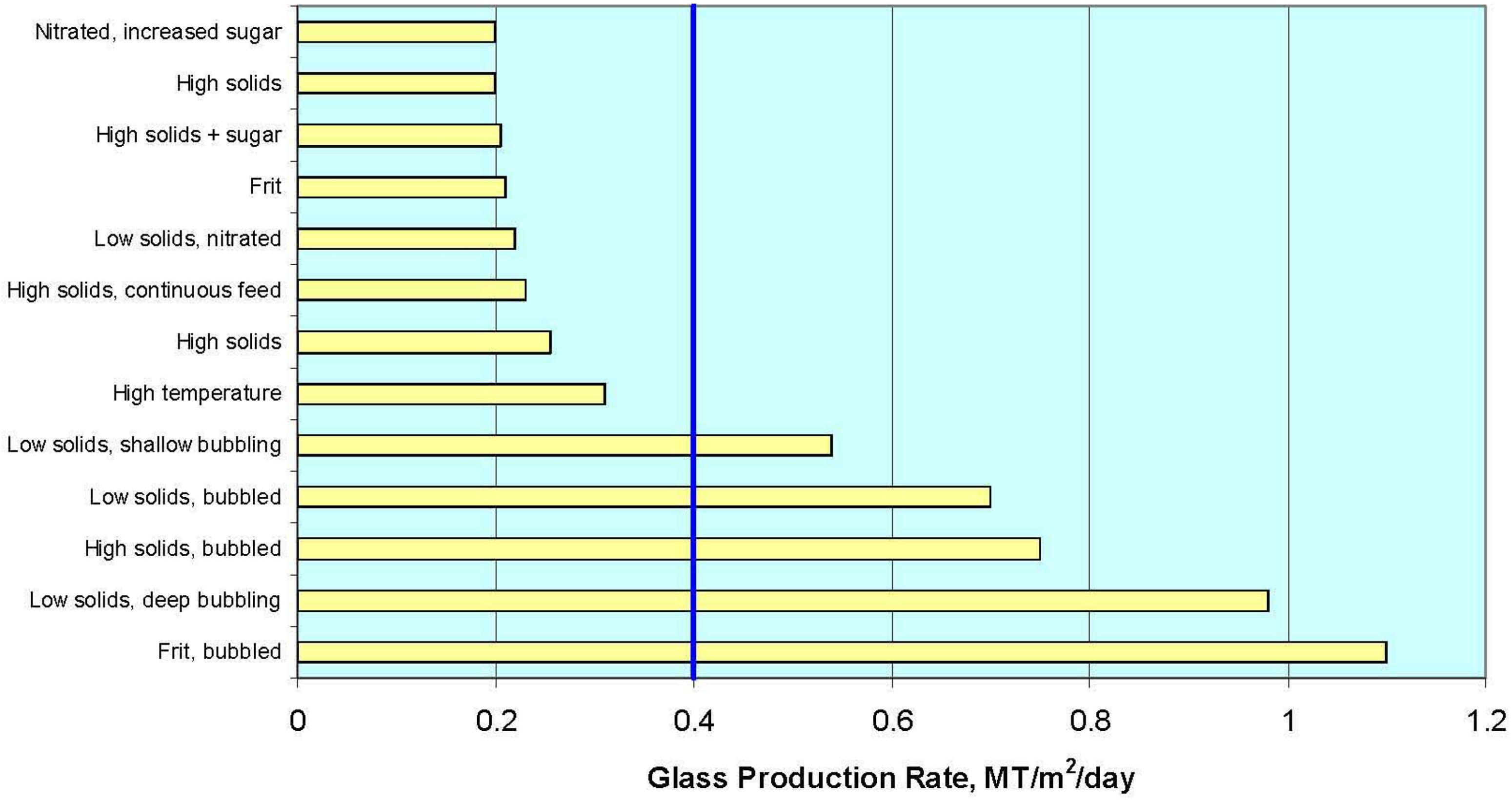


**Figure 3.2. Comparison of steady state glass production rates for HLW AZ-101 melter tests without bubbling and with bubbling using two single outlet bubblers [3, 9].**

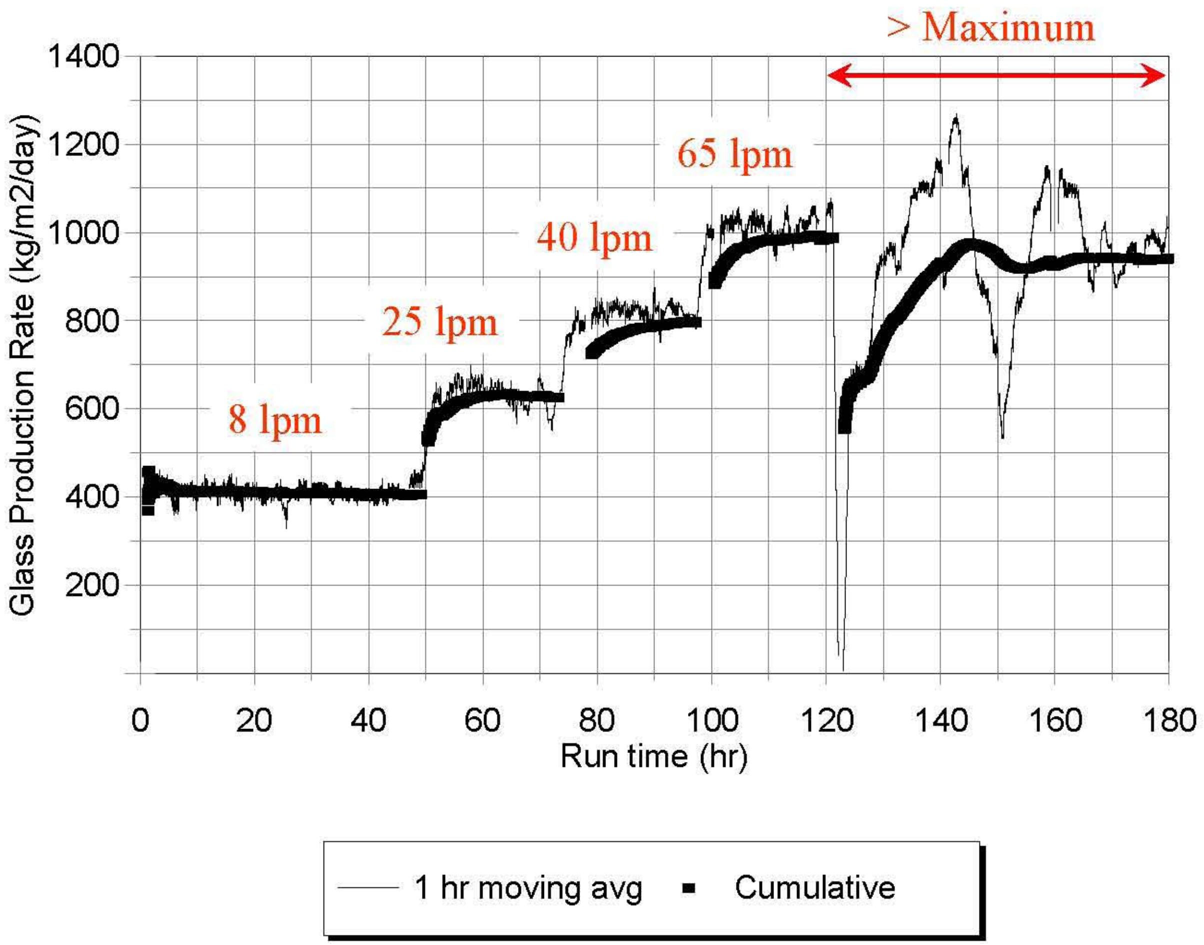


**Figure 3.3. Glass production rates for HLW AZ-101 waste simulants with bubbling using two single outlet bubblers [17].**

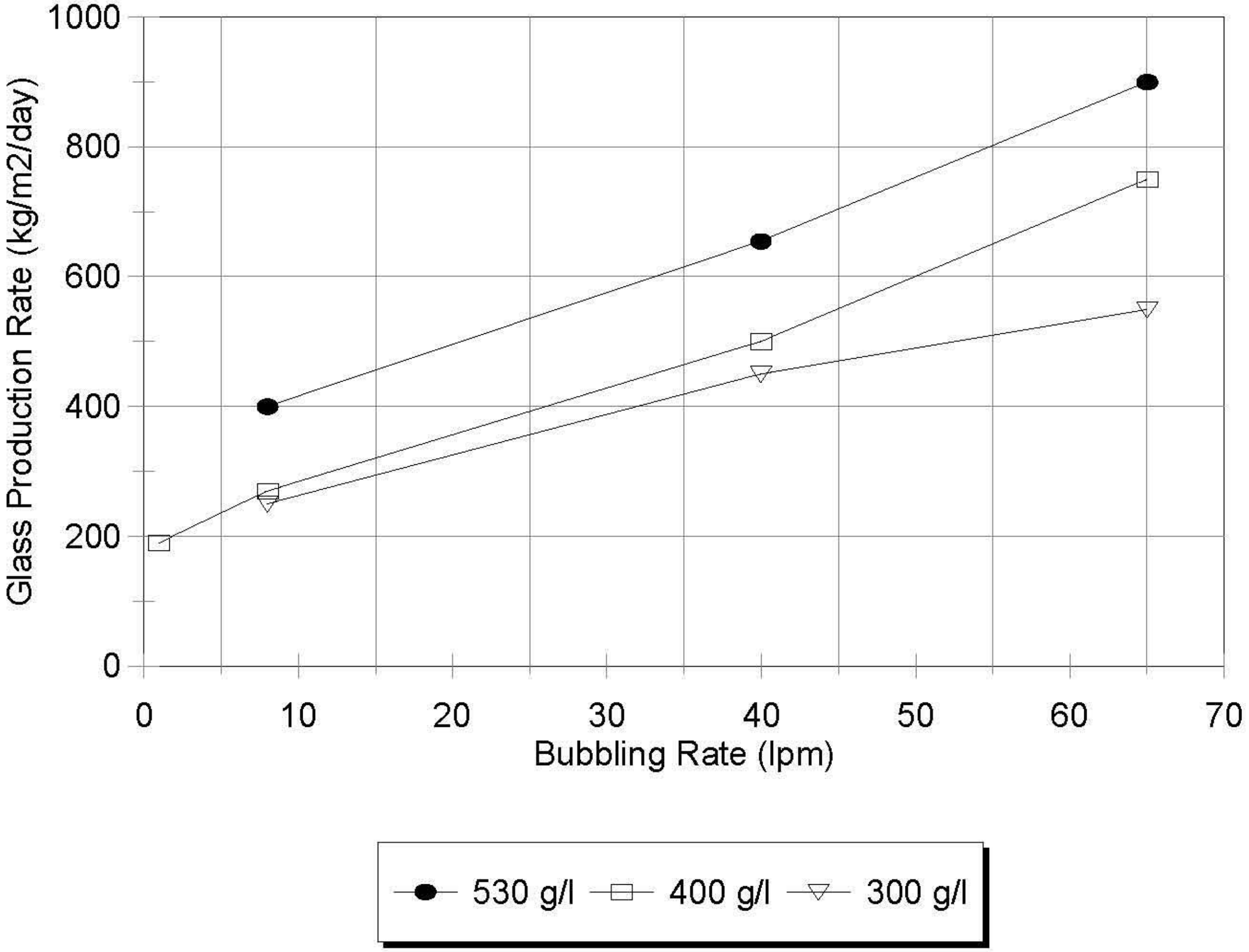


**Figure 3.4. Comparison of steady state glass production rates for HLW AZ-101 melter tests using two single outlet bubblers [17].**

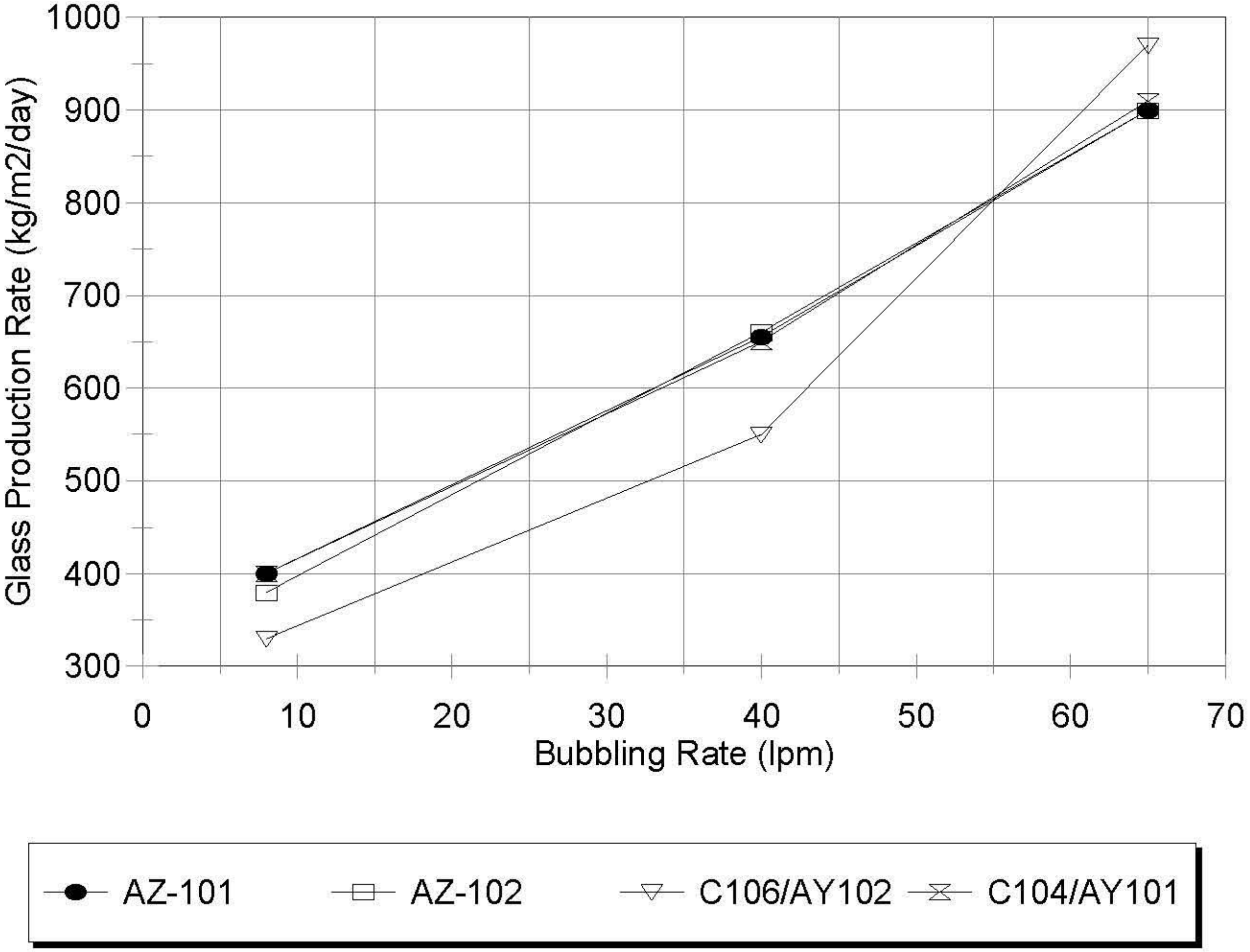


**Figure 3.5. Comparison of steady state glass production rates for 20% UDS HLW waste simulants using two single outlet bubblers [17, 23, 26, 28].**

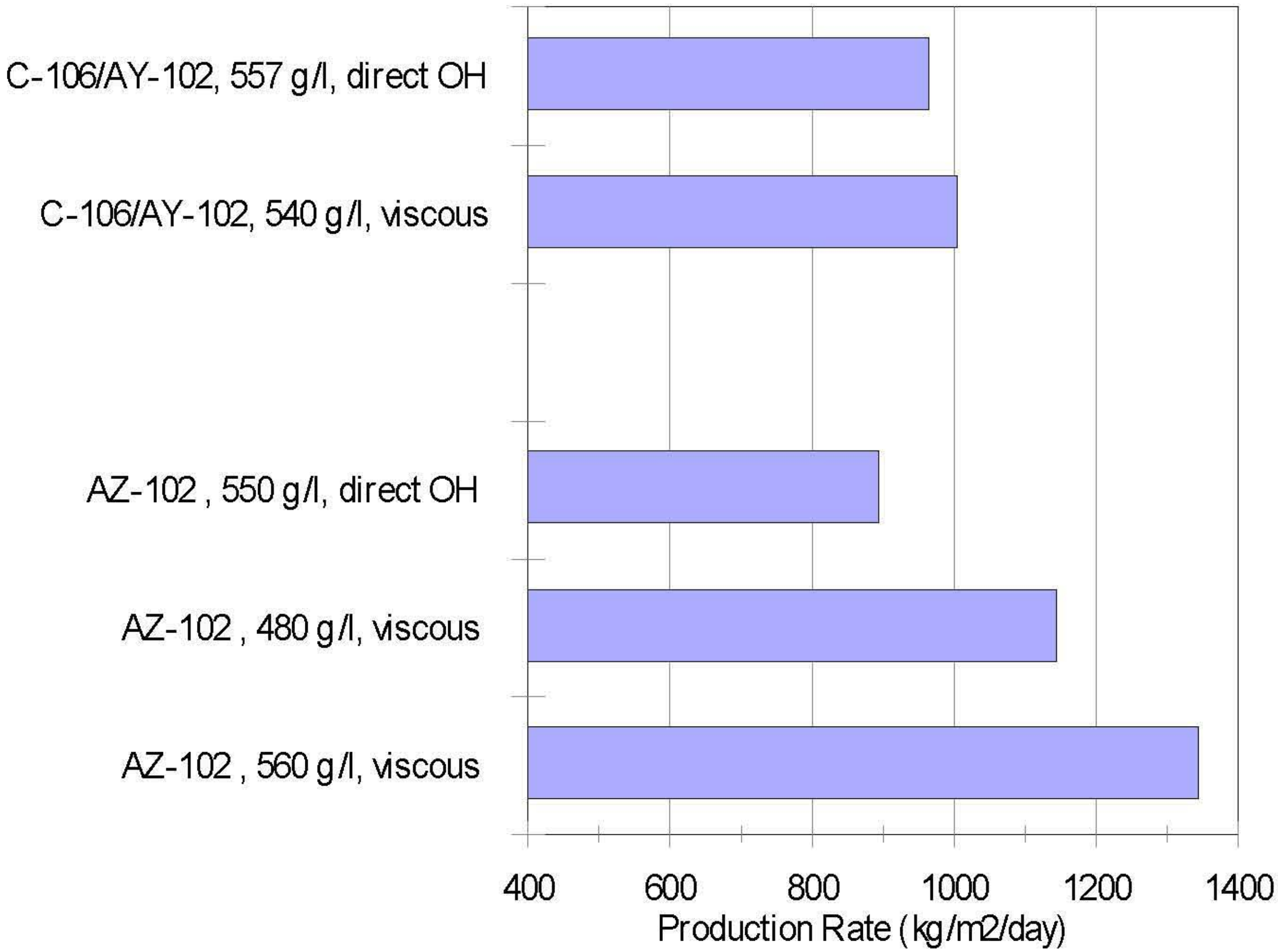


**Figure 3.6. Comparison of steady state glass production rates for HLW waste simulants of varying viscosities using two single outlet bubblers at 65 lpm [23, 26, 35].**

