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Alternate Reductant Cold Cap Evaluation Furnace Phase II Testing

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September 2014

SRNL-STI-2014-00157, Revision 0

SRNL.DOE.GOV

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Printed in the United States of America

Prepared for
U.S. Department of Energy

Keywords: *alternate reductant, cold cap evaluation furnace (CEF)*

Retention: *Permanent*

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Prepared for the U.S. Department of Energy under contract number DE-AC09-08SR22470.

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PREFACE OR ACKNOWLEDGEMENTS

The authors would like to thank: Jake Amoroso, David Best, Mona Blume, Paul Burket, Alex Choi, Jeff Coughlin, Gene Daniel, Mark Duignan, Jon Duvall, Mike Feller, Andy Foreman, Mark Fowley, Holly Hall, Dave Healy, Minnie Hightower, Dan Lambert, Mike Lee, Dale Marzolf, Wanda Matthews, Dave McGuire, Bridget Miller, David Mitchell, John Pareizs, Monica Philips, Mike Restivo, Whitney Riley, Dianne Scott, Geoff Smoland, Doug Sumpter, Beverly Wall, Frances Williams, Mike Williams, Vickie Williams, Phyllis Workman, Kim Wyszynski and Jack Zamecnik for their support throughout system setup, testing and sample analysis.

EXECUTIVE SUMMARY

Savannah River Remediation (SRR) conducted a Systems Engineering Evaluation (SEE) to determine the optimum alternate reductant flowsheet for the Defense Waste Processing Facility (DWPF). Specifically, two proposed flowsheets (nitric–formic–glycolic and nitric–formic–sugar) were evaluated based upon results from preliminary testing. Comparison of the two flowsheets among evaluation criteria indicated a preference towards the nitric–formic–glycolic flowsheet. Further research and development of this flowsheet eliminated the formic acid, and as a result, the nitric–glycolic flowsheet was recommended for further testing.

Based on the development of a roadmap for the nitric–glycolic acid flowsheet, Waste Solidification Engineering (WS-E) issued a Technical Task Request (TTR) to address flammability issues that may impact the implementation of this flowsheet. Melter testing was requested in order to define the DWPF flammability envelope for the nitric-glycolic acid flowsheet. The Savannah River National Laboratory (SRNL) Cold Cap Evaluation Furnace (CEF), a 1/12th scale DWPF melter, was selected by the SRR Alternate Reductant project team as the melter platform for this testing. The overall scope was divided into the following sub-tasks as discussed in the Task Technical and Quality Assurance Plan (TTQAP):

- Phase I - A nitric–formic acid flowsheet melter test (unbubbled) to baseline the CEF cold cap and vapor space data to the benchmark melter flammability models
- Phase II - A nitric–glycolic acid flowsheet melter test (unbubbled and bubbled) to:
  - Define new cold cap reactions and global kinetic parameters in support of the melter flammability model development
  - Quantify off-gas surging potential of the feed
  - Characterize off-gas condensate for complete organic and inorganic carbon species

After charging the CEF with cullet from Phase I CEF testing, the melter was slurry-fed with glycolic flowsheet based SB6-Frit 418 melter feed at 36% waste loading and was operated continuously for 25 days. Process data was collected throughout testing and included melter operation parameters and off-gas chemistry. In order to generate off-gas data in support of the flammability model development for the nitric-glycolic flowsheet, vapor space steady state testing in the range of ~300-750°C was conducted under the following conditions, (i) 100% (nominal and excess antifoam levels) and 125% stoichiometry feed and (ii) with and without argon bubbling. Adjustments to feed rate, heater outputs and purge air flow were necessary in order to achieve vapor space temperatures in this range. Surge testing was also completed under nominal conditions for four days with argon bubbling and one day without argon bubbling.

The following items are notable observations and results from Phase II testing.

- Very little glycolate is evaporated from the feed and nearly all (>99.5%) of the glycolate fed to the melter is destroyed.

- The amount of uncombusted organics in the off-gas is negligible.

- The REDuction/OXidation (REDOX) of the glasses collected from the pour stream were generally fully oxidized (all Fe^{3+}), which was not expected based on anticipated values for the melter feeds based on sealed crucible studies ($Fe^{2+}/\sum Fe$ in the range of 0.25-0.42).

- The appearance of the cold cap during nitric-glycolic testing was no different than that of the nitric-formic flowsheet during non-bubbled steady state testing.

- There was no evidence of foaming in the melter during any of the test conditions.

- At vapor space temperatures above 500°C a glass production rate in the range of 27-30 g/min was achieved for the nitric-formic flowsheet and 31-44 g/min was attained for the nitric-glycolic flowsheet during non-bubbled steady state conditions.

- An obvious difference in the consistency of the melter feeds of different acid stoichiometries was observed; 100% was quite thin (5 cP), while the 125% was considerably thicker (15 cP).

- Lard-like material was found in the drums of the Sludge Receipt and Adjustment Tank (SRAT) product prior to mixing. It is likely that this material is organic and further analysis is planned. A suitable analytical approach is under development and results will be issued in a separate report.

- Iridescent flakes were observed in the off-gas condensate system solids. Based on the limited analyses the material is amorphous and also contains quartz and magnetite. No further investigation of how and why this material formed has been pursued at present time.

Based on the results from this testing, the following items are recommended for future study in support of the implementation of the nitric-glycolic flowsheet.

- Further REDOX testing and data interpretation are necessary in order to more thoroughly understand the effect of the nitric-glycolic flowsheet on glass REDOX during melter runs, as well as the impact of the testing protocol.

- Further testing to determine the impact of acid stoichiometry on the rheological properties of SME product. Increasing yield stress as acid stoichiometry increases has been noted during CPC testing, thus a better understanding of when increased acid stoichiometry begins to result in higher yield stress is needed.

- Further analysis of the flakes that were present in some of the solids collected from the off-gas condensate system filters. Determine if there are any negative impacts to processing.

- Further analysis of the lard-like material found in some of the drums of SRAT product. Determine if there are any negative impacts to processing.

The following item is recommended for an enhanced understanding of the nitric-glycolic flowsheet.

- Conduct melt rate testing using the melt rate furnace (MRF) and potentially the slurry fed melt rate furnace (SMRF) with melter feeds fabricated with leftover CEF SRAT products to compare the nitric-formic and nitric-glycolic flowsheets. These samples should then be submitted for analysis by X-ray computed tomography (CT) so that more quantitative comparisons can be made. Melt rate testing under bubbled conditions would also be of interest. The CEF could also be operated under nominal conditions to generate bubbled melt rate data under nominal conditions if feed is available.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%RSD	Relative Standard Deviation
AD	Analytical Development
ARP	Actinide Removal Process
CEF	Cold Cap Evaluation Furnace
CT	Computed Tomography
DVR	Digital Video Recorder
DWPF	Defense Waste Processing Facility
FTIR	Fourier Transform Infrared
GC	Gas Chromatograph
HMDSO	Hexamethyl Disiloxane
IC	Ion Chromatography
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
inwc	Inches of Water Column
MCU	Modular Caustic Side Solvent Extraction Unit
MRF	Melt Rate Furnace
MS	Mass Spectrometer
OGCT	Off-gas Condensate Tank
PEG	Poly(ethylene) glycol
PSAL	Process Science Analytical Laboratory
REDOX	REDuction/OXidation
RPM	Rotations per Minute
SB6	Sludge Batch 6
scfm	Standard Cubic Feet per Minute
SEE	Systems Engineering Evaluation
SME	Slurry Mix Evaporator
SMRF	Slurry Fed Melt Rate Furnace
SRAT	Slurry Receipt and Adjustment Tank
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation
SVOA	Semivolatile Organic Analysis
TOC	Total Organic Carbon
TTQAP	Task Technical and Quality Assurance Plan
TTR	Technical Task Request
UV-Vis	Ultraviolet-visible
VSL	Vitreous State Laboratory
WS-E	Waste Solidification Engineering

1.0 Introduction

Savannah River Remediation (SRR) conducted a Systems Engineering Evaluation (SEE)[1] to determine the optimum alternate reductant flowsheet for the Defense Waste Processing Facility (DWPF). Specifically, two proposed flowsheets (nitric–formic–glycolic and nitric–formic–sugar) were evaluated based upon results from preliminary testing.[2,3] Comparison of the two flowsheets among evaluation criteria indicated a preference towards the nitric–formic–glycolic flowsheet. Further research and development of this flowsheet eliminated the formic acid[4], and as a result, the nitric–glycolic flowsheet was recommended for further testing.

Based on the development of a roadmap for the nitric–glycolic acid flowsheet[5], Waste Solidification Engineering (WS-E) issued a Technical Task Request[6] (TTR) to address flammability issues that may impact the implementation of this flowsheet. Melter testing was requested in order to define the DWPF flammability envelope for the nitric-glycolic acid flowsheet.

The Savannah River National Laboratory (SRNL) Cold Cap Evaluation Furnace (CEF), a 1/12th scale DWPF melter, was selected by the SRR Alternate Reductant project team as the melter platform for this testing.[7] Both the CEF and DWPF melter have cylindrical cavities of the same or nearly the same diameter from the top to bottom and, therefore, their vapor space-to-melt pool cross-sectional area ratios are approximately 1.8. The melt pool aspect ratio of the CEF, which is defined as the melt pool diameter-to-melt pool depth, is also practically identical to that of the DWPF melter; however, the vapor space aspect ratio of the CEF was designed at ½ of the DWPF melter in an effort to reduce off-gas carryover under bubbled conditions.

The overall scope was divided into the following sub-tasks as discussed in the Task Technical and Quality Assurance Plan (TTQAP)[8]:

- Phase I - A nitric–formic acid flowsheet melter test (unbubbled) to baseline the CEF cold cap and steady state vapor space data to the benchmark melter flammability models over a series of vapor space temperatures
- Phase II - A nitric–glycolic acid flowsheet melter test (unbubbled and bubbled) to:
  - Define new cold cap reactions and global kinetic parameters for the melter flammability models
  - Quantify off-gas surging potential of the feed
  - Characterize off-gas condensate for complete organic and inorganic carbon species

Phase I testing and results of the data analysis and model validation were discussed in previous reports.[9,10] The intent of this report is to provide a summary of the Phase II melter testing conditions that were used in support of the task objectives listed above. A compilation of sample data will also be presented. It should be noted that the interpretation and discussion of operating data and sample data for Phase II testing will be limited. A detailed analysis of the off-gas chemistry, surge potential and the flammability model development for the nitric-glycolic acid flowsheet will be addressed separately.[11]

2.0 System Description

The CEF is a 30 inch tall, 20 inch diameter Inconel® 690 vessel that was fabricated at SRNL to conduct observations of cold cap behavior under a variety of melter conditions.[12-28] The unit consists of 5 heating zones that are controlled separately.[29] The heaters are spiral wound silicon carbide resistance heater elements that provide heat externally to the vessel. Four vapor space heaters are located inside the vessel and are surrounded by alumina tubes to protect them from the environment. A section view of the CEF is shown in Figure 2-1. The melter, along with the off-gas and condensate systems, were installed in the

Engineering Development Laboratory (786-A). A schematic of the entire melter and off-gas system that was used to support Phase II testing is shown in Figure 2-2 and Figure 2-3. The melter is operated under a slight negative pressure (nominally -5 inches of water [inwc]), which captures the volatile components through a quencher/scrubber system. An instrumentation list for the entire system is shown in Table 2-1 through Table 2-3.

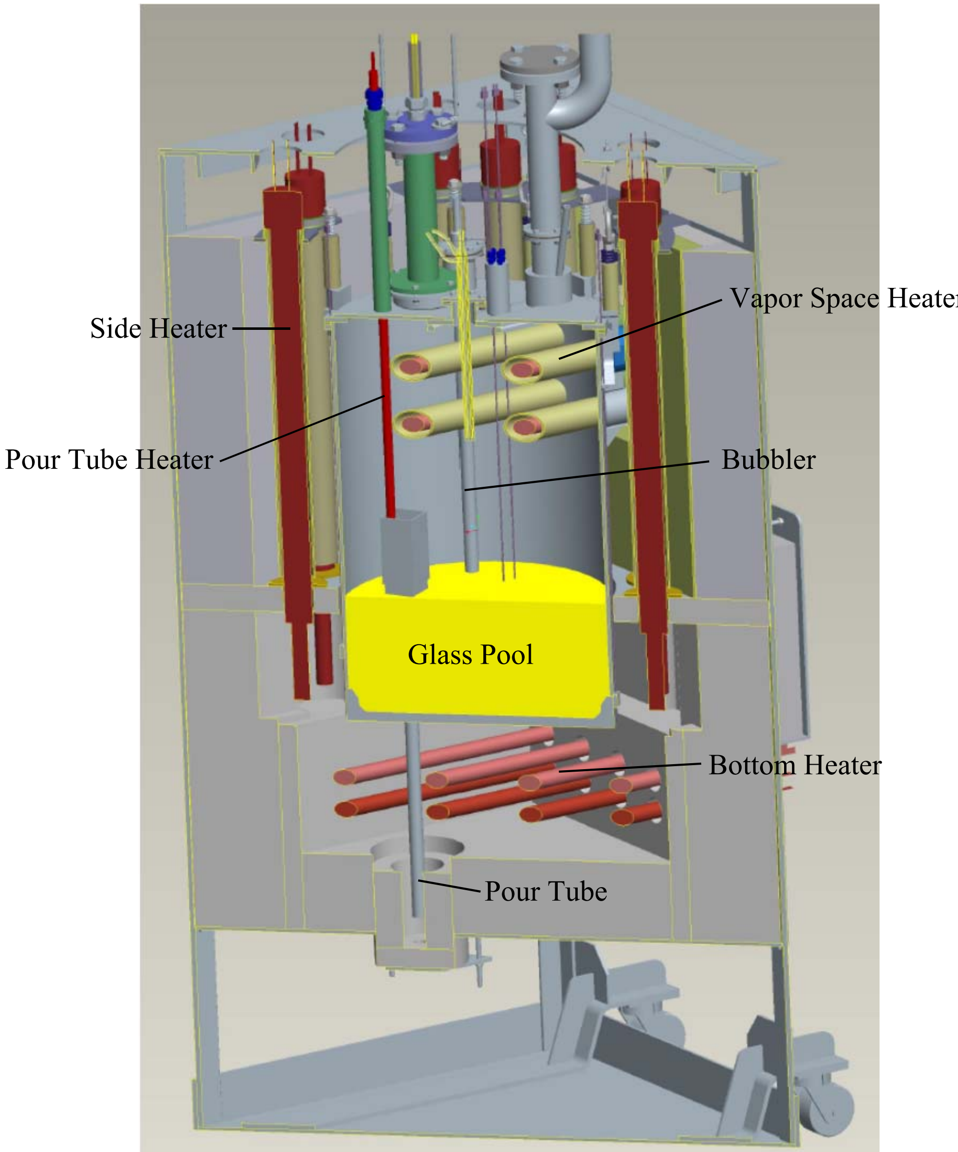


Figure 2-1. CEF cross-section.

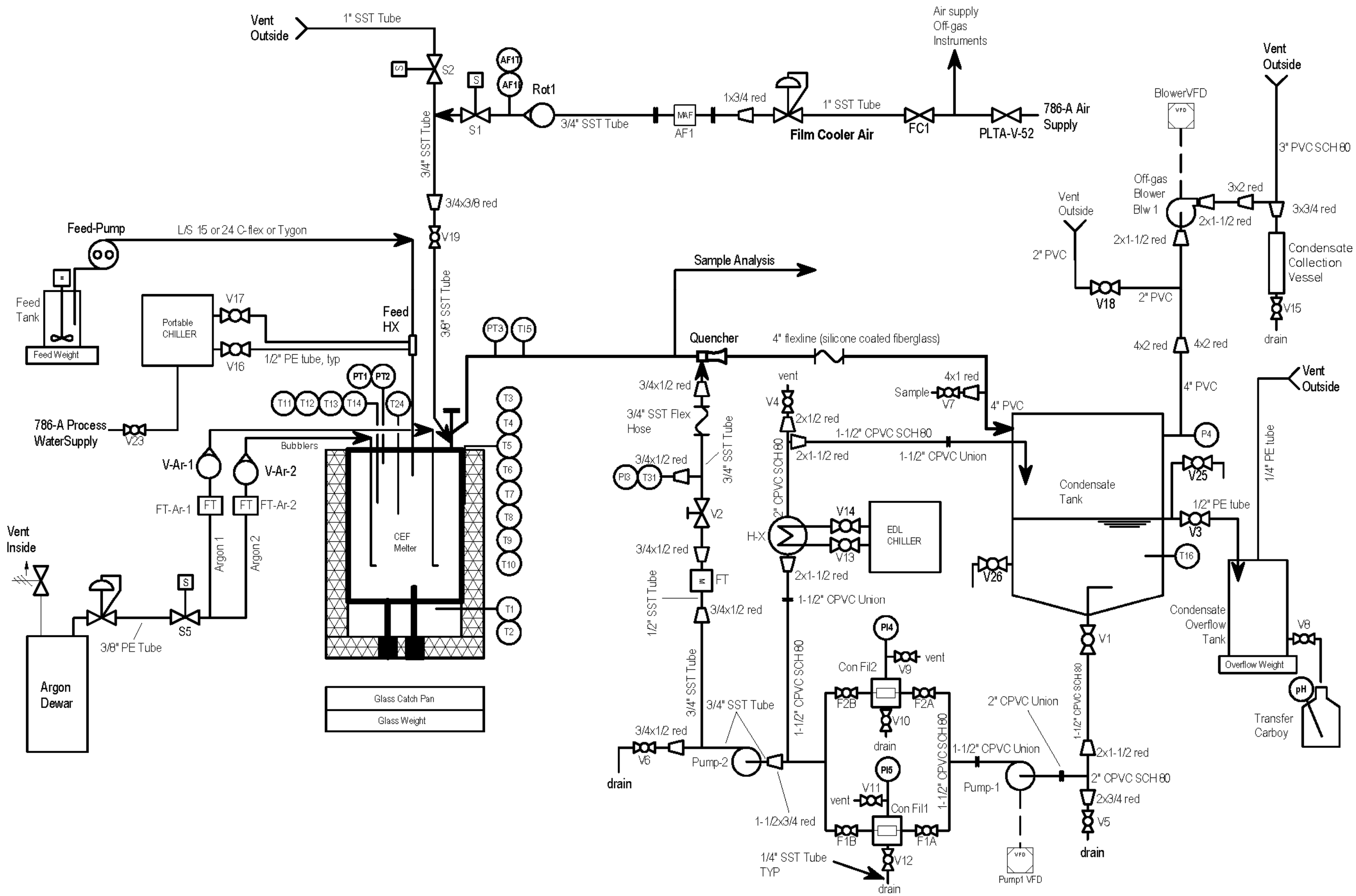


Figure 2-2. CEF system sketch.

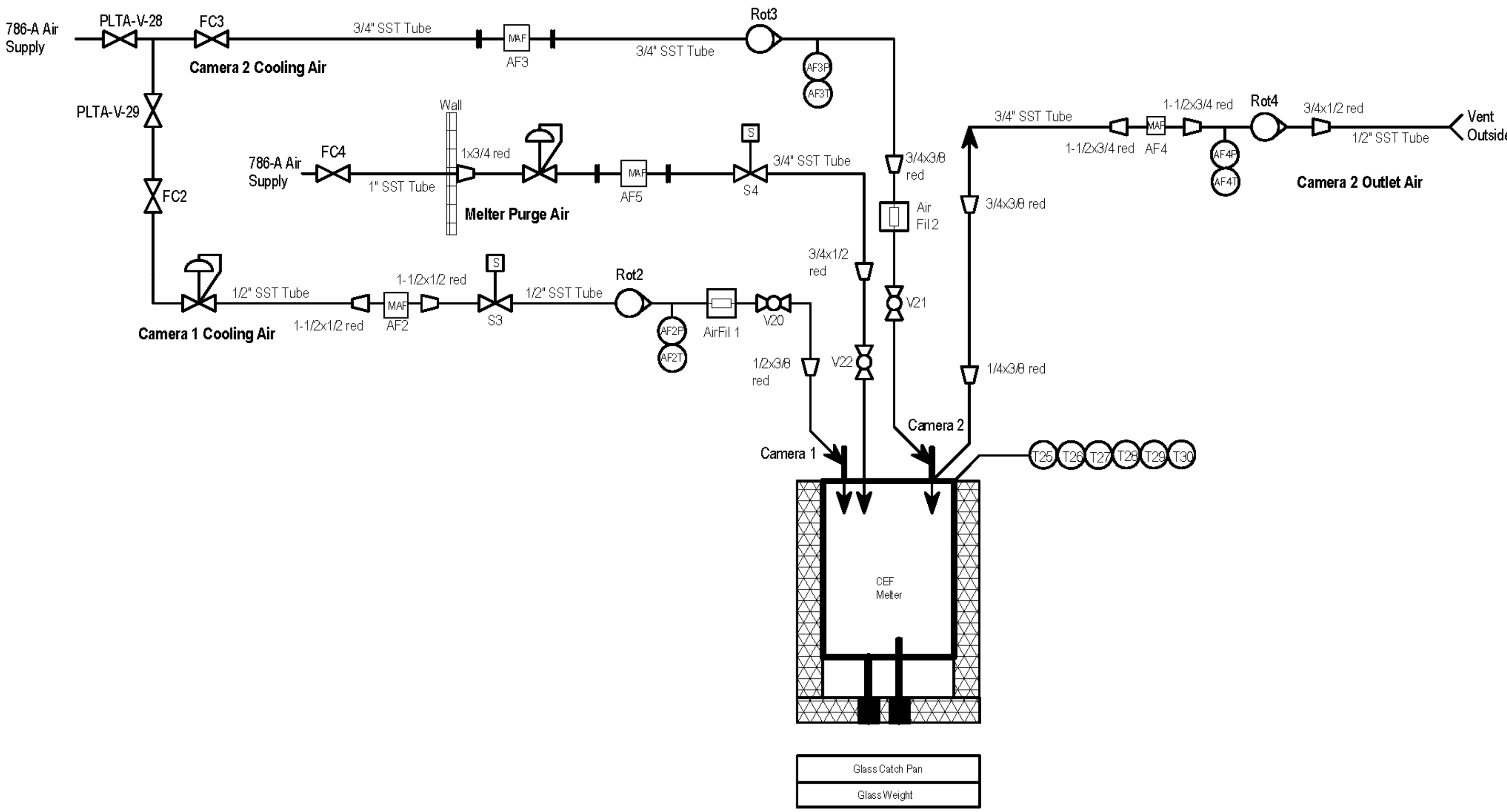


Figure 2-3. CEF camera system sketch.

Table 2-1. Instrumentation List Set 1[a]

System	Designation	Description	Range	Tolerance	Electronic Output
Melter	PT1	Melter vapor space pressure 1, transmitter	-20 to +20 in H_2O	+/- 0.5 % fs	4 - 20 mA
Melter	PT2	Melter vapor space pressure 2, transmitter	-20 to +20 in H_2O	+/- 0.5 % fs	4 - 20 mA
Melter	V-Ar-1	Bubbler 1 argon flow, rotameter	0 - 0.7 scfm	manuf. spec.	---
Melter	FT-Ar-1	Bubbler 1 mass flow controller	0 - 0.75 scfm	+/-(0.5%rdg + 4%fs)	4 - 20 mA
Melter	V-Ar-2	Bubbler 2 argon flow, rotameter	0 - 0.7 scfm	manuf. spec.	---
Melter	FT-Ar-2	Bubbler 2 mass flow controller	0 - 0.75 scfm	+/-(0.5%rdg + 1.5%fs)	4 - 20 mA
Melter	T1a	Vessel bottom 1, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T1b	Vessel bottom 1, type K T/C, spare	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T2a	Vessel bottom 2, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T2b	Vessel bottom 2, type K T/C, spare	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T3	Vessel side elev. 1A, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T4	Vessel side elev. 1B, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T5	Vessel side elev. 2A, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T6	Vessel side elev. 2B, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T7	Vessel side elev. 3A, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T8	Vessel side elev. 3B, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T9	Vessel side elev. 4A, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T10	Vessel side elev. 4B, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T11	Vapor space 1, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T12	Vapor space 2, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T13	Glass pool 1, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T14	Glass pool 2, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T24	Pour tube heater, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T25	Rod Support 1, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T26	Rod Support 2, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T27	Rod Support 3, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV

[a] Inches of water (in H_2O), percent of full scale (%fs), milliamps (mA), standard cubic feet per minute (scfm), percent of reading (%rdg), thermocouple (T/C) and millivolts (mV).

Table 2-2. Instrumentation List Set 2[b]

System	Designation	Description	Range	Tolerance	Electronic Output
Melter	T28	Rod Support 4, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T29	Rod Support 5, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	T30	Rod Support 6, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Melter	Glass Weight	Poured glass container platform scale	0 - 30 Kg	+/- 0.75 %rdg	---
Off-Gas	PT3	Off-gas pressure transmitter	-20 to +20 in H_2O	+/- 0.5 % fs	4 - 20 mA
Off-Gas	T15	Off-gas, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Off-Gas	P4	Condensate tank pressure	0 to +30 in H_2O	manuf. spec.	---
Condensate	P13	Quencher condensate inlet pressure gauge	0 to 180 psig	manuf. spec.	---
Condensate	FT	Quencher condensate inlet flow transmitter, 15 mm	0 to 15 gpm	+/- (0.5%rdg+1.0%fs))	4 - 20 mA
Condensate	pH	Condensate overflow pH	manuf. spec.	manuf. spec.	---
Condensate	Overflow Weight	Condensate overflow vessel platform scale	0 - 30 Kg	+/- 0.75 %rdg	---
Condensate	T31	Quencher condensate inlet, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Condensate	PI4	Condensate filter housing 1 pressure gauge	0 to 30 psig	manuf. spec.	---
Condensate	PI5	Condensate filter housing 2 pressure gauge	0 to 30 psig	manuf. spec.	---
Condensate	T16	Condensate Tank temperature, type K T/C	-200 to 1250 °C	manuf. spec.	-5.9 to 50.6 mV
Feed	Feed Weight	Melter feed vessel platform scale	0 - 30 Kg	+/- 0.75 %rdg	---
Air Supply	Rot1	Flim cooler air flow, rotameter	0 - 50 scfm	---	---
Air Supply	AF1	Flim cooler air flow, mass flow meter	0 - 40 scfm	+/-(0.5 %rdg + 2.5%fs)	4 - 20 mA
Air Supply	AF1T	Rotameter 1 temperature, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV

[b] Inches of water (in H_2O), percent of full scale (%fs), milliamps (mA), standard cubic feet per minute (scfm), percent of reading (%rdg), thermocouple (T/C) and millivolts (mV), pounds per square inch gauge (psig) and gallons per minute (gpm).

Table 2-3. Instrumentation List Set 3[c]

System	Designation	Description	Range	Tolerance	Electronic Output
Air Supply	AF1P	Rotameter 1 pressure, pressure gauge	0-100 psig	manuf. spec.	---
Air Supply	Rot2	Camera 1 (Canty) air flow, rotameter	0 - 25 scfm	+/-(0.5%rdg + 3%fs)	---
Air Supply	AF2	Camera 1 (Canty) air flow, mass flow meter	0 - 25 scfm	+/-(0.5 %rdg + 2.5%fs)	4 - 20 mA
Air Supply	AF2T	Rotameter 2 temperature, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Air Supply	AF2P	Rotameter 2 pressure, pressure gauge	0-60 psig	manuf. spec.	---
Air Supply	Rot3	Camera 2 (SRNL) inlet air flow, rotameter	0 - 25 scfm	+/-(0.5%rdg + 3%fs)	---
Air Supply	AF3	Camera 2 (SRNL) inlet air flow, mass flow meter	0 - 40 scfm	+/-(0.5 %rdg + 2.5%fs)	4 - 20 mA
Air Supply	AF3T	Rotameter 3 temperature, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Air Supply	AF3P	Rotameter 3 pressure, pressure gauge	0-100 psig	manuf. spec.	---
Air Supply	Rot4	Camera 2 (SRNL) outlet air flow, rotameter	0 - 25 scfm	+/-(0.5%rdg + 3%fs)	---
Air Supply	AF4	Camera 2 (SRNL) outlet air flow, mass flow meter	0 - 25 scfm	+/-(1 %rdg + 5%fs)	4 - 20 mA
Air Supply	AF4T	Rotameter 4 temperature, type K T/C	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Air Supply	AF4P	Rotameter 4 pressure, pressure gauge	0-60 psig	manuf. spec.	---
Air Supply	AF5	Melter purge air flow, mass flow meter	0 - 75 scfm	+/-(0.5 %rdg + 2.5%fs)	4 - 20 mA
System	**Designation**	**Description**	**Voltage**	**Function**	**Body**
Solenoids	S1	Film cooler air shutoff	110	NC	brass
Solenoids	S2	Film cooler air vent	110	NO	brass
Solenoids	S3	Canty camera shutoff	110	NO	brass
Solenoids	S4	Melte stoke air shutoff	110	NC	SST
Solenoids	S5	Argon bubblers shutoff	110	NC	---

[c] Pounds per square inch gauge (psig), standard cubic feet per minute (scfm), percent of reading (%rdg), percent of full scale (%fs), milliamps (mA), millivolts (mV), normally close (NC), normally open (NO), stainless steel (SST).

2.1 Modifications

Details of modifications made prior to Phase I testing are provided in the Phase I testing report.[9] Prior to Phase II testing, several changes were made to the system based on experience gained during Phase I testing. Brief descriptions of the new modifications are provided below.

- The air mass flow transmitters were updated either by replacement or recalibration to a more appropriate range. These changes allowed for a higher air purge rates to be used during testing without being limited by the actual and/or calibrated range of transmitters.

- Several melter thermocouples were replaced based on wear that had occurred during Phase I testing.

- All four of the vapor space heater alumina thermowells were replaced due to cracking that had occurred after Phase I testing was completed. Four vapor space heater elements were also replaced due to breakage.

- In order to reduce air in-leakage (i) each vapor space assembly was re-packed and re-tightened, (ii) high temperature moldable alumina insulation[d] was also applied on the outer surface of each heater assembly, and (iii) the entire vessel top was also packed with the high temperature moldable alumina insulation.

- The exhaust blower was replaced with a regenerative blower and a variable speed drive was added so that -5 inwc could be maintained in the condensate tank during high air purge test conditions. Room temperature testing was conducted prior to heat-up to develop a performance curve for the system.

- The auxiliary pour tube rod heater was replaced. Visual inspection of the existing heater did not indicate major deterioration, but it was replaced due to the length of the planned Phase II testing campaign.

- One of the bubblers was replaced with a new unit that had a small cage welded near the bottom, into which a sample of K3 refractory was loaded. The sample was removed after Phase II testing for evaluation, the results of which will be issued in a separate report.[30]

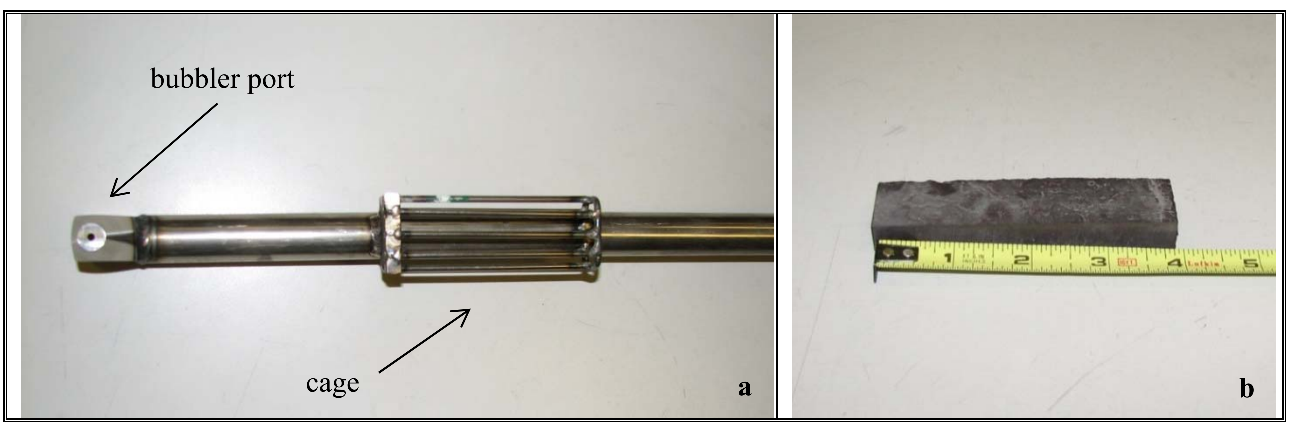


Figure 2-4. Images of bubbler (a) and K3 refractory coupon (b).

[d] Zircar Ceramics, Inc. Alumina Insulation Type SALI Moldable (color – light green).

- The quencher was removed for visual inspection. A flush of the quencher was also performed prior to re-assembly to clear out any particulate that had built up during Phase I testing.

- The camera designed at SRNL (Camera 2) was removed since it was no longer in focus. Breaches in the bellows assembly were repaired and the camera was replaced with a fixed focal length.

During Phase II testing, it was necessary to make several additional modifications as described below.

- A metal crossbar was placed on the top of the off-gas condensate tank (OGCT) to support the Lexan cover, which allowed operation at higher vacuum conditions.

- The regenerative blower was replaced after failure during surge testing and a 55-gallon poly drum was installed before the blower to capture condensate and extend the life of the blower.

- One of the stainless steel transition pieces in the feed line was re-designed to have a 45° instead of a 90° angle in order to reduce the possibility of a feed blockage. The new piece was also machined and de-burred to remove any internal edges that could cause a buildup of feed.

- A peristaltic pump was added to the condensate sample collection valve on the OGCT so that condensate samples could be collected at lower vapor space temperatures when the air purge was utilized.

3.0 Experimental Procedure

3.1 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.

3.2 Melter Feed

The processing strategy for the Sludge Receipt and Adjustment Tank (SRAT) product runs was developed by SRNL to prepare melter feeds that meet the following guidelines.[31,32]

- Nitric-glycolic acid flowsheet at 100% and 125% Koopman[33] acid stoichiometry
- No noble metals or mercury[34]
- $Fe^{2+}/\sum Fe$ between 0.10 and 0.25; the higher end of this range is desired
- Yield stress <25 Pa
- Total solids after frit addition: 42 to 50 wt%
- Antifoam added: 2000 mg/kg on a carbon basis
- Abbreviated SRAT cycle (compared to typical DWPF processing), no Slurry Mix Evaporator (SME) cycle[35]
- No Actinide Removal Process (ARP) or Modular Caustic Side Solvent Extraction Unit (MCU) material added (sludge only)

The Sludge Batch 6 (SB6I) simulant was produced by BlueGrass Chemical Specialties, LLC and was processed into SRAT product by abbreviated SRAT cycles at Harrell Industries, Inc. in June, July and August 2013.[e,f] Samples of the 100% and 125% SRAT products were analyzed by SRNL for verification

[e] The SB6I simulant was produced by BlueGrass Chemical Specialties, LLC of New Albany, IN.

prior to shipment (Table 3-1 through Table 3-4) and memos recommending acceptance of these batches were issued.[36,37] The SRAT products were transferred into 30-gallon poly drums at Harrell Industries and shipped to SRNL in July and August 2013.

Table 3-1. Physical Properties of the Harrell SB6I 100% and 125% SRAT Products[g]

Property	100% SB6I SRAT Product	125% SB6I SRAT Product	Units
Total Solids	32.3	32.8	weight %
Insoluble Solids	15.8	15.7	weight %
Soluble Solids	16.5	17.1	weight %
Calcine Solids	18.0	17.7	weight %
Slurry Density	1.2514	1.2553	g/mL at 25°C
Supernate Density	1.134	1.1526	g/mL at 25°C
pH	5.03	3.21	
Yield Stress	0.76	4.9	Pa
Consistency	5.44	15.2	cP

Table 3-2. Harrell SB6I SRAT Product Compositions (wt% calcine solids basis)

Element	100% SB6I SRAT Product	125% SB6I SRAT Product
Al	13.6	13.6
Ba	0.148	0.112
Ca	1.30	1.27
Cr	0.20	0.18
Cu	0.119	0.104
Fe	23.1	22.0
K	0.090	0.097
Mg	0.65	0.71
Mn	7.4	6.73
Na	12.9	14.2
Ni	2.88	3.09
P	0.090	Not Measured
Si	1.40	1.15
Ti	0.03	0.035
Zn	0.114	0.111
Zr	0.30	0.28

Table 3-3. Harrell SB6I SRAT Product Supernate Compositions (mg/L)

Element	100% SB6I	125% SB6I
Al	349	1100
Ba	1.72	3.46
Ca	2,650	3,140
Cr	1.54	4.35
Cu	56.1	183
Fe	305	2,700
K	894	1,070
Mg	2,020	2,350
Mn	14,600	13,600
Na	31,900	34,000
Ni	2,720	5,350
P	<10.0	18.6
S	818	766
Si	707	298
Sn	9.51	6.23
Ti	0.323	3.53
Zn	55.7	144
Zr	<0.100	0.100

[f] The SB6I SRAT product was produced by Harrell Industries, Inc. of Rock Hill, SC.
[g] Pascal (Pa) and centipoise (cP).

Table 3-4. Harrell SB6I SRAT Products Anions and TOC (mg/kg)

Species	100% SB6I	125% SB6I
F	<500	<500
Cl	417	<500
NO_2	<500	<500
NO_3	67,000	84,900
$C_2H_3O_3$	44,500	43,500
SO_4	1,860	2,700
C_2O_4	2,010	2,160
HCO_2	3,140	<500
PO_4	<500	<500
TOC	12,500	23,300

It should be noted that the measured REDOX via the sealed crucible method did not meet the $Fe^{2+}/\sum Fe$ targets for either of these as-received SRAT products as part of the acceptance criteria. The target REDOX for the 100% stoichiometry melter feed was 0.15 $Fe^{2+}/\sum Fe$, while the measured REDOX was 0.47. The target REDOX for the 125% stoichiometry melter feed was 0.2-0.3 $Fe^{2+}/\sum Fe$, while the measured REDOX was <0.02. While the SRAT products were acceptable for shipment to SRNL, it was recommended that (i) the melter feed based on the 125% stoichiometry SRAT product be remediated with glycolic acid at SRNL, and (ii) the melter feed based on the 100% stoichiometry SRAT product be remediated with nitric acid at SRNL. Additional sealed crucible REDOX testing was performed to remediate the melter feed with nitric acid for the 100% SRAT product and glycolic acid for the 125% SRAT product. A series of melter feed samples were prepared with a range of acid concentrations (low, medium and high) for each of the SRAT products to obtain a REDOX response curve, the results of which are shown in Table 3-5.[h,38,39] Based on these results the "low" nitric acid concentration was selected for the 100% melter feed and a blend point interpolated between the "low" and "medium" glycolic acid concentrations was selected for the 125% melter feed.

Table 3-5. Remediation REDOX Results

Melter Feed	Acid	Sample	Target $Fe^{2+}/\sum Fe$	Average $Fe^{2+}/\sum Fe$
100%	---	*as-received*	*0.15*	*0.47*
	nitric	low	0.25	0.25
	nitric	medium		All Fe^{3+}
	nitric	high		All Fe^{3+}
125%	---	*as-received*	*0.2-0.3*	*All Fe^{3+}*
	glycolic	low	0.35	0.10
	glycolic	medium		0.48
	glycolic	high		0.58

[h] The target $Fe^{2+}/\sum Fe$ was selected to be 0.1 higher than initial targets due to oxidation in the CEF that was observed in Phase I CEF testing.

Six different melter feeds were used to generate off-gas flammability data (vapor space steady state testing) and surge potential data in support of the task objectives. The melter feed used for the CEF testing was produced by combining the Harrell Industries SB6I SRAT product with dry Frit 418 at a target waste loading of 36% and nitric or glycolic acid to adjust the REDOX (Table 3-6). Depending on the testing conditions additional water was added to yield a total solids content of either ~45 wt% or ~42 wt% in order to facilitate feeding. Note that there were issues with the 125% stoichiometry melter feed at 49 wt% and the total solids was further reduced to 45 wt%. There were also difficulties in achieving steady state conditions with the 100% stoichiometry melter feed spiked with approximately three times the nominal amount (~3X) and the antifoam spike was reduced to two times the nominal amount (~2X).

Table 3-6. Remediation of Harrell SRAT Product (kg/30-gallon drum)

Melter Feed	**100%**		**100% ~3X Antifoam Spike**	**100% ~2X Antifoam Spike**	**125%**	
Objective	**Surge**	**Steady State**	**Steady State**	**Steady State**	**Steady State**	**Steady State**
Total Solids (%)	**42**	**45**	**45**	**45**	**49**	**45**
Glycolic Acid	---	---	---	---	1.5	1.5
Nitric Acid	2	2	2	2	---	---
Water	19.7	8.4	8.4	8.4	---	10.5
Antifoam 747	---	---	0.7	0.4	---	---

3.3 Startup Cullet

The melter was loaded with ~105 kg of SB6-Frit 418 startup cullet (36% waste loading) that was produced during the 2013 Phase I CEF testing and its level in the vessel was approximately 17-19" from the site port seal surface.[9] This glass was chosen since it was the same composition to the CEF Phase II melter feed, thus reducing the quantity of feed required for the test and the time involved to reach steady state conditions.

3.4 Post-Run Sample Analysis

3.4.1 Weight Percent Solids

Total, dissolved and/or calcined solids were measured by the Process Science Analytical Laboratory (PSAL) for the melter feed, filter solids and condensate samples per procedure.[40]

3.4.2 Composition Measurements

Melter feed, off-gas condensate system bag filter solids and glass samples were prepared by PSAL using the following fusions: sodium peroxide/sodium hydroxide[41], lithium metaborate[42] and lithium tetraborate/lithium nitrate[43] and aqua regia[44] for cations and potassium hydroxide[45] and for anions. Cations were measured with Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES) and anions were measured with Ion Chromatography (IC).[46,47] Melter feed anions were also measured by the SRNL Analytical Laboratory (AD) per procedure.[48] Total organic carbon (TOC) content of the melter feed and condensate samples were measured by the DWPF laboratory.[49] Semi volatile organic analysis (SVOA) was measured by AD per procedure on the sorbent tubes containing coconut charcoal that were placed in the off-gas line prior to the analyzers.[50]

3.4.3 Reduction/Oxidation (REDOX) Measurements

Triplicate samples of remediated melter feed were prepared according to the sealed crucible method.[38] Additional samples were prepared by heating melter feed in a quartz crucible under a flowing argon atmosphere.[i,51] The resulting glass samples, as well as glass samples collected directly from the pour stream during CEF Phase II testing were crushed, dissolved and analyzed by PSAL via Ultraviolet-Visible (UV-Vis) spectroscopy according to procedure.[39]

4.0 Results and Discussion

Multiple vapor space temperatures in the range of ~250-750°C were evaluated during various test conditions in order to generate off-gas data in support of the melter flammability model development. A summary of the test conditions is shown in Table 4-1. Note that the vapor space temperature targets were only approximations of temperatures that could actually be achieved during melter testing. Two different acid stoichiometries (100% and 125%) were used so that there would be additional data for the off-gas flammability model development. An acid stoichiometry of 100% is more prototypical of the expected stoichiometry to be recommended during nitric-glycolic flowsheet processing at DWPF. The antifoam spike test was performed in order to (i) better understand how antifoam degrades in the cold cap by comparing the resulting off-gas profiles of CO and H_2 to those of the baseline case, and (ii) evaluate the antifoam decomposition scheme used in the current off-gas flammability model. Bubbling was not needed to evaluate the antifoam degradation products.

Table 4-1. Summary of the Vapor Space Temperature Steady State Testing Conditions

Acid Stoichiometry	Condition	Vapor Space Temperature Targets (°C)
125%	bubbled and non-bubbled	<300°C, 350°C, 400°C, 500°C, 600°C and 700°C
100%	bubbled and non-bubbled	<300°C, 350°C, 400°C, 500°C, 600°C and 700°C
100% with ~2X antifoam spike	non-bubbled	<300°C, 350°C, 400°C, 500°C, 600°C and 700°C

During these tests it was desired to maintain consistent cold cap coverage and steady state conditions while collecting off-gas data for approximately two hours at each target vapor space temperature. Steady state was defined by the following three parameters:

- Vapor space temperature (±25°C)
- Feed rate
- Off-gas readings (H_2, CO_2 and NO_x)

A combination of feed rate, heater output and air flow adjustments were necessary to achieve the various vapor space temperatures. In some cases, several hours were required to achieve steady state conditions. As the vapor space temperature was reduced, feed rate reductions were required to prevent overfeeding of the melter. Deviations in the melt pool thermocouple temperatures (T13 and T14) were an indicator of overfeeding, but there was a substantial delay between overfeeding and the subsequent temperature deviation, which prolonged the time necessary to reach steady state conditions. Underfeeding of the melter was characterized by a cold cap that was light in color and/or cracked. It was desired to have approximately 90% cold cap coverage with the presence of some vent holes without overfeeding or underfeeding the melter.

[i] More details of the experimental setup is provided in SRNL-STI-2014-00286.

Surge testing was performed in order to collect off-gas surge potential data in terms of melter pressure and off-gas compositional spikes while operating the melter at a nominal vapor space temperature in the range of 700-750°C. A summary of the test conditions is shown in Table 4-2. Again the 100% stoichiometry melter feed was selected for the surge testing as this stoichiometry is closer to the stoichiometry expected to be recommended for DWPF operation based on chemical process cell (CPC) testing performed to date.

Table 4-2. Summary of the Surge Testing Conditions

Acid Stoichiometry	Condition	Vapor Space Temperature Target (°C)
100%	bubbled and non-bubbled	nominal (700-750°C)

More details of these tests will be provided in the following Sections 4.3 through 4.5. Dates and approximate times for the various conditions and tests are provided for reference in Table 4-3 and Table 4-4. It should be noted that a discussion of the off-gas data and the flammability model development is provided in a separate report.[11]

All raw data collected by the data acquisition system every 30 seconds throughout testing is available in SRNL-L3100-2014-00081.[52] Plots of data collected throughout testing are shown in the Appendix Figure A-1 through Figure A-50 and include:

- Bottom and side thermocouple temperatures
- Vapor space and glass pool thermocouple temperatures
- Air flows and argon bubbler flows
- Vapor space and off-gas line pressures
- Heater outputs
- Feed rate
- Support block thermocouple temperatures

4.1 Melter Heat-up

The melter was energized on February 24, 2014 at approximately 11:36 and the bottom and side heaters were ramped to ~1125°C in approximately 11.5 hours. Vapor space heaters were ramped slowly in manual mode, which resulted in a vapor space temperature of ~860°C.[j] The side and bottom heaters were operated in manual mode until the temperature approached the target temperature of 1125°C, at which point automatic mode was used. The pour heater and auxiliary pour tube rod heater were controlled in manual mode as needed to facilitate pouring of the cullet once melting had occurred. Standard air flows were used during the time required for heat-up.[k] Just prior to feeding, the melt pool temperature had reached an average temperature of 1040°C.

[j] An attempt was made to heat the vapor space heaters at no more than 2.5°C/min in order to protect the integrity of the alumina tubes surrounding the vapor space heater elements; however, the automatic heater control ramp rate was not precise and it was necessary to use manual control.

[k] 16 scfm (AF1 – film cooler), 8 scfm (AF2 – camera 1), 8 scfm (AF3 – camera 2 inlet), 7 scfm (AF4 – camera 2 outlet) and ~0 scfm (AF5 – melter stoke air). Note that these are approximate values.

Table 4-3. Test Conditions, Dates and Approximate Times Set 1

Feed Stoichiometry	Total Solids Target	Antifoam Target	Average Bubbling Rate	Average Vapor Space Temperature	Condition	Start Date/Time	End Date/Time
125%	49%	nominal	---	---	---	2/24/2014 22:55	2/26/2014 16:39
125%	45%	nominal	0.2 scfm	705°C	steady state	2/26/2014 20:28	2/26/2014 22:28
125%	45%	nominal	0.2 scfm	625°C	steady state	2/27/2014 5:15	2/27/2014 7:15
125%	45%	nominal	0.2 scfm	481°C	steady state	2/27/2014 13:20	2/27/2014 15:20
125%	45%	nominal	0.2 scfm	405°C	steady state	2/28/2014 1:05	2/28/2014 3:59
125%	45%	nominal	0.2 scfm	358°C	steady state	2/28/2014 8:40	2/28/2014 11:42
125%	45%	nominal	0.1 scfm	271°C	steady state	2/28/2014 14:45	2/28/2014 16:47
125%	45%	nominal	0.002 scfm	309°C	steady state	2/28/2014 21:54	3/1/2014 0:00
125%	45%	nominal	0.002 scfm	351°C	steady state	3/1/2014 4:11	3/1/2014 6:32
125%	45%	nominal	0.002 scfm	393°C	steady state	3/1/2014 10:19	3/1/2014 13:30
125%	45%	nominal	0.002 scfm	709°C	steady state	3/2/2014 4:40	3/2/2014 6:40
100%	45%	nominal	0.001 scfm	697°C	steady state	3/2/2014 16:20	3/2/2014 18:20
100%	45%	nominal	0.002 scfm	600°C	steady state	3/2/2014 21:10	3/2/2014 23:10
100%	45%	nominal	0.003 scfm	496°C	steady state	3/3/2014 3:13	3/3/2014 5:13
100%	45%	nominal	0.003 scfm	410°C	steady state	3/3/2014 8:30	3/3/2014 11:10
100%	45%	nominal	0.002 scfm	344°C	steady state	3/4/2014 0:12	3/4/2014 2:12
100%	45%	nominal	0.002 scfm	326°C	steady state	3/4/2014 4:05	3/4/2014 6:05
100%	45%	nominal	0.2 scfm	323°C	steady state	3/4/2014 20:24	3/4/2014 22:24
100%	45%	nominal	0.2 scfm	373°C	steady state	3/5/2014 7:30	3/5/2014 9:30
100%	45%	nominal	0.2 scfm	471°C	steady state	3/6/2014 0:45	3/6/2014 2:45
100%	45%	nominal	0.2 scfm	521°C	steady state	3/6/2014 3:25	3/6/2014 5:00
100%	45%	nominal	0.2 scfm	607°C	steady state	3/7/2014 17:00	3/7/2014 19:00
100%	45%	nominal	0.2 scfm	705°C	steady state	3/8/2014 1:45	3/8/2014 3:45
100%	45%	nominal	0.2 scfm	750°C	steady state	3/8/2014 6:00	3/8/2014 8:30

Note that “---“ signifies test conditions during which difficulties were encountered. No data were generated for steady state or surge testing.

Table 4-4. Test Conditions, Dates and Approximate Times Set 2

Feed Stoichiometry	Total Solids Target	Antifoam Target	Average Bubbling Rate	Average Vapor Space Temperature	Condition	Start Date/Time	End Date/Time
100%	45%	nominal	---	---	---	3/8/2014 10:16	3/10/2014 17:33
100%	42%	nominal	0.5 scfm	720°C	surge	3/10/2014 17:33	3/15/2014 9:40
100%	42%	nominal	0.003 scfm	713°C	surge	3/15/2014 13:24	3/16/2014 13:50
100%	45%	~3X nominal	---	---	---	3/16/2014 16:48	3/17/2014 12:12
100%	45%	~2X nominal	0.003 scfm	604°C	steady state	3/17/2014 18:12	3/17/2014 20:27
100%	45%	~2X nominal	0.003 scfm	519°C	steady state	3/18/2014 6:40	3/18/2014 8:42
100%	45%	~2X nominal	0.003 scfm	397°C	steady state	3/18/2014 13:08	3/18/2014 15:08
100%	45%	~2X nominal	0.003 scfm	323°C	steady state	3/18/2014 19:32	3/18/2014 21:32
100%	45%	~2X nominal	0.003 scfm	293°C	steady state	3/18/2014 22:38	3/18/2014 23:08
125%	45%	nominal	0.003 scfm	486°C	steady state	3/19/2014 16:13	3/19/2014 18:13
125%	45%	nominal	0.003 scfm	604°C	steady state	3/20/2014 0:30	3/20/2014 2:45
100%	45%	~2X nominal	0.003 scfm	722°C	steady state	3/20/2014 21:26	3/20/2014 22:00

Note that "---" signifies test conditions during which difficulties were encountered. No data were generated for steady state or surge testing.

4.2 Turnover

The first 125% stoichiometry feed[l] addition occurred on February 24, 2014 at approximately 22:55. Approximately 24 hours of feeding with a feed rate in the range of 132-305 g/min under argon bubbling (~0.002-0.5 scfm per bubbler[m]) were required to complete one turnover of the melter volume. Approximately 108 kg of glass were poured from the melter.[n] This time was also used to monitor temperature and controller responses throughout the system. The average melt pool temperature during turnover was approximately 1016°C, while the vapor space was maintained at an average temperature of 732°C. Melter turnover was completed on February 25, 2014 at approximately 22:38.

4.3 125% Stoichiometry Melter Feed

After the melter turnover was completed, several attempts were made to conduct the 700°C vapor space steady state testing on February 26 with an argon bubbling rate of ~0.5 scfm per bubbler. Steady state conditions were not achieved with the ~49 wt% total solids feed and thus the bubbling rate was reduced to ~0.25 scfm per bubbler. After approximately 5 hours the bubbling rate was further reduced to ~0.2 scfm per bubbler and a decision was made by the technical lead to dilute the feed to 45wt% total solids. Feeding was initiated with the 45 wt% total solids feed on February 26 at 16:39. More details of specific tests performed with this melter feed will be provided in the following sections.

4.3.1 Steady State Vapor Space Testing (Bubbled)

Steady state testing with the 125% stoichiometry feed (45wt% total solids) with an argon bubbling rate of ~0.1-0.2 scfm per bubbler began on February 26 at 20:28 and was completed on February 28 at 16:47. A summary of the primary test conditions for each vapor space temperature test are shown in Table 4-5 and Table 4-6. The initial temperature was ~705°C and the feed rate, vapor space heater output and air purge were incrementally adjusted to *reduce* the target vapor space temperature. Additional purge air in the range of 15-51 scfm was required to achieve vapor space temperatures below ~625°C. Feed rate was reduced somewhat linearly (R^2 = 0.94) in the range of 72-215 g/min for each vapor space temperature below 700°C as shown in Figure 4-1. A comparison of the actual glass production rate and calculated rate is shown in Figure 4-2. The actual glass production rates are comparable; however, there is a larger deviation between the two values at 705°C. A cause for this difference is unknown. Images of the cold cap throughout steady state testing are shown in Figure 4-3 and Figure 4-4. Generally, it appears that feeding was sufficient at each of the vapor space temperatures to meet the desired cold cap coverage with the presence of some vent holes without overfeeding or underfeeding the melter.

Table 4-5. 125% Bubbled Steady State Vapor Space Temperature Test Conditions

Average Vapor Space Temperature (°C)	Average Glass Pool Temperature (°C)	Average Film Cooler Flow (scfm)	Average Melter Air Purge (scfm)
705	1033	16	1
625	1032	16	1
481	1025	16	15
405	1026	16	22
358	1017	9	40
271	1035	6	51

[l] 49 wt% total solids
[m] There are two bubblers in the CEF melt pool.
[n] Prior to testing the melter was filled with approximately 105 kg of glass that was fabricated during Phase I testing (SB6-Frit 418).

Table 4-6. 125% Bubbled Steady State Vapor Space Temperature Test Conditions

Average Vapor Space Temperature (°C)	Average Feed Rate (g/min)	Average Melter Pressure (inwc)	Average Vapor Space Output (volts)
705	215	-5	123
625	161	-5	67
481	108	-5	19
405	99	-5	8
358	79	-4	8
271	72	-1	8

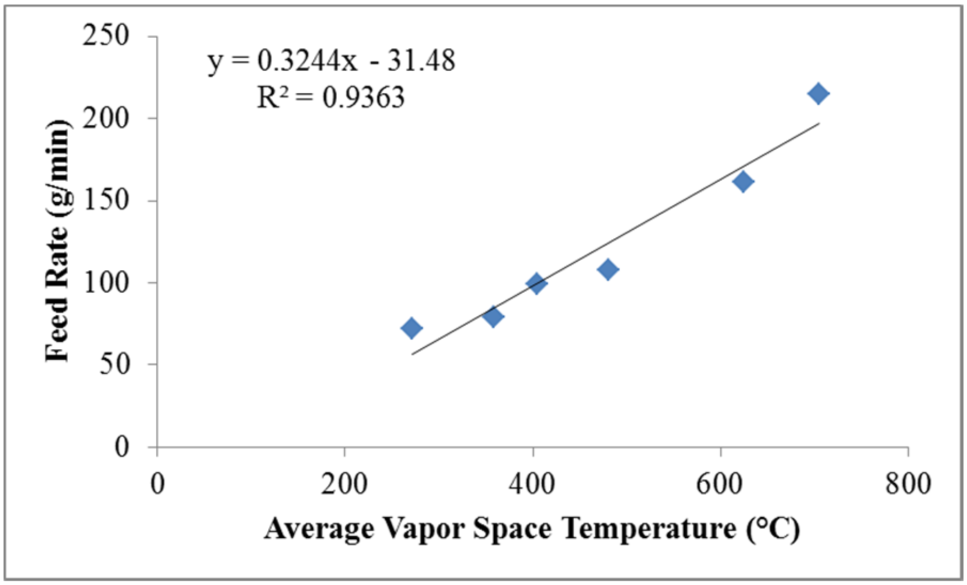


Figure 4-1. 125% stoichiometry bubbled feed rate as a function of vapor space temperature.

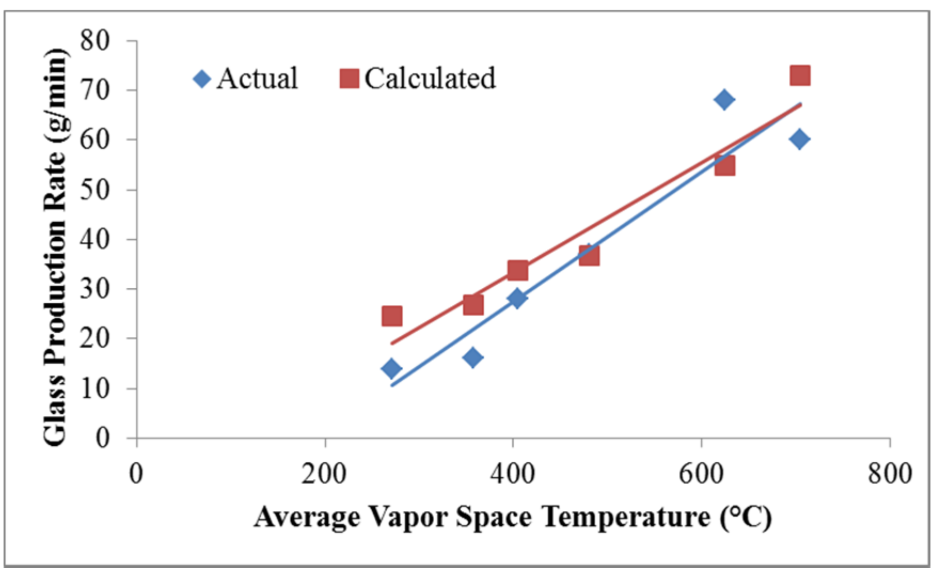
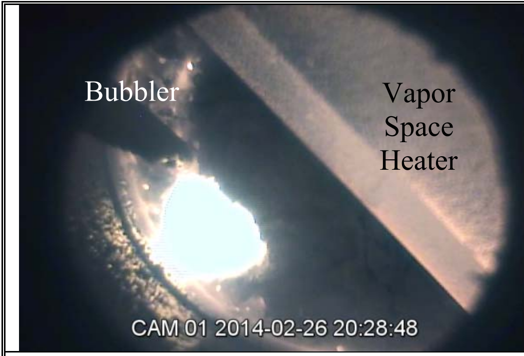


Figure 4-2. 125% stoichiometry bubbled condition glass production rates.



~705°C February 26, 2014 at 20:28

~705°C February 26, 2014 at 21:28

~705°C February 26, 2014 at 22:27

~625°C February 27, 2014 at 5:20

~625°C February 27, 2014 at 6:21

~625°C February 27, 2014 at 7:15

~481°C February 27, 2014 at 13:21

~481°C February 27, 2014 at 14:21

~481°C February 27, 2014 at 15:20

Figure 4-3. Cold cap images during the 125% stoichiometry bubbled testing.

~405°C February 28, 2014 at 1:05 | ~405°C February 28, 2014 at 2:05 | ~405°C February 28, 2014 at 3:05

~358°C February 28, 2014 at 8:40 | ~358°C February 28, 2014 at 9:40 | ~358°C February 28, 2014 at 10:41

~271°C February 28, 2014 at 14:45 | ~271°C February 28, 2014 at 15:45 | ~271°C February 28, 2014 at 16:47

Figure 4-4. Cold cap images during the 125% stoichiometry bubbled testing.

4.3.2 Steady State Vapor Space Conditions (Non-Bubbled)

Steady state testing with the 125% stoichiometry feed (45 wt% total solids) with an argon bubbling rate of ~0.002 scfm per bubbler began on February 28 at 21:54 and was completed on March 2 at 6:40.[o] It should be noted that the 500°C and 600°C vapor space temperature tests were repeated on March 19-20 due to insufficient feed rates during the first attempts for these tests. A summary of the primary test conditions for each vapor space temperature test are shown in Table 4-7.[p]

Table 4-7. 125% Non-Bubbled Steady State Vapor Space Temperature Test Conditions

Average Vapor Space Temperature (°C)	Average Glass Pool Temperature (°C)	Average Film Cooler Flow (scfm)	Average Melter Air Purge (scfm)
709	1083	16	1
604	1060	16	0
486	1059	16	0
393	1085	16	15
351	1083	16	21
309	1080	16	30

Average Vapor Space Temperature (°C)	Average Feed Rate (g/min)	Average Melter Pressure (inwc)	Average Vapor Space Output (volts)
709	99	-6	106
604	100	-5	83
486	86	-6	16
393	54	-6	8
351	44	-5	10
309	35	-5	8

The initial temperature was ~309°C and the feed rate, vapor space heater output and air purge were incrementally adjusted to *increase* the target vapor space temperature. Additional purge air in the range of 15-30 scfm was required to achieve vapor space temperatures below ~486°C. Feed rates in the range of 35-100 g/min were used for this test as compared to feed rates of 72-215 g/min that were used for the bubbled testing. This offset is to be expected since convection in the glass pool facilitates melting of the cold cap. As mentioned previously, the 500°C and 600°C tests were repeated at a later date, which could account for the lower R^2 value shown in Figure 4-5. It is possible that a slightly higher feed rate for the ~709°C test could have been used based on the linear fit of the data. A comparison of the actual and calculated glass production rates is shown in Figure 4-6. The 486°C test was repeated at a later date, which could be the cause of the deviation between the two rates. Images of the cold cap throughout steady state testing are shown in Figure 4-7 and Figure 4-8. The light color of the cold cap for the 709°C test indicates that a higher feed rate could have been used, which is consistent with Figure 4-5. Cracks in the cold cap of the ~393°C and ~604°C also suggest that a slightly higher feed rate may have been necessary to obtain more consistent coverage. Visually, the characteristics of the cold cap from this

[o] During non-bubbled conditions, a minimal bubbling rate was maintained in order to reduce the risk of plugging the bubbler ports.

[p] The melter conditions for the repeated 500°C and 600°C steady state tests are presented.

nitric-glycolic feed are no different than those observed during the nitric-formic non-bubbled steady state testing conducted for Phase I.[q,52]

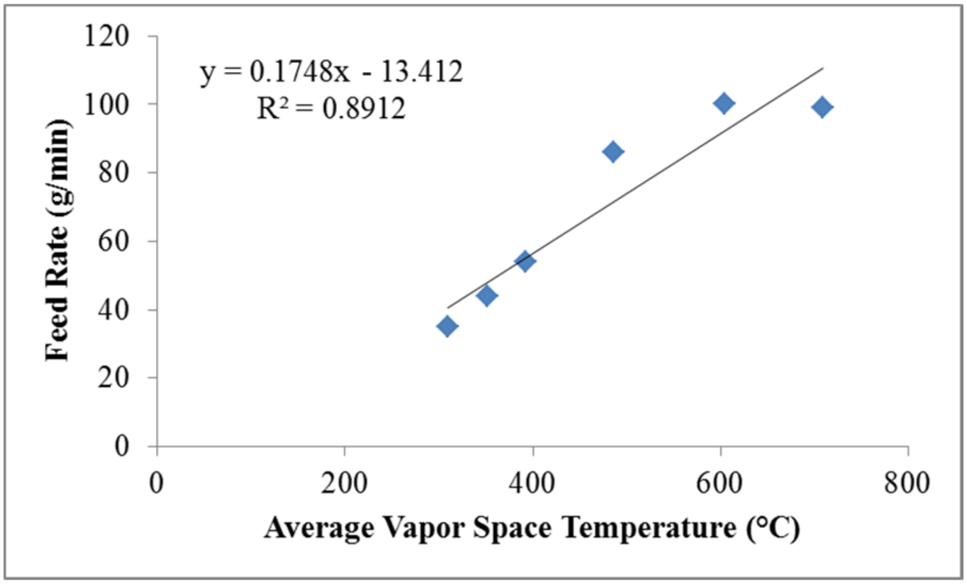


Figure 4-5. 125% stoichiometry non-bubbled feed rate as a function of vapor space temperature.

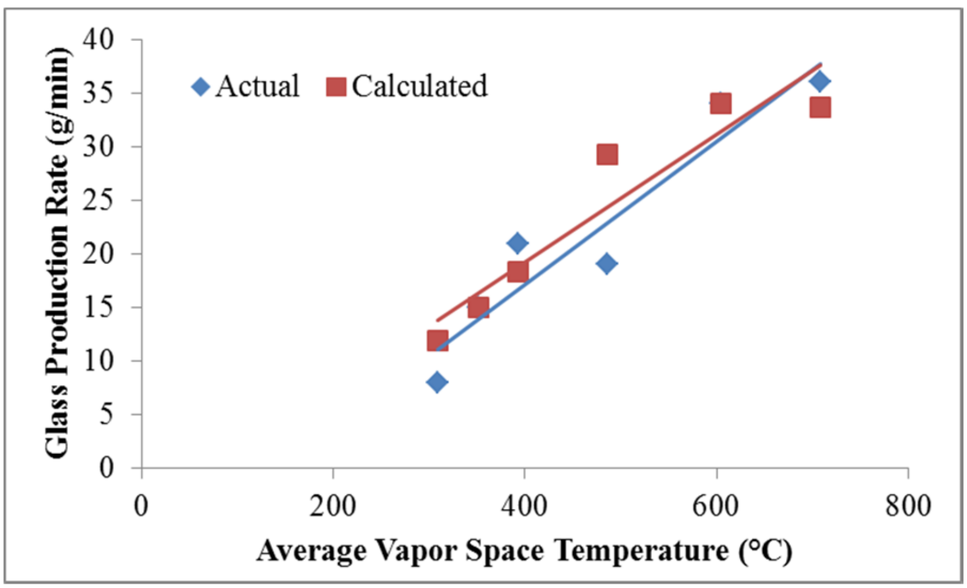


Figure 4-6. 125% stoichiometry non-bubbled condition glass production rates.

[q] Images of the cold cap during non-bubbled steady state testing were compared between the nitric-glycolic and nitric-formic flowsheets. Images of the nitric-formic flowsheet are shown in the Phase I testing report (SRNL-STI-2014-00005).

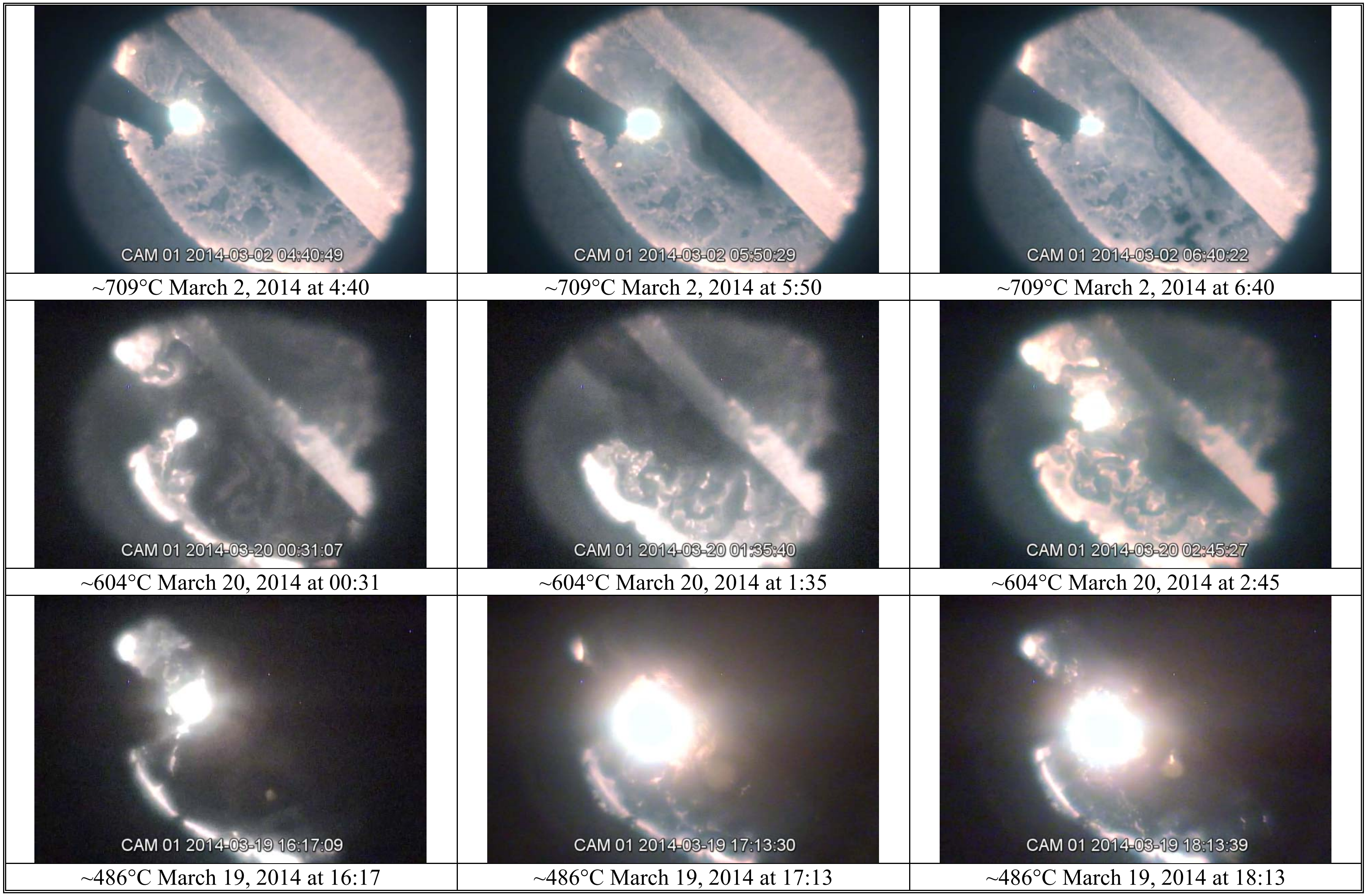
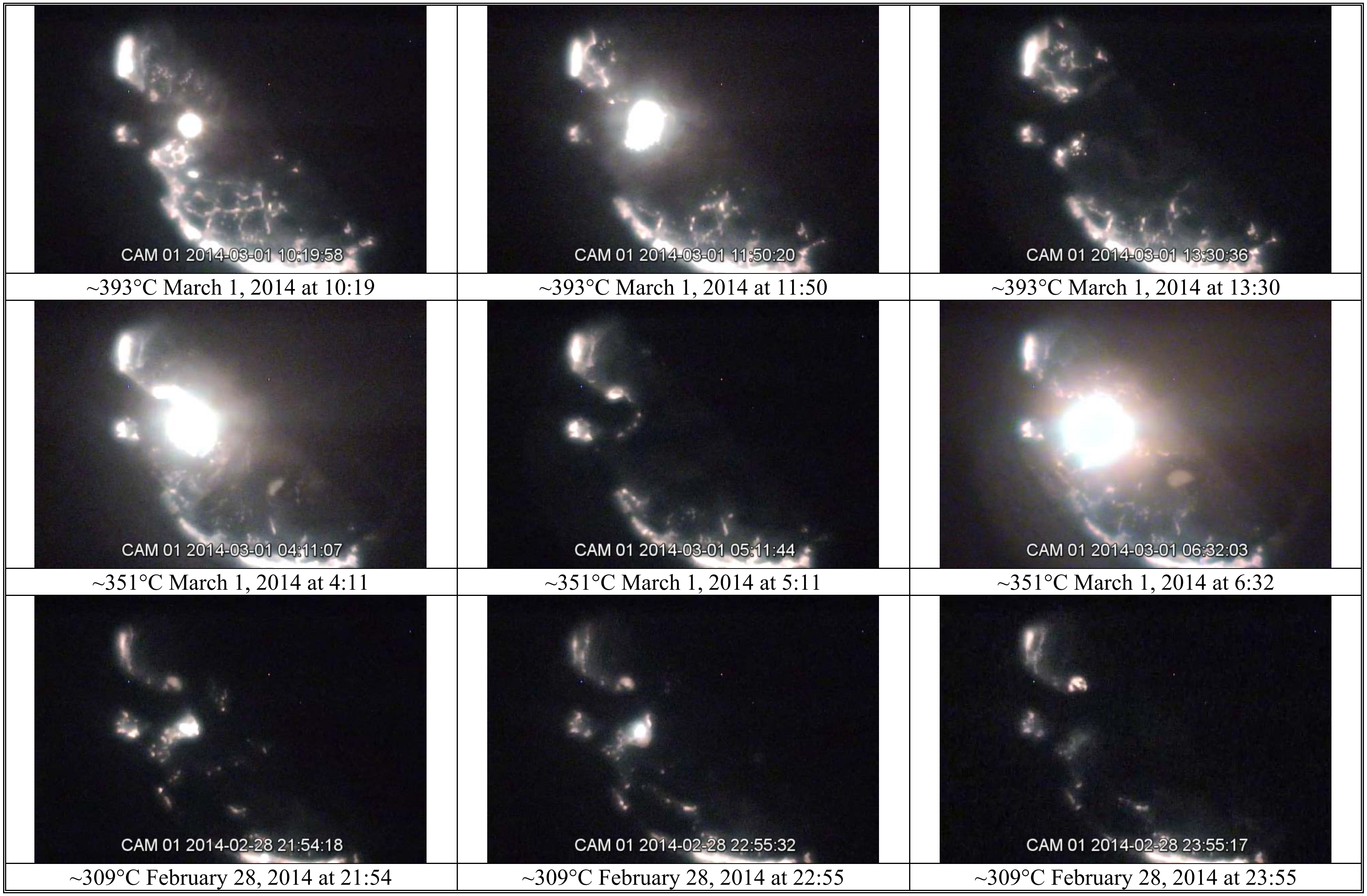


Figure 4-7. Cold cap images during the 125% stoichiometry non-bubbled testing.



