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Alternate Reductant Cold Cap Evaluation Furnace Phase I Testing

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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 evaluation of this flowsheet eliminated the formic acid[1], 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 Cold Cap Evaluation Furnace (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 for the melter flammability models
    - Quantify off-gas surging potential of the feed
    - Characterize off-gas condensate for complete organic and inorganic carbon species

Prior to startup, a number of improvements and modifications were made to the CEF, including addition of cameras, vessel support temperature measurement, and a heating element near the pour tube. After charging the CEF with cullet from a previous Sludge Batch 6 (SB6) run, the melter was slurry-fed with SB6-Frit 418 melter feed at 36% waste loading and was operated continuously for 6 days. Process data was collected throughout testing and included melter operation variables and off-gas chemistry. In order to satisfy the objective of Phase I testing, vapor space steady testing in the range of ~300°C-700°C was conducted without argon bubbling to baseline the melter data to the existing DWPF melter flammability model. Adjustments to heater outputs, air flows and feed rate were necessary in order to achieve the vapor space temperatures in this range.

The results of the Phase I testing demonstrated that the CEF is capable of operating under the low vapor space temperatures A melter pressure of -5 inches of water was not sustained throughout the run, but the melter did remain slightly negative even with the maximum air flows required for the lowest temperature conditions were used. The auxiliary pour tube heater improved the pouring behavior at all test conditions, including reduced feed rates required for the low vapor space testing. Argon bubbling can be used to promote mixing and increase feed rate at multiple conditions. Improvements due to bubbling have been determined previously; however, the addition of the cameras to the CEF allows for visual observation during a range of bubbling configurations. The off-gas analysis system proved to be robust and capable of operating for long durations.

The total operational hours on the melter vessel are approximately 385 hours. Dimensional measurements taken prior to Phase I testing and support block temperatures recorded during Phase I testing are available if an extension of service life beyond 1250 hours is desired in the future.

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LIST OF ABBREVIATIONS

%RSD	Relative Standard Deviation
AD	Analytical Development
ARP	Actinide Removal Process
CEF	Cold Cap Evaluation Furnace
DAS	Data Acquisition System (DAS)
DVR	Digital Video Recorder
DWPF	Defense Waste Processing Facility
FTIR	Fourier Transform Infrared
GC	Gas Chromatograph
IC	Ion Chromatography
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
inwc	Inches of Water Column
MCU	Modular Caustic Side Solvent Extraction Unit
MS	Mass Spectrometer
OGCT	Off-gas Condensate Tank
PSAL	Process Science Analytical Laboratory
REDOX	REDuction/OXidation
SB6	Sludge Batch 6
scfm	Standard Cubic Feet per Minute
SEE	Systems Engineering Evaluation
SME	Slurry Mix Evaporator
SRAT	Slurry Receipt and Adjustment Tank
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TTQAP	Task Technical and Quality Assurance Plan
TTR	Technical Task Request
UV-Vis	Ultraviolet-visible
WSE	Waste Solidification Engineering

1.0 Introduction

Savannah River Remediation (SRR) conducted a Systems Engineering Evaluation (SEE)[2] 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.[3,4] Comparison of the two flowsheets among evaluation criteria indicated a preference towards the nitric–formic–glycolic flowsheet. Further evaluation of this flowsheet eliminated the formic acid[1], 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 overall scope was divided into the following sub-tasks as discussed in the Task Technical and Quality Assurance Plan (TTQAP)[7]:

- Phase I - A nitric–formic acid flowsheet melter test (unbubbled) to baseline the Cold Cap Evaluation Furnace (CEF) cold cap and 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

The Savannah River National Laboratory (SRNL) CEF, a 1/12th scale DWPF melter, was selected by the SRR Alternate Reductant project team as the melter platform for this testing.[8] 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 intent of this report is to provide a description of the system in its present state, operating conditions throughout testing and a compilation of sample data for Phase I testing only. It should be noted that the interpretation and discussion of operating data and sample data will be limited. A detailed analysis of the off-gas chemistry and the flammability model assessment will be addressed separately.[9] Phase II testing will be discussed in a subsequent report.