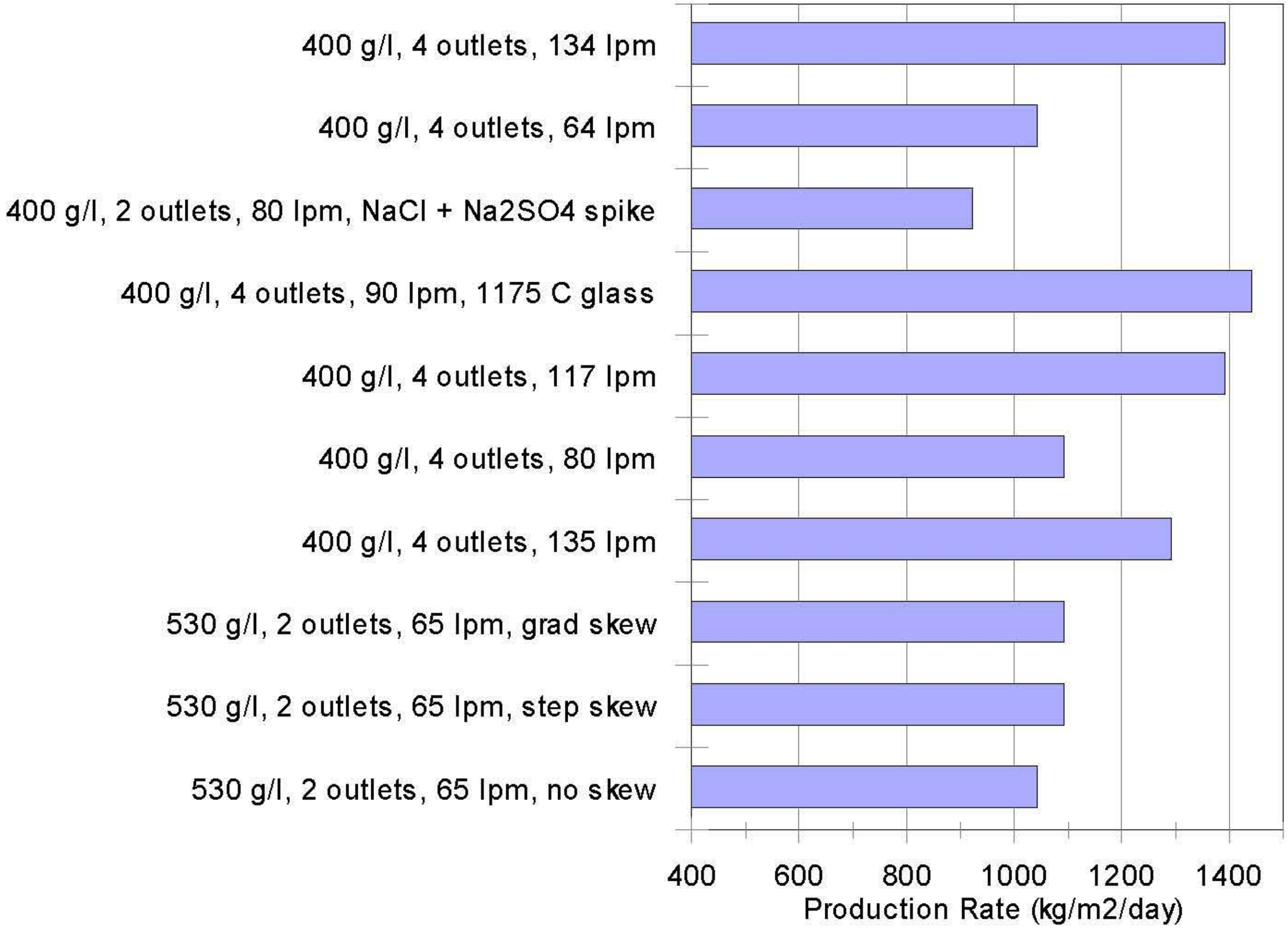


**Figure 3.7. Steady state glass production rates for HLW AZ-101 waste simulants obtained during bubbler configuration tests [30].**

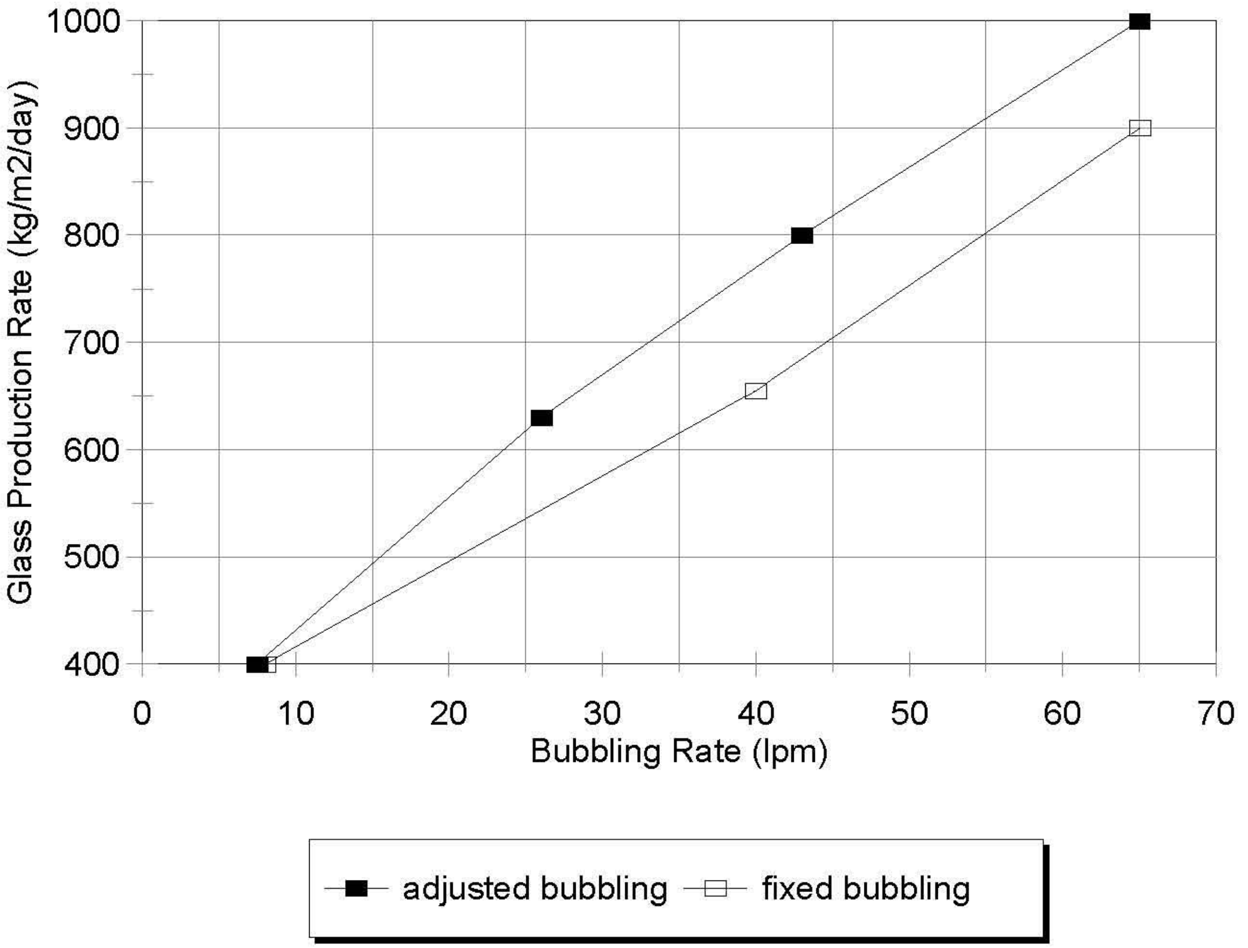


**Figure 3.8. Comparison of steady state glass production rates for HLW AZ-101 melter tests using two single outlet bubblers [30].**

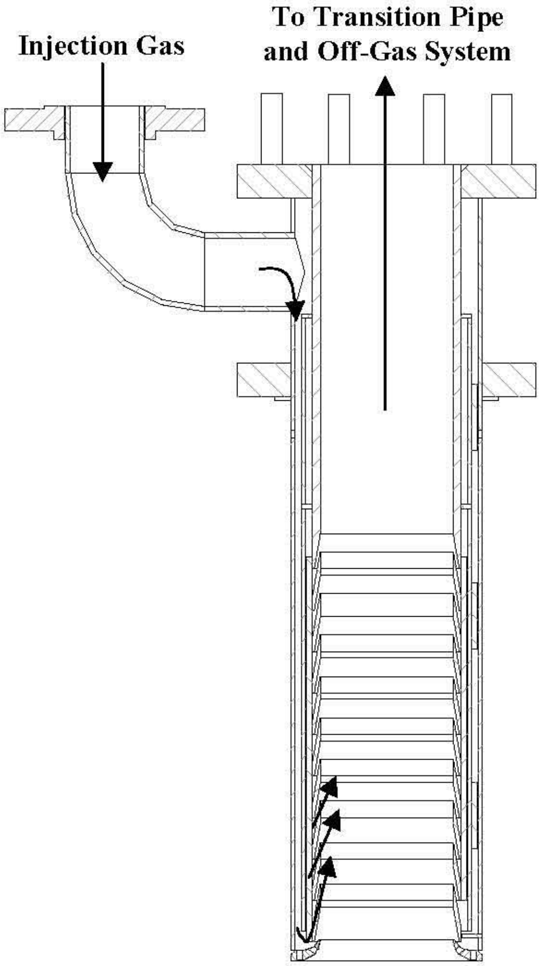


**Figure 4.1. Schematic of the DM1200 film cooler.**

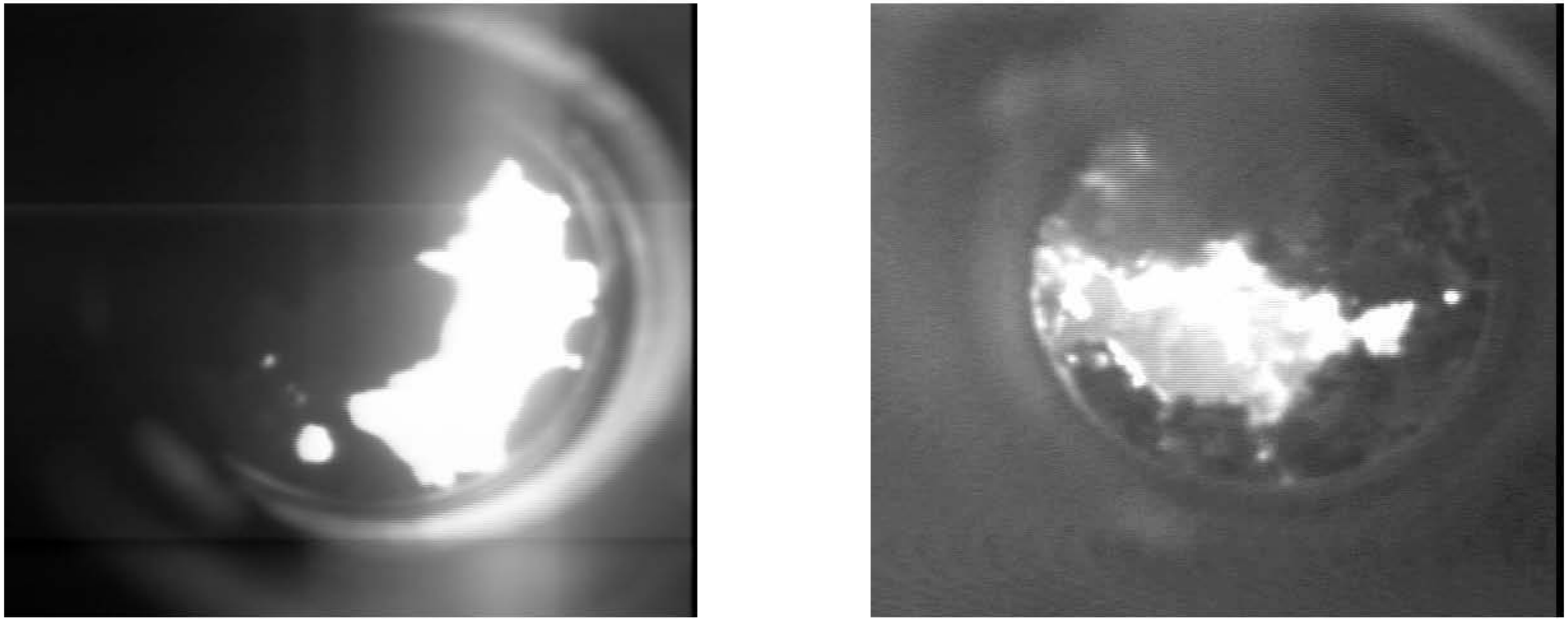


**Figure 4.2. Typical views of particulate buildup/plugging of the film cooler. View from the top of the film cooler looking down.**

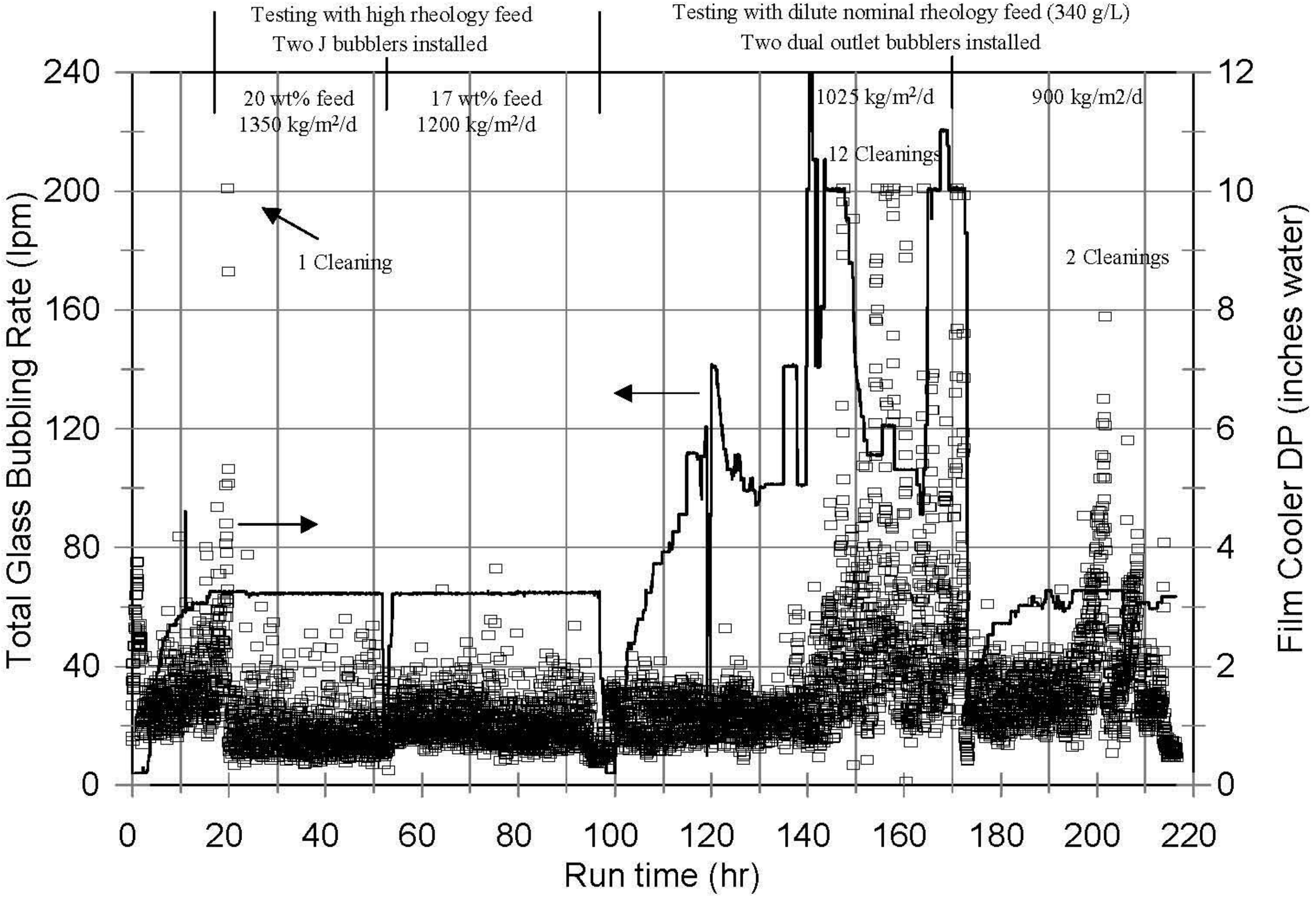


**Figure 4.3. Glass pool bubbling rate versus film cooler DP for the HLW AZ-102 tests [35].**

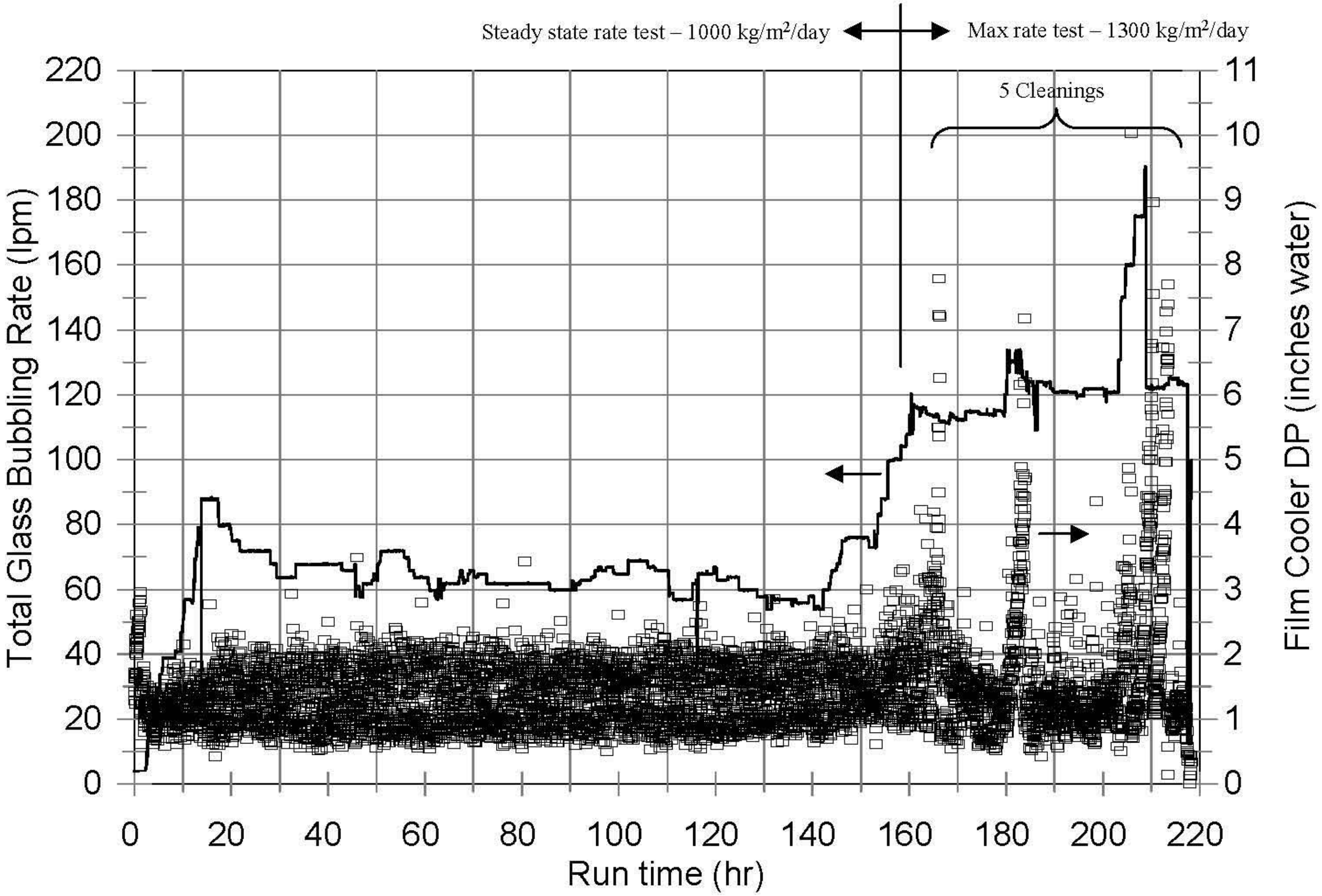


**Figure 4.4. Glass pool bubbling rate versus film cooler DP from Test 9 employing the optimum bubbler configuration [30].**