~393°C March 1, 2014 at 10:19	~393°C March 1, 2014 at 11:50	~393°C March 1, 2014 at 13:30
~351°C March 1, 2014 at 4:11	~351°C March 1, 2014 at 5:11	~351°C March 1, 2014 at 6:32
~309°C February 28, 2014 at 21:54	~309°C February 28, 2014 at 22:55	~309°C February 28, 2014 at 23:55

Figure 4-8. Cold cap images during the 125% stoichiometry non-bubbled testing.

4.4 100% Stoichiometry Melter Feed

Feeding was initiated on March 2, 2014 at approximately 8:38 and ended on March 16 at approximately 13:50. More details of specific tests performed with this melter feed will be provided in the following sections.

4.4.1 Steady State Vapor Space Testing (Non-Bubbled)

Steady state testing with the 100% stoichiometry feed (45 wt% total solids[r]) with an argon bubbling rate of ~0.001-0.003 scfm per bubbler began on March 2 at 8:38 and was completed on March 4 at 6:05.[s] A summary of the primary test conditions for each vapor space temperature test are shown in Table 4-8. The initial temperature was ~697°C and the feed rate, vapor space heater output and air purge were incrementally adjusted to *reduce* the vapor space temperature to ~326°C. Additional purge air in the range of 13-35 scfm was required to achieve vapor space temperatures below ~496°C, which is comparable to the range of 15-30 scfm that was used for the 125% stoichiometry non-bubbled testing. Feed rate was decreased linearly (R^2 = 0.97) in the range of 43-118 g/min for each vapor space temperature below ~697°C as shown in Figure 4-9. A comparison of the actual and calculated glass production rates are shown in Figure 4-10. Images of the cold cap throughout steady state testing are shown in Figure 4-11 and Figure 4-12. The light color (orange glow) of the cold cap for the ~697°C and ~600°C test is an indication of underfeeding, as well as the cracks in the cold cap that were present for the ~496°C test.

Table 4-8. 100% Non-Bubbled Steady State Vapor Space Temperature Test Conditions

Average Vapor Space Temperature (°C)	Average Glass Pool Temperature (°C)	Average Film Cooler Flow (scfm)	Average Melter Air Purge (scfm)
697	1086	16	0
600	1085	17	0
496	1068	17	0
410	1074	17	13
344	1078	16	28
326	1079	10	35

Average Vapor Space Temperature (°C)	Average Feed Rate (g/min)	Average Melter Pressure (inwc)	Average Vapor Space Output (volts)
697	118	-5	114
600	92	-6	80
496	85	-6	20
410	55	-6	8
344	47	-5	8
326	43	-4	8

[r] Since the 125% stoichiometry feed was diluted to 45 wt% total solids, the 100% stoichiometry feed was also diluted to 45 wt% total solids so that direct comparisons could be made for the flammability model development.

[s] During non-bubbled conditions, a minimal bubbling rate was maintained in order to reduce the risk of plugging the bubbler ports.

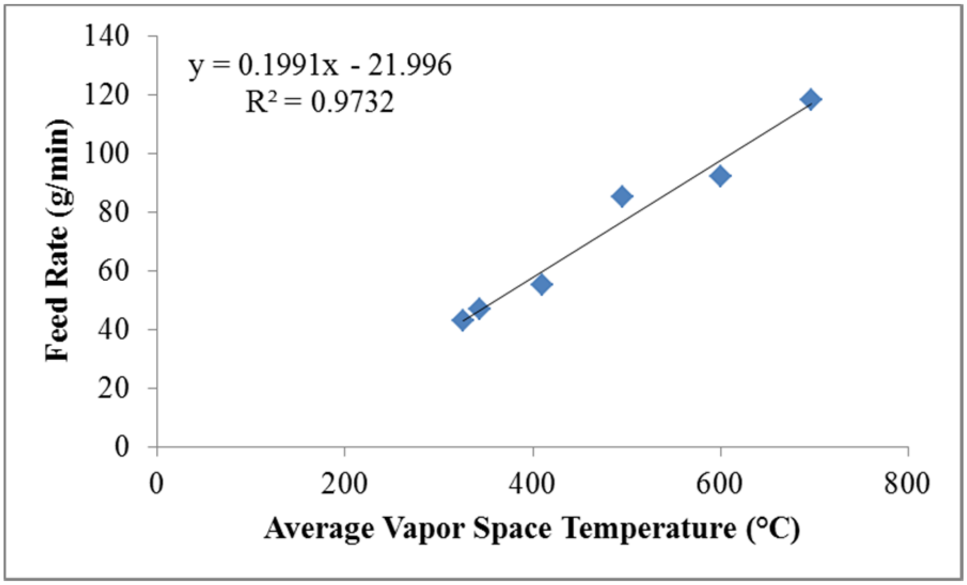


Figure 4-9. 100% stoichiometry non-bubbled feed rate as a function of vapor space temperature.

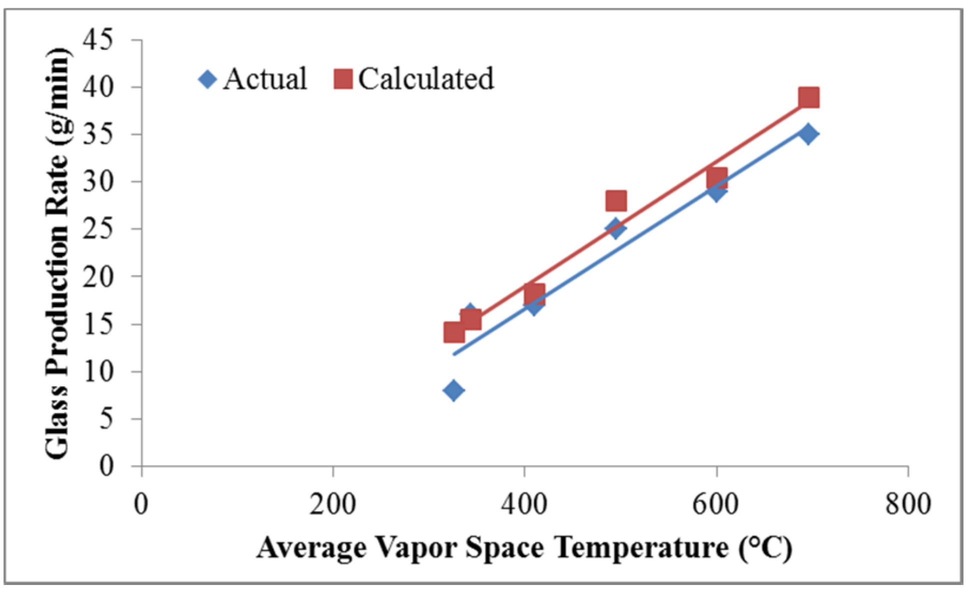


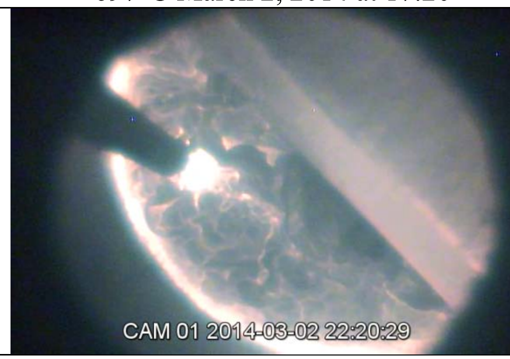
Figure 4-10. 100% stoichiometry non-bubbled condition glass production rates.

~697°C March 2, 2014 at 16:20

~697°C March 2, 2014 at 17:20

~697°C March 2, 2014 at 18:20

~600°C March 2, 2014 at 21:10

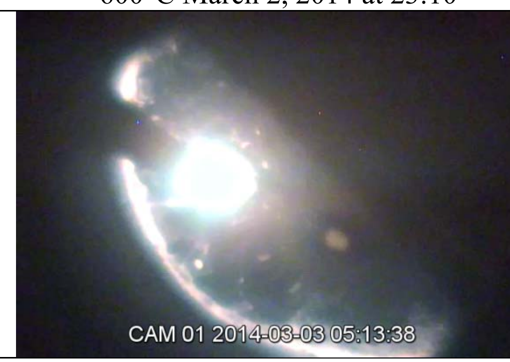


~600°C March 2, 2014 at 22:20

~600°C March 2, 2014 at 23:10

~496°C March 3, 2014 at 3:13

~496°C March 3, 2014 at 4:15



~496°C March 3, 2014 at 5:13

Figure 4-11. Cold cap images during the 100% stoichiometry non-bubbled testing.

~410°C March 3, 2014 at 8:30

~410°C March 3, 2014 at 10:00

~410°C March 3, 2014 at 11:02

~344°C March 4, 2014 at 00:12

~344°C March 4, 2014 at 1:11

~344°C March 4, 2014 at 2:12

~326°C March 4, 2014 at 4:05

~326°C March 4, 2014 at 5:05

~326°C March 4, 2014 at 6:05

Figure 4-12. Cold cap images during the 100% stoichiometry non-bubbled testing.

4.4.2 Steady State Vapor Space Testing (Bubbled)

Steady state testing with the 100% stoichiometry feed (45 wt% total solids) with an argon bubbling rate of ~0.2 scfm per bubbler began on March 4 at 20:24 and was completed on March 8 at 8:30. A summary of the primary test conditions for each vapor space temperature test are shown in Table 4-9. The initial temperature was ~323°C and the feed rate, vapor space heater output and air purge were incrementally adjusted to *increase* the vapor space temperature to ~750°C. Additional purge air in the range of 6-46 scfm was required to achieve vapor space temperatures below ~521°C, which is comparable to the range used for the 125% stoichiometry bubbled testing. Feed rate was increased linearly (R^2 = 0.97) in the range of 88-179 g/min for each vapor space temperature above ~323°C as shown in Figure 4-13. As expected, these feed rates during bubbled testing were higher than those during non-bubbled testing due to the convection in the melt pool. A comparison of the actual and calculated glass production rates are shown in Figure 4-14. Images of the cold cap throughout steady state testing are shown in Figure 4-15 through Figure 4-17. In general, there do not appear to be any signs of underfeeding or overfeeding.

Table 4-9. 100% Bubbled Steady State Vapor Space Temperature Test Conditions

Average Vapor Space Temperature (°C)	Average Glass Pool Temperature (°C)	Average Film Cooler Flow (scfm)	Average Melter Air Purge (scfm)
750	1054	15	1
705	1050	15	1
607	1053	15	0
521	1035	15	1
471	1041	15	6
373	1025	16	26
323	1031	6	46

Average Vapor Space Temperature (°C)	Average Feed Rate (g/min)	Average Melter Pressure (inwc)	Average Vapor Space Output (volts)
750	179	-5	136
705	171	-5	136
607	156	-5	95
521	118	-5	8
471	112	-4	8
373	101	-5	8
323	88	-1	8

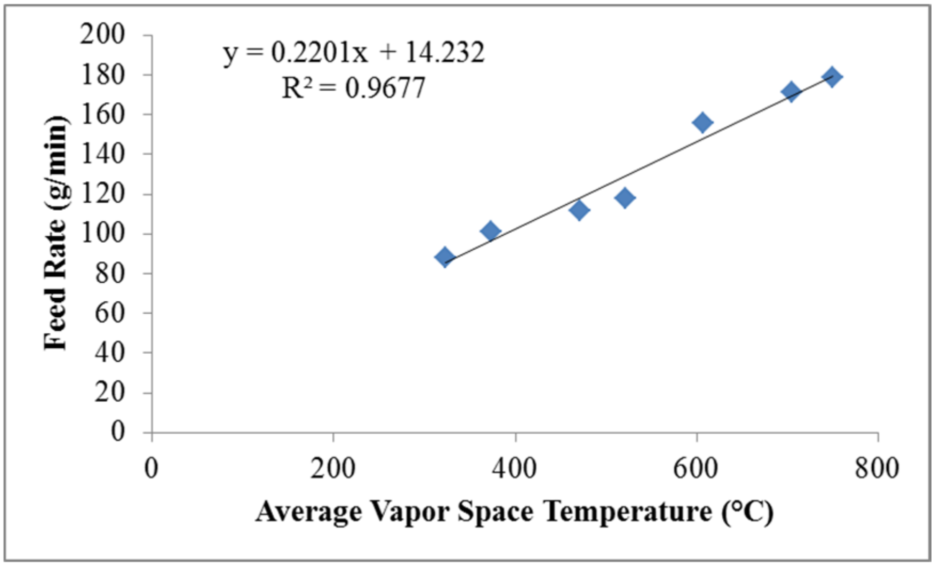


Figure 4-13. 100% stoichiometry bubbled feed rate as a function of vapor space temperature.

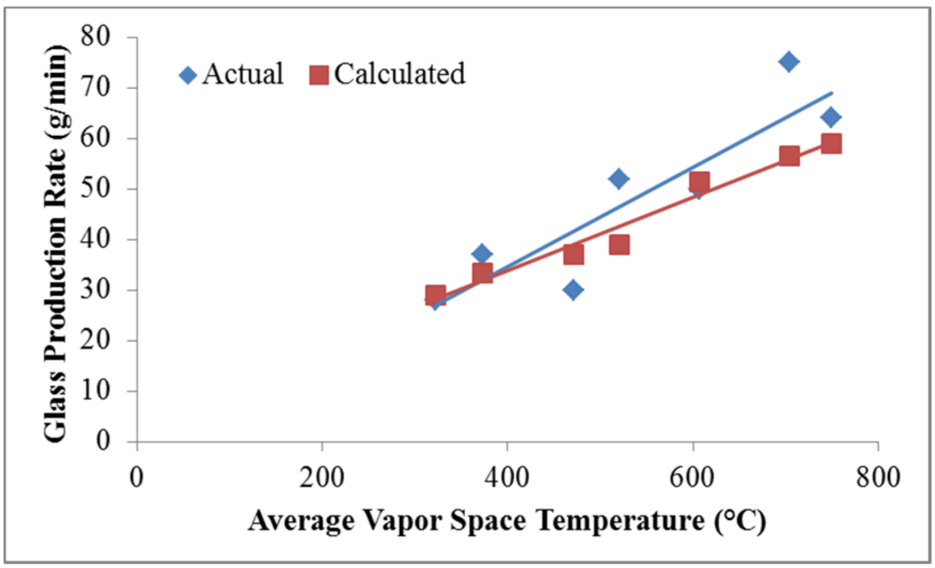
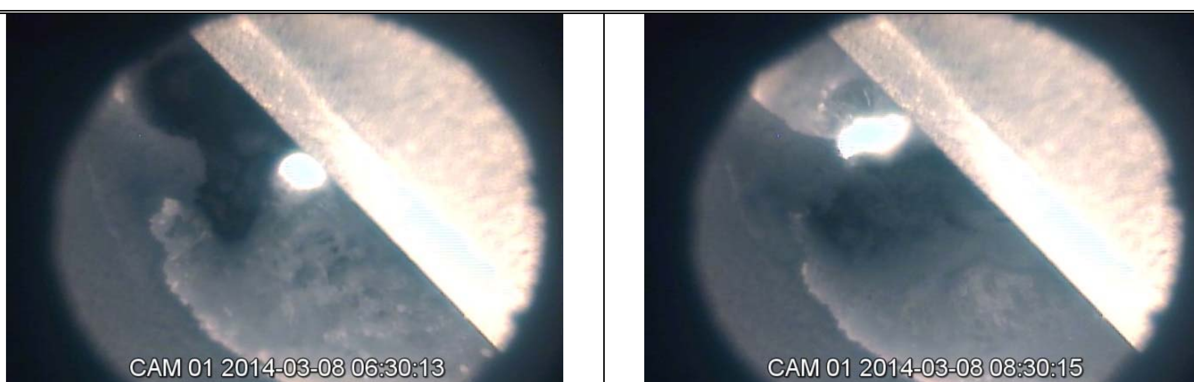
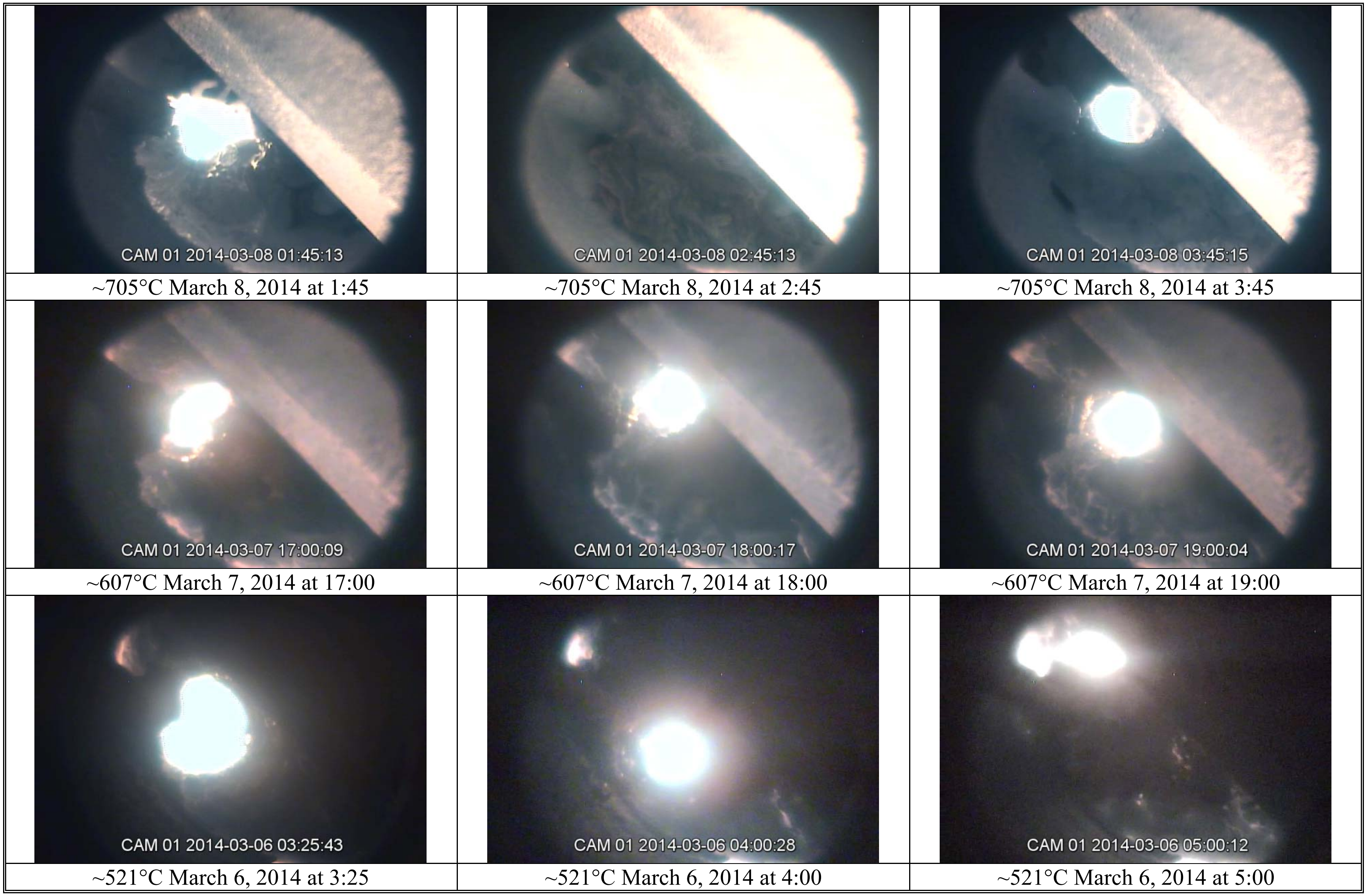


Figure 4-14. 100% stoichiometry bubbled condition glass production rates.



~750°C March 8, 2014 at 6:30	~750°C March 8, 2014 at 8:30

Figure 4-15. Cold cap images during the 100% stoichiometry bubbled testing.



~705°C March 8, 2014 at 1:45	~705°C March 8, 2014 at 2:45	~705°C March 8, 2014 at 3:45
~607°C March 7, 2014 at 17:00	~607°C March 7, 2014 at 18:00	~607°C March 7, 2014 at 19:00
~521°C March 6, 2014 at 3:25	~521°C March 6, 2014 at 4:00	~521°C March 6, 2014 at 5:00

Figure 4-16. Cold cap images during the 100% stoichiometry bubbled testing.

~471°C March 6. 2014 at 00:45

~471°C March 6. 2014 at 1:45

~471°C March 6. 2014 at 2:45

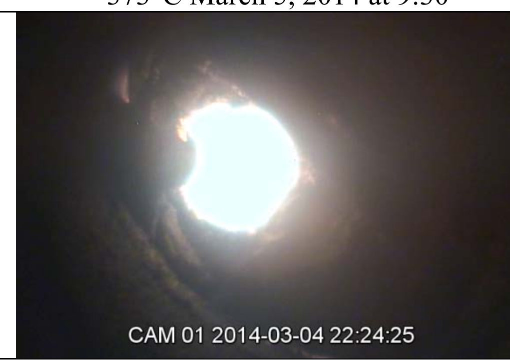
~373°C March 5, 2014 at 7:30

~373°C March 5, 2014 at 8:30

~373°C March 5, 2014 at 9:30

~323°C March 4, 2014 at 20:24

~323°C March 4, 2014 at 21:25



~323°C March 4, 2014 at 22:24

Figure 4-17. Cold cap images during the 100% stoichiometry bubbled testing.

4.4.3 Surge Testing (Bubbled at 45 wt% total solids)

Bubbled surge testing was initiated with the 100% stoichiometry feed at a 45 wt% total solids target on March 8, 2014 at approximately 10:15 with an argon rate of ~0.5 per bubbler (~1 scfm total). The first pressure spike above 0 inwc occurred on March 9, 2014 at approximately 3:30, which was followed by several positive pressure spikes starting at approximately 8:05 (elapsed time of 307.1 hours) as shown in Figure 4-18. At approximately 10:08 (elapsed time of 309.1 hours), a pressure surge reached an average of +16 inwc, which activated a system safety interlock. As a result of the safety interlock, feeding was automatically stopped and after 10 seconds, air to the film cooler (AF1), cameras (AF2 and AF3) and argon bubblers (FT-Ar-1 and FT-Ar-2) were shut off by the control software. The pressure in the melter dropped to an average of -20 inwc (Figure 4-18). It should be noted that the safety interlock and subsequent actions are unique to this system and are not prototypic of DWPF operations. An attempt was made to re-establish nominal conditions; however, at 10:42 the off-gas system blower started malfunctioning, which was thought to be caused by feed material in the off-gas line. The blower was replaced and to prevent a future failure, a 55-gallon poly drum was attached to the off-gas line in between the melter and blower to collect condensate and particulate.

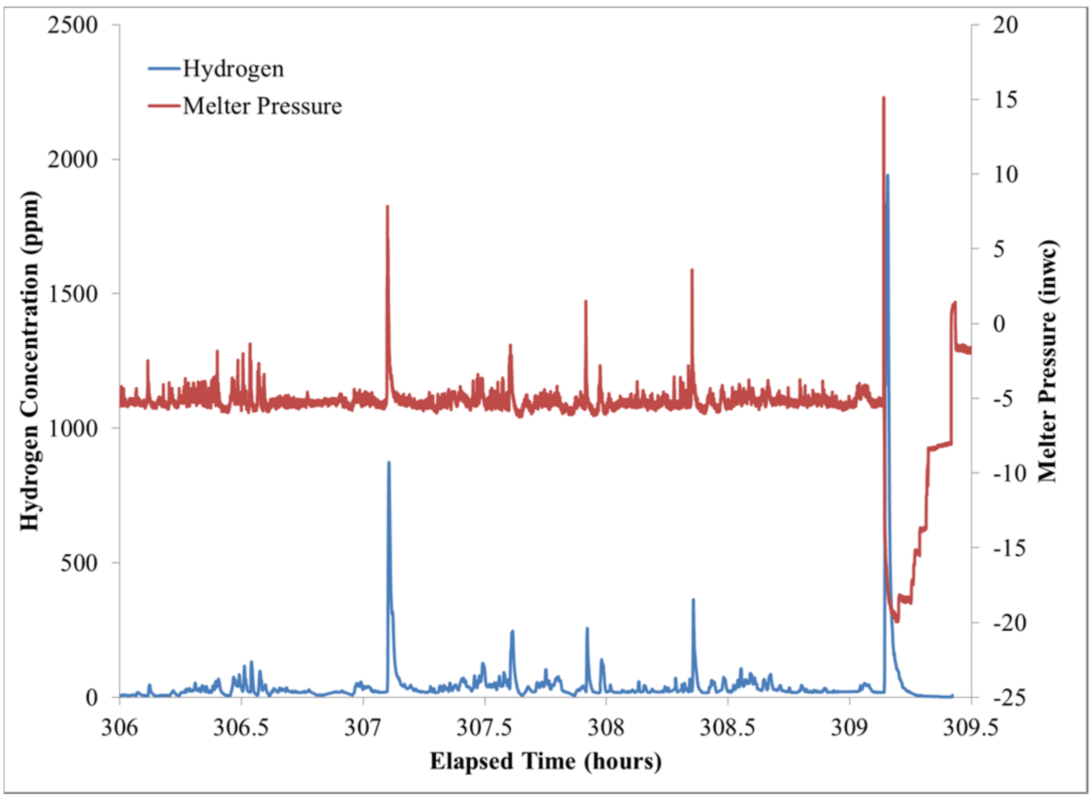


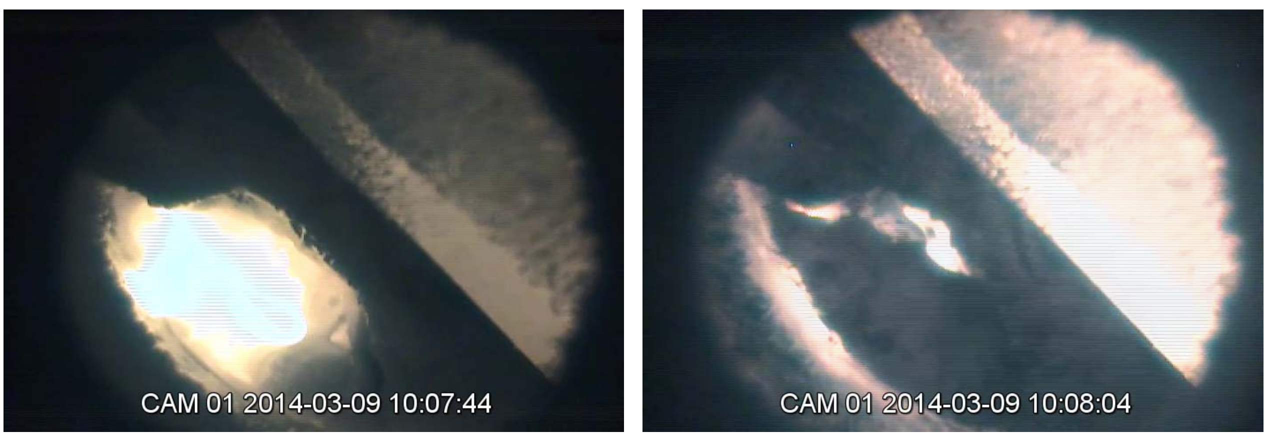
Figure 4-18. Melter pressure (PT1) before and after +16 inwc pressure surge.

Air and argon flows to the melter twenty four hours prior to this event were quite stable as shown in Table 4-10. During this time feed rate was increased from ~199-250 g/min, which was not unusual compared to feed rates used at the beginning of testing during turnover. The average melt pool temperature was 996°C with a minimum temperature of 869°C, which was somewhat low compared to other times during testing.

Table 4-10. Conditions in Melter Prior to Surge

Parameter	Average	Minimum	Maximum
Feed Rate (g/min)	---	199	251
Vapor Space Temperature (°C)	731	641	764
Melt Pool Temperature (°C)	996	869	1036
Argon Flow (scfm)	0.5	---	---
Film Cooler Air Flow (scfm)	16	---	---
Purge Air Flow (scfm)	~0	---	---
Camera 1 Air Flow (scfm)	8	---	---
Camera 2 Air Flow, Inlet (scfm)	8	---	---
Camera 2 Air Flow, Outlet (scfm)	7	---	---

One difference that should be noted is the feed itself; 125% stoichiometry feed was used during melter turnover. Visually, the 125% and 100% melter feeds were very different during mixing, which was expected based on the consistency measurements for the SRAT products; 15.2 cP for the 125% stoichiometry feed versus 5.4 cP for the 100% stoichiometry feed.[36,37] During testing, the as-received 125% melter feed was described as being "very thick", while the 100% feed was described as being "thin and watery," which was also confirmed by the video recorded from Camera 1 during the surge. Prior to the surge a large vent hole was observed near one of the bubblers (Figure 4-19a) and the +16 inwc pressure spike occurred as melter feed flooded the entire vent hole (Figure 4-19b).



(a) (b)

Figure 4-19. Images of cold cap and vent hole pre-surge (a) and during +16 inwc surge (b).

At this time, hydrogen concentration also increased to ~2000 ppm. A comparison of hydrogen concentration and pressure is shown in Figure 4-18. Each spike in hydrogen concentration has a corresponding spike in pressure, which is characteristic of surges in the melter. Unfortunately the view from Camera 2 was unclear and it was not possible to see if a "pool" of feed had been forming in the center of the melter over time. Several of the pressure surges leading up to this event were also viewed and feed entered the vent hole in each case; however, the amount of feed was much less in these occurrences. Intuitively, the 125% stoichiometry feed should have been thinner as compared to the 100% feed due to increased acid; however, the thick consistency of the 125% stoichiometry SRAT product was also observed during recent SRAT runs performed at SRNL.[53] It is possible that the thin consistency of the 100% feed coupled with the low melt pool temperature created the ideal conditions for this massive surge to occur in the melter. Lower melt pool temperatures are conducive to a more rigid cold cap. Had the melt pool temperature been higher, it is possible that there would not have been as much potential for "pooling" of the melter feed, which caused the surge as the significant amount of feed entered the vent hole.

At approximately 23:27 on March 9, 2014, feeding was restarted with the 100% stoichiometry feed at ~80 g/min and the argon bubbler rate was increased to ~0.5 scfm per bubbler at approximately 1:45 on March 10, 2014. By 13:51, the average feed rate was 225 g/min. The average melt pool temperature was 1011°C, which is 15°C higher than the average temperature prior to the +16 inwc surge. Air flow and argon flows were also stable. During this instance of feeding the 100% stoichiometry feed at 45 wt% total solids, only one instance of positive pressure was observed (~1 inwc). The cold cap appeared to be uniform and somewhat fluid, which is significantly different than cold cap prior to the +16 inwc surge, which was raised and rigid around the vent hole. The higher melt pool temperatures during this instance of the 45 wt% total solids testing could have prevented a thick cold cap from forming, thus reducing the chance for feed to pool in the center of the melter and cause a significant surge to occur. Based on a discussion with the customer, the total solids target of the 100% stoichiometry feed was reduced to 42 wt% in order to make comparisons to surge testing that had been completed in 2010 with nitric-formic acid feed.

4.4.4 Surge Testing (Bubbled at 42 wt% total solids)

At 17:33 on March 10, 2014, the feed was further diluted to 42 wt% total solids. After a subsequent heater failure and replacement (19:40 – 2:00 on March 11, 2014), feeding was restarted at 4:31 on March 11, 2014 (elapsed time of 351.5 hours) with a bubbling rate of ~0.5 scfm per bubbler and continued under nominal conditions until March 15, 2014 at 9:40.

Average values of vapor space temperature, melt pool temperature and argon flow during this time are shown in Table 4-11. While the average argon flow was ~0.5 scfm per bubbler, there were instances during the test in which the bubbling rate was lowered in order to increase the melt pool temperature.

Table 4-11. Melter Conditions During Bubbled Surge Testing

Average Vapor Space Temperature (°C)	Average Melt Pool Temperature (°C)	Average Argon Flow (scfm) per bubbler
720	996	0.5

Nominal air flows to the melter were held constant.[t] Feed rate was varied in the range of 72 – 270 g/min as shown in Figure 4-20.[u] Feed line blockages are noted by a feed rate value of 0 g/min.[v] Melter pressure and hydrogen concentration are shown for the ~4 days of bubbled surge testing in Figure 4-21. Positive melter pressures were not observed until the elapsed test time had reached approximately 411 hours, the highest of which reached approximately +8 inwc. Hydrogen concentrations for these positive pressures were in the range of ~300-700 ppm. Camera 1 video again confirmed that these surges were caused by feed flooding into the vent hole. The cold cap prior to the largest surge (+8 inwc) had a raised and rigid appearance (Figure 4-22) around the vent hole similar to the cold cap prior to the +16 inwc surge. Had

[t] AF1 (Film Cooler) ≈ 17 scfm, AF2 (Camera 1) ≈ 8 scfm, AF3 (Camera 2 Inlet) ≈ 8 scfm, AF4 (Camera 2 Outlet) ≈ 7 scfm and AF5 (Melter Stoke Air) ≈ 0 scfm.

[u] Feed rate was estimated by using a conversion factor of 3.6 for the feed pump RPM values listed in the laboratory notebooks (SRNL-NB-2013-00020 and SRNL-NB-2014-00007).

[v] Feed line blockages occurred throughout testing and are only mentioned in this section due to the feed rate points of 0 g/min in Figure 4-20.

the average melt pool temperature been comparable to the DWPF operating temperature, it is possible that some of the surges could have been avoided in this system.

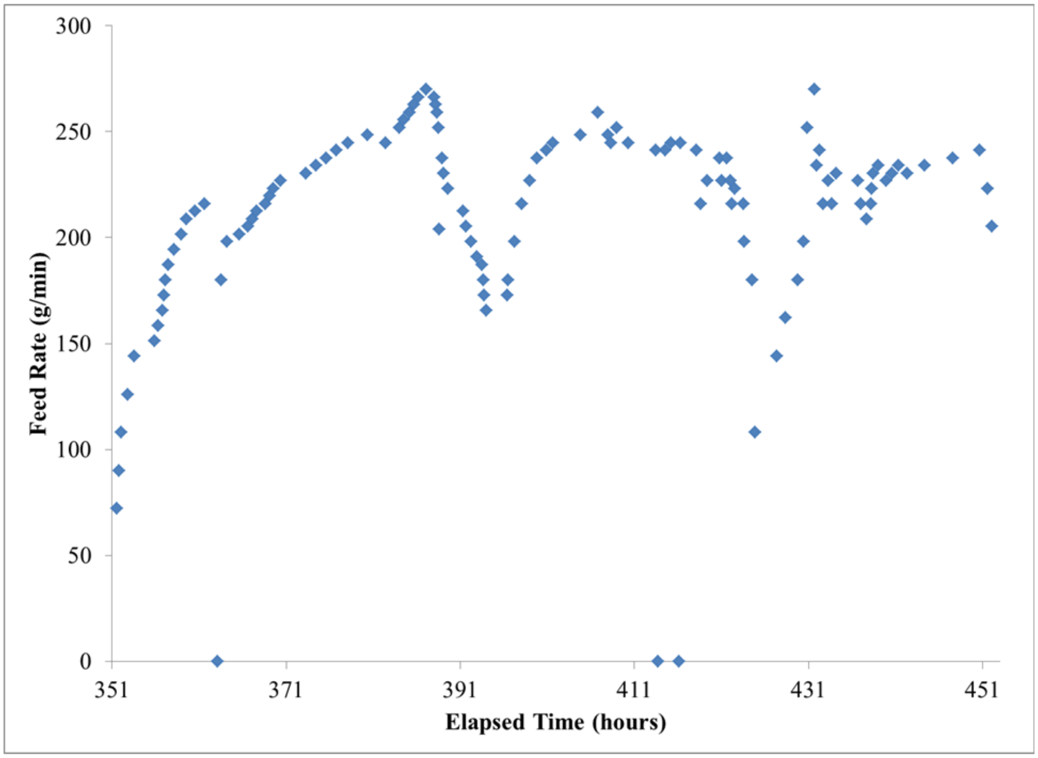


Figure 4-20. Feed rates during bubbled surge testing.

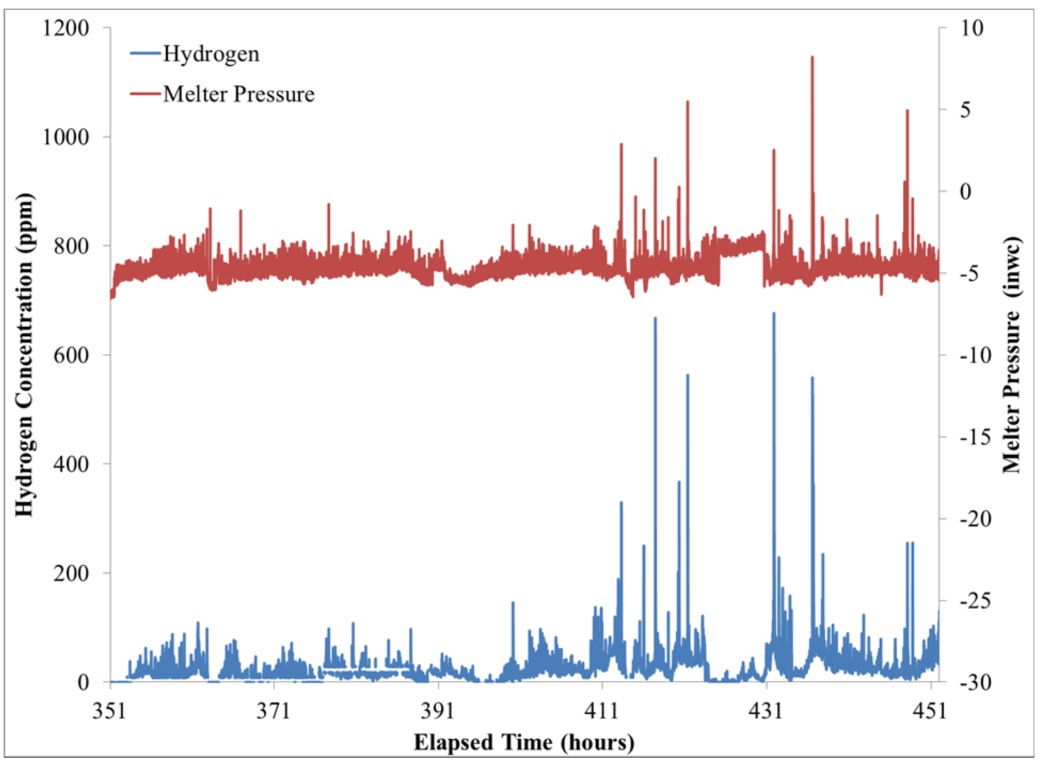


Figure 4-21. Melter pressure and hydrogen concentration during bubbled surge testing.

Figure 4-22. Image of the cold cap and vent hole prior to the +8 inwc surge.

4.4.5 Surge Testing (Non-bubbled)

Non-bubbled surge testing was initiated with the 100% stoichiometry feed at a 42 wt% total solids target on March 15, 2014 at approximately 13:24 with an argon rate of ~0.003 per bubbler (~0.006 scfm total).[w] Average values of vapor space temperature, melt pool temperature and argon flow during this time are shown in Table 4-12.

Table 4-12. Melter Conditions During Non-Bubbled Surge Testing

Average Vapor Space Temperature (°C)	Average Melt Pool Temperature (°C)	Average Argon Flow (scfm) per bubbler
713	1067	0.003

Nominal air flows to the melter were held constant.[x] Feed rate was varied in the range of 105 – 165 g/min as shown in Figure 4-23.[y] Melter pressure and hydrogen concentration are shown for the 1 day of non-bubbled testing in Figure 4-24. The only positive pressure (+5 inwc) occurred at approximately 465 hours with a corresponding peak in hydrogen at ~70 ppm. The view from Camera 1 did not show any obvious conditions in the melter that would have caused a positive surge. While there was liquid feed on the surface of the cold cap, there was not a visible vent hole that feed was entering as shown in Figure 4-25. The view from Camera 2 was unclear, but there also did not appear to be a vent hole.

[w] During non-bubbled conditions, a minimal bubbling rate was maintained in order to reduce the risk of plugging the bubbler ports.
[x] AF1 (Film Cooler) ≈ 16 scfm, AF2 (Camera 1) ≈ 8 scfm, AF3 (Camera 2 Inlet) ≈ 8 scfm, AF4 (Camera 2 Outlet) ≈ 7 scfm and AF5 (Melter Stoke Air) ≈ 0.4 scfm.
[y] Feed rate was estimated by using a conversion factor of 3.6 for the feed pump RPM values listed in the laboratory notebooks (SRNL-NB-2013-00020 and SRNL-NB-2014-00007).

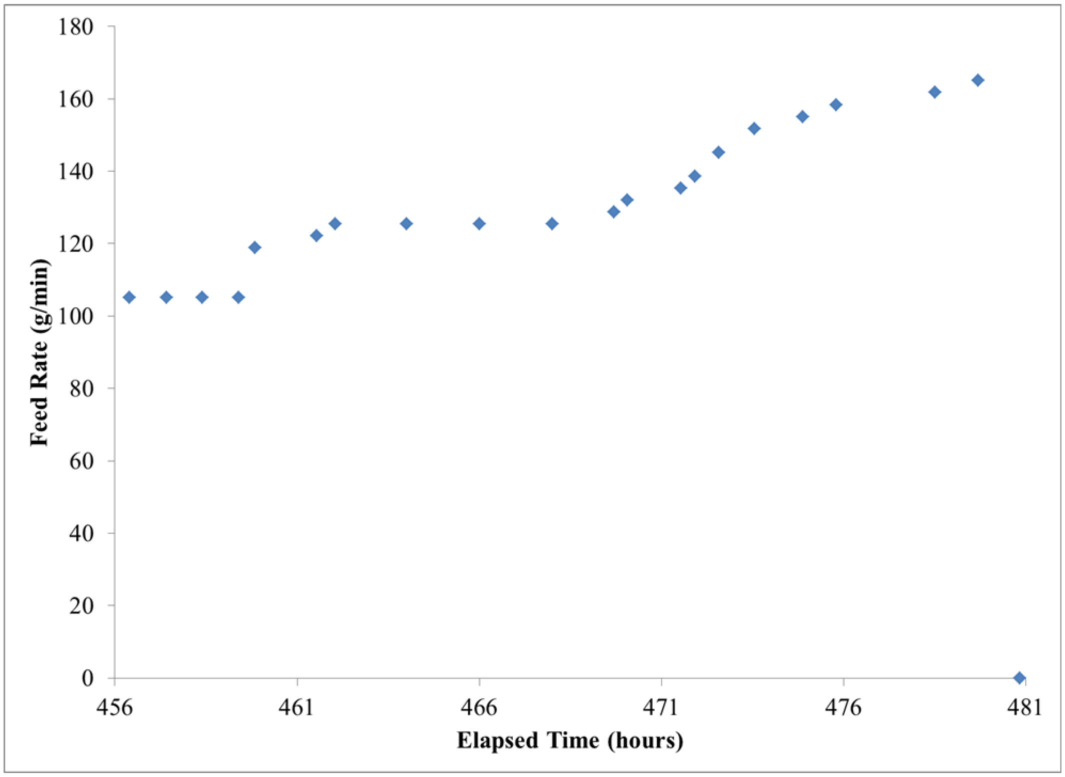


Figure 4-23. Feed rates during non-bubbled surge testing.

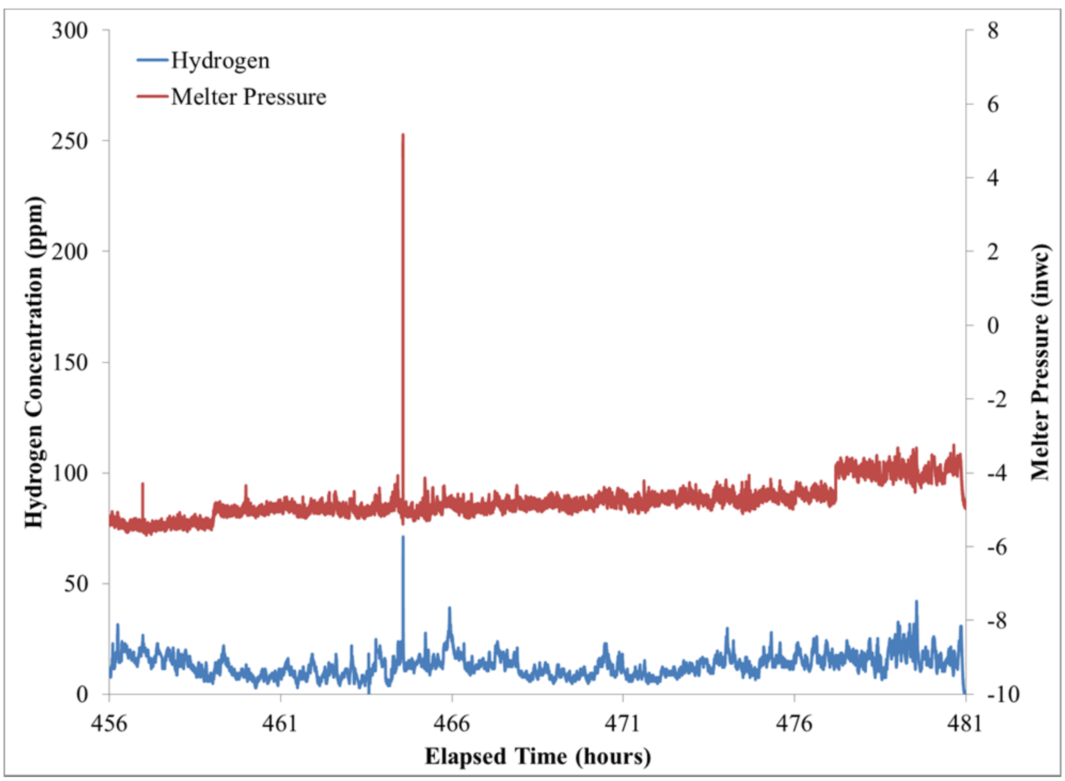


Figure 4-24. Melter pressure and hydrogen concentration during non-bubbled surge testing.

Figure 4-25. Image of the cold cap prior to the +5 inwc surge during non-bubbled conditions.

4.5 100% Stoichiometry Melter Feed with Antifoam Spike (Non-bubbled)

Feeding was initiated on March 16, 2014 at ~16:48 with an argon bubbling rate of ~0.003 scfm per bubbler.[z] Approximately three times (~3X) the nominal amount of Antifoam 747 was added to each batch (0.7 kg as shown in Table 3-6 of Section 3.2) and the feed was diluted to a target total solids of 45 wt%. Visually, the consistency of this antifoam spiked melter feed was reduced as compared to the 100% stoichiometry melter feed without excess antifoam. As the feed was mixing in the feed pot, a considerable amount of foam was generated as shown in Figure 4-26; however, no foaming was observed inside of the melter. It should be noted that foaming from excessive antifoam additions has occurred during previous testing.

Figure 4-26. Foamy melter feed.

The 100% stoichiometry melter feed with the antifoam spike appeared very fluid in the Camera 1 view and despite constant feeding at an average rate of 68-194 g/min for at least 10 hours, the cold cap remained light in color and cracked, which is an indication of underfeeding (Figure 4-27).

[z] During non-bubbled conditions, a minimal bubbling rate was maintained in order to reduce the risk of plugging the bubbler ports.

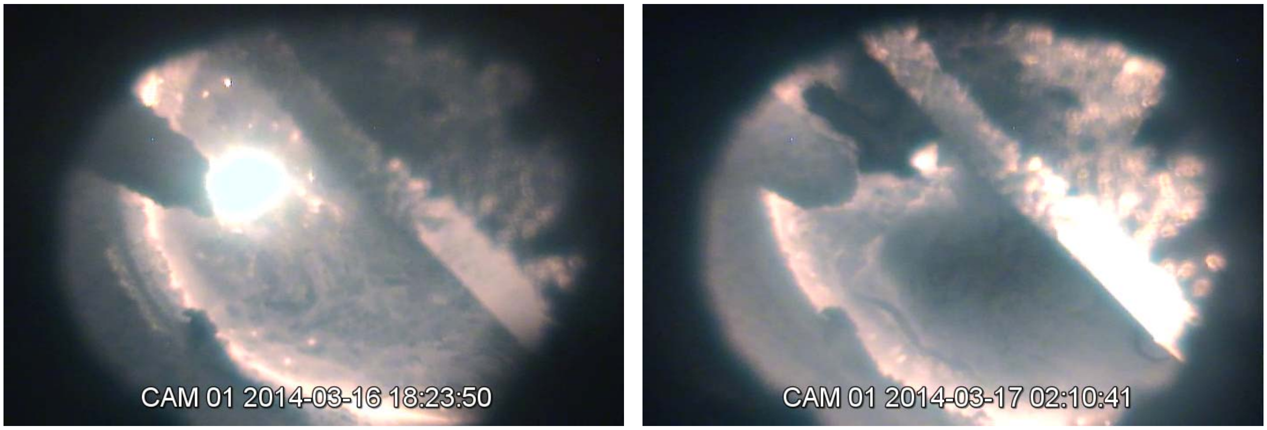


Figure 4-27. Cold cap images during the ~3X antifoam spike.

The correlation between the feed pump rotations per minute (RPM) and the calculated feed rates[aa] was extremely inconsistent for this feed, which was related to the foam present in the feed pot. In one instance the calculated feed rate for 56 RPM was 152 g/min, while a calculation at a later time resulted in a feed rate of 191 g/min. Air entrained in the feed caused there to be less feed being fed to the melter, which resulted in underfeeding even though sufficiently high pump speeds were being used. During this time a sufficient cold cap could not form.

An attempt was made to conduct the first ~700°C steady state test at 4:30 on March 17; however, the vapor space temperature dropped by more than 30°C at the end of the two-hour period and the feed rate was inconsistent. By 8:00, the vapor space temperatures were still not steady even though no changes had been made to the system since 3:00. Based on the difficulties with the steady state testing, a decision was made by the technical lead to reduce the antifoam spike to two times (~2X) the nominal amount per batch (0.4 kg as shown in Table 3-6 of Section 3.2). The total solids target remained at 45 wt%. Foam was still present in the feed pot, but to a lesser extent than the ~3X antifoam spiked melter feed.

4.5.1 Steady State Vapor Space Testing (~2X Antifoam Spike, Non-Bubbled)

Steady state testing with the 100% stoichiometry feed (~2X antifoam spike and 45 wt% total solids) with an argon bubbling rate of ~0.002 scfm per bubbler began on March 17 at 12:12 and was completed on March 19 at 0:42.[bb] It should be noted that the 700°C vapor space temperature test was repeated on March 20 since the initial test had been conducted with the ~3X antifoam spiked feed. A summary of the primary test conditions for each vapor space temperature test are shown in Table 4-13.[cc] The initial temperature was ~604°C and the feed rate, vapor space heater output and air purge were incrementally adjusted to *decrease* the vapor space temperature to ~293°C. Additional purge air in the range of 19-34 scfm was required to achieve vapor space temperatures below ~519°C. Feed rates in the range of 36-103 g/min were used, which is comparable to previous non-bubbled steady state tests. As previously mentioned, the correlation between pump RPM and calculated feed rate was not very consistent for this feed, which is also evident in Figure 4-28. For all other feeds, the linear fit of feed rate and vapor space temperature had a relatively high R^2 value (> 0.89); however, the value for this feed was only 0.8. A comparison of the actual and calculated feed rates is shown in Figure 4-29. The 722°C test was repeated at a later date, which could be the cause for the large deviation between the two rates. Images of the cold cap throughout steady state testing are shown in Figure 4-30 and Figure 4-31. Compared to images from the previous non-bubbled tests, there appears to be much more cold cap coverage, as there is no additional

[aa] Feed rate was calculated by the change in mass of the feed scale per unit time.
[bb] During non-bubbled conditions, a minimal bubbling rate was maintained in order to reduce the risk of plugging the bubbler ports.
[cc] The melter conditions for the repeated 700°C steady state test is presented.

orange glow from the glass melt besides the vent hole. There was no evidence of overfeeding as no significant deviations in melt pool temperature were observed. The average glass pool temperature was in the range of 1052-1097°C through testing.

Table 4-13. Antifoam Spike Non-Bubbled Steady State Vapor Space Temperature Test Conditions

Average Vapor Space Temperature (°C)	Average Glass Pool Temperature (°C)	Average Film Cooler Flow (scfm)	Average Melter Air Purge (scfm)
722	1097	16	0
604	1071	16	0
519*	1066	16	0
397*	1052	16	19
323*	1057	10	28
293	1066	6	34

Average Vapor Space Temperature (°C)	Average Feed Rate (g/min)	Average Melter Pressure (inwc)	Average Vapor Space Output (volts)
722	103	-3	128
604	122	-5	93
519	59	-5	21
397	49	-5	8
323	39	-4	8
293	36	-3	8

* During this time there were issues with T11 and T12, so the average vapor space temperature during this time was taken from the thermocouple with the steadier readings.

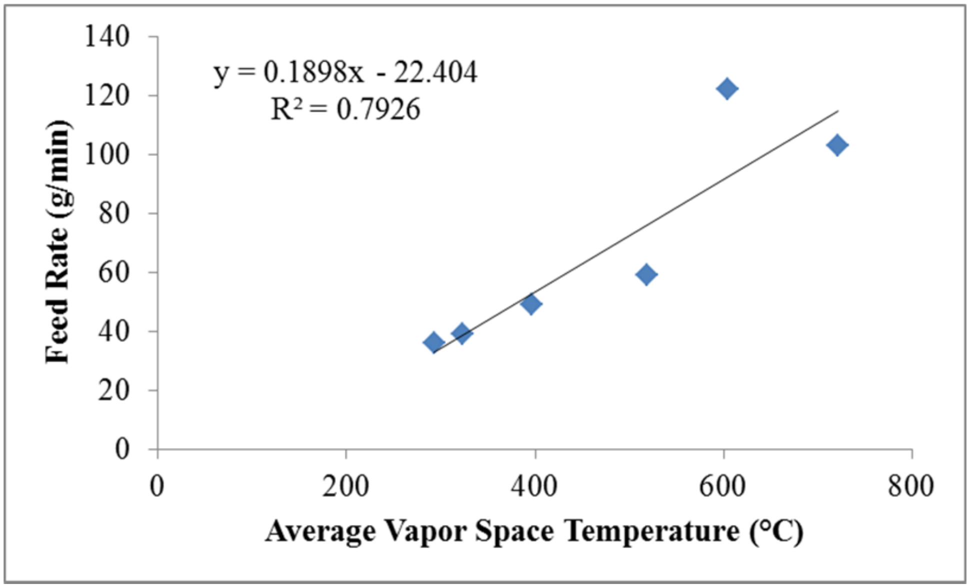


Figure 4-28. 100% stoichiometry (~2X antifoam spike) non-bubbled feed rate as a function of vapor space temperature.

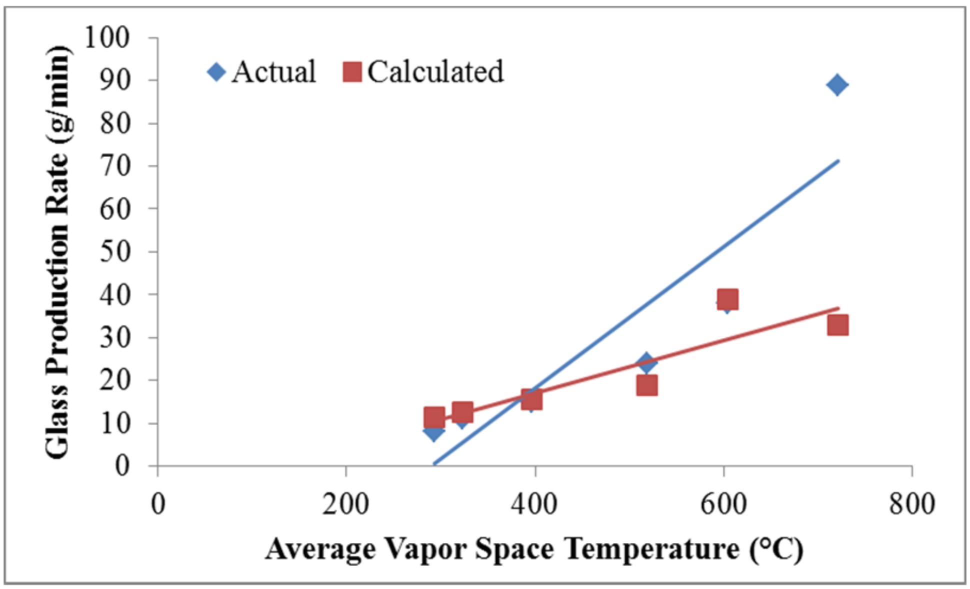


Figure 4-29. 100% stoichiometry (~2X antifoam spike) non-bubbled condition glass production rates.

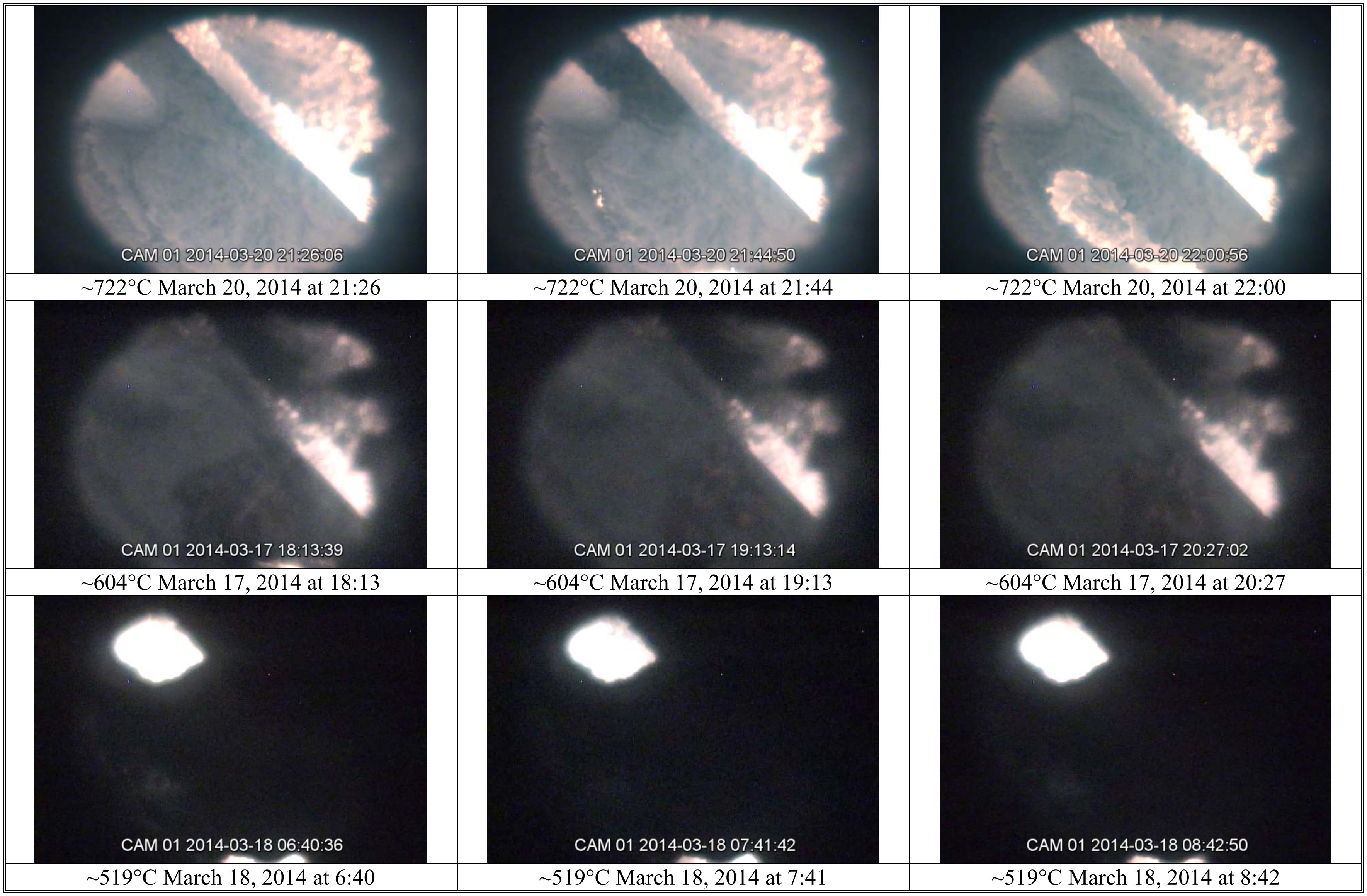


Figure 4-30. Cold cap images during the 100% stoichiometry (~2X antifoam spike) non-bubbled testing.

~397°C March 18, 2014 at 13:09

~397°C March 18, 2014 at 14:09

~397°C March 18, 2014 at 15:08

~323°C March 18, 2014 at 19:32

~323°C March 18, 2014 at 20:33

~323°C March 18, 2014 at 21:32

~293°C March 18, 2014 at 22:38

~293°C March 18, 2014 at 22:55

~293°C March 18, 2014 at 23:08

Figure 4-31. Cold cap images during the 100% stoichiometry (~2X antifoam spike) non-bubbled testing.

4.6 Glass Production Rate

Although melt rate was not one of the objectives of this alternate reductant melter testing, conditions used for Phase I and Phase II testing provide an opportunity to gain some insight into potential differences in melt rate or glass production rate. Therefore, the results are presented for information only. Since Phase I testing was limited in scope, only the non-bubbled, steady state testing points can be used for comparison with the Phase II data. At vapor space temperatures above 500°C, a glass production rate in the range of 27-30 g/min was achieved for the nitric-formic flowsheet and 31-44 g/min was attained for the nitric-glycolic flowsheet during steady state conditions as shown in Figure 4-32. It should be noted that the operation of the CEF is subjective, which can introduce a considerable amount of variation in any feed rate or melt rate data. In order to compare melt rate under similar conditions, both of these feeds should be further tested with the melt rate furnace (MRF) and analyzed with X-ray computed tomography (CT), which is a method that has been used successfully in the past for melt rate assessments for DWPF.[54-56] The MRF testing and CT analysis techniques would eliminate much of the subjectivity that was introduced during these particular CEF tests, thus providing more un-biased melt rate data. Bubbled melt rate testing under nominal conditions using the CEF would also be of interest.

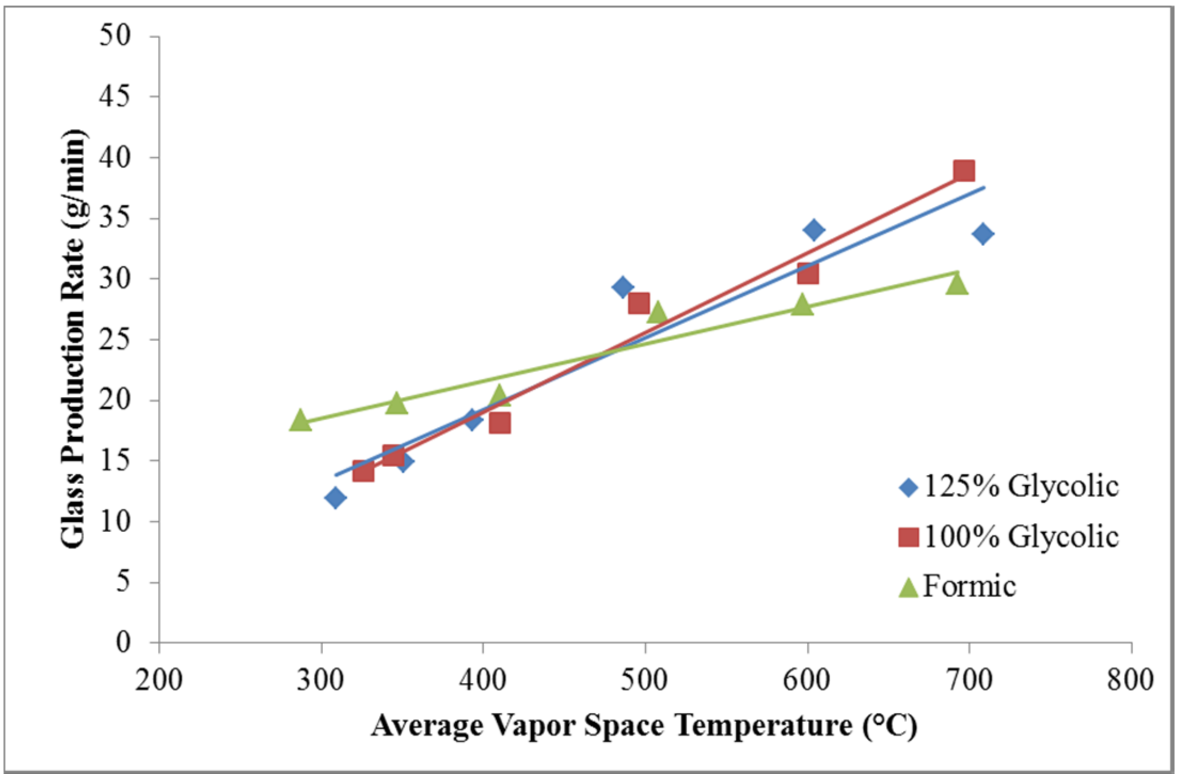


Figure 4-32. Comparison of non-bubbled glass production rates (calculated) as a function of vapor space temperature.

4.7 Vessel Dimensional Documentation

In support of future melter life assessments in terms of structural creep, the temperatures of the thermocouples that were welded to five of the support blocks were monitored and recorded throughout testing.[57,58] Plots of the recorded temperatures are shown in the Appendix (Figure A-46 through Figure A-50). The average temperature was 568°C (standard deviation of 151°C) with a maximum temperature of 893°C. It is important to note that all of the measured support block temperatures were well below the 1093°C value that was used prior to Phase I testing to estimate melter life based on creep concerns.[57,58]

Prior to the start of Phase II testing, the melter vessel had been operated for approximately 385 hours total since 2010. Phase II testing resulted in an additional 672 hours, which brings the current total operational hours on the vessel to approximately 1057 hours. The recommended service life from the previous assessments was 1250 hours, thus if future scope requires use of the current CEF vessel, it is advised to perform measurements of the vessel and support tension rods and repeat the melter life assessment with the new data.

4.8 Sample Analysis

Samples were taken on a regular basis throughout testing. Feed samples were collected each time a new 30 gallon drum of SRAT product was prepared in to melter feed. Glass samples were pulled from the pour stream at ~4 hour intervals. Condensate samples were taken from the overflow tank in the OGCT recirculation line at ~1 hour intervals. The 25 µm bag filters[dd] were removed from service when the discharge pressure dropped by ~ 3 psi. The bags were dried at 50ºC and the solids were collected for analysis.

Sorbent tubes containing coconut shell granular activated carbon were placed in line between the melter and off-gas instrumentation in order to adsorb any organic species from the off-gas stream during portions of testing.

The complete sets of sample results are shown in the Appendix Table A-3 through Table A-53.

4.8.1 Feed Analysis

As fresh drums of Harrell SRAT product were opened, it was observed that a somewhat thick, lard-like material was present in the bottom of some of the drums as the contents were initially mixed with a paddle.[ee] An image of this material from one of the as-received 100% stoichiometry SRAT drums is shown in Figure 4-33. As the SRAT material was further stirred with a drum mixer, this material appeared to break down. It is likely that this material is organic and further analysis is planned. A suitable analytical approach is under development and results will be issued in a separate report.

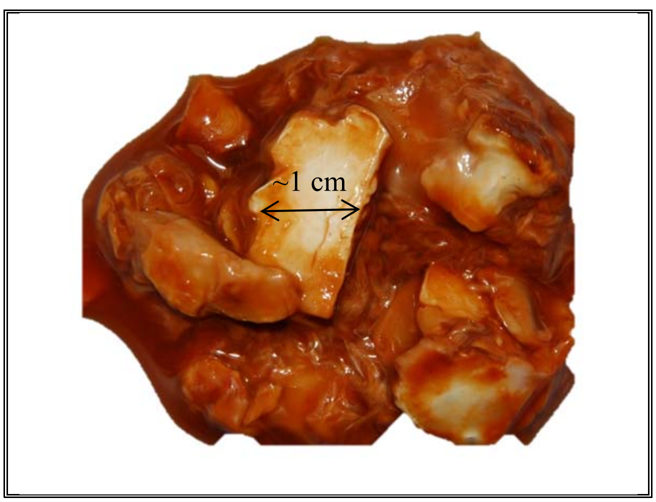


Figure 4-33. Image of lard-like material collected from a 100% SRAT product drum.

[dd] The filters are located after the recirculation pump, but before the booster pump on the condensate system, which protects the multistage pump used to supply water to the quencher.

[ee] It is uncertain as to whether this material was only present in some drums or all of them.

Average measured compositions of select melter feed samples is shown in Table 4-14. Some of the analytes were below the detection limit of the instrument and are noted by a result preceded by a "<." The relative standard deviation (%RSD) values for a majority of the feed constituents are less than 8%, which confirms that the melter feed was batched consistently. As mentioned previously, the consistency of the 100% stoichiometry melter feed was quite thin, which made it difficult to pull a representative sample for the total solids measurements. Thus, a majority of the measured values are slightly lower than the target values as shown in Table 4-15.

Table 4-14. Average Measured Melter Feed Composition (wt% calcined at 1100°C)

Component	Al	B	Ba	Ca	Cr	Cu	Fe
Average	5.28	1.52	0.049	0.412	0.072	0.045	8.01
%RSD	7.0	7.7	5.7	6.2	5.6	14.6	7.2
Component	**K**	**Li**	**Mg**	**Mn**	**Na**	**Ni**	**P**
Average	0.152	2.26	0.328	2.49	8.94	1.06	<0.100
%RSD	5.2	4.9	7.3	7.6	3.3	6.4	---
Component	**S**	**Si**	**Sn**	**Ti**	**Zn**	**Zr**	
Average	0.113	23.0	<0.100	<0.100	<0.100	0.109	
%RSD	9.4	4.8	---	---	---	5.9	

Table 4-15. Melter Feed Physical Data

Feed ID	Antifoam	Total Solids		Wt% Calcined	pH	Density (g/cm^3)
		Target	Average Measured			
125%	nominal	45%	45.6%	34.3%	3.21	1.37
100%	nominal	45%	43.1%	32.9%	3.82	1.34
100%	nominal	42%	41.9%	32.7%	3.66	1.31
100%	~3X	45%	44.0%	33.5%	3.68	1.34
100%	~2X	45%	43.0%	32.4%	3.62	1.34

Average measured anions are shown in Table 4-16. For comparison, some of the melter feeds were measured by both analytical laboratories; PSAL and AD. The nitrate and oxalate were comparable; however, the glycolate values measured by AD were significantly higher (more representative) than PSAL. Other discrepancies include sulfate for the antifoam spiked feed and formate for the 125% and 100% stoichiometry feeds.

The measured TOC content of the various melter feeds were in the range of 14,098-17,548 ppm as shown in Table 4-17. The TOC values for the 100% stoichiometry antifoam spiked feeds were somewhat low as compared to feeds with the nominal antifoam amounts. Based on the foaminess of these melter feeds it was likely difficult to collect a representative sample, which could account for the low values.