1.1 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.

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.[10-26] The unit consists of 5 heating zones that are controlled separately.[27] 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 was installed in the Engineering Development Laboratory (786-A) along with the off-gas system, which was similar to the system used in previous runs. The new configuration uses a blower to exhaust the gasses from the off-gas condensate tank (OGCT) to atmosphere. In the previous configuration the OGCT vented into a walk-in hood. A schematic of the entire system is shown in Figure 2-2. 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.

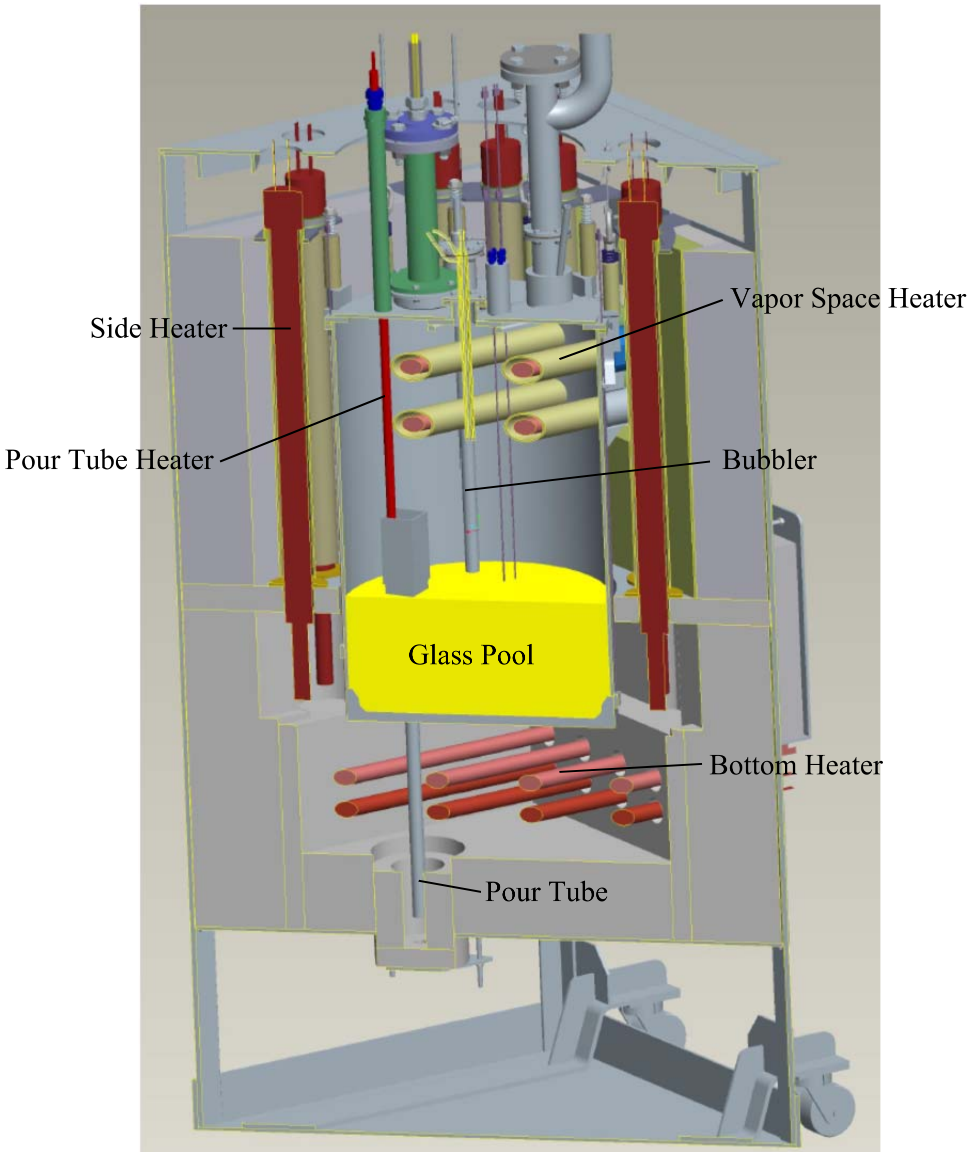

Figure 2-1. CEF cross-section.