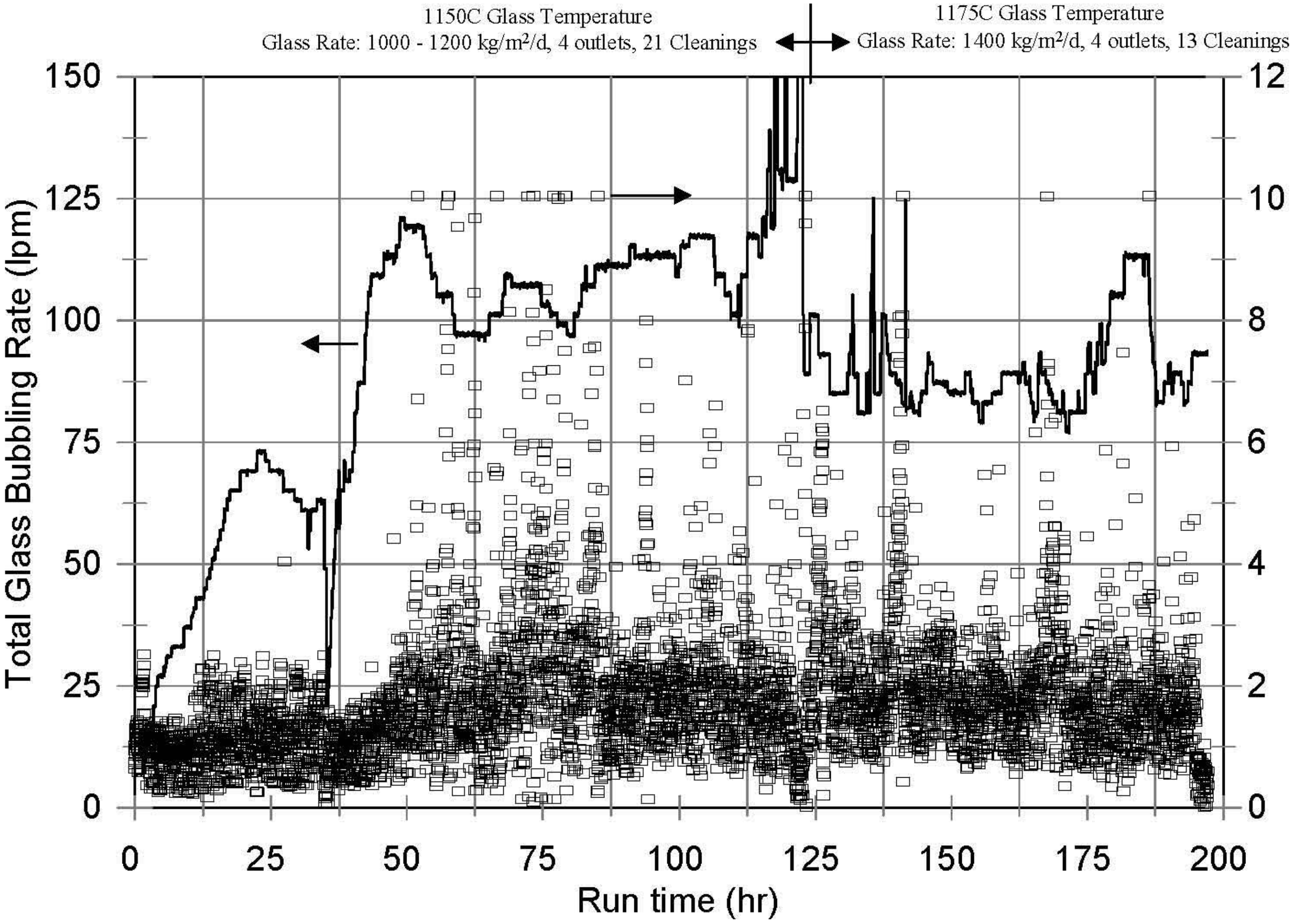


**Figure 4.5. Glass pool bubbling rate versus film cooler DP from Test 8 of the optimum bubbler configuration tests [30].**

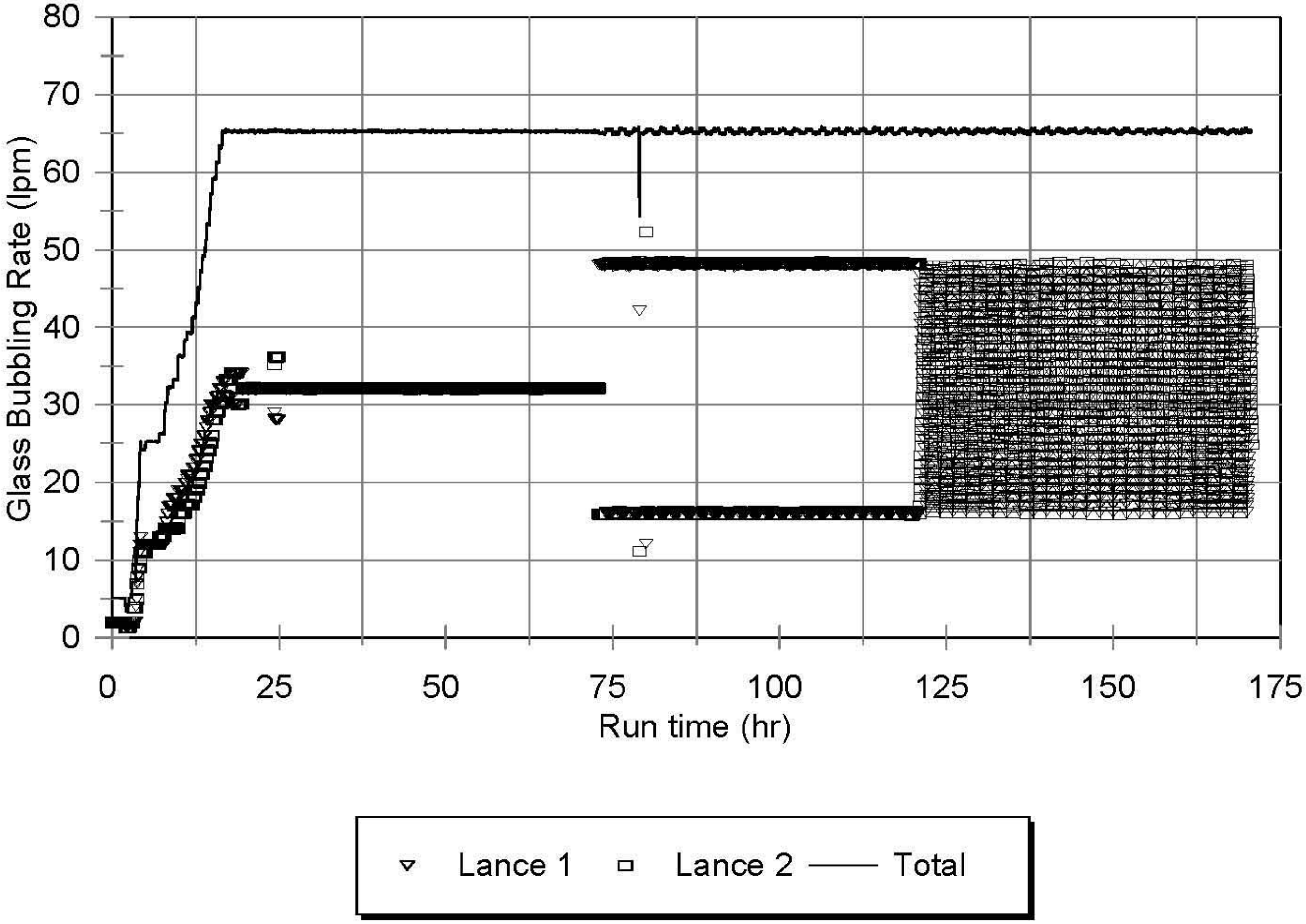


**Figure 4.6. Glass pool bubbling rates from Test 1 of the bubbler configuration tests [30].**

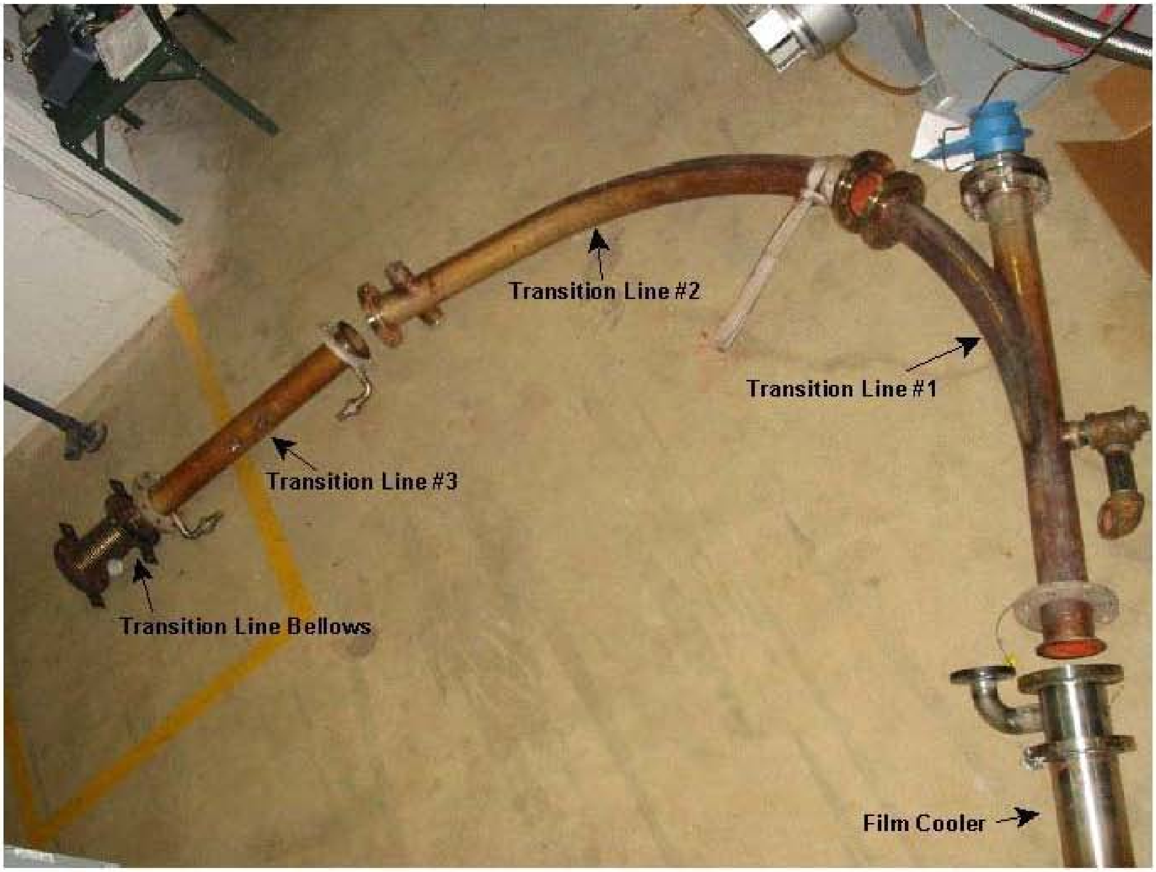


**Figure 4.7. Layout of film cooler and transition line sections.**

**Figure 4.8. View of top of the installed film cooler after tests (pre-cleaning) with LAW Sub-Envelope A1 simulants [14].**

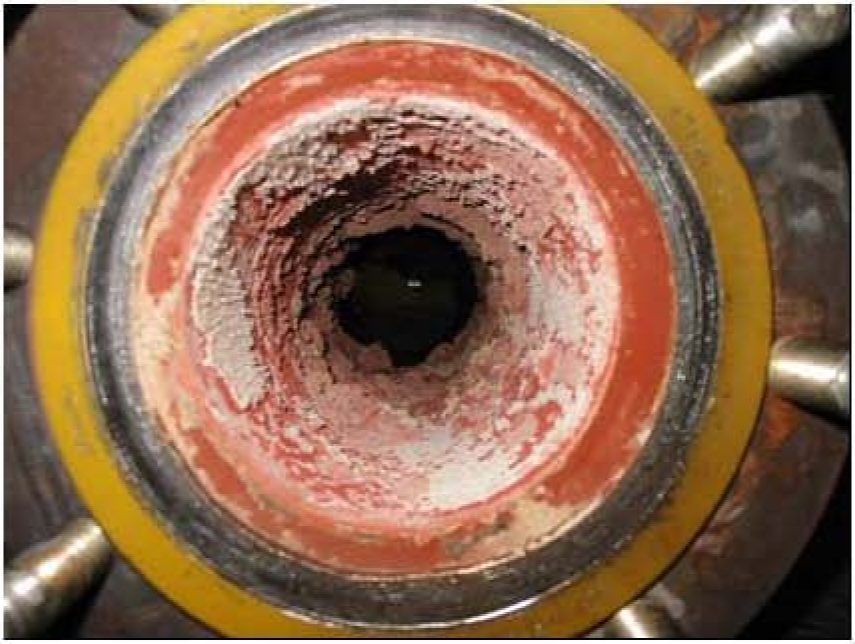


**Figure 4.9. View of top of the removed film cooler after tests (pre-cleaning) with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.10. View of bottom of the removed film cooler (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

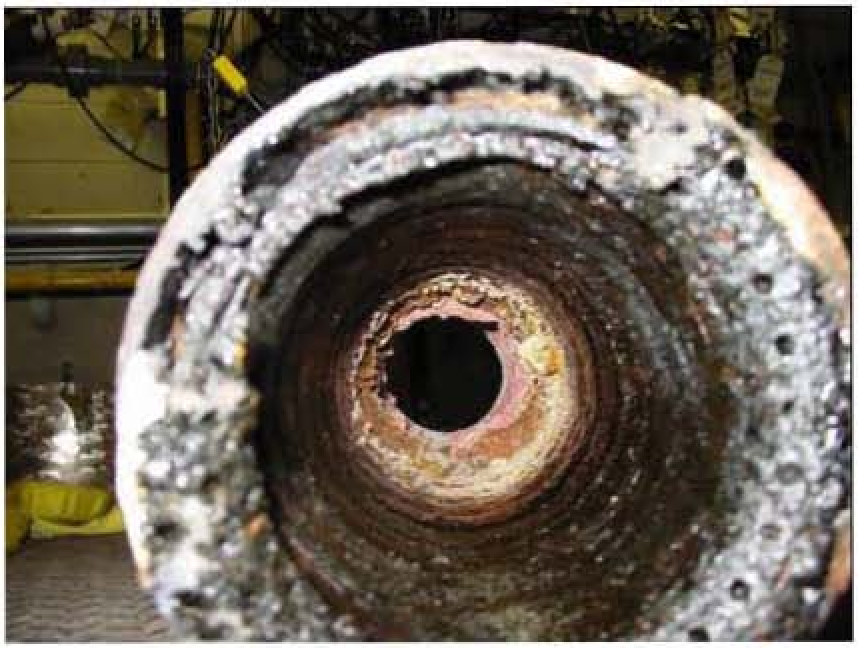


**Figure 4.11. Close-up view of bottom of the removed film cooler (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.12. View of fractured bottom ring of the film cooler (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.13. View of the bottom ring and throat of the film cooler (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.14. Another bottom view of the film cooler (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.15. View of detachment of the film cooler bottom ring (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.16. View of glass and weld beneath the failed region of film cooler (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.17. View of louvers of the film cooler (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.18. View of louvers of the film cooler (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.19. Side view of the film cooler (pre-cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.20. View of damage to the bottom ring of film cooler (post cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