Table 4-16. Average Measured Melter Feed Anions (mg/Kg)

Component	Cl	NO_3	$C_2H_3O_3$	SO_4	C_2O_4	HCO_2
125% Stoichiometry (45% total solids target)						
Average (PSAL)	289	63,917	36,783	1,256	1,248	1,597
%RSD	5	7	5	25	9	36
Average (AD)	<500	67,341	43,250	1,282	1,218	764
%RSD	---	1	5	1	20	1
100% Stoichiometry (45% total solids target)						
Average (PSAL)	311	61,450	26,600	1,405	928	2,413
%RSD	4	2	2	0	3	1
Average (AD)	<500	58,804	34,665	1,292	1,130	1,721
%RSD	---	0	0	6	1	2
100% Stoichiometry (42% total solids target)						
Average (PSAL)	273	48,325	29,100	1,138	980	1,540
%RSD	1	1	5	3	3	2
100% Stoichiometry with ~3X Antifoam Spike (45% total solids target)						
Average (PSAL)	280	52,700	26,775	944	1,025	2,025
%RSD	1	1	2	2	1	1
100% Stoichiometry with ~2X Antifoam Spike (45% total solids target)						
Average (PSAL)	291	55,233	31,033	854	944	1,838
%RSD	2	3	3	3	4	6
Average (AD)	<500	61,760	36,239	1,313	1,152	1,787
%RSD	---	3	2	2	3	5

Table 4-17. Average Measured Melter Feed TOC

TOC (ppm)	
125% Stoichiometry (45% total solids target)	
Average	17,548
%RSD	5
100% Stoichiometry (45% total solids target)	
Average	16,199
%RSD	5
100% Stoichiometry (42% total solids target)	
Average	14,098
%RSD	6
100% Stoichiometry with ~3X Antifoam Spike (45% total solids target)	
Average	16,935
%RSD	2
100% Stoichiometry with ~2X Antifoam Spike (45% total solids target)	
Average	17,336
%RSD	6

4.8.2 Condensate Analysis

The off-gas condensate and filtered solids collected during testing were analyzed to answer two fundamental questions: 1) how much glycolate is in the melter condensate and 2) are significant amounts of any other compounds in the melter condensate. Initial modelling of the melter off-gas indicated that ~50% of the glycolate fed to the melter simply evaporated and would be condensed in the off-gas system. The melter testing performed at the Vitreous State Laboratory (VSL) to support the off-gas modelling did not have a condenser, therefore the model result could not be confirmed with experimental data.[2]

Testing indicates that very little glycolate is evaporated from the feed and that nearly all (>99.5%) of the glycolate fed to the melter is destroyed. Glycolate concentrations in the melter off-gas condensate were typically in the 100 to 150 ppm range as shown in Figure 4-34. Given that the initial fill of the condensate vessel was with process water, the upward trend during initial operation was expected. Peak glycolate concentrations were noted prior to the end of bubbled surge testing. Thus, the initial concentrations are lower than the steady state emissions while concentrations after the peak are higher than steady state emissions; however, the overall amount of glycolate noted in the condensate did not warrant more rigorous calculations. TOC in the melter off-gas condensate was very low and tracked closely with formate as shown in Figure 4-35. Organic carbon was always less than 300 ppm and was typically less than 200 ppm. When compared to the TOC determined by calculating carbon from glycolate and formate (oxalate was not detected), the TOC measurement indicated from 50 to 150 ppm of unaccounted for carbon. This difference could simply be the result of compilation of analytical errors or could indicate that presence of a small amount of a carbon species other than the anions listed. As with glycolate, the amount of TOC present did not warrant further investigation.

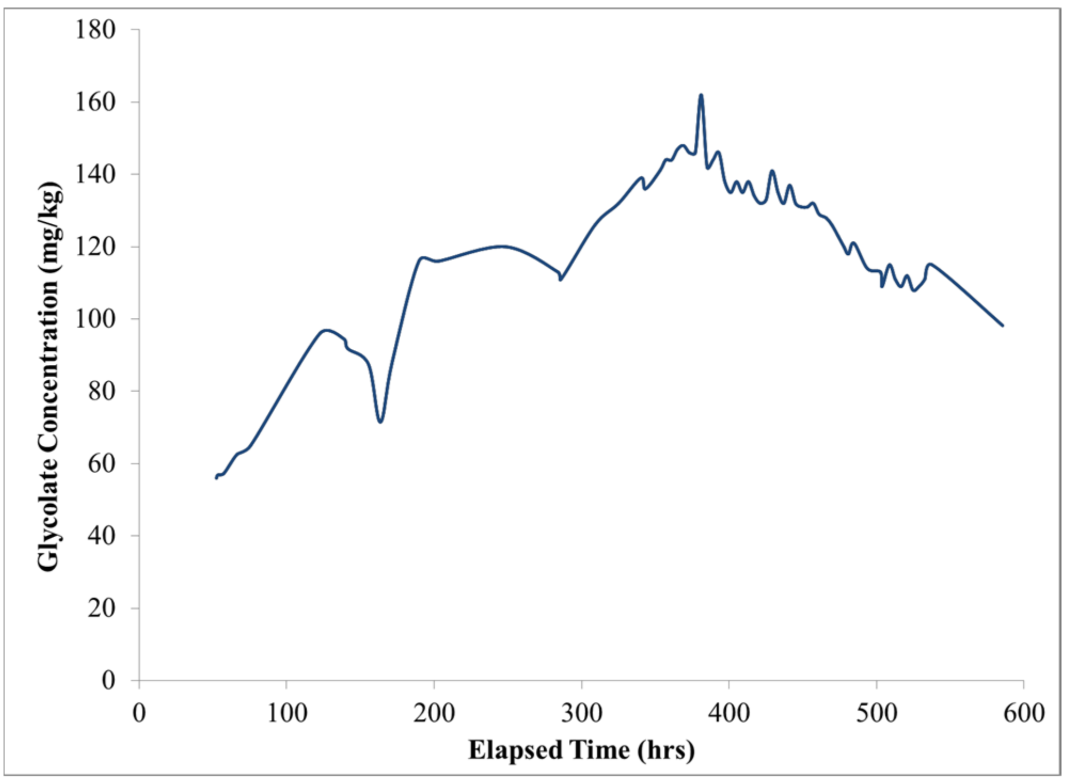


Figure 4-34. Glycolate concentration in the condensate throughout testing.

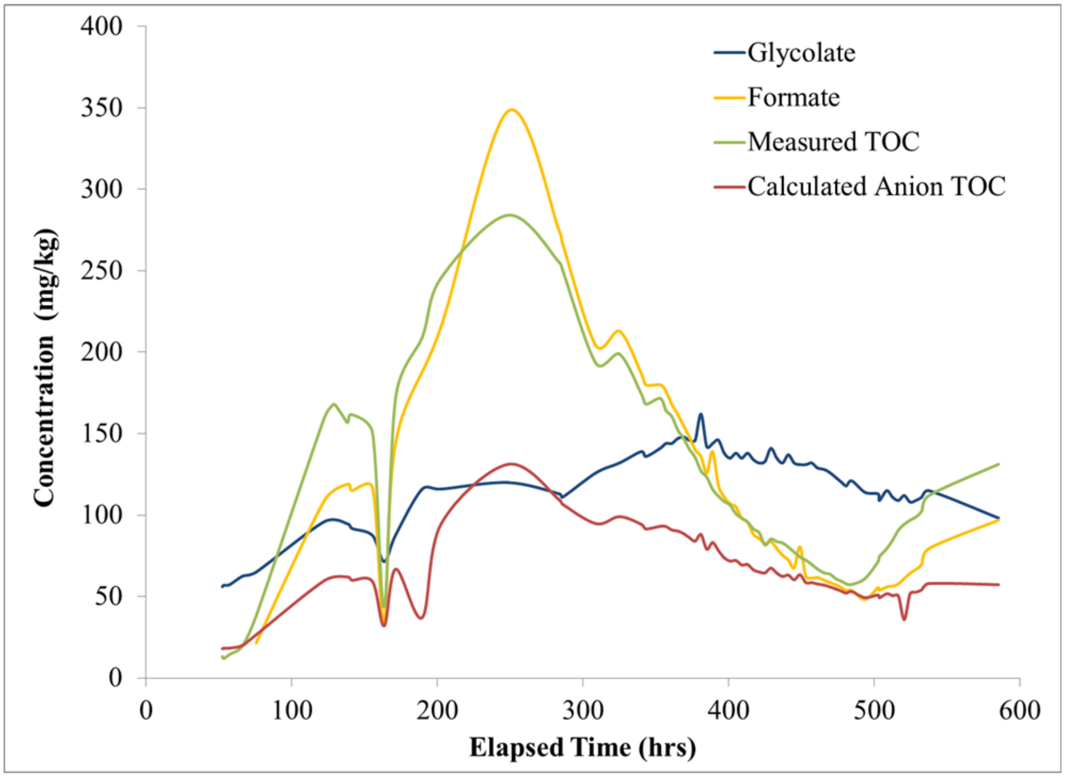


Figure 4-35. Glycolate, formate and TOC concentrations in the condensate.

The anion results indicate that nitrate was the predominant anion with concentrations more than 10 times higher than any other anion, as shown in Figure 4-36. As discussed for the glycolate concentration, the steady state emission rates are not well represented by the graph as the condensate tank started with a charge of process water. As in the case of glycolate, concentrations were not sufficiently high to warrant rigorous calculations. Nitrate in the off-gas indicates either decomposition of nitrate in the melter to NO_x, which is then absorbed into the off-gas condensate and converted to nitric acid, or entrainment of feed into the off-gas. Given that the other anions are much lower than would be explained by entrainment, the nitrate in the off-gas is primarily the result of nitrate decomposition in the melter; however, the pH of the condensate does not match the predicted pH of the condensate assuming the nitrate is present as nitric acid as shown in Figure 4-37. It is assumed that one of the solids species (such as frit) present in the condensate is buffering the pH.

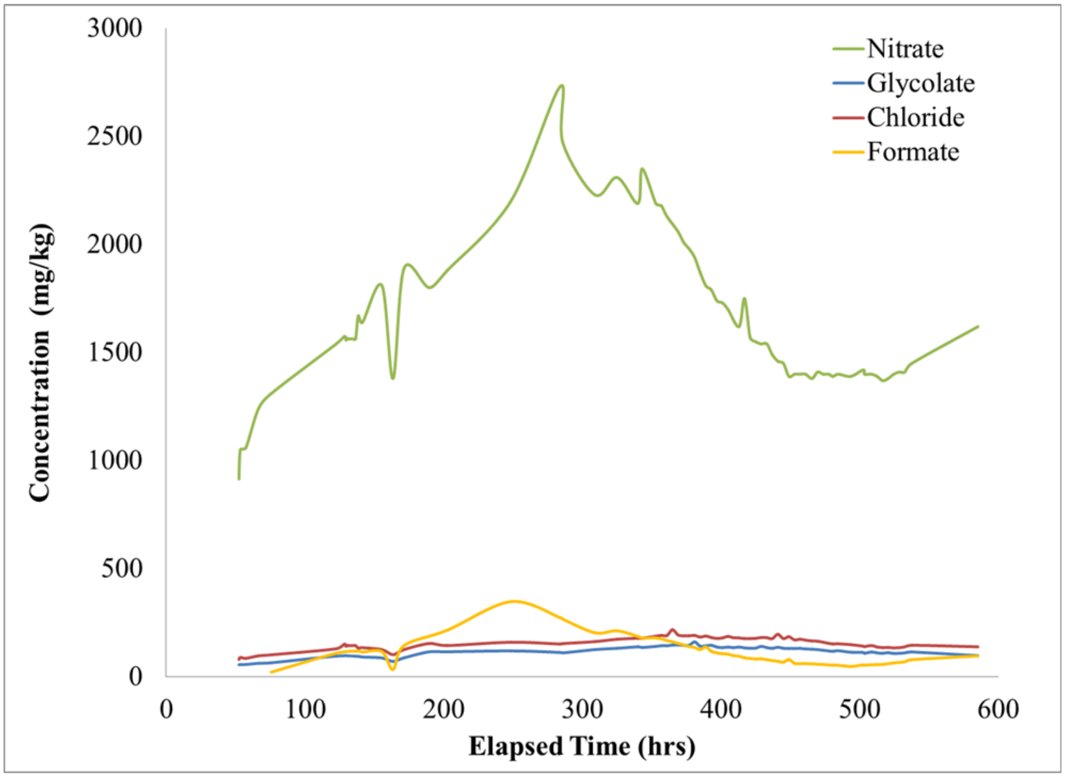


Figure 4-36. Comparison of anion concentrations in the condensate.

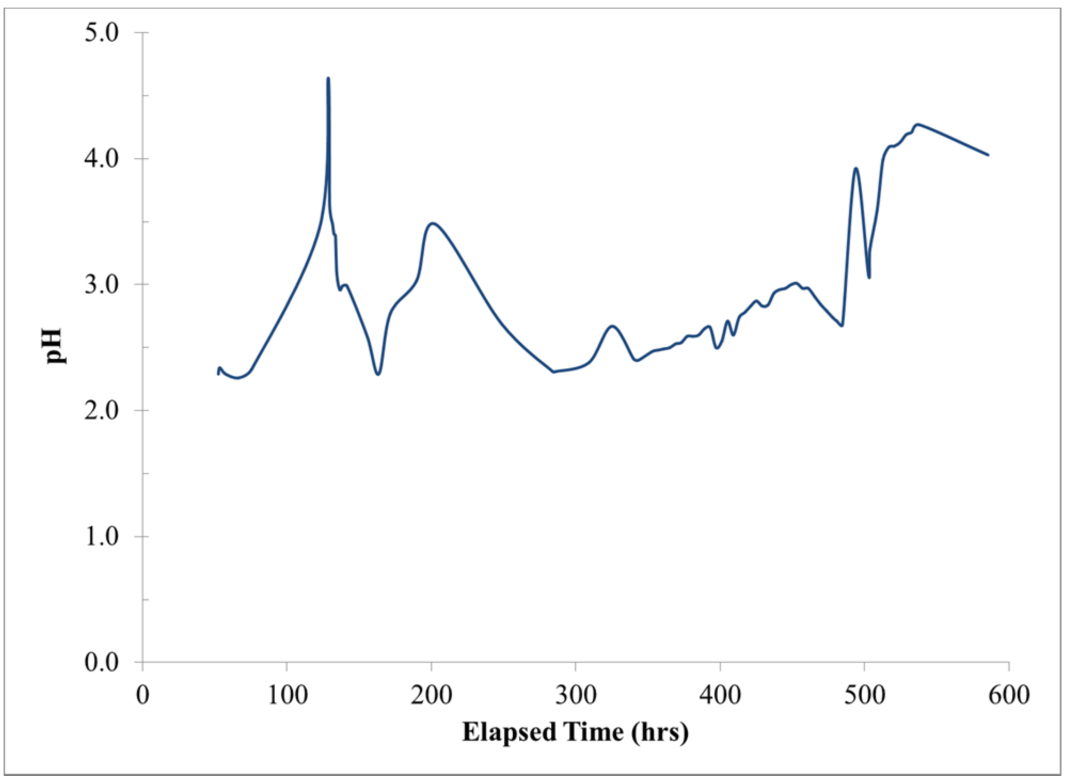


Figure 4-37. pH of the condensate throughout testing.

Entrainment of solids during the CEF testing was typically around 0.05%, but had a few peaks up to 0.3% of solids fed to the melter. Solids entrainment was measured by determining the amount of solids collected on the filters and dividing by the amount of solids fed to the melter. Figure 4-38 shows the entrainment during the run as well as when the bubblers were in operation. It should be noted that approximately 150 grams of solids were collected in the condensate compared with 830 grams collected on the filters. Therefore, the entrainment values determined are somewhat lower than actual, but are within 20% of the actual values based on the amounts collected elsewhere.

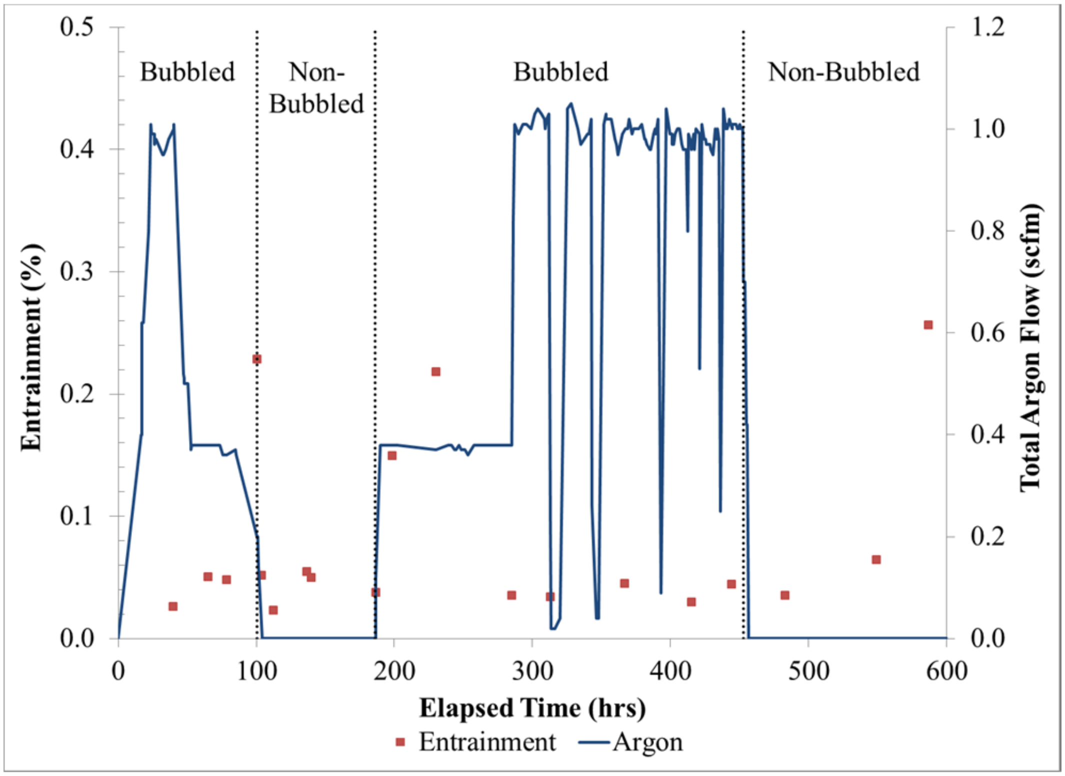


Figure 4-38. Comparison of entrainment and total argon flow throughout testing.

Cation results from the condensate samples were driven by solubility. Sodium was the dominant cation in the supernate, followed by aluminum, sulfur, boron[ff], manganese, and silicon as shown in Figure 4-39. Silicon was noted in higher concentrations during the spiked antifoam testing, as expected from degradation products of the antifoam.

Solids remaining in the condensate collection tank at the conclusion of the testing were deficient insoluble species as well as frit components as shown in Table 4-18. Soluble species were expected to be depleted since those solids would dissolve into the condensate versus collecting in the vessel. However, depletion of frit components was not expected as the frit solids should be larger than the feed solids. One possibility is that the frit carried into the off-gas was predominantly the fines from the frit addition versus being representative of the particle size of the bulk frit. The smaller frit particles would be easily suspended and would collect on the condensate filters versus collecting on the vessel bottom. Anion concentrations were very low compared to the amount of metals measured by ICP-AES, therefore it is presumed that the metals are predominately oxides.

[ff] Boron was measured only for a small number of samples.

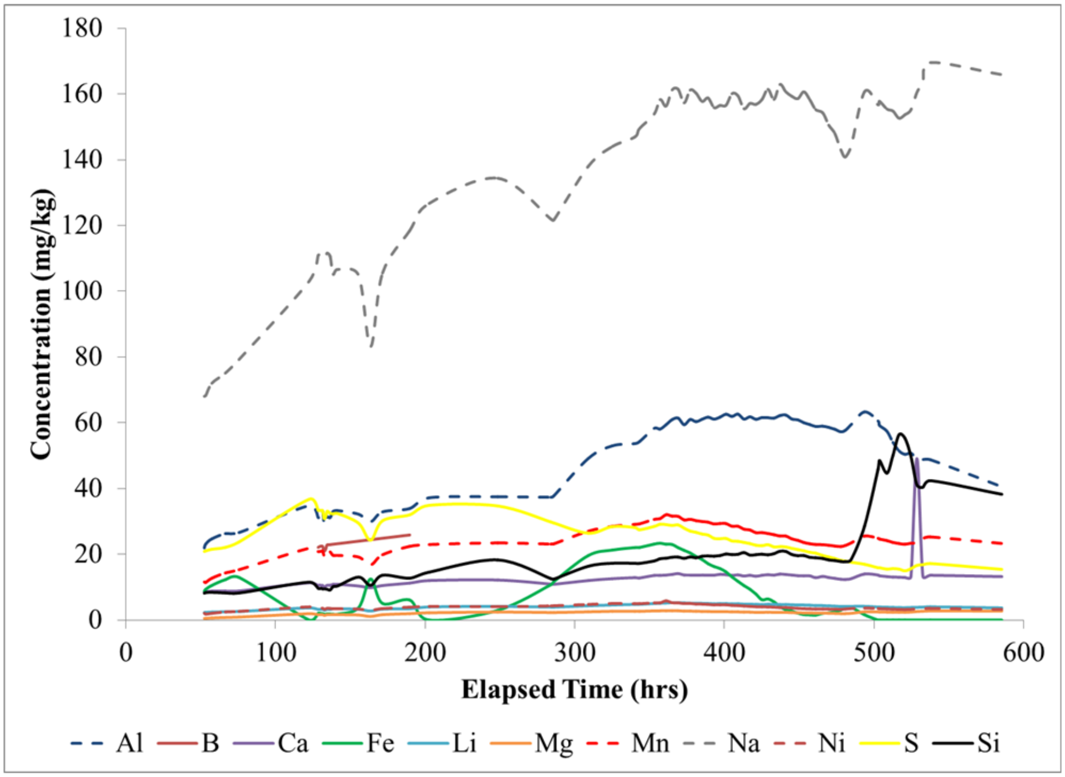


Figure 4-39. Metal concentrations in the condensate throughout testing.

Table 4-18. Composition of Condensate Tank Residual Solids (mg/kg)

Component	**Al**	**Ba**	**Ca**	**Cr**	**Cu**
Average	19700	186	699	124	414
Component	**Fe**	**K**	**Li**	**Mg**	**Mn**
Average	101000	91	560	3185	21300
Component	**Na**	**Ni**	**P**	**Pb**	**S**
Average	2250	12050	497	102	2045
Component	**Si**	**Sn**	**Ti**	**Zn**	**Zr**
Average	850	55	160	514	15
Component	**F**	**Cl**	**NO_2**	**NO_3**	**$C_2H_3O_3$**
Average	<100	622	113	5245	<100
Component	**SO_4**	**C_2O_4**	**HCO_2**	**PO_4**	
Average	495	<100	527	<100	

4.8.3 Off-gas Filter Solids Analysis

Metals in the off-gas filter solids are shown Figure 4-40. The species are generally present in proportion to their proportion in the melter feed or frit. Few notable trends were noted in the off-gas data, but one trend was identified in the type of solids entrained during the testing. During periods of bubbled operation, the iron and other sludge components were generally present in higher concentrations than frit components. During non-bubbled operation, the concentration of frit components in the condensate slightly increased as highlighted in Figure 4-41. The change in the curves around 300 hours is due to the large surge that occurred, which forced feeding to be stopped for more than 12 hours while the blower was replaced (see Section 4.4.3). During the low vapor space temperature testing, the frit components surpassed the sludge components in concentration. While an interesting observation, the overall amount of entrainment was so low that further evaluation was not considered. It is noted that the CEF vapor space height was increased versus the DWPF melter to reduce entrainment.

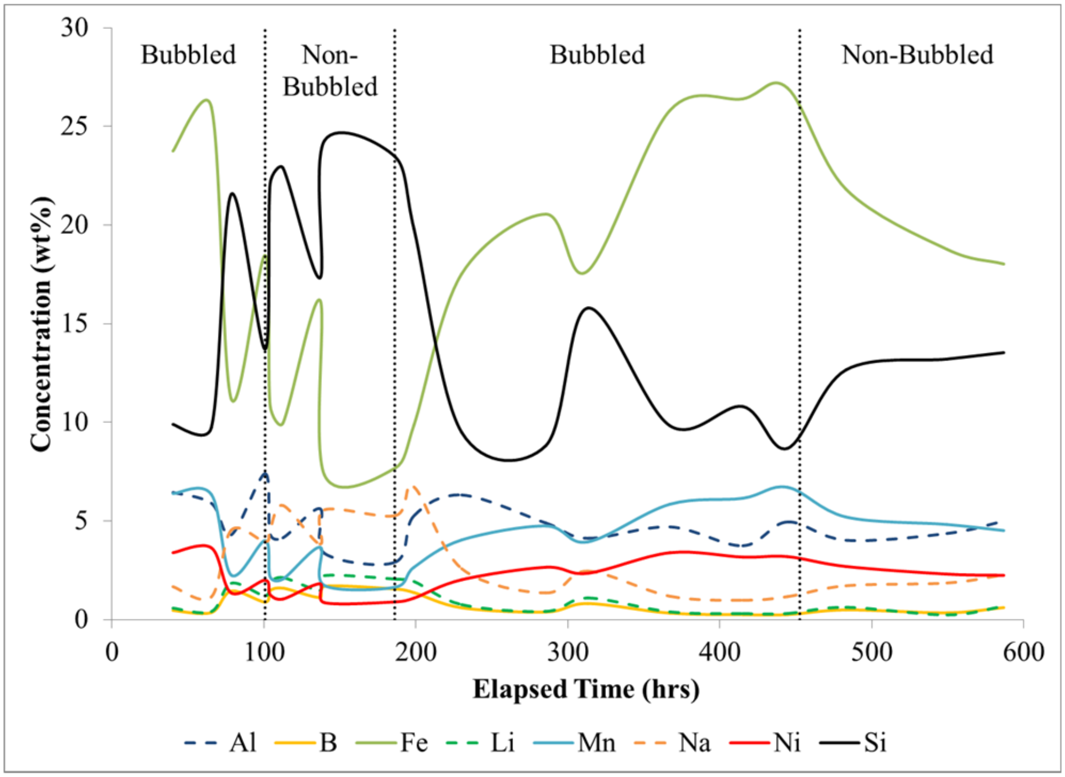


Figure 4-40. Metals composition in the off-gas filter solids as a function of time.

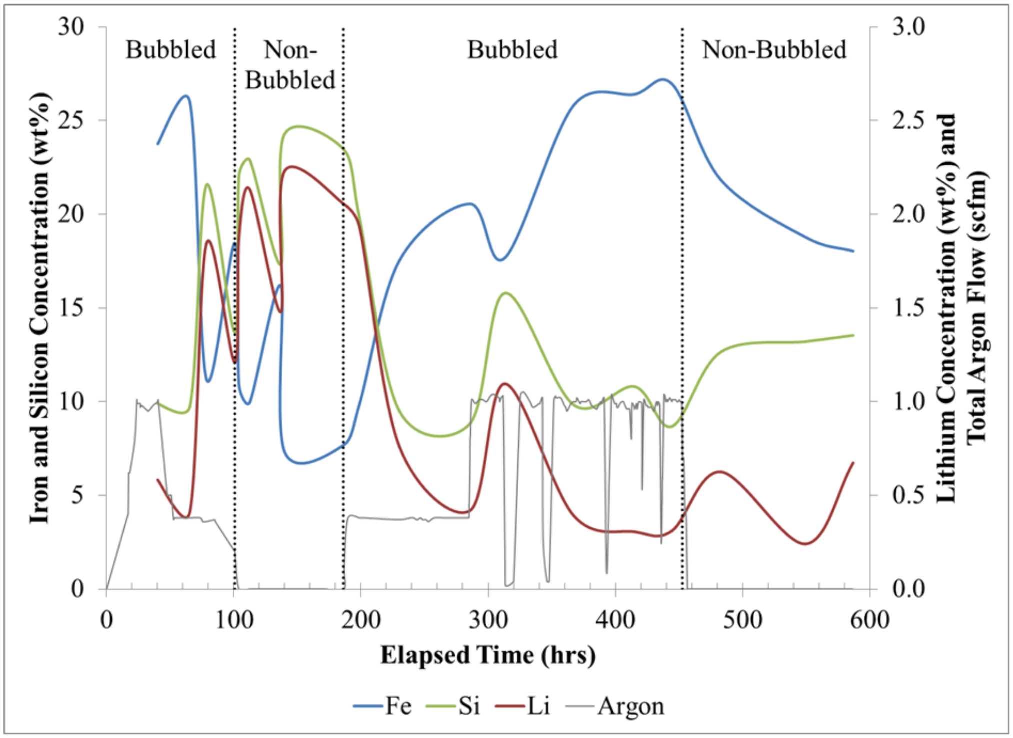


Figure 4-41. Comparison of Fe, Si and Li concentrations in the off-gas filter solids. Note that the Li concentration is plotted on the secondary axis.

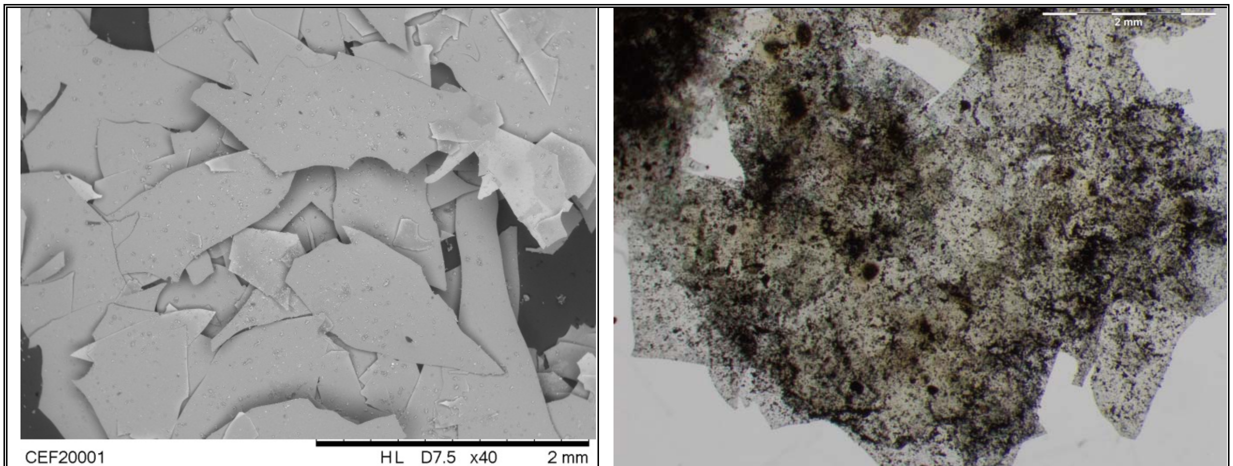
Iridescent flakes were observed in some, but not all, of the off-gas condensate system filter solids that were collected from the nineteen bag filters that were used throughout testing.[gg] The flakes were observed during a variety of melter conditions; 125% and 100% stoichiometry melter feeds, both bubbled and non-bubbled. A comparison of the typical solids collected from these filters and the flake material is shown in Figure 4-42(a) and (b), respectively. Magnified views of the flakes are shown in Figure 4-43(a) and (b).

(a)	(b)

Figure 4-42. Image of typical filter solids (a) and filter solids containing flakes (b).

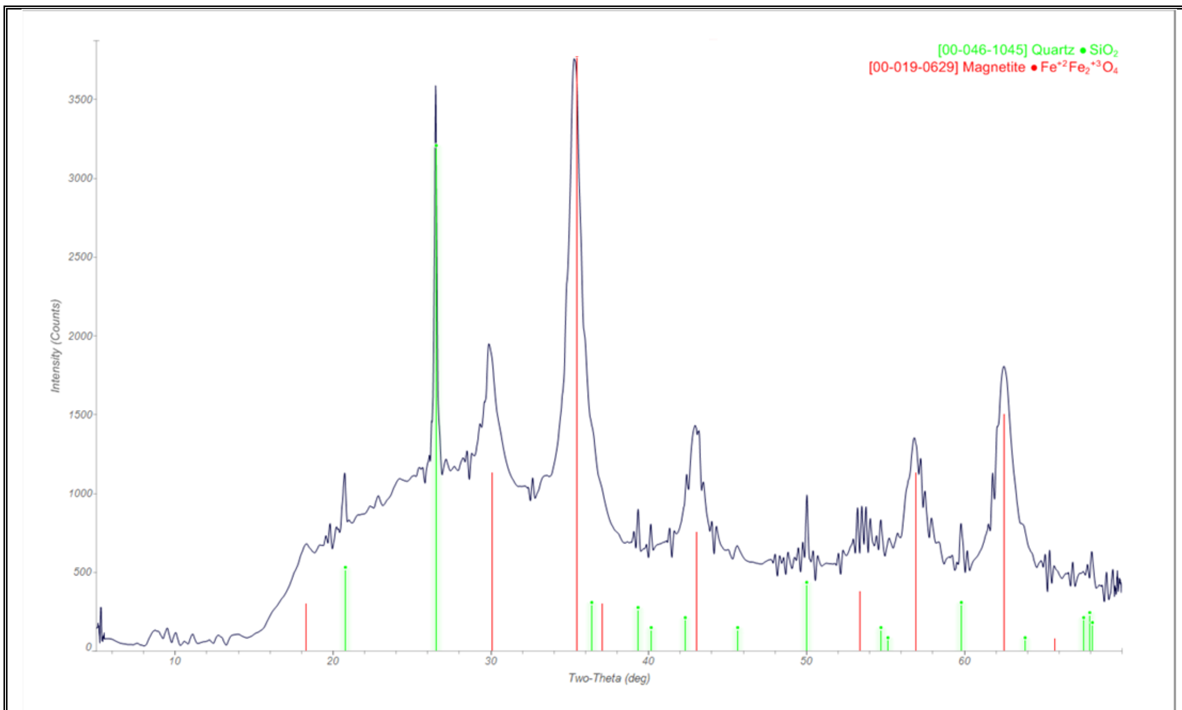
[gg] Filters were observed with the naked eye only. The filter IDs are as follows: CEF2-FL-Q, -G, -D, -F, -H, -K and -L.

The flakes are quite thin and are covered in small solid particles as shown in Figure 4-43(b) that are likely representative of the feed components. X-ray diffraction of both types of filter solids indicated that quartz (SiO_2) and magnetite ($Fe^{+2}Fe_2^{+3}O_4$) are present along with amorphous material, which is to be expected based on the composition of the SRAT product and frit. The amorphous hump is more pronounced in the filter solids containing flakes as shown in Figure 4-44; however, no conclusions can be drawn at this time based on these cursory scans. After a sample of flakes was heated to 500°C, there was no indication that melting had occurred, so it does not appear to be a polymer or organic material. Based on the current analyses the flakes are amorphous and contain quartz and magnetite, but no further investigation of how and why this material formed has been pursued at present time.

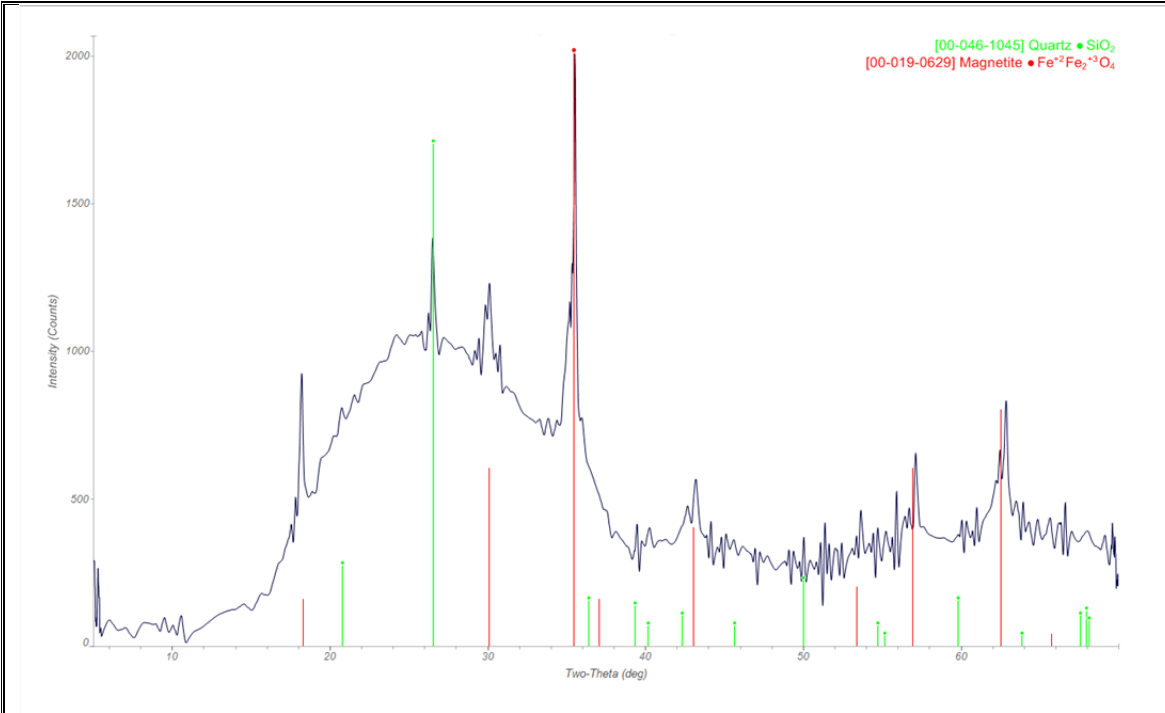


(a)	(b)

Figure 4-43. SEM image (a) and optical microscope image (b) of the iridescent flakes.



(a)



(b)

Figure 4-44. XRD spectra of typical filter solids (a) and filter solids containing flakes (b).

4.8.4 Carbon Tube Analysis

The gas chromatography-mass spectrometry (GCMS) analysis indicates that organics in the off-gas were present at very low quantities.[59,60,hh] Approximately 7.9 mg/kg of C_8-C_{12} siloxanes (antifoam fragments) and ~22 mg/kg of aliphatic hydrocarbons (impurities) were measured. The aliphatic hydrocarbons consisted primarily of butylcyclohexane, 6-dodecene, 1,5-diethyl-2,3-dimethylcyclohexane and hexylcyclohexane. While the siloxanes were present due to the antifoam, none of the hydrocarbon species would be expected to be in the melter feed or off-gas and could potentially be a contaminant from the vendor tanks. The siloxane content translates to 0.09 ppmv in the off-gas per sample, or 0.63 ppmv if all of the siloxanes were assumed to come from just one sample (worst case), which is still quite low. Thus, the amount of uncombusted organics in the off-gas is negligible.

Based on these results, one sample of the 100% stoichiometry melter feed was also submitted for SVOA and was extracted using dichloromethane (Table 4-19). This method is qualitative for many of the antifoam degradation polyethylene glycol (PEG) fragments. The main components in Antifoam 747 are not observed by this method. Starting with ~2000 mg/kg of antifoam in the feed, approximately 24 mg/kg of antifoam fragments were found by GCMS. The detected PEG species are compounds resulting from the degradation of the antifoam molecule (Table 4-20) and are best matches (not exact) to the NIST standard reference database. The presence of PEG ether cleavage products is expected. Under heated acidic conditions, cleavage of the ether linkages in the PEG molecule can occur resulting in shorter PEG molecules terminated in an alcohol functional group. The other fragments generated during degradation are trimethylsiloxy groups that are mostly evolved during the SRAT cycle to form HMDSO (hexamethyl disiloxane) in the off-gas. Some of the trimethylsiloxy groups are likely to polymerize to ring siloxanes (5,6). Components 2-4 are ring species that would result from the PEG fragments. Species 7-9 are not

[hh] Twenty-four (24) carbon tube samples were taken during the CEF run. Seven of these were sent to AD for SVOA organics analysis. An error was made during analysis and all seven sample tubes were combined into one sample and analyzed.

expected to be in the melter feed; these may have been present as impurities from the equipment used by the vendors that made the simulant and processed it into the SRAT product.

Table 4-19. Results of SVOA Analysis on Melter Feed

	Component	Amount (mg/kg)	Comments
1	Cumulative PEG concentration (Table 4-20)	21.6	antifoam fragments
2	Hexaethylene glycol dimethyl ether	0.82	antifoam fragment
3	Cyclopentene, 1,2,3,4,5-pentamethyl-	0.25	antifoam fragment
4	2,5,8,11,14-Pentaoxahexadecan-16-ol	1.01	antifoam fragment
5	Cyclotetrasiloxane, octamethyl-	0.13	antifoam fragment
6	1-Propene 3-[2-(2-methoxyethoxy)ethoxy]-	0.11	antifoam fragment
	SUM OF ANTIFOAM FRAGMENTS	***24.32***	
7	1 2-Bis(trimethylsilyl)benzene	0.33	potentially from column bleed
8	Formamide N N-dioctyl-	0.18	unexpected
9	1 2-Monooctyl phthalic acid ester	0.14	potentially from plasticizer (sample bottles)
	SUM OF UNEXPECTED SPECIES	***0.65***	

Table 4-20. PEG Species in Melter Feed

PEG Species	Amount (mg/kg)
$CH_3O\text{-}(CH_2CH_2O)_7\text{-}CH_2CH_2OOCCH_3$	10.4
$CH_3O\text{-}(CH_2CH_2O)_6\text{-}CH_2CH_2OOCCH_3$	3.42
$CH_3O\text{-}(CH_2CH_2O)_6\text{-}CH_2CH_2OH$	0.13
$CH_3O\text{-}(CH_2CH_2O)_8\text{-}CH_2CH_2OH$	0.21
$CH_3O\text{-}(CH_2CH_2O)_9\text{-}CH_2CH_2OH$	0.18
$HO\text{-}(CH_2CH_2O)_6\text{-}CH_2CH_2OH$	3.90
$HO\text{-}(CH_2CH_2O)_{11}\text{-}CH_2CH_2OH$	2.15
$CH_3O\text{-}(CH_2CH_2O)_4\text{-}Si(CH_3)_2C(CH_3)_3$	0.30
$CH_3O\text{-}(CH_2CH_2O)_5\text{-}Si(CH_3)_2C(CH_3)_3$	0.30
$CH_3O\text{-}(CH_2CH_2O)_9\text{-}Si(CH_3)_2C(CH_3)_3$	0.13
$CH_3O\text{-}(CH_2CH_2O)_{10}\text{-}Si(CH_3)_2C(CH_3)_3$	0.27
$CH_3O\text{-}(CH_2CH_2O)_{11}\text{-}Si(CH_3)_3$	0.22

4.8.5 Glass Analysis

The average measured glass composition is shown in Table 4-21.[ii] The %RSD values for the major glass components (> 0.5 wt%) are less than 5%, which confirms consistent melter feed batching. A comparison of the calculated glass composition, average measured melter feed composition and average measured glass composition are shown in Table 4-22. The calculated glass composition was determined by combining the average measured SB6I 100% and 125% as-received SRAT composition with the target Frit 418 composition at a waste loading of 36%. No significant deviations are present between the

[ii] Seventeen (17) pour stream glasses collected over the duration of testing were selected for analysis.

calculated and measured compositions, which indicate that the melter feed was batched according to the targets specified on the batch sheets from an elemental perspective.

Table 4-21. Average Glass Composition (wt%)

Oxide	Average	%RSD	Oxide	Average	%RSD
Al_2O_3	9.21	1.8	MnO	3.19	1.3
B_2O_3	4.86	2.6	Na_2O	11.6	1.3
BaO	0.06	1.7	NiO	1.35	4.8
CaO	0.59	4.5	P_2O_5	<0.23	---
Cr_2O_3	0.11	8.7	SO_4	0.40	3.1
CuO	0.11	51.3	SiO_2	49.7	1.2
Fe_2O_3	10.8	1.3	SnO_2	<0.13	---
K_2O	0.14	2.7	TiO_2	0.04	1.0
Li_2O	4.95	1.4	ZnO	0.05	1.5
MgO	0.58	1.2	ZrO_2	0.14	2.2

Table 4-22. Comparison of Calculated and Measured Compositions (wt%)

Component	Calculated Glass Composition	Average Measured Melter Feed Composition	Average Measured Glass Composition
Al_2O_3	9.49	9.98	9.21
B_2O_3	5.12	4.90	4.86
CaO	0.59	0.58	0.59
Fe_2O_3	11.0	11.5	10.8
Li_2O	5.12	4.85	4.95
MgO	0.50	0.54	0.58
MnO	3.17	3.22	3.19
Na_2O	11.6	12.1	11.6
NiO	1.34	1.34	1.35
SiO_2	49.8	49.2	49.7

$Fe^{2+}/\sum Fe$ ratios for select glass samples are shown in Table 4-23. Initial $Fe^{2+}/\sum Fe$ values were approximately 0.05 and generally decreased with time. The first measured sample (CEF2-GL-001) was collected after feeding with 125% stoichiometry melter feed for approximately 1.5 days under bubbled conditions. By the seventh day of testing (March 2, 2014), the pour stream glass was fully oxidized as shown by sample CEF2-GL-026 and samples remained fully oxidized for the remainder of testing. For comparison, the $Fe^{2+}/\sum Fe$ values for the Phase I nitric-formic acid flowsheet CEF testing were in the range of 0.08-0.20.[52] Laboratory studies and actual DWPF pour stream and melter feed samples have shown that both argon bubbling and excess antifoam increase the $Fe^{2+}/\sum Fe$ ratio, thus it would have been expected that a majority, if not all of the CEF pour stream glasses, should not have been so oxidized.[61,62]

Table 4-23. Glass REDOX

Sample ID	Date	Time	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
CEF2-GL-001	2/26/2014	8:55	0.06	0.05
CEF2-GL-003	2/26/2014	19:05	0.05	0.05
CEF2-GL-004	2/26/2014	23:00	0.04	0.04
CEF2-GL-006	2/27/2014	7:00	0.04	0.04
CEF2-GL-008	2/27/2014	15:00	0.03	0.03
CEF2-GL-010	2/27/2014	23:50	0.04	0.04
CEF2-GL-012	2/28/2014	8:12	0.04	0.03
CEF2-GL-013	2/28/2014	15:32	0.02	0.02
CEF2-GL-014	2/28/2014	21:25	0.02	0.02
CEF2-GL-016	3/1/2014	5:25	0.02	0.02
CEF2-GL-018	3/1/2014	13:47	0.02	0.02
CEF2-GL-020	3/1/2014	21:30	0.03	0.02
CEF2-GL-022	3/2/2014	6:32	0.02	0.02
CEF2-GL-024	3/2/2014	14:20	0.02	0.02
CEF2-GL-026	3/2/2014	22:40	All Fe^{3+}	All Fe^{3+}

In order to further determine the source of these results, sealed crucible samples were made post-run with each of the three types of remediated melter feeds that were prepared during actual CEF testing (100% stoichiometry, 125% stoichiometry and ~2X antifoam spike). For comparison, two additional glass samples were prepared from the 100% stoichiometry and ~2X antifoam spike melter feeds using an open top quartz crucible with flowing argon.[51] The $Fe^{2+}/\sum Fe$ data from these tests are shown in Table 4-24. As expected, the post-test $Fe^{2+}/\sum Fe$ values of 0.44 and 0.57 for the melter feed spiked with additional antifoam are considerably higher than the baseline values of 0.25 and 0.27 for the 100% feed. Even though antifoam spiked feed was added to the melter for ~2.2 days, the pour stream glass was still oxidized. Of these ~2.2 days, the first ~16 hours were dedicated to melter feed that was spiked with *three* times the nominal amount of antifoam. While not measured, it is expected that the $Fe^{2+}/\sum Fe$ value of this glass would exceed the 0.42 value that was measured for the ~2X antifoam spiked feed.

Table 4-24. Comparison of $Fe^{2+}/\sum Fe$ Values

Pre Test Remediated Melter Feed (sealed crucible)	Post Test Remediated Melter Feed (sealed crucible)	Post Test Remediated Melter Feed (open quartz crucible)	CEF Pour Stream Glass
125% Stiochiometry			
0.10-0.48*	0.27	---	0.02 - 0.05
100% Stoichiometry			
0.25	0.25	0.27	fully oxidized
100% Stoichiometry with ~2X Antifoam Spike			
---	0.44	0.57	fully oxidized

*As stated in Section 3.2, a blend of the "low" and "medium" glycolic acid concentrations was selected for the 125% melter feed and there is not a pre-test measured REDOX measurement for the blend.

The configuration of the melter was not changed between Phase I and Phase II testing. Preliminary un-reviewed air in-leakage calculations in support of the flammability model development indicate that air in-leakage was comparable to Phase I testing. While higher air purge rates were used during portions of Phase II testing, which would have created conditions for more oxidized glass, the REDOX should have also been oppositely impacted by the argon bubblers and especially the excess antifoam additions. Thus, some of the samples should have exhibited $Fe^{2+}/\sum Fe$ values greater than 0 based solely on the testing environment and additions of antifoam. Based on the inconclusive data, the cause for the differences in REDOX is still under investigation.

4.9 Off-gas Analysis

Continuous monitoring of the off-gas stream was conducted using the mass spectrometer, gas chromatograph and FTIR. The primary components of interest were H_2, CO, CO_2 and to a lesser extent NO and NO_2. Only an overview of the off-gas analysis is presented in this report. A discussion of the off-gas analysis and relationship of this data to the flammability model development is provided in a separate report.[11] Hydrogen generation during bubbled and non-bubbled surge testing conditions was an area of particular interest as shown in Figure 4-45 for the 100% stoichiometry feed at 42 wt% total solids. Increases in hydrogen concentration were most prevalent during bubbled testing with the highest peaks at ~700 ppm. During non-bubbled conditions, the hydrogen concentration remained less than 100 ppm. All data for H_2 and CO are shown in Appendix Figure A-51 through Figure A-60. It should be noted that increased air purges were used during certain segments of the steady state vapor space temperature testing, which resulted in more dilution of the off-gas stream.

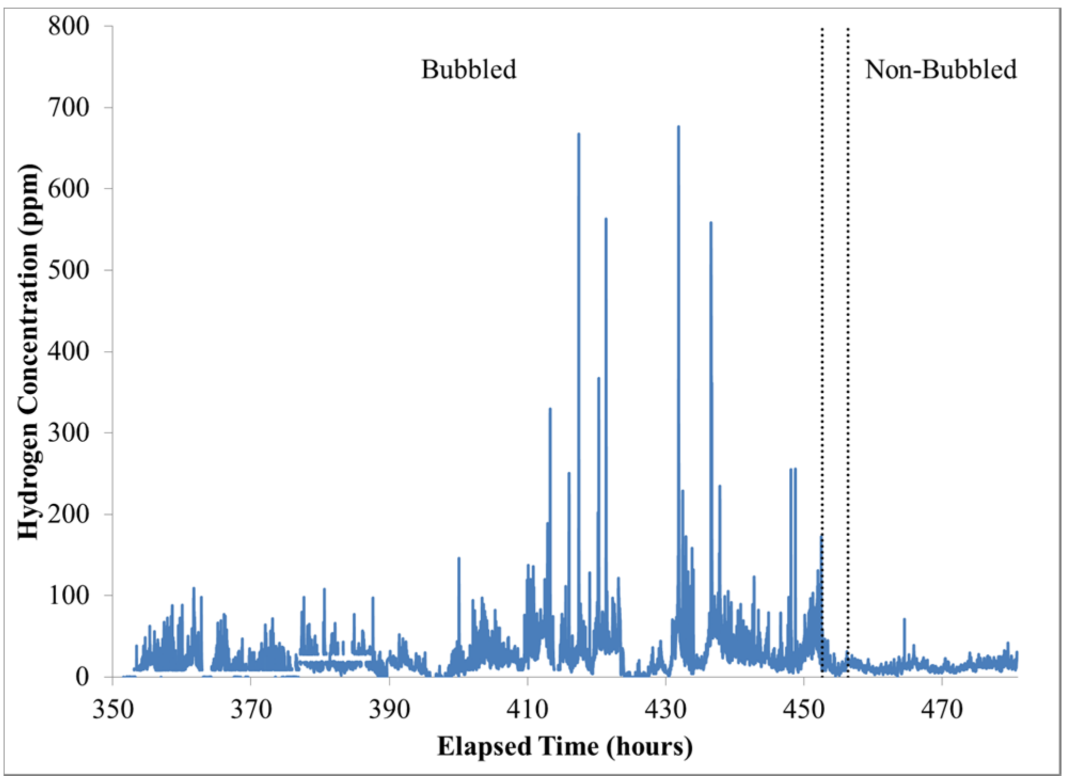


Figure 4-45. Hydrogen generation during bubbled and non-bubbled surge testing.

5.0 Conclusions

After charging the CEF with cullet from Phase I CEF testing, the melter was slurry-fed with glycolic flowsheet based SB6-Frit 418 melter feed at 36% waste loading and was operated continuously for 25 days. Process data was collected throughout testing and included melter operation parameters and off-gas chemistry. In order to support the flammability model development for the nitric-glycolic flowsheet, vapor space steady state testing in the range of ~250-750°C was conducted under the following conditions, (i) 100% (nominal and excess antifoam levels) and 125% stoichiometry feed and (ii) with and without argon bubbling. Adjustments to feed rate, heater outputs and purge air flow were necessary in order to achieve vapor space temperatures in this range. Surge testing was also completed under nominal conditions for 4 days with argon bubbling and 1 day without argon bubbling in order to assess the surge potential for the new flowsheet.

The results of the Phase II testing demonstrated that the current configuration of the CEF is capable of operating under the low vapor space temperatures. A melter pressure of -5 inwc was not sustained throughout the run, but the melter did remain slightly negative even when the maximum air flow required for the lowest temperature conditions were used. By limiting the output on the auxiliary pour tube heater to 175 watts, the heater lasted the duration of testing even though the conditions in the CEF are highly atypical for this type of heater. As in the Phase I campaign, the J.M. Canty, Inc. high temperature camera provided exceptional views of the cold cap throughout testing.

Obvious differences in the consistency of the melter feeds of different acid stoichiometries were observed; 100% was quite thin, while the 125% was considerably thicker. Intuitively, the 125% stoichiometry feed should have been thinner as compared to the 100% feed due to increased acid. The addition of excess antifoam caused foaming in the mixing pot, but there was no evidence of foaming in the melter. Generally, the appearance of the cold cap during nitric-glycolic testing was no different than that of the nitric-formic flowsheet, which was observed during Phase I testing during non-bubbled steady state testing. At vapor space temperatures above 500°C, a glass production rate in the range of 27-30 g/min was achieved for the nitric-formic flowsheet and 31-44 g/min was attained for the nitric-glycolic flowsheet during non-bubbled conditions.

Testing indicates that very little glycolate is evaporated from the feed and that nearly all (>99.5%) of the glycolate fed to the melter is destroyed. TOC in the melter off-gas condensate was very low and tracked closely with formate. The condensate anion results indicate that nitrate was the predominant anion with concentrations approximately 10 times higher than any other anion. Entrainment of solids during the CEF testing was typically around 0.05%, but had a few peaks up to 0.3% of solids fed to the melter. Cation results from the condensate samples were driven by solubility. Sodium was the dominant cation in the supernate, followed by aluminum, sulfur, boron, manganese, and silicon. Solids remaining in the condensate collection tank at the conclusion of the testing were deficient in soluble species as well as frit components. Depletion of frit components was not expected as the frit solids should be larger than the feed solids. One possibility is that the frit carried into the off-gas was predominantly the fines from the frit addition versus being representative of the particle size of the bulk frit Anion concentrations were very low compared to the amount of metals present, therefore it is presumed that the metals are predominately oxides. Metals in the off-gas filter solids were generally present in proportion to their proportion in the melter feed, with the exception of frit components, which were present in much lower concentrations than in the melter feed.

Generally, the REDOX of the glasses collected from the pour stream were fully oxidized (all Fe^{3+}), which was not expected based on anticipated values for the melter feeds. Sealed crucible studies of the various melter feeds resulted in $Fe^{2+}/\sum Fe$ values in the range of 0.25-0.42. Laboratory studies and actual DWPF pour stream and melter feed samples have shown that both argon bubbling and excess antifoam increase the $Fe^{2+}/\sum Fe$ ratio; however, no impact was observed during this testing.

The total operational hours on the melter vessel is approximately 1057 hours after Phase II testing. Dimensional measurements taken prior to Phase I testing and support block temperatures recorded during Phase I/Phase II testing are available if an extension of service life beyond 1250 hours is desired in the future.

6.0 Recommendations, Path Forward or Future Work

Based on the results from this testing, the following items are recommended for future study in support of the implementation of the nitric-glycolic flowsheet.

- Further REDOX testing and data interpretation are necessary in order to more thoroughly understand the effect of the nitric-glycolic flowsheet on glass REDOX during melter runs, as well as the impact of the testing protocol.

- Further testing to determine the impact of acid stoichiometry on the rheological properties of SME product. Increasing yield stress as acid stoichiometry increases has been noted during CPC testing, thus a better understanding of when increased acid stoichiometry begins to result in higher yield stress is needed.

- Further analysis of the flakes that were present in some of the solids collected from the off-gas condensate system filters. Determine if there are any negative impacts to processing.

- Further analysis of the lard-like material found in some of the drums of SRAT product. Determine if there are any negative impacts to processing.

- Conduct melt rate testing using the melt rate furnace (MRF) and potentially the slurry fed melt rate furnace (SMRF) with melter feeds fabricated with leftover CEF SRAT products to compare the nitric-formic and nitric-glycolic flowsheets. These samples should then be submitted for analysis by X-ray computed tomography (CT) so that more quantitative comparisons can be made. Melt rate testing under bubbled conditions would also be of interest. The CEF could also be operated under nominal conditions to generate bubbled melt rate data under nominal conditions if feed is available.

The following items are recommended prior to any future testing with the current CEF melter vessel.

- Perform dimensional measurements of the vessel and tension rod length measurements.

- Conduct a melter life assessment using the thermocouple data from Phase I and II testing and the post-test measurements to determine if the service life could be safely extended beyond 1250 hours.

- Add an argon purge to the pour tube in order to reduce the oxidizing effect of air contacting the molten glass pour stream and minimize REDOX uncertainty.

- Replace all heaters and thermocouples.

- Design and construct a new feeding system to minimize feed line blockages.

- Add a second Canty MINITEMP™ high temperature camera if possible with current nozzle configuration.

- Add a higher capacity regenerative blower so that -5 inwc can be maintained if testing at lower vapor space temperatures is required. Install an air intake filter and a relief valve to protect against damage from overheating.

- Install longer thermocouples so that the connections do not overheat and they can be more easily tightened.

- Install a more robust lid for the OGCT if low vacuum testing will be performed.

- Modify the condensate overflow drain line to include a dip leg or other component to stabilize flow.

- If possible, move the pour heater slightly to help re-center the pour tube to reduce the possibility of glass making contact with the refractory and heater elements.

- If possible, replace SiC vapor space heater elements with a different type of heater that is not prone to breaking (e.g., high temperature cartridge heater).

- Modify the back pulse of the off-gas sample line so that it can be controlled by a solenoid valve if possible.

- Add a second set of viewing monitors to reduce frequency of screen changes.

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Appendix A. Supplementary Figures and Tables

Table A-1. Sealed Crucible REDOX Remediation Results (100%)

Sample ID	Lab ID	Fe^{2+}	Fe^{3+}	∑Fe	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
EA	EA	0.082	0.365	0.447	0.225	0.183
Baseline-1 (A)	S-750	0.202	0.248	0.450	0.815	0.449
Baseline-1 (B)	S-750	0.202	0.249	0.451	0.811	0.448
Baseline-2 (A)	S-751	0.240	0.243	0.483	0.988	0.497
Baseline-2 (B)	S-751	0.239	0.244	0.483	0.980	0.495
Baseline-3 (A)	S-752	0.242	0.241	0.483	1.004	0.501
Baseline-3 (B)	S-752	0.242	0.240	0.482	1.008	0.502
Lo Na-1 (A)	S-753	0.091	0.332	0.423	0.274	0.215
Lo Na-1 (B)	S-753	0.092	0.334	0.426	0.275	0.216
Lo Na-2 (A)	S-754	0.117	0.333	0.450	0.351	0.260
Lo Na-2 (B)	S-754	0.116	0.336	0.452	0.345	0.257
Lo Na-3 (A)	S-755	0.128	0.321	0.449	0.399	0.285
Lo Na-3 (B)	S-755	0.127	0.321	0.448	0.396	0.283
Med Na-1 (A)	S-756	<0.010	0.531	0.531	All Fe^{3+}	All Fe^{3+}
Med Na-1 (B)	S-756	<0.010	0.533	0.533	All Fe^{3+}	All Fe^{3+}
Med Na-2 (A)	S-757	<0.010	0.533	0.533	All Fe^{3+}	All Fe^{3+}
Med Na-2 (B)	S-757	<0.010	0.530	0.530	All Fe^{3+}	All Fe^{3+}
Med NA-3 (A)	S-758	0.011	0.488	0.499	0.023	0.022
Med NA-3 (B)	S-758	0.010	0.491	0.501	0.020	0.020
Hi Na-1 (A)	S-759	<0.010	0.497	0.497	All Fe^{3+}	All Fe^{3+}
Hi Na-1 (B)	S-759	<0.010	0.498	0.498	All Fe^{3+}	All Fe^{3+}
Hi Na-2 (A)	S-760	<0.010	0.493	0.493	All Fe^{3+}	All Fe^{3+}
Hi Na-2 (B)	S-760	<0.010	0.494	0.494	All Fe^{3+}	All Fe^{3+}
Hi Na-3 (A)	S-761	<0.010	0.529	0.529	All Fe^{3+}	All Fe^{3+}
Hi Na-3 (B)	S-761	<0.010	0.530	0.530	All Fe^{3+}	All Fe^{3+}

Table A-2. Sealed Crucible REDOX Remediation Results (125%)

Sample ID	Lab ID	Fe^{2+}	Fe^{3+}	∑Fe	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
EA	EA	0.083	0.363	0.446	0.229	0.186
Baseline-1 (A)	S-766	<0.010	0.501	0.501	All Fe^{3+}	All Fe^{3+}
Baseline-1 (B)	S-766	<0.010	0.504	0.504	All Fe^{3+}	All Fe^{3+}
Baseline-2 (A)	S-767	<0.010	0.516	0.516	All Fe^{3+}	All Fe^{3+}
Baseline-2 (B)	S-767	<0.010	0.518	0.518	All Fe^{3+}	All Fe^{3+}
Baseline-3 (A)	S-768	<0.010	0.513	0.513	All Fe^{3+}	All Fe^{3+}
Baseline-3 (B)	S-768	<0.010	0.512	0.512	All Fe^{3+}	All Fe^{3+}
Lo Na-1 (A)	S-769	0.052	0.383	0.435	0.136	0.120
Lo Na-1 (B)	S-769	0.053	0.382	0.435	0.139	0.122
Lo Na-2 (A)	S-770	0.025	0.456	0.481	0.055	0.052
Lo Na-2 (B)	S-770	0.025	0.457	0.482	0.055	0.052
Lo Na-3 (A)	S-771	0.055	0.382	0.437	0.144	0.126
Lo Na-3 (B)	S-771	0.055	0.383	0.438	0.144	0.126
Med Na-1 (A)	S-772	0.226	0.250	0.476	0.904	0.475
Med Na-1 (B)	S-772	0.225	0.251	0.476	0.896	0.473
Med Na-2 (A)	S-773	0.226	0.240	0.466	0.942	0.485
Med Na-2 (B)	S-773	0.226	0.242	0.468	0.934	0.483
Med NA-3 (A)	S-774	0.224	0.251	0.475	0.892	0.472
Med NA-3 (B)	S-774	0.225	0.249	0.474	0.904	0.475
Hi Na-1 (A)	S-775	0.311	0.199	0.510	1.563	0.610
Hi Na-1 (B)	S-775	0.313	0.200	0.513	1.565	0.610
Hi Na-2 (A)	S-776	0.263	0.210	0.473	1.252	0.556
Hi Na-2 (B)	S-776	0.263	0.211	0.474	1.246	0.555
Hi Na-3 (A)	S-777	0.310	0.223	0.533	1.390	0.582
Hi Na-3 (B)	S-777	0.312	0.219	0.531	1.425	0.588

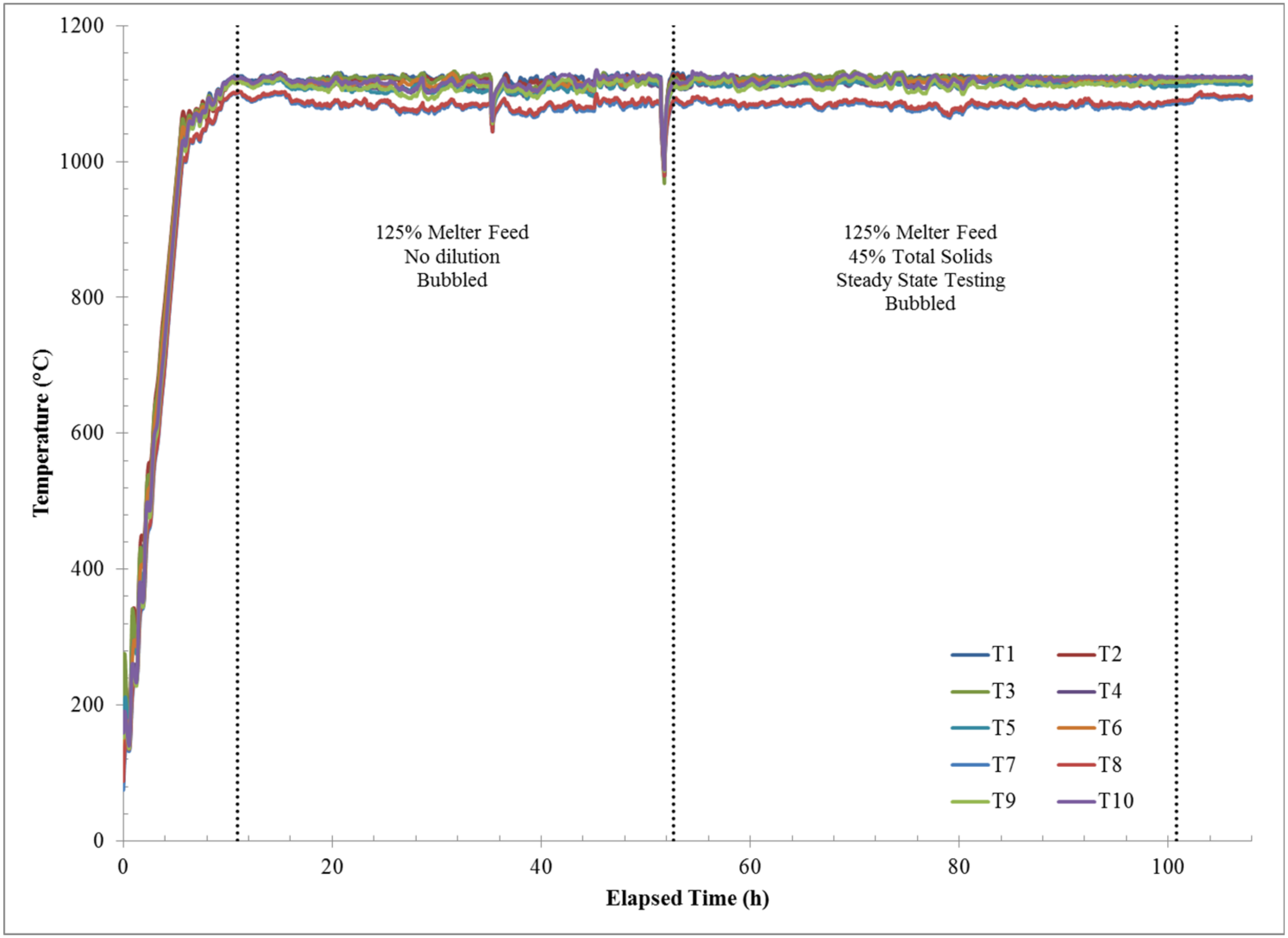

Figure A-1. Melter bottom (T1, T2) and melter side (T3-T10) thermocouple temperatures (elapsed time=0 at 12:00 February 24, 2014).

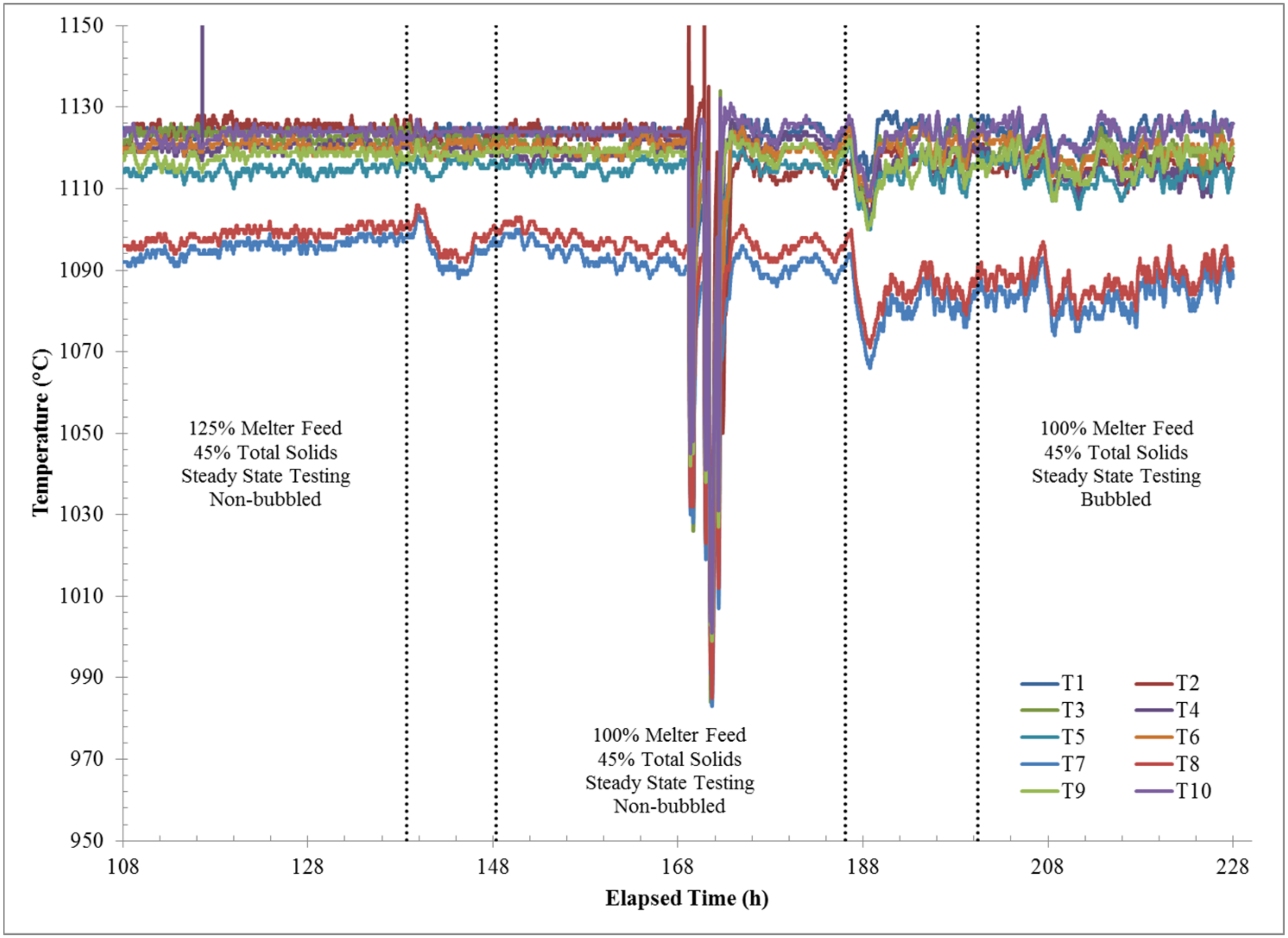

Figure A-2. Melter bottom (T1, T2) and melter side (T3-T10) thermocouple temperatures (elapsed time=108 at 00:00 March 1, 2014).

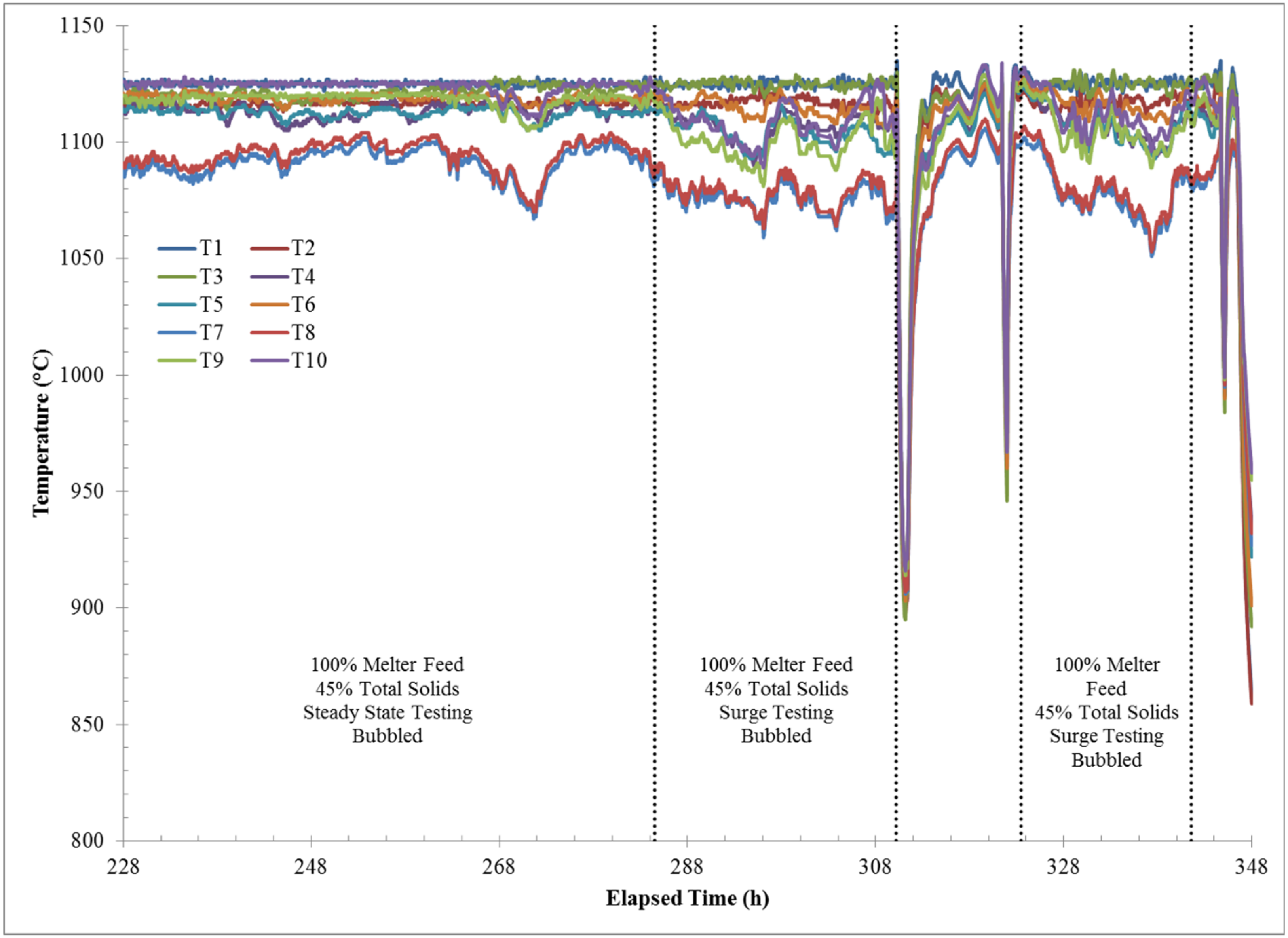

Figure A-3. Melter bottom (T1, T2) and melter side (T3-T10) thermocouple temperatures (elapsed time=228 at 00:00 March 6, 2014).