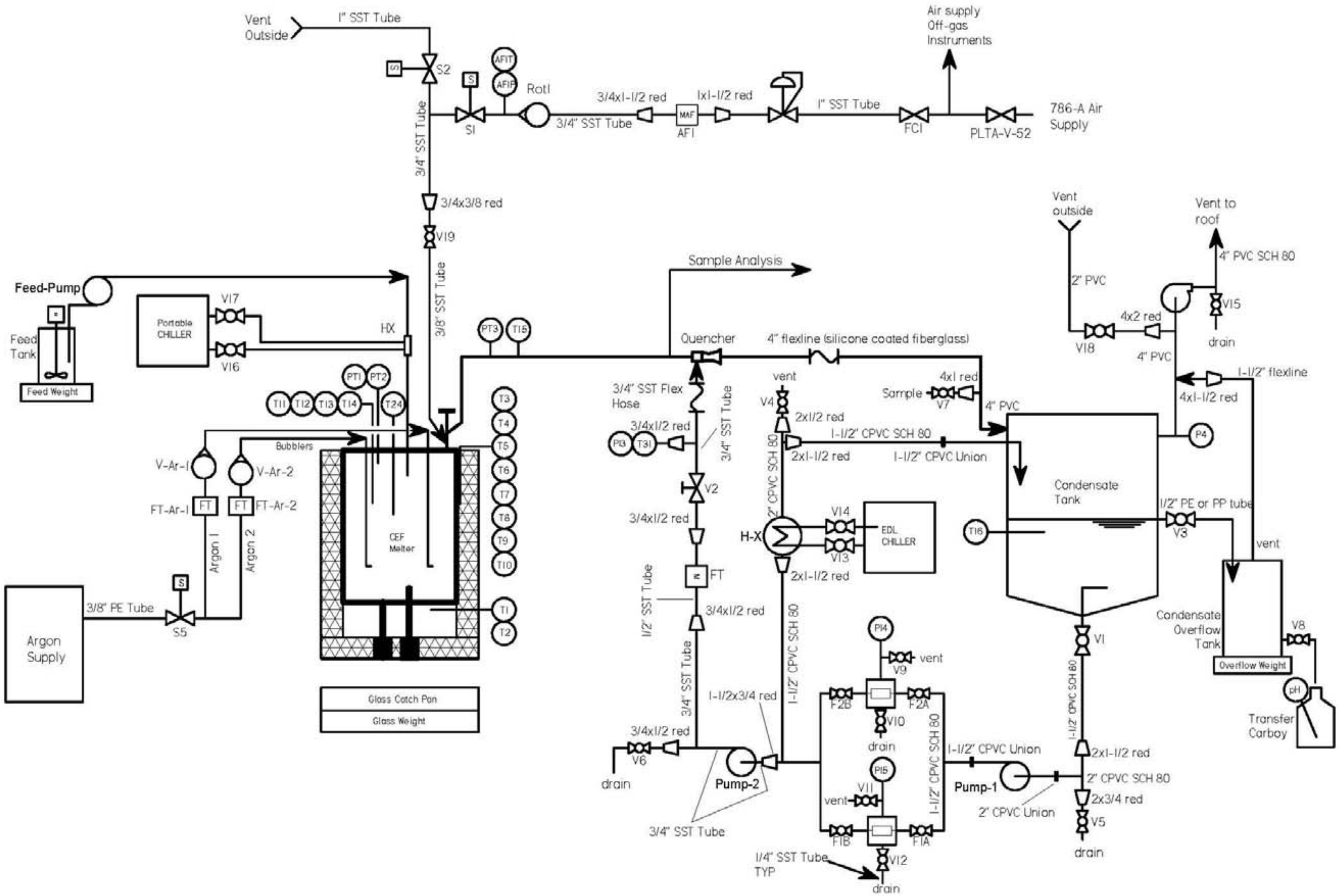

Figure 2-2. CEF system sketch.