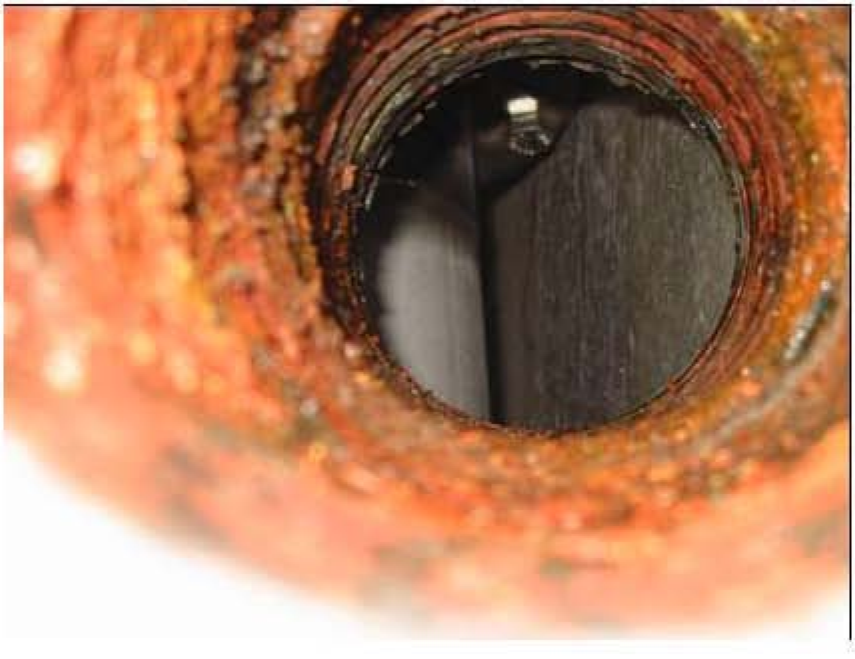


**Figure 4.21. View of louvers of the film cooler (post cleaning) after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.22. View of exit end of the film cooler (post cleaning) after tests with LAW Sub-Envelope A1 simulants.**

**Figure 4.23. Close-up view of exit end of the film cooler (post cleaning) after tests with LAW Sub-Envelope A1 simulants.**

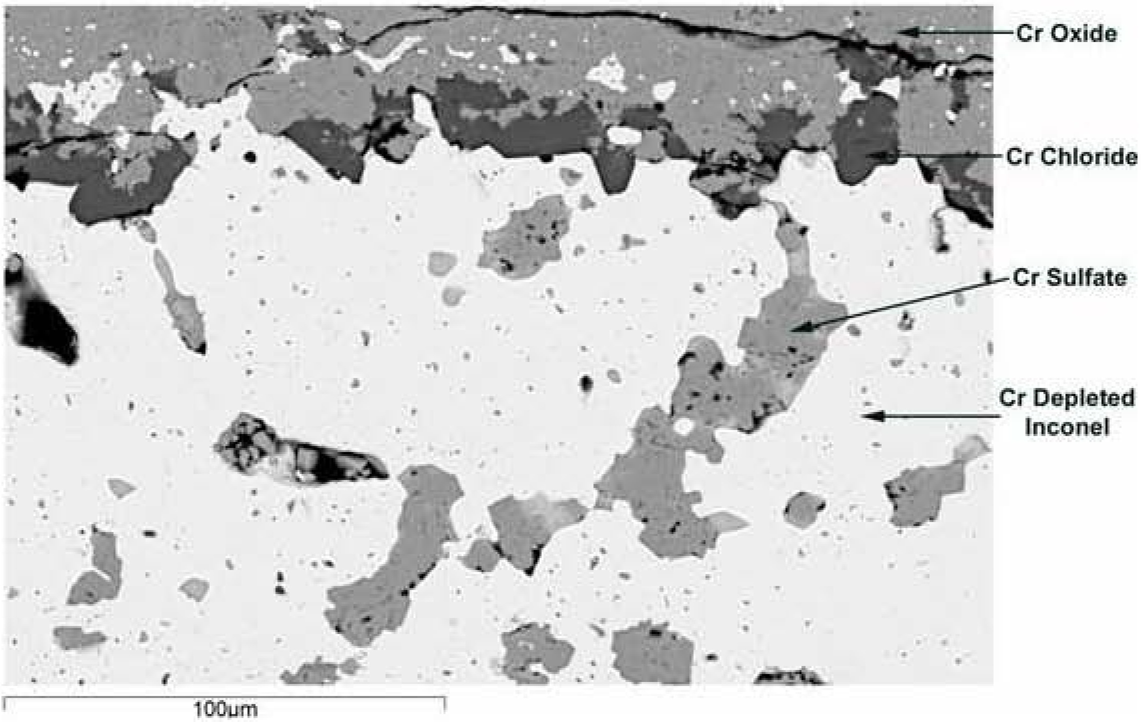


**Figure 4.24. SEM micrograph of a sample removed from the film cooler bottom ring after tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.25. View of flexible bellows (pre-cleaning) during tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.26. Inside view of the SBS-side of the flexible bellows (pre-cleaning) after 121.6 hours of operations during tests with LAW Sub-Envelope A1 simulants [14].**

**Figure 4.27. Film cooler inlet after tests with HLW C-104/AY-101 simulants [28].**

**Figure 4.28. Film cooler inlet close-up after tests with HLW C-104/AY-101 simulants [28].**

**Figure 4.29. Transition line section #2 inlet after tests with HLW C-104/AY-101 simulants [28].**

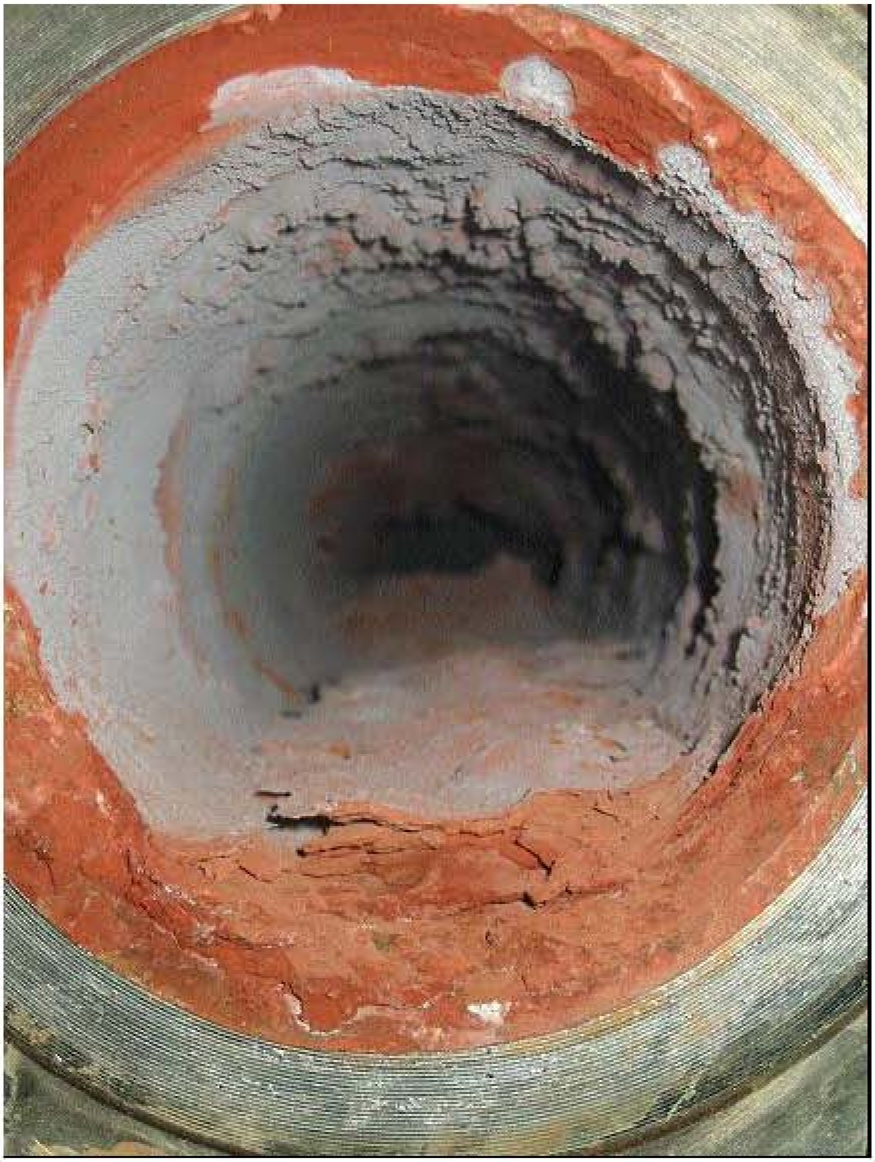


**Figure 4.30. Transition line section #2 outlet after tests with HLW C-104/AY-101 simulants [28].**

**Figure 4.31. Transition line section #3 inlet after tests with HLW C-104/AY-101 simulants [28].**

**Figure 4.32. View of transition line section #3 inlet after tests with HLW C-104/AY-101 simulants [28].**

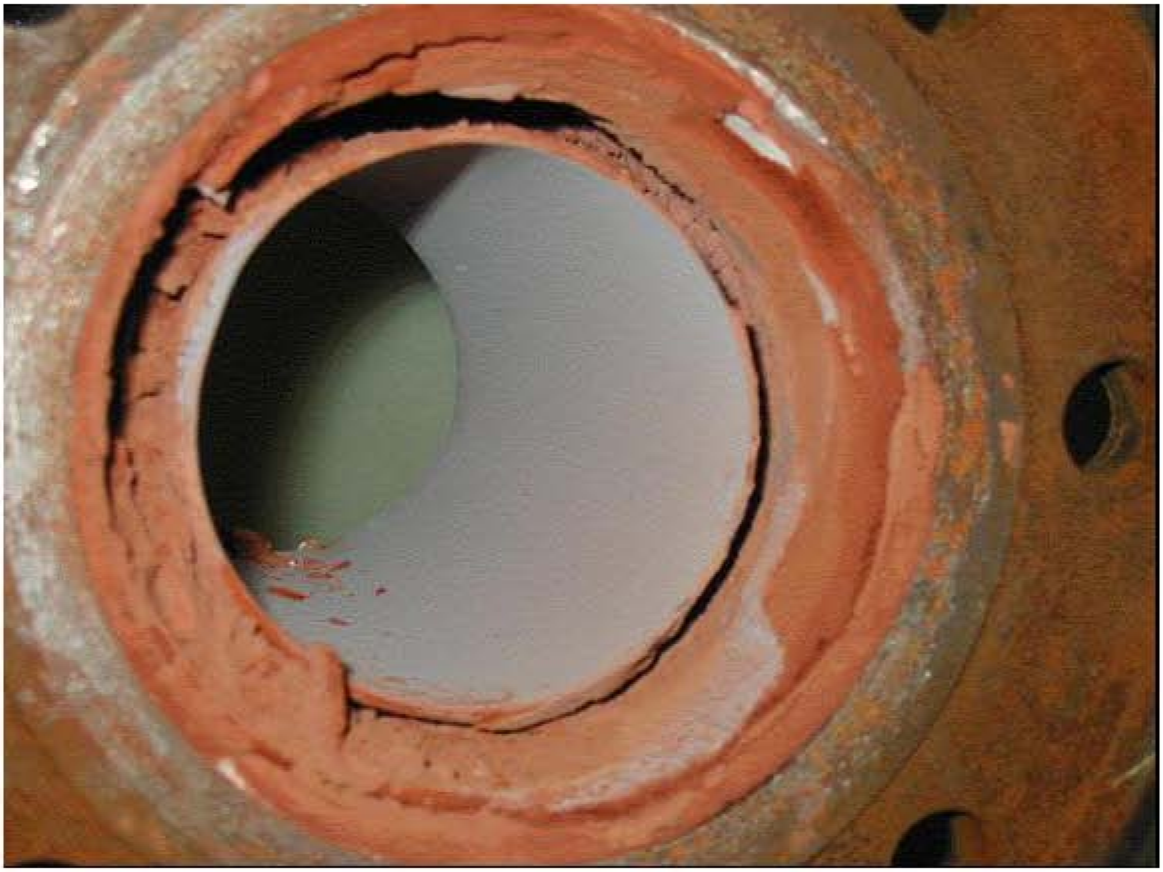


**Figure 4.33. Transition line bellows outlet after tests with HLW C-104/AY-101 simulants [28].**

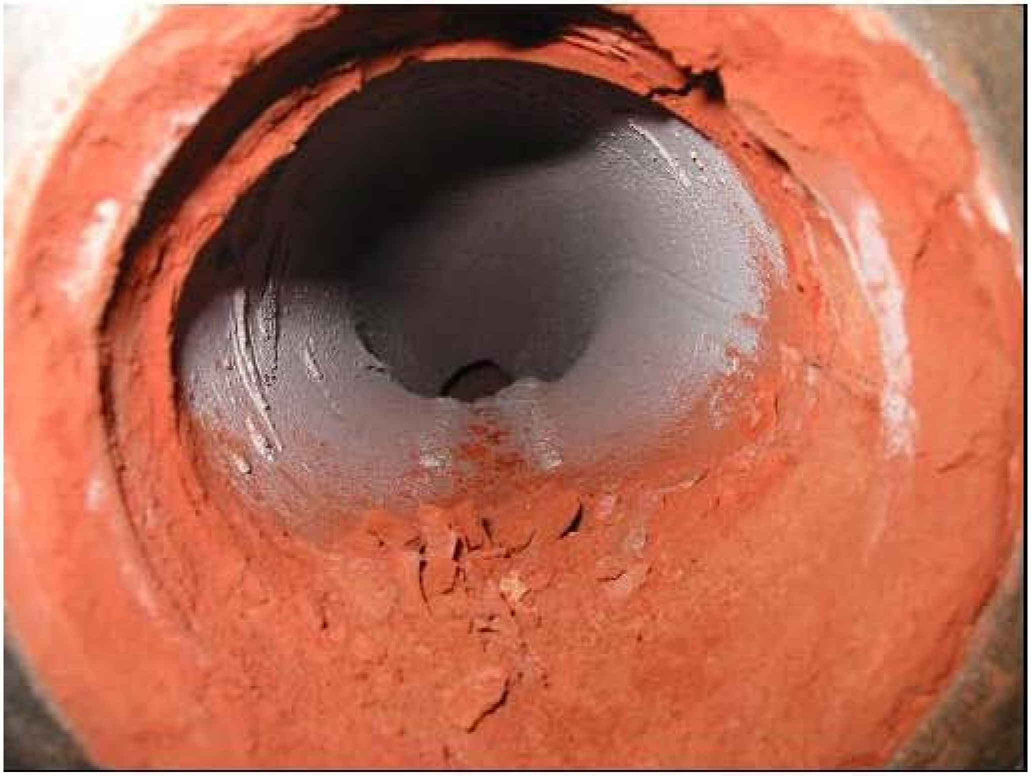


**Figure 4.34. SBS transition line inlet after tests with HLW C-104/AY-101 simulants [28].**

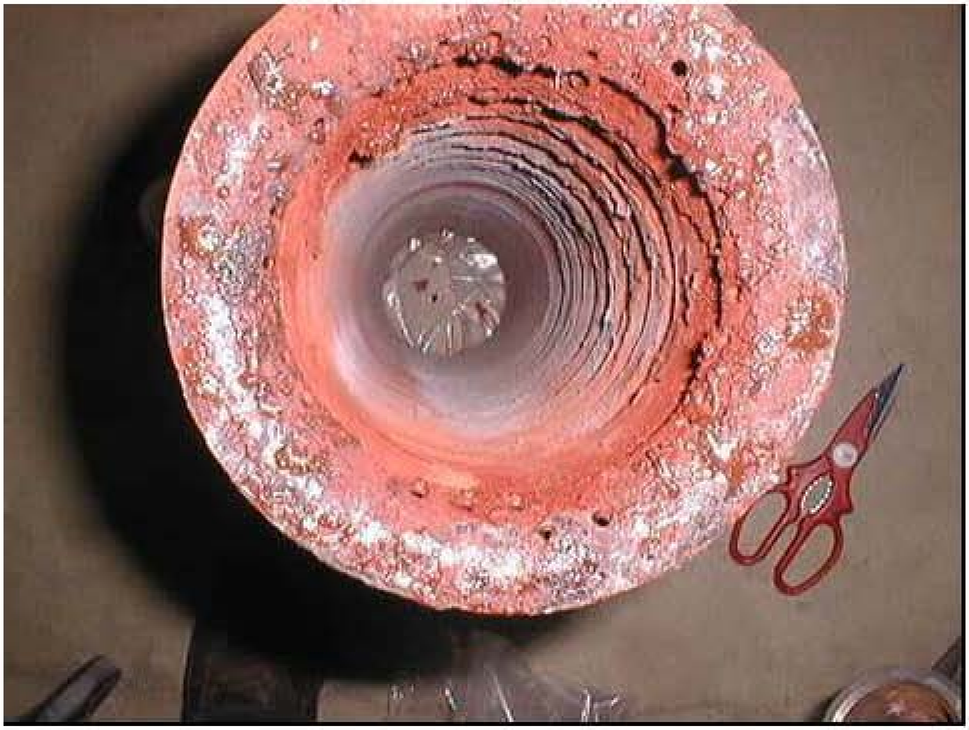


**Figure 4.35. Film cooler inlet after Configuration Test 2 [30].**

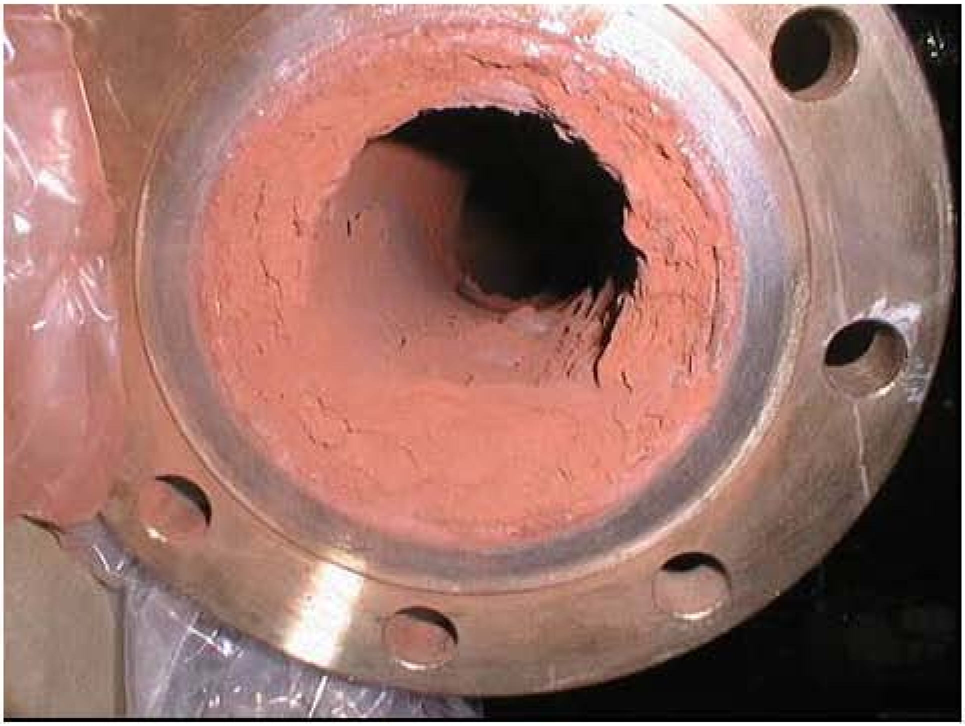


**Figure 4.36. Transition line section #1 outlet after Configuration Test 2 [30].**

**Figure 4.37. Transition line section #2 inlet after Configuration Test 2 [30].**

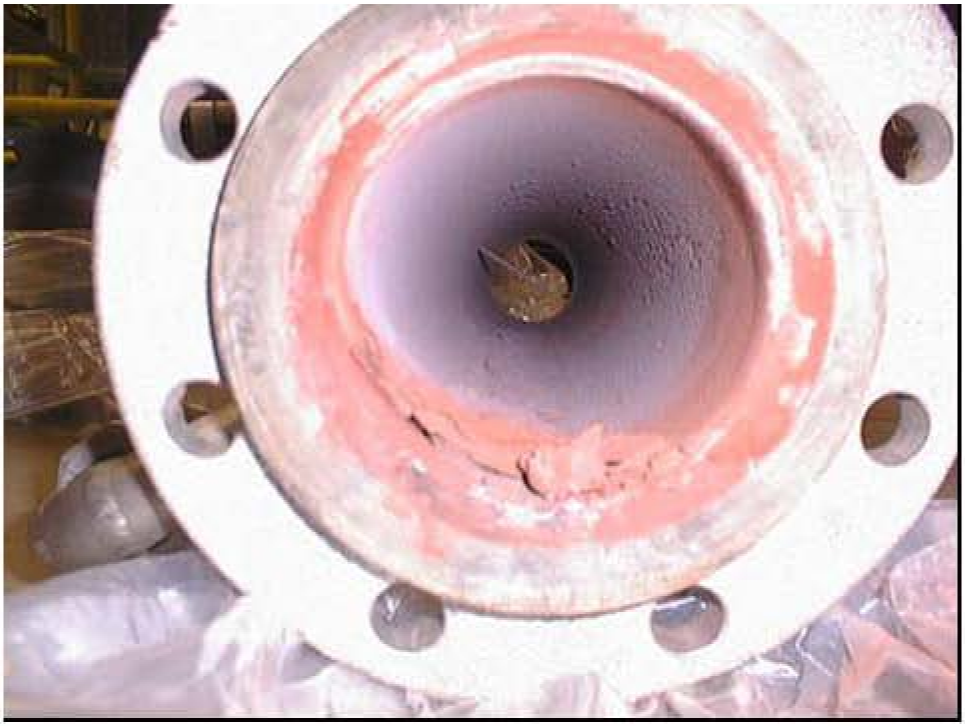


**Figure 4.38. Transition line section #3 inlet after Configuration Test 2 [30].**

Figure 4.39. Transition line bellows inlet after Configuration Test 2 [30].