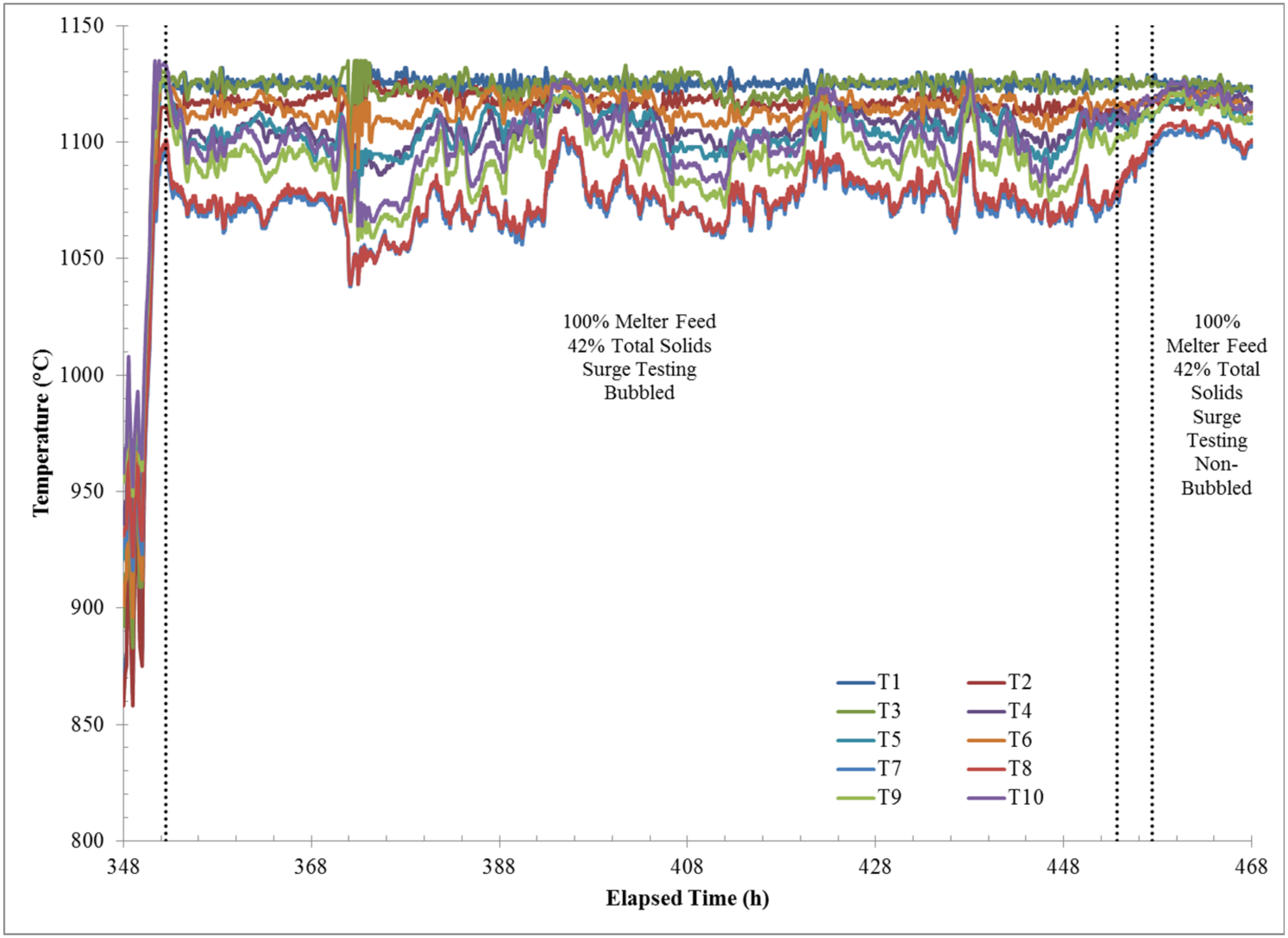

Figure A-4. Melter bottom (T1, T2) and melter side (T3-T10) thermocouple temperatures (elapsed time=348 at 00:00 March 11, 2014).

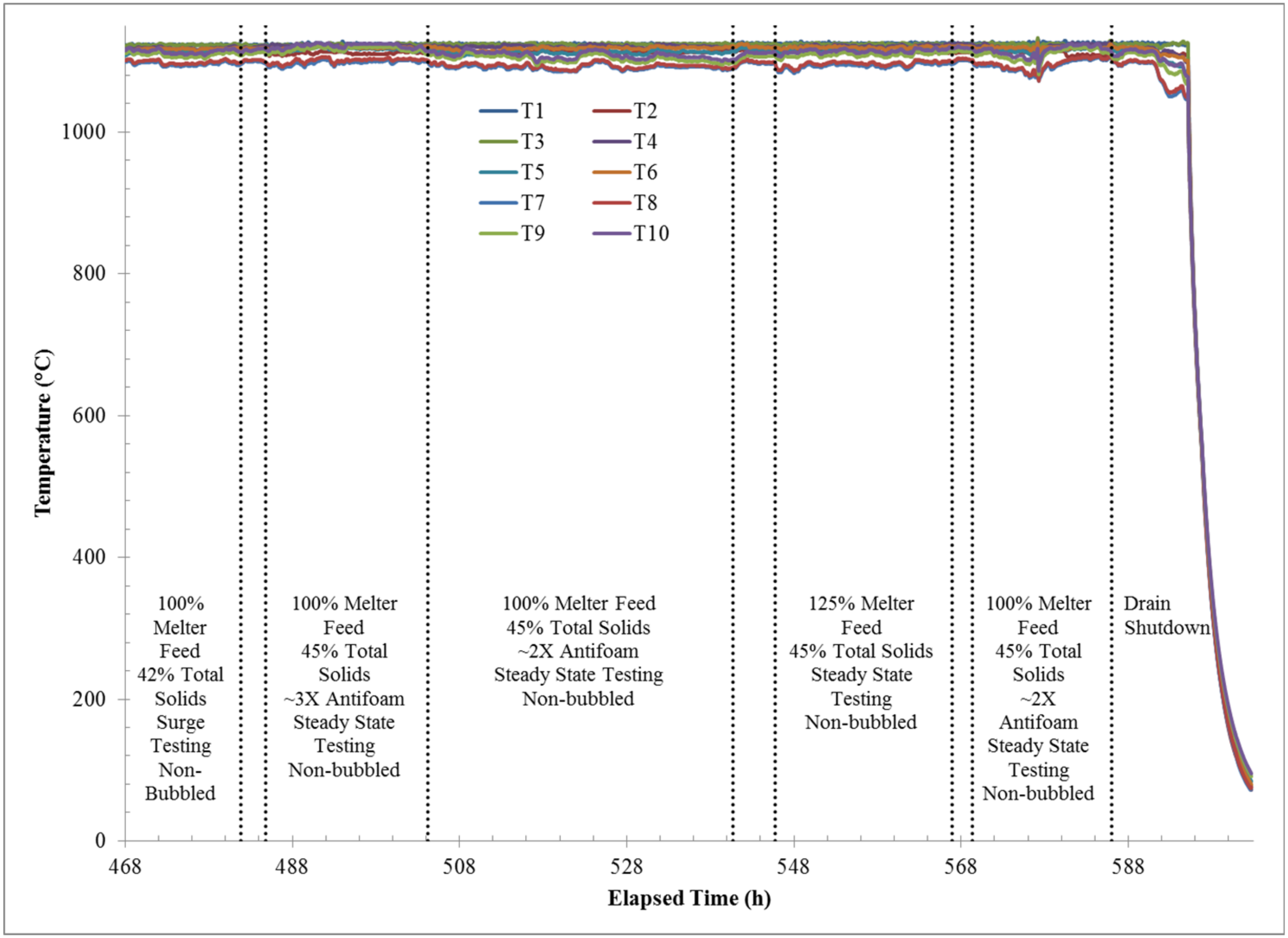

Figure A-5. Melter bottom (T1, T2) and melter side (T3-T10) thermocouple temperatures (elapsed time=468 at 00:00 March 16, 2014).

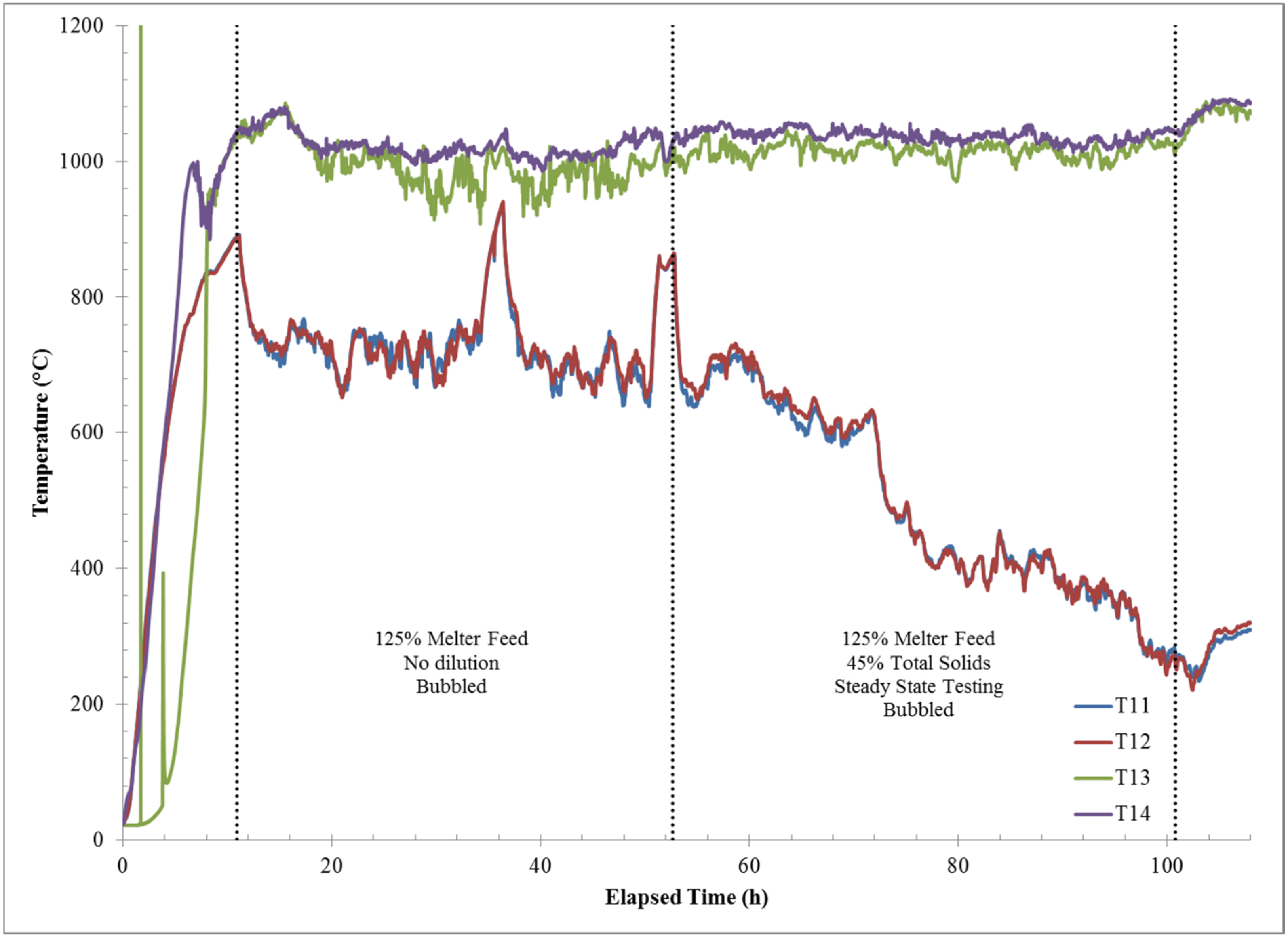

Figure A-6. Vapor space (T11,T12) and melt pool (T13, T14) thermocouple temperatures (elapsed time=0 at 12:00 February 24, 2014).

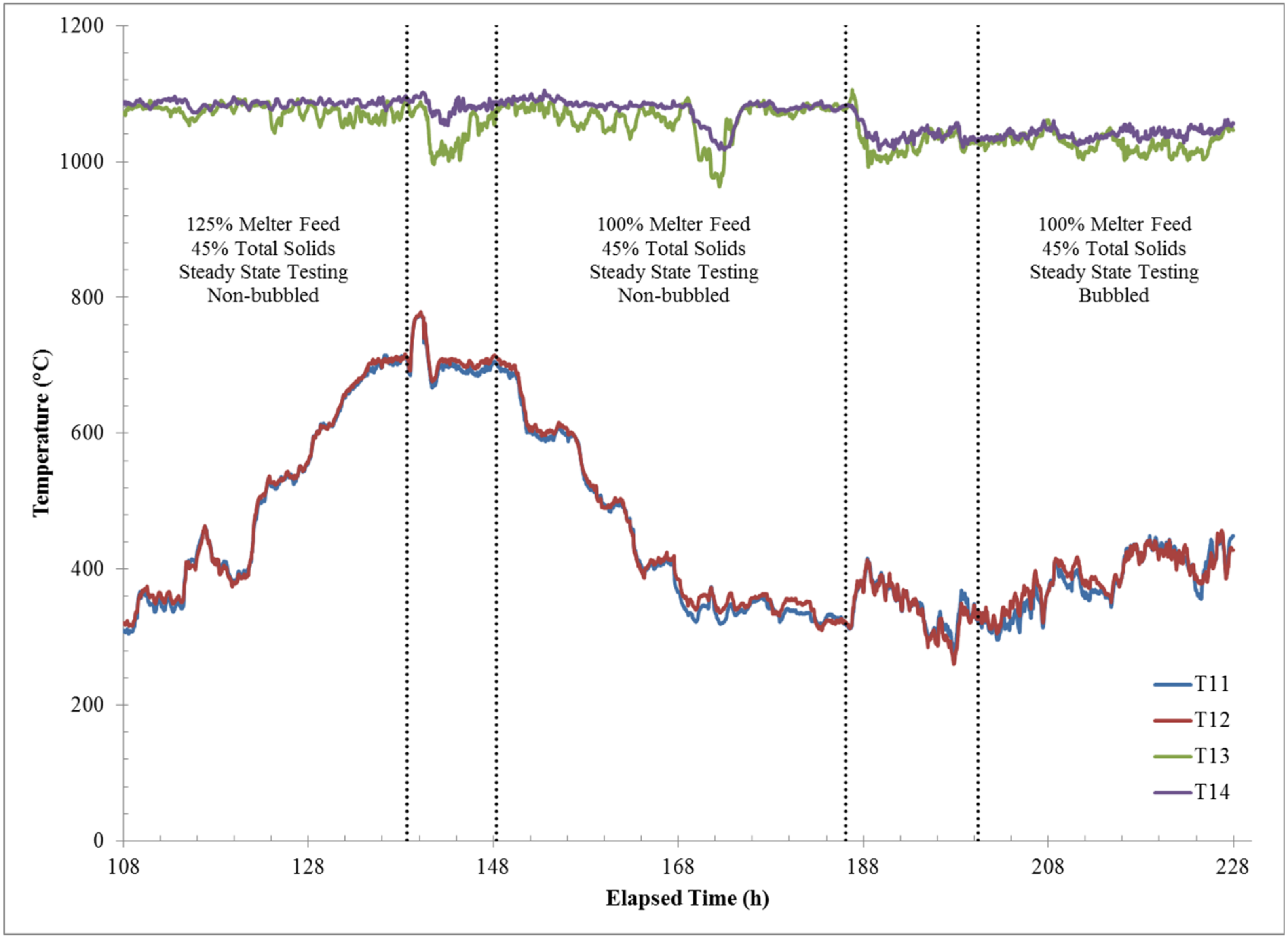

Figure A-7. Vapor space (T11,T12) and melt pool (T13, T14) thermocouple temperatures (elapsed time=108 at 00:00 March 1, 2014).

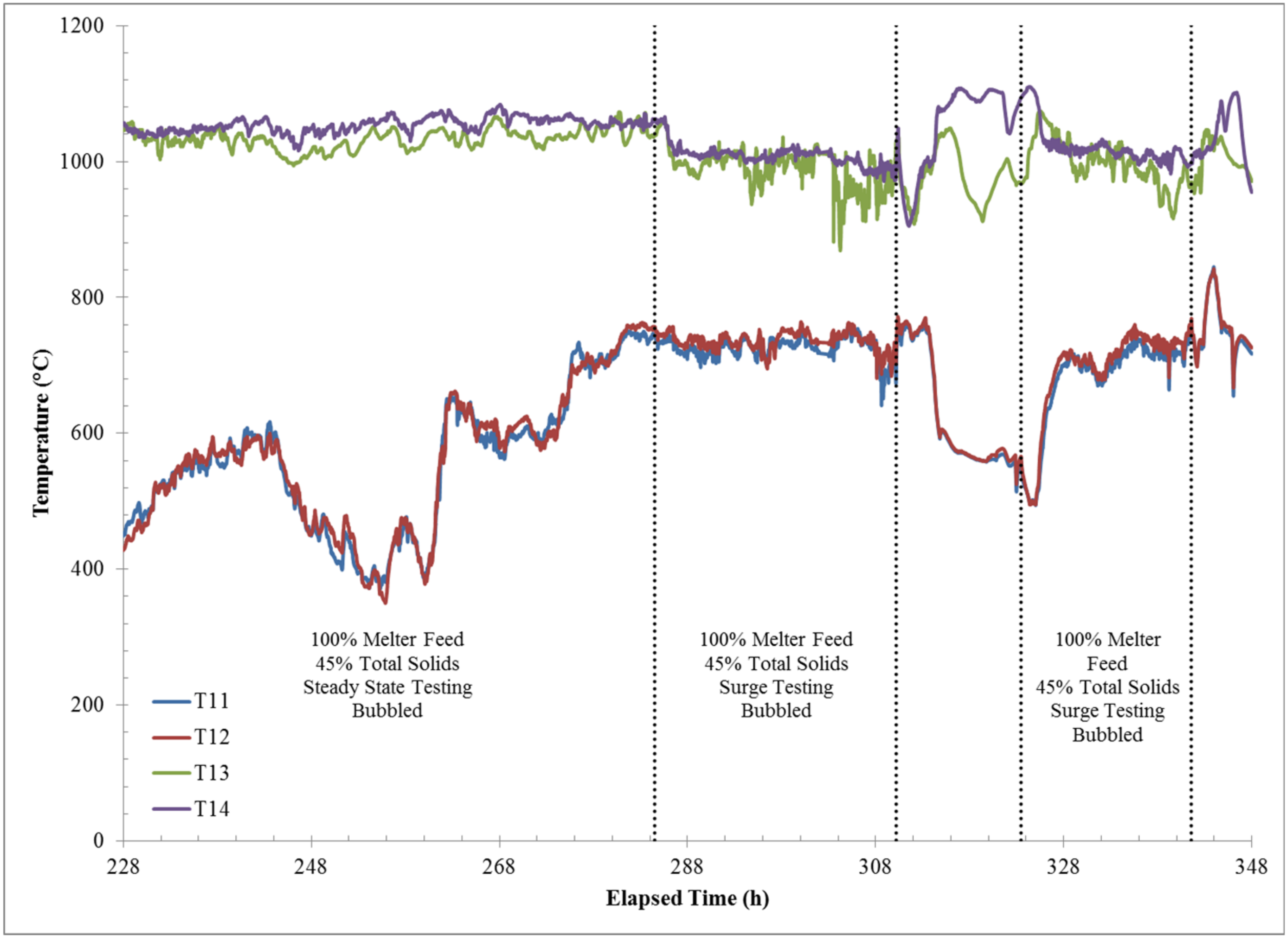

Figure A-8. Vapor space (T11,T12) and melt pool (T13, T14) thermocouple temperatures (elapsed time=228 at 00:00 March 6, 2014).

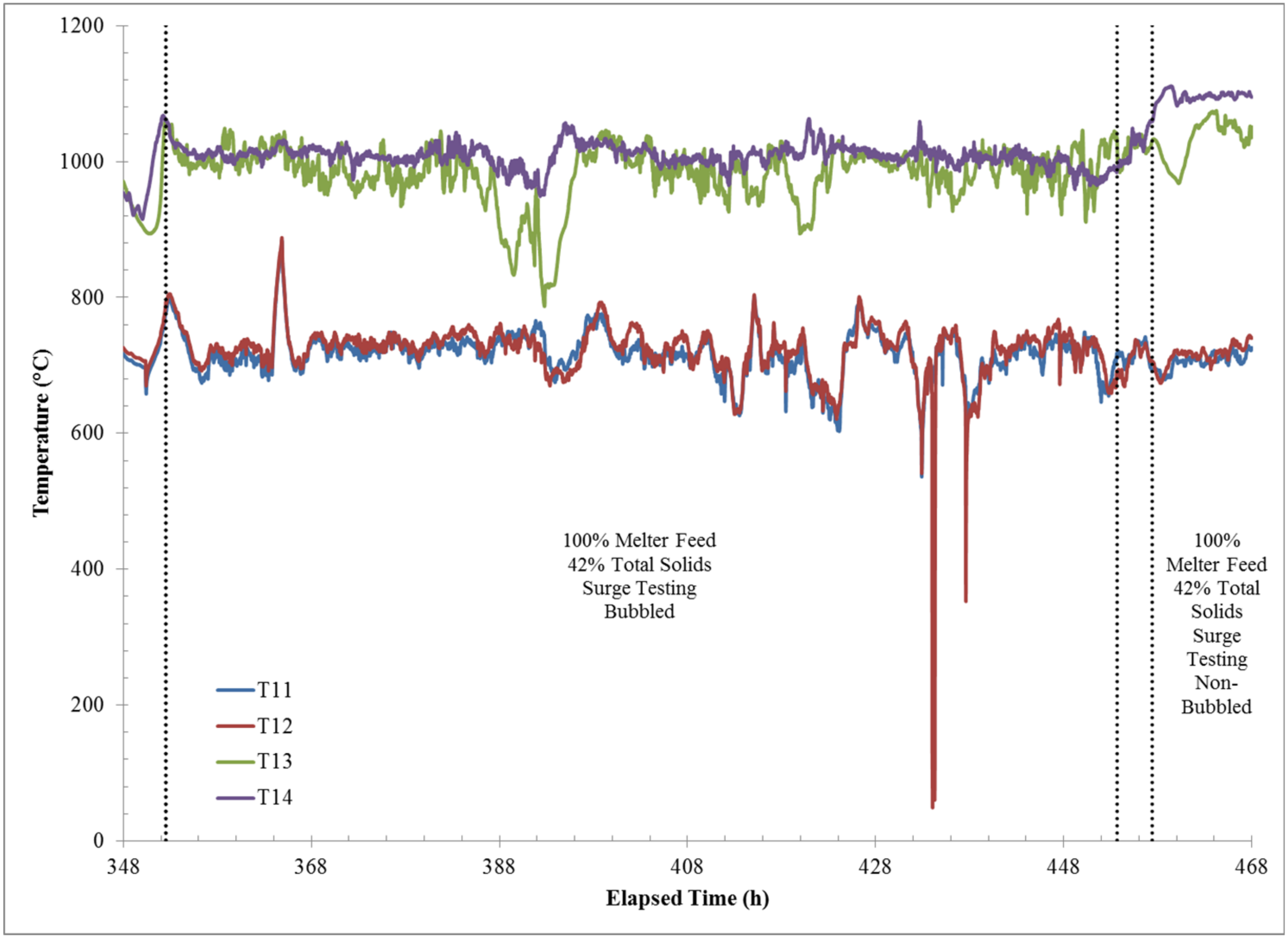

Figure A-9. Vapor space (T11,T12) and melt pool (T13, T14) thermocouple temperatures (elapsed time=348 at 00:00 March 11, 2014).

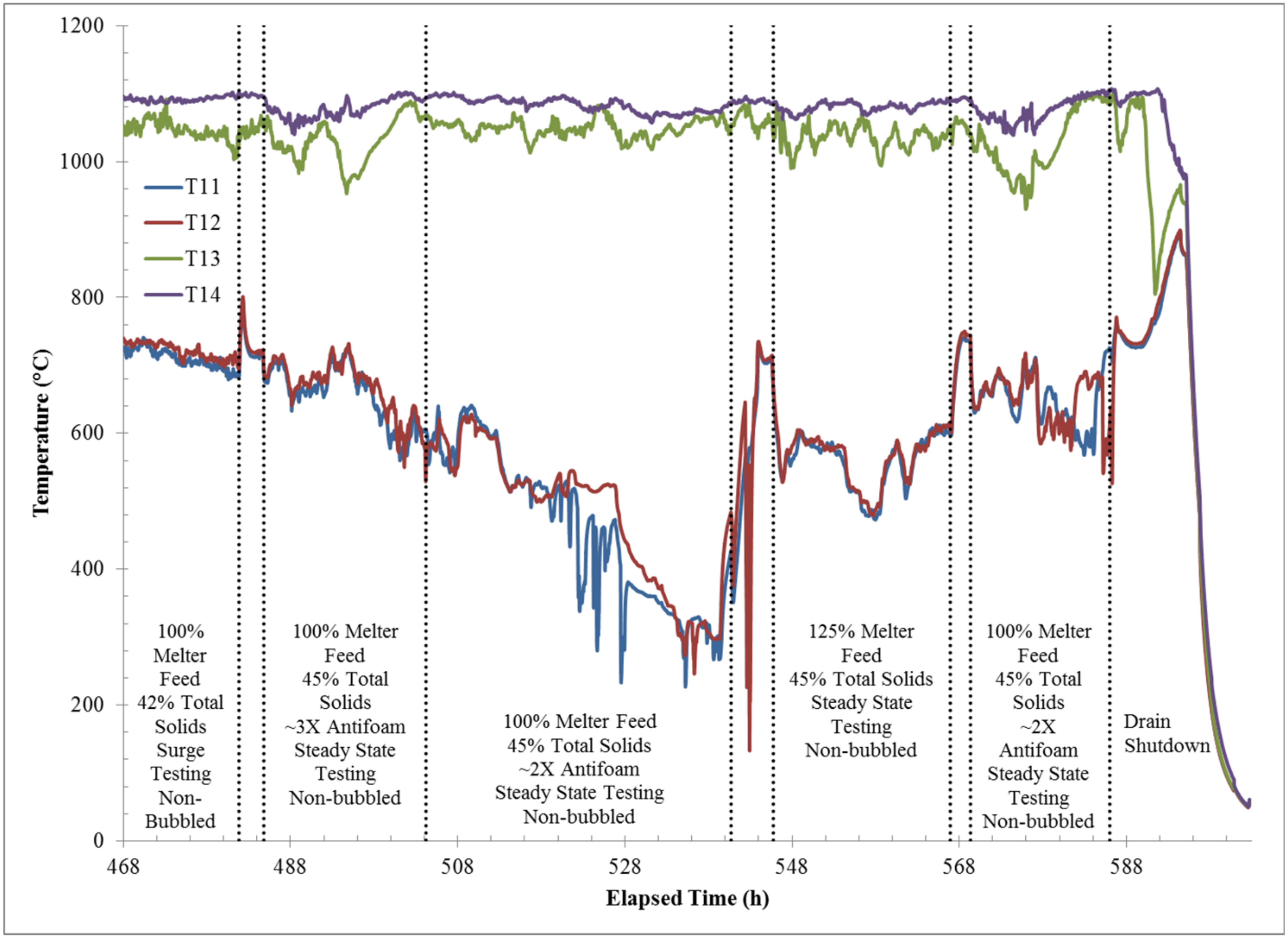

Figure A-10. Vapor space (T11,T12) and melt pool (T13, T14) thermocouple temperatures (elapsed time=468 at 00:00 March 16, 2014).

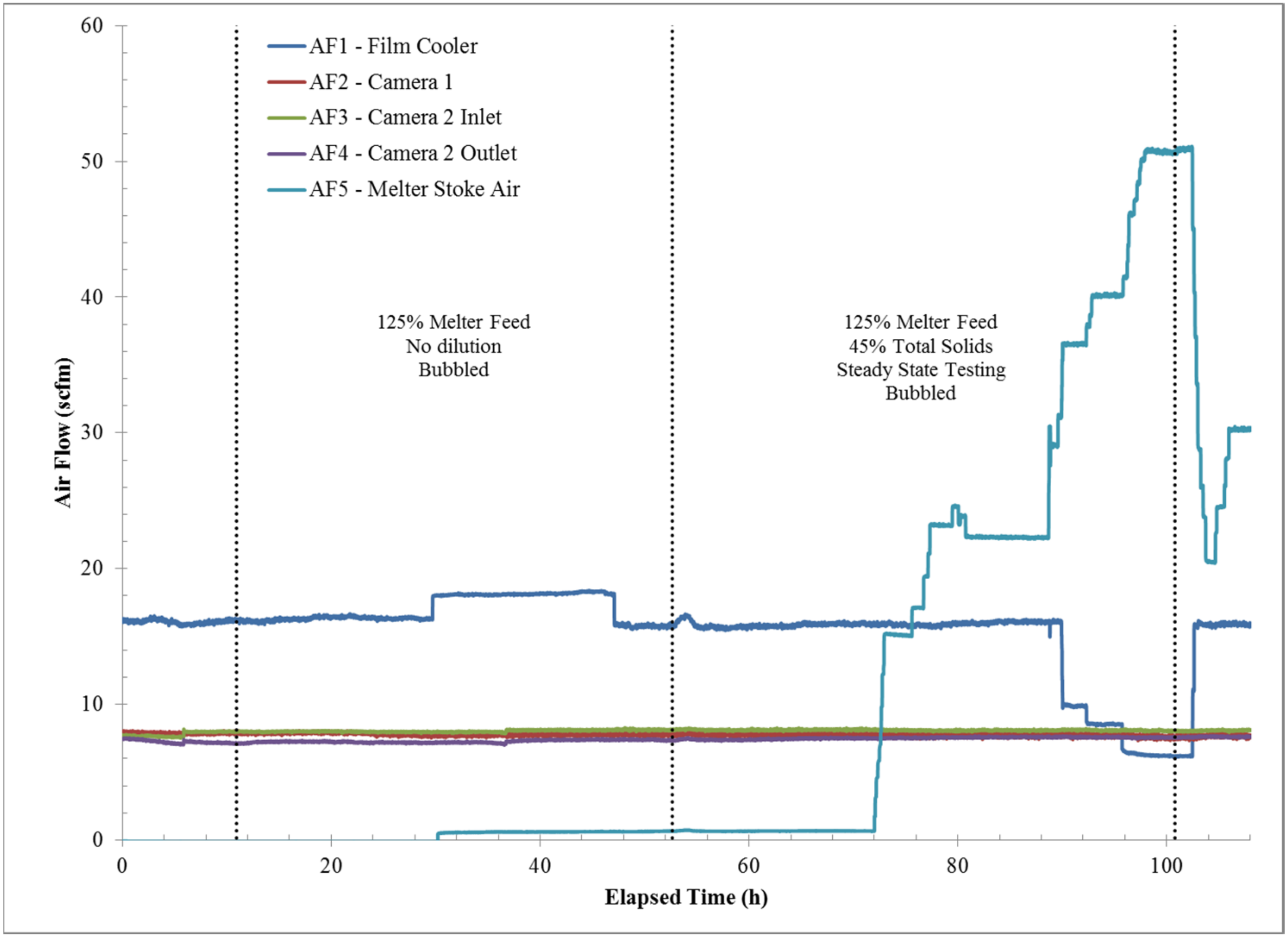

Figure A-11. Air flows (elapsed time=0 at 12:00 February 24, 2014).

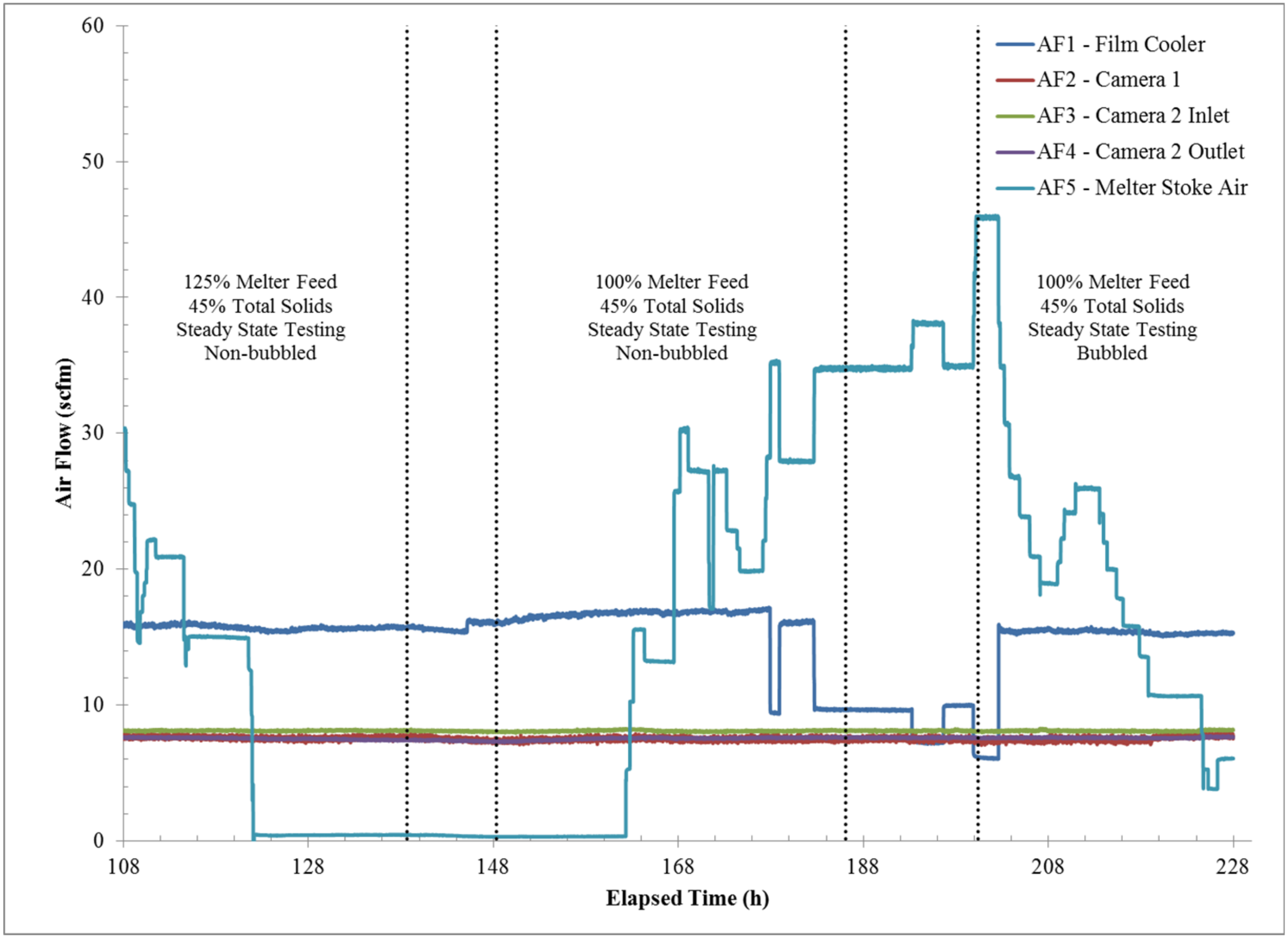

Figure A-12. Air flows (elapsed time=108 at 00:00 March 1, 2014).

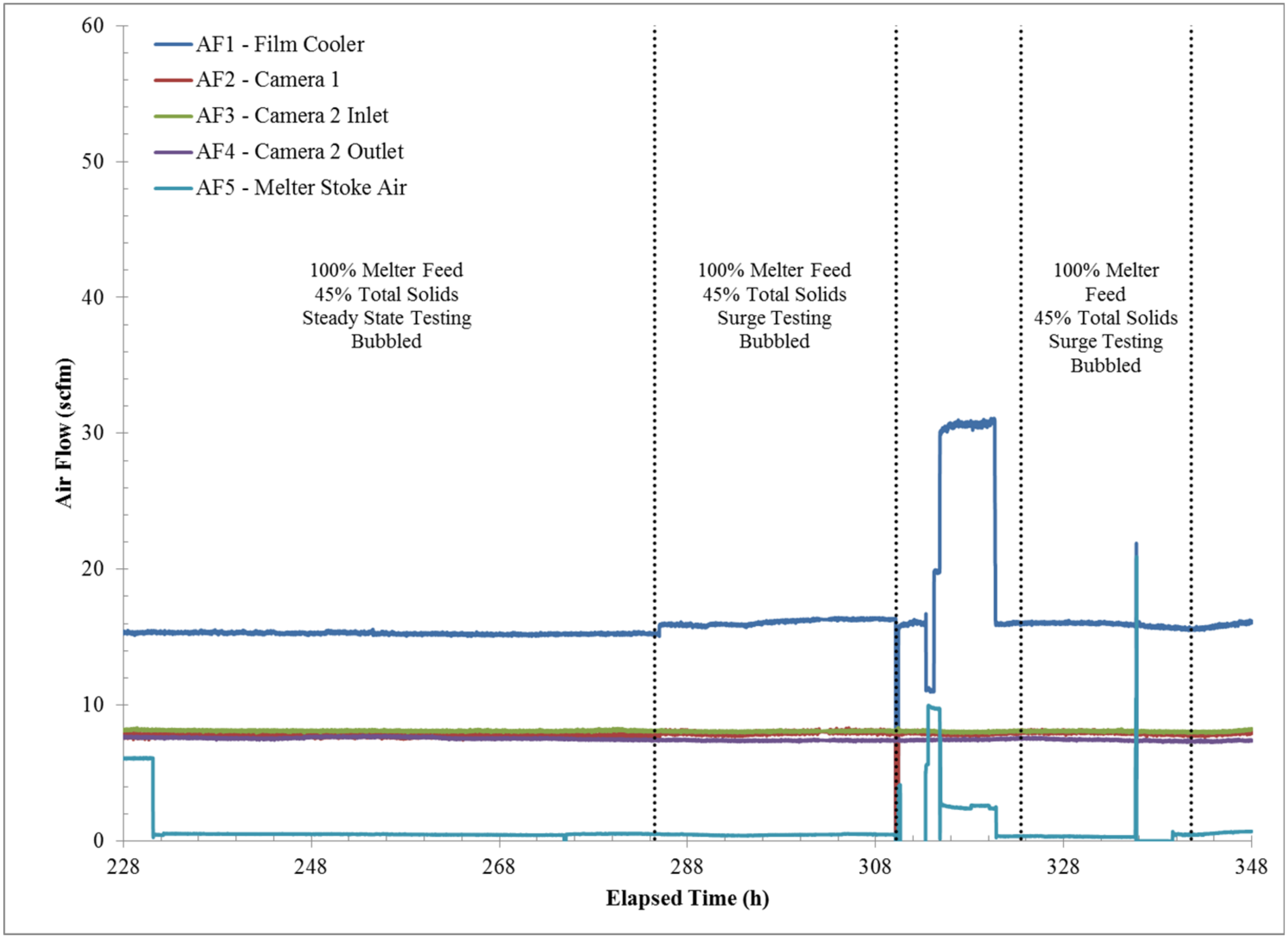

Figure A-13. Air flows (elapsed time=228 at 00:00 March 6, 2014).

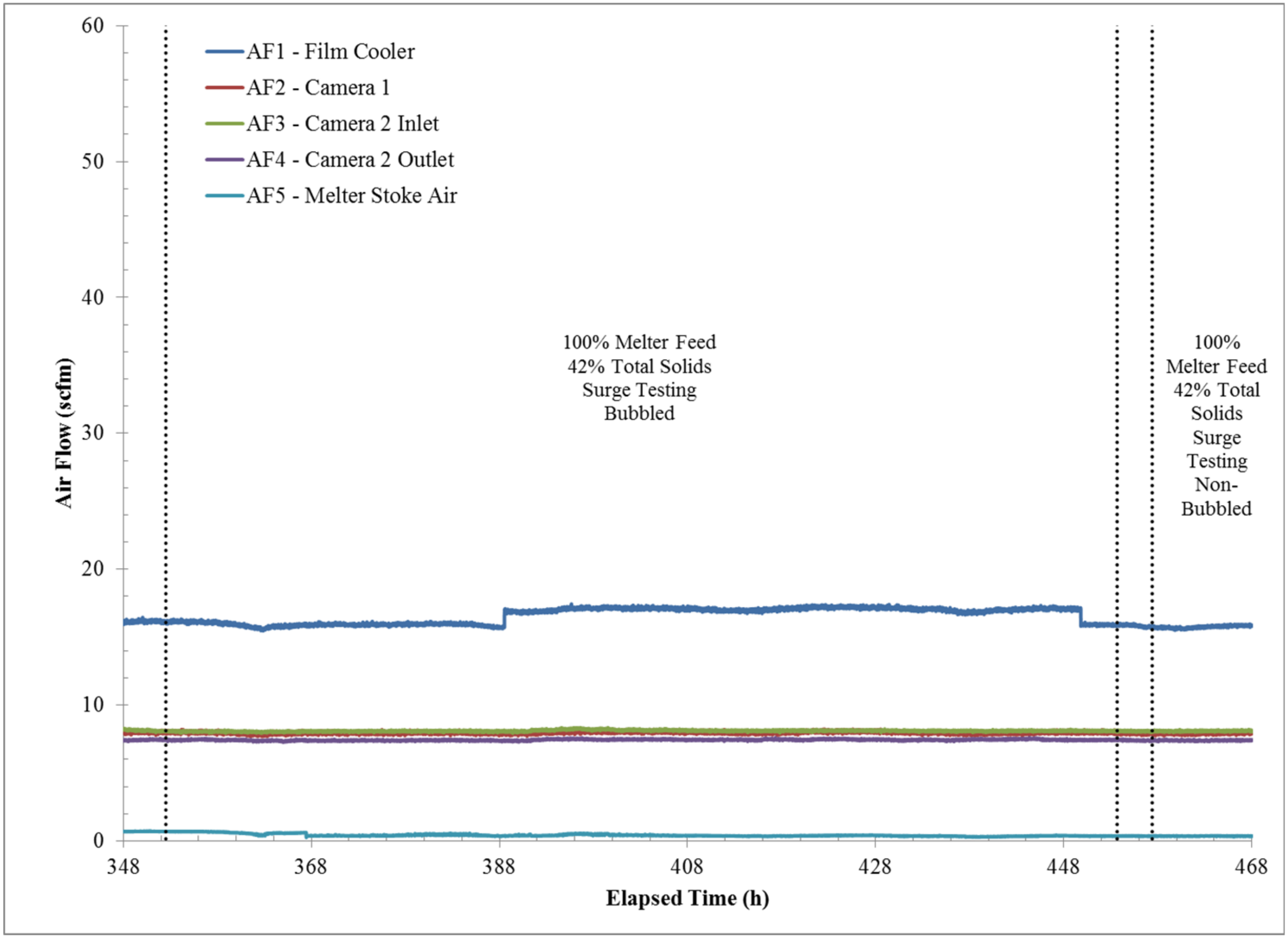

Figure A-14. Air flows (elapsed time=348 at 00:00 March 11, 2014).

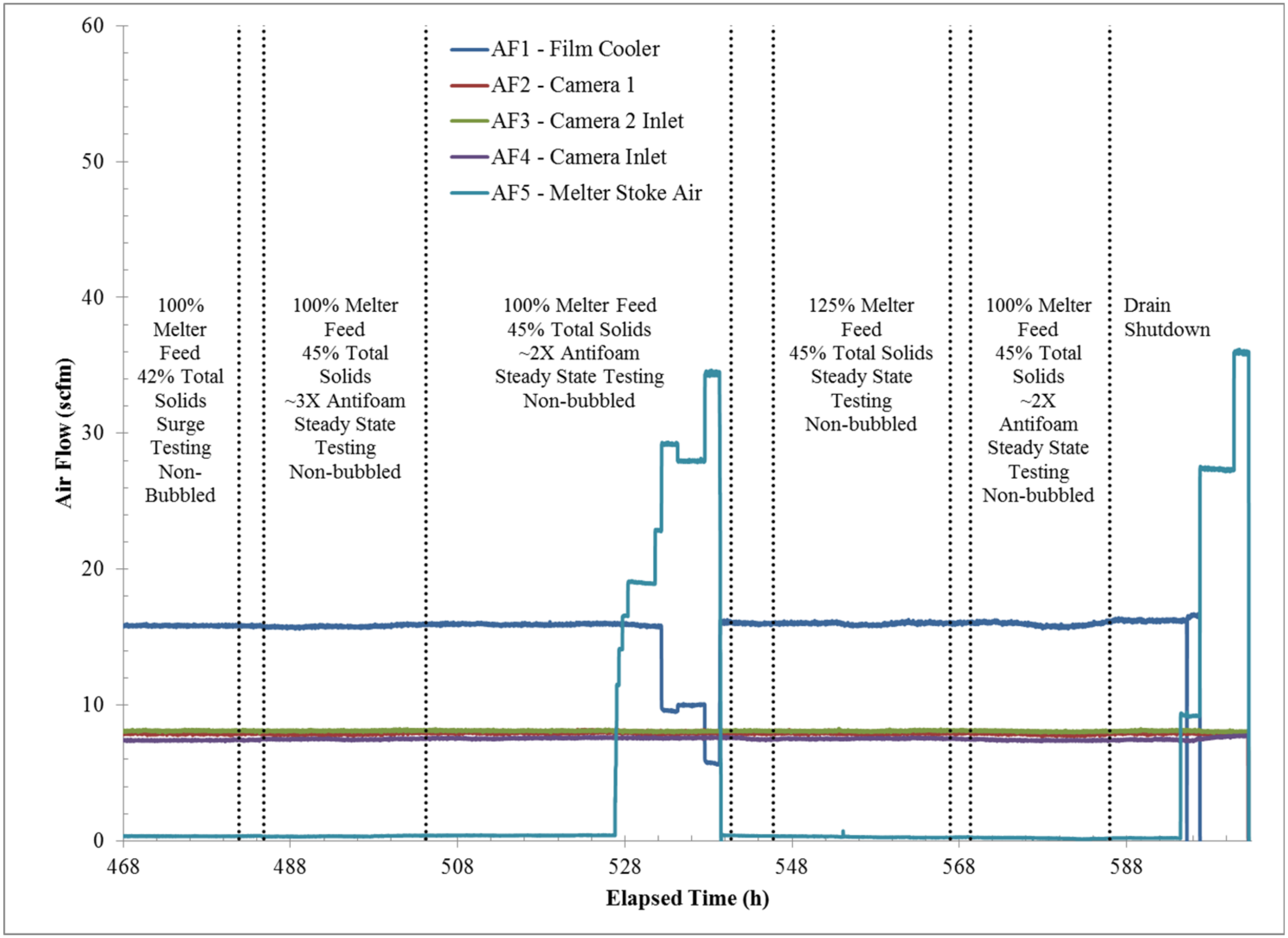

Figure A-15. Air flows (elapsed time=468 at 00:00 March 16, 2014).

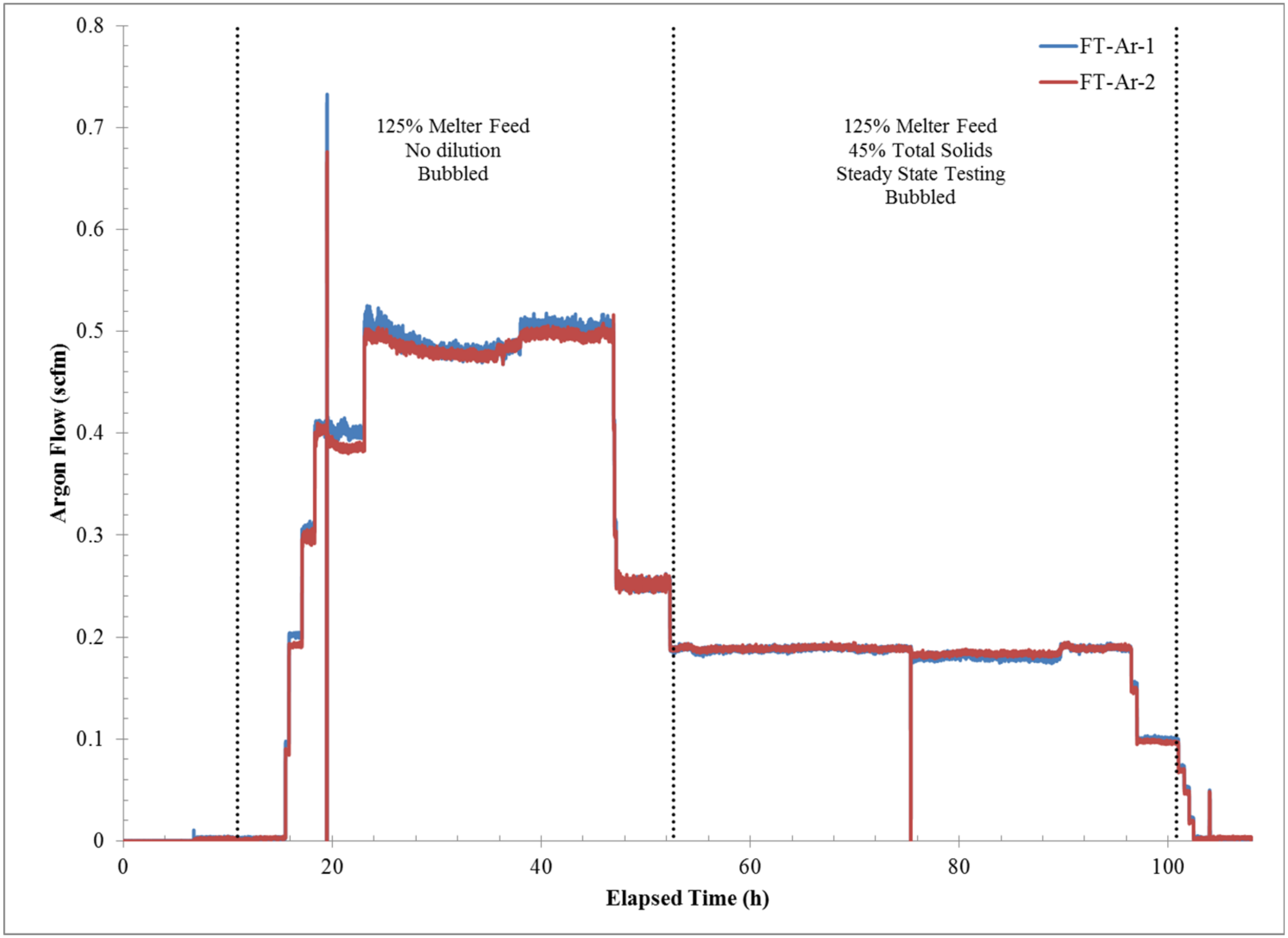

Figure A-16. Argon bubbler flows (elapsed time=0 at 12:00 February 24, 2014).

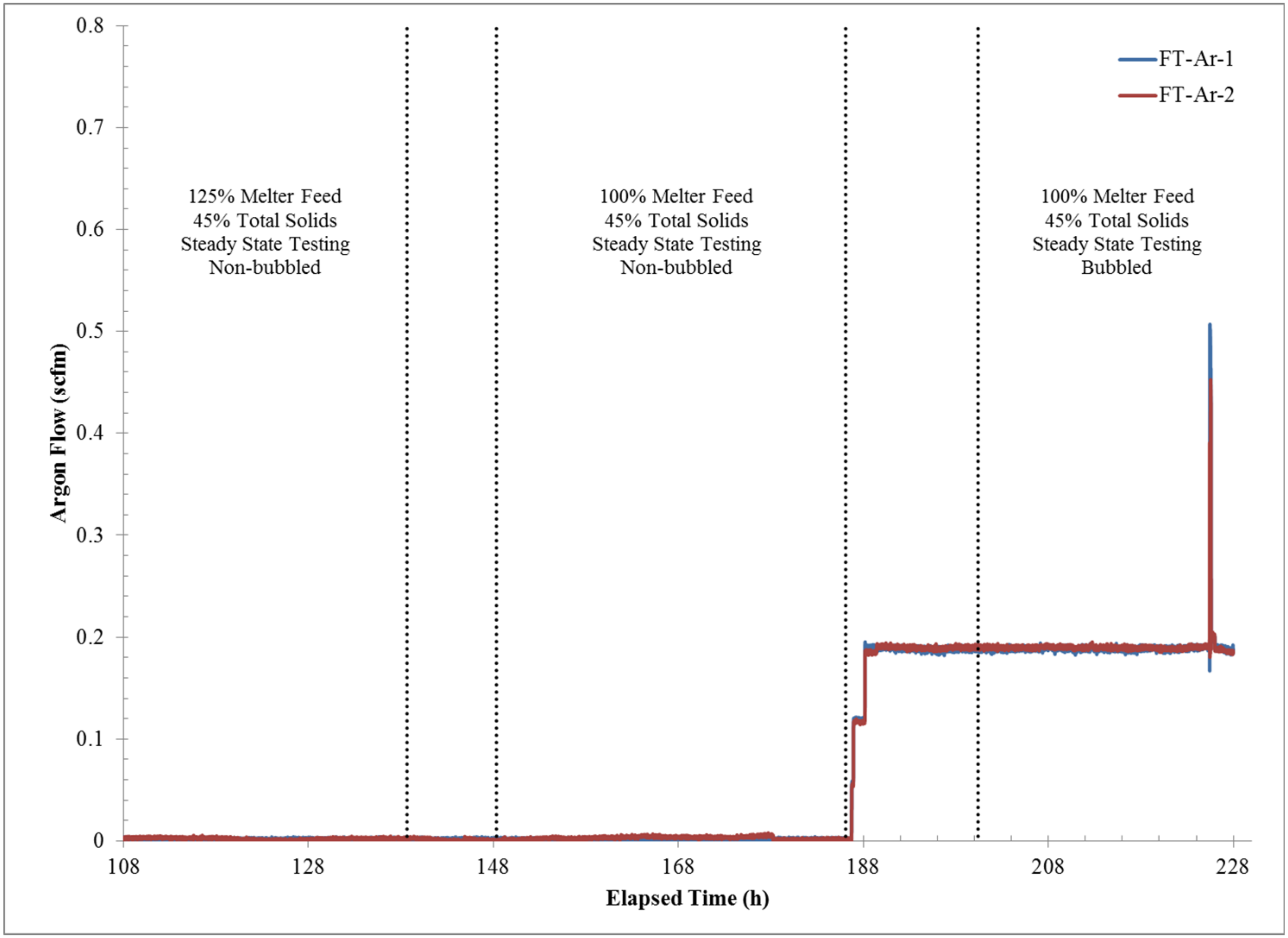

Figure A-17. Argon bubbler flows (elapsed time=108 at 00:00 March 1, 2014).

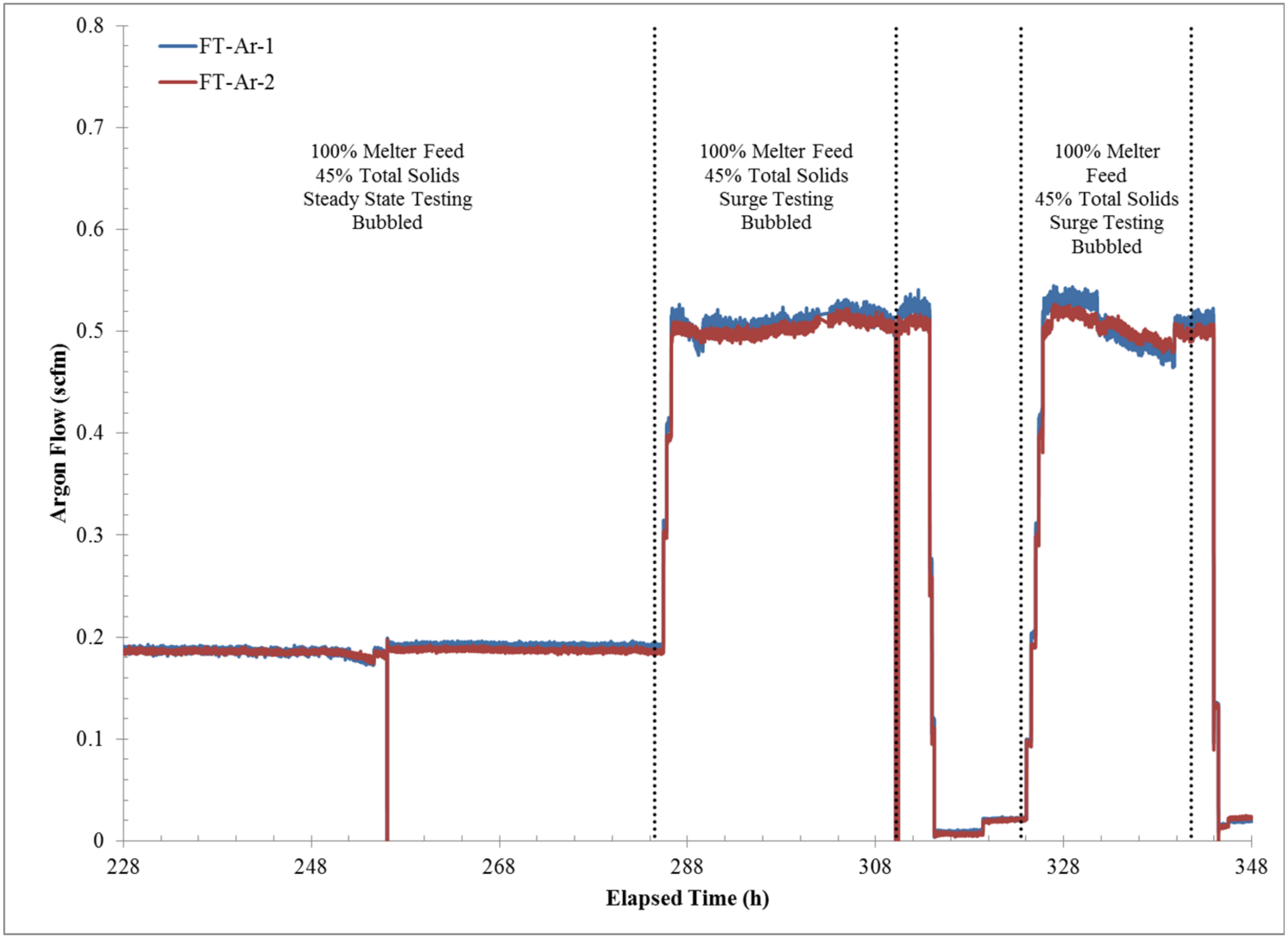

Figure A-18. Argon bubbler flows (elapsed time=228 at 00:00 March 6, 2014).

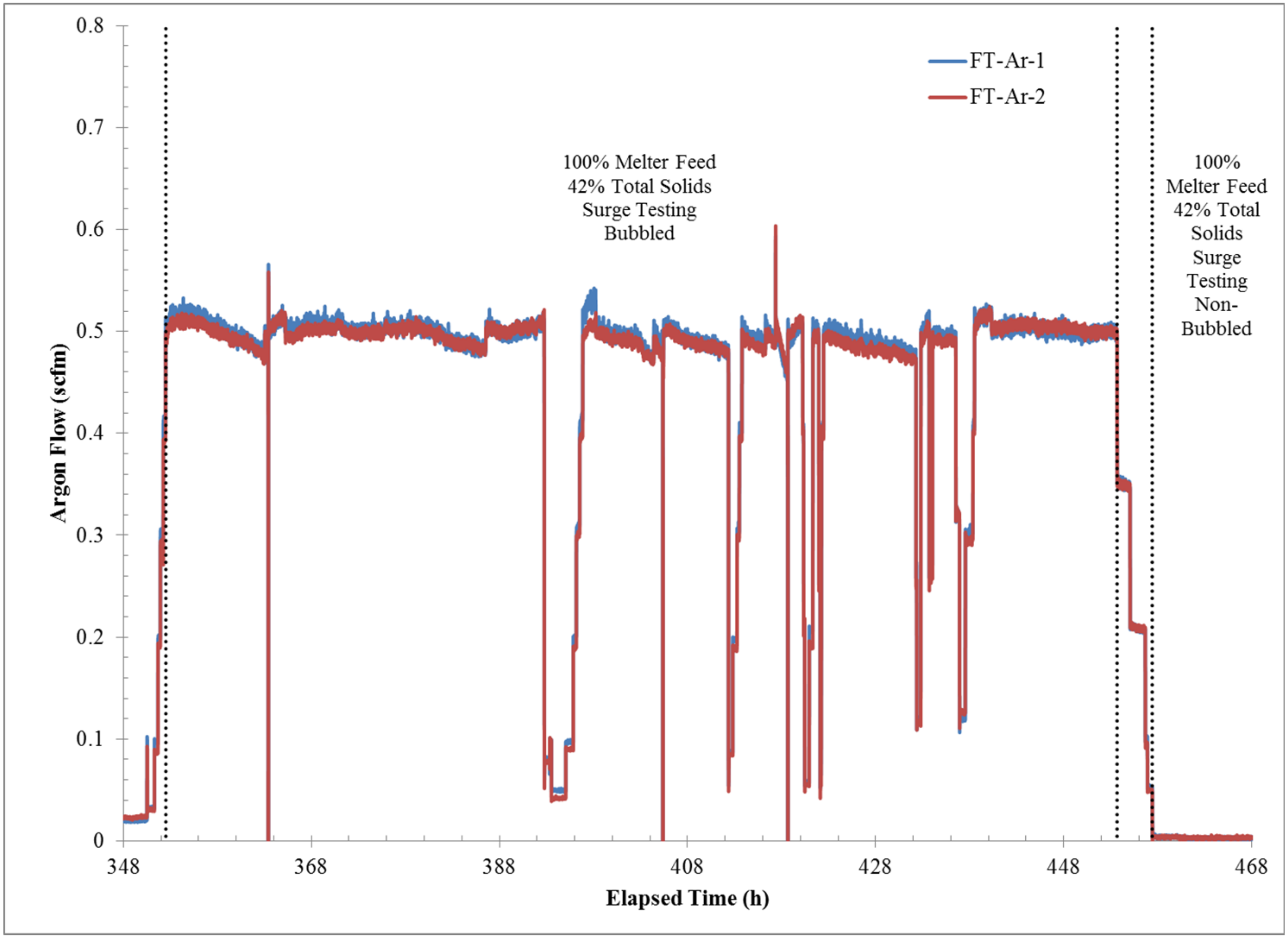

Figure A-19. Argon bubbler flows (elapsed time=348 at 00:00 March 11, 2014).

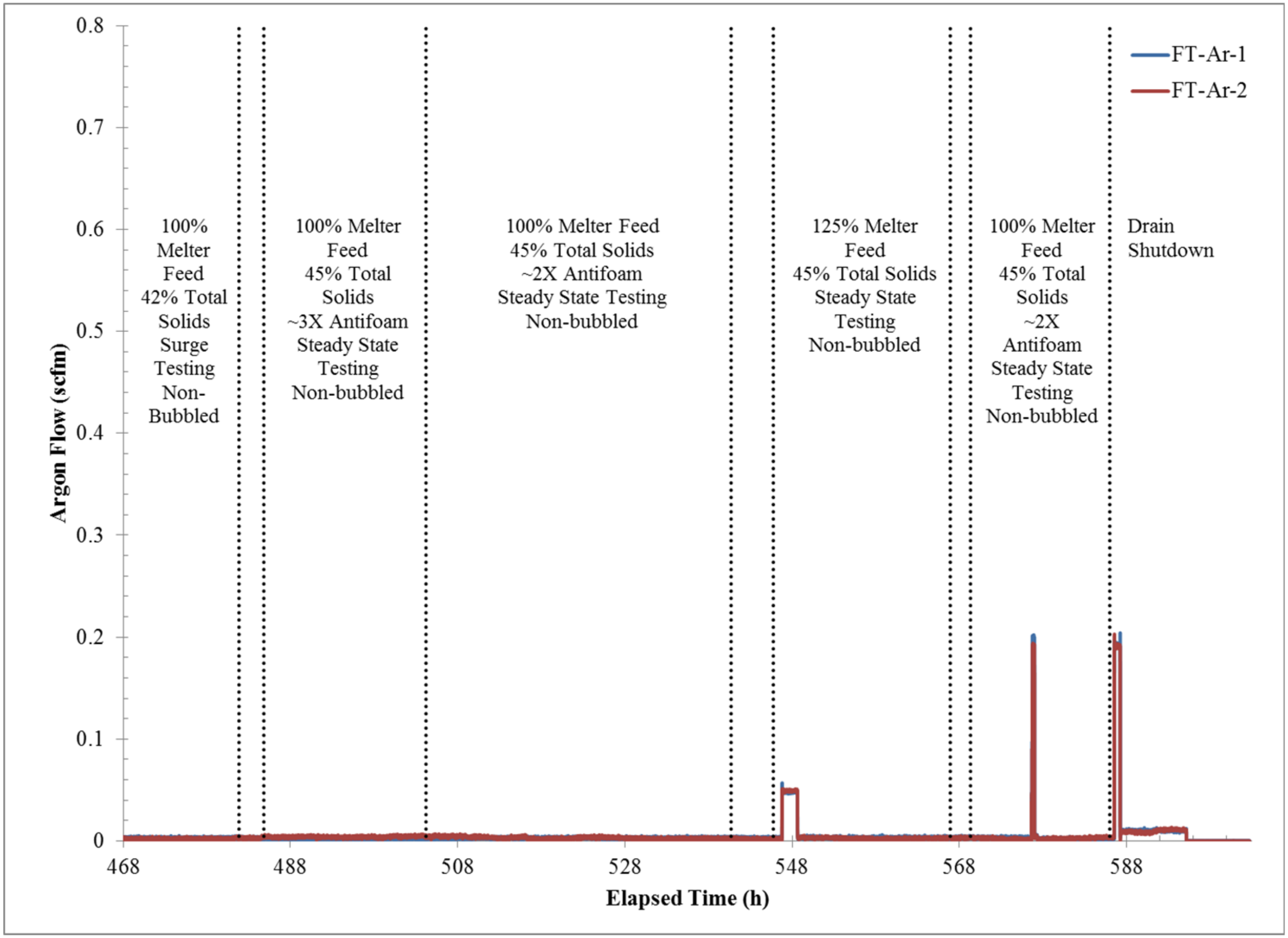

Figure A-20. Argon bubbler flows (elapsed time=468 at 00:00 March 16, 2014).

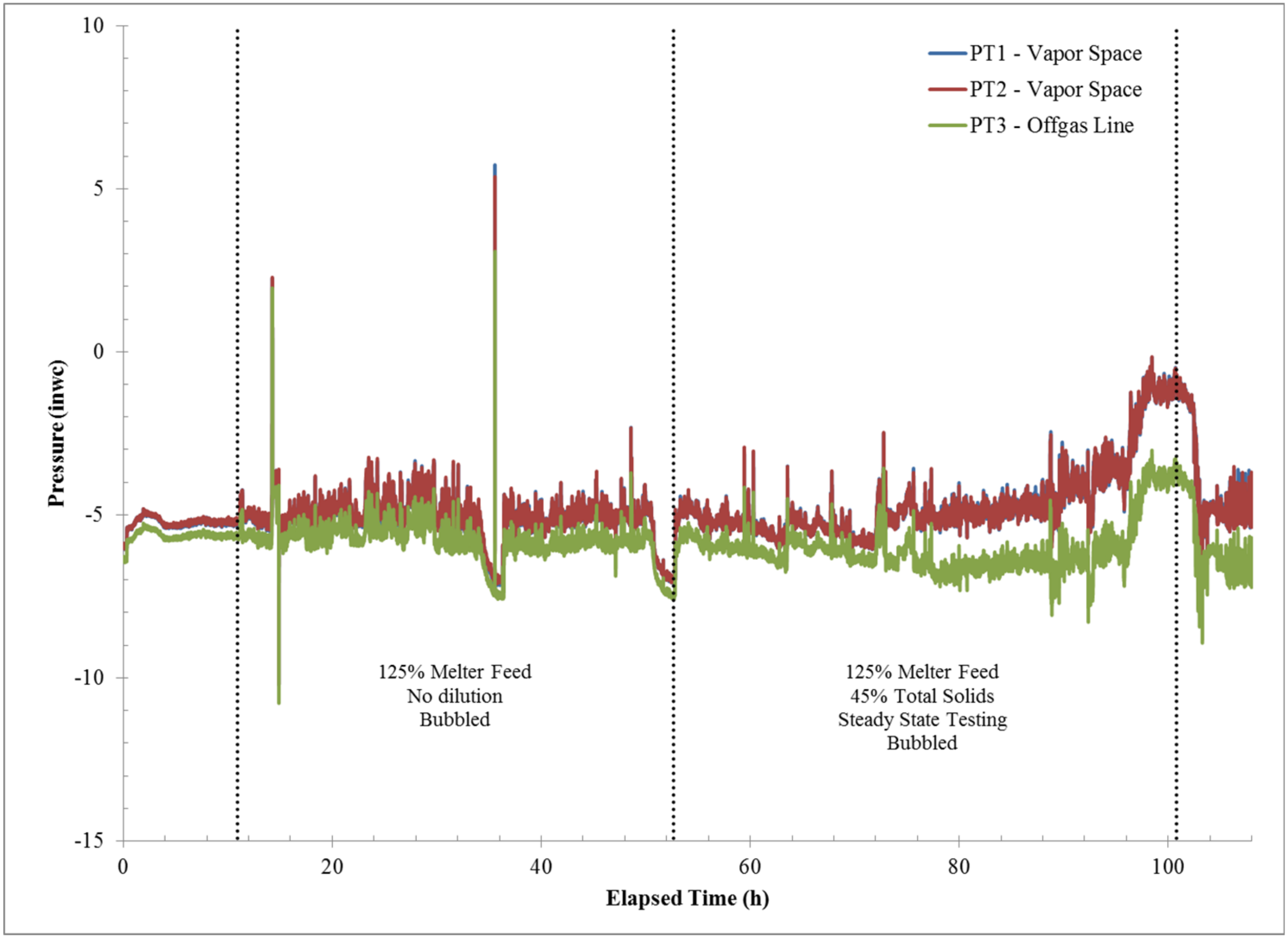

Figure A-21. Vapor space and off-gas line pressures (elapsed time=0 at 12:00 February 24, 2014).