Table 2-1. Instrumentation List[a]

System	Designation	Description	Range	Tolerance	Electronic
Melter	PT1	Melter vapor space pressure 1,	-20 to +20 in H2O	+/- 0.5 % fs	4 - 20 mA
Melter	PT2	Melter vapor space pressure 2,	-20 to +20 in H2O	+/- 0.5 % fs	4 - 20 mA
Melter	V-Ar-1	Bubbler 1 argon flow, rotameter	0 - 0.7 scfm	manuf. spec.	N/A
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.	N/A
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
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

[a] Inches of water (in H2O), percent of full scale (%fs), milliamps (mA), standard cubic feet per meter (scfm), percent of reading (%rdg), thermocouple (T/C) and millivolts (mV).

Table 2-2. Instrumentation List[b]

System	Designation	Description	Range	Tolerance	Electronic
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	0 - 30 Kg	+/- 0.75 %rdg	---
Off-Gas	PT3	Off-gas pressure transmitter	-20 to +20 in H2O	+/- 0.5 % fs	4 - 20 mA
Off-Gas	T15	Off-gas, type K T/C	-200 to 1250 °C	+/- 2.2 °C	---
Condensate	P1	Quencher condensate inlet	0 to 180 psig	manuf. spec.	---
Condensate	FT	Quencher condensate inlet flow	0 to 15 gpm	+/- 0.2 gpm	4 - 20 mA
Condensate	pH	Condensate overflow pH	manuf. spec.	manuf. spec.	N/A
Condensate	Overflow Weight	Condensate overflow vessel	0 - 30 Kg	+/- 0.75 %rdg	---
Condensate	T31	Quencher condensate inlet, type K	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Condensate	PI4	Condensate filter housing 1	0 to 30 psig	manuf. spec.	N/A
Condensate	PI5	Condensate filter housing 2	0 to 30 psig	manuf. spec.	N/A
Condensate	T16	Condensate Tank temperature,	-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	Film cooler air flow, rotameter	0 - 25 scfm	+/-(0.5%rdg + 3%fs)	N/A
Air Supply	AF1	Film cooler air flow, mass flow meter	0 - 25 scfm	+/-(0.5 %rdg + 2.5 %fs)	4 - 20 mA
Air Supply	AF1T	Rotameter 1 temperature, type K	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Air Supply	AF1P	Rotameter 1 pressure, pressure	0-100 psig	manuf. spec.	N/A
Air Supply	Rot2	Camera 1 (Canty) air flow,	0 - 25 scfm	+/-(0.5%rdg + 3%fs)	N/A
Air Supply	AF2	Camera 1 (Canty) air flow, mass	0 - 150 scfm	+/-(0.5 %rdg + 2 %fs)	4 - 20 mA
Air Supply	AF2T	Rotameter 2 temperature, type K	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Air Supply	AF2P	Rotameter 2 pressure, pressure	0-60 psig	manuf. spec.	N/A
Air Supply	Rot3	Camera 2 (JG) inlet air flow,	0 - 25 scfm	+/-(0.5%rdg + 3%fs)	N/A
Air Supply	AF3	Camera 2 (JG) inlet air flow, mass	0 - 25 scfm	+/-(1 %rdg + 5 %fs)	4 - 20 mA
Air Supply	AF3T	Rotameter 3 temperature, type K	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Air Supply	AF3P	Rotameter 3 pressure, pressure	0-100 psig	manuf. spec.	N/A
Air Supply	Rot4	Camera 2 (JG) outlet air flow,	0 - 25 scfm	+/-(0.5%rdg + 3%fs)	N/A
Air Supply	AF4	Camera 2 (JG) outlet air flow, mass	0 - 25 scfm	+/-(1 %rdg + 1 %fs)	4 - 20 mA
Air Supply	AF4T	Rotameter 4 temperature, type K	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV

[b] Inches of water (in H2O), percent of full scale (%fs), milliamps (mA), standard cubic feet per meter (scfm), percent of reading (%rdg), thermocouple (T/C), millivolts (mV), pounds per square inch gauge (psig) and gallons per minute (gpm).