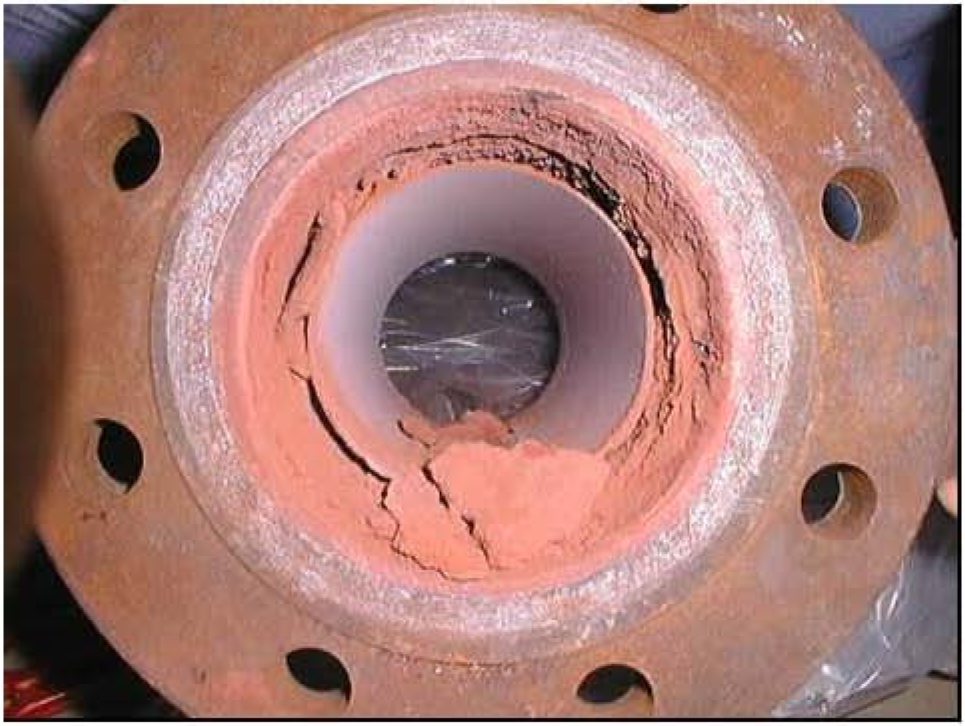


**Figure 4.40. Transition line bellows outlet after Configuration Test 2 [30].**

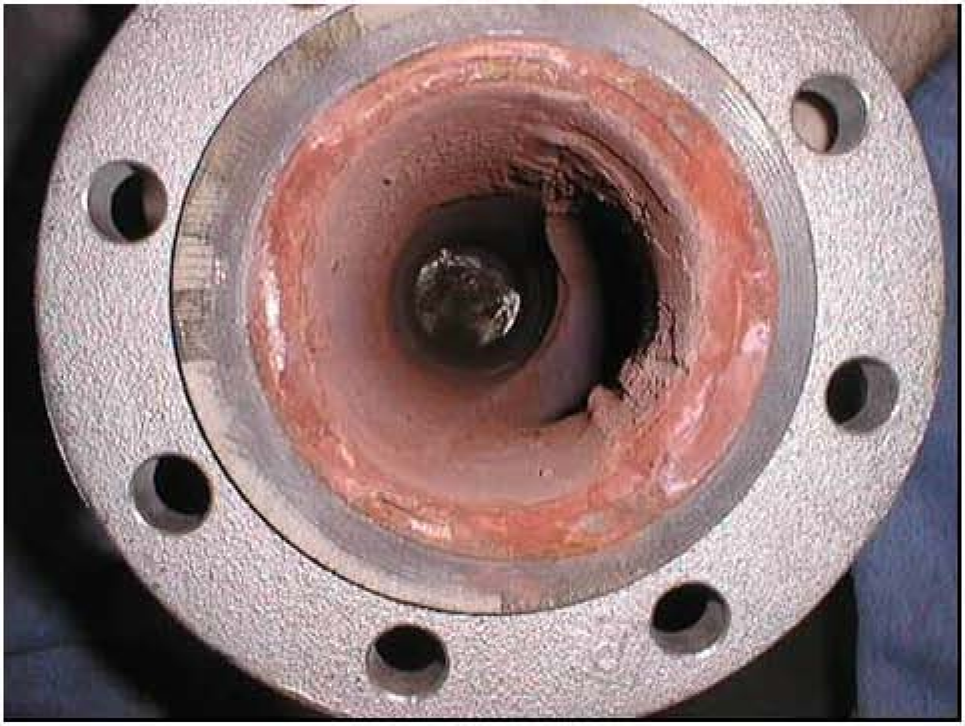


**Figure 4.41. Outlet of transition line section in between bellows and SBS inlet after Configuration Test 2 [30].**

**Figure 4.42. Transition line bellows inlet after Configuration Test 1 [30].**

**Figure 4.43.a. View of large debris removed from transition line bellows inlet during Configuration Test 3 [30].**

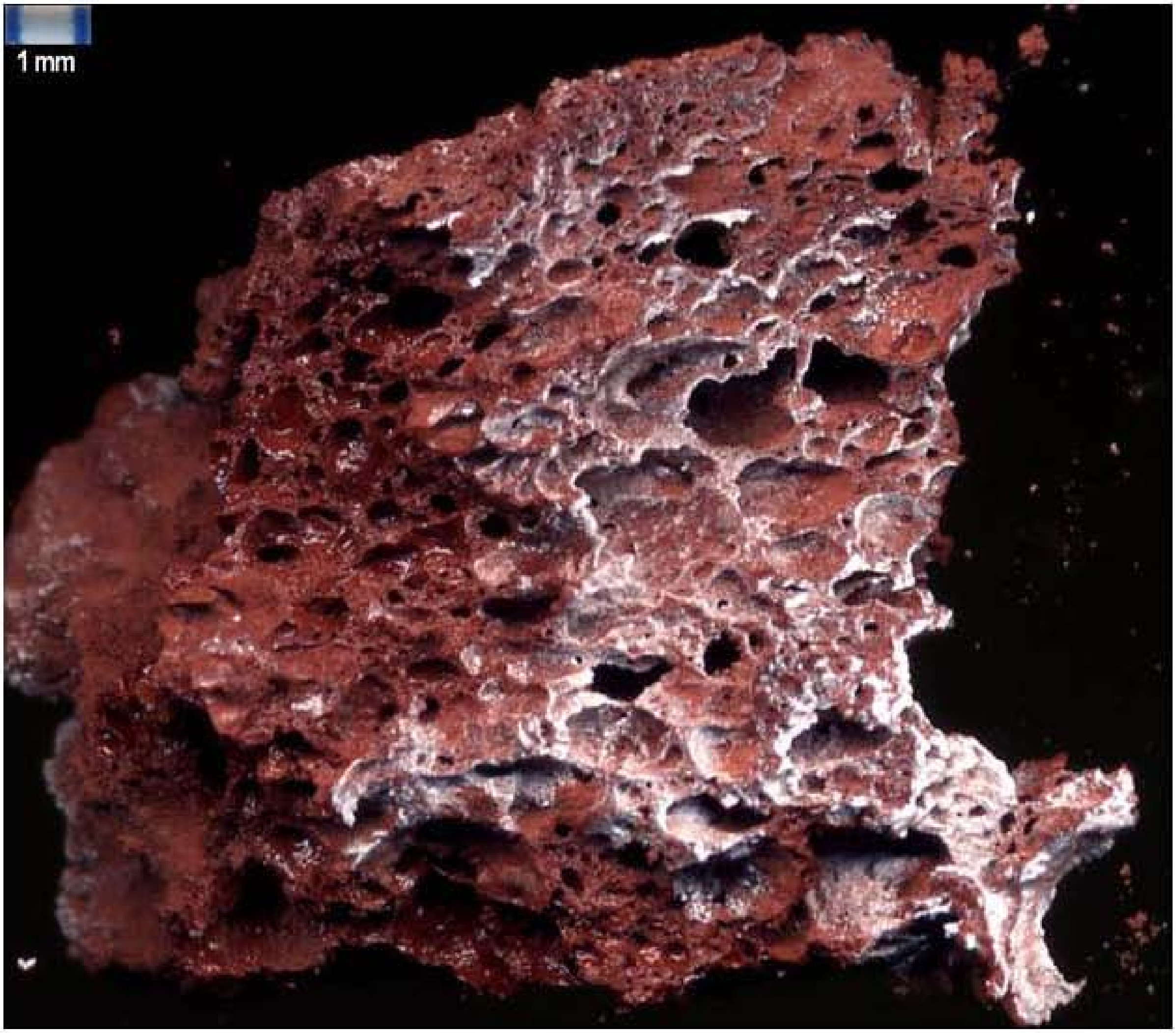


**Figure 4.43.b. Macro image of sample removed from the transition line during Configuration Test 3 [30] (Sample # 1D2-O-25A).**

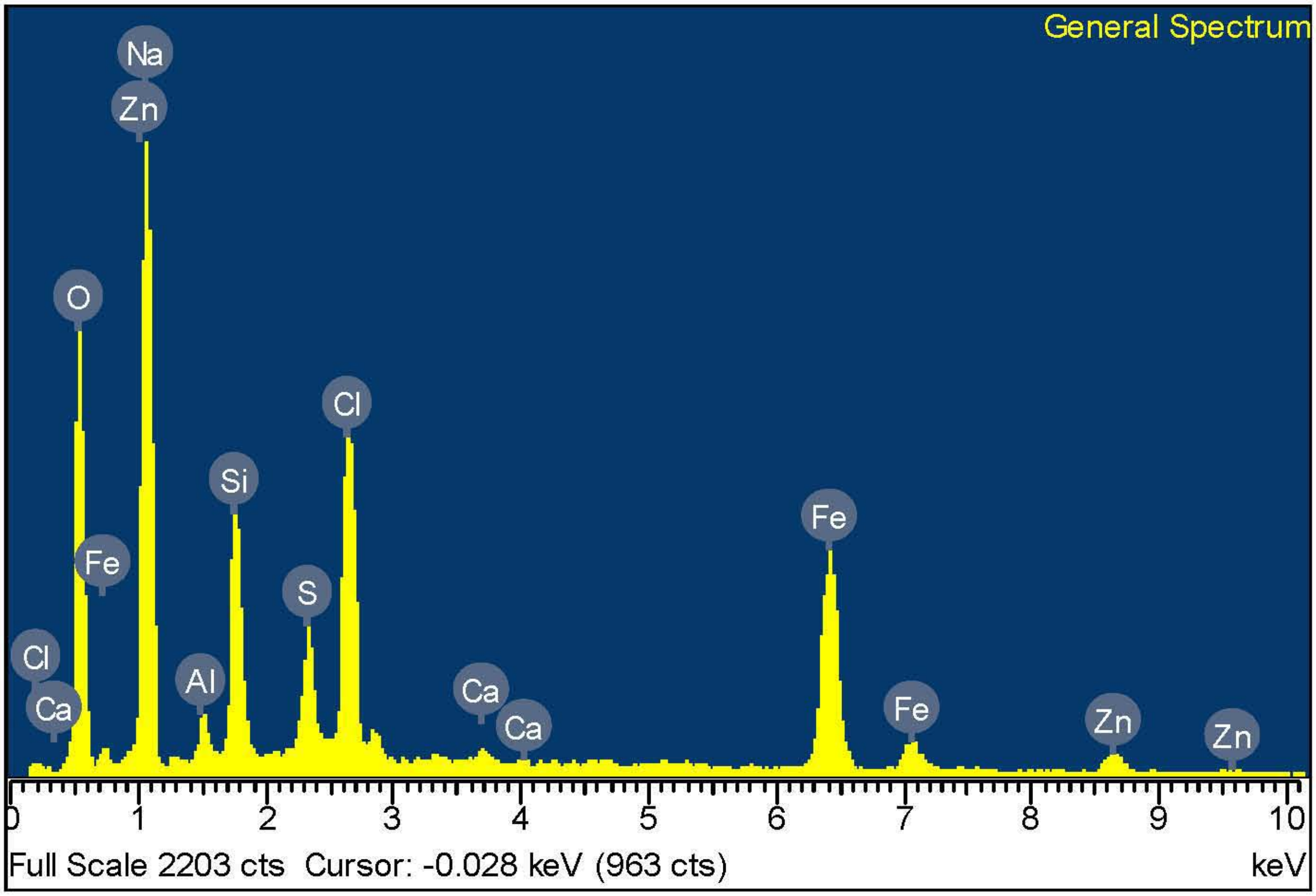


**Figure 4.43.c. EDS spectrum of the transition line sample (Sample # 1D2-O-25A).**

**Figure 4.44. Close-up of clogged perforation of film cooler inlet after Configuration Test 3 [30].**

**Figure 4.45. Film cooler inlet after Configuration Test 10 [30].**

**Figure 4.46. Close-up of film cooler inlet after Configuration Test 10 [30].**

**Figure 4.47. Transition line section #1 outlet after Configuration Test 10 [30].**

**Figure 4.48. Transition line section #2 inlet after Configuration Test 10 [30].**

**Figure 4.49. Transition line section #3 inlet after Configuration Test 10 [30].**

**Figure 4.50. Transition line section #3 outlet after Configuration Test 10 [30].**

**Figure 4.51. Transition line bellows inlet after Configuration Test 10 [30].**

**Figure 4.52. Transition line bellows outlet after Configuration Test 10 [30].**

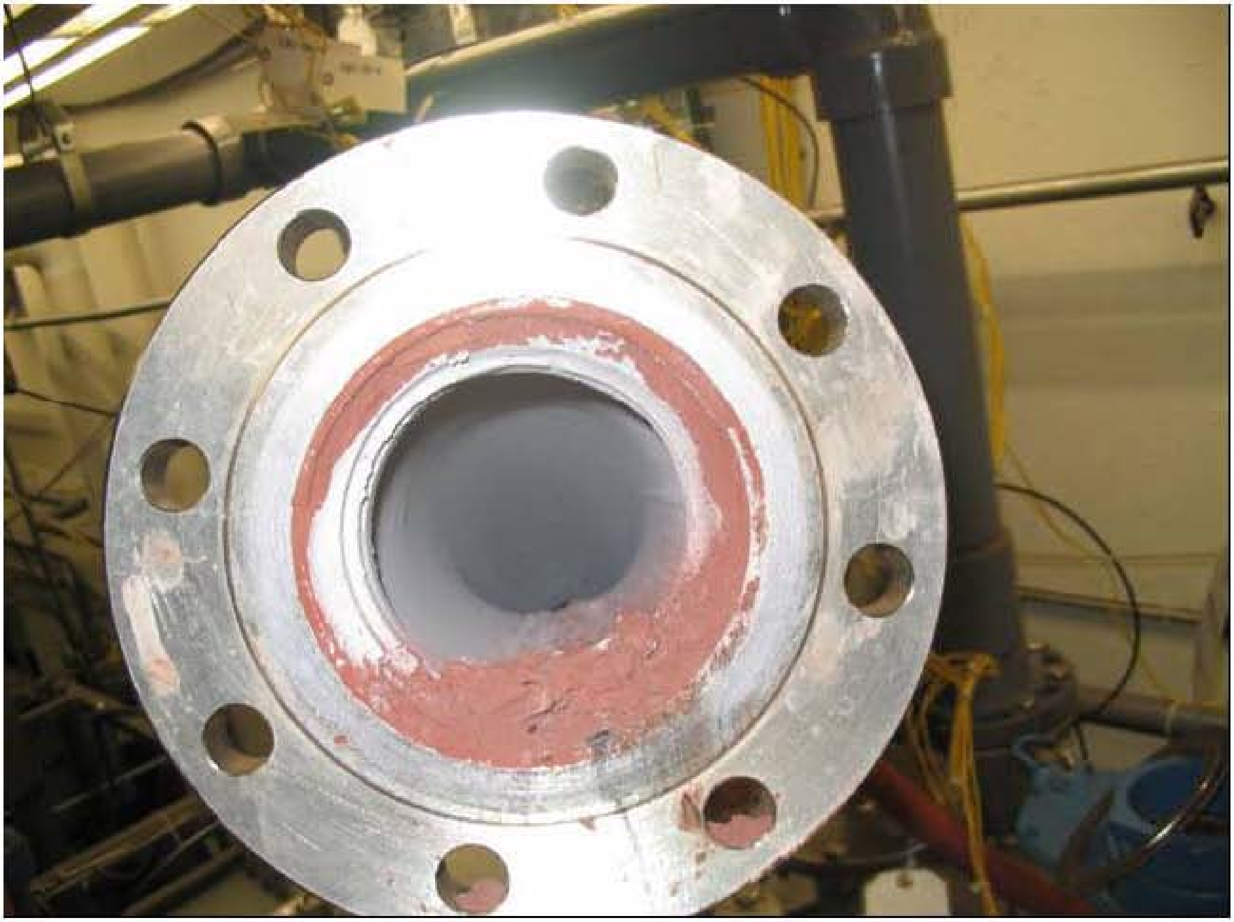


**Figure 4.53. Inlet of transition line section in between bellows and SBS inlet after Configuration Test 10**

**Figure 4.54. Film cooler inlet (post-cleaning) after Configuration Test 10 [30].**

**Figure 4.55. Film cooler inlet and internals after Configuration Test 9 [30].**

**Figure 4.56. Inlet of transition line section in between bellows and SBS inlet (on bellows side) after Configuration Test 9 [30].**