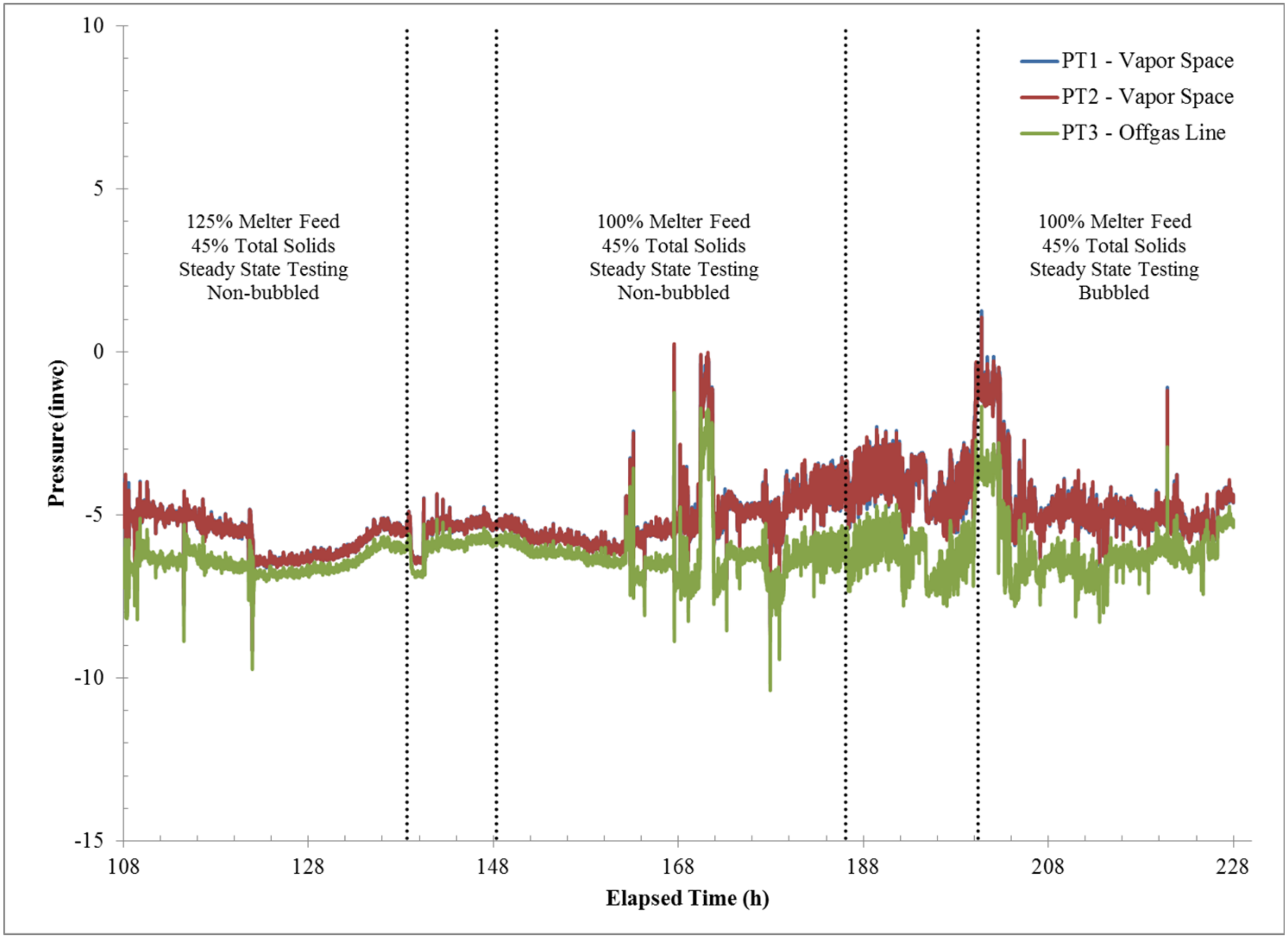

Figure A-22. Vapor space and off-gas line pressures (elapsed time=108 at 00:00 March 1, 2014).

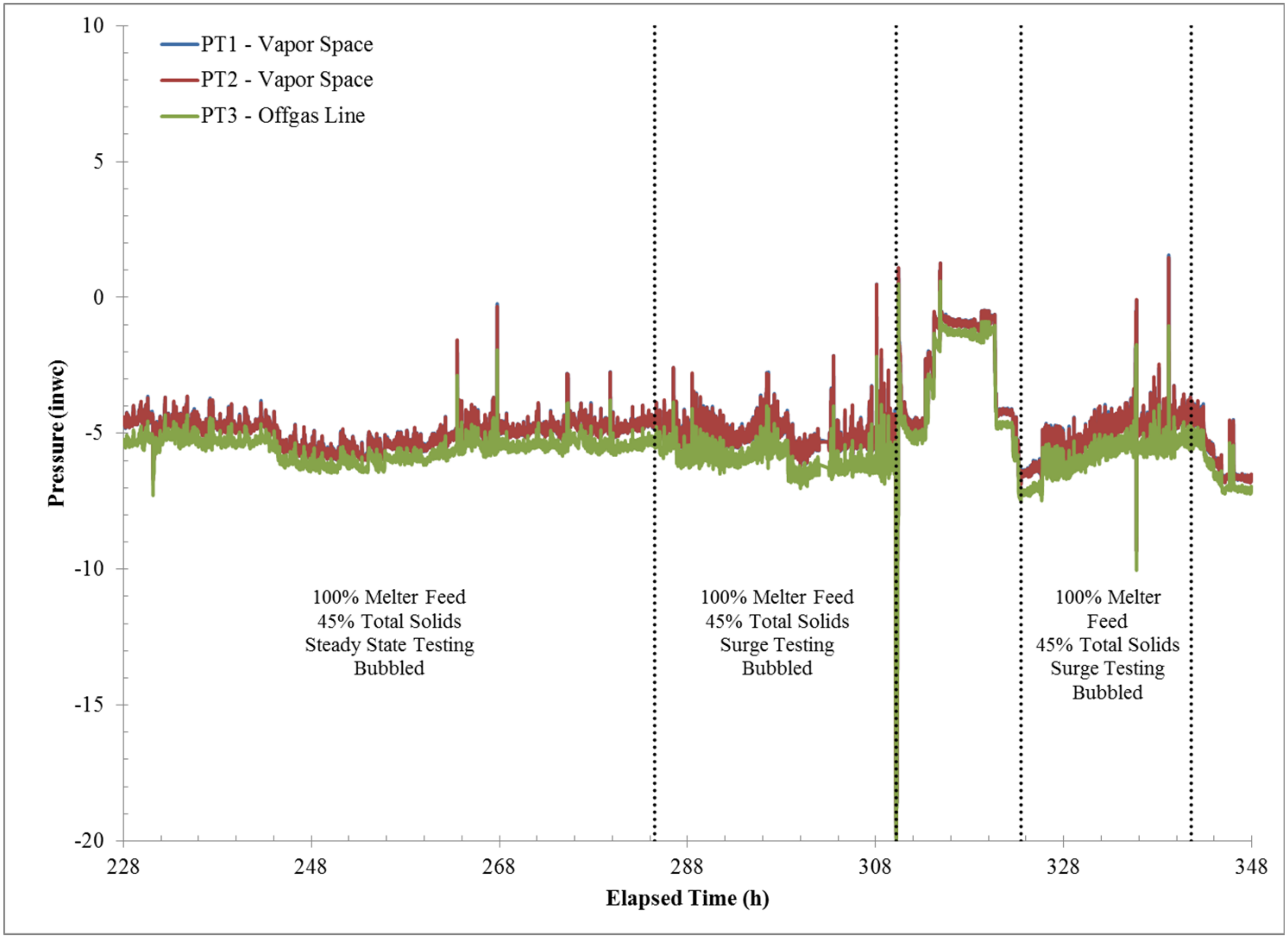

Figure A-23. Vapor space and off-gas line pressures (elapsed time=228 at 00:00 March 6, 2014).

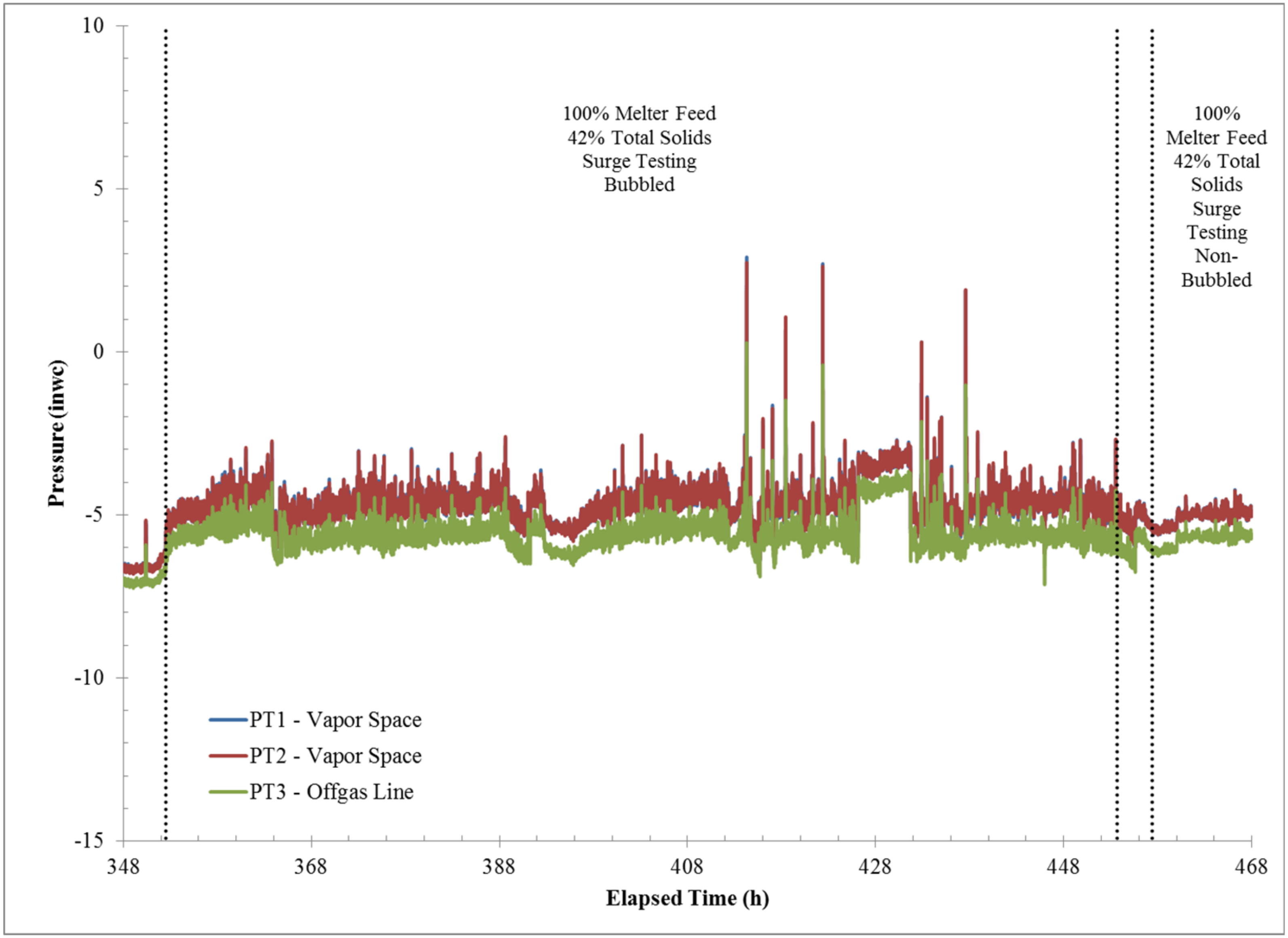

Figure A-24. Vapor space and off-gas line pressures (elapsed time=348 at 00:00 March 11, 2014).

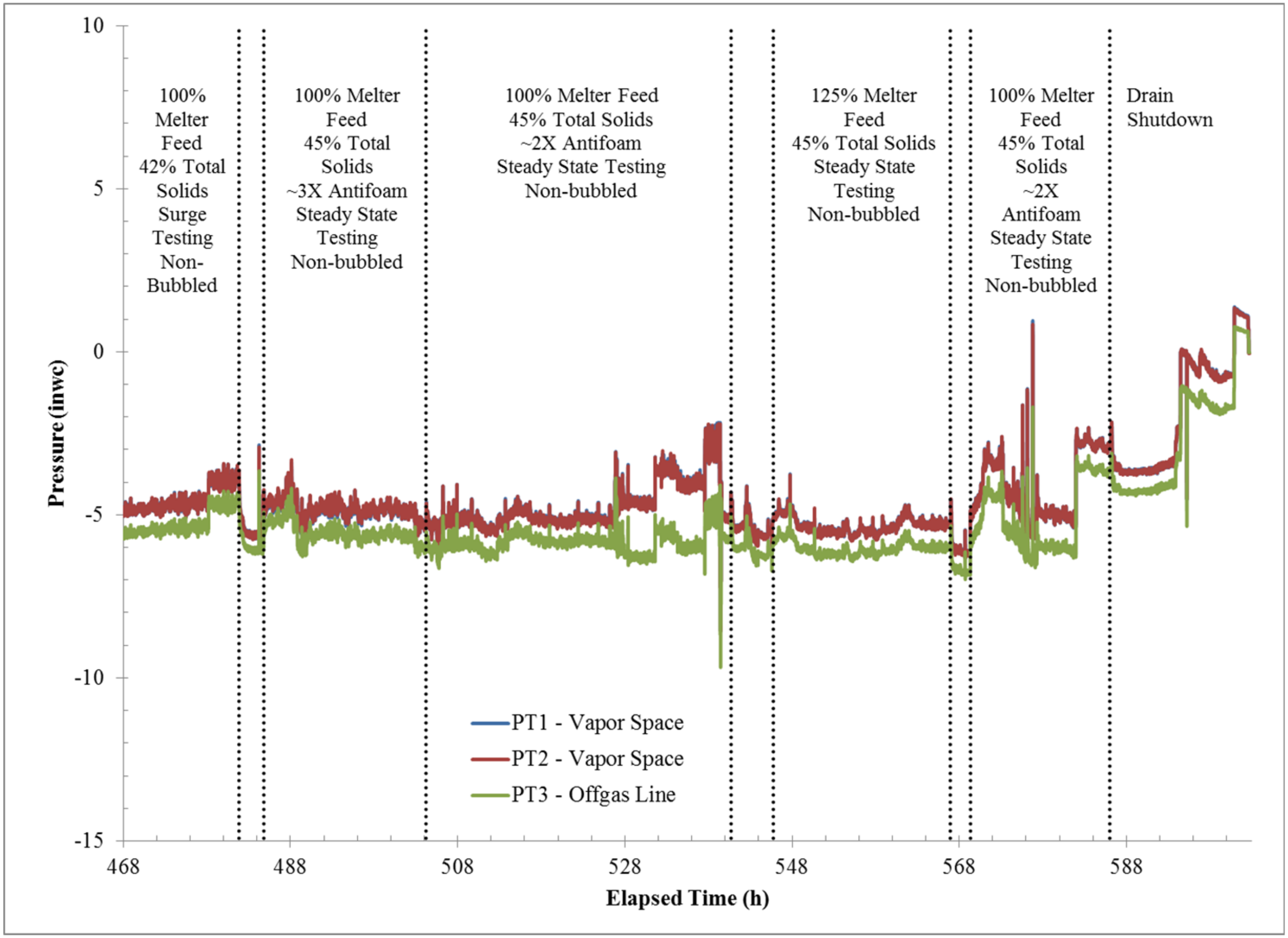

Figure A-25. Vapor space and off-gas line pressures (elapsed time=468 at 00:00 March 16, 2014).

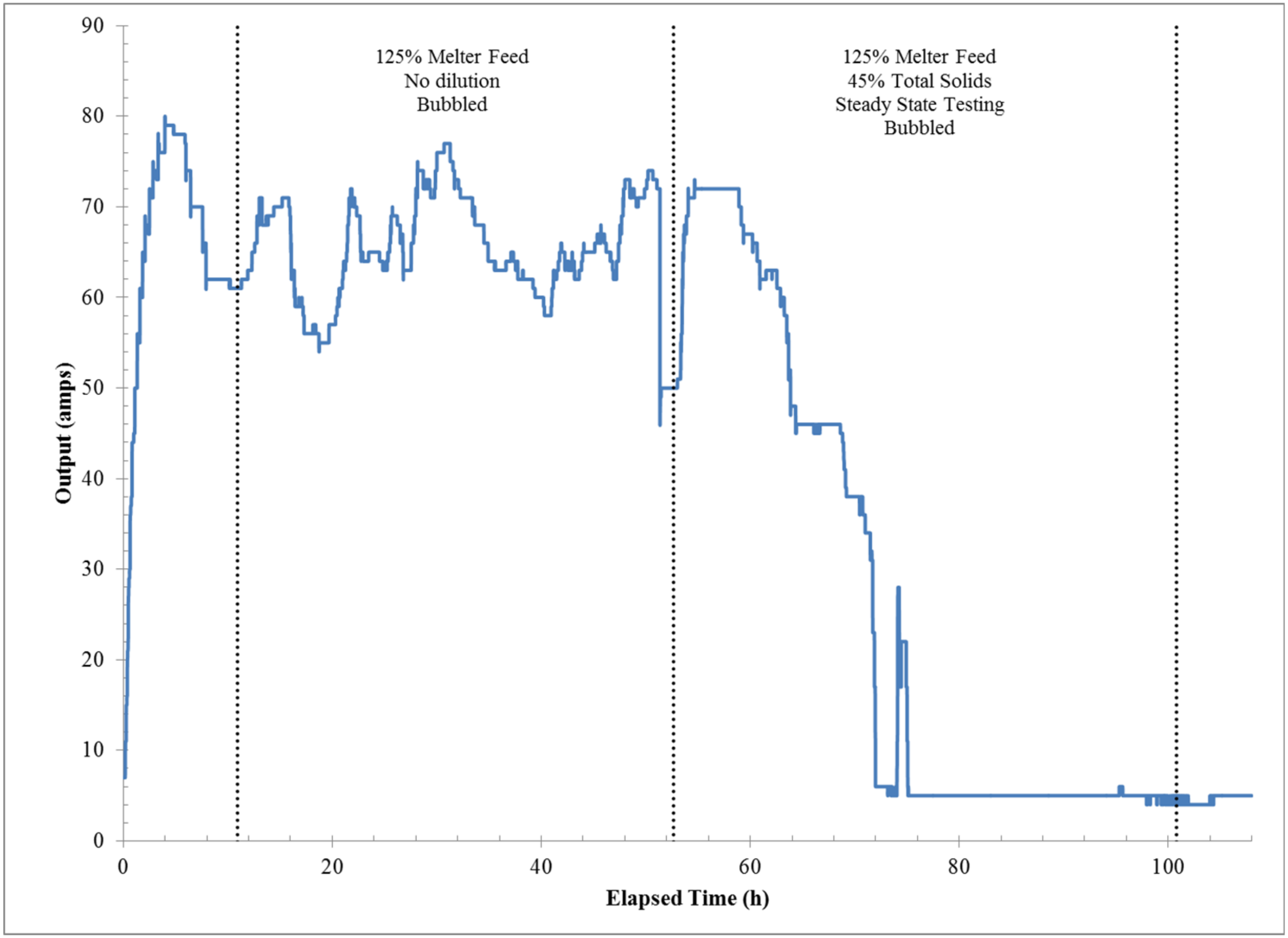

Figure A-26. Vapor space heater output (elapsed time=0 at 12:00 February 24, 2014).

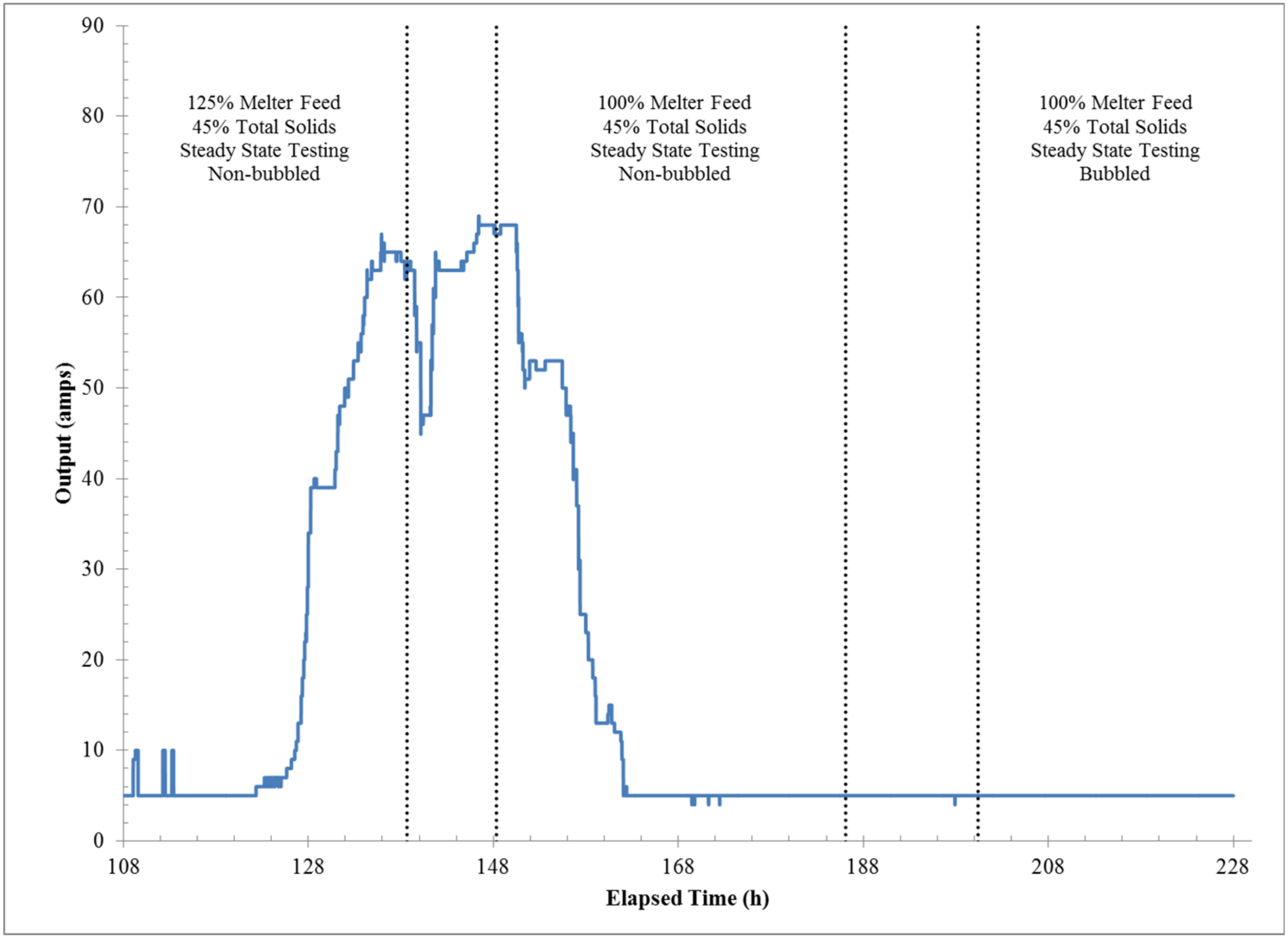

Figure A-27. Vapor space heater output (elapsed time=108 at 00:00 March 1, 2014).

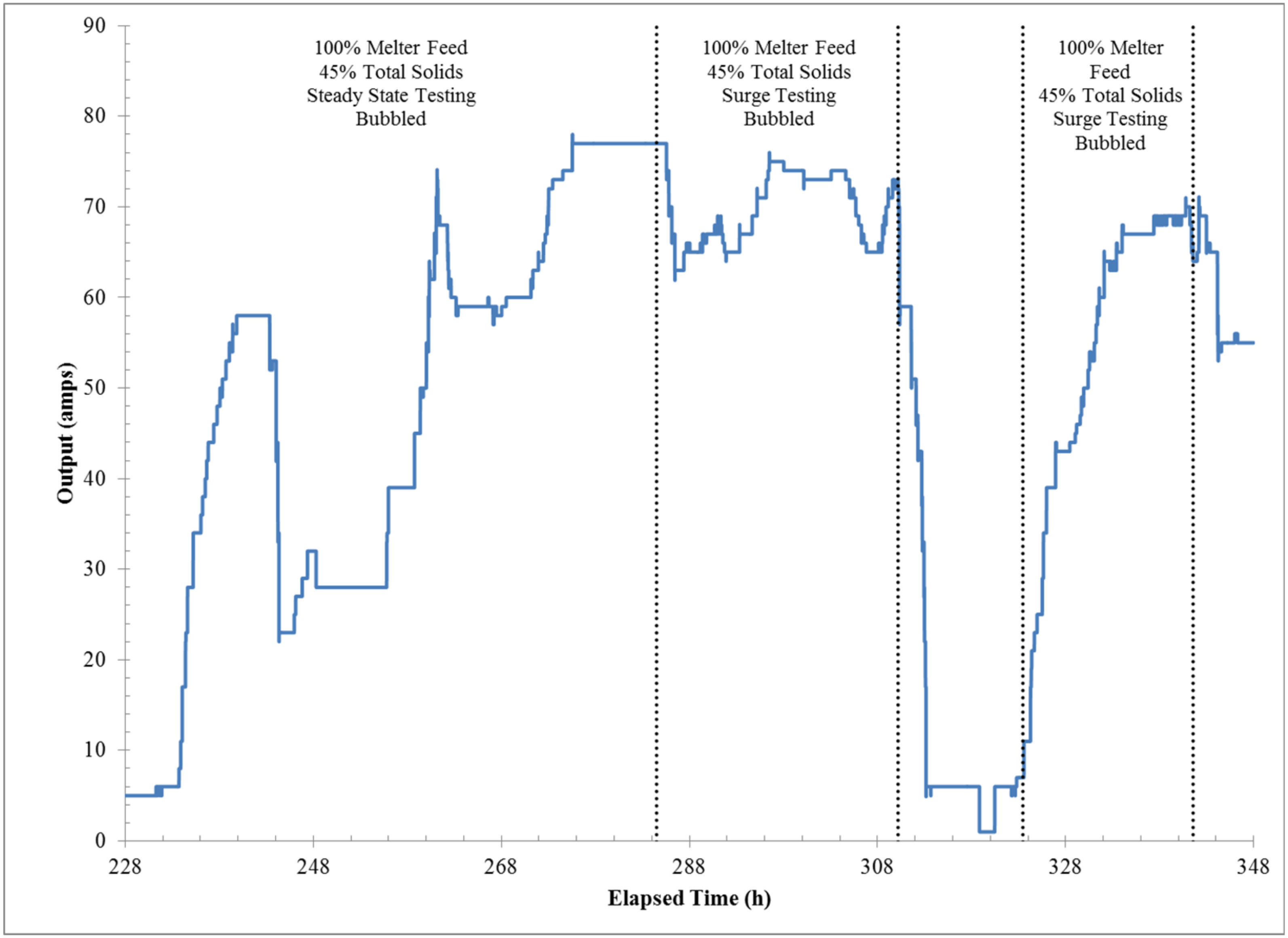

Figure A-28. Vapor space heater output (elapsed time=228 at 00:00 March 6, 2014).

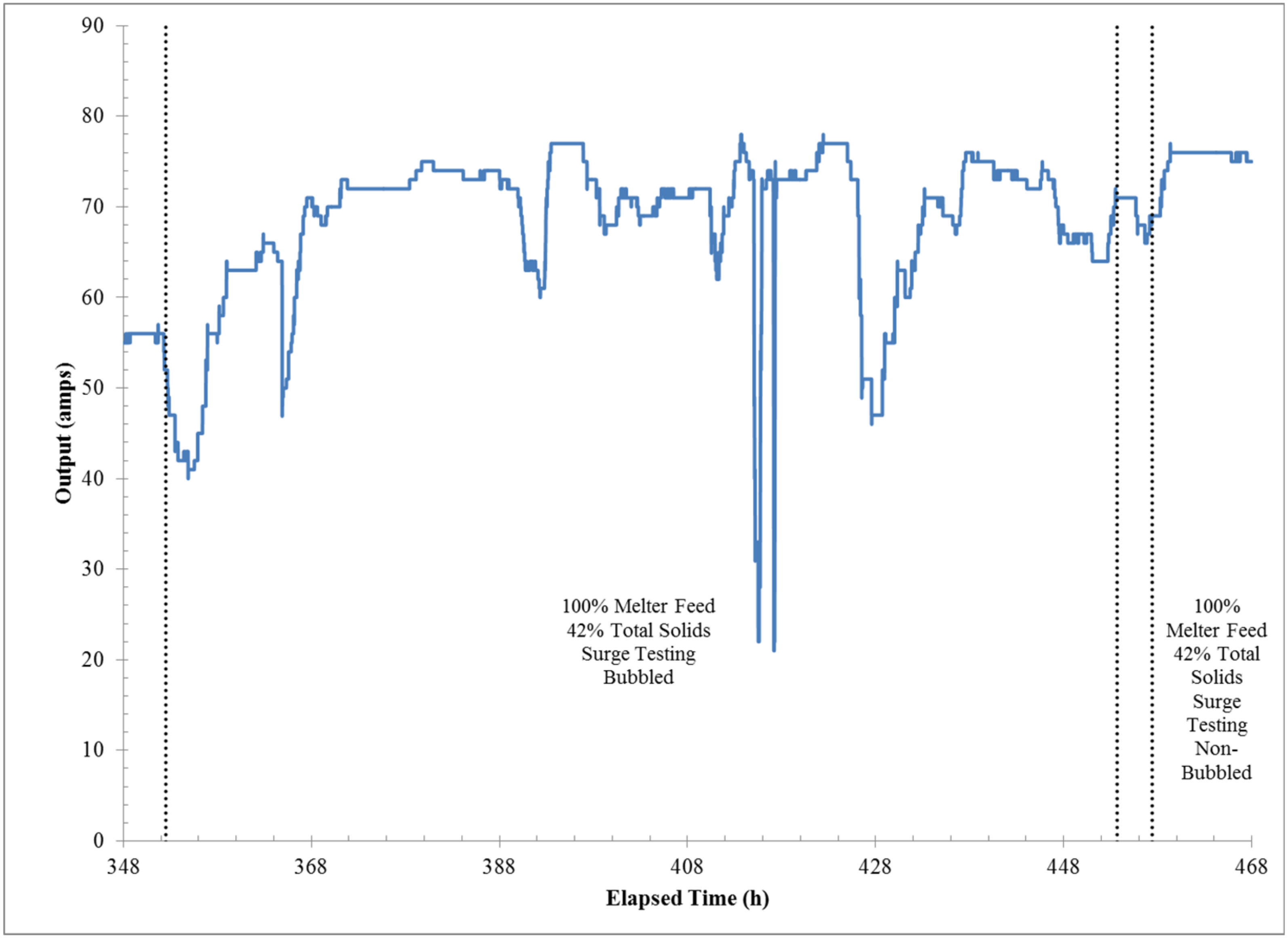

Figure A-29. Vapor space heater output (elapsed time=348 at 00:00 March 11, 2014).

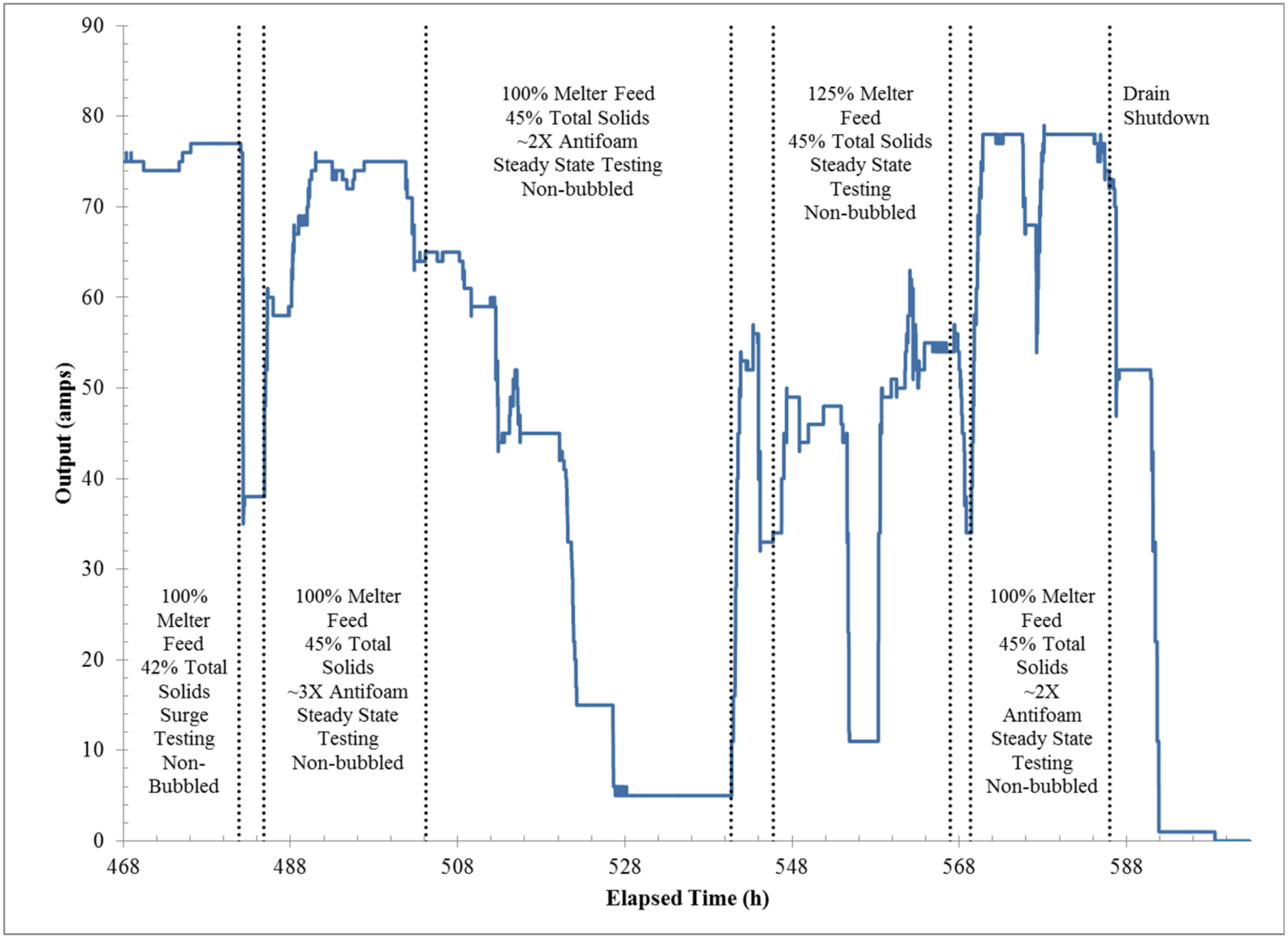

Figure A-30. Vapor space heater output (elapsed time=468 at 00:00 March 16, 2014).

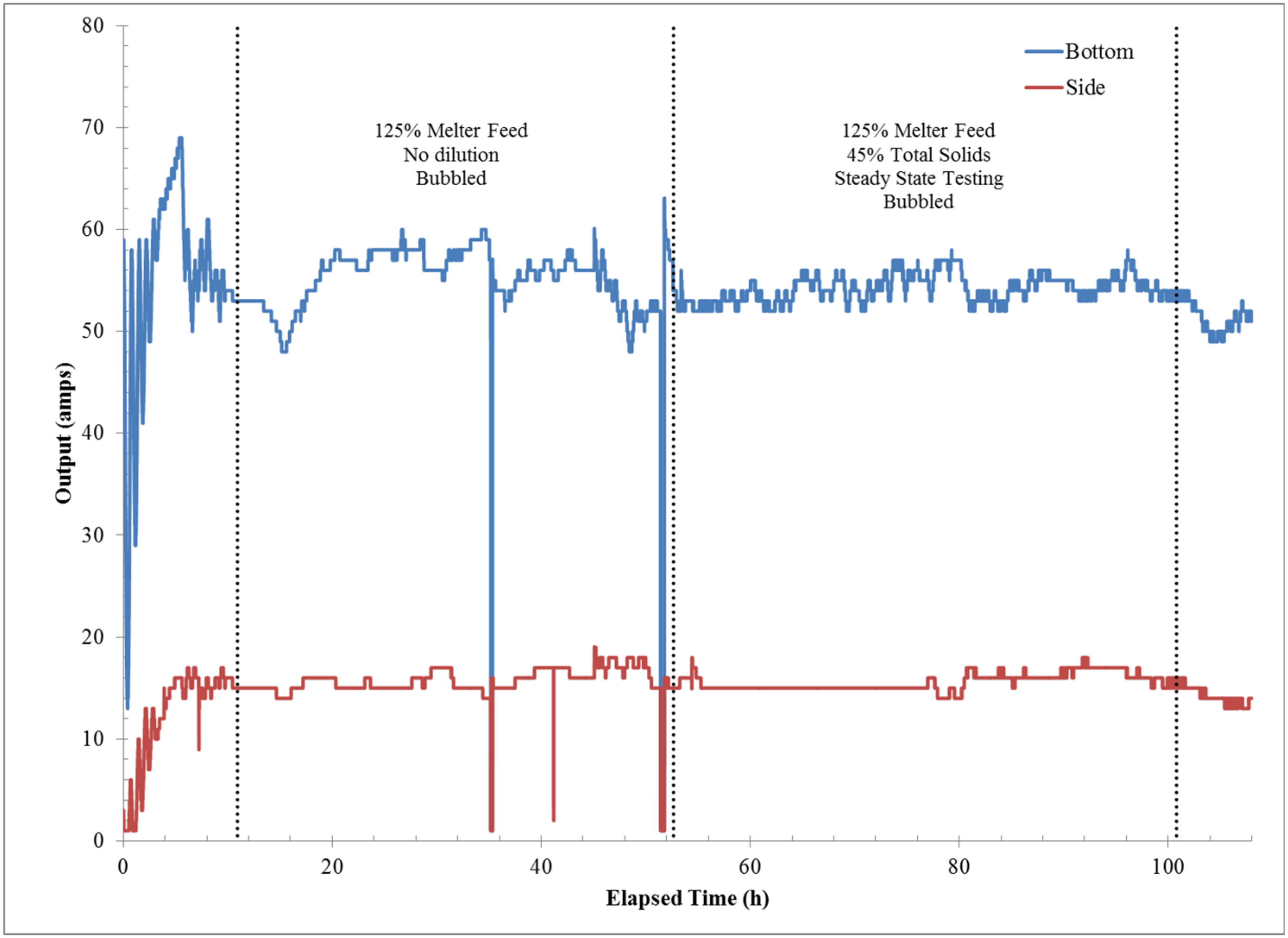

Figure A-31. Bottom and side heater outputs (elapsed time=0 at 12:00 February 24, 2014).

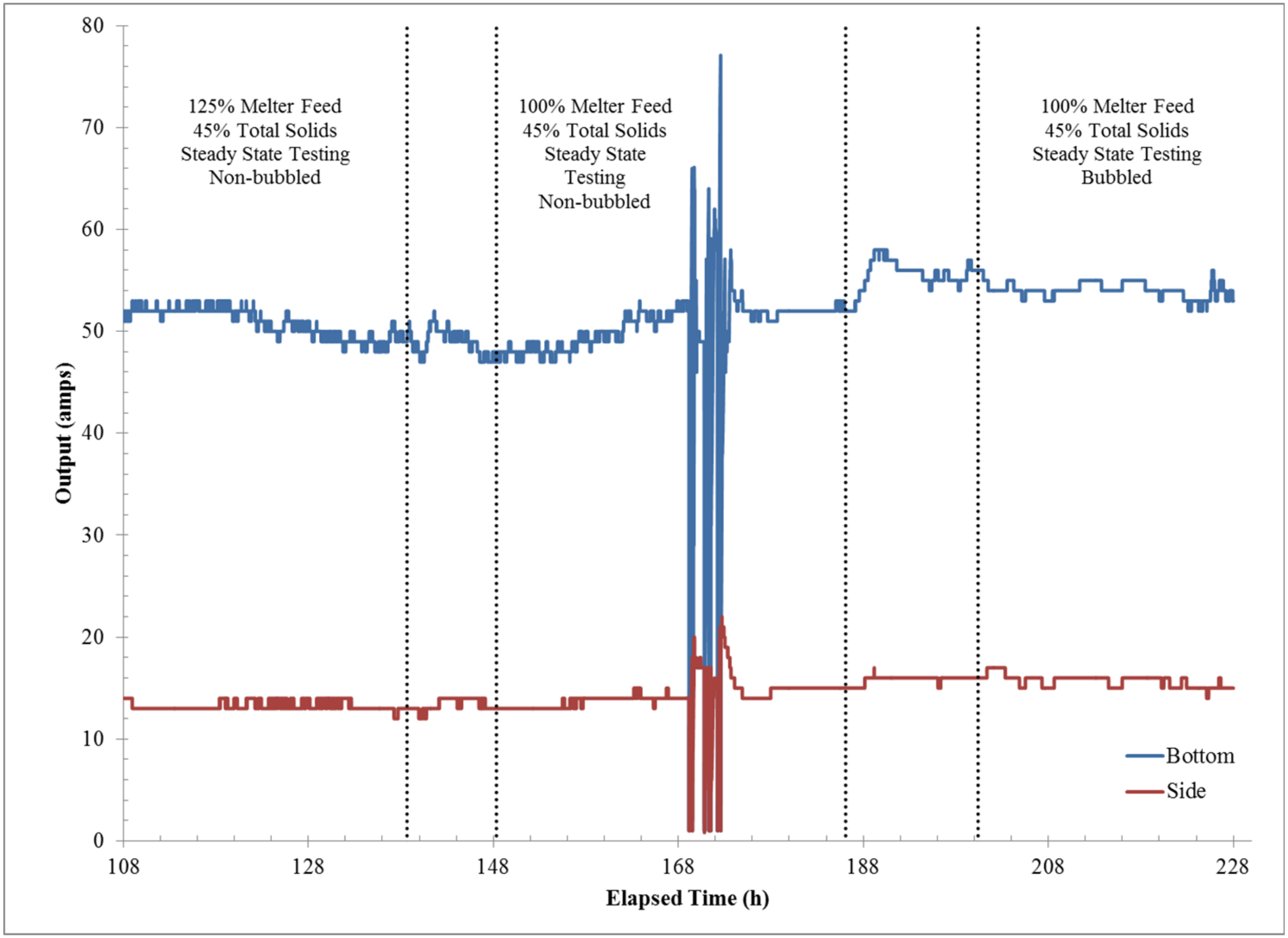

Figure A-32. Bottom and side heater outputs (elapsed time=108 at 00:00 March 1, 2014).

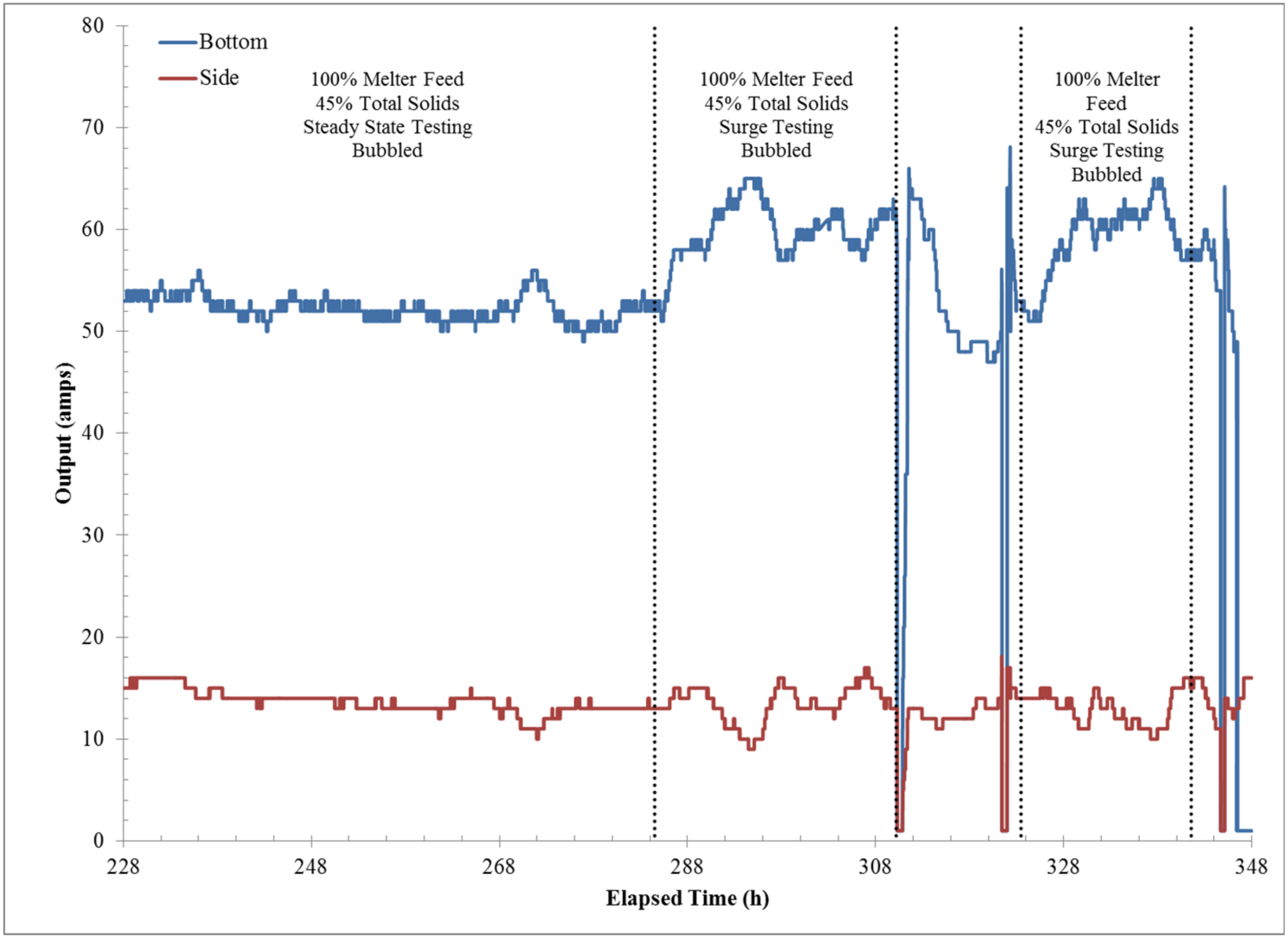

Figure A-33. Bottom and side heater outputs (elapsed time=228 at 00:00 March 6, 2014).

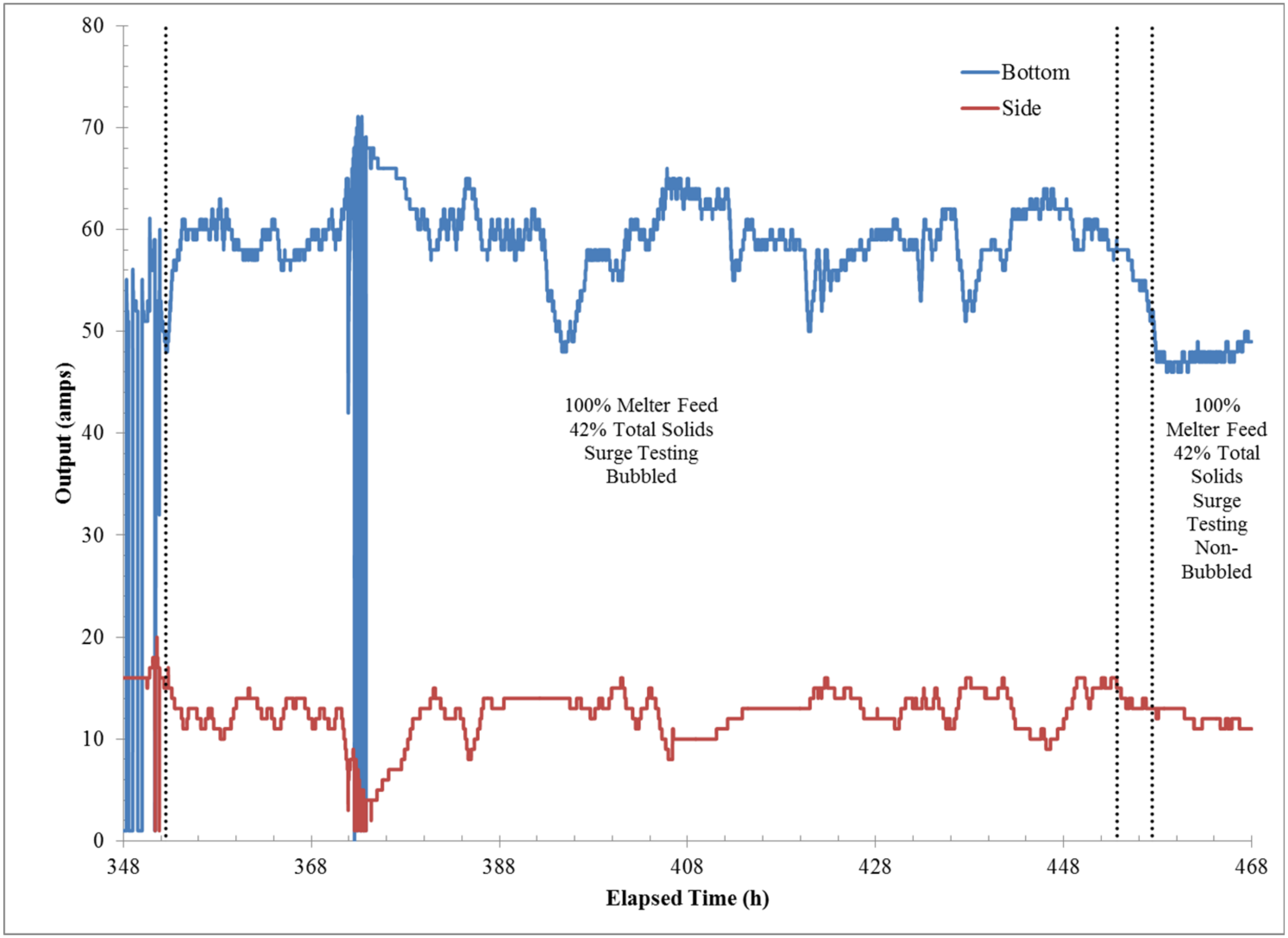

Figure A-34. Bottom and side heater outputs (elapsed time=348 at 00:00 March 11, 2014).

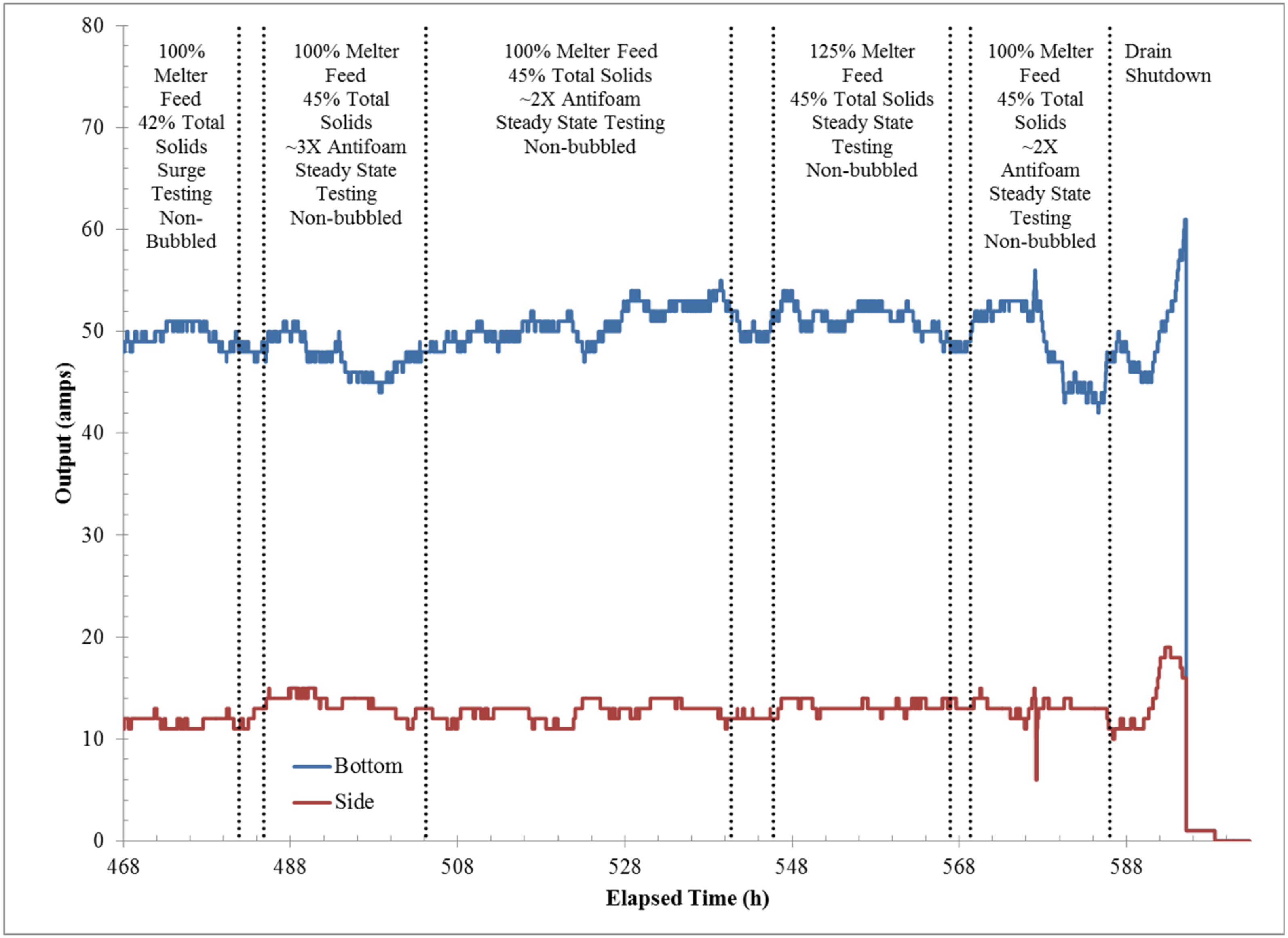

Figure A-35. Bottom and side heater outputs (elapsed time=468 at 00:00 March 16, 2014).

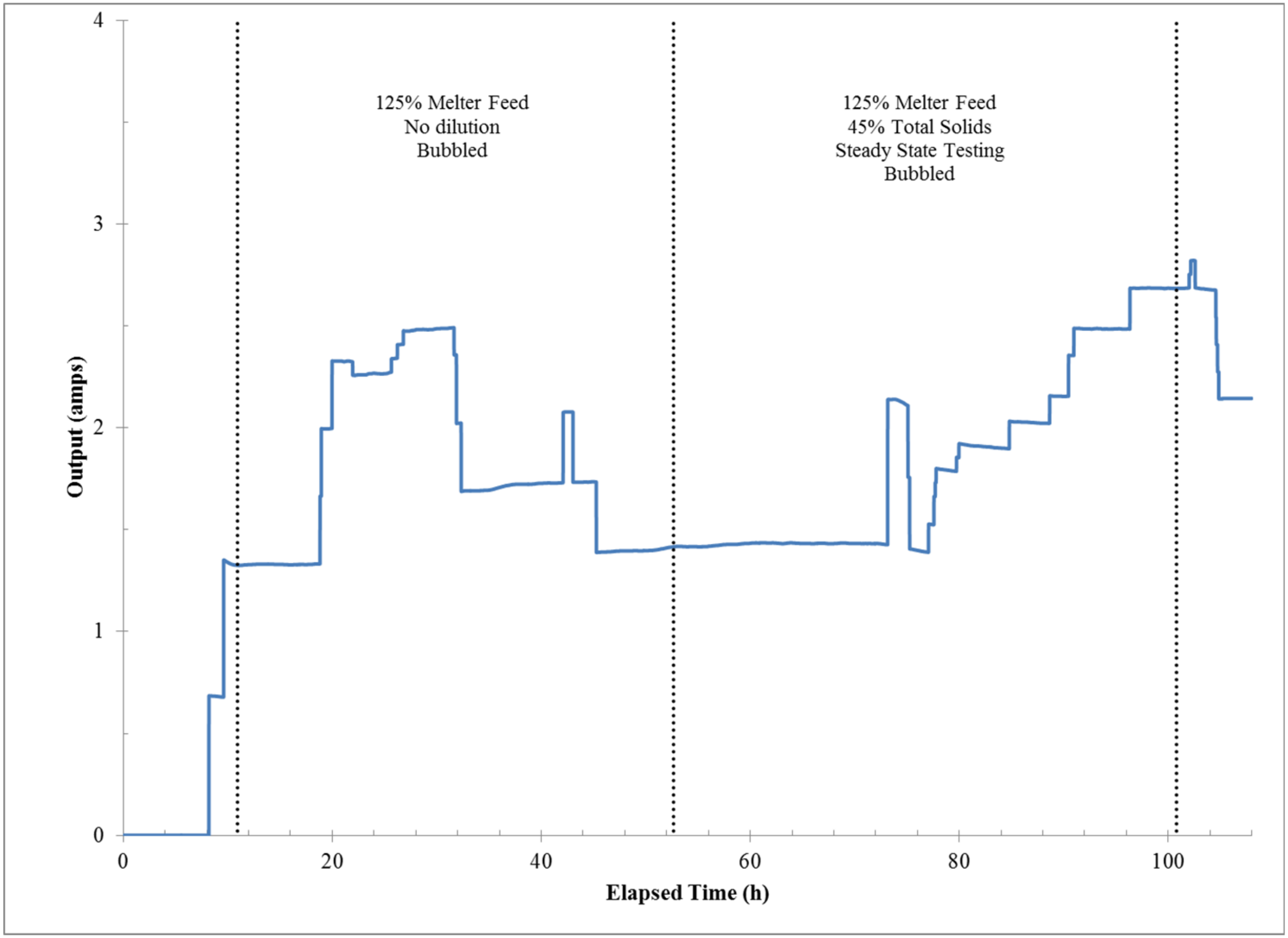

Figure A-36. Auxiliary pour tube rod heater output (elapsed time=0 at 12:00 February 24, 2014).

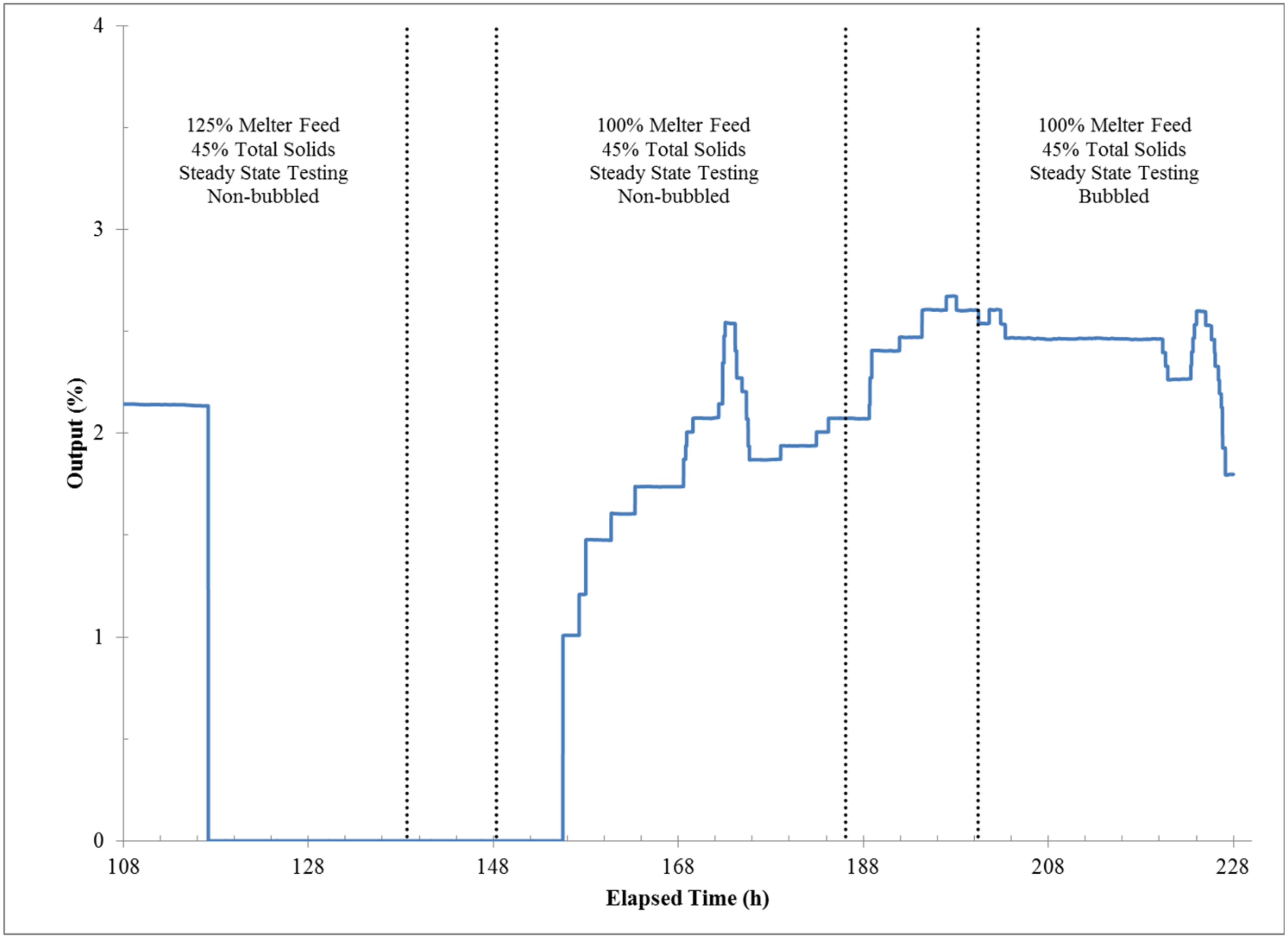

Figure A-37. Auxiliary pour tube rod heater output (elapsed time=108 at 00:00 March 1, 2014).

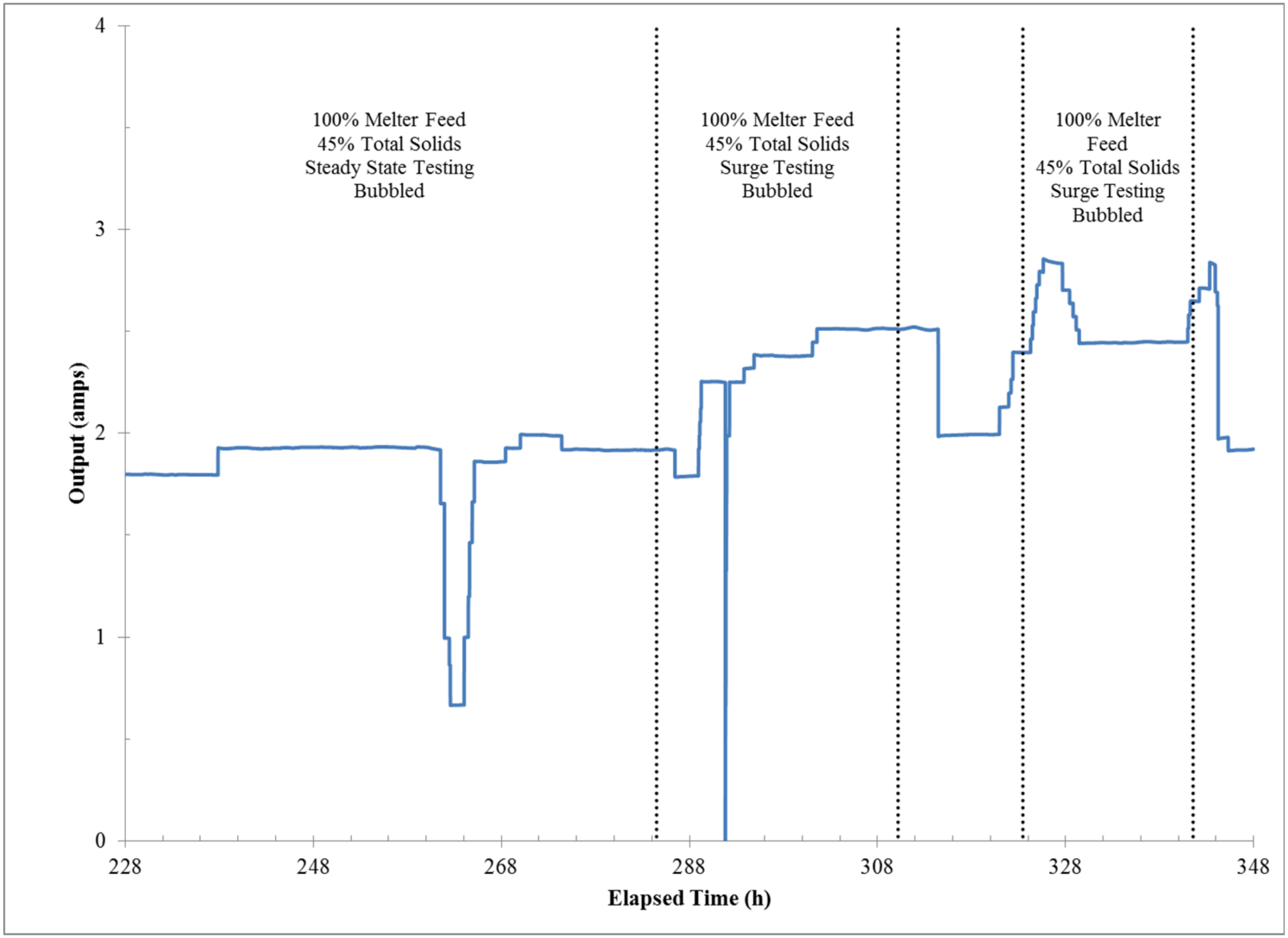

Figure A-38. Auxiliary pour tube rod heater output (elapsed time=228 at 00:00 March 6, 2014).

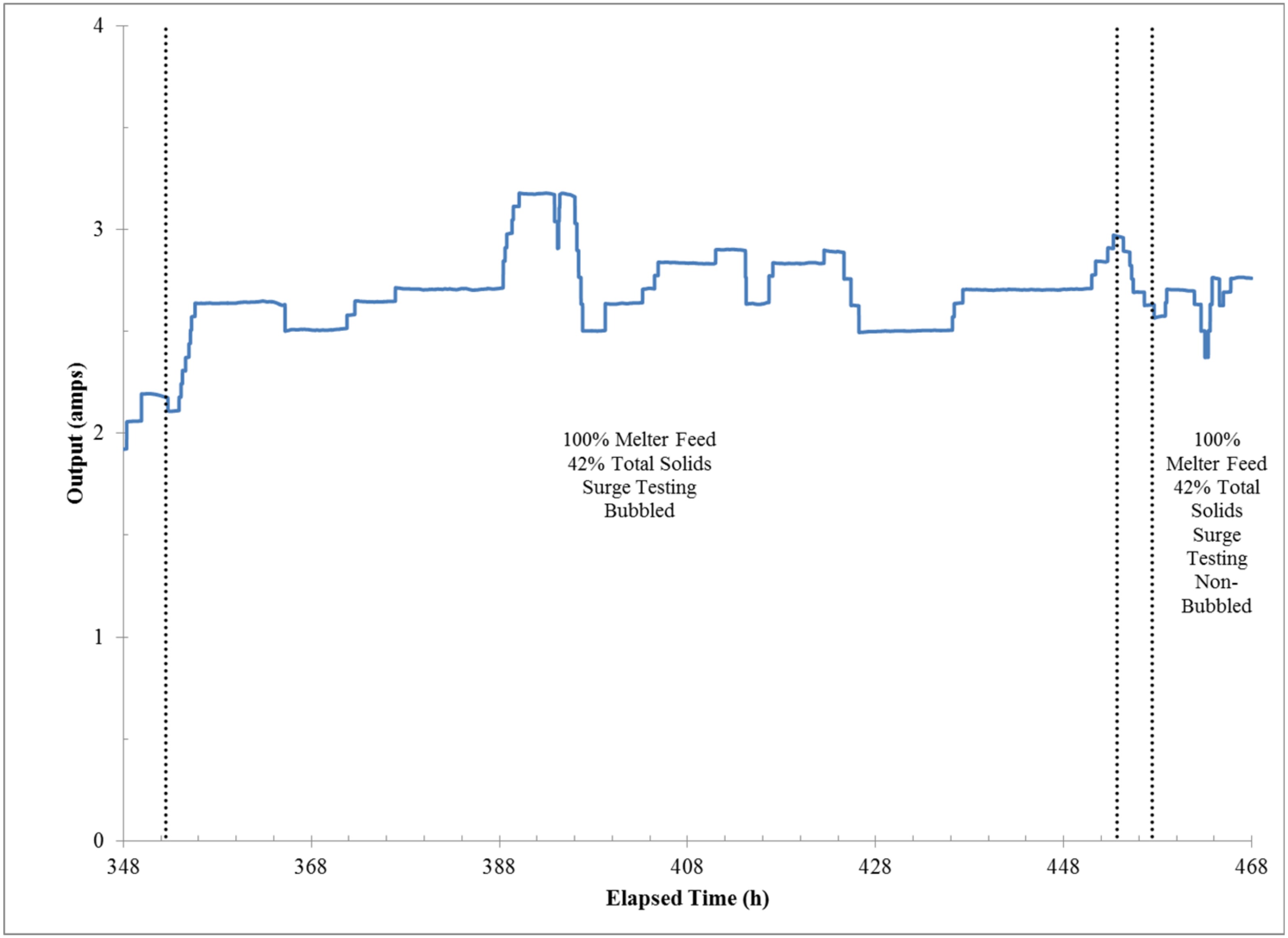

Figure A-39. Auxiliary pour tube rod heater output (elapsed time=348 at 00:00 March 11, 2014).

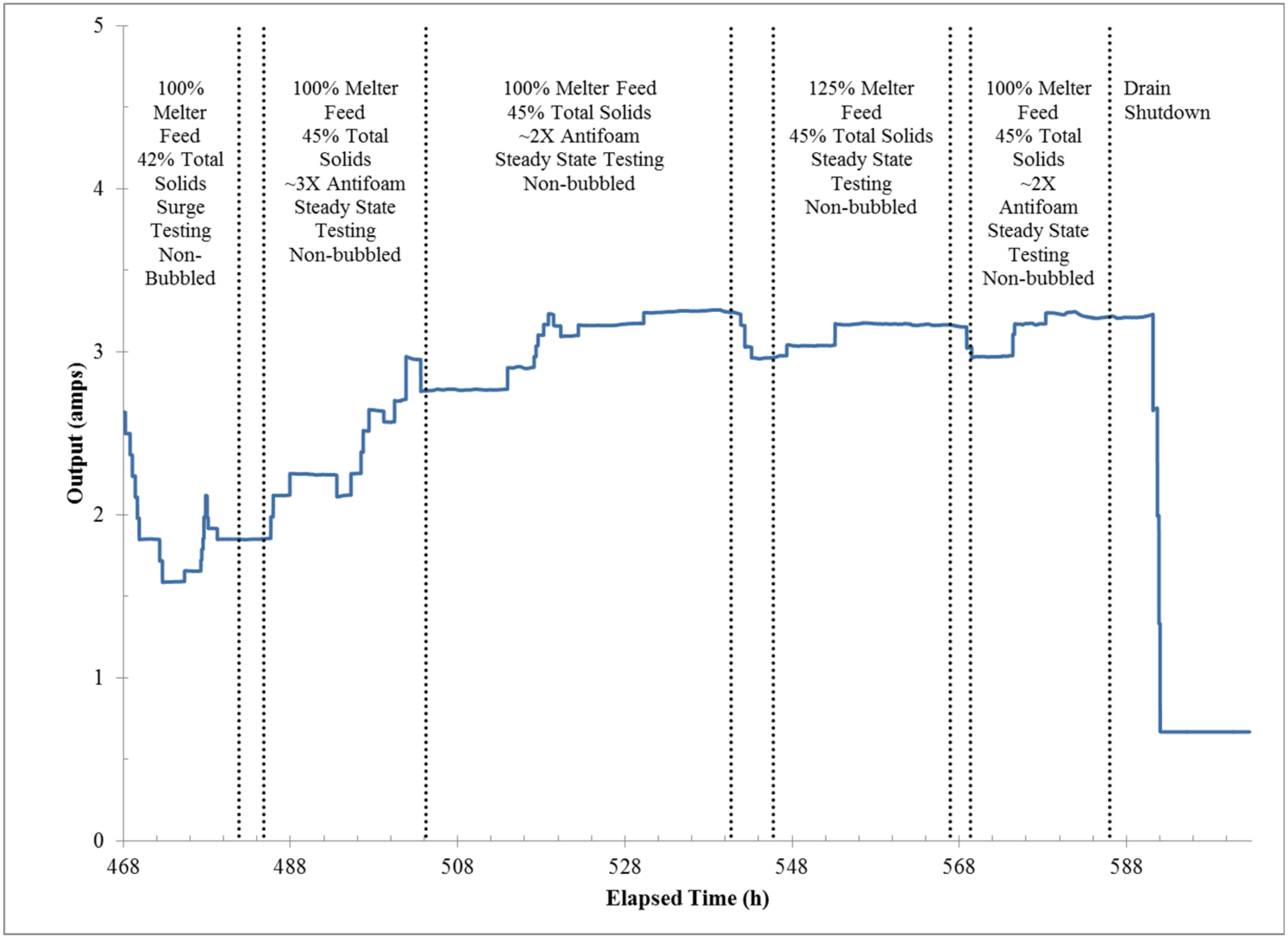

Figure A-40. Auxiliary pour tube rod heater output (elapsed time=468 at 00:00 March 16, 2014).