Table 2-3. Instrumentation List[c]

System	Designation	Description	Range	Tolerance	Electronic
Air Supply	AF4P	Rotameter 4 pressure, pressure	0-60 psig	manuf. spec.	N/A
Air Supply	Rot5	Melter stoke air flow, rotameter	0 - 15 scfm	+/-(1%rdg + 4%fs)	N/A
Air Supply	AF5T	Rotameter 5 temperature, type K	-200 to 1250 °C	+/- 2.2 °C	-5.9 to 50.6 mV
Air Supply	AF5P	Rotameter 5 pressure, pressure	0-100 psig	manuf. spec.	N/A
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	Melter 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), millivolt (mV), normally closed (NC), normally open (NO), stainless steel (SST).

2.1 Vessel Dimensional Documentation

Since the Inconel® 690 vessel is operated at elevated temperature, structural creep has always been a concern, especially since the vessel is suspended. After the top of the melter was removed, measurements indicated that the vessel had not undergone major dimensional changes during the previous cycles.[28] The original melter service life was set at 500 hours; however, due to the alternate reductant test durations, a service life beyond 500 hours was desired. W. Daugherty conducted a creep life assessment of the Inconel® 690 melter vessel based on a reduced temperature at the lug areas and estimated that the service life could be extended to 1250 hours.[d,29] It was also recommended that periodic measurements of vessel dimensions should be performed to track actual creep strain so that there would be a basis for additional increases in service life.

An additional calculation related specifically to the tension rods from which the melter is suspended indicated that the *total* life of the tension rods should be limited to 1250 hours, which is consistent with the creep life calculation by Daugherty for the vessel.[30] Tension rod length measurements and temperature monitoring were recommended as requirements for continued operation of the melter. As a result, thermocouples were welded onto the support blocks of the vessel to gather information for use in future creep and melter life calculations.

2.2 System Modifications

Based on previous tests involving the CEF, several modifications were made to improve the performance of the melter system.

2.2.1 *Inleakage*

To reduce air inleakage into the vessel, the top was removed and the sealing areas were resurfaced. In addition, a new thicker gasket was added between the top and the vessel flange. A fixture was designed and fabricated that provided a packing gland seal to be installed on the vapor space heaters tubes. Both the vessel nozzles and alumina tubes had seals provided using a high temperature gasket material. The double gasket seals are shown in black in Figure 2-3.

Testing prior to heat-up indicated that the melter air inleakage had been reduced from previous campaigns. Vacuum testing identified several sources of leaks that were reduced through tightening and replacement of connections. Argon was used as a tracer gas along with the mass spectrometer to measure inleakage over a range of quencher flows.

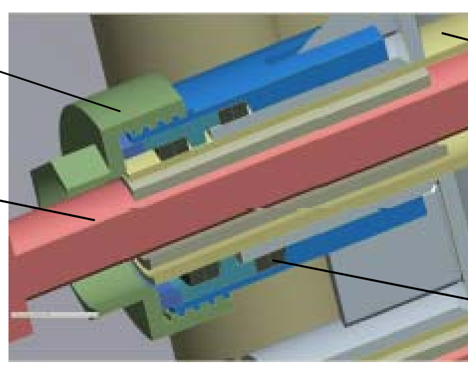

Figure 2-3. Vapor space sealing fixture.

[d] At the time the report was issued, the vessel had been operated ~250 hours. It was estimated that decreasing the temperature of the lug areas from 1125°C to 1050°C would increase the *remaining* service life from 250 hours to approximately 2500 hours; however, operation was limited to an additional 1000 hours to account for uncertainties in the analysis.

2.2.2 *New Pour Tube Heater*

Previous testing with the CEF had indicated that some locations in the melt pool were more than ~100°C lower than the control temperature. Since Phase I testing would involve reduced vapor space temperatures, it was decided to add an auxiliary heater to the melt pool in order to increase melt pool temperature and reduce the glass viscosity near the pour tube for improved pouring. An Inconel® sheathed cartridge heater was installed inside the chimney surrounding the pour tube (Figure 2-4).