**Figure 4.57. View of film cooler inlet and internals (partial post-cleaning) after Configuration Test 9 [30].**

**Figure 4.58. Transition line section #2 outlet after Foaming Test [31].**

**Figure 4.59. Close-up of transition line section #2 oulet after Foaming Test [31].**

**Figure 4.60. Transition line section #3 inlet after Foaming Test [31].**

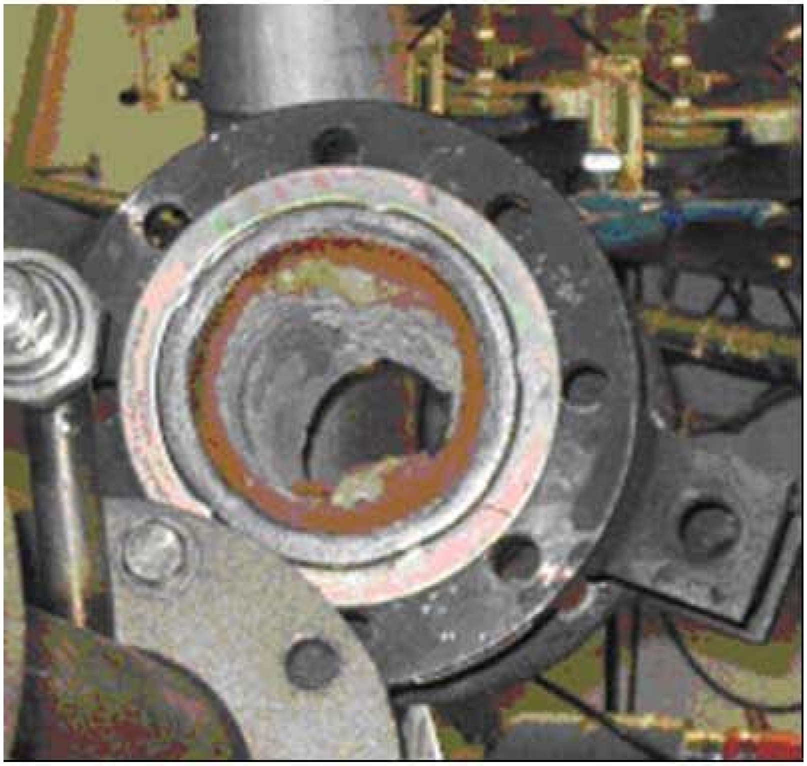


**Figure 4.61. Transition line bellows at 26.9 hours of HLW Turnover Test following the MACT tests [41].**

**Figure 4.62. Inlet of transition line section in between bellows and SBS inlet at 26.9 hours of HLW Turnover Test following the MACT tests [41].**

**Figure 4.63. Film cooler inlet after HLW Turnover Test following the MACT tests [41].**

**Figure 4.64. Tip of the film cooler inlet showing damage after HLW Turnover Test following the MACT tests [41].**

**Figure 4.65. Close-up view of inlet and louvers of the film cooler after HLW Turnover Test following the MACT tests [41].**

**Figure 4.66. Film cooler outlet after HLW Turnover Test following the MACT tests [41].**

**Figure 4.67. View of bottom end of film cooler (post-cleaning) after Configuration Tests [30] (bottom) and HLW Turnover Test following the MACT tests [41] (top).**

**Figure 4.68. Close-up view of bottom end of film cooler (post-cleaning) after HLW Turnover Test following the MACT tests [41].**

**Figure 4.69. Transition line section #1 inlet after HLW Turnover Test following the MACT tests [41].**

**Figure 4.70. Transition line section #1 outlet after HLW Turnover Test following the MACT tests [41].**

**Figure 4.71. Transition line section #2 outlet after HLW Turnover Test following the MACT tests [41].**

**Figure 4.72. Transition line section #3 inlet after HLW Turnover Test following the MACT tests [41].**

**Figure 4.73. Solids that fell out of Transition line section #3 after HLW Turnover Test following the MACT tests [41].**

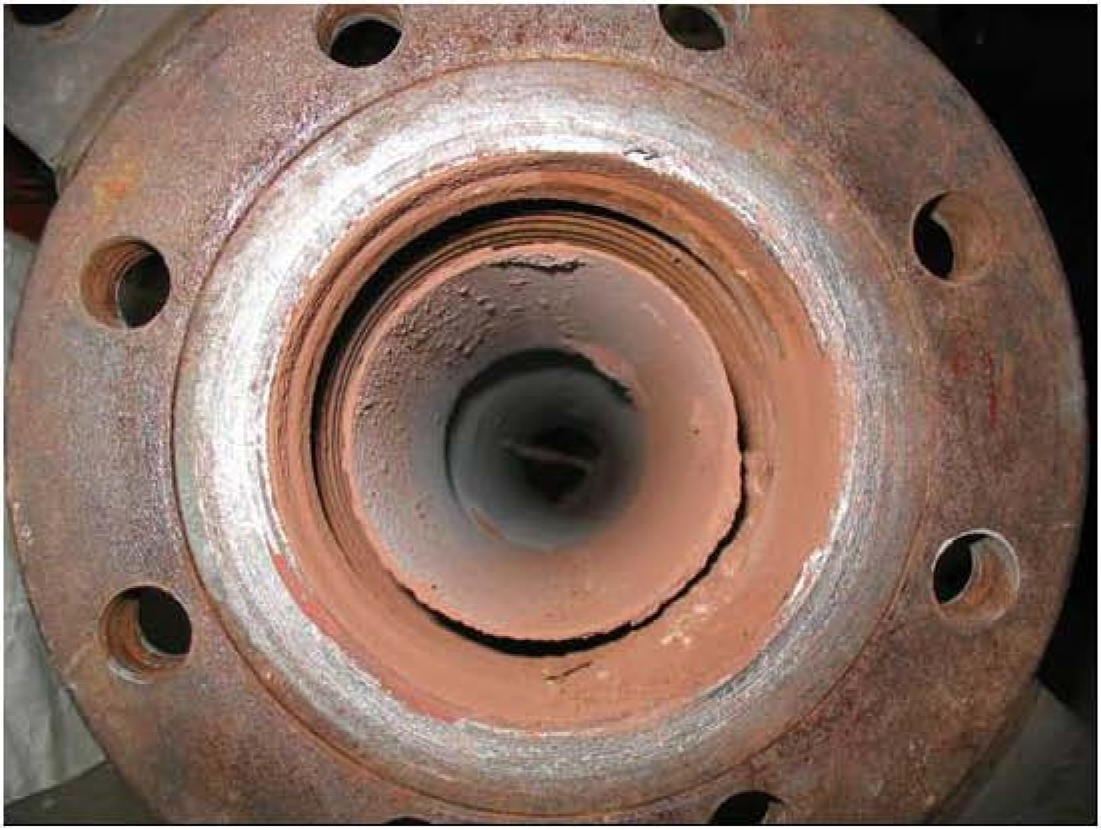


**Figure 4.74. Transition line bellows outlet after HLW Turnover Test following the MACT tests [41].**

**Figure 4.75. Inlet of transition line section in between bellows and SBS inlet after HLW Turnover Test following the MACT tests [41].**

**Figure 4.76. Outlet of transition line section in between the bellows and SBS inlet after HLW Turnover Test following the MACT tests [41].**

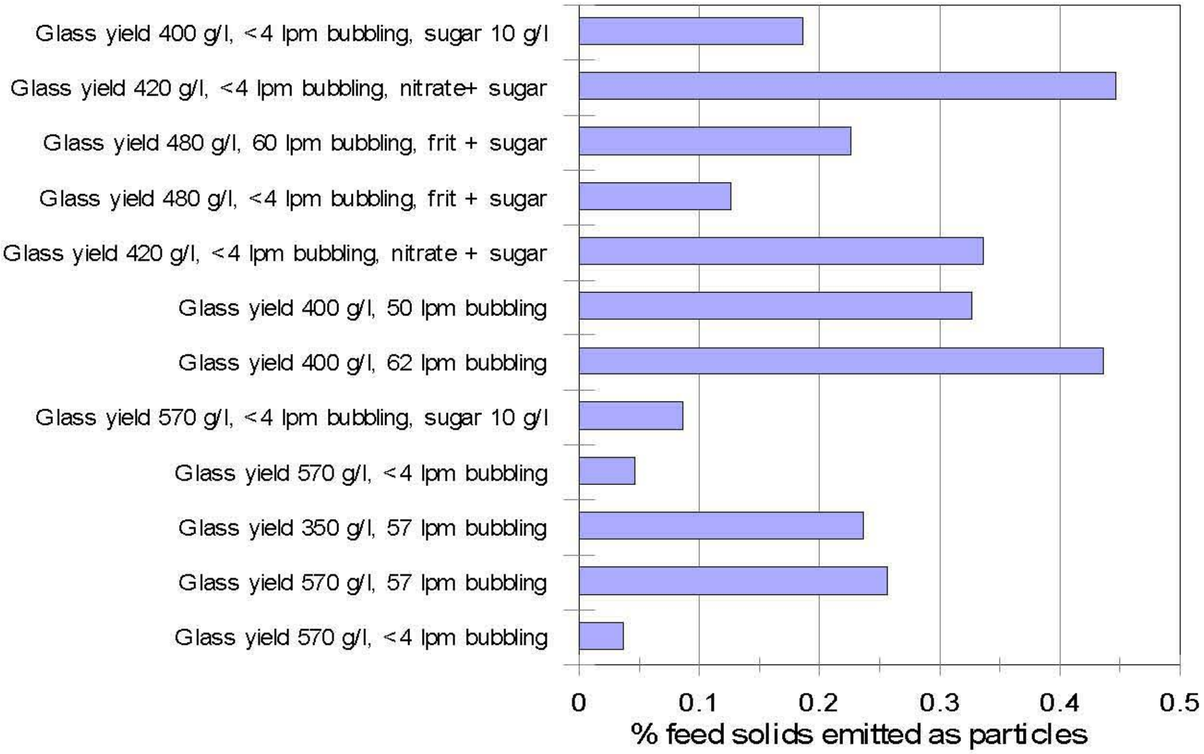


**Figure 5.1. Carryover from the DM1200 during initial HLW AZ-101 tests [3, 9].**

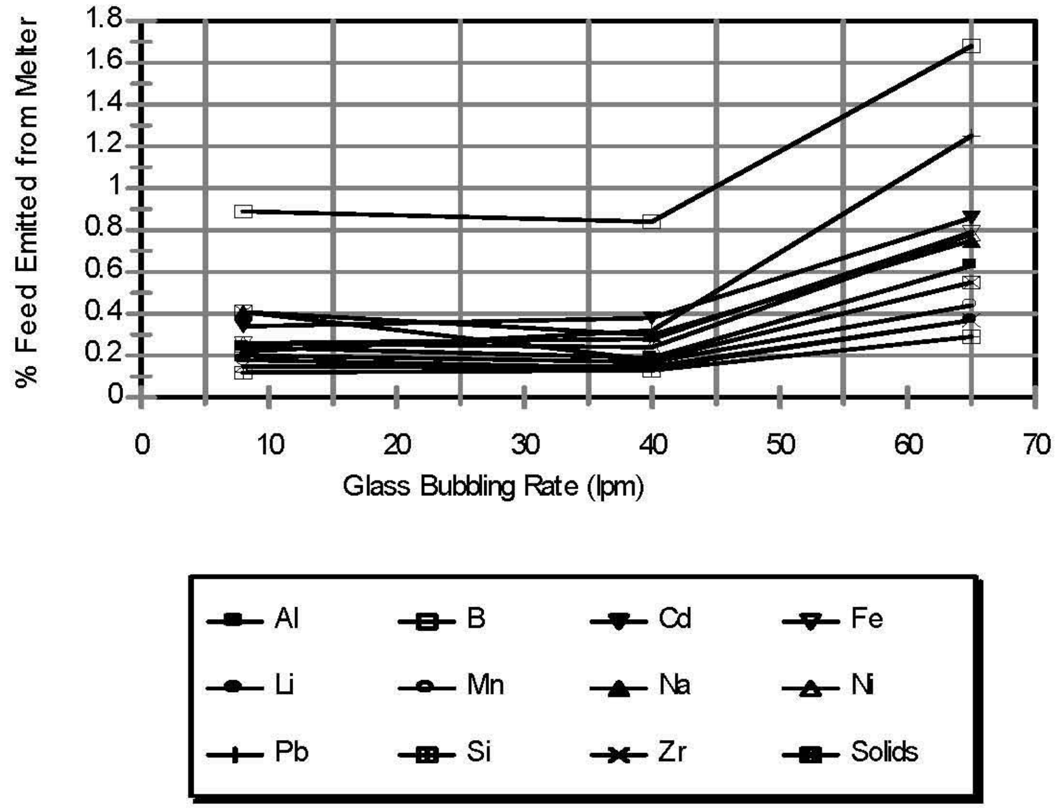


**Figure 5.2. DM1200 emissions during HLW AZ-101 tests [17] conducted with feed at 530 g glass per liter and two single outlet bubblers.**

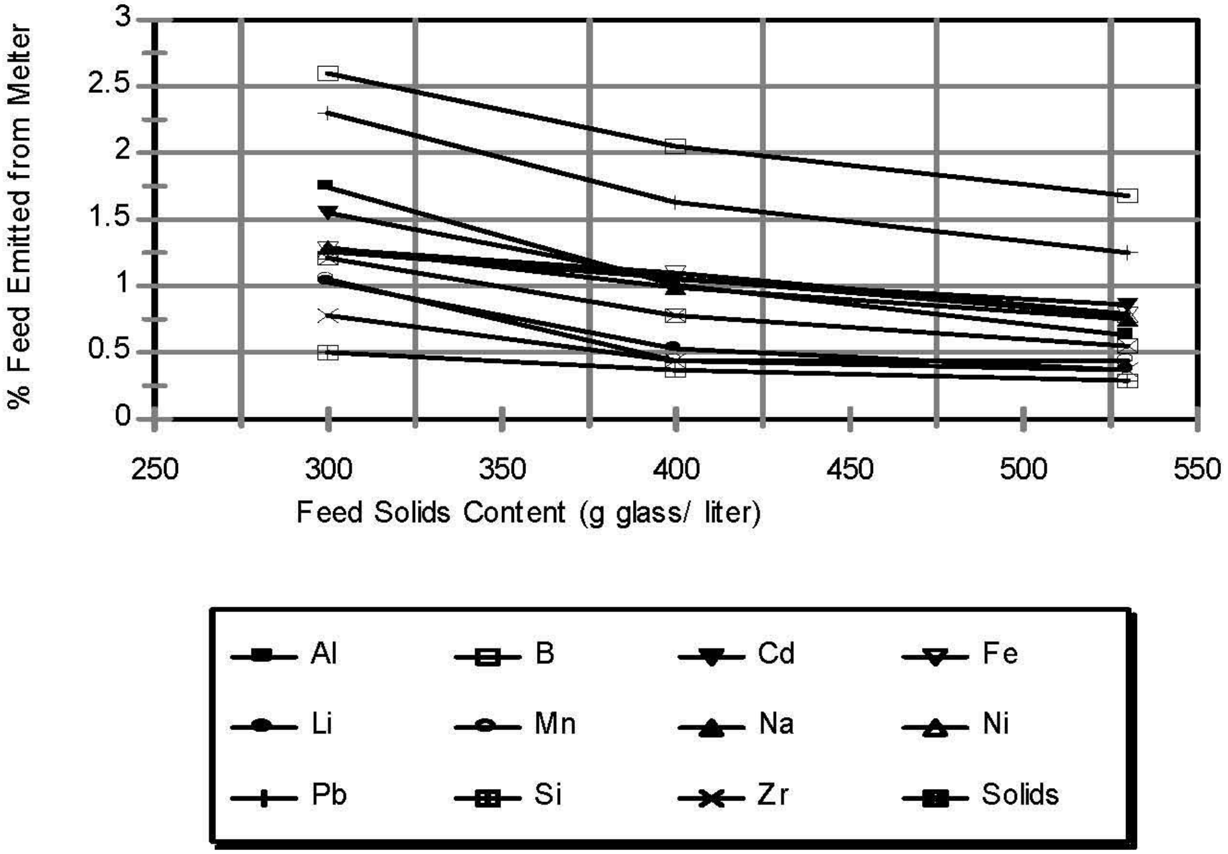


**Figure 5.3. DM1200 emissions during HLW AZ-101 tests [17] conducted with two single outlet bubblers at a total constant flow of 65 lpm.**