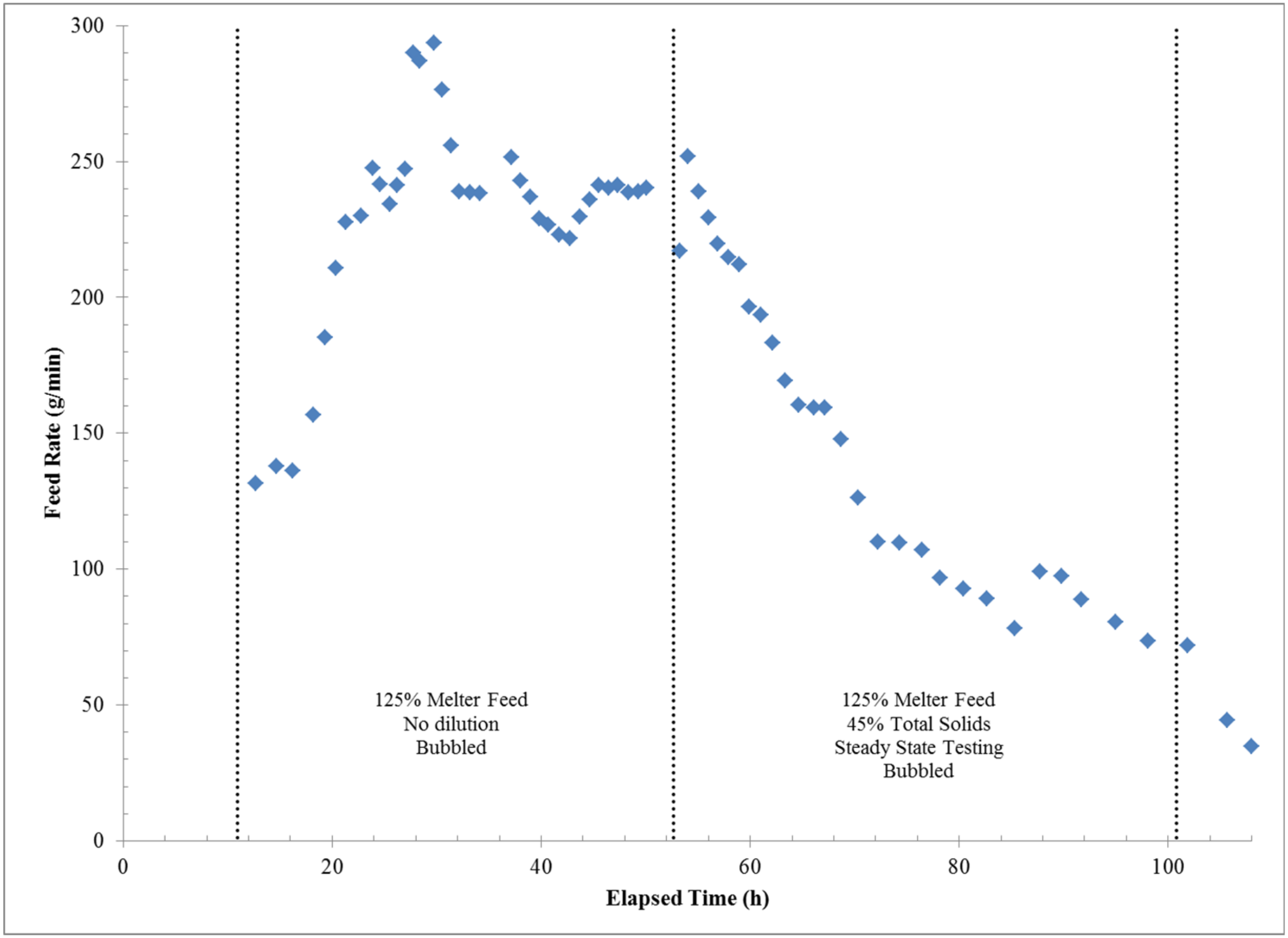

Figure A-41. Feed rate (elapsed time=0 at 12:00 February 24, 2014).

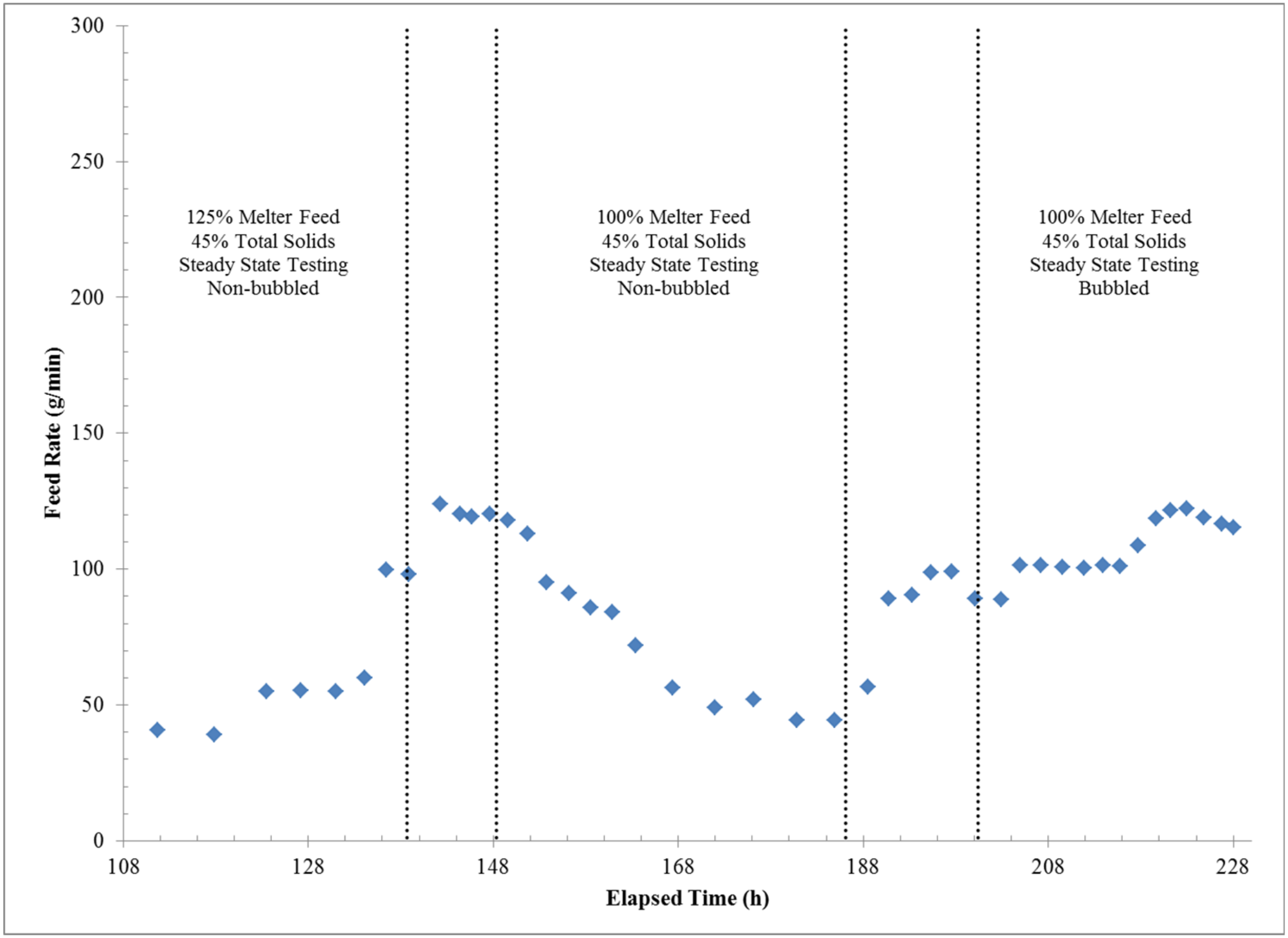

Figure A-42. Feed rate (elapsed time=108 at 00:00 March 1, 2014).

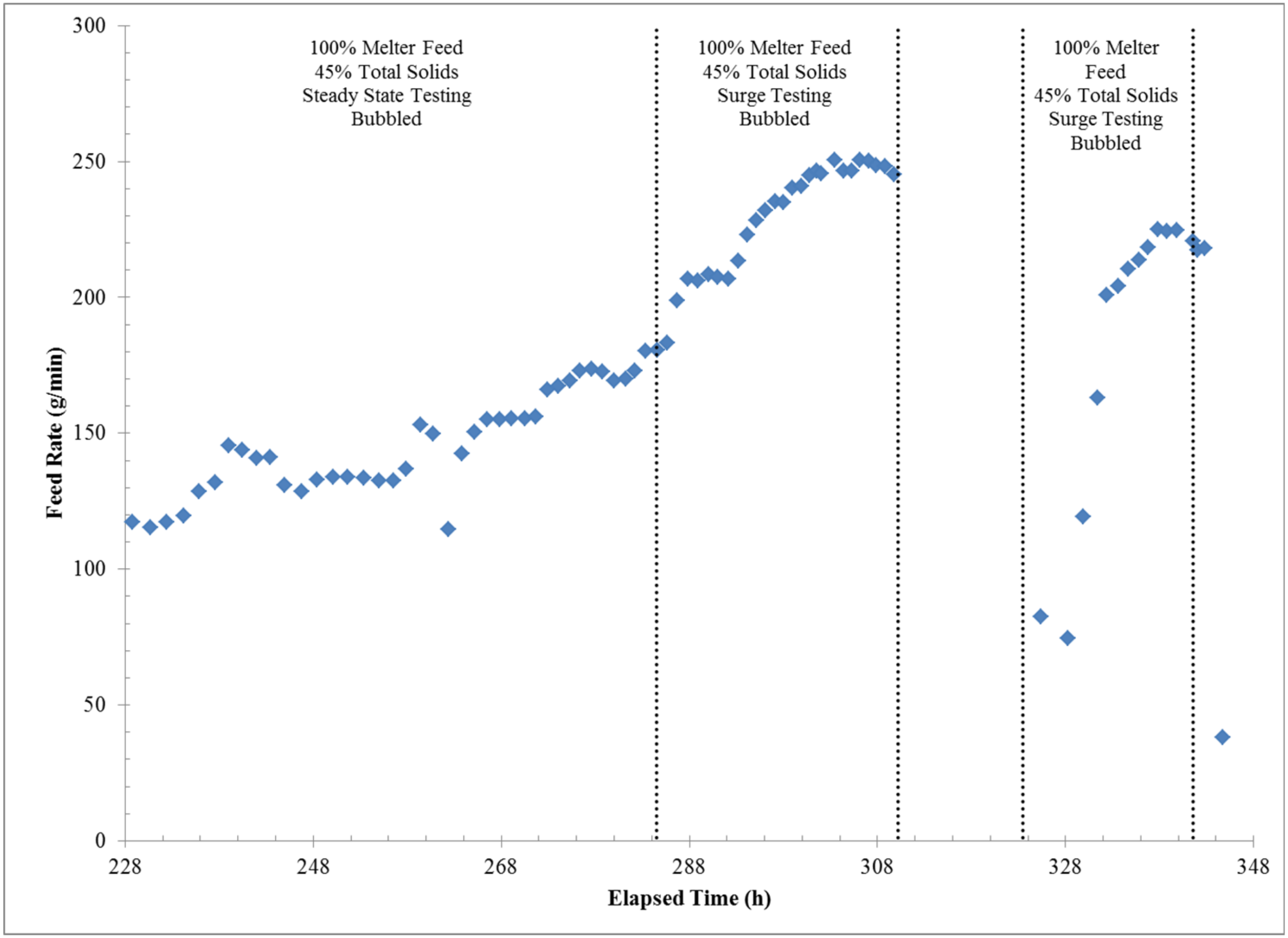

Figure A-43. Feed rate (elapsed time=228 at 00:00 March 6, 2014).

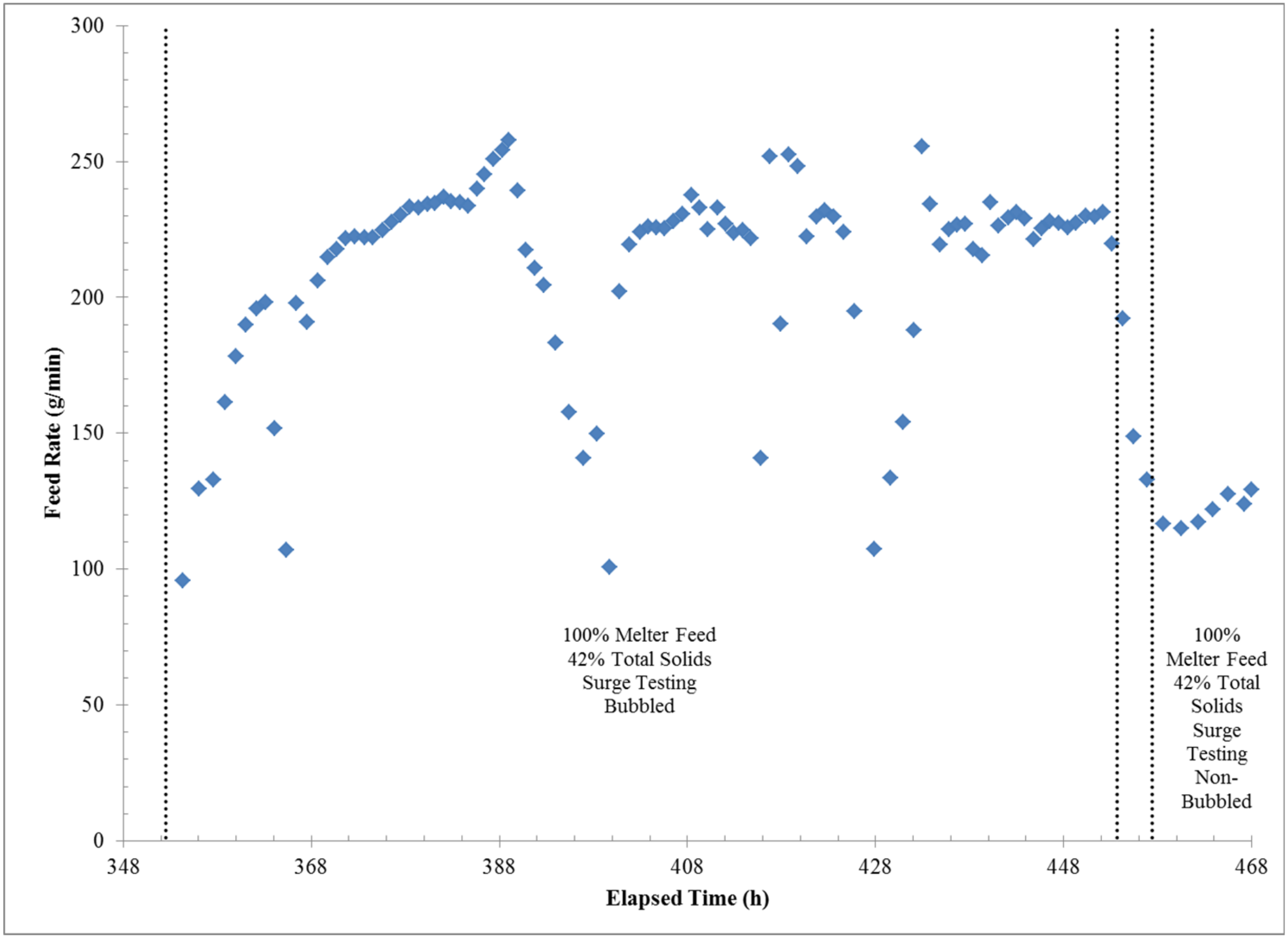

Figure A-44. Feed rate (elapsed time=348 at 00:00 March 11, 2014).

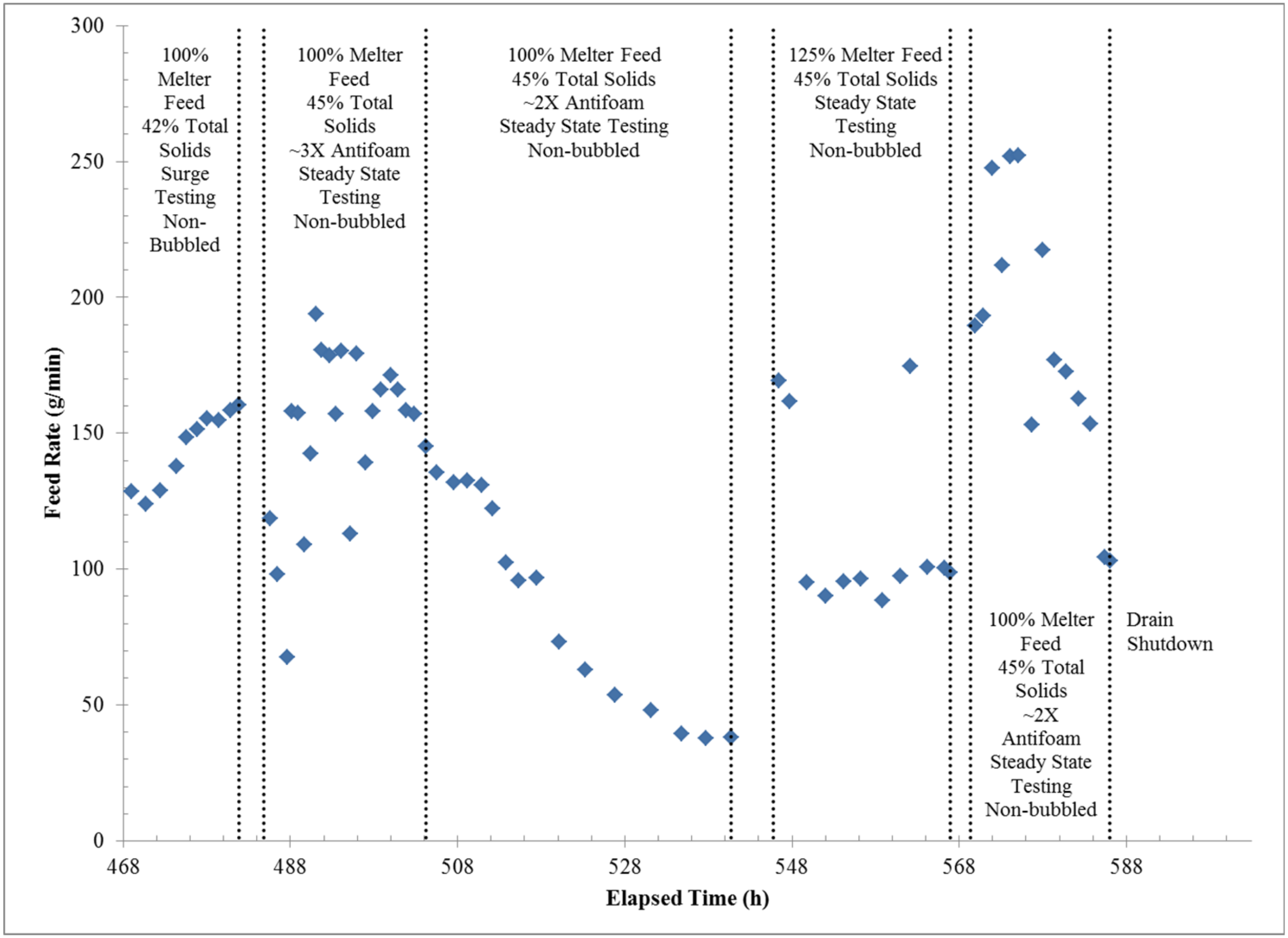

Figure A-45. Feed rate (elapsed time=468 at 00:00 March 16, 2014).

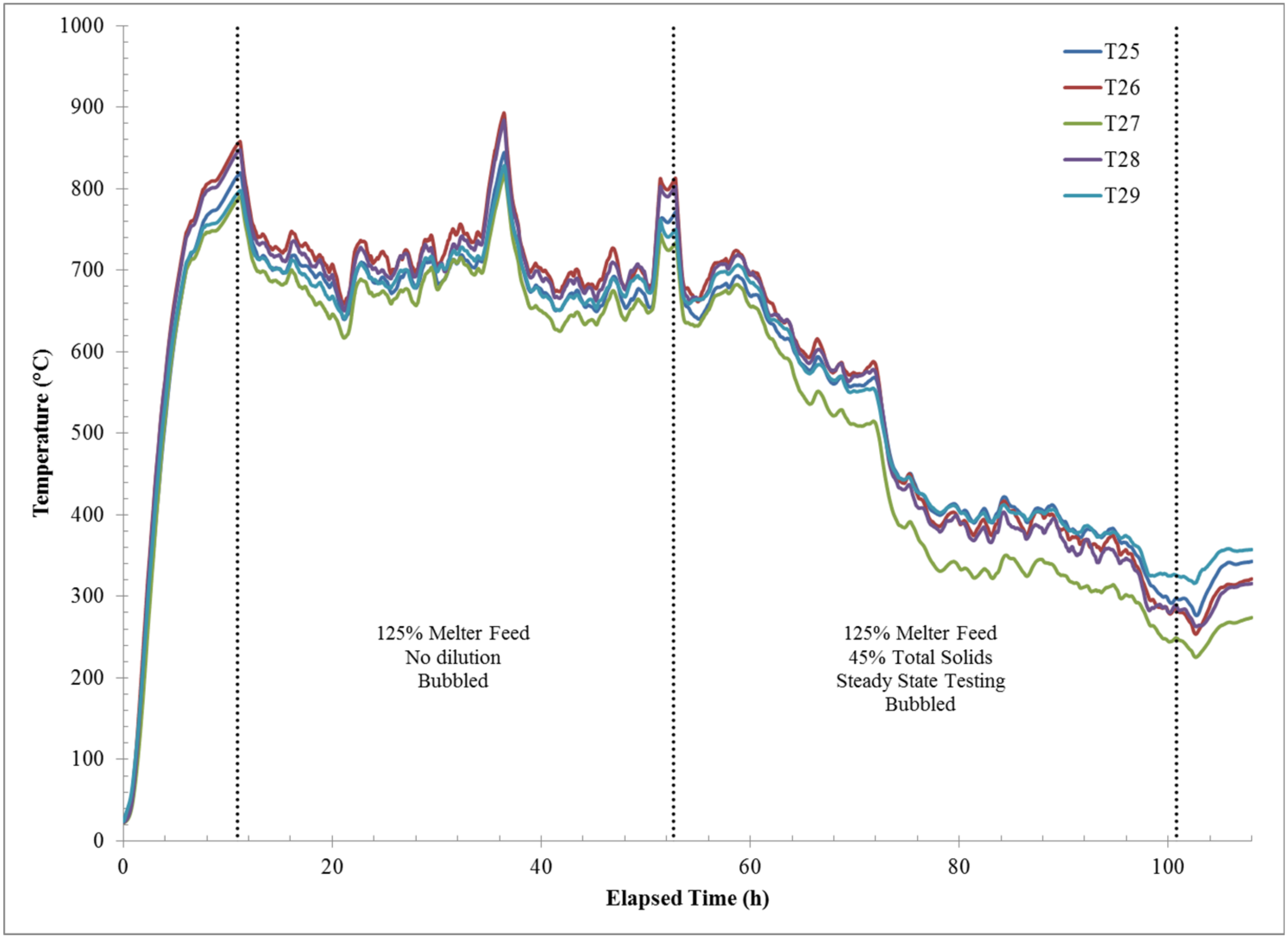

Figure A-46. Support block temperatures (elapsed time=0 at 12:00 February 24, 2014).

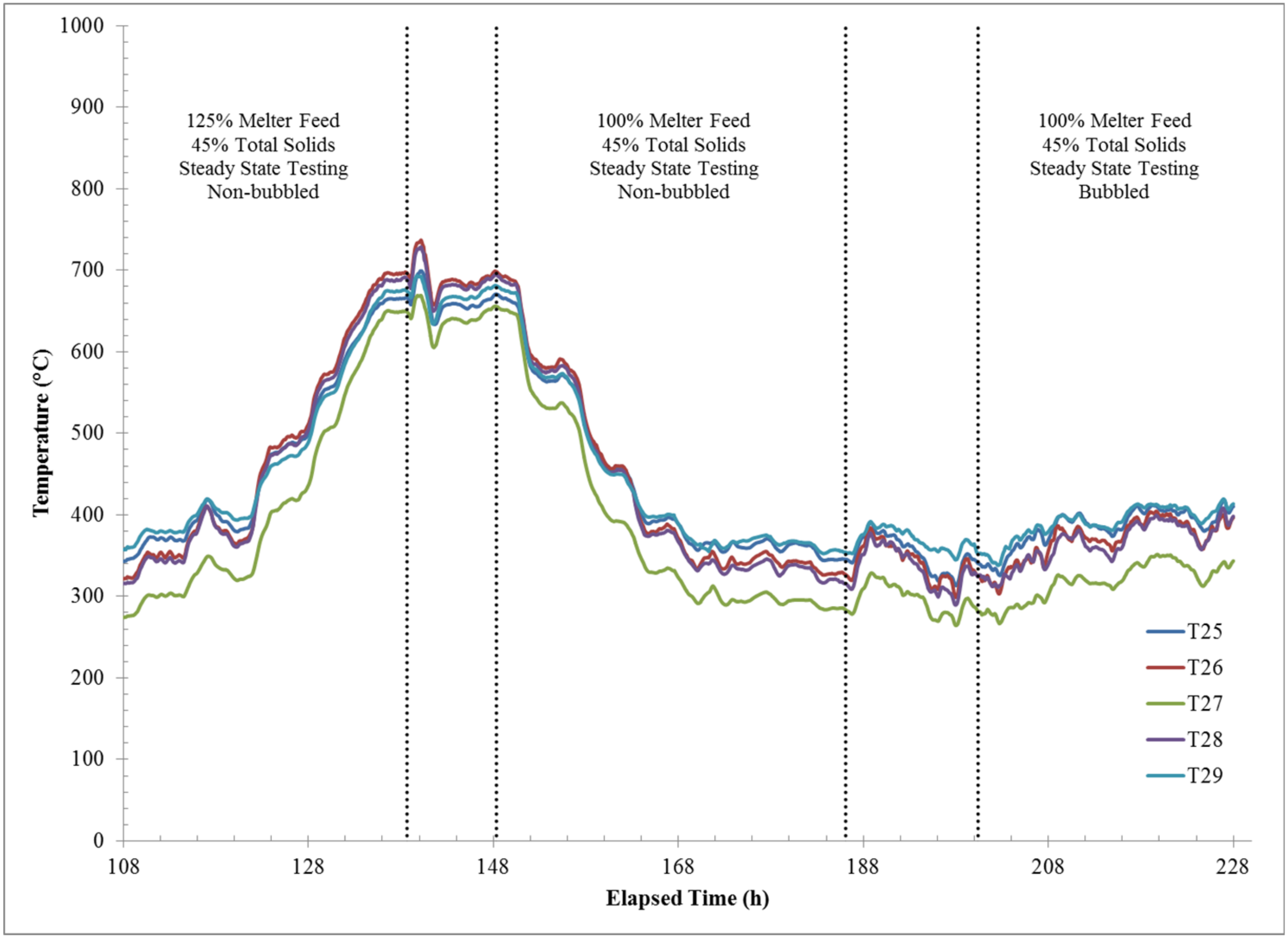

Figure A-47. Support block temperatures (elapsed time=108 at 00:00 March 1, 2014).

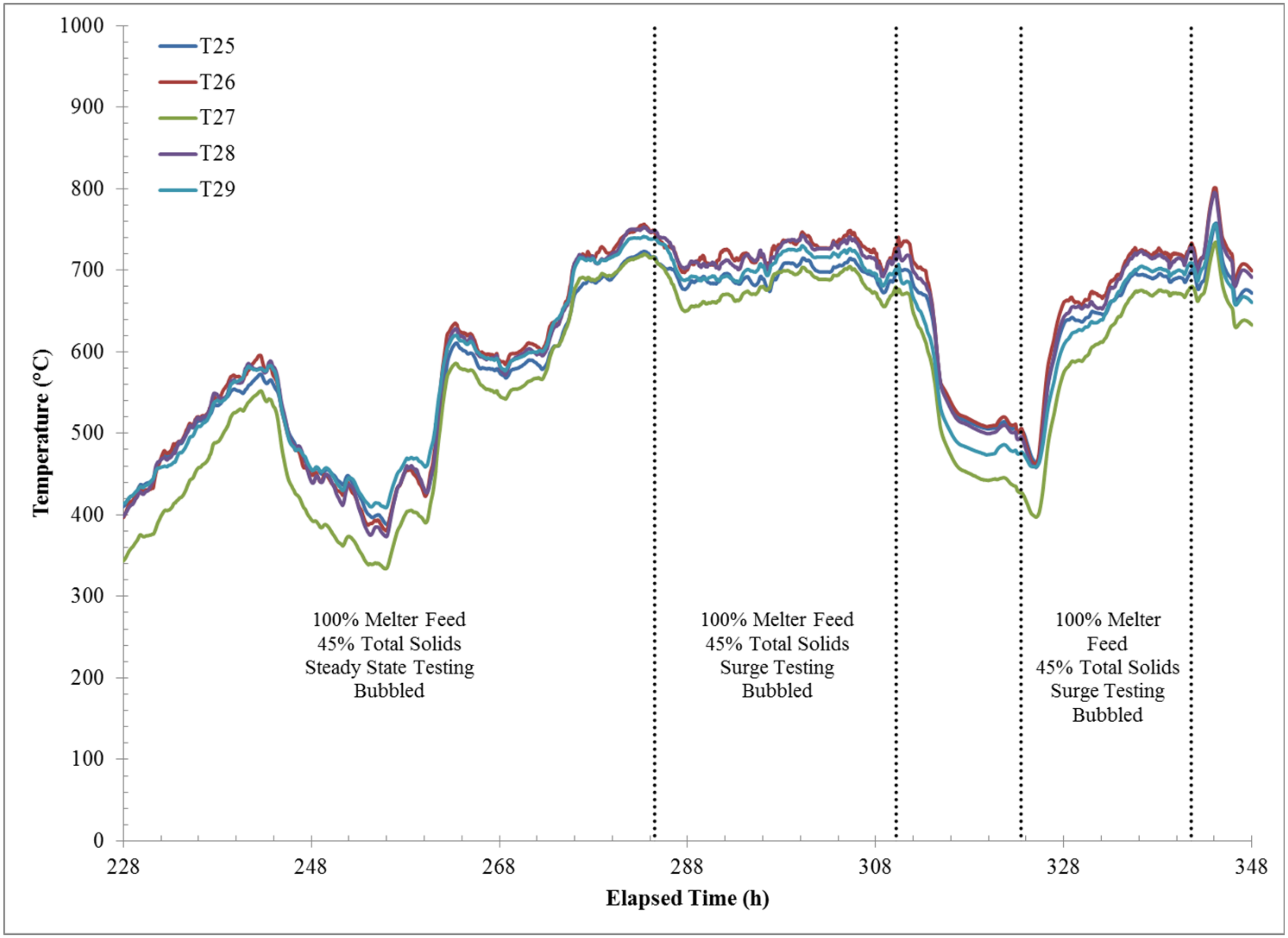

Figure A-48. Support block temperatures (elapsed time=228 at 00:00 March 6, 2014).

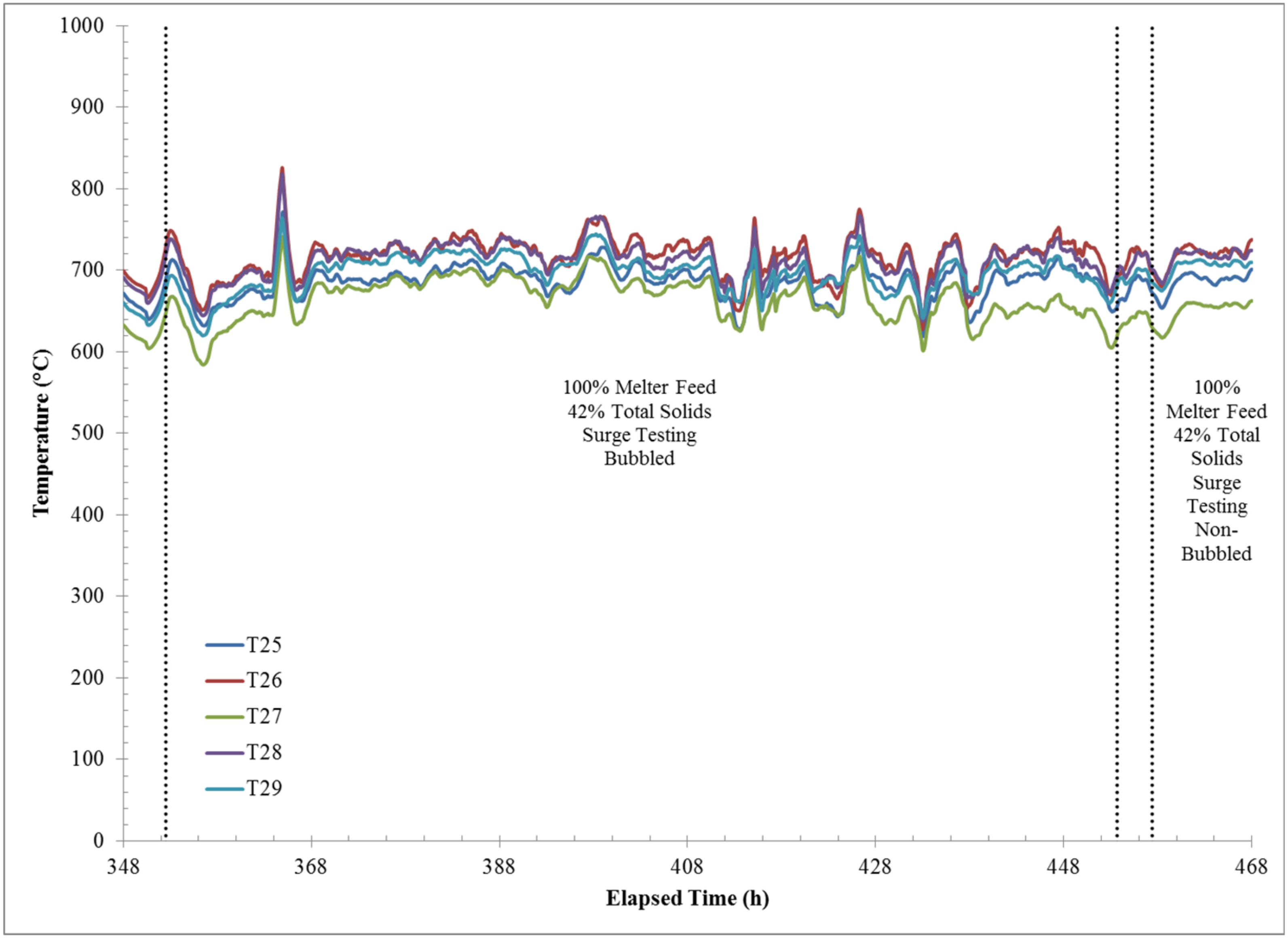

Figure A-49. Support block temperatures (elapsed time=348 at 00:00 March 11, 2014).

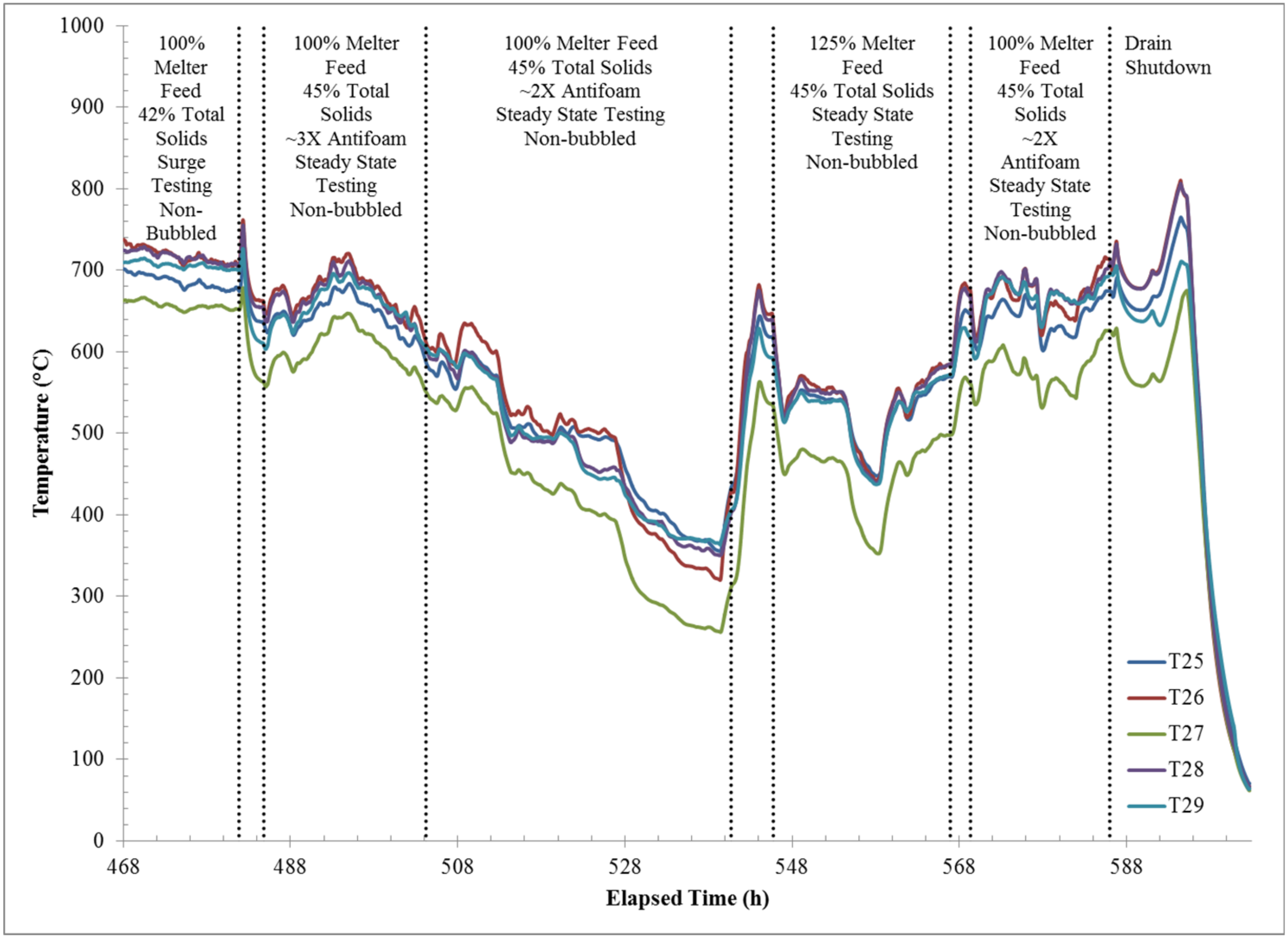

Figure A-50. Support block temperatures (elapsed time=468 at 00:00 March 16, 2014).

Table A-3. Feed Sample Summary

Sample ID	Lab ID	Collection Date	Collection Time	Feed Stoichoimetry	Total Solids Target	Antifoam Target
CEF2-F-007	S801	2/26/2014	17:20	125%	45%	nominal
CEF2-F-008	---	2/27/2014	5:45	125%	45%	nominal
CEF2-F-009	---	2/28/2014	1:30	125%	45%	nominal
CEF2-F-010	S802	2/28/2014	16:15	125%	45%	nominal
CEF2-F-011	S820	3/2/2014	8:15	100%	45%	nominal
CEF2-F-013	S803	3/3/2014	4:33	100%	45%	nominal
CEF2-F-015	S804	3/5/2014	5:30	100%	45%	nominal
CEF2-F-018	S821	3/7/2014	3:00	100%	45%	nominal
CEF2-F-023	S822	3/9/2014	7:05	100%	45%	nominal
CEF2-F-027	S814	3/11/2014	13:08	100%	42%	nominal
CEF2-F-030	S815	3/12/2014	18:00	100%	42%	nominal
CEF2-F-038	S888	3/16/2014	15:45	100%	45%	~3X nominal
CEF2-F-039	S889	3/17/2014	0:35	100%	45%	~3X nominal
CEF2-F-041	S823	3/17/2014	12:10	100%	45%	~2X nominal
CEF2-F-042	S824	3/18/2014	3:50	100%	45%	~2X nominal
CEF2-F-044	S825	3/19/2014	7:40	125%	45%	nominal
CEF2-F-047	S826	3/20/2014	16:47	100%	45%	~2X nominal

Table A-4. ICP-AES Analysis of Feed Set 1A (elemental wt% calcined at 1100°C)

Sample ID	Lab ID	Al	B	Ba	Ca	Cr	Cu	Fe	K	Li	Mg
CEF2-F-007 (A)	S-801	5.57	1.47	0.045	0.402	0.069	0.027	8.34	0.143	2.28	0.320
CEF2-F-007 (B)	S-801	5.57	1.47	0.046	0.402	0.071	0.035	8.03	0.169	2.27	0.327
CEF2-F-010 (A)	S-802	5.62	1.49	0.044	0.390	0.069	0.046	8.02	0.155	2.33	0.315
CEF2-F-010 (B)	S-802	5.62	1.50	0.046	0.403	0.071	0.042	8.12	0.152	2.34	0.329
CEF2-F-013 (A)	S-803	5.61	1.43	0.048	0.434	0.073	0.039	8.59	0.149	2.25	0.356
CEF2-F-013 (B)	S-803	5.72	1.44	0.049	0.450	0.075	0.052	8.76	0.157	2.23	0.363
CEF2-F-015 (A)	S-804	5.79	1.39	0.050	0.466	0.077	0.048	9.14	0.159	2.16	0.380
CEF2-F-015 (B)	S-804	5.83	1.38	0.051	0.471	0.078	0.053	9.21	0.156	2.15	0.386
CEF2-F-027 (A)	S-814	4.72	1.75	0.048	0.414	0.065	0.051	7.27	0.147	2.38	0.315
CEF2-F-027 (B)	S-814	4.85	1.79	0.048	0.410	0.065	0.049	7.44	0.141	2.46	0.309
CEF2-F-030 (A)	S-815	4.93	1.75	0.048	0.410	0.066	0.053	7.61	0.144	2.41	0.318
CEF2-F-030 (B)	S-815	4.83	1.68	0.049	0.407	0.068	0.047	7.46	0.144	2.36	0.318
CEF2-F-038 (A)	S-888	5.13	1.49	0.050	0.408	0.072	0.042	7.82	0.160	2.28	0.308
CEF2-F-038 (B)	S-888	5.12	1.50	0.050	0.410	0.072	0.042	7.85	0.153	2.29	0.311
CEF2-F-039 (A)	S-889	4.96	1.55	0.048	0.412	0.069	0.042	7.52	0.154	2.35	0.303
CEF2-F-039 (B)	S-889	4.99	1.54	0.049	0.408	0.071	0.041	7.55	0.155	2.35	0.310
CEF2-F-041 (A)	S-823	5.66	1.43	0.053	0.402	0.077	0.051	8.70	0.153	2.10	0.328
CEF2-F-041 (B)	S-823	5.75	1.39	0.055	0.420	0.079	0.057	8.58	0.168	2.07	0.338
CEF2-F-042 (A)	S-824	4.88	1.60	0.047	0.386	0.070	0.047	7.44	0.143	2.24	0.313
CEF2-F-042 (B)	S-824	4.86	1.57	0.047	0.381	0.070	0.045	7.44	0.142	2.19	0.313
CEF2-F-044 (A)	S-825	5.08	1.55	0.047	0.371	0.071	0.041	7.52	0.142	2.30	0.306
CEF2-F-044 (B)	S-825	5.00	1.54	0.047	0.372	0.071	0.040	7.44	0.144	2.26	0.306
CEF2-F-047 (A)	S-826	5.27	1.45	0.053	0.433	0.076	0.046	8.20	0.154	2.07	0.351
CEF2-F-047 (B)	S-826	5.35	1.41	0.053	0.433	0.077	0.044	8.13	0.154	2.06	0.350

Table A-5. ICP-AES Analysis of Feed Set 1B (elemental wt% calcined at 1100°C)

Sample ID	Lab ID	Mn	Na	Ni	P	Pb	S	Si	Sn	Ti	Zn	Zr
CEF2-F-007 (A)	S-801	2.36	9.20	0.993	<0.100	<0.100	0.109	22.5	<0.100	<0.100	<0.100	0.100
CEF2-F-007 (B)	S-801	2.32	9.15	0.969	<0.100	<0.100	0.114	22.3	<0.100	<0.100	<0.100	0.103
CEF2-F-010 (A)	S-802	2.37	9.24	1.01	<0.100	<0.100	0.103	22.8	<0.100	<0.100	<0.100	0.097
CEF2-F-010 (B)	S-802	2.38	9.08	1.01	<0.100	<0.100	0.106	22.9	<0.100	<0.100	<0.100	0.102
CEF2-F-013 (A)	S-803	2.74	9.28	1.12	<0.100	<0.100	0.121	22.1	<0.100	<0.100	<0.100	0.104
CEF2-F-013 (B)	S-803	2.73	9.17	1.12	<0.100	<0.100	0.118	21.9	<0.100	<0.100	<0.100	0.106
CEF2-F-015 (A)	S-804	2.92	9.47	1.20	<0.100	<0.100	0.133	21.4	<0.100	<0.100	<0.100	0.106
CEF2-F-015 (B)	S-804	2.91	9.42	1.20	<0.100	<0.100	0.136	21.3	<0.100	<0.100	<0.100	0.107
CEF2-F-027 (A)	S-814	2.40	8.77	1.04	<0.100	<0.100	0.112	24.7	<0.100	<0.100	<0.100	0.106
CEF2-F-027 (B)	S-814	2.35	8.57	1.06	<0.100	<0.100	0.109	24.2	<0.100	<0.100	<0.100	0.104
CEF2-F-030 (A)	S-815	2.36	8.63	1.10	<0.100	<0.100	0.111	23.5	<0.100	<0.100	<0.100	0.106
CEF2-F-030 (B)	S-815	2.36	8.80	1.05	<0.100	<0.100	0.108	23.2	<0.100	<0.100	<0.100	0.106
CEF2-F-038 (A)	S-888	2.42	8.45	1.03	<0.100	<0.100	0.116	23.8	<0.100	<0.100	<0.100	0.116
CEF2-F-038 (B)	S-888	2.44	8.52	1.04	<0.100	<0.100	0.122	23.9	<0.100	<0.100	<0.100	0.116
CEF2-F-039 (A)	S-889	2.38	8.51	1.01	<0.100	<0.100	0.117	24.2	<0.100	<0.100	<0.100	0.115
CEF2-F-039 (B)	S-889	2.39	8.74	1.00	<0.100	<0.100	0.121	24.1	<0.100	<0.100	<0.100	0.116
CEF2-F-041 (A)	S-823	2.64	9.01	1.13	<0.100	<0.100	0.107	21.0	<0.100	<0.100	<0.100	0.118
CEF2-F-041 (B)	S-823	2.60	9.16	1.11	<0.100	<0.100	0.110	21.2	<0.100	<0.100	<0.100	0.121
CEF2-F-042 (A)	S-824	2.43	8.70	1.01	<0.100	<0.100	0.111	24.0	<0.100	<0.100	<0.100	0.107
CEF2-F-042 (B)	S-824	2.36	8.85	0.973	<0.100	<0.100	0.108	23.9	<0.100	<0.100	<0.100	0.107
CEF2-F-044 (A)	S-825	2.34	8.84	1.00	<0.100	<0.100	0.091	23.8	<0.100	<0.100	<0.100	0.107
CEF2-F-044 (B)	S-825	2.31	8.79	0.992	<0.100	<0.100	0.092	23.8	<0.100	<0.100	<0.100	0.107
CEF2-F-047 (A)	S-826	2.69	9.10	1.11	<0.100	<0.100	0.124	22.6	<0.100	<0.100	<0.100	0.118
CEF2-F-047 (B)	S-826	2.66	9.11	1.11	<0.100	<0.100	0.123	22.1	<0.100	<0.100	<0.100	0.117

Table A-6. IC Analysis by PSAL of Feed Anions (mg/Kg)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	$C_2H_3O_3$	SO_4	C_2O_4	HCO_2	PO_4
CEF2-F-007 (A)	S-801	<100	302	<100	68000	36400	1440	1300	1980	<100
CEF2-F-007 (B)	S-801	<100	300	<100	68000	36300	1440	1170	1950	<100
CEF2-F-010 (A)	S-802	<100	305	<100	65600	34800	1460	1430	2130	<100
CEF2-F-010 (B)	S-802	<100	276	<100	64600	35100	1490	1250	1800	<100
CEF2-F-013 (A)	S-803	<100	306	<100	63000	27400	1400	962	2440	<100
CEF2-F-013 (B)	S-803	<100	308	<100	62100	26500	1410	943	2430	<100
CEF2-F-015 (A)	S-804	<100	300	<100	60400	26300	1400	905	2390	<100
CEF2-F-015 (B)	S-804	<100	328	<100	60300	26200	1410	901	2390	<100
CEF2-F-027 (A)	S-814	<100	271	<100	49000	27900	1140	977	1500	<100
CEF2-F-027 (B)	S-814	<100	273	<100	48600	28000	1190	1020	1520	<100
CEF2-F-030 (A)	S-815	<100	275	<100	47900	30200	1100	960	1570	<100
CEF2-F-030 (B)	S-815	<100	273	<100	47800	30300	1120	964	1570	<100
CEF2-F-038 (A)	S-888	<100	282	<100	52400	27100	932	1040	2030	<100
CEF2-F-038 (B)	S-888	<100	278	<100	52400	27200	932	1020	2000	<100
CEF2-F-039 (A)	S-889	<100	278	<100	52900	26400	960	1010	2020	<100
CEF2-F-039 (B)	S-889	<100	280	<100	53100	26400	952	1030	2050	<100
CEF2-F-041 (A)	S-823	<100	291	<100	57500	31400	869	980	1960	<100
CEF2-F-041 (B)	S-823	<100	301	<100	56700	31800	896	976	1970	<100
CEF2-F-042 (A)	S-824	<100	282	<100	53200	30000	847	927	1850	<100
CEF2-F-042 (B)	S-824	<100	285	<100	53800	30100	824	889	1840	<100
CEF2-F-044 (A)	S-825	<100	274	<100	59200	38900	827	1130	840	<100
CEF2-F-044 (B)	S-825	<100	274	<100	58100	39200	881	1210	880	<100
CEF2-F-047 (A)	S-826	<100	296	<100	55200	32000	822	937	1670	<100
CEF2-F-047 (B)	S-826	<100	288	<100	55000	30900	864	957	1740	<100

Table A-7. IC Analysis by AD of Feed Anions (mg/Kg)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	$C_2H_3O_3$	SO_4	C_2O_4	HCO_2	PO_4
CEF2-F-007	300311426	<500	<500	<500	67730	41755	1275	1394	769	<500
CEF2-F-010	300311427	<500	<500	<500	66952	44744	1290	1042	760	<500
CEF2-F-013	300311428	<500	<500	<500	58632	34691	1343	1121	1701	<500
CEF2-F-015	300311429	<500	<500	<500	58977	34639	1241	1138	1741	<500
CEF2-F-041	300311430	<500	<500	<500	63061	36778	1332	1178	1849	<500
CEF2-F-042	300311431	<500	<500	<500	60459	35699	1295	1127	1724	<500

Table A-8. ICP-AES Analysis of Feed Supernate Cations Set 1A (mg/L)

Sample ID	Lab ID	Al	B	Ba	Ca	Cd	Cr	Cu	Fe	K	Li	Mg
CEF2-F-007 (A)	S-801	1260	41.9	4.06	2730	<0.100	7.65	196	3530	717	106	1400
CEF2-F-007 (B)	S-801	1270	41.5	4.05	2750	<0.100	7.70	197	3540	702	107	1400
CEF2-F-010 (A)	S-802	1200	33.1	3.85	2580	<0.100	7.15	185	3400	691	95.7	1320
CEF2-F-010 (B)	S-802	1200	33.0	3.84	2580	<0.100	7.18	185	3450	683	94.8	1330
CEF2-F-013 (A)	S-803	507	27.5	2.01	2430	<0.100	2.97	126	863	635	87.0	1570
CEF2-F-013 (B)	S-803	508	27.5	1.99	2900	<0.100	2.99	125	866	633	86.6	1570
CEF2-F-015 (A)	S-804	496	27.8	1.97	2460	<0.100	2.87	127	872	659	86.7	1600
CEF2-F-015 (B)	S-804	496	27.2	1.96	2450	<0.100	2.85	125	877	687	86.2	1600
CEF2-F-027 (A)	S-814	510	22.9	1.53	2230	<0.100	2.59	112	940	530	71.5	1750
CEF2-F-027 (B)	S-814	514	22.1	1.52	2220	<0.100	2.60	112	919	540	71.5	1750
CEF2-F-030 (A)	S-815	479	19.0	1.45	2140	<0.100	2.42	106	941	523	60.3	1660
CEF2-F-030 (B)	S-815	478	19.2	1.45	2140	<0.100	2.44	107	941	522	60.2	1670
CEF2-F-038 (A)	S-888	452	30.6	1.64	2630	<0.100	3.73	114	461	536	103	1958
CEF2-F-038 (B)	S-888	453	30.5	1.64	2630	<0.100	3.74	113	472	553	103	1955
CEF2-F-039 (A)	S-889	430	31.2	1.70	2640	<0.100	3.81	114	418	569	103	1996
CEF2-F-039 (B)	S-889	431	31.4	1.67	2650	<0.100	3.79	114	426	575	103	2105
CEF2-F-041 (A)	S-823	534	30.9	2.03	2610	<0.100	3.40	121	691	736	100	2050
CEF2-F-041 (B)	S-823	537	30.2	2.02	2600	<0.100	3.37	121	691	741	100	2060
CEF2-F-042 (A)	S-824	520	30.2	1.95	2540	<0.100	3.25	120	672	735	103	2030
CEF2-F-042 (B)	S-824	516	30.1	1.97	2570	<0.100	3.32	119	653	724	103	2050
CEF2-F-044 (A)	S-825	1280	35.6	3.68	2640	<0.100	7.46	167	3230	730	111	1410
CEF2-F-044 (B)	S-825	1280	35.4	3.69	2640	<0.100	7.46	169	3180	722	111	1420
CEF2-F-047 (A)	S-826	510	31.7	1.97	2530	<0.100	3.21	114	702	728	103	2010
CEF2-F-047 (B)	S-826	513	31.9	1.96	2580	<0.100	3.12	117	700	739	105	2040

Table A-9. ICP-AES Analysis of Feed Supernate Cations Set 1B (mg/L)

Sample ID	Lab ID	Mn	Na	Ni	P	Pb	S	Si	Sn	Ti	Zn	Zr
CEF2-F-007 (A)	S-801	12300	31400	2210	34.9	4.15	761	279	11.5	5.69	78.0	<1.00
CEF2-F-007 (B)	S-801	12400	31700	2200	35.6	4.13	750	275	11.5	5.72	76.7	<1.00
CEF2-F-010 (A)	S-802	11800	30800	2100	32.1	3.74	685	276	10.9	5.28	74.2	<1.00
CEF2-F-010 (B)	S-802	11700	30100	2110	33.4	3.90	683	270	10.9	5.29	74.3	<1.00
CEF2-F-013 (A)	S-803	14100	28700	2910	<10.0	1.81	699	578	10.8	1.78	84.2	<1.00
CEF2-F-013 (B)	S-803	14200	29400	2940	<10.0	1.94	712	577	10.9	1.77	83.6	<1.00
CEF2-F-015 (A)	S-804	14300	28900	2980	<10.0	1.94	732	381	11.2	1.70	83.9	<1.00
CEF2-F-015 (B)	S-804	14300	29500	2980	<10.0	1.95	734	386	10.8	1.74	82.5	<1.00
CEF2-F-027 (A)	S-814	12800	27000	2690	3.98	1.42	660	371	8.5	1.60	73.2	<1.00
CEF2-F-027 (B)	S-814	12800	27400	2690	3.46	1.25	647	379	8.52	1.61	73.3	<1.00
CEF2-F-030 (A)	S-815	12200	26000	2530	2.66	1.21	653	340	8.23	1.46	69.6	<1.00
CEF2-F-030 (B)	S-815	12200	26100	2520	3.60	1.31	643	342	8.15	1.46	71.4	<1.00
CEF2-F-038 (A)	S-888	14078	26600	3410	2.29	1.55	684	1451	8.91	2.62	87.3	<1.00
CEF2-F-038 (B)	S-888	13980	26800	3410	2.80	1.54	687	1383	9.07	2.61	87.3	<1.00
CEF2-F-039 (A)	S-889	13300	27200	3330	2.26	1.61	697	1028	9.03	2.72	90.7	<1.00
CEF2-F-039 (B)	S-889	13300	27200	3340	2.70	1.54	692	1009	9.16	2.73	92.0	<1.00
CEF2-F-041 (A)	S-823	14500	30300	3300	3.28	1.59	769	722	11.1	2.34	94.7	<1.00
CEF2-F-041 (B)	S-823	14400	29400	3350	3.31	1.61	775	717	11.0	2.33	94.7	<1.00
CEF2-F-042 (A)	S-824	14300	28400	3280	3.38	1.53	773	716	10.8	2.27	92.5	<1.00
CEF2-F-042 (B)	S-824	14300	30200	3340	3.81	1.61	756	705	10.8	2.30	93.5	<1.00
CEF2-F-044 (A)	S-825	11500	31400	1920	30.6	3.33	738	288	10.0	5.32	64.4	<1.00
CEF2-F-044 (B)	S-825	11500	31400	1920	31.3	3.32	734	282	10.2	5.36	64.6	<1.00
CEF2-F-047 (A)	S-826	14100	29700	3220	3.68	1.65	739	733	10.6	2.20	88.9	<1.00
CEF2-F-047 (B)	S-826	14200	29800	3260	2.93	1.63	747	752	10.6	2.21	89.6	<1.00

Table A-10. IC Analysis by PSAL of Feed Supernate Anions (mg/L)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	$C_2H_3O_3$	SO_4	C_2O_4	HCO_2	PO_4
CEF2-F-007 (A)	S-801	<100	566	<100	114000	38000	2230	2260	1520	<100
CEF2-F-007 (B)	S-801	<100	573	<100	116000	37100	2260	2190	1540	<100
CEF2-F-010 (A)	S-802	<100	584	<100	108000	38600	2260	2230	1480	<100
CEF2-F-010 (B)	S-802	<100	584	<100	108000	38600	2280	2260	1480	<100
CEF2-F-013 (A)	S-803	<100	516	<100	99200	35200	1930	1160	2500	<100
CEF2-F-013 (B)	S-803	<100	510	<100	100000	35500	1900	1120	2460	<100
CEF2-F-015 (A)	S-804	<100	528	<100	100000	37800	2010	1100	2590	<100
CEF2-F-015 (B)	S-804	<100	508	<100	100000	38400	2000	1090	2600	<100
CEF2-F-027 (A)	S-814	<100	476	<100	86300	43100	1720	1260	3340	<100
CEF2-F-027 (B)	S-814	<100	470	<100	85000	42700	1740	1240	3420	<100
CEF2-F-030 (A)	S-815	<100	455	<100	83900	43500	1690	1220	3140	<100
CEF2-F-030 (B)	S-815	<100	460	<100	84100	44200	1690	1220	3280	<100
CEF2-F-038 (A)	S-888	<100	461	<100	89300	35700	1640	1480	3040	<100
CEF2-F-038 (B)	S-888	<100	462	<100	90300	35900	1650	1470	3050	<100
CEF2-F-039 (A)	S-889	<100	479	<100	93100	36200	1710	1540	3120	<100
CEF2-F-039 (B)	S-889	<100	486	<100	93100	37600	1710	1520	3050	<100
CEF2-F-041 (A)	S-823	<100	525	<100	99700	43400	1720	1420	3080	<100
CEF2-F-041 (B)	S-823	<100	491	<100	101000	43700	1950	1430	3040	<100
CEF2-F-042 (A)	S-824	<100	520	<100	99900	43300	1780	1380	3180	<100
CEF2-F-042 (B)	S-824	<100	523	<100	100000	43200	1770	1390	3050	<100
CEF2-F-044 (A)	S-825	<100	564	<100	106000	38000	1530	2010	1280	<100
CEF2-F-044 (B)	S-825	<100	500	<100	103000	36000	1520	2000	1380	<100
CEF2-F-047 (A)	S-826	<100	497	<100	97000	43000	1710	1380	3050	<100
CEF2-F-047 (B)	S-826	<100	520	<100	97100	43000	1650	1360	3110	<100

Table A-11. Feed Solids Data, Density and pH

Sample	Lab ID	Total Solids	Insoluble Solids	Wt % Calcined	Soluble Solids	pH	Density (g/cm^3)	Supernate Density (g/cm^3)
CEF2-F-007 (A)	S-801	46.4%	34.4%	34.9%	12.0%	3.07	1.3810	1.1372
CEF2-F-007 (B)	S-801	46.3%	34.3%	34.8%	12.0%		1.3809	1.1373
CEF2-F-010 (A)	S-802	45.3%	33.6%	34.1%	11.8%	3.60	1.3574	1.1319
CEF2-F-010 (B)	S-802	45.2%	33.3%	34.0%	11.9%		1.3573	1.1319
CEF2-F-011 (A)	S-820	44.1%	32.7%	34.4%	11.4%	---	---	---
CEF2-F-011 (B)	S-820	43.9%	32.5%	34.2%	11.4%	---	---	---
CEF2-F-013 (A)	S-803	42.8%	30.6%	32.6%	12.2%	3.86	1.3343	1.1257
CEF2-F-013 (B)	S-803	42.6%	30.3%	32.3%	12.3%		1.3346	1.1250
CEF2-F-015 (A)	S-804	41.5%	28.7%	30.9%	12.8%	3.78	1.3398	1.1282
CEF2-F-015 (B)	S-804	41.9%	29.2%	31.3%	12.7%		1.3400	1.1282
CEF2-F-018 (A)	S-821	44.2%	32.4%	34.0%	11.8%	---	---	---
CEF2-F-018 (B)	S-821	45.0%	33.3%	34.3%	11.6%	---	---	---
CEF2-F-023 (A)	S-822	43.0%	30.9%	32.7%	12.1%	---	---	---
CEF2-F-023 (B)	S-822	42.4%	30.2%	31.9%	12.2%	---	---	---
CEF2-F-027 (A)	S-814	42.8%	31.5%	33.5%	11.3%	3.64	1.3154	1.1153
CEF2-F-027 (B)	S-814	42.3%	31.0%	33.0%	11.4%		1.3154	1.1153
CEF2-F-030 (A)	S-815	41.2%	29.9%	32.0%	11.4%	3.67	1.3005	1.1149
CEF2-F-030 (B)	S-815	41.5%	30.2%	32.3%	11.3%		1.3009	1.1149
CEF2-F-038 (A)	S-888	43.6%	31.7%	33.1%	11.9%	3.62	1.3234	1.1207
CEF2-F-038 (B)	S-888	43.6%	31.7%	33.1%	11.9%		1.3200	1.1208
CEF2-F-039 (A)	S-889	44.3%	30.9%	33.9%	13.5%	3.73	1.3526	1.1247
CEF2-F-039 (B)	S-889	44.4%	32.4%	34.0%	12.1%		1.3590	1.1247
CEF2-F-041 (A)	S-823	41.7%	27.9%	30.8%	13.7%	3.59	1.3283	1.1342
CEF2-F-041 (B)	S-823	41.7%	27.9%	30.8%	13.7%		1.3283	1.1341
CEF2-F-042 (A)	S-824	44.6%	31.9%	34.4%	12.7%	3.64	1.3614	1.1328
CEF2-F-042 (B)	S-824	44.6%	31.7%	34.3%	12.9%		1.3615	1.1328
CEF2-F-044 (A)	S-825	45.3%	33.4%	34.1%	11.9%	2.97	1.3659	1.1320
CEF2-F-044 (B)	S-825	45.3%	33.5%	34.0%	11.8%		1.3659	1.1320
CEF2-F-047 (A)	S-826	42.7%	30.3%	32.0%	12.5%	3.63	1.3265	1.1310
CEF2-F-047 (B)	S-826	42.8%	29.8%	32.1%	13.0%		1.3264	1.1310

Table A-12. Feed TOC

Sample ID	Average TOC (ppm)
CEF2-F-007	17,211
CEF2-F-008	17,317
CEF2-F-009	18,298
CEF2-F-010	18,593
CEF2-F-013	16,169
CEF2-F-015	17,160
CEF2-F-018	16,274
CEF2-F-023	15,193
CEF2-F-027	14,744
CEF2-F-030	13,452
CEF2-F-038	16,730
CEF2-F-039	17,139
CEF2-F-041	18,141
CEF2-F-042-1	16,676
CEF2-F-042-2	18,783
CEF2-F-044	16,320
CEF2-F-047-1	16,449
CEF2-F-047-2	16,627

Table A-13. Sealed Crucible REDOX Results

Sample ID	Lab ID	Fe^{2+}	Fe^{3+}	$\sum Fe$	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
EA	EA	0.082	0.372	0.454	0.220	0.181
CEF2-F-008-1 (A)	S-990	0.085	0.218	0.303	0.390	0.281
CEF2-F-008-1 (B)	S-990	0.084	0.220	0.304	0.382	0.276
CEF2-F-008-2 (A)	S-991	0.121	0.281	0.402	0.431	0.301
CEF2-F-008-2 (B)	S-991	0.123	0.280	0.403	0.439	0.305
CEF2-F-008-3 (A)	S-992	0.107	0.258	0.365	0.415	0.293
CEF2-F-008-3 (B)	S-992	0.107	0.259	0.366	0.413	0.292
CEF2-F-009-1 (A)	S-993	0.080	0.296	0.376	0.270	0.213
CEF2-F-009-1 (B)	S-993	0.080	0.296	0.376	0.270	0.213
CEF2-F-014-1 (A)	S-994	0.089	0.303	0.392	0.294	0.227
CEF2-F-014-1 (B)	S-994	0.090	0.302	0.392	0.298	0.230
CEF2-F-014-2 (A)	S-995	0.087	0.274	0.361	0.318	0.241
CEF2-F-014-2 (B)	S-995	0.088	0.270	0.358	0.326	0.246
CEF2-F-014-3 (A)	S-996	0.084	0.253	0.337	0.332	0.249
CEF2-F-014-3 (B)	S-996	0.085	0.251	0.336	0.339	0.253
CEF2-F-019-1 (A)	S-997	0.097	0.263	0.360	0.369	0.269
CEF2-F-019-1 (B)	S-997	0.097	0.265	0.362	0.366	0.268
EA	EA	0.079	0.361	0.440	0.219	0.180
CEF2-F-041-1 (A)	S-1029	0.199	0.268	0.467	0.743	0.426
CEF2-F-041-1 (B)	S-1029	0.201	0.267	0.468	0.753	0.429
CEF2-F-041-2 (A)	S-1030	0.142	0.202	0.344	0.703	0.413
CEF2-F-041-2 (B)	S-1030	0.142	0.202	0.344	0.703	0.413
CEF2-F-042-1 (A)	S-1031	0.151	0.201	0.352	0.751	0.429
CEF2-F-042-1 (B)	S-1031	0.151	0.202	0.353	0.748	0.428
CEF2-F-042-2 (A)	S-1032	0.207	0.218	0.425	0.950	0.487
CEF2-F-042-2 (B)	S-1032	0.208	0.216	0.424	0.963	0.491

Table A-14. Quartz Crucible REDOX Results (open-top vessel under flowing argon)

Sample ID	Lab ID	Fe^{2+}	Fe^{3+}	$\sum Fe$	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
EA	EA	0.079	0.361	0.440	0.219	0.180
CEF2-F-014-1 (A)	S-1289	0.110	0.314	0.424	0.350	0.259
CEF2-F-014-1 (B)	S-1289	0.110	0.314	0.424	0.350	0.259
CEF2-F-014-2 (A)	S-1290	0.101	0.260	0.361	0.388	0.280
CEF2-F-014-2 (B)	S-1290	0.101	0.259	0.360	0.390	0.281
CEF2-F-041-1 (A)	S-1291	0.198	0.149	0.347	1.329	0.571
CEF2-F-041-1 (B)	S-1291	0.196	0.151	0.347	1.298	0.565
CEF2-F-041-2 (A)	S-1292	0.200	0.154	0.354	1.299	0.565
CEF2-F-041-2 (B)	S-1292	0.200	0.155	0.355	1.290	0.563

Table A-15. Condensate Sample Summary Set 1

Sample ID	Lab ID	Collection Date	Collection Time	Condition	Test	Feed Stoichoimetry	Total Solids Target	Antifoam Target
CEF2-C-035	S829	2/26/2014	16:25	bubbled	steady state	125%	49.2% as received	nominal
CEF2-C-036	S830	2/26/2014	17:25	bubbled	steady state	125%	45%	nominal
CEF2-C-040	S831	2/26/2014	21:25	bubbled	steady state	125%	45%	nominal
CEF2-C-049	S832	2/27/2014	6:25	bubbled	steady state	125%	45%	nominal
CEF2-C-058	S833	2/27/2014	15:35	bubbled	steady state	125%	45%	nominal
CEF2-C-073	S966	3/1/2014	14:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-079	S805	3/1/2014	20:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-080	S806	3/1/2014	21:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-081	S807	3/1/2014	22:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-082	S808	3/1/2014	23:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-083	S809	3/2/2014	0:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-084	S810	3/2/2014	1:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-085	S811	3/2/2014	2:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-087	S812	3/2/2014	4:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-089	S834	3/2/2014	6:30	non-bubbled	steady state	125%	45%	nominal
CEF2-C-092	S835	3/2/2014	9:30	non-bubbled	steady state	100%	45%	nominal
CEF2-C-106	S836	3/2/2014	23:30	non-bubbled	steady state	100%	45%	nominal
CEF2-C-114	S837	3/3/2014	7:30	non-bubbled	steady state	100%	45%	nominal
CEF2-C-122	S838	3/3/2014	15:30	non-bubbled	steady state	100%	45%	nominal
CEF2-C-265	S813	3/4/2014	9:40	bubbled	steady state	100%	45%	nominal
CEF2-C-140	S839	3/4/2014	22:42	bubbled	steady state	100%	45%	nominal
CEF2-C-176	S840	3/6/2014	20:30	bubbled	steady state	100%	45%	nominal
CEF2-C-211	S841	3/8/2014	8:00	bubbled	steady state	100%	45%	nominal
CEF2-C-213	S842	3/8/2014	10:00	bubbled	surge	100%	45%	nominal
CEF2-C-236	S843	3/9/2014	10:00	bubbled	surge	100%	45%	nominal
CEF2-C-242	S844	3/10/2014	2:05	bubbled	surge	100%	45%	nominal
CEF2-C-257	S845	3/10/2014	17:05	bubbled	surge	100%	45%	nominal

Table A-16. Condensate Sample Summary Set 2

Sample ID	Lab ID	Collection Date	Collection Time	Condition	Test	Feed Stoichoimetry	Total Solids Target	Antifoam Target
CEF2-C-260	S846	3/10/2014	20:15	bubbled	surge	100%	42%	nominal
CEF2-C-261	S847	3/11/2014	6:03	bubbled	surge	100%	42%	nominal
CEF2-C-266	S848	3/11/2014	10:05	bubbled	surge	100%	42%	nominal
CEF2-C-270	S849	3/11/2014	14:03	bubbled	surge	100%	42%	nominal
CEF2-C-274	S850	3/11/2014	18:05	bubbled	surge	100%	42%	nominal
CEF2-C-278	S851	3/11/2014	22:05	bubbled	surge	100%	42%	nominal
CEF2-C-282	S852	3/12/2014	2:05	bubbled	surge	100%	42%	nominal
CEF2-C-286	S853	3/12/2014	6:05	bubbled	surge	100%	42%	nominal
CEF2-C-290	S854	3/12/2014	10:05	bubbled	surge	100%	42%	nominal
CEF2-C-294	S855	3/12/2014	14:05	bubbled	surge	100%	42%	nominal
CEF2-C-298	S856	3/12/2014	18:05	bubbled	surge	100%	42%	nominal
CEF2-C-302	S857	3/12/2014	22:05	bubbled	surge	100%	42%	nominal
CEF2-C-306	S858	3/13/2014	2:05	bubbled	surge	100%	42%	nominal
CEF2-C-310	S859	3/13/2014	6:05	bubbled	surge	100%	42%	nominal
CEF2-C-314	S860	3/13/2014	10:05	bubbled	surge	100%	42%	nominal
CEF2-C-318	S861	3/13/2014	14:05	bubbled	surge	100%	42%	nominal
CEF2-C-322	S862	3/13/2014	18:05	bubbled	surge	100%	42%	nominal
CEF2-C-327	S863	3/13/2014	22:05	bubbled	surge	100%	42%	nominal
CEF2-C-331	S864	3/14/2014	2:05	bubbled	surge	100%	42%	nominal
CEF2-C-335	S865	3/14/2014	6:05	bubbled	surge	100%	42%	nominal
CEF2-C-339	S866	3/14/2014	10:05	bubbled	surge	100%	42%	nominal
CEF2-C-343	S867	3/14/2014	14:10	bubbled	surge	100%	42%	nominal
CEF2-C-347	S868	3/14/2014	18:05	bubbled	surge	100%	42%	nominal
CEF2-C-351	S869	3/14/2014	22:05	bubbled	surge	100%	42%	nominal
CEF2-C-355	S870	3/15/2014	2:05	bubbled	surge	100%	42%	nominal
CEF2-C-359	S871	3/15/2014	6:05	bubbled	surge	100%	42%	nominal