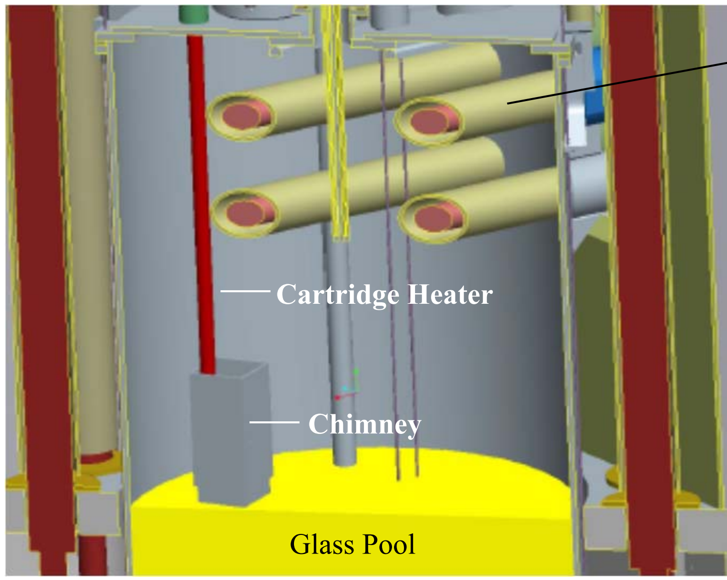

Figure 2-4. CEF cross section with close-up of cartridge heater and chimney.

Since conditions in the CEF are atypical for this type of heater it was desired to perform an assessment of the heater prior to actual testing, which would simulate conditions experienced in the melter. Small scale testing of a similar cartridge heater using a laboratory scale furnace and a platinum alloy crucible filled with glass indicated that the heater would potentially remain operational during the Phase I test conditions.[e]

2.2.3 *Camera Installation*

Two new cameras were installed on the CEF to provide better views of the cold cap surface during operation. The camera system in detail is shown in Figure 2-5.[f] An air cooled high temperature camera supplied by J.M. Canty, Inc. was installed in a vessel top opening previously used as a sight port.[g] The camera specifications are as follows:

- System video format – U.S. Color
- Power Supply – 120V and 60Hz Input
- System diameter – 2.875 inches
- System view angle – 42° H x 32° V
- Optical shield – clear quartz
- Material of construction for shell – 304L stainless steel

[e] The furnace temperature was held at approximately 735°C for 19 days to simulate temperatures experienced in the melter vapor space. The cartridge heater was used to maintain a temperature of approximately 1120°C in the glass. In general, heater operation was limited to daytime operation only (~ 9 hours per day), with the exception of 3 days of continuous operation.
[f] Camera 1 refers to the J.M. Canty, Inc. high temperature camera and Camera 2 refers to the camera designed at SRNL.
[g] Canty MINITEMP^{TM} High Temperature Camera, Part Number: MHT-B1S2A1A

- Cooling requirements – 8 standard cubic feet minute (scfm) of air or nitrogen

A high temperature camera designed by SRNL specifically for this system[h] was also installed in a modified top port to provide a second view of the cold cap surface.[31-35] The cameras were connected to a monitor so that the cold cap could be viewed in real time and a digital video recorder (DVR) to save the video during testing.

2.2.4 *Purge Air*

In order to establish lower vapor space temperatures and ensure adequate combustion, a separate purge line was added to supply a variable amount of air as needed during testing. This purge air was in addition to the cooling air provided for the cameras (up to 13 scfm for the J.M. Canty, Inc. camera and approximately 1 scfm for the SRNL camera[i]).

2.2.5 *Off-gas Sampling System and Off-gas Instrumentation*

Offgas sampling was performed using a gas sampling system connected to a process mass spectrometer (MS) (Extrel CMS model MAX300-LG), a process Fourier Transform Infrared (FTIR) spectrometer (MKS model MG-2030) and a gas chromatograph (GC) (Agilent Micro Gas Chromatograph). A backup mass spectrometer (Monitor Instruments) was also available for use, but was not used.