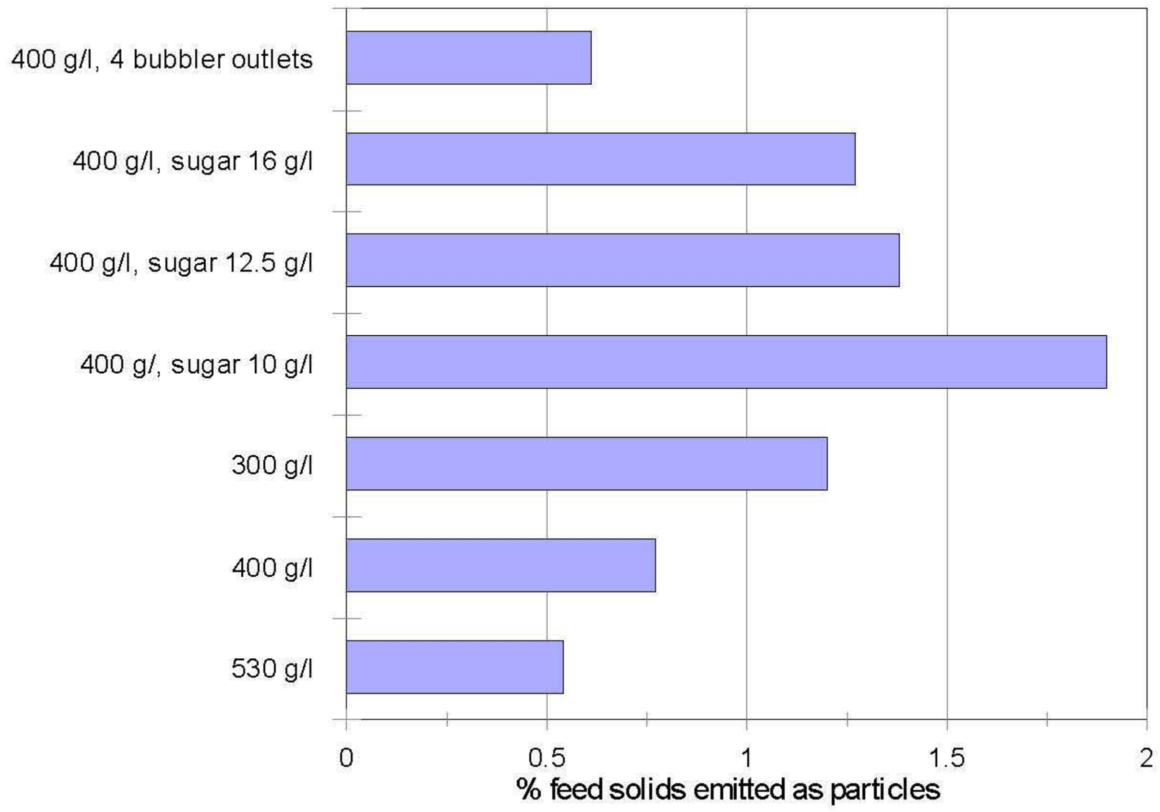


**Figure 5.4. Carryover from the DM1200 during HLW AZ-101 tests [17, 29, 30] conducted with a total constant flow of 65 lpm.**

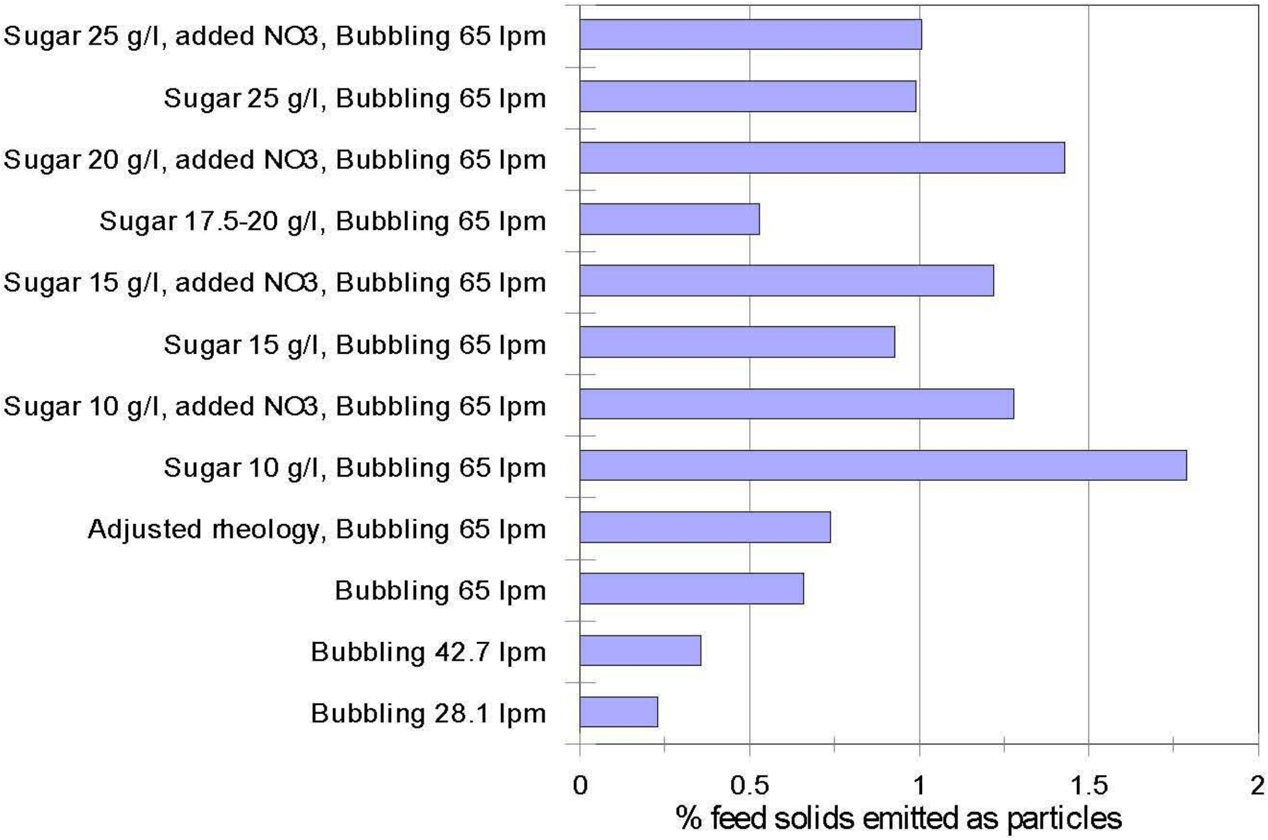


**Figure 5.5. Carryover from the DM1200 during HLW C-106/AY-102 tests [17, 29, 35, 41].**

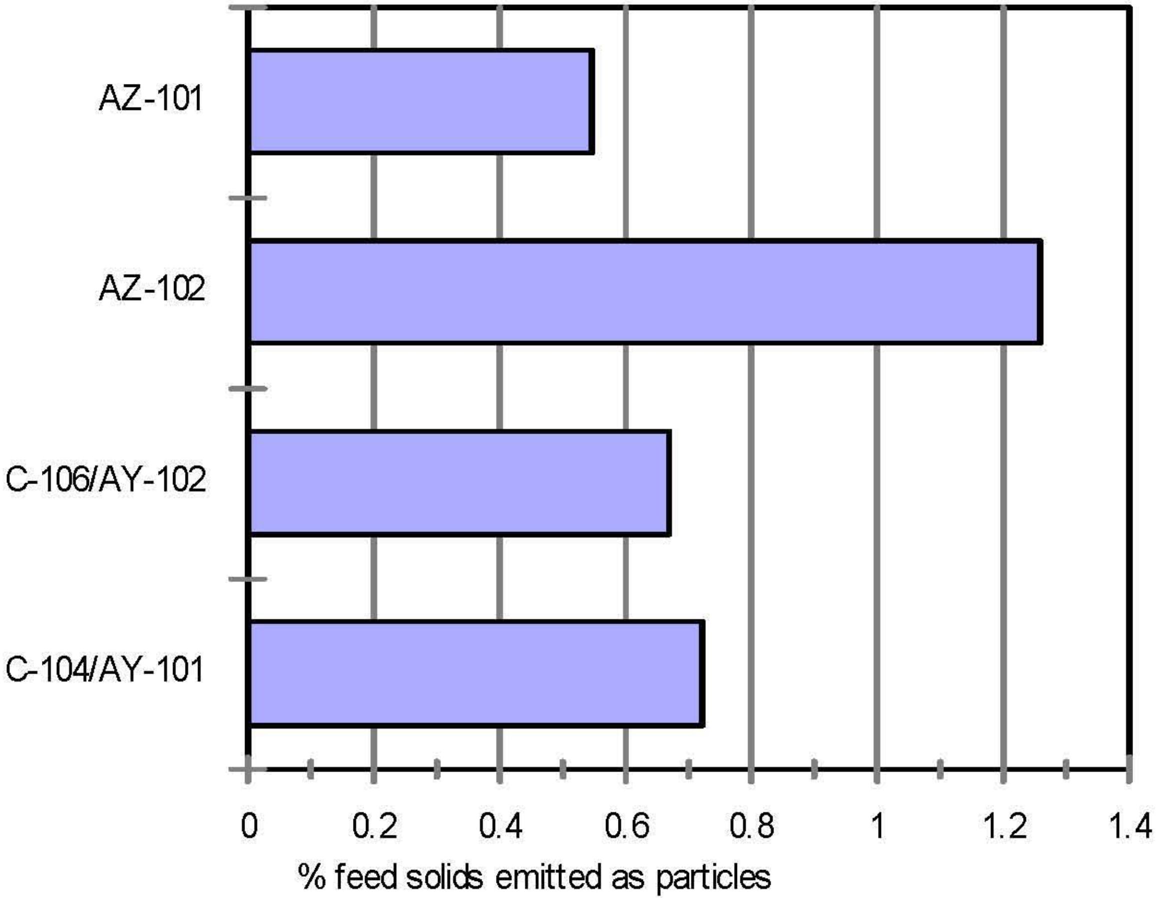


**Figure 5.6. Carryover from the DM1200 during HLW tests [17, 26, 28, 29] conducted with two single outlet bubblers at a total constant flow of 65 lpm.**