Table A-17. Condensate Sample Summary Set 3

Sample ID	Lab ID	Collection Date	Collection Time	Condition	Test	Feed Stoichiometry	Total Solids Target	Antifoam Target
CEF2-C-363	S872	3/15/2014	10:05	non-bubbled	surge	100%	42%	nominal
CEF2-C-367	S873	3/15/2014	14:06	non-bubbled	surge	100%	42%	nominal
CEF2-C-371	S874	3/15/2014	18:00	non-bubbled	surge	100%	42%	nominal
CEF2-C-376	S875	3/15/2014	22:45	non-bubbled	surge	100%	42%	nominal
CEF2-C-380	S876	3/16/2014	2:45	non-bubbled	surge	100%	42%	nominal
CEF2-C-384	S877	3/16/2014	6:50	non-bubbled	surge	100%	42%	nominal
CEF2-C-388	S878	3/16/2014	10:50	non-bubbled	surge	100%	42%	nominal
CEF2-C-391	S879	3/16/2014	13:50	non-bubbled	surge	100%	42%	nominal
CEF2-C-392	S880	3/16/2014	17:40	non-bubbled	steady state	100%	45%	~3X nominal
CEF2-C-401	S881	3/17/2014	2:40	non-bubbled	steady state	100%	45%	~3X nominal
CEF2-C-410	S882	3/17/2014	11:40	non-bubbled	steady state	100%	45%	~3X nominal
CEF2-C-411	S883	3/17/2014	12:40	non-bubbled	steady state	100%	45%	~2X nominal
CEF2-C-416	S884	3/17/2014	17:40	non-bubbled	steady state	100%	45%	~2X nominal
CEF2-C-420	S885	3/17/2014	21:40	non-bubbled	steady state	100%	45%	~2X nominal
CEF2-C-424	S886	3/18/2014	1:40	non-bubbled	steady state	100%	45%	~2X nominal
CEF2-C-428	S887	3/18/2014	5:40	non-bubbled	steady state	100%	45%	~2X nominal
CEF2-C-432	S890	3/18/2014	9:40	non-bubbled	steady state	100%	45%	~2X nominal
CEF2-C-436	S891	3/18/2014	13:40	non-bubbled	steady state	100%	45%	~2X nominal
CEF2-C-440	S892	3/18/2014	17:40	non-bubbled	steady state	100%	45%	~2X nominal
CEF2-C-445	S893	3/18/2014	22:40	non-bubbled	steady state	100%	45%	~2X nominal
CEF2-C-486	S894	3/20/2014	22:25			*end of test*		

Table A-18. Condensate Cations Set 1A (mg/L)

Sample ID	Lab ID	Al	Ba	Ca	Cr	Cu	Fe	K	Li	Mg	Mn
CEF2-C-035	S-829a	21.8	<0.100	8.53	0.131	0.271	8.74	2.73	2.29	0.468	11.0
CEF2-C-035	S-829b	22.0	<0.100	8.54	0.135	0.421	8.87	2.73	2.29	0.483	12.2
CEF2-C-036	S-830a	23.2	<0.100	8.59	0.137	0.190	9.37	2.77	2.35	0.517	11.5
CEF2-C-036	S-830b	23.1	<0.100	8.68	0.134	0.196	9.39	2.76	2.34	0.508	11.4
CEF2-C-040	S-831a	24.7	<0.100	8.80	0.138	0.252	10.4	2.80	2.41	0.632	12.7
CEF2-C-040	S-831b	24.7	<0.100	8.82	0.142	0.259	10.6	2.84	2.42	0.643	12.7
CEF2-C-049	S-832a	26.3	<0.100	8.80	0.142	0.316	12.3	2.87	2.52	0.779	14.3
CEF2-C-049	S-832b	26.3	<0.100	8.88	0.144	0.313	12.3	2.90	2.51	0.786	14.3
CEF2-C-058	S-833a	26.6	<0.100	8.83	0.145	0.373	13.0	2.97	2.63	0.904	15.3
CEF2-C-058	S-833b	26.6	<0.100	8.86	0.145	0.375	13.0	2.97	2.62	0.908	15.3
CEF2-C-073	S-966a	34.8	<0.100	11.3	0.155	0.767	<0.100	3.66	3.71	1.93	21.9
CEF2-C-073	S-966b	34.8	<0.100	11.4	0.158	0.768	<0.100	3.70	3.72	1.93	21.8
CEF2-C-079 (A)	S-805	31.2	0.205	10.5	0.177	0.587	2.09	3.54	3.25	1.64	20.9
CEF2-C-079 (B)	S-805	31.2	0.205	10.5	0.178	0.595	2.10	3.55	3.24	1.63	20.8
CEF2-C-080 (A)	S-806	31.2	0.204	10.7	0.175	0.619	2.10	3.55	3.24	1.65	20.8
CEF2-C-080 (B)	S-806	31.9	0.203	10.6	0.178	0.694	2.07	3.55	3.24	1.64	20.9
CEF2-C-081 (A)	S-807	31.2	0.202	10.5	0.181	0.579	2.01	3.53	3.24	1.63	20.9
CEF2-C-081 (B)	S-807	31.2	0.205	10.5	0.172	0.591	2.00	3.53	3.24	1.64	20.9
CEF2-C-082 (A)	S-808	33.6	0.202	10.5	0.177	0.602	1.97	3.56	3.25	1.66	20.9
CEF2-C-082 (B)	S-808	32.9	0.201	10.6	0.178	0.637	1.95	3.58	3.26	1.66	21.1
CEF2-C-083 (A)	S-809	29.1	0.200	9.79	0.153	0.529	1.73	3.43	3.03	1.44	19.5
CEF2-C-083 (B)	S-809	29.2	0.206	9.94	0.154	0.566	1.90	3.44	3.02	1.45	19.5
CEF2-C-084 (A)	S-810	29.7	0.855	10.2	0.152	0.707	1.76	3.44	3.09	1.51	19.9
CEF2-C-084 (B)	S-810	29.7	0.850	10.3	0.160	0.713	1.76	3.49	3.10	1.52	20.0
CEF2-C-085 (A)	S-811	31.4	0.201	10.6	0.171	0.631	1.88	3.56	3.29	1.66	21.1
CEF2-C-085 (B)	S-811	31.4	0.204	10.5	0.176	0.637	1.93	3.53	3.26	1.65	21.0
CEF2-C-087 (A)	S-812	31.2	0.206	10.5	0.168	0.612	1.86	3.50	3.24	1.64	20.7
CEF2-C-087 (B)	S-812	31.1	0.206	10.6	0.174	0.738	1.83	3.49	3.23	1.63	20.8

Table A-19. Condensate Cations Set 1B (mg/L)

Sample ID	Lab ID	Na	Ni	P	Pb	S	Si	Sn	Ti	Zn	Zr
CEF2-C-035	S-829a	67.6	1.71	<1.00	<0.100	20.7	8.16	<0.100	<0.100	<0.100	0.719
CEF2-C-035	S-829b	68.5	2.44	<1.00	<0.100	21.0	8.17	<0.100	<0.100	<0.100	0.719
CEF2-C-036	S-830a	68.4	1.80	<1.00	<0.100	20.8	8.35	<0.100	<0.100	<0.100	0.716
CEF2-C-036	S-830b	68.2	1.80	<1.00	<0.100	21.3	8.38	<0.100	<0.100	<0.100	0.716
CEF2-C-040	S-831a	71.7	2.06	<1.00	<0.100	21.4	8.41	<0.100	<0.100	<0.100	0.717
CEF2-C-040	S-831b	72.4	2.05	<1.00	<0.100	21.7	8.43	<0.100	<0.100	<0.100	0.717
CEF2-C-049	S-832a	75.2	2.47	<1.00	<0.100	22.1	8.29	<0.100	<0.100	<0.100	0.717
CEF2-C-049	S-832b	75.0	2.44	<1.00	<0.100	22.1	8.25	<0.100	<0.100	<0.100	0.718
CEF2-C-058	S-833a	79.5	2.63	<1.00	<0.100	23.7	8.19	<0.100	<0.100	<0.100	0.717
CEF2-C-058	S-833b	78.9	2.65	<1.00	<0.100	23.8	8.26	<0.100	<0.100	<0.100	0.718
CEF2-C-073	S-966a	104	4.04	<1.00	<0.100	36.8	11.6	<0.100	<0.100	<0.100	0.715
CEF2-C-073	S-966b	103	4.01	<1.00	<0.100	36.7	11.4	<0.100	<0.100	<0.100	0.718
CEF2-C-079 (A)	S-805	113	3.56	0.442	<0.100	33.3	9.86	0.805	<0.100	<0.100	<1.00
CEF2-C-079 (B)	S-805	109	3.58	0.406	<0.100	33.4	9.40	0.811	<0.100	<0.100	<1.00
CEF2-C-080 (A)	S-806	110	3.58	0.456	<0.100	33.6	9.48	0.789	<0.100	<0.100	<1.00
CEF2-C-080 (B)	S-806	112	3.60	0.444	<0.100	33.2	9.62	0.824	<0.100	<0.100	<1.00
CEF2-C-081 (A)	S-807	112	3.57	0.421	<0.100	33.2	9.77	0.787	<0.100	<0.100	<1.00
CEF2-C-081 (B)	S-807	109	3.60	0.429	<0.100	33.4	9.55	0.811	<0.100	<0.100	<1.00
CEF2-C-082 (A)	S-808	110	3.61	0.421	<0.100	33.5	9.29	0.823	<0.100	<0.100	<1.00
CEF2-C-082 (B)	S-808	111	3.59	0.460	<0.100	33.1	9.63	0.819	<0.100	<0.100	<1.00
CEF2-C-083 (A)	S-809	111	3.29	0.425	<0.100	30.7	9.62	0.782	<0.100	<0.100	<1.00
CEF2-C-083 (B)	S-809	110	3.32	0.484	<0.100	31.1	9.39	0.814	<0.100	<0.100	<1.00
CEF2-C-084 (A)	S-810	110	3.37	0.443	<0.100	31.2	9.34	0.800	<0.100	<0.100	<1.00
CEF2-C-084 (B)	S-810	111	3.38	0.437	<0.100	31.7	9.59	0.816	<0.100	<0.100	<1.00
CEF2-C-085 (A)	S-811	111	3.60	0.441	<0.100	33.3	9.22	0.798	<0.100	<0.100	<1.00
CEF2-C-085 (B)	S-811	113	3.58	0.380	<0.100	32.9	9.50	0.786	<0.100	<0.100	<1.00
CEF2-C-087 (A)	S-812	111	3.56	0.418	<0.100	32.7	9.24	0.810	<0.100	<0.100	<1.00
CEF2-C-087 (B)	S-812	110	3.52	0.428	<0.100	32.3	9.09	0.806	<0.100	<0.100	<1.00

Table A-20. Condensate Cations Set 2A (mg/L)

Sample ID	Lab ID	Al	Ba	Ca	Cr	Cu	Fe	K	Li	Mg	Mn
CEF2-C-089	S-834a	33.0	<0.100	10.8	0.145	0.735	1.79	3.51	3.43	1.63	19.6
CEF2-C-089	S-834b	33.1	<0.100	10.9	0.143	0.737	1.77	3.55	3.46	1.64	19.7
CEF2-C-092	S-835a	33.3	<0.100	10.9	0.151	0.722	1.77	3.70	3.46	1.64	19.7
CEF2-C-092	S-835b	33.2	<0.100	10.9	0.149	0.727	1.78	3.68	3.46	1.65	19.7
CEF2-C-106	S-836a	32.2	<0.100	10.4	0.157	0.713	3.73	3.43	3.29	1.54	19.2
CEF2-C-106	S-836b	32.1	<0.100	10.4	0.154	0.768	3.76	3.44	3.26	1.54	19.2
CEF2-C-114	S-837a	30.0	<0.100	9.80	0.184	0.396	12.4	3.04	2.75	1.10	16.8
CEF2-C-114	S-837b	29.9	<0.100	9.89	0.184	0.410	12.5	3.03	2.75	1.10	16.8
CEF2-C-122	S-838a	32.9	<0.100	10.4	0.172	0.784	5.04	3.46	3.34	1.62	19.8
CEF2-C-122	S-838b	32.9	<0.100	10.6	0.171	0.793	5.07	3.46	3.33	1.62	19.9
CEF2-C-265 (A)	S-813	34.0	0.672	11.3	0.244	1.099	6.22	3.67	3.44	1.96	22.4
CEF2-C-265 (B)	S-813	33.8	0.675	11.3	0.264	1.115	5.95	3.66	3.42	1.95	22.4
CEF2-C-140	S-839a	37.1	<0.100	12.0	0.173	1.03	<0.100	3.92	3.99	2.21	22.9
CEF2-C-140	S-839b	37.3	<0.100	12.0	0.178	0.991	<0.100	3.92	3.99	2.21	23.0
CEF2-C-176	S-840a	37.5	<0.100	12.1	0.147	1.18	3.06	4.09	4.13	2.42	23.4
CEF2-C-176	S-840b	37.5	<0.100	12.2	0.148	1.18	2.86	4.11	4.16	2.43	23.5
CEF2-C-211	S-841a	37.4	<0.100	10.9	0.151	1.09	10.8	3.86	3.95	2.30	23.2
CEF2-C-211	S-841b	37.3	<0.100	11.0	0.151	1.11	10.6	3.85	3.94	2.28	23.1
CEF2-C-213	S-842a	37.7	<0.100	10.9	0.158	1.07	11.6	3.83	3.93	2.27	23.1
CEF2-C-213	S-842b	37.8	<0.100	10.9	0.163	1.12	11.8	3.86	3.94	2.29	23.3
CEF2-C-236	S-843a	49.1	<0.100	12.0	0.217	1.11	19.8	4.06	4.33	2.49	27.0
CEF2-C-236	S-843b	49.2	0.101	12.0	0.220	1.12	19.5	4.07	4.34	2.50	27.0
CEF2-C-242	S-844a	53.0	0.105	12.5	0.249	1.21	21.4	4.20	4.58	2.66	28.5
CEF2-C-242	S-844b	53.0	0.109	12.6	0.246	1.21	21.2	4.21	4.58	2.65	28.5
CEF2-C-257	S-845a	53.7	0.140	12.9	0.254	1.24	22.1	4.26	4.76	2.64	29.1
CEF2-C-257	S-845b	53.7	0.141	12.8	0.254	1.20	22.0	4.26	4.79	2.64	29.1
CEF2-C-260	S-846a	54.3	0.142	12.8	0.263	1.28	22.1	4.27	4.78	2.65	29.2
CEF2-C-260	S-846b	54.3	0.140	12.8	0.262	1.28	22.1	4.26	4.79	2.65	29.3

Table A-21. Condensate Cations Set 2B (mg/L)

Sample ID	Lab ID	Na	Ni	P	Pb	S	Si	Sn	Ti	Zn	Zr
CEF2-C-089	S-834a	103	3.44	<1.00	<0.100	32.2	10.1	<0.100	<0.100	<0.100	0.717
CEF2-C-089	S-834b	107	3.45	<1.00	<0.100	32.4	10.2	<0.100	<0.100	<0.100	0.718
CEF2-C-092	S-835a	106	3.47	<1.00	<0.100	32.5	10.4	<0.100	<0.100	<0.100	0.716
CEF2-C-092	S-835b	107	3.47	<1.00	<0.100	32.4	10.4	<0.100	<0.100	<0.100	0.716
CEF2-C-106	S-836a	107	3.33	<1.00	<0.100	29.8	13.1	<0.100	<0.100	<0.100	0.717
CEF2-C-106	S-836b	103	3.33	<1.00	<0.100	29.2	13.0	<0.100	<0.100	<0.100	0.718
CEF2-C-114	S-837a	83.3	2.97	<1.00	<0.100	24.4	10.6	<0.100	<0.100	<0.100	0.718
CEF2-C-114	S-837b	83.1	2.96	<1.00	<0.100	24.2	10.5	<0.100	<0.100	<0.100	0.717
CEF2-C-122	S-838a	106	3.49	<1.00	<0.100	30.3	13.7	<0.100	<0.100	<0.100	0.719
CEF2-C-122	S-838b	105	3.49	<1.00	<0.100	30.1	13.6	<0.100	<0.100	<0.100	0.718
CEF2-C-265 (A)	S-813	117	3.93	0.411	<0.100	31.9	12.6	0.839	<0.100	<0.100	<1.00
CEF2-C-265 (B)	S-813	120	3.91	0.440	<0.100	32.1	12.9	0.818	<0.100	<0.100	<1.00
CEF2-C-140	S-839a	129	4.16	<1.00	<0.100	34.9	14.5	<0.100	<0.100	<0.100	0.716
CEF2-C-140	S-839b	124	4.15	<1.00	<0.100	34.9	14.6	<0.100	<0.100	<0.100	0.716
CEF2-C-176	S-840a	133	4.08	<1.00	<0.100	34.4	18.2	<0.100	<0.100	2.21	0.718
CEF2-C-176	S-840b	136	4.10	<1.00	<0.100	35.0	18.3	<0.100	<0.100	2.22	0.715
CEF2-C-211	S-841a	122	4.30	<1.00	<0.100	29.9	12.7	<0.100	<0.100	2.93	0.718
CEF2-C-211	S-841b	122	4.30	<1.00	<0.100	29.8	12.5	<0.100	<0.100	2.90	0.717
CEF2-C-213	S-842a	122	4.35	<1.00	<0.100	29.3	12.5	<0.100	<0.100	2.92	0.717
CEF2-C-213	S-842b	121	4.34	<1.00	<0.100	29.7	12.4	<0.100	<0.100	2.95	0.718
CEF2-C-236	S-843a	139	4.75	<1.00	<0.100	26.3	16.3	<0.100	<0.100	3.05	0.715
CEF2-C-236	S-843b	137	4.74	<1.00	<0.100	26.5	16.4	<0.100	<0.100	3.05	0.717
CEF2-C-242	S-844a	144	5.03	<1.00	<0.100	28.4	17.2	0.145	<0.100	3.32	0.716
CEF2-C-242	S-844b	144	5.05	<1.00	<0.100	28.5	17.3	0.117	<0.100	3.35	0.715
CEF2-C-257	S-845a	147	5.00	<1.00	<0.100	28.2	17.2	0.103	<0.100	2.98	0.716
CEF2-C-257	S-845b	147	4.95	<1.00	<0.100	28.1	17.3	0.105	<0.100	2.98	0.715
CEF2-C-260	S-846a	150	5.00	<1.00	<0.100	27.3	17.2	0.128	<0.100	2.92	0.716
CEF2-C-260	S-846b	149	4.98	<1.00	<0.100	27.6	17.2	0.114	<0.100	2.92	0.716

Table A-22. Condensate Cations Set 3A (mg/L)

Sample ID	Lab ID	Al	Ba	Ca	Cr	Cu	Fe	K	Li	Mg	Mn
CEF2-C-261	S-847a	58.3	0.136	13.5	0.296	1.38	23.0	4.48	5.03	2.80	30.7
CEF2-C-261	S-847b	58.3	0.141	13.6	0.289	1.69	23.1	4.47	5.03	2.77	30.5
CEF2-C-266	S-848a	58.1	0.168	13.6	0.306	1.37	23.4	4.45	5.13	2.82	30.9
CEF2-C-266	S-848b	58.0	0.162	13.6	0.300	1.37	23.3	4.44	5.11	2.80	30.8
CEF2-C-270	S-849a	59.4	0.157	13.7	0.307	1.28	23.3	4.49	5.18	2.82	31.3
CEF2-C-270	S-849b	59.5	0.157	13.7	0.302	1.80	22.8	4.52	5.18	2.79	32.8
CEF2-C-274	S-850a	61.0	0.161	13.9	0.320	1.30	22.8	4.52	5.28	2.84	31.7
CEF2-C-274	S-850b	60.9	0.152	13.9	0.321	1.30	23.1	4.50	5.28	2.84	31.5
CEF2-C-278	S-851a	61.3	0.181	14.1	0.323	1.46	22.1	4.54	5.27	2.84	31.6
CEF2-C-278	S-851b	61.5	0.177	14.2	0.319	1.46	21.9	4.55	5.31	2.83	31.5
CEF2-C-282	S-852a	59.6	0.173	13.7	0.312	1.29	21.2	4.45	5.21	2.73	30.6
CEF2-C-282	S-852b	59.3	0.173	13.7	0.310	1.28	21.2	4.67	5.18	2.71	30.4
CEF2-C-286	S-853a	61.0	0.156	13.7	0.306	1.25	20.4	4.46	5.12	2.71	30.6
CEF2-C-286	S-853b	61.0	0.159	13.7	0.309	1.29	20.4	4.47	5.13	2.73	30.7
CEF2-C-290	S-854a	60.4	0.163	13.6	0.308	1.25	19.3	4.43	5.09	2.67	30.2
CEF2-C-290	S-854b	60.3	0.166	13.6	0.304	1.27	19.4	4.41	5.07	2.68	30.2
CEF2-C-294	S-855a	61.2	0.170	13.6	0.303	1.23	18.4	4.45	5.08	2.64	30.0
CEF2-C-294	S-855b	61.0	0.173	13.7	0.303	1.32	18.4	4.43	5.06	2.63	30.0
CEF2-C-298	S-856a	61.8	0.172	13.6	0.298	1.20	17.1	4.42	5.04	2.60	29.8
CEF2-C-298	S-856b	61.6	0.171	13.6	0.303	1.21	17.2	4.42	5.02	2.60	29.8
CEF2-C-302	S-857a	60.8	0.193	13.5	0.304	1.22	16.2	4.37	4.95	2.55	29.2
CEF2-C-302	S-857b	61.4	0.181	13.8	0.294	1.44	16.4	4.38	4.94	2.57	29.2
CEF2-C-306	S-858a	61.6	0.179	13.8	0.300	1.23	15.7	4.44	4.96	2.56	29.3
CEF2-C-306	S-858b	61.8	0.181	14.0	0.303	1.25	15.6	4.44	4.98	2.58	29.4
CEF2-C-310	S-859a	62.6	0.174	13.7	0.302	1.18	14.6	4.42	4.99	2.57	29.3
CEF2-C-310	S-859b	62.6	0.174	13.9	0.302	1.21	14.7	4.44	5.00	2.57	29.4
CEF2-C-314	S-860a	61.9	0.176	13.6	0.295	1.14	13.3	4.37	4.92	2.49	28.6
CEF2-C-314	S-860b	61.9	0.171	13.6	0.293	1.15	12.9	4.39	4.92	2.48	28.5

Table A-23. Condensate Cations Set 3B (mg/L)

Sample ID	Lab ID	Na	Ni	P	Pb	S	Si	Sn	Ti	Zn	Zr
CEF2-C-261	S-847a	154	5.23	<1.00	<0.100	28.6	18.0	0.120	<0.100	2.94	0.722
CEF2-C-261	S-847b	154	5.24	<1.00	<0.100	28.4	17.9	0.115	<0.100	2.97	0.717
CEF2-C-266	S-848a	158	5.25	<1.00	<0.100	29.3	18.7	0.143	<0.100	2.91	0.720
CEF2-C-266	S-848b	158	5.22	<1.00	<0.100	29.0	18.6	0.091	<0.100	2.88	0.718
CEF2-C-270	S-849a	157	5.29	<1.00	<0.100	29.4	18.9	0.141	<0.100	2.78	0.715
CEF2-C-270	S-849b	156	6.42	<1.00	<0.100	28.7	18.7	0.155	<0.100	2.87	0.718
CEF2-C-274	S-850a	162	5.26	<1.00	<0.100	28.8	19.1	0.142	<0.100	2.71	0.716
CEF2-C-274	S-850b	160	5.26	<1.00	<0.100	28.8	19.1	0.142	<0.100	2.71	0.716
CEF2-C-278	S-851a	161	5.21	<1.00	<0.100	28.8	19.1	0.143	<0.100	2.63	0.717
CEF2-C-278	S-851b	162	5.24	<1.00	<0.100	29.0	19.2	0.133	<0.100	2.61	0.716
CEF2-C-282	S-852a	156	5.03	<1.00	<0.100	28.0	18.8	0.128	<0.100	2.52	0.717
CEF2-C-282	S-852b	159	5.00	<1.00	<0.100	27.9	18.7	0.142	<0.100	2.53	0.716
CEF2-C-286	S-853a	160	5.09	<1.00	<0.100	27.0	19.1	0.134	<0.100	2.44	0.719
CEF2-C-286	S-853b	163	5.02	<1.00	<0.100	27.1	19.3	0.135	<0.100	2.46	0.716
CEF2-C-290	S-854a	161	4.89	<1.00	<0.100	26.6	19.0	0.110	<0.100	2.46	0.716
CEF2-C-290	S-854b	159	4.86	<1.00	<0.100	26.8	18.9	0.148	<0.100	2.47	0.717
CEF2-C-294	S-855a	159	4.84	<1.00	<0.100	26.4	19.4	0.132	<0.100	2.47	0.716
CEF2-C-294	S-855b	157	4.84	<1.00	<0.100	25.9	19.4	0.127	<0.100	2.48	0.714
CEF2-C-298	S-856a	159	4.76	<1.00	<0.100	25.9	19.5	0.147	<0.100	2.48	0.715
CEF2-C-298	S-856b	159	4.77	<1.00	<0.100	25.8	19.5	0.133	<0.100	2.48	0.717
CEF2-C-302	S-857a	156	4.61	<1.00	<0.100	24.8	19.4	0.149	<0.100	2.41	0.720
CEF2-C-302	S-857b	155	4.62	<1.00	<0.100	24.9	19.4	0.154	<0.100	2.45	0.717
CEF2-C-306	S-858a	156	4.62	<1.00	<0.100	24.7	19.6	0.131	<0.100	2.37	0.717
CEF2-C-306	S-858b	157	4.65	<1.00	<0.100	24.8	19.7	0.133	<0.100	2.40	0.716
CEF2-C-310	S-859a	156	4.63	<1.00	<0.100	24.8	20.1	0.130	<0.100	2.28	0.715
CEF2-C-310	S-859b	157	4.68	<1.00	<0.100	24.8	20.1	0.130	<0.100	2.28	0.716
CEF2-C-314	S-860a	160	4.48	<1.00	<0.100	24.3	19.8	0.115	<0.100	2.16	0.716
CEF2-C-314	S-860b	160	4.46	<1.00	<0.100	23.9	20.0	0.144	<0.100	2.15	0.716

Table A-24. Condensate Cations Set 4A (mg/L)

Sample ID	Lab ID	Al	Ba	Ca	Cr	Cu	Fe	K	Li	Mg	Mn
CEF2-C-318	S-861a	62.7	0.177	13.7	0.297	1.19	11.8	4.46	4.96	2.49	28.6
CEF2-C-318	S-861b	62.6	0.178	13.8	0.295	1.25	11.7	4.46	4.95	2.49	28.5
CEF2-C-322	S-862a	61.3	0.183	13.5	0.277	1.13	10.5	4.47	4.86	2.43	27.7
CEF2-C-322	S-862b	61.0	0.185	13.3	0.277	1.11	10.5	4.36	4.82	2.41	27.7
CEF2-C-327	S-863a	61.7	0.206	13.5	0.277	1.18	9.37	4.39	4.84	2.41	27.4
CEF2-C-327	S-863b	61.9	0.206	13.7	0.278	1.18	9.36	4.43	4.85	2.41	27.3
CEF2-C-331	S-864a	61.1	0.195	13.3	0.260	1.10	7.91	4.41	4.76	2.33	26.6
CEF2-C-331	S-864b	61.0	0.196	13.3	0.261	1.11	7.92	4.36	4.76	2.33	26.6
CEF2-C-335	S-865a	61.5	0.191	13.5	0.256	1.07	6.20	4.35	4.73	2.36	26.6
CEF2-C-335	S-865b	61.7	0.195	13.7	0.254	1.14	6.14	4.36	4.70	2.35	26.6
CEF2-C-339	S-866a	61.6	0.210	13.8	0.266	1.08	6.40	4.47	4.80	2.37	26.3
CEF2-C-339	S-866b	61.5	0.205	13.8	0.265	1.10	6.42	4.46	4.80	2.38	26.3
CEF2-C-343	S-867a	61.4	0.193	13.6	0.253	1.13	5.47	4.41	4.76	2.35	26.0
CEF2-C-343	S-867b	61.4	0.197	13.7	0.257	1.42	5.62	4.45	4.77	2.35	25.9
CEF2-C-347	S-868a	62.2	0.187	13.9	0.246	1.09	4.14	4.42	4.74	2.32	25.6
CEF2-C-347	S-868b	62.1	0.186	14.0	0.239	1.08	4.10	4.40	4.71	2.31	25.5
CEF2-C-351	S-869a	62.4	0.188	13.8	0.234	1.03	3.11	4.41	4.73	2.33	25.5
CEF2-C-351	S-869b	62.3	0.185	13.9	0.237	1.03	3.09	4.44	4.73	2.34	25.6
CEF2-C-355	S-870a	61.4	0.208	13.6	0.218	1.18	2.75	4.42	4.66	2.27	24.7
CEF2-C-355	S-870b	60.9	0.207	13.7	0.219	1.18	2.72	4.43	4.65	2.26	24.7
CEF2-C-359	S-871a	60.9	0.204	13.5	0.207	1.00	2.10	4.39	4.59	2.22	24.3
CEF2-C-359	S-871b	60.9	0.201	13.5	0.209	1.00	2.08	4.38	4.58	2.21	24.2
CEF2-C-363	S-872a	59.9	0.212	13.4	0.201	0.967	1.65	4.39	4.57	2.18	23.6
CEF2-C-363	S-872b	60.1	0.209	13.5	0.199	0.975	1.66	4.42	4.55	2.18	23.6
CEF2-C-367	S-873a	59.5	0.208	13.4	0.191	0.965	1.58	4.37	4.51	2.16	23.3
CEF2-C-367	S-873b	59.5	0.207	13.5	0.192	0.983	1.57	4.36	4.50	2.15	23.2
CEF2-C-371	S-874a	58.8	0.570	12.9	0.177	1.07	1.51	4.34	4.39	2.12	23.0
CEF2-C-371	S-874b	58.9	0.398	12.9	0.182	1.10	1.52	4.34	4.46	2.13	23.0

Table A-25. Condensate Cations Set 4B (mg/L)

Sample ID	Lab ID	Na	Ni	P	Pb	S	Si	Sn	Ti	Zn	Zr
CEF2-C-318	S-861a	161	4.42	<1.00	<0.100	24.1	20.1	0.127	<0.100	2.12	0.716
CEF2-C-318	S-861b	158	4.42	<1.00	<0.100	23.8	19.9	0.115	<0.100	2.13	0.716
CEF2-C-322	S-862a	157	4.29	<1.00	<0.100	23.6	20.5	0.141	<0.100	2.06	0.716
CEF2-C-322	S-862b	154	4.25	<1.00	<0.100	23.6	20.5	0.132	<0.100	2.03	0.715
CEF2-C-327	S-863a	157	4.19	<1.00	<0.100	23.1	19.8	0.112	<0.100	1.96	0.715
CEF2-C-327	S-863b	157	4.17	<1.00	<0.100	23.5	19.8	0.129	<0.100	1.95	0.715
CEF2-C-331	S-864a	156	4.06	<1.00	<0.100	22.7	19.9	<0.100	<0.100	1.86	0.716
CEF2-C-331	S-864b	158	4.07	<1.00	<0.100	22.8	19.9	<0.100	<0.100	1.86	0.715
CEF2-C-335	S-865a	159	4.04	<1.00	<0.100	22.5	20.1	0.110	<0.100	1.81	0.717
CEF2-C-335	S-865b	157	4.01	<1.00	<0.100	22.7	20.0	0.102	<0.100	1.81	0.717
CEF2-C-339	S-866a	161	3.97	<1.00	<0.100	22.8	19.9	0.142	<0.100	1.86	0.719
CEF2-C-339	S-866b	162	3.99	<1.00	<0.100	23.0	19.8	0.118	<0.100	1.87	0.716
CEF2-C-343	S-867a	158	3.92	<1.00	<0.100	22.4	20.2	0.099	<0.100	1.99	0.716
CEF2-C-343	S-867b	159	3.92	<1.00	<0.100	22.1	20.2	0.114	<0.100	2.02	0.715
CEF2-C-347	S-868a	162	3.82	<1.00	<0.100	22.2	21.0	<0.100	<0.100	1.99	0.723
CEF2-C-347	S-868b	164	3.79	<1.00	<0.100	22.5	20.9	<0.100	<0.100	1.99	0.718
CEF2-C-351	S-869a	163	3.80	<1.00	<0.100	22.3	20.9	<0.100	<0.100	2.04	0.715
CEF2-C-351	S-869b	159	3.82	<1.00	<0.100	22.1	20.8	<0.100	<0.100	2.05	0.717
CEF2-C-355	S-870a	158	3.64	<1.00	<0.100	21.7	19.9	<0.100	<0.100	2.11	0.715
CEF2-C-355	S-870b	160	3.68	<1.00	<0.100	21.9	19.9	<0.100	<0.100	2.11	0.716
CEF2-C-359	S-871a	160	3.60	<1.00	<0.100	21.5	19.6	0.100	<0.100	2.15	0.714
CEF2-C-359	S-871b	158	3.53	<1.00	<0.100	21.4	19.6	0.100	<0.100	2.14	0.716
CEF2-C-363	S-872a	160	3.43	<1.00	<0.100	21.0	19.6	<0.100	<0.100	2.18	0.716
CEF2-C-363	S-872b	161	3.46	<1.00	<0.100	21.2	19.7	<0.100	<0.100	2.18	0.717
CEF2-C-367	S-873a	157	3.38	<1.00	<0.100	20.7	19.1	<0.100	<0.100	2.18	0.716
CEF2-C-367	S-873b	159	3.40	<1.00	<0.100	20.5	19.1	0.126	<0.100	2.20	0.716
CEF2-C-371	S-874a	156	3.33	<1.00	<0.100	20.1	18.9	0.116	<0.100	2.15	0.716
CEF2-C-371	S-874b	154	3.34	<1.00	<0.100	20.6	19.0	0.112	<0.100	2.12	0.716

Table A-26. Condensate Cations Set 5A (mg/L)

Sample ID	Lab ID	Al	Ba	Ca	Cr	Cu	Fe	K	Li	Mg	Mn
CEF2-C-376	S-875a	59.0	0.194	13.2	0.175	1.25	2.24	4.76	4.41	2.11	22.9
CEF2-C-376	S-875b	58.9	0.194	13.4	0.174	1.14	1.85	4.89	4.39	2.12	22.9
CEF2-C-380	S-876a	58.6	0.190	12.9	0.174	0.996	2.18	4.24	4.31	2.06	22.8
CEF2-C-380	S-876b	58.6	0.184	13.0	0.171	1.01	2.14	4.24	4.31	2.06	22.7
CEF2-C-384	S-877a	57.9	0.176	12.7	0.166	0.964	2.50	4.20	4.24	2.02	22.5
CEF2-C-384	S-877b	58.1	0.174	12.7	0.163	0.964	2.50	4.20	4.25	2.02	22.5
CEF2-C-388	S-878a	57.3	0.164	12.4	0.161	0.949	3.05	4.10	4.13	1.96	22.4
CEF2-C-388	S-878b	57.2	0.167	12.4	0.160	0.951	3.02	4.10	4.13	1.96	22.3
CEF2-C-391	S-879a	57.7	0.164	12.4	0.159	0.953	3.80	4.07	4.11	1.96	22.7
CEF2-C-391	S-879b	57.7	0.163	12.3	0.159	0.944	3.74	4.07	4.12	1.96	22.7
CEF2-C-392	S-880a	59.4	0.172	12.6	0.162	0.987	3.93	4.13	4.16	2.05	23.4
CEF2-C-392	S-880b	59.5	0.171	12.6	0.163	0.984	3.92	4.16	4.16	2.05	23.5
CEF2-C-401	S-881a	63.3	0.200	13.9	0.142	1.02	1.61	4.37	4.17	2.50	25.6
CEF2-C-401	S-881b	63.4	0.202	14.1	0.143	1.03	1.60	4.38	4.18	2.50	25.5
CEF2-C-410	S-882a	59.9	0.200	13.6	0.103	0.996	<0.100	4.26	3.98	2.47	24.8
CEF2-C-410	S-882b	61.2	0.230	13.8	0.105	1.12	<0.100	4.31	3.99	2.50	24.9
CEF2-C-411	S-883a	59.2	0.199	13.5	<0.100	0.996	<0.100	4.24	3.97	2.47	24.7
CEF2-C-411	S-883b	59.1	0.201	13.5	<0.100	0.998	<0.100	4.26	3.97	2.46	24.6
CEF2-C-416	S-884a	57.4	0.188	13.2	<0.100	0.920	<0.100	4.22	3.91	2.42	24.2
CEF2-C-416	S-884b	57.4	0.185	13.3	<0.100	0.925	<0.100	4.24	3.89	2.42	24.1
CEF2-C-420	S-885a	54.0	0.187	13.0	<0.100	0.895	<0.100	4.19	3.84	2.38	23.6
CEF2-C-420	S-885b	54.1	0.186	13.1	<0.100	0.921	<0.100	4.19	3.85	2.42	23.6
CEF2-C-424	S-886a	51.7	0.182	13.0	<0.100	0.851	<0.100	4.14	3.79	2.38	23.4
CEF2-C-424	S-886b	51.3	0.176	13.1	<0.100	0.859	<0.100	4.15	3.77	2.37	23.2
CEF2-C-428	S-887a	50.4	0.173	12.9	<0.100	0.818	<0.100	4.11	3.75	2.35	23.0
CEF2-C-428	S-887b	50.4	0.172	13.0	<0.100	0.831	<0.100	4.13	3.77	2.37	23.1
CEF2-C-432	S-890a	50.8	0.178	13.1	<0.100	0.828	<0.100	4.19	3.83	2.44	23.4
CEF2-C-432	S-890b	50.7	0.180	13.1	<0.100	0.840	<0.100	4.19	3.82	2.44	23.3

Table A-27. Condensate Cations Set 5B (mg/mL)

Sample ID	Lab ID	Na	Ni	P	Pb	S	Si	Sn	Ti	Zn	Zr
CEF2-C-376	S-875a	153	3.35	<1.00	<0.100	19.6	18.8	0.053	<0.100	2.18	0.715
CEF2-C-376	S-875b	156	3.35	<1.00	<0.100	19.7	18.7	<0.100	<0.100	2.19	0.714
CEF2-C-380	S-876a	150	3.31	<1.00	<0.100	19.2	18.3	<0.100	<0.100	1.98	0.718
CEF2-C-380	S-876b	151	3.32	<1.00	<0.100	19.2	18.3	<0.100	<0.100	1.97	0.714
CEF2-C-384	S-877a	148	3.29	<1.00	<0.100	18.7	18.1	<0.100	<0.100	1.93	0.715
CEF2-C-384	S-877b	148	3.28	<1.00	<0.100	18.7	18.1	<0.100	<0.100	1.92	0.716
CEF2-C-388	S-878a	143	3.26	<1.00	<0.100	18.2	17.8	<0.100	<0.100	1.88	0.714
CEF2-C-388	S-878b	143	3.25	<1.00	<0.100	18.1	17.8	<0.100	<0.100	1.88	0.715
CEF2-C-391	S-879a	141	3.34	<1.00	<0.100	17.9	17.8	<0.100	<0.100	1.87	0.716
CEF2-C-391	S-879b	141	3.35	<1.00	<0.100	18.0	17.7	<0.100	<0.100	1.86	0.716
CEF2-C-392	S-880a	144	3.50	<1.00	<0.100	17.7	18.4	<0.100	<0.100	1.86	0.716
CEF2-C-392	S-880b	144	3.50	<1.00	<0.100	17.5	18.3	<0.100	<0.100	1.86	0.716
CEF2-C-401	S-881a	160	3.62	<1.00	<0.100	16.8	28.5	<0.100	<0.100	1.78	0.715
CEF2-C-401	S-881b	161	3.65	<1.00	<0.100	17.1	28.6	<0.100	<0.100	1.79	0.716
CEF2-C-410	S-882a	156	3.52	<1.00	<0.100	15.9	45.4	<0.100	<0.100	1.71	0.716
CEF2-C-410	S-882b	157	3.51	<1.00	<0.100	15.9	46.3	<0.100	<0.100	1.75	0.721
CEF2-C-411	S-883a	157	3.46	<1.00	<0.100	16.0	48.6	<0.100	<0.100	1.72	0.715
CEF2-C-411	S-883b	158	3.46	<1.00	<0.100	15.8	48.4	<0.100	<0.100	1.70	0.716
CEF2-C-416	S-884a	155	3.38	<1.00	<0.100	15.4	44.9	<0.100	<0.100	1.63	0.714
CEF2-C-416	S-884b	156	3.35	<1.00	<0.100	15.6	44.5	<0.100	<0.100	1.62	0.716
CEF2-C-420	S-885a	155	3.29	<1.00	<0.100	15.5	50.2	<0.100	<0.100	1.58	0.718
CEF2-C-420	S-885b	154	3.30	<1.00	<0.100	15.8	50.0	<0.100	<0.100	1.59	0.719
CEF2-C-424	S-886a	151	3.24	<1.00	<0.100	15.8	57.1	<0.100	<0.100	1.53	0.718
CEF2-C-424	S-886b	154	3.25	<1.00	<0.100	15.2	55.6	<0.100	<0.100	1.52	0.717
CEF2-C-428	S-887a	154	3.18	<1.00	<0.100	15.1	54.9	<0.100	<0.100	1.47	0.716
CEF2-C-428	S-887b	154	3.21	<1.00	<0.100	14.8	55.7	<0.100	<0.100	1.49	0.716
CEF2-C-432	S-890a	153	3.25	<1.00	<0.100	15.6	50.0	<0.100	<0.100	1.49	0.716
CEF2-C-432	S-890b	158	3.25	<1.00	<0.100	15.6	49.6	<0.100	<0.100	1.50	0.717

Table A-28. Condensate Cations Set 6 (mg/L)

Sample ID	Lab ID	Al	Ba	Ca	Cr	Cu	Fe	K	Li	Mg	Mn
CEF2-C-436	S-891a	49.1	0.696	49.1	1.07	0.908	<0.100	4.16	3.87	2.60	22.6
CEF2-C-436	S-891b	49.1	0.208	49.1	<0.100	0.908	<0.100	4.16	3.87	2.60	24.5
CEF2-C-440	S-892a	48.9	0.209	13.3	<0.100	0.803	<0.100	4.25	3.96	2.69	24.9
CEF2-C-440	S-892b	48.7	0.214	13.3	<0.100	0.886	<0.100	4.25	3.94	2.67	24.8
CEF2-C-445	S-893a	48.8	0.216	13.6	<0.100	0.827	<0.100	4.27	4.03	2.78	25.3
CEF2-C-445	S-893b	48.7	0.217	13.7	<0.100	0.944	<0.100	4.27	4.02	2.77	25.3
CEF2-C-486	S-894a	40.6	0.177	13.2	<0.100	0.711	<0.100	4.15	3.70	2.72	23.3
CEF2-C-486	S-894b	40.5	0.178	13.2	<0.100	0.807	<0.100	4.15	3.70	2.73	23.3

Sample ID	Lab ID	Na	Ni	P	Pb	S	Si	Sn	Ti	Zn	Zr
CEF2-C-436	S-891a	160	3.43	<1.00	<0.100	16.6	41.1	<0.100	<0.100	1.59	0.717
CEF2-C-436	S-891b	161	3.43	<1.00	<0.100	16.6	41.1	<0.100	<0.100	1.59	0.717
CEF2-C-440	S-892a	163	3.50	<1.00	<0.100	16.9	40.5	<0.100	<0.100	1.60	0.717
CEF2-C-440	S-892b	164	3.43	<1.00	<0.100	16.8	40.2	<0.100	<0.100	1.61	0.718
CEF2-C-445	S-893a	170	3.54	<1.00	<0.100	17.3	42.2	<0.100	<0.100	1.61	0.716
CEF2-C-445	S-893b	169	3.56	<1.00	<0.100	17.0	42.6	<0.100	<0.100	1.62	0.716
CEF2-C-486	S-894a	165	3.24	<1.00	<0.100	15.5	38.5	<0.100	<0.100	1.22	0.715
CEF2-C-486	S-894b	167	3.22	<1.00	<0.100	15.4	38.0	<0.100	<0.100	1.22	0.717

Table A-29. Condensate Anions Set 1 (mg/L)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	$C_2H_3O_3$	SO_4	C_2O_4	HCO_2	PO_4
CEF2-C-035	S829	<100	80.1	<10.0	915	56.0	<100	<100	<10.0	<10.0
CEF2-C-036	S830	<100	89.8	<10.0	1050	56.9	<100	<100	<10.0	<10.0
CEF2-C-040	S831	<100	85.9	<10.0	1060	57.3	<100	<100	<10.0	<10.0
CEF2-C-049	S832	<100	97.3	<10.0	1240	62.6	<100	<100	<10.0	<10.0
CEF2-C-058	S833	<100	102	<10.0	1310	65.0	<100	<100	21.5	<10.0
CEF2-C-073	S966	<100	130	<10.0	1540	96.0	<100	<100	109	<10.0
CEF2-C-079 (A)	S-805	<100	151	<100	1570	<100	<100	<100	<100	<100
CEF2-C-079 (B)	S-805	<100	153	<100	1580	<100	<100	<100	<100	<100
CEF2-C-080 (A)	S-806	<100	149	<100	1570	<100	<100	<100	<100	<100
CEF2-C-080 (B)	S-806	<100	152	<100	1570	<100	<100	<100	<100	<100
CEF2-C-081 (A)	S-807	<100	156	<100	1590	<100	<100	<100	<100	<100
CEF2-C-081 (B)	S-807	<100	155	<100	1600	<100	<100	<100	<100	<100
CEF2-C-082 (A)	S-808	<100	156	<100	1590	<100	<100	<100	<100	<100
CEF2-C-082 (B)	S-808	<100	155	<100	1590	<100	<100	<100	<100	<100
CEF2-C-083 (A)	S-809	<100	151	<100	1590	<100	<100	<100	<100	<100
CEF2-C-083 (B)	S-809	<100	151	<100	1590	<100	<100	<100	<100	<100
CEF2-C-084 (A)	S-810	<100	153	<100	1600	<100	<100	<100	<100	<100
CEF2-C-084 (B)	S-810	<100	153	<100	1600	<100	<100	<100	<100	<100
CEF2-C-085 (A)	S-811	<100	151	<100	1590	<100	<100	<100	<100	<100
CEF2-C-085 (B)	S-811	<100	152	<100	1590	<100	<100	<100	<100	<100
CEF2-C-087 (A)	S-812	<100	152	<100	1610	<100	<100	<100	<100	<100
CEF2-C-087 (B)	S-812	<100	151	<100	1620	<100	<100	<100	<100	<100
CEF2-C-089	S834	<100	133	<10.0	1670	94.6	<100	<100	119	<10.0
CEF2-C-092	S835	<100	135	<10.0	1640	91.8	<100	<100	115	<10.0
CEF2-C-106	S836	<100	126	<10.0	1810	87.5	<100	<100	117	<10.0
CEF2-C-114	S837	<100	103	<10.0	1380	71.5	<100	<100	34.1	<10.0
CEF2-C-122	S838	<100	126	<10.0	1890	88.0	<100	<100	145	<10.0
CEF2-C-265 (A)	S-813	<100	154	<100	1800	115	<100	<100	<100	<100

Table A-30. Condensate Anions Set 2 (mg/L)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	$C_2H_3O_3$	SO_4	C_2O_4	HCO_2	PO_4
CEF2-C-265 (B)	S-813	<100	155	<100	1800	117	<100	<100	<100	<100
CEF2-C-140	S839	<100	145	<10.0	1880	116	<100	<100	216	<10.0
CEF2-C-176	S840	<100	160	<10.0	2200	120	<100	<100	348	<10.0
CEF2-C-211	S841	<100	152	<10.0	2730	113	<100	<100	274	<10.0
CEF2-C-213	S842	<100	154	<10.0	2470	111	<100	<100	267	<10.0
CEF2-C-236	S843	<100	163	<10.0	2230	126	<100	<100	204	<10.0
CEF2-C-242	S844	<100	174	<10.0	2310	132	<100	<100	213	<10.0
CEF2-C-257	S845	<100	179	<10.0	2190	139	<100	<100	187	<10.0
CEF2-C-260	S846	<100	179	<10.0	2350	136	<100	<100	180	<10.0
CEF2-C-261	S847	<100	188	<10.0	2190	141	<100	<100	180	<10.0
CEF2-C-266	S848	<100	192	<10.0	2180	144	<100	<100	176	<10.0
CEF2-C-270	S849	<100	191	<10.0	2130	144	<100	<100	168	<10.0
CEF2-C-274	S850	<100	218	<10.0	43.7	147	<100	<100	162	<10.0
CEF2-C-278	S851	<100	194	<10.0	2060	148	<100	<100	155	<10.0
CEF2-C-282	S852	<100	190	<10.0	2010	146	<100	<100	148	<10.0
CEF2-C-286	S853	<100	190	<10.0	1980	146	<100	<100	140	<10.0
CEF2-C-290	S854	<100	192	<10.0	1940	162	<100	<100	136	<10.0
CEF2-C-294	S855	<100	184	<10.0	1870	142	<100	<100	126	<10.0
CEF2-C-298	S856	<100	189	<10.0	1810	144	<100	<100	139	<10.0
CEF2-C-302	S857	<100	182	<10.0	1790	146	<100	<100	118	<10.0
CEF2-C-306	S858	<100	178	<10.0	1740	138	<100	<100	111	<10.0
CEF2-C-310	S859	<100	180	<10.0	1730	135	<100	<100	107	<10.0
CEF2-C-314	S860	<100	187	<10.0	1700	138	<100	<100	105	<10.0
CEF2-C-318	S861	<100	181	<10.0	25.3	135	<100	<100	98.1	<10.0
CEF2-C-322	S862	<100	180	<10.0	1620	138	<100	<100	95.7	<10.0
CEF2-C-327	S863	<100	177	<10.0	1750	134	<100	<100	88.2	<10.0
CEF2-C-331	S864	<100	177	<10.0	1570	132	<100	<100	85.6	<10.0
CEF2-C-335	S865	<100	178	<10.0	1550	133	<100	<100	82.5	<10.0

Table A-31. Condensate Anions Set 3 (mg/L)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	$C_2H_3O_3$	SO_4	C_2O_4	HCO_2	PO_4
CEF2-C-339	S866	<100	182	<10.0	1540	141	<100	<100	83.8	<10.0
CEF2-C-343	S867	<100	181	<10.0	1540	135	<100	<100	79.4	<10.0
CEF2-C-347	S868	<100	177	<10.0	1490	132	<100	<100	75.4	<10.0
CEF2-C-351	S869	<100	197	<10.0	1460	137	<100	<100	72.4	<10.0
CEF2-C-355	S870	<100	177	<10.0	1450	132	<100	<100	67.7	<10.0
CEF2-C-359	S871	<100	186	<10.0	1390	131	<100	<100	80.5	<10.0
CEF2-C-363	S872	<100	171	<10.0	1400	131	<100	<100	62.4	<10.0
CEF2-C-367	S873	<100	174	<10.0	1400	132	<100	<100	61.2	<10.0
CEF2-C-371	S874	<100	170	<10.0	1400	129	<100	<100	61.7	<10.0
CEF2-C-376	S875	<100	166	<10.0	1380	128	<100	<100	60.0	<10.0
CEF2-C-380	S876	<100	165	<10.0	1410	126	<100	<100	58.5	<10.0
CEF2-C-384	S877	<100	160	<10.0	1400	123	<100	<100	57.1	<10.0
CEF2-C-388	S878	<100	155	<10.0	1400	120	<100	<100	55.4	<10.0
CEF2-C-391	S879	<100	152	<10.0	1390	118	<100	<100	53.7	<10.0
CEF2-C-392	S880	<100	153	<10.0	1400	121	<100	<100	53.7	<10.0
CEF2-C-401	S881	<100	149	<10.0	1390	114	<100	<100	48.3	<10.0
CEF2-C-410	S882	<100	142	<10.0	1420	113	<100	<100	55.4	<10.0
CEF2-C-411	S883	<100	140	<10.0	1400	109	<100	<100	53.9	<10.0
CEF2-C-416	S884	<100	145	<10.0	1400	115	<100	<100	55.9	<10.0
CEF2-C-420	S885	<100	138	<10.0	1390	111	<100	<100	56.4	<10.0
CEF2-C-424	S886	<100	135	<10.0	1370	109	<100	<100	57.8	<10.0
CEF2-C-428	S887	<100	136	<10.0	1380	112	<100	<100	<10.0	<10.0
CEF2-C-432	S890	<100	134	<10.0	1400	108	<100	<100	64.3	<10.0
CEF2-C-436	S891	<100	135	<10.0	1410	109	<100	<100	66.7	<10.0
CEF2-C-440	S892	<100	139	<10.0	1410	111	<100	<100	69.8	<10.0
CEF2-C-445	S893	<100	146	<10.0	1450	115	<100	<100	79.5	<10.0
CEF2-C-486	S894	<100	139	<10.0	1620	98.2	<100	<100	96.9	<10.0

Table A-32. Condensate pH, Density and Total Solids Set 1

Sample ID	Lab ID	pH	Density (g/cm^3)	Total Solids
CEF2-C-035	S829	2.29	0.999	<0.10%
CEF2-C-036	S830	2.34	0.999	<0.10%
CEF2-C-040	S831	2.29	0.999	<0.10%
CEF2-C-049	S832	2.26	0.999	<0.10%
CEF2-C-058	S833	2.33	0.999	<0.10%
CEF2-C-073	S966	3.45	0.999	<0.10%
CEF2-C-079 (A)	S-805	4.64	1.00	0.21%
CEF2-C-079 (B)	S-805		1.00	0.13%
CEF2-C-080 (A)	S-806	3.63	1.00	0.19%
CEF2-C-080 (B)	S-806		1.00	0.13%
CEF2-C-081 (A)	S-807	3.53	1.00	0.26%
CEF2-C-081 (B)	S-807		1.00	0.17%
CEF2-C-082 (A)	S-808	3.48	1.00	<0.10%
CEF2-C-082 (B)	S-808		1.00	<0.10%
CEF2-C-083 (A)	S-809	3.40	1.00	0.18%
CEF2-C-083 (B)	S-809		1.00	0.17%
CEF2-C-084 (A)	S-810	3.39	1.00	0.17%
CEF2-C-084 (B)	S-810		1.00	<0.10%
CEF2-C-085 (A)	S-811	3.08	1.00	0.12%
CEF2-C-085 (B)	S-811		1.00	0.17%
CEF2-C-087 (A)	S-812	2.96	1.00	0.13%
CEF2-C-087 (B)	S-812		1.00	<0.10%
CEF2-C-089	S834	2.99	0.999	0.21%
CEF2-C-092	S835	2.99	0.999	0.23%
CEF2-C-106	S836	2.59	1.00	0.22%
CEF2-C-114	S837	2.29	0.999	<0.10%
CEF2-C-122	S838	2.77	1.00	<0.10%
CEF2-C-265 (A)	S-813	3.03	1.00	<0.10%
CEF2-C-265 (B)	S-813		1.00	0.13%
CEF2-C-140	S839	3.48	1.00	0.21%
CEF2-C-176	S840	2.69	1.00	0.35%
CEF2-C-211	S841	2.31	1.00	0.31%
CEF2-C-213	S842	2.31	1.00	0.37%
CEF2-C-236	S843	2.38	1.00	0.21%
CEF2-C-242	S844	2.67	1.00	0.35%
CEF2-C-257	S845	2.41	1.00	0.37%
CEF2-C-260	S846	2.40	1.00	0.36%
CEF2-C-261	S847	2.47	1.00	0.33%
CEF2-C-266	S848	2.48	1.00	0.32%
CEF2-C-270	S849	2.49	1.00	0.37%
CEF2-C-274	S850	2.50	1.00	0.47%

Table A-33. Condensate pH, Density and Total Solids Set 2

Sample ID	Lab ID	pH	Density (g/cm^3)	Total Solids
CEF2-C-278	S851	2.53	1.00	0.27%
CEF2-C-282	S852	2.54	1.00	0.30%
CEF2-C-286	S853	2.59	1.00	<0.10%
CEF2-C-290	S854	2.59	1.00	<0.10%
CEF2-C-294	S855	2.60	0.999	0.31%
CEF2-C-298	S856	2.65	0.999	0.37%
CEF2-C-302	S857	2.66	0.999	0.32%
CEF2-C-306	S858	2.50	0.999	0.36%
CEF2-C-310	S859	2.55	0.999	0.34%
CEF2-C-314	S860	2.71	0.999	0.32%
CEF2-C-318	S861	2.60	0.999	0.21%
CEF2-C-322	S862	2.74	0.999	0.32%
CEF2-C-327	S863	2.78	0.999	0.26%
CEF2-C-331	S864	2.83	0.999	0.37%
CEF2-C-335	S865	2.87	0.999	0.10%
CEF2-C-339	S866	2.83	0.999	0.26%
CEF2-C-343	S867	2.84	0.999	0.15%
CEF2-C-347	S868	2.93	0.999	0.31%
CEF2-C-351	S869	2.96	0.999	0.36%
CEF2-C-355	S870	2.97	0.999	0.32%
CEF2-C-359	S871	3.00	0.999	0.15%
CEF2-C-363	S872	3.01	0.999	0.32%
CEF2-C-367	S873	2.97	0.999	<0.10%
CEF2-C-371	S874	2.97	0.999	<0.10%
CEF2-C-376	S875	2.90	0.999	0.25%
CEF2-C-380	S876	2.84	0.999	0.21%
CEF2-C-384	S877	2.79	0.999	0.31%
CEF2-C-388	S878	2.74	0.999	0.26%
CEF2-C-391	S879	2.71	0.999	0.16%
CEF2-C-392	S880	2.68	0.999	0.24%
CEF2-C-401	S881	3.92	0.999	<0.10%
CEF2-C-410	S882	3.08	0.999	0.10%
CEF2-C-411	S883	3.28	0.999	<0.10%
CEF2-C-416	S884	3.59	0.999	<0.10%
CEF2-C-420	S885	3.99	0.999	0.10%
CEF2-C-424	S886	4.09	0.999	0.10%
CEF2-C-428	S887	4.10	0.999	<0.10%
CEF2-C-432	S890	4.13	0.999	<0.10%
CEF2-C-436	S891	4.19	0.999	0.15%
CEF2-C-440	S892	4.21	0.999	0.20%
CEF2-C-445	S893	4.27	0.999	0.20%
CEF2-C-486	S894	4.03	0.999	0.21%

Table A-34. Condensate TOC

Sample ID	TOC (ppm)
CEF2-C-035	13.19
CEF2-C-036	11.99
CEF2-C-040	14.46
CEF2-C-049	19.89
CEF2-C-058	38.06
CEF2-C-073	159.88
CEF2-C-079	167.89
CEF2-C-083	164.33
CEF2-C-087	158.96
CEF2-C-089	156.93
CEF2-C-092	161.66
CEF2-C-106	150.58
CEF2-C-114	43.68
CEF2-C-122	172.84
CEF2-C-265	209.11
CEF2-C-140	245.8
CEF2-C-176	284.16
CEF2-C-211	255
CEF2-C-213	250.61
CEF2-C-236	193.19
CEF2-C-242	198.93
CEF2-C-257	174.55
CEF2-C-260	168.18
CEF2-C-261	171.67

Sample ID	TOC (ppm)
CEF2-C-266	164.28
CEF2-C-270	160.57
CEF2-C-274	152.37
CEF2-C-278	147.19
CEF2-C-282	140.45
CEF2-C-286	135.44
CEF2-C-290	127.11
CEF2-C-294	123.33
CEF2-C-298	115.85
CEF2-C-302	111.57
CEF2-C-306	108.31
CEF2-C-310	106.12
CEF2-C-314	100.81
CEF2-C-318	98.12
CEF2-C-322	95.79
CEF2-C-327	91.46
CEF2-C-331	89.18
CEF2-C-335	87.63
CEF2-C-335	87.04
CEF2-C-335	76.24
CEF2-C-339	85.29
CEF2-C-343	83.76
CEF2-C-347	82.89
CEF2-C-351	80.8

Sample ID	TOC (ppm)
CEF2-C-351	79.93
CEF2-C-359	74.32
CEF2-C-363	72.35
CEF2-C-367	69.78
CEF2-C-371	66.9
CEF2-C-376	64.5
CEF2-C-380	63.69
CEF2-C-384	60.89
CEF2-C-388	59.27
CEF2-C-391	57.79
CEF2-C-392	57.42
CEF2-C-401	61
CEF2-C-410	71.45
CEF2-C-411	74.55
CEF2-C-416	79.41
CEF2-C-420	84.56
CEF2-C-424	90.76
CEF2-C-426	94.35
CEF2-C-432	96.89
CEF2-C-436	98.89
CEF2-C-440	102.47
CEF2-C-445	112.04
CEF2-C-486	131.23

Table A-35. Condensate Tank Solids Cations (mg/Kg)

Sample ID	Lab ID	Al	Ba	Ca	Cr	Cu	Fe	K	Li	Mg	Mn
Condensate Tank Solids (A)	S989	19600	185	698	124	413	101000	90.0	560	3190	21300
Condensate Tank Solids (B)	S989	19800	186	699	124	415	101000	91.0	560	3180	21300

Sample ID	Lab ID	Na	Ni	P	Pb	S	Si	Sn	Ti	Zn	Zr
Condensate Tank Solids (A)	S989	2240	12100	498	102	2040	856	55.0	160	512	15.0
Condensate Tank Solids (B)	S989	2260	12000	495	102	2050	844	55.0	160	515	15.2

Table A-36. Condensate Tank Solids Anions (mg/Kg)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	$C_2H_3O_3$	SO_4	C_2O_4	HCO_2	PO_4
Condensate Tank Solids (A)	S989	<100	618	112	5270	<100	495	<100	520	<100
Condensate Tank Solids (B)	S989	<100	625	113	5220	<100	495	<100	534	<100

Table A-37. Off-gas Filter Solids Summary

Sample ID	Lab ID	Date/Time In	Date/Time Out	Initial Weight (g)	Final Weight (g)	Solids Weight (g)	Test Conditions
CEF2-FL-B$	S967	2/24/14 11:36	2/26/14 4:09	59.5	116.5	57.0	125% feed, bubbled
CEF2-FL-C	S968	2/26/14 4:09	2/27/14 5:14	59.5	112.0	52.5	125% feed, bubbled
CEF2-FL-M	S969	2/27/14 5:14	2/27/04 18:15	61.6	72.5	10.9	125% feed, bubbled
CEF2-FL-A*	S970	2/27/14 18:15	2/28/14 1:05	59.2	65.5	6.3	125% feed, bubbled
CEF2-FL-Q	S971	2/28/14 1:05	2/28/14 16:47	60.3	90.0	29.7	125% feed, bubbled
CEF2-FL-A*	S970	2/28/14 16:47	2/28/14 20:05	59.2	65.5	6.3	125% feed, bubbled
CEF2-FL-G	S972	2/28/14 20:05	3/1/14 4:11	58.8	62.5	3.7	125% feed, non-bubbled
CEF2-FL-D	S973	3/1/14 4:11	3/2/14 4:40	62.5	91.5	29.0	125% feed, non-bubbled
CEF2-FL-E	S974	3/2/14 4:40	3/2/14 7:47	61.9	64.5	2.6	125% feed, non-bubbled
CEF2-FL-F	S975	3/2/14 7:47	3/4/14 6:20	61.6	92.0	30.4	100% feed, non-bubbled
CEF2-FL-H	S976	3/4/14 6:20	3/4/14 18:45	61.0	107.0	46.0	100% feed, non-bubbled
CEF2-FL-K	S977	3/4/14 18:45	3/6/14 2:00	59.0	119.0	60.0	100% feed, bubbled
CEF2-FL-L	S978	3/6/14 2:00	3/8/14 9:30	61.8	132.5	70.7	100% feed, bubbled
CEF2-FL-N	S979	3/8/14 9:30	3/9/14 14:03	58.5	103.0	44.5	100% feed, bubbled
CEF2-FL-P	S980	3/9/14 14:03	3/11/14 20:10	61.0	117.0	56.0	100% feed, bubbled
CEF2-FL-O	S981	3/11/14 20:10	3/13/14 20:01	62.3	130.0	67.7	100% feed, bubbled
CEF2-FL-U	S982	3/13/14 20:01	3/15/14 1:29	59.5	120.5	61.0	100% feed, bubbled
CEF2-FL-J	S983	3/15/14 1:29	3/16/14 16:00	58.0	105.5	47.5	100% feed, bubbled/non-bubbled
CEF2-FL-S	S984	3/16/14 16:00	3/19/14 10:31	61.6	150.0	88.4	various feeds, non-bubbled
CEF2-FL-T	S985	3/19/14 10:41	3/21/14 12:41	61.4	126.0	64.6	various feeds, non-bubbled
CEF2-FL-R	S986	---	---	58.0	58.5	0.5	various feeds, non-bubbled

$ Filter was also in place for the initial startup of Phase II in January 2014.
* Filter was not removed after initial use, so it was in service two separate times.