The gas sampling system consisted of two parallel coalescing filters to remove particulates and condensable water; the parallel arrangement was used so that one filter could be taken offline and changed. Redundant gas sampling diaphragm pumps were used in parallel so that an installed spare was always available. The gas sample was extracted from the melter off-gas system between the film cooler and the quencher at a rate of 1-6 L/min. The gas sample was conditioned using a PermaPure MiniGASS sample conditioner that consisted of an additional coalescing filter and a Nafion dryer to remove water to a dew point of less than 0°C (typically less than -10°C).

The mass spectrometer was calibrated to measure H_2, O_2, N_2, NO, NO_2, Ar, CO_2, and SO_2. N_2O could not be measured by MS and its presence causes the measured concentrations of CO_2, NO, and N_2 to be slightly higher than the actual values because N_2O has mass-to-charge (m/z) fragments with the same mass as CO_2 (44), NO (30) and N_2 (28). Similarly, CO interferes with N_2 as it has the same m/z (28).[j] The MS measured the sample concentration approximately every 6-7 seconds.

The FTIR measured CO, CO_2, H_2O, N_2O, NO, NO_2, SO_2, and various organic species. The only organic species detected was a small amount (<16 ppm) of methane (CH_4). The FTIR measured the gas concentrations about every 3.5 seconds. The gas chromatograph was used to measure H_2, O_2, N_2, CO_2, and N_2O. The sampling frequency of the GC was one sample every 4 minutes.

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[h] Due to a focusing issue, the SRNL camera was not utilized during testing.

[i] Approximately 8 scfm enters the camera for cooling and approximately 7 scfm is vented; at normal conditions, only 1 scfm enters the melter.

[j] The interference of CO on N_2 is negligible. The interferences of N_2O on CO_2, NO and N_2 can be approximately accounted for during post-run processing of the data. Post-run processing of Chemical Process Cell (CPC) data has shown these corrections to be very accurate.