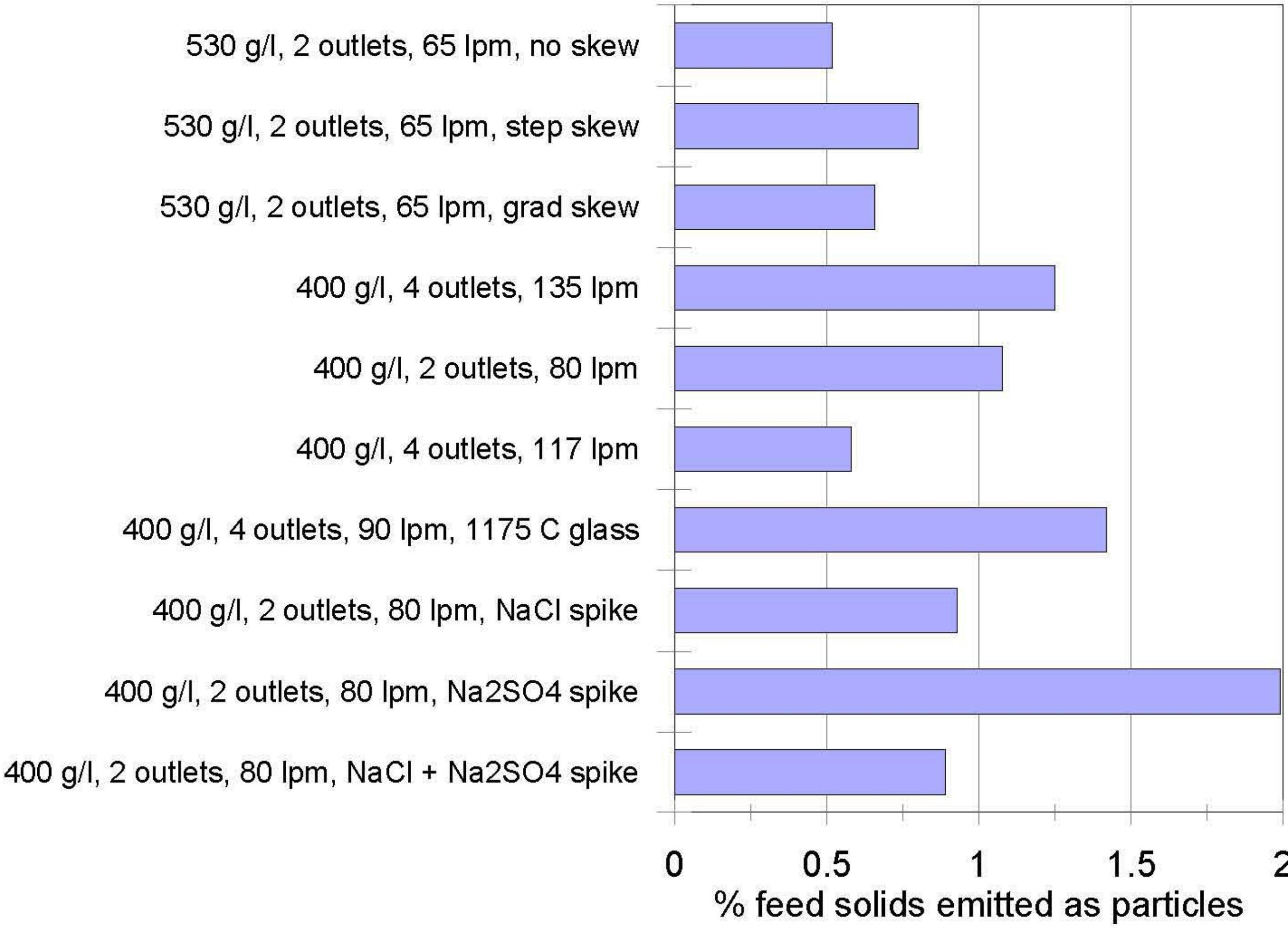


**Figure 5.7. Carryover from the DM1200 during HLW AZ-101 Configuration Tests [30].**

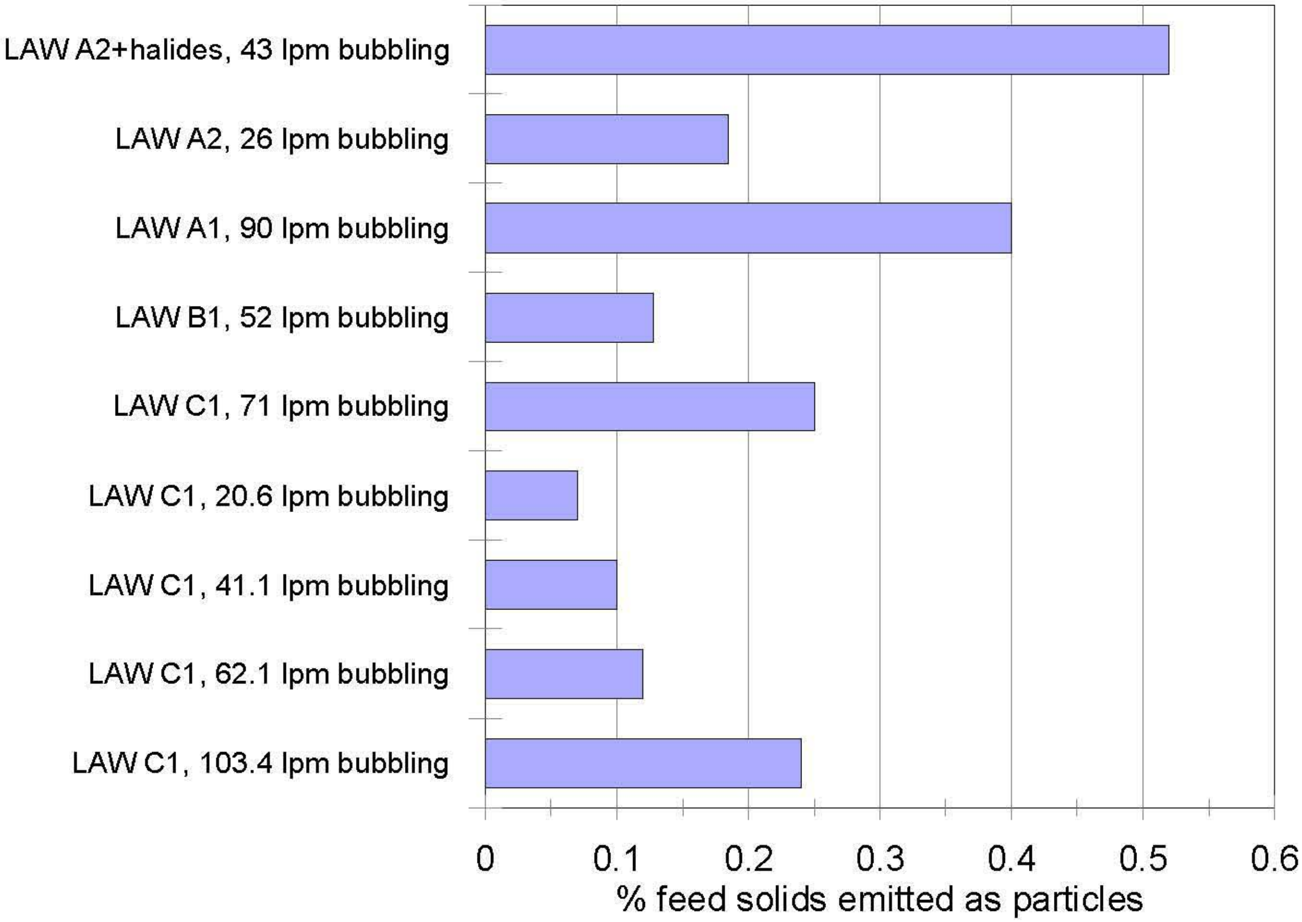


**Figure 5.8. Carryover from the DM1200 during LAW tests [10, 14, 21, 31, 41].**

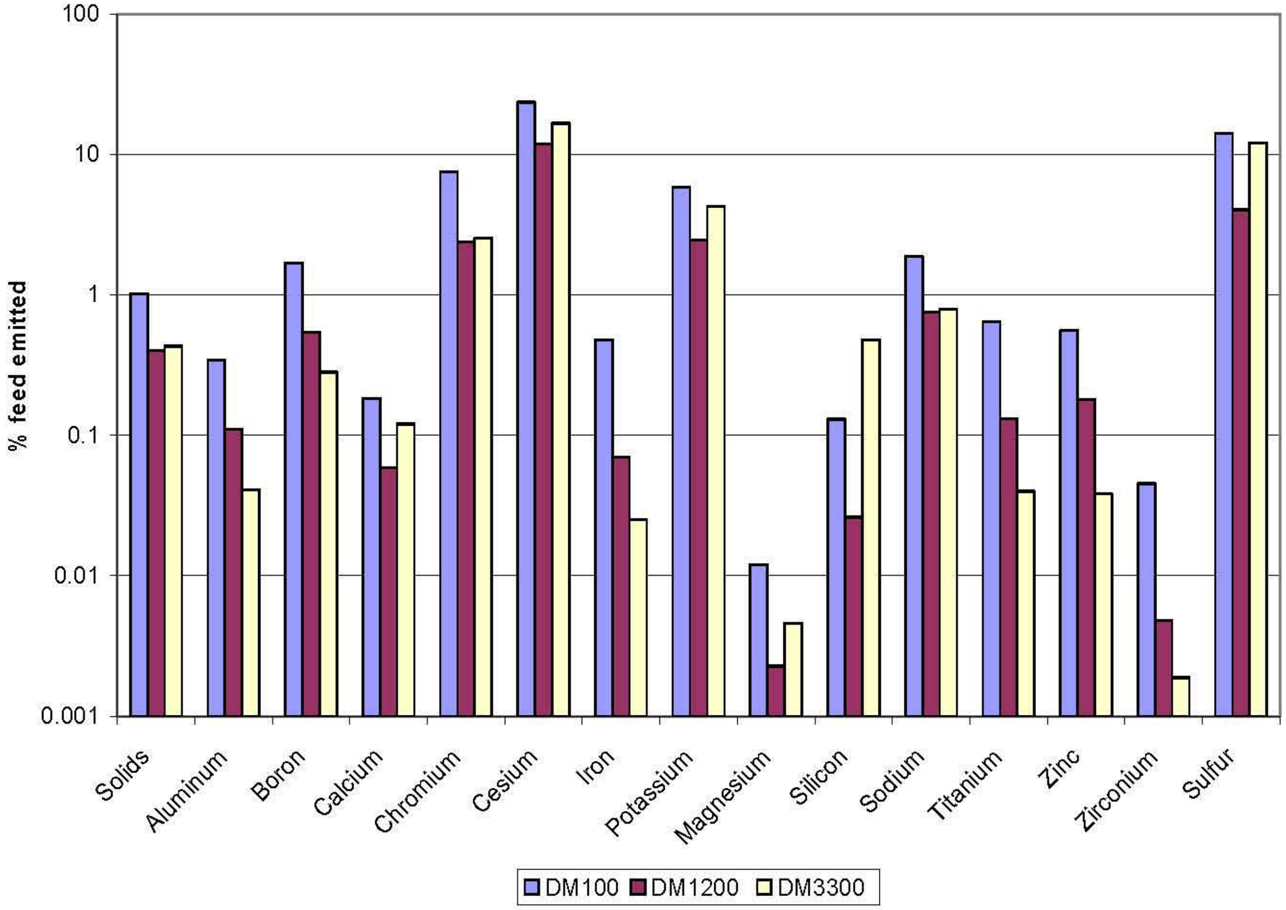


**Figure 5.9. DM1200 emissions during LAW Sub-Envelope A1 tests [14, 46].**

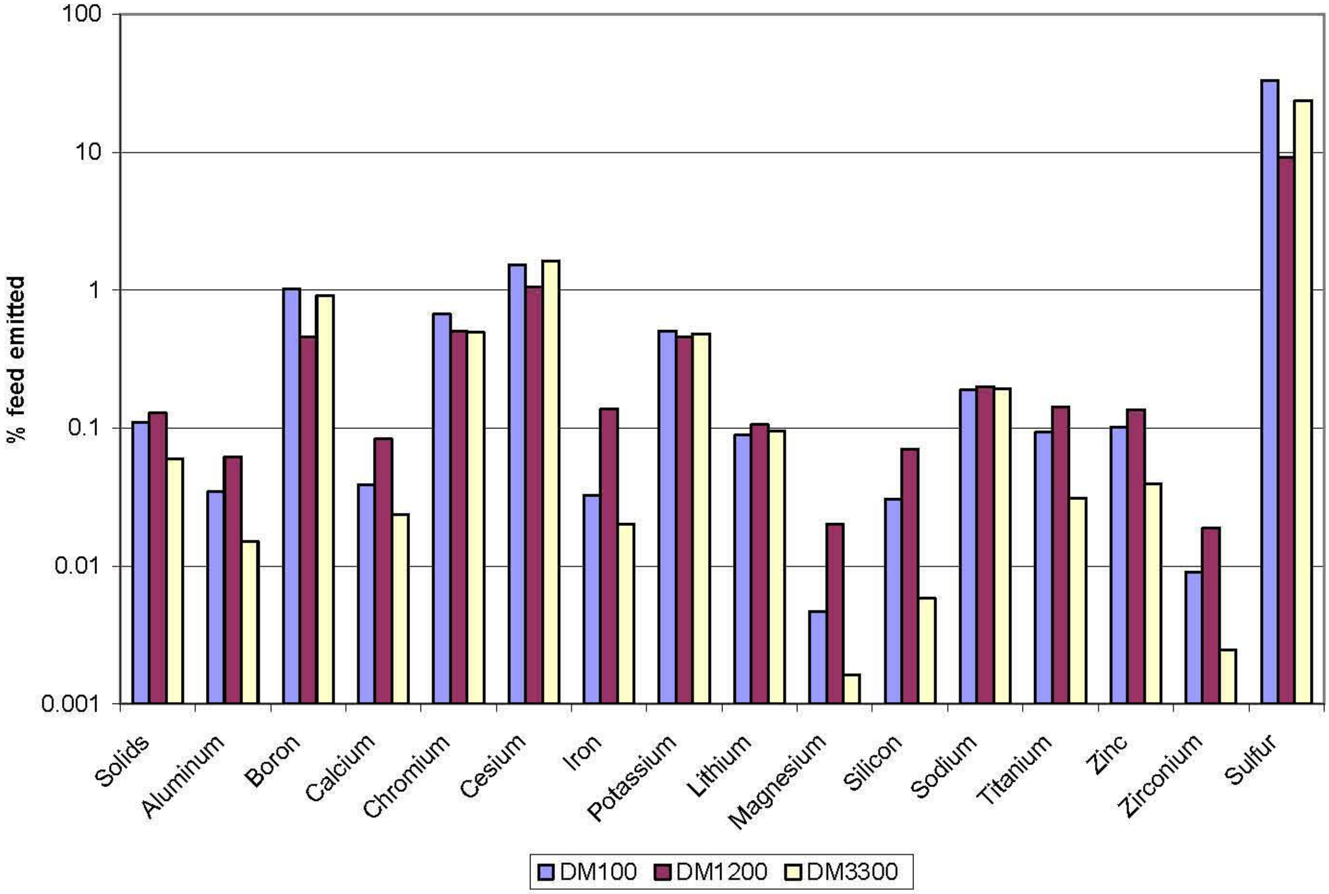


**Figure 5.10. DM1200 emissions during LAW Sub-Envelope B1 tests [21, 46].**

# R&T Technology
# Issues Summary

Page 1 of 1

**Test Report Title:** Summary of DM1200 Operations at VSL

**Test Report Number:** VSL-06R6710-2

**Prepared By:** Lawrence Petkus **Date:** September 29, 2006

**Signature:** Lawrence Petkus 9/29/06

VJ 9/29

| | Yes | No |
|---|---|---|
| Does the Testing or Report reveal any new discoveries, technology issues, or suggest potential follow-on work? | ☒ | ☐ |

If yes, describe the suggested activity.

See attached

| | Yes | No |
|---|---|---|
| If appropriate, is a Request for Technology Development attached. | ☐ | ☒ |

Additional comments (include researcher recommendations):

**See Attached**

Suggested Activities

1. These tests showed that significant improvements in HLW glass production rates could be achieved by refining the bubbler configurations, even when this refinement is subject to the significant constraints imposed by the existing melter lid design. These improvements appear to be sufficient to more than make up for the production rate short-fall brought about by the reduction in the solids content in the HLW feed from pretreatment from 20 wt% to 15 wt% undissolved solids. However, attainment of the target rate was not possible for all HLW simulants after yet further reduction in feed solids content. Attempts to achieve the target rate with low solids content HLW feed resulted in unstable melter conditions and frequent blockages of the film cooler. Overall, the success demonstrated to date suggests that there is considerable further scope for HLW production rate enhancement.

2. The observed differences in processing rates for different waste compositions for adjusted rheology feeds and lower solids content feeds underscores the need for pilot-scale production rate testing across the full range of feed compositions and likely solids contents.

3. Film cooler clogging events continued to be a significant operational problem; their frequency appeared to increase with bubbling rate and glass production rate. Feeds with low solids contents further exacerbate this issue because of the need for increased bubbling rates in order to maintain glass production rates. None of the film cooler washing procedures were effective for preventing clogging with HLW feeds. No mechanical cleaning device has been tested. Consequently, this would appear to be a significant issue with respect to the ability of the WTP to meet HLW throughput requirements. These findings have been reported to the WTP Project and decisions regarding resolution are pending.

4. Per WTP Project direction, maintaining a cold cap limited feed rate during DM1200 tests was dependent on frequent visual monitoring of conditions in the melter. In contrast, operation of the WTP melters will be based only on non-visual data, such as plenum temperature. This could lead to either under feeding of the melter, resulting in under-achievement of otherwise attainable production rates, or over feeding of the melter, resulting in excessive cold-cap buildup as well as other operational difficulties. Testing under such conditions is therefore recommended to determine whether the required glass production rates can be achieved without employing the artificial visual data.

R&T Comments

1. Acceptable production rates were obtained for the contract feeds at between 20 wt % and 15 wt % undissolved solids using bubbler rates which are sustainable in the melter. WTP initiatives have started to look at other potential feeds, additional bubblers, and at the Pretreatment system's ability to deliver feed to Vitrification at flow sheet rates and concentrations.

2. Feeds of different rheology were processed. The thicker, non-Newtonian feeds demonstrated higher production rates, so that testing results are probably conservative (low). Feeds beyond the four contract tanks are not within the scope of this work.
3. A film cooler cleaner is included in the WTP design baseline. An assessment of plugging potential is being made based on expected feed composition (wt % solids), bubbler rated to achieve production, and the number of available bublers.
4. Observations were used as part of the control strategy for the test melters to assure that test parameters were maintained. The melter design has provisions for a CCTV camera in the lid, however, more recently, remote camera design and procurement has been put on hold. No scope has been identified to mitigate the lack of available observation. It has been identified as a start up issue.

# R&T Subcontractor Document Review Record

Page 1 of 1

| **1) To Be Completed by Cognizant R&T Personnel** | | |
|---|---|---|
| Document Number<br>VSL-06R6710-2 | Revision<br>A | Document Title<br>Summary of DM1200 Operations at VSL |
| Test Spec: Various | | Scoping Statement(s): VH-4, VHO-3, VHO-1, VLO-5, VLO-1 |

R&T Contact: Lawrence Petkus (Name (Print)) | MS6-N1 (MSIN) | 371-4557 (Telephone Number) | July 11, 2006 (Date)

**Review Distribution**

| **Organization** | **Contact** | **MSIN** | **Required?** |
|---|---|---|---|
| Process Engineering | T Valenti | MS4-C1 | Yes ☒ No ☐ |
| Quality Assurance | M Mitchell | MS14-4A | Yes ☐ No ☒ |
| Environmental and Nuclear Safety | E&NS Doc Rev | MS4-D2 | Yes ☐ No ☒ |
| Commissioning and Training | S Gourley | MS12-B | Yes ☐ No ☒ |
| Engineering | M Ongpin | MS4-A2 | Yes ☐ No ☒ |
| R&T Functional Manager | S Barnes | MS6-P1 | Yes ☒ No ☐ |
| | | | Yes ☐ No ☐ |
| | | | Yes ☐ No ☐ |
| | | | Yes ☐ No ☐ |
| | | | Yes ☐ No ☐ |

**Comments Due By:** July 26, 2006

*Required Reviewers are required to respond to the R&T Contact.*

**2) To be Completed by Reviewer**

Reviewer ____________________ Name (Print) ____________________ Organization ____________ Date

| | | | |
|---|---|---|---|
| ☐<br>Accepted,<br>No Comments | ☐<br>Accepted,<br>Comments Not Significant | ☐<br>Significant Comments, Form<br>24590-MGT-F00006 Attached | ☐<br>Significant Comments,<br>Comments Marked on Document |

**3) To be Completed by Reviewer***

My significant comments have been addressed.

Acceptance: ____________________ *Print/Type Name* ____________________ *Signature* ____________ *Date*

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

## Petkus, Lawrence

**From:** Valenti, Thomas
**Sent:** Tuesday, September 26, 2006 12:31 PM
**To:** Petkus, Lawrence
**Subject:** RE: DM1200 Summary Report VSL-06R6710-1

*Engineering and Process Engineering has reviewed and accepts resolution of comments to the subject summary report.*

Thomas J. Valenti

Process Engineering Group
MPF C120A
509/ 371-3760

-----Original Message-----
**From:** Petkus, Lawrence
**Sent:** Tuesday, September 26, 2006 12:21 PM
**To:** Valenti, Thomas
**Subject:** DM1200 Summary Report VSL-06R6710-1

Tom,
I have all of the individual acceptances, but not the final Engineering acceptance.

Larry Petkus
R&T, ETC-1
MS6-N1
Ph. 371-4557
<< Message: FW: Responses to Comments on DM1200 Summary Report, VSL-06R6710-2 >> << Message: RE: Responses to Comments on DM1200 Summary Report >> << Message: RE: Responses to Comments on DM1200 Summary Report >> << File: DM1200 ComResp - Proc Eng.doc >>

# *COMMENT RESOLUTION FORM*

Page 1 of 1

Return to: Lawrence Petkus

Comments Due: July 26, 2006

| | | | |
|---|---|---|---|
| Document Title: Summary of DM1200 Operations at VSL | Document No.<br>VSL-06R6710-2 | Revision:<br>A | Date:<br>July 11, 2006 |

| | | | | | |
|---|---|---|---|---|---|
| Reviewer:<br>L. Petkus for S. Barnes | Date:<br>July 27, 2006 | Response by: | Date: | Comments Resolved:<br>Lawrence Petkus | Date:<br>8/24/06 |

| Item No. | Section/ Paragraph | Comment | Significance[a] | "M" Comment Justification[B] | Response | Resolution |
|---|---|---|---|---|---|---|
| 1 | Summary G | Melter control based on visual monitoring is mentioned in the issues section, but not supported in the main body of the report. Add a section to discuss melter control issues. | I | | Agreed. Text will be added to Section 3.0 to discuss visual monitoring and melter control. | |
| 2 | 2.3.1 | Type K thermocouples will undergo a calibration shift when they at temperature for an extended period of time. Was there any noticeable temperature reading shift at change out ? Was change- out staggered to minimize the effect? | I | | We will add the rationale for changing thermocouples to the text. Data will be reviewed to determine if a shift occurred after routine thermocouple change outs. | |

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

[b] Justification required for Mandatory Comments.

Ref: 24590-WTP-GPP-MGT-007

**Petkus, Lawrence**

---

**From:** Randklev, Edward H [Edward_H_Randklev@RL.gov]
**Sent:** Thursday, September 28, 2006 3:31 PM
**To:** Petkus, Lawrence
**Cc:** Randklev, Edward H
**Subject:** FW: DM1200 Summary

Larry,

Thanks for checking on this matter for me. I am satisfied with the revised VSL phrasing regarding their reporting/concern about the lack of a demonstrated (workable) film cooler cleaning method, and I take your word for it that the Section 6 entry on this same topic was similarly revised by VSL.

With that I consider my primary review comment to be satisfactorily resolved.

Thanks,

Ed R.

---

**From:** Petkus, Lawrence [mailto:llpetkus@bechtel.com]
**Sent:** Thursday, September 28, 2006 2:45 PM
**To:** Randklev, Edward H
**Subject:** DM1200 Summary

Ed,
I checked your original comment S6. Duratek has added words that the project is looking at the resolution of the issue. Again, I have included excised section G. Section 6 uses the same words.

*Larry Petkus*
R&T, ETC-1
MS6-N1
Ph. 371-4557
<<Report Summary SecG.doc>>

**Petkus, Lawrence**

---

**From:** Randklev, Edward H [Edward_H_Randklev@RL.gov]
**Sent:** Thursday, August 24, 2006 5:35 PM
**To:** Petkus, Lawrence
**Cc:** Randklev, Edward H
**Subject:** FW: Response to Comments on VSL-06R6710-2 "Summary of DM1200 Operations at VSL"

Larry,

1) I have reviewed the VSL proposed responses to my review comments, and I find them to be acceptable except for the VSL proposed response to one comment.
2) The one exception, to my approval of the VSL responses, is in regards to my Comment S-6 and the VSL response. (Film cooler issue and the dramatic VSL conclusions about it, including potential WTP Contract requirement violation.)
a) You noted how BNI (R&T, et al) tracks, by separate reporting documentation, the issue that are brought to the attention of BNI R&T via contractor work, and then BNI efforts to resolve the issue. Sounds fine. I do not propose that this be included in this VSL report.
b) What I do propose, as an acceptable response/resolution path, regarding my comment, is that VSL at least include a statement in the report that notes that VSL has made recommendations to the WTP Project regarding resolution of this issue and Project decisions are pending. Without such a statement, a general reader is left to wonder if BNI is even paying attention to this dramatic conclusion.

I believe this simple additional statement needs to go into this report in <u>each location</u> where the VSL authors have made the dramatic conclusion that the issue of film cooler plugging, unless fixed, will result in the system not being able to meet the WTP Contract requirements on production throughput. (A very serious claim.) Examples of such locations include the Summary of Testing section (e.g. on page 14 next to their dramatic conclusion), and also in the Section 4.2.6 discussion on the MACT work (again put it next to the VSL claim that a lack of a method fix film cooler plugging is going to jeoprodize the WTP Contract requirement on throughput) and also include it in the Summary and Conclusions section (6.0).

Later,
Ed R.

---

**From:** Petkus, Lawrence [mailto:llpetkus@bechtel.com]
**Sent:** Tuesday, August 22, 2006 4:06 PM
**To:** Randklev, Edward H
**Subject:** Response to Comments on VSL-06R6710-2 "Summary of DM1200 Operations at VSL"

Ed,
Attached are the responses to you comments. Please let me know if these responses are acceptable.

*Larry Petkus*
R&T, ETC-1
MS6-N1
Ph. 371-4557
<<ORPcoms 8-22-6.doc>>

**Petkus, Lawrence**

---

**From:** Babel, Carol A [Carol_A_Babel@RL.gov]
**Sent:** Monday, July 31, 2006 10:51 AM
**To:** Petkus, Lawrence
**Cc:** Hamel, William
**Subject:** RE: Document Review: VSL-06R6710-2 "Summary of DM1200 Operation at VSL

Larry,

Thank you for the opportunity to review the draft report VSL-06R6710-2 "Summary of DM1200 Operation at VSL," Rev A., containing the history of the DM1200 Melter operation and development across many runs for both HLW and LAW. These summary reports are very useful for the project. I have no comments at this time.

Carol

---

**From:** Petkus, Lawrence [mailto:llpetkus@bechtel.com]
**Sent:** Wednesday, July 12, 2006 7:28 AM
**To:** Babel, Carol A; Randklev, Edward H
**Subject:** Document Review: VSL-06R6710-2 "Summary of DM1200 Operation at VSL

Carol and Ed
VSL has submitted a draft report, VSL-06R6710-2 "Summary of DM1200 Operation at VSL," Rev A. This report reviews the history of the DM1200 Melter operation and development across many runs, both HLW and LAW. Please have the appropriate staff review this document and return **comments to Larry Petkus by July 26, 2006**.

The report is too big to E-mail, so I am mailing a CD to Carol this morning. I hope you can share.

Thank you,

Larry Petkus
R&T, ETC-1
MS6-N1
Ph. 371-4557