Table A-38. Off-gas Filter Solids Cations Set 1A

Sample ID	Lab ID	Al	B	Ba	Ca	Cr	Cu	Fe	K	Li	Mg
CEF2-FL-B	S-967a	6.45	0.477	0.058	0.267	0.366	0.101	23.7	0.030	0.593	0.888
CEF2-FL-B	S-967b	6.45	0.453	0.058	0.129	0.363	0.099	23.8	0.028	0.572	0.892
CEF2-FL-C	S-968a	5.83	0.362	0.056	0.333	0.244	0.114	25.6	0.020	0.411	0.937
CEF2-FL-C	S-968b	5.97	0.360	0.058	0.168	0.254	0.108	26.4	0.022	0.411	0.966
CEF2-FL-M	S-969a	4.31	1.43	0.041	0.067	0.097	0.039	11.2	0.053	1.82	0.204
CEF2-FL-M	S-969b	4.29	1.47	0.041	0.084	0.097	0.043	11.2	0.057	1.87	0.199
CEF2-FL-A	S-970a	4.32	1.47	0.036	0.098	0.100	0.033	10.8	0.051	1.87	0.147
CEF2-FL-A	S-970b	4.36	1.48	0.036	0.102	0.100	0.033	10.9	0.051	1.89	0.150
CEF2-FL-Q	S-971a	7.42	0.901	0.064	0.267	0.164	0.088	18.5	0.066	1.23	0.397
CEF2-FL-Q	S-971b	7.37	0.878	0.066	0.230	0.161	0.088	18.4	0.068	1.19	0.392
CEF2-FL-G	S-972a	4.09	1.57	0.038	0.157	0.087	0.045	9.86	0.070	2.11	0.115
CEF2-FL-G	S-972b	4.21	1.62	0.038	0.176	0.101	0.038	10.1	0.072	2.16	0.121
CEF2-FL-D	S-973a	5.71	1.16	0.052	0.202	0.144	0.089	16.4	0.052	1.52	0.363
CEF2-FL-D	S-973b	5.53	1.08	0.052	0.179	0.147	0.073	15.9	0.050	1.44	0.347
CEF2-FL-E	S-974a	3.39	1.71	0.035	0.139	0.074	0.116	7.39	0.043	2.25	0.076
CEF2-FL-E	S-974b	3.33	1.68	0.035	0.129	0.074	0.117	7.28	0.044	2.21	0.070
CEF2-FL-F	S-975a	2.86	1.51	0.032	0.133	0.075	0.045	7.57	0.061	2.01	0.085
CEF2-FL-F	S-975b	2.98	1.59	0.032	0.156	0.078	0.032	7.81	0.060	2.10	0.094
CEF2-FL-H	S-976a	5.27	1.40	0.049	0.420	0.081	0.183	9.88	0.101	1.95	0.198
CEF2-FL-H	S-976b	5.26	1.35	0.050	0.405	0.076	0.203	9.85	0.100	1.91	0.194
CEF2-FL-K	S-977a	6.26	0.593	0.066	0.178	0.175	0.078	17.5	0.038	0.750	0.346
CEF2-FL-K	S-977b	6.37	0.609	0.066	0.268	0.172	0.089	17.6	0.039	0.770	0.350
CEF2-FL-L	S-978a	4.98	0.389	0.071	0.250	0.221	0.089	20.8	0.027	0.422	0.541
CEF2-FL-L	S-978b	4.82	0.383	0.072	0.262	0.215	0.082	20.3	0.027	0.414	0.520
CEF2-FL-N	S-979a	4.06	0.841	0.054	0.198	0.176	0.136	17.4	0.028	1.12	0.477
CEF2-FL-N	S-979b	4.19	0.791	0.053	0.178	0.174	0.118	18.0	0.029	1.07	0.498
CEF2-FL-P	S-980a	4.65	0.325	0.065	0.169	0.221	0.089	25.7	0.022	0.386	0.801
CEF2-FL-P	S-980b	4.75	0.333	0.065	0.160	0.221	0.092	25.9	0.022	0.399	0.809

Table A-39. Off-gas Filter Solids Cations Set 1B

Lab ID	Mn	Na	Ni	P	S	Si	Sn	Ti	Zn	Zr
S-967a	6.38	1.67	3.39	<0.100	0.464	9.93	<0.100	0.061	0.123	0.144
S-967b	6.40	1.67	3.40	<0.100	0.454	9.86	<0.100	0.060	0.122	0.121
S-968a	6.26	1.16	3.58	<0.100	0.548	9.75	<0.100	0.065	0.129	0.087
S-968b	6.44	1.15	3.71	<0.100	0.564	9.72	<0.100	0.066	0.134	0.094
S-969a	2.27	4.53	1.35	<0.100	0.313	21.4	<0.100	0.032	0.050	0.119
S-969b	2.25	4.54	1.35	<0.100	0.313	21.7	<0.100	0.031	0.051	0.120
S-970a	2.16	4.58	1.26	<0.100	0.303	22.1	<0.100	0.029	0.045	0.113
S-970b	2.17	4.56	1.26	<0.100	0.305	22.1	<0.100	0.029	0.045	0.113
S-971a	4.00	3.94	2.00	<0.100	0.394	13.6	<0.100	0.047	0.072	0.121
S-971b	4.02	3.95	2.00	<0.100	0.405	13.8	<0.100	0.047	0.072	0.121
S-972a	2.04	5.80	1.03	<0.100	0.228	23.0	<0.100	0.025	0.039	0.109
S-972b	2.08	5.78	1.06	<0.100	0.227	22.8	<0.100	0.025	0.039	0.109
S-973a	3.73	3.84	1.85	<0.100	0.347	17.3	<0.100	0.037	0.065	0.126
S-973b	3.61	3.82	1.78	<0.100	0.366	17.4	<0.100	0.037	0.064	0.121
S-974a	1.75	5.58	0.870	<0.100	0.120	24.3	<0.100	0.020	0.036	0.115
S-974b	1.72	5.55	0.852	<0.100	0.123	24.2	<0.100	0.020	0.036	0.115
S-975a	1.62	5.29	0.882	<0.100	0.175	23.3	<0.100	0.024	0.034	0.087
S-975b	1.68	5.26	0.920	<0.100	0.168	23.5	<0.100	0.024	0.034	0.087
S-976a	2.67	6.77	1.10	<0.100	0.155	19.8	<0.100	0.026	0.066	0.121
S-976b	2.64	6.68	1.08	<0.100	0.162	19.8	<0.100	0.026	0.066	0.120
S-977a	4.02	2.56	2.02	<0.100	0.257	9.48	<0.100	0.040	0.074	0.107
S-977b	4.06	2.61	2.03	<0.100	0.254	9.50	<0.100	0.040	0.074	0.109
S-978a	4.81	1.36	2.70	<0.100	0.395	8.78	<0.100	0.055	0.098	0.093
S-978b	4.68	1.35	2.61	<0.100	0.392	8.85	<0.100	0.055	0.099	0.102
S-979a	3.88	2.43	2.31	<0.100	0.348	15.6	<0.100	0.050	0.100	0.094
S-979b	4.00	2.49	2.39	<0.100	0.350	16.0	<0.100	0.049	0.099	0.094
S-980a	5.82	1.17	3.37	<0.100	0.507	9.83	<0.100	0.072	0.127	0.085
S-980b	5.88	1.20	3.41	<0.100	0.495	9.83	<0.100	0.074	0.127	0.088

Table A-40. Off-gas Filter Solids Cations Set 2A

Sample ID	Lab ID	Al	B	Ba	Ca	Cr	Cu	Fe	K	Li	Mg
CEF2-FL-O	S-981a	3.75	0.250	0.055	0.115	0.213	0.089	26.4	0.022	0.307	0.740
CEF2-FL-O	S-981b	3.74	0.252	0.055	0.146	0.209	0.089	26.4	0.021	0.304	0.741
CEF2-FL-U	S-982a	4.94	0.239	0.064	0.167	0.212	0.095	26.7	0.027	0.292	0.753
CEF2-FL-U	S-982b	4.96	0.271	0.065	0.150	0.209	0.092	27.2	0.026	0.331	0.765
CEF2-FL-J	S-983a	4.00	0.513	0.061	0.117	0.238	0.095	21.9	0.041	0.652	0.615
CEF2-FL-J	S-983b	4.04	0.473	0.059	0.092	0.225	0.091	21.8	0.038	0.598	0.605
CEF2-FL-S	S-984a	4.35	0.350	0.056	0.245	0.197	0.101	18.7	0.081	0.246	0.463
CEF2-FL-S	S-984b	4.39	0.344	0.054	0.213	0.199	0.102	18.9	0.079	0.236	0.469
CEF2-FL-T	S-985a	5.06	0.648	0.055	0.180	0.268	0.087	18.2	0.056	0.723	0.454
CEF2-FL-T	S-985b	4.92	0.570	0.056	0.151	0.283	0.089	17.9	0.059	0.624	0.444
CEF2-FL-R	*not enough sample for analysis*										

Table A-41. Off-gas Filter Solids Cations Set 2B

Sample ID	Lab ID	Mn	Na	Ni	P	S	Si	Sn	Ti	Zn	Zr
CEF2-FL-O	S-981a	6.15	0.982	3.17	<0.100	0.468	10.8	<0.100	0.069	0.116	0.070
CEF2-FL-O	S-981b	6.15	0.986	3.17	<0.100	0.453	10.8	<0.100	0.069	0.115	0.068
CEF2-FL-U	S-982a	6.64	1.16	3.15	<0.100	0.469	8.67	<0.100	0.066	0.116	0.087
CEF2-FL-U	S-982b	6.77	1.17	3.24	<0.100	0.486	8.70	<0.100	0.065	0.118	0.066
CEF2-FL-J	S-983a	5.22	1.69	2.70	<0.100	0.463	12.4	<0.100	0.059	0.108	0.097
CEF2-FL-J	S-983b	5.18	1.75	2.69	<0.100	0.445	12.9	<0.100	0.057	0.103	0.096
CEF2-FL-S	S-984a	4.80	1.84	2.29	<0.100	0.336	13.2	<0.100	0.050	0.095	0.063
CEF2-FL-S	S-984b	4.85	1.87	2.32	<0.100	0.332	13.2	<0.100	0.048	0.093	0.063
CEF2-FL-T	S-985a	4.55	2.26	2.27	<0.100	0.346	13.3	<0.100	0.049	0.093	0.087
CEF2-FL-T	S-985b	4.48	2.28	2.22	<0.100	0.351	13.8	<0.100	0.050	0.097	0.088
CEF2-FL-R	*not enough sample for analysis*										

Table A-42. Off-gas Filter Solids Total Solids

Sample ID	Lab ID	Total Solids
CEF2-FL-B	S-967	96.0%
CEF2-FL-C	S-968	95.6%
CEF2-FL-M	S-969	97.3%
CEF2-FL-A	S-970	96.7%
CEF2-FL-Q	S-971	97.0%
CEF2-FL-G	S-972	98.3%
CEF2-FL-D	S-973	96.7%
CEF2-FL-E	S-974	98.1%
CEF2-FL-F	S-975	98.5%
CEF2-FL-H	S-976	99.0%
CEF2-FL-K	S-977	97.7%
CEF2-FL-L	S-978	96.9%
CEF2-FL-N	S-979	96.2%
CEF2-FL-P	S-980	95.6%
CEF2-FL-O	S-981	95.6%
CEF2-FL-U	S-982	95.7%
CEF2-FL-J	S-983	95.5%
CEF2-FL-S	S-984	96.3%
CEF2-FL-T	S-985	95.9%
CEF2-FL-R	*not enough sample for analysis*	

Table A-43. ICP-AES Glass Analysis (wt%) Set 1A

Lab ID	Collection Date	Collection Time	Al	B	Ba	Ca	Cr	Cu	Fe	K	Li	Mg
S-896a	2/26/2014	8:55	4.96	1.60	0.052	0.427	0.074	0.063	7.38	0.119	2.39	0.343
S-896b	2/26/2014	8:55	5.02	1.57	0.053	0.435	0.075	0.058	7.44	0.118	2.35	0.344
S-903a	2/28/2014	15:32	5.10	1.54	0.054	0.443	0.075	0.056	7.46	0.119	2.33	0.351
S-903b	2/28/2014	15:32	5.00	1.56	0.052	0.416	0.069	0.053	7.41	0.117	2.33	0.341
S-908a	3/2/2014	6:32	5.01	1.55	0.052	0.421	0.073	0.136	7.43	0.119	2.31	0.343
S-908b	3/2/2014	6:32	5.04	1.55	0.052	0.428	0.074	0.130	7.47	0.119	2.33	0.345
S-915a	3/4/2014	4:26	4.84	1.51	0.052	0.408	0.070	0.050	7.39	0.116	2.31	0.340
S-915b	3/4/2014	4:26	4.86	1.58	0.052	0.411	0.076	0.060	7.43	0.117	2.34	0.342
S-927a	3/8/2014	6:05	4.85	1.54	0.054	0.454	0.080	0.191	7.58	0.118	2.32	0.349
S-927b	3/8/2014	6:05	4.91	1.55	0.054	0.451	0.075	0.197	7.68	0.119	2.30	0.352
S-931a	3/9/2014	7:15	4.75	1.55	0.052	0.402	0.076	0.095	7.46	0.114	2.31	0.338
S-931b	3/9/2014	7:15	4.71	1.52	0.053	0.409	0.075	0.124	7.39	0.116	2.32	0.339
S-932a	3/10/2014	8:00	4.82	1.51	0.053	0.418	0.074	0.052	7.53	0.117	2.31	0.348
S-932b	3/10/2014	8:00	4.86	1.53	0.053	0.422	0.074	0.053	7.59	0.117	2.34	0.348
S-934a	3/11/2014	9:18	4.93	1.50	0.053	0.424	0.074	0.102	7.75	0.118	2.27	0.348
S-934b	3/11/2014	9:18	4.81	1.50	0.053	0.424	0.074	0.116	7.41	0.117	2.27	0.347
S-937a	3/12/2014	10:30	4.77	1.50	0.053	0.416	0.074	0.191	7.52	0.119	2.28	0.345
S-937b	3/12/2014	10:30	4.81	1.49	0.053	0.414	0.073	0.206	7.60	0.118	2.30	0.345
S-940a	3/13/2014	10:32	4.90	1.48	0.054	0.425	0.078	0.063	7.67	0.120	2.26	0.349
S-940b	3/13/2014	10:32	4.94	1.45	0.057	0.497	0.073	0.066	7.73	0.118	2.27	0.354
S-942a	3/14/2014	9:17	4.80	1.44	0.053	0.420	0.074	0.071	7.53	0.121	2.23	0.348
S-942b	3/14/2014	9:17	4.78	1.46	0.053	0.419	0.076	0.073	7.54	0.121	2.29	0.348
S-945a	3/15/2014	9:35	4.80	1.51	0.053	0.410	0.072	0.092	7.50	0.121	2.30	0.345
S-945b	3/15/2014	9:35	4.83	1.50	0.053	0.408	0.077	0.093	7.53	0.121	2.30	0.344

Table A-44. ICP-AES Glass Analysis Set 1B (wt%)

Lab ID	Collection Date	Collection Time	Mn	Na	Ni	P	S	Si	Sn	Ti	Zn	Zr
S-896a	2/26/2014	8:55	2.42	8.73	1.03	<0.100	0.126	24.1	<0.100	0.025	0.043	0.101
S-896b	2/26/2014	8:55	2.44	8.69	1.04	<0.100	0.130	23.6	<0.100	0.025	0.042	0.101
S-903a	2/28/2014	15:32	2.44	8.89	1.03	<0.100	0.131	23.2	<0.100	0.025	0.042	0.102
S-903b	2/28/2014	15:32	2.43	8.58	1.02	<0.100	0.134	23.4	<0.100	0.025	0.043	0.100
S-908a	3/2/2014	6:32	2.43	8.55	1.02	<0.100	0.134	23.2	<0.100	0.025	0.043	0.101
S-908b	3/2/2014	6:32	2.44	8.67	1.03	<0.100	0.132	23.5	<0.100	0.025	0.043	0.101
S-915a	3/4/2014	4:26	2.42	8.55	1.03	<0.100	0.131	23.1	<0.100	0.025	0.042	0.099
S-915b	3/4/2014	4:26	2.43	8.67	1.04	<0.100	0.130	23.4	<0.100	0.025	0.042	0.099
S-927a	3/8/2014	6:05	2.51	8.39	1.07	<0.100	0.137	23.3	<0.100	0.026	0.044	0.109
S-927b	3/8/2014	6:05	2.51	8.54	1.08	<0.100	0.136	23.0	<0.100	0.025	0.044	0.109
S-931a	3/9/2014	7:15	2.44	8.48	1.07	<0.100	0.126	23.2	<0.100	0.024	0.042	0.102
S-931b	3/9/2014	7:15	2.43	8.46	1.05	<0.100	0.127	23.2	<0.100	0.025	0.043	0.103
S-932a	3/10/2014	8:00	2.45	8.52	1.06	<0.100	0.133	23.1	<0.100	0.025	0.043	0.105
S-932b	3/10/2014	8:00	2.50	8.58	1.07	<0.100	0.129	23.4	<0.100	0.025	0.045	0.104
S-934a	3/11/2014	9:18	2.53	8.62	1.09	<0.100	0.133	23.1	<0.100	0.025	0.043	0.103
S-934b	3/11/2014	9:18	2.43	8.37	1.04	<0.100	0.138	23.0	<0.100	0.025	0.043	0.103
S-937a	3/12/2014	10:30	2.49	8.51	1.06	<0.100	0.134	23.1	<0.100	0.025	0.043	0.104
S-937b	3/12/2014	10:30	2.49	8.55	1.07	<0.100	0.134	23.1	<0.100	0.025	0.043	0.104
S-940a	3/13/2014	10:32	2.50	8.54	1.07	<0.100	0.136	23.0	<0.100	0.025	0.043	0.104
S-940b	3/13/2014	10:32	2.53	8.73	1.08	<0.100	0.137	22.9	<0.100	0.025	0.043	0.104
S-942a	3/14/2014	9:17	2.50	8.58	1.07	<0.100	0.136	22.7	<0.100	0.025	0.043	0.103
S-942b	3/14/2014	9:17	2.47	8.54	1.06	<0.100	0.134	23.0	<0.100	0.025	0.043	0.103
S-945a	3/15/2014	9:35	2.45	8.48	1.04	<0.100	0.131	23.3	<0.100	0.025	0.043	0.104
S-945b	3/15/2014	9:35	2.46	8.41	1.06	<0.100	0.137	23.3	<0.100	0.025	0.043	0.103

Table A-45. ICP-AES Glass Analysis Set 2A (wt%)

Lab ID	Collection Date	Collection Time	Al	B	Ba	Ca	Cr	Cu	Fe	K	Li	Mg
S-948a	3/16/2014	11:04	4.87	1.50	0.053	0.410	0.076	0.072	7.64	0.121	2.31	0.345
S-948b	3/16/2014	11:04	4.81	1.49	0.053	0.411	0.109	0.075	7.56	0.122	2.29	0.346
S-951a	3/17/2014	12:25	4.92	1.48	0.054	0.422	0.070	0.057	7.69	0.127	2.25	0.354
S-951b	3/17/2014	12:25	4.88	1.47	0.054	0.421	0.075	0.055	7.62	0.127	2.24	0.354
S-955a	3/18/2014	20:37	4.81	1.50	0.053	0.407	0.070	0.057	7.53	0.123	2.30	0.345
S-955b	3/18/2014	20:37	4.79	1.50	0.053	0.410	0.074	0.056	7.47	0.124	2.28	0.344
S-959a	3/20/2014	2:48	4.84	1.47	0.053	0.466	0.074	0.050	7.52	0.125	2.32	0.348
S-959b	3/20/2014	2:48	4.85	1.48	0.053	0.418	0.071	0.052	7.52	0.125	2.34	0.350
S-962a	3/20/2014	20:13	4.86	1.48	0.053	0.423	0.069	0.102	7.49	0.124	2.30	0.351
S-962b	3/20/2014	20:13	4.90	1.49	0.053	0.421	0.068	0.113	7.56	0.123	2.35	0.350

Table A-46. ICP-AES Glass Analysis Set 2B (wt%)

Lab ID	Collection Date	Collection Time	Mn	Na	Ni	P	S	Si	Sn	Ti	Zn	Zr
S-948a	3/16/2014	11:04	2.51	8.67	1.07	<0.100	0.135	23.3	<0.100	0.025	0.043	0.101
S-948b	3/16/2014	11:04	2.49	8.63	1.33	<0.100	0.137	23.2	<0.100	0.025	0.044	0.101
S-951a	3/17/2014	12:25	2.51	8.63	1.06	<0.100	0.145	22.8	<0.100	0.025	0.044	0.105
S-951b	3/17/2014	12:25	2.48	8.66	1.05	<0.100	0.138	22.8	<0.100	0.025	0.044	0.105
S-955a	3/18/2014	20:37	2.47	8.50	1.05	<0.100	0.135	23.3	<0.100	0.025	0.043	0.102
S-955b	3/18/2014	20:37	2.47	8.44	1.09	<0.100	0.137	23.1	<0.100	0.025	0.043	0.102
S-959a	3/20/2014	2:48	2.48	8.55	1.05	<0.100	0.139	23.1	<0.100	0.025	0.044	0.102
S-959b	3/20/2014	2:48	2.47	8.62	1.06	<0.100	0.138	23.4	<0.100	0.025	0.043	0.102
S-962a	3/20/2014	20:13	2.50	8.49	1.04	<0.100	0.140	23.1	<0.100	0.025	0.043	0.103
S-962b	3/20/2014	20:13	2.49	8.46	1.05	<0.100	0.139	23.7	<0.100	0.025	0.043	0.103

Table A-47. Glass REDOX Set 1

Sample ID	Lab ID	Collection Date	Collection Time	Fe^{2+}	Fe^{3+}	∑Fe	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
EA	EA	---	---	0.082	0.368	0.450	0.223	0.182
CEF2-GL-001 (A)	S-896	2/26/2014	8:55	0.027	0.471	0.498	0.057	0.054
CEF2-GL-001 (B)	S-896	2/26/2014	8:55	0.026	0.470	0.496	0.055	0.052
CEF2-GL-003 (A)	S-897	2/26/2014	19:05	0.023	0.433	0.456	0.053	0.050
CEF2-GL-003 (B)	S-897	2/26/2014	19:05	0.024	0.432	0.456	0.056	0.053
CEF2-GL-004 (A)	S-898	2/26/2014	23:00	0.016	0.412	0.428	0.039	0.037
CEF2-GL-004 (B)	S-898	2/26/2014	23:00	0.018	0.410	0.428	0.044	0.042
CEF2-GL-006 (A)	S-899	2/27/2014	7:00	0.020	0.463	0.483	0.043	0.041
CEF2-GL-006 (B)	S-899	2/27/2014	7:00	0.019	0.463	0.482	0.041	0.039
CEF2-GL-008 (A)	S-900	2/27/2014	15:00	0.016	0.497	0.513	0.032	0.031
CEF2-GL-008 (B)	S-900	2/27/2014	15:00	0.016	0.497	0.513	0.032	0.031
CEF2-GL-010 (A)	S-901	2/27/2014	23:50	0.020	0.477	0.497	0.042	0.040
CEF2-GL-010 (B)	S-901	2/27/2014	23:50	0.019	0.477	0.496	0.040	0.038
CEF2-GL-012 (A)	S-902	2/28/2014	8:12	0.018	0.517	0.535	0.035	0.034
CEF2-GL-012 (B)	S-902	2/28/2014	8:12	0.019	0.517	0.536	0.037	0.035
CEF2-GL-013 (A)	S-903	2/28/2014	15:32	0.015	0.611	0.626	0.025	0.024
CEF2-GL-013 (B)	S-903	2/28/2014	15:32	0.015	0.613	0.628	0.024	0.024
CEF2-GL-014 (A)	S-904	2/28/2014	21:25	0.012	0.494	0.506	0.024	0.024
CEF2-GL-014 (B)	S-904	2/28/2014	21:25	0.012	0.495	0.507	0.024	0.024
CEF2-GL-016 (A)	S-905	3/1/2014	5:25	0.011	0.468	0.479	0.024	0.023
CEF2-GL-016 (B)	S-905	3/1/2014	5:25	0.012	0.467	0.479	0.026	0.025
CEF2-GL-018 (A)	S-906	3/1/2014	13:47	0.012	0.603	0.615	0.020	0.020
CEF2-GL-018 (B)	S-906	3/1/2014	13:47	0.012	0.602	0.614	0.020	0.020
CEF2-GL-020 (A)	S-907	3/1/2014	21:30	0.013	0.555	0.568	0.023	0.023
CEF2-GL-020 (B)	S-907	3/1/2014	21:30	0.015	0.554	0.569	0.027	0.026
CEF2-GL-022 (A)	S-908	3/2/2014	6:32	0.010	0.615	0.625	0.016	0.016
CEF2-GL-022 (B)	S-908	3/2/2014	6:32	0.010	0.615	0.625	0.016	0.016

Table A-48. Glass REDOX Set 2

Sample ID	Lab ID	Collection Date	Collection Time	Fe^{2+}	Fe^{3+}	$\sum Fe$	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
CEF2-GL-024 (A)	S-909	3/2/2014	14:20	0.010	0.594	0.604	0.017	0.017
CEF2-GL-024 (B)	S-909	3/2/2014	14:20	0.010	0.594	0.604	0.017	0.017
CEF2-GL-026 (A)	S-910	3/2/2014	22:40	<0.010	0.575	0.575	All Fe^{3+}	All Fe^{3+}
CEF2-GL-026 (B)	S-910	3/2/2014	22:40	<0.010	0.575	0.575	All Fe^{3+}	All Fe^{3+}
CEF2-GL-027 (A)	S-911	3/3/2014	2:41	<0.010	0.490	0.490	All Fe^{3+}	All Fe^{3+}
CEF2-GL-027 (B)	S-911	3/3/2014	2:41	<0.010	0.492	0.492	All Fe^{3+}	All Fe^{3+}
CEF2-GL-029 (A)	S-912	3/3/2014	10:36	<0.010	0.580	0.580	All Fe^{3+}	All Fe^{3+}
CEF2-GL-029 (B)	S-912	3/3/2014	10:36	<0.010	0.582	0.582	All Fe^{3+}	All Fe^{3+}
CEF2-GL-031 (A)	S-913	3/3/2014	20:00	<0.010	0.526	0.526	All Fe^{3+}	All Fe^{3+}
CEF2-GL-031 (B)	S-913	3/3/2014	20:00	<0.010	0.527	0.527	All Fe^{3+}	All Fe^{3+}
CEF2-GL-032 (A)	S-914	3/4/2014	0:15	<0.010	0.603	0.603	All Fe^{3+}	All Fe^{3+}
CEF2-GL-032 (B)	S-914	3/4/2014	0:15	<0.010	0.604	0.604	All Fe^{3+}	All Fe^{3+}
CEF2-GL-033 (A)	S-915	3/4/2014	4:26	<0.010	0.535	0.535	All Fe^{3+}	All Fe^{3+}
CEF2-GL-033 (B)	S-915	3/4/2014	4:26	<0.010	0.536	0.536	All Fe^{3+}	All Fe^{3+}
CEF2-GL-034 (A)	S-916	3/4/2014	8:33	<0.010	0.517	0.517	All Fe^{3+}	All Fe^{3+}
CEF2-GL-034 (B)	S-916	3/4/2014	8:33	<0.010	0.516	0.516	All Fe^{3+}	All Fe^{3+}
CEF2-GL-036 (A)	S-917	3/4/2014	21:14	<0.010	0.512	0.512	All Fe^{3+}	All Fe^{3+}
CEF2-GL-036 (B)	S-917	3/4/2014	21:14	<0.010	0.510	0.510	All Fe^{3+}	All Fe^{3+}
CEF2-GL-038 (A)	S-918	3/5/2014	5:10	<0.010	0.545	0.545	All Fe^{3+}	All Fe^{3+}
CEF2-GL-038 (B)	S-918	3/5/2014	5:10	<0.010	0.547	0.547	All Fe^{3+}	All Fe^{3+}
CEF2-GL-040 (A)	S-919	3/5/2014	13:26	<0.010	0.495	0.495	All Fe^{3+}	All Fe^{3+}
CEF2-GL-040 (B)	S-919	3/5/2014	13:26	<0.010	0.496	0.496	All Fe^{3+}	All Fe^{3+}

Table A-49. Glass REDOX Set 3

Sample ID	Lab ID	Collection Date	Collection Time	Fe^{2+}	Fe^{3+}	$\sum Fe$	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
CEF2-GL-042 (A)	S-920	3/5/2014	21:32	<0.010	0.512	0.512	All Fe^{3+}	All Fe^{3+}
CEF2-GL-042 (B)	S-920	3/5/2014	21:32	<0.010	0.510	0.510	All Fe^{3+}	All Fe^{3+}
CEF2-GL-044 (A)	S-921	3/6/2014	5:30	<0.010	0.467	0.467	All Fe^{3+}	All Fe^{3+}
CEF2-GL-044 (B)	S-921	3/6/2014	5:30	<0.010	0.464	0.464	All Fe^{3+}	All Fe^{3+}
CEF2-GL-046 (A)	S-922	3/6/2014	13:28	<0.010	0.523	0.523	All Fe^{3+}	All Fe^{3+}
CEF2-GL-046 (B)	S-922	3/6/2014	13:28	<0.010	0.523	0.523	All Fe^{3+}	All Fe^{3+}
CEF2-GL-048 (A)	S-923	3/6/2014	21:30	<0.010	0.504	0.504	All Fe^{3+}	All Fe^{3+}
CEF2-GL-048 (B)	S-923	3/6/2014	21:30	<0.010	0.504	0.504	All Fe^{3+}	All Fe^{3+}
CEF2-GL-050 (A)	S-924	3/7/2014	5:32	<0.010	0.552	0.552	All Fe^{3+}	All Fe^{3+}
CEF2-GL-050 (B)	S-924	3/7/2014	5:32	<0.010	0.551	0.551	All Fe^{3+}	All Fe^{3+}
CEF2-GL-052 (A)	S-925	3/7/2014	14:07	<0.010	0.489	0.489	All Fe^{3+}	All Fe^{3+}
CEF2-GL-052 (B)	S-925	3/7/2014	14:07	<0.010	0.490	0.490	All Fe^{3+}	All Fe^{3+}
CEF2-GL-054 (A)	S-926	3/7/2014	22:07	<0.010	0.539	0.539	All Fe^{3+}	All Fe^{3+}
CEF2-GL-054 (B)	S-926	3/7/2014	22:07	<0.010	0.540	0.540	All Fe^{3+}	All Fe^{3+}
CEF2-GL-056 (A)	S-927	3/8/2014	6:05	<0.010	0.488	0.488	All Fe^{3+}	All Fe^{3+}
CEF2-GL-056 (B)	S-927	3/8/2014	6:05	<0.010	0.490	0.490	All Fe^{3+}	All Fe^{3+}
CEF2-GL-058 (A)	S-928	3/8/2014	14:06	<0.010	0.451	0.451	All Fe^{3+}	All Fe^{3+}
CEF2-GL-058 (B)	S-928	3/8/2014	14:06	<0.010	0.451	0.451	All Fe^{3+}	All Fe^{3+}
CEF2-GL-060 (A)	S-929	3/8/2014	22:09	<0.010	0.526	0.526	All Fe^{3+}	All Fe^{3+}
CEF2-GL-060 (B)	S-929	3/8/2014	22:09	<0.010	0.527	0.527	All Fe^{3+}	All Fe^{3+}
CEF2-GL-061 (A)	S-930	3/9/2014	3:30	<0.010	0.479	0.479	All Fe^{3+}	All Fe^{3+}
CEF2-GL-061 (B)	S-930	3/9/2014	3:30	<0.010	0.476	0.476	All Fe^{3+}	All Fe^{3+}

Table A-50. Glass REDOX Set 4

Sample ID	Lab ID	Collection Date	Collection Time	Fe^{2+}	Fe^{3+}	$\sum Fe$	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
EA	EA	---	---	0.083	0.365	0.448	0.227	0.185
CEF2-GL-062 (A)	S-931	3/9/2014	7:15	<0.010	0.545	0.545	All Fe^{3+}	All Fe^{3+}
CEF2-GL-062 (B)	S-931	3/9/2014	7:15	<0.010	0.548	0.548	All Fe^{3+}	All Fe^{3+}
CEF2-GL-063 (A)	S-932	3/10/2014	8:00	<0.010	0.544	0.544	All Fe^{3+}	All Fe^{3+}
CEF2-GL-063 (B)	S-932	3/10/2014	8:00	<0.010	0.545	0.545	All Fe^{3+}	All Fe^{3+}
CEF2-GL-064 (A)	S-933	3/10/2014	11:59	<0.010	0.460	0.460	All Fe^{3+}	All Fe^{3+}
CEF2-GL-064 (B)	S-933	3/10/2014	11:59	<0.010	0.459	0.459	All Fe^{3+}	All Fe^{3+}
CEF2-GL-065 (A)	S-934	3/11/2014	9:18	<0.010	0.457	0.457	All Fe^{3+}	All Fe^{3+}
CEF2-GL-065 (B)	S-934	3/11/2014	9:18	<0.010	0.458	0.458	All Fe^{3+}	All Fe^{3+}
CEF2-GL-067 (A)	S-935	3/11/2014	17:20	<0.010	0.475	0.475	All Fe^{3+}	All Fe^{3+}
CEF2-GL-067 (B)	S-935	3/11/2014	17:20	<0.010	0.477	0.477	All Fe^{3+}	All Fe^{3+}
CEF2-GL-069 (A)	S-936	3/12/2014	2:30	<0.010	0.509	0.509	All Fe^{3+}	All Fe^{3+}
CEF2-GL-069 (B)	S-936	3/12/2014	2:30	<0.010	0.509	0.509	All Fe^{3+}	All Fe^{3+}
CEF2-GL-071 (A)	S-937	3/12/2014	10:30	<0.010	0.437	0.437	All Fe^{3+}	All Fe^{3+}
CEF2-GL-071 (B)	S-937	3/12/2014	10:30	<0.010	0.440	0.440	All Fe^{3+}	All Fe^{3+}
CEF2-GL-073 (A)	S-938	3/12/2014	18:30	<0.010	0.461	0.461	All Fe^{3+}	All Fe^{3+}
CEF2-GL-073 (B)	S-938	3/12/2014	18:30	<0.010	0.462	0.462	All Fe^{3+}	All Fe^{3+}
CEF2-GL-075 (A)	S-939	3/13/2014	2:40	<0.010	0.458	0.458	All Fe^{3+}	All Fe^{3+}
CEF2-GL-075 (B)	S-939	3/13/2014	2:40	<0.010	0.457	0.457	All Fe^{3+}	All Fe^{3+}
CEF2-GL-077 (A)	S-940	3/13/2014	10:32	<0.010	0.484	0.484	All Fe^{3+}	All Fe^{3+}
CEF2-GL-077 (B)	S-940	3/13/2014	10:32	<0.010	0.485	0.485	All Fe^{3+}	All Fe^{3+}
CEF2-GL-079 (A)	S-941	3/13/2014	18:35	<0.010	0.487	0.487	All Fe^{3+}	All Fe^{3+}
CEF2-GL-079 (B)	S-941	3/13/2014	18:35	<0.010	0.486	0.486	All Fe^{3+}	All Fe^{3+}

Table A-51. Glass REDOX Set 5

Sample ID	Lab ID	Collection Date	Collection Time	Fe^{2+}	Fe^{3+}	∑Fe	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
CEF2-GL-081 (A)	S-942	3/14/2014	9:17	<0.010	0.479	0.479	All Fe^{3+}	All Fe^{3+}
CEF2-GL-081 (B)	S-942	3/14/2014	9:17	<0.010	0.480	0.480	All Fe^{3+}	All Fe^{3+}
CEF2-GL-083 (A)	S-943	3/14/2014	17:30	<0.010	0.467	0.467	All Fe^{3+}	All Fe^{3+}
CEF2-GL-083 (B)	S-943	3/14/2014	17:30	<0.010	0.467	0.467	All Fe^{3+}	All Fe^{3+}
CEF2-GL-085 (A)	S-944	3/15/2014	1:25	<0.010	0.539	0.539	All Fe^{3+}	All Fe^{3+}
CEF2-GL-085 (B)	S-944	3/15/2014	1:25	<0.010	0.541	0.541	All Fe^{3+}	All Fe^{3+}
CEF2-GL-087 (A)	S-945	3/15/2014	9:35	<0.010	0.451	0.451	All Fe^{3+}	All Fe^{3+}
CEF2-GL-087 (B)	S-945	3/15/2014	9:35	<0.010	0.452	0.452	All Fe^{3+}	All Fe^{3+}
CEF2-GL-089 (A)	S-946	3/15/2014	18:24	<0.010	0.497	0.497	All Fe^{3+}	All Fe^{3+}
CEF2-GL-089 (B)	S-946	3/15/2014	18:24	<0.010	0.498	0.498	All Fe^{3+}	All Fe^{3+}
CEF2-GL-091 (A)	S-947	3/16/2014	2:32	<0.010	0.494	0.494	All Fe^{3+}	All Fe^{3+}
CEF2-GL-091 (B)	S-947	3/16/2014	2:32	<0.010	0.495	0.495	All Fe^{3+}	All Fe^{3+}
CEF2-GL-093 (A)	S-948	3/16/2014	11:04	<0.010	0.468	0.468	All Fe^{3+}	All Fe^{3+}
CEF2-GL-093 (B)	S-948	3/16/2014	11:04	<0.010	0.468	0.468	All Fe^{3+}	All Fe^{3+}
CEF2-GL-094 (A)	S-949	3/16/2014	18:23	<0.010	0.514	0.514	All Fe^{3+}	All Fe^{3+}
CEF2-GL-094 (B)	S-949	3/16/2014	18:23	<0.010	0.515	0.515	All Fe^{3+}	All Fe^{3+}
CEF2-GL-096 (A)	S-950	3/17/2014	4:27	<0.010	0.471	0.471	All Fe^{3+}	All Fe^{3+}
CEF2-GL-096 (B)	S-950	3/17/2014	4:27	<0.010	0.473	0.473	All Fe^{3+}	All Fe^{3+}
CEF2-GL-098 (A)	S-951	3/17/2014	12:25	<0.010	0.573	0.573	All Fe^{3+}	All Fe^{3+}
CEF2-GL-098 (B)	S-951	3/17/2014	12:25	<0.010	0.572	0.572	All Fe^{3+}	All Fe^{3+}
CEF2-GL-100 (A)	S-952	3/17/2014	20:31	<0.010	0.496	0.496	All Fe^{3+}	All Fe^{3+}
CEF2-GL-100 (B)	S-952	3/17/2014	20:31	<0.010	0.496	0.496	All Fe^{3+}	All Fe^{3+}

Table A-52. Glass REDOX Set 6

Sample ID	Lab ID	Collection Date	Collection Time	Fe^{2+}	Fe^{3+}	∑Fe	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
CEF2-GL-102 (A)	S-953	3/18/2014	4:40	<0.010	0.573	0.573	All Fe^{3+}	All Fe^{3+}
CEF2-GL-102 (B)	S-953	3/18/2014	4:40	<0.010	0.572	0.572	All Fe^{3+}	All Fe^{3+}
CEF2-GL-104 (A)	S-954	3/18/2014	12:25	<0.010	0.493	0.493	All Fe^{3+}	All Fe^{3+}
CEF2-GL-104 (B)	S-954	3/18/2014	12:25	<0.010	0.494	0.494	All Fe^{3+}	All Fe^{3+}
CEF2-GL-106 (A)	S-955	3/18/2014	20:37	<0.010	0.533	0.533	All Fe^{3+}	All Fe^{3+}
CEF2-GL-106 (B)	S-955	3/18/2014	20:37	<0.010	0.534	0.534	All Fe^{3+}	All Fe^{3+}
CEF2-GL-108 (A)	S-956	3/19/2014	6:25	<0.010	0.449	0.449	All Fe^{3+}	All Fe^{3+}
CEF2-GL-108 (B)	S-956	3/19/2014	6:25	<0.010	0.450	0.450	All Fe^{3+}	All Fe^{3+}
CEF2-GL-110 (A)	S-957	3/19/2014	14:28	<0.010	0.470	0.470	All Fe^{3+}	All Fe^{3+}
CEF2-GL-110 (B)	S-957	3/19/2014	14:28	<0.010	0.472	0.472	All Fe^{3+}	All Fe^{3+}
CEF2-GL-112 (A)	S-958	3/19/2014	22:07	<0.010	0.480	0.480	All Fe^{3+}	All Fe^{3+}
CEF2-GL-112 (B)	S-958	3/19/2014	22:07	<0.010	0.481	0.481	All Fe^{3+}	All Fe^{3+}
CEF2-GL-113 (A)	S-959	3/20/2014	2:48	<0.010	0.476	0.476	All Fe^{3+}	All Fe^{3+}
CEF2-GL-113 (B)	S-959	3/20/2014	2:48	<0.010	0.478	0.478	All Fe^{3+}	All Fe^{3+}
CEF2-GL-114 (A)	S-960	3/20/2014	6:48	<0.010	0.456	0.456	All Fe^{3+}	All Fe^{3+}
CEF2-GL-114 (B)	S-960	3/20/2014	6:48	<0.010	0.459	0.459	All Fe^{3+}	All Fe^{3+}
CEF2-GL-116 (A)	S-961	3/20/2014	14:25	<0.010	0.442	0.442	All Fe^{3+}	All Fe^{3+}
CEF2-GL-116 (B)	S-961	3/20/2014	14:25	<0.010	0.445	0.445	All Fe^{3+}	All Fe^{3+}
CEF2-GL-117 (A)	S-962	3/20/2014	20:13	<0.010	0.518	0.518	All Fe^{3+}	All Fe^{3+}
CEF2-GL-117 (B)	S-962	3/20/2014	20:13	<0.010	0.517	0.517	All Fe^{3+}	All Fe^{3+}
CEF2-GL-118 (A)	S-963	3/21/2014	1:35	<0.010	0.529	0.529	All Fe^{3+}	All Fe^{3+}
CEF2-GL-118 (B)	S-963	3/21/2014	1:35	<0.010	0.528	0.528	All Fe^{3+}	All Fe^{3+}

Table A-53. Glass REDOX Set 7

Sample ID	Lab ID	Collection Date	Collection Time	Fe^{2+}	Fe^{3+}	∑Fe	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
CEF2-GL-119 (A)	S-964	3/21/2014	5:12	<0.010	0.537	0.537	All Fe^{3+}	All Fe^{3+}
CEF2-GL-119 (B)	S-964	3/21/2014	5:12	<0.010	0.535	0.535	All Fe^{3+}	All Fe^{3+}
CEF2-GL-120 (A)	S-965	3/21/2014	1:10	<0.010	0.575	0.575	All Fe^{3+}	All Fe^{3+}
CEF2-GL-120 (B)	S-965	3/21/2014	1:10	<0.010	0.575	0.575	All Fe^{3+}	All Fe^{3+}

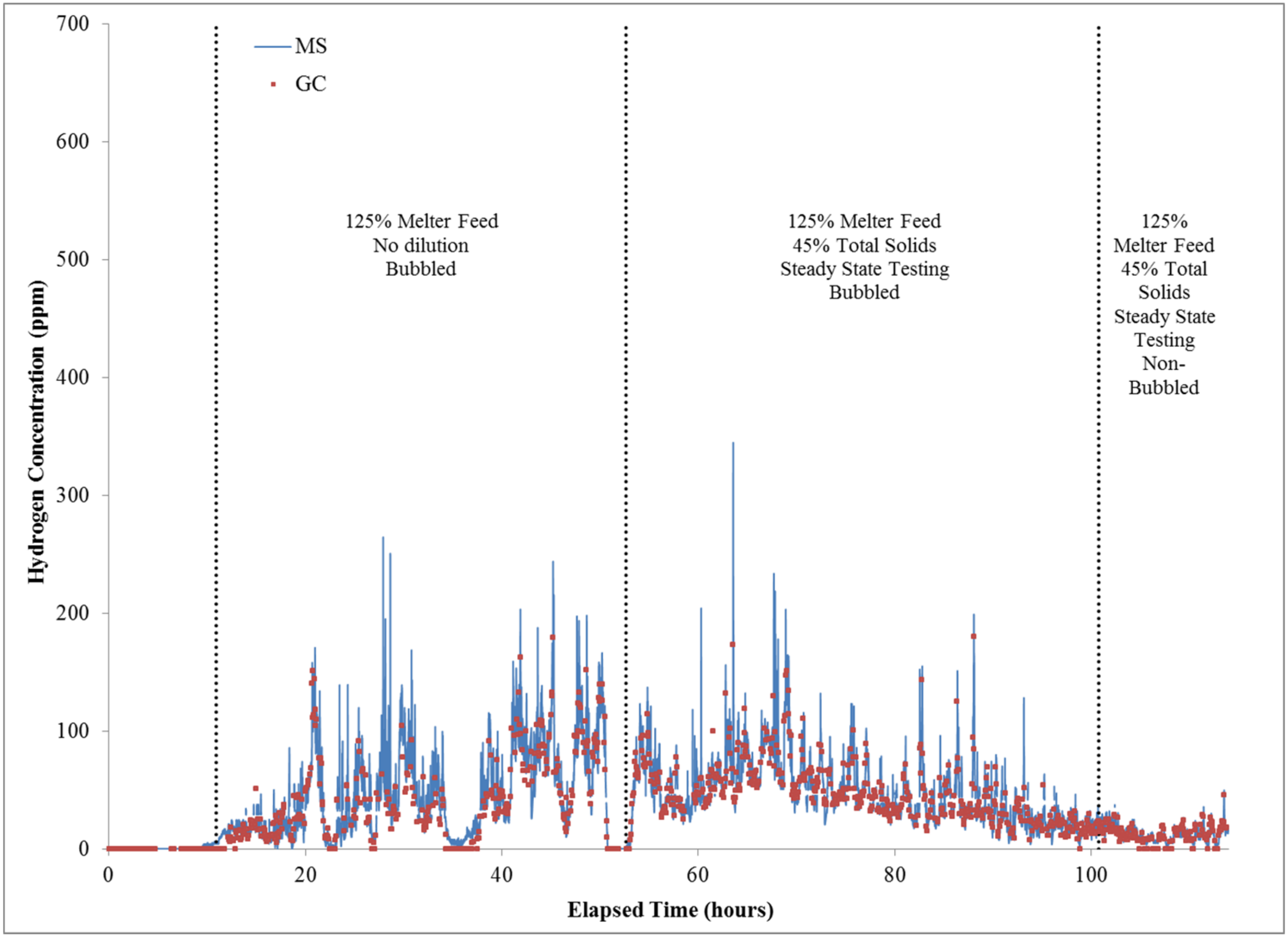

Figure A-51. Hydrogen generation (elapsed time = 0 at 12:00 February 24, 2014).

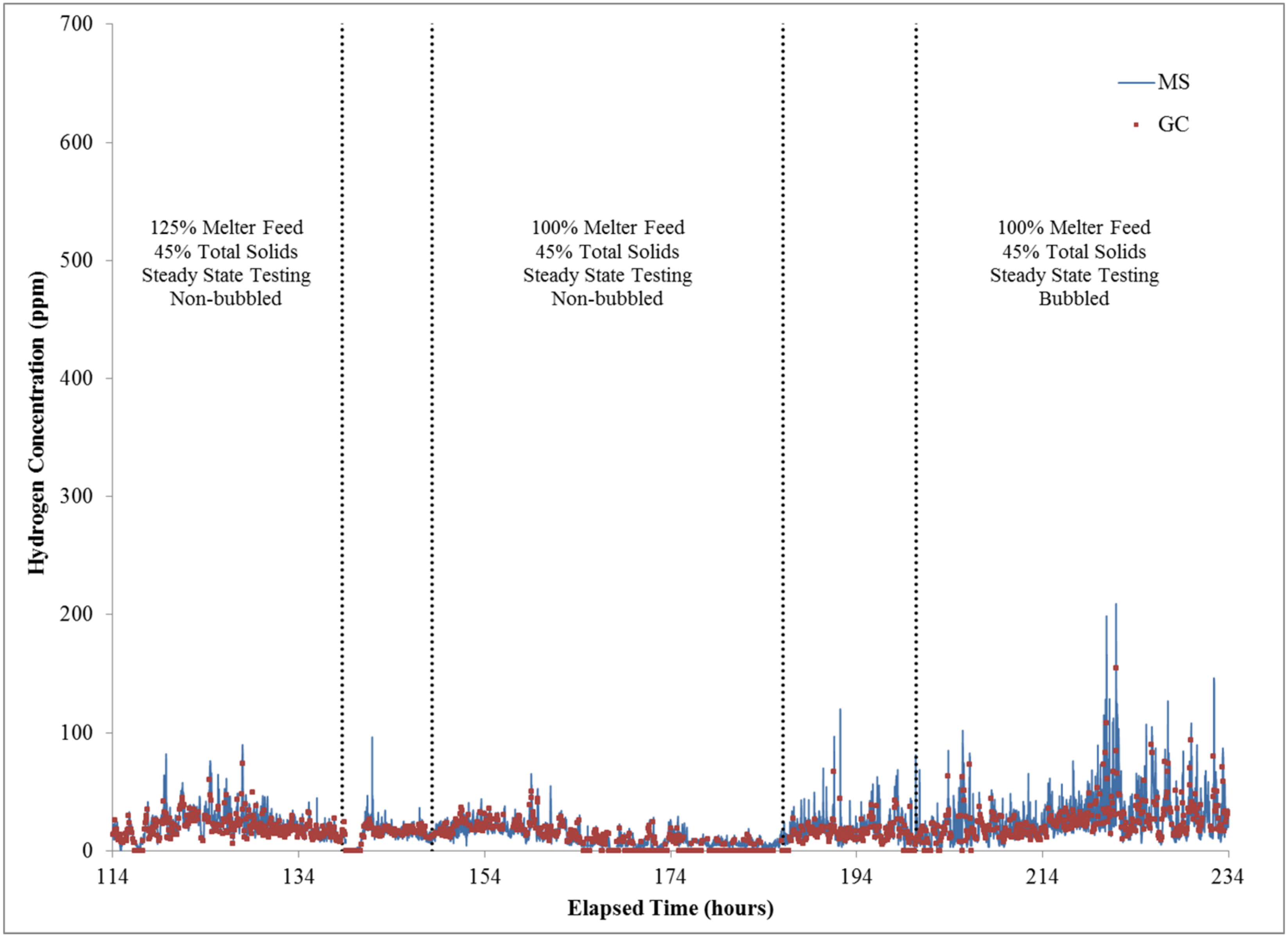

Figure A-52. Hydrogen generation (elapsed time = 114 hours at 6:00 March 1, 2014).

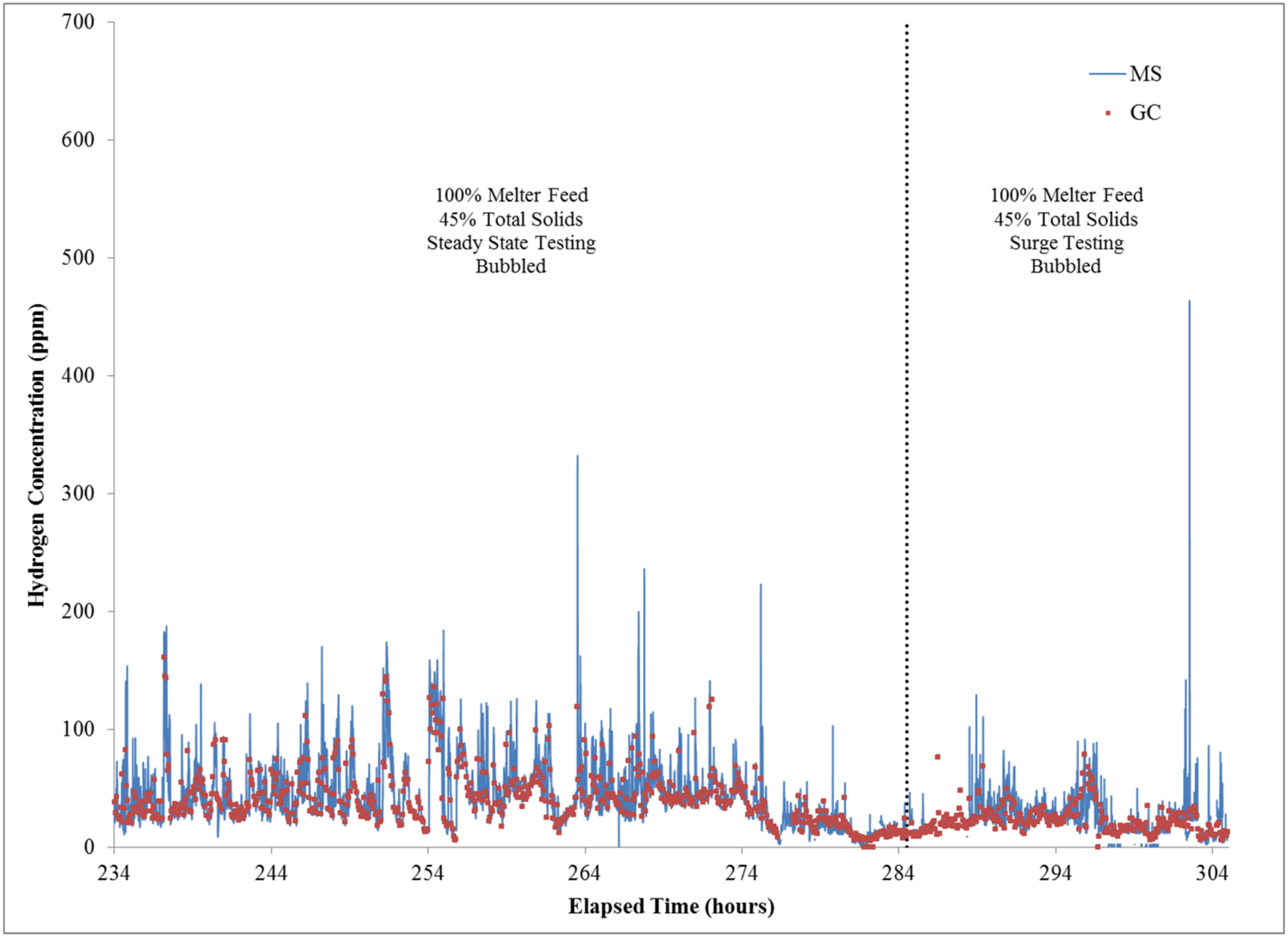

Figure A-53. Hydrogen generation (elapsed time = 234 hours at 6:00 March 6, 2014).

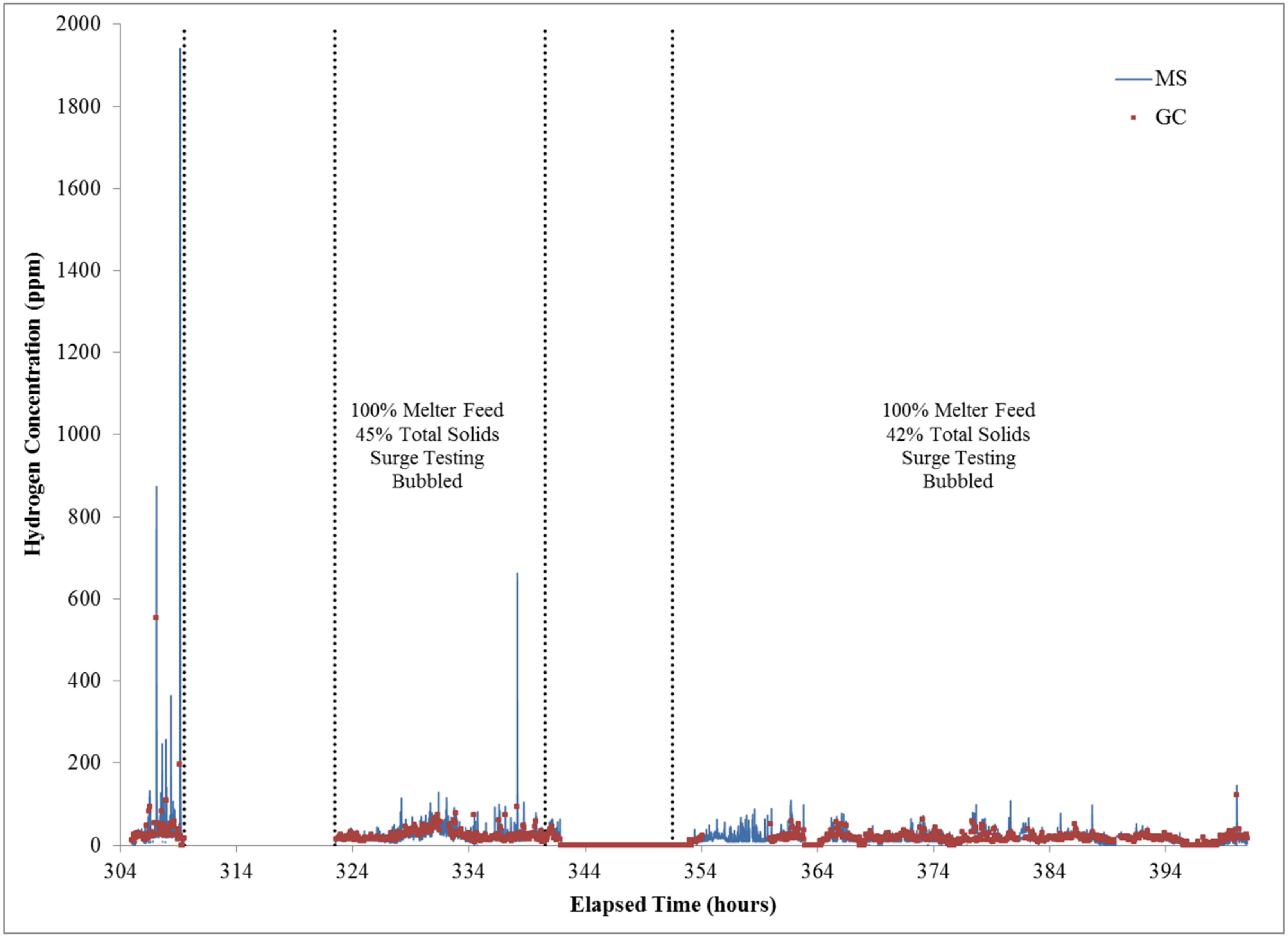

Figure A-54. Hydrogen generation (elapsed time = 305 hours at 6:00 March 9, 2014).

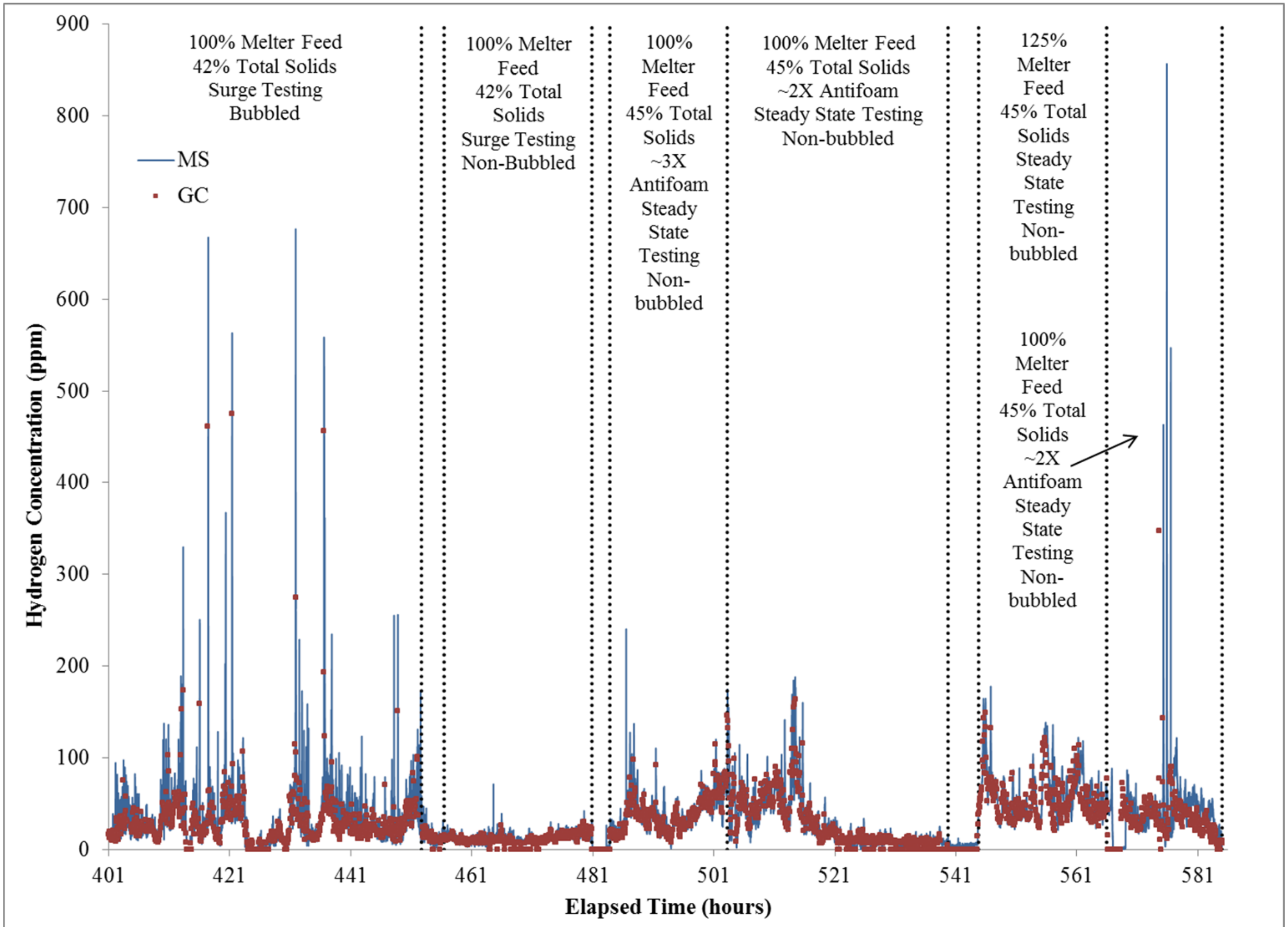

Figure A-55. Hydrogen generation (elapsed time = 401 hours at 6:00 March 13, 2014).

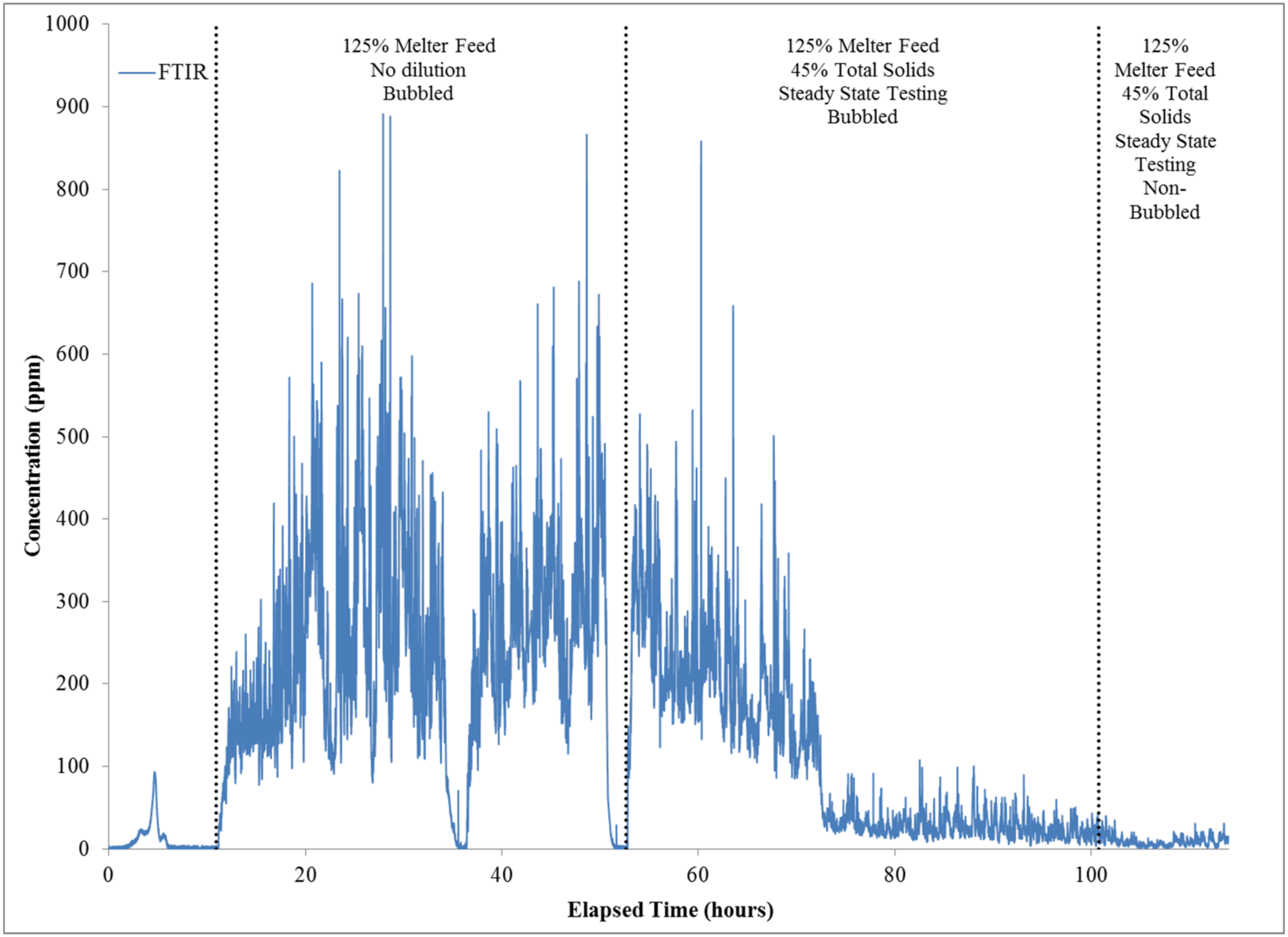

Figure A-56. Carbon monoxide generation (elapsed time = 0 at 12:00 February 24, 2014).

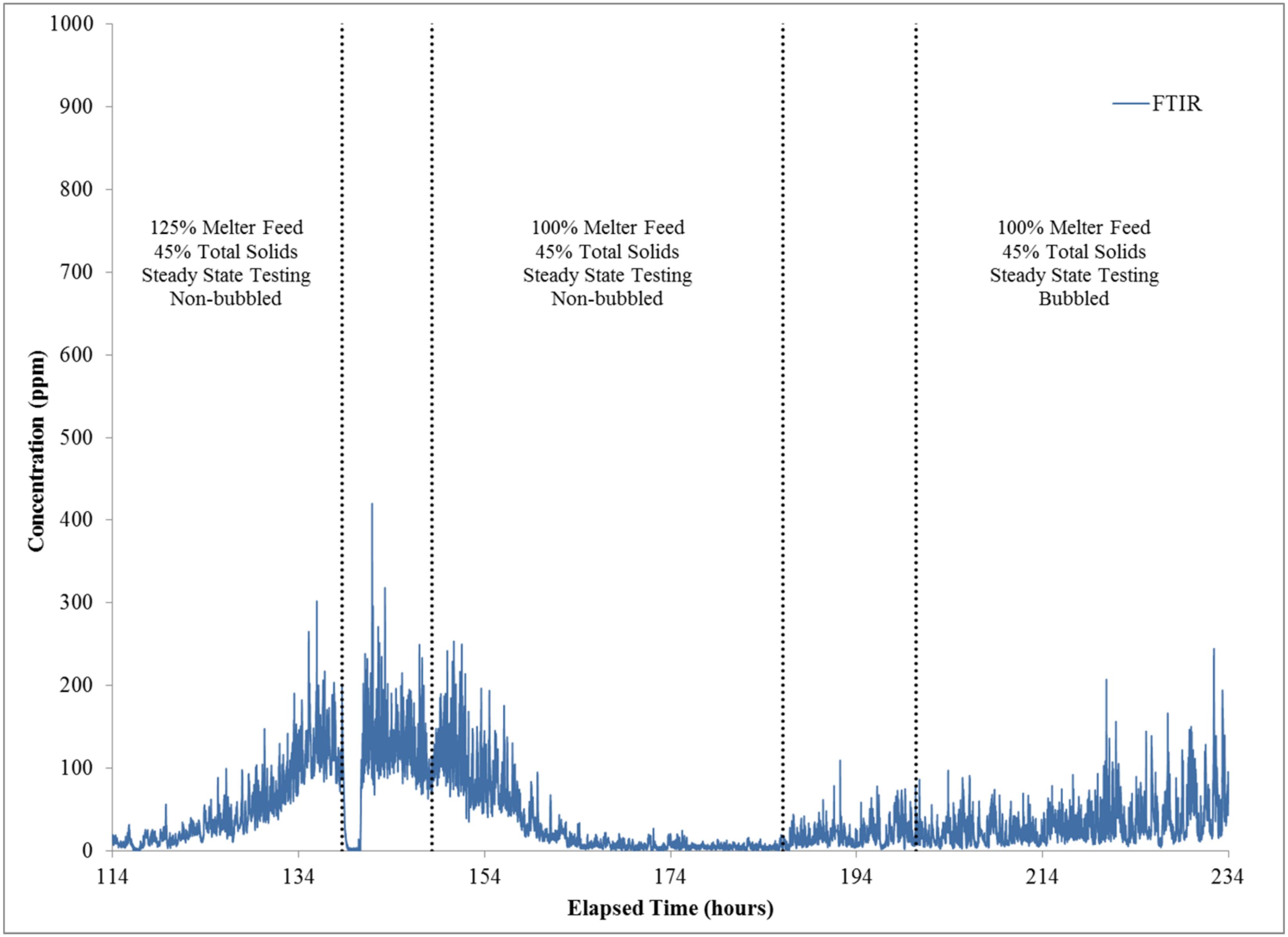

Figure A-57. Carbon monoxide generation (elapsed time = 114 hours at 6:00 March 1, 2014).

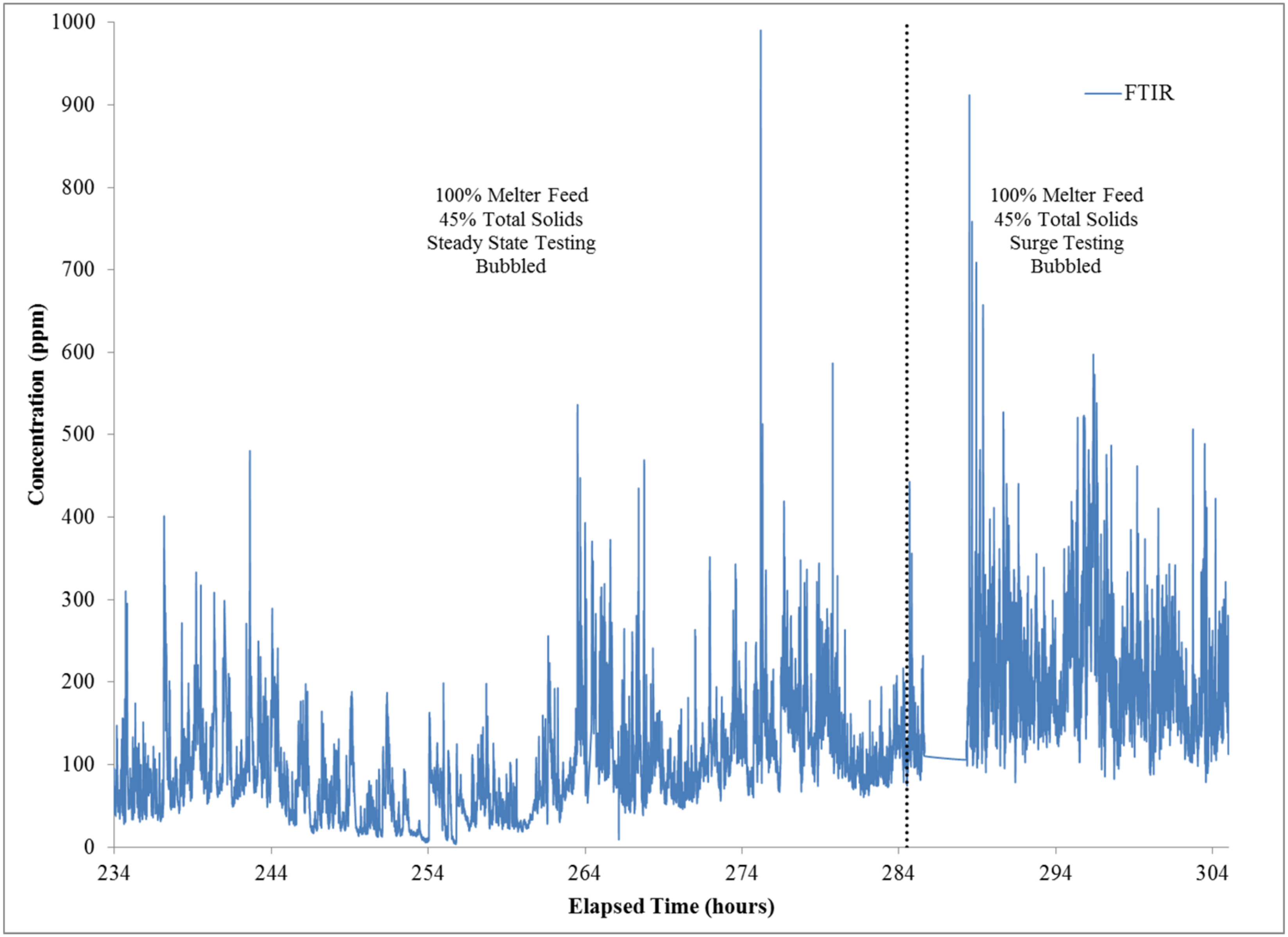

Figure A-58. Carbon monoxide generation (elapsed time = 234 hours at 6:00 March 6, 2014).

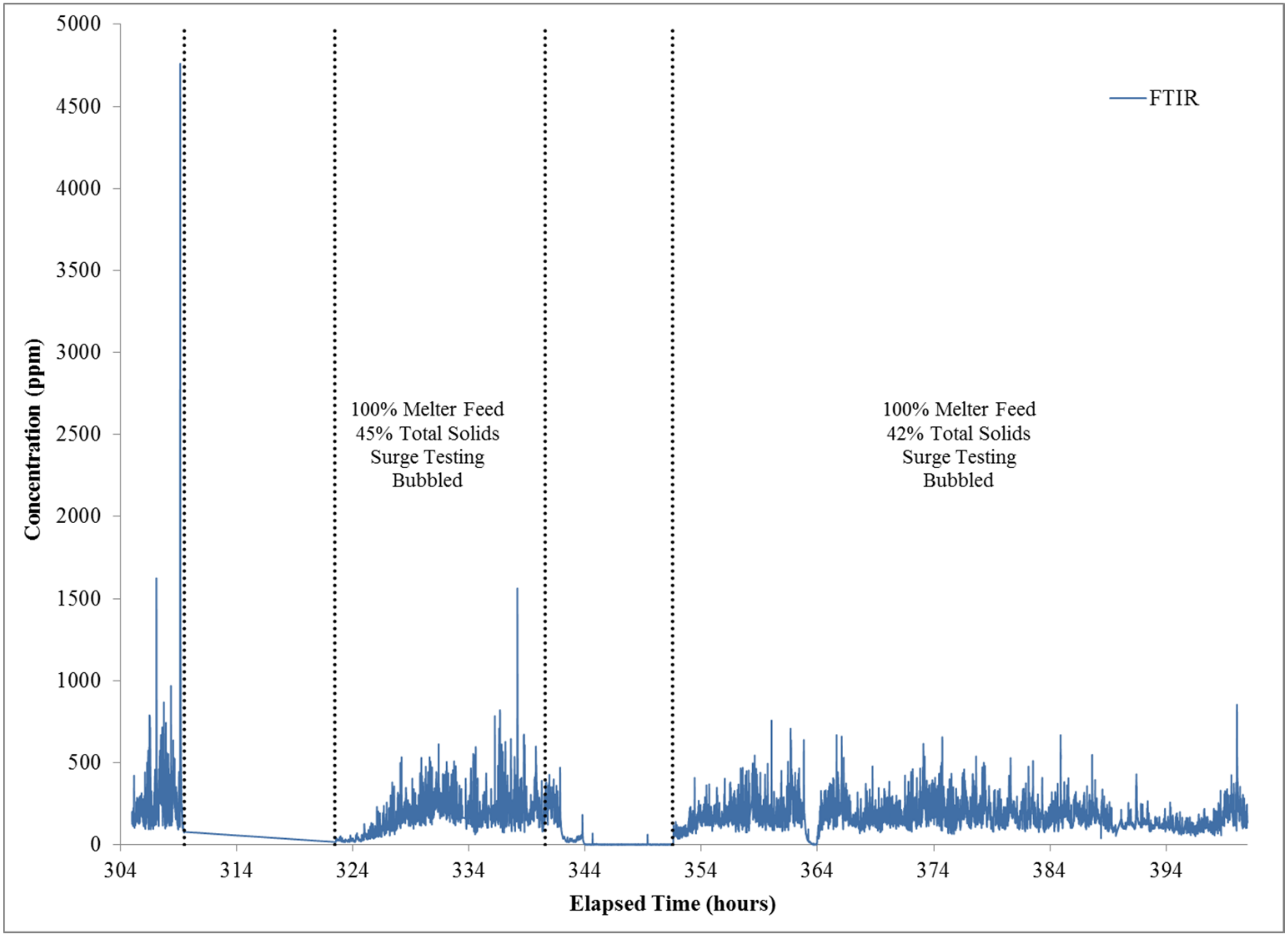

Figure A-59. Carbon monoxide generation (elapsed time = 305 hours at 6:00 March 9, 2014).

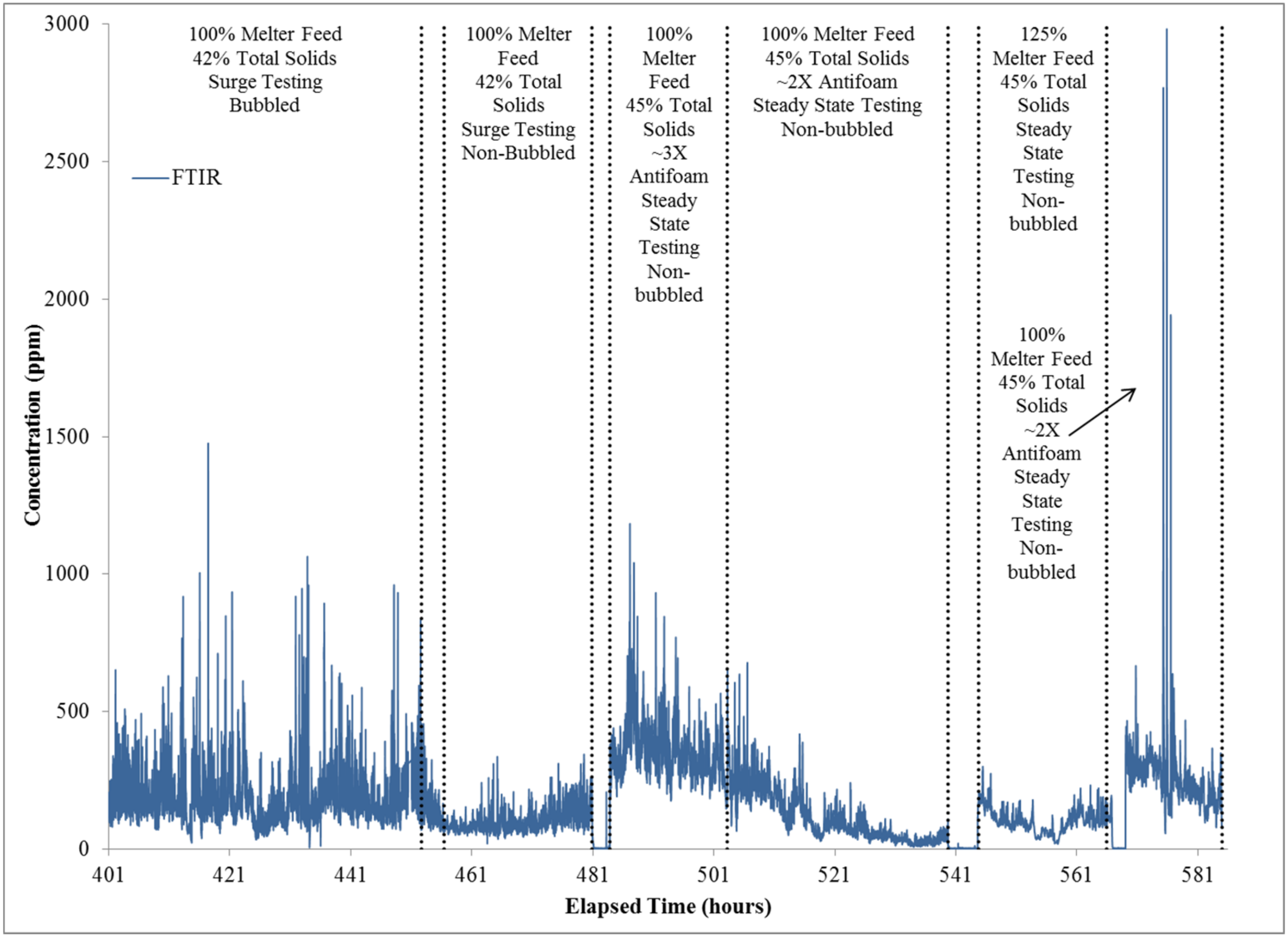

Figure A-60. Carbon monoxide generation (elapsed time = 401 hours at 6:00 March 13, 2014).

Distribution:

S. L. Marra, 773-A
T. B. Brown, 773-A
D. H. McGuire, 999-W
S. D. Fink, 773-A
C. C. Herman, 773-A
E. N. Hoffman, 999-W
F. M. Pennebaker, 773-42A
W. R. Wilmarth, 773-A
Records Administration (EDWS)
J. M. Bricker, 704-30S
R.E. Edwards, 766-H
T. L. Fellinger, 766-H
E. J. Freed, 704-S
J. M. Gillam, 766-H
B. A. Hamm, 766-H
E. W. Holtzscheiter, 766-H
J. F. Iaukea, 704-27S
D. K. Peeler, 999-W
J. W. Ray, 704-27S
P. J. Ryan, 704-S
H. B. Shah, 766-H
D. C. Sherburne, 704-S
M. E. Stone, 999-W
M.E. Smith, 704-30S
S.T. Isom, 766-H
W.O. Pepper, 704-71S/5
H.P. Boyd, 704-27S
A. Samadi-Dezfouli, 704-27S
S.G. Phillips, 704-25S
P. R. Jackson, DOE-SR, 703-46A
V. Jain, 766-H