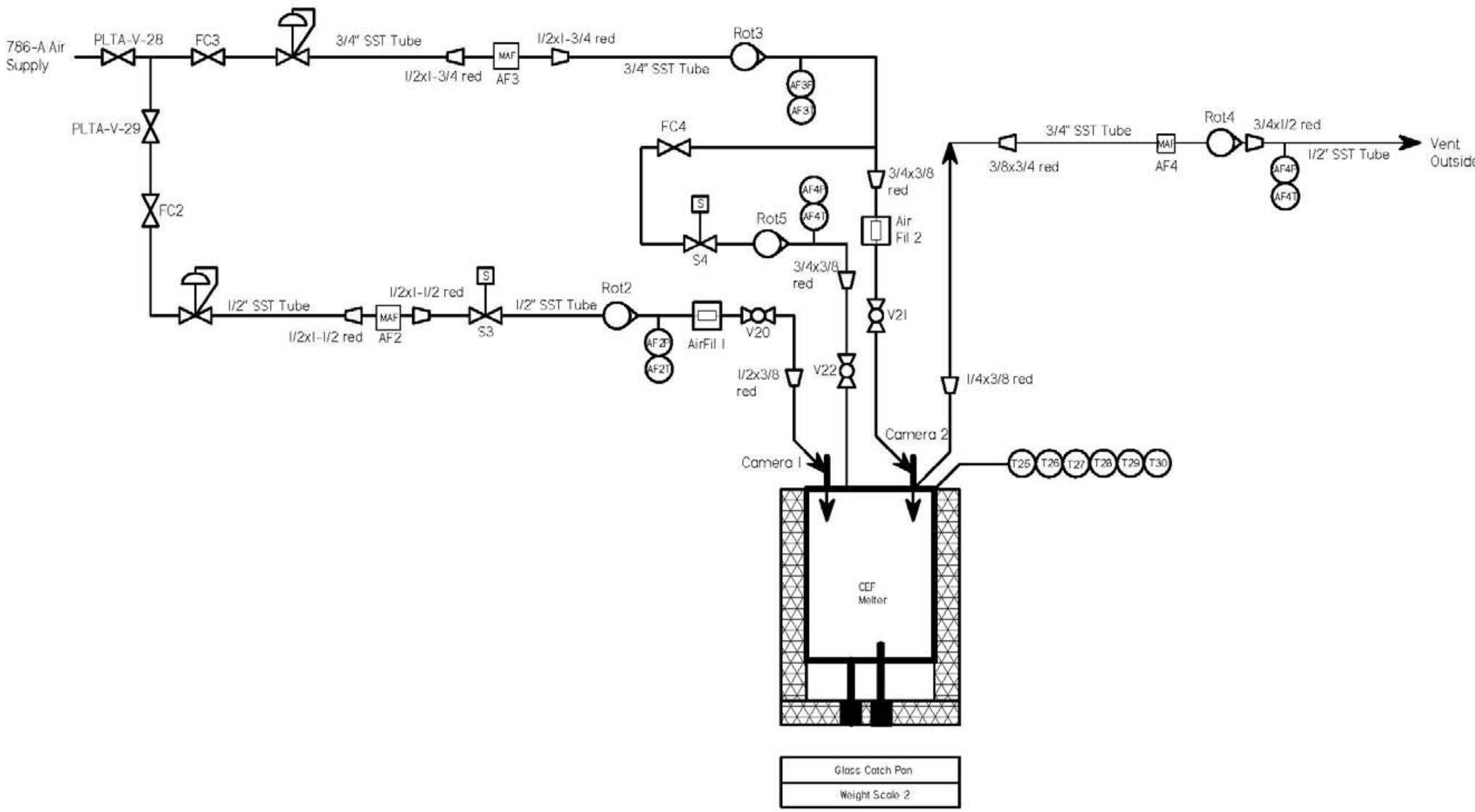


Figure 2-5. CEF camera system sketch.

3.0 Experimental Procedure

3.1 Melter Feed

The processing strategy for the Sludge Receipt and Adjustment Tank (SRAT) product run was developed by SRNL to prepare melter feed from SRAT product that meets the following guidelines.[36]

- Nitric/formic acid Flowsheet at 105% Koopman[37] acid stoichiometry
- Nitrate between 15,000 and 30,000 mg/kg slurry
- No noble metals or mercury[38]
- Total organic carbon (TOC) must meet current DWPF limits
- REDOX (Fe^{2+}/Fe total) 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: 1000 to 2000 mg/kg on a carbon basis
- Abbreviated SRAT cycle (compared to typical DWPF processing), no Slurry Mix Evaporator (SME) cycle[36]
- No Actinide Removal Process (ARP) or Modular Caustic Side Solvent Extraction Unit (MCU) material added (sludge only)

The SB6i simulant was produced by BlueGrass Chemical Specialties, LLC[k] and was processed into SRAT product by an abbreviated SRAT cycle at Harrell Industries, Inc.[l] in March 2013. A sample was analyzed by SRNL for verification prior to shipment and a memo recommending acceptance of the SRAT batch was issued.[39] The SRAT product was transferred into 30-gallon poly drums at Harrell Industries and shipped to SRNL in April 2013. Results of the analysis performed at SRNL as part of the SRAT product acceptance is summarized in Table 3-1 through Table 3-4.

The melter feed used for the CEF testing was produced by combining the Harrell Industries SB6i SRAT product with dry Frit 418 (no slurry) at a target waste loading of 36%. Additional water was added to yield a total solids content of 42% in order to facilitate feeding.

Table 3-1. Physical Properties of the Harrell SB6i SRAT Product

Property	Measured Value	Units
Total Solids	28.3	weight %
Insoluble Solids	15.8	weight %
Soluble Solids	12.5	weight %
Calcine Solids	17.7	weight %
Slurry Density	1.1494	g/mL at 25°C
Supernate Density	1.0972	g/mL at 25°C
pH	4.95	
Yield Stress	4.0	Pa
Consistency	3.7	cP

[k] The SB6i simulant was produced by BlueGrass Chemical Specialties, LLC of New Albany, IN.
[l] The SB6i SRAT product was produced by Harrell Industries, Inc. of Rock Hill, SC.

Table 3-2. Harrell SB6i SRAT and BlueGrass Chemical SB6i Simulant Compositions

Element	SRAT Product	Simulant
	wt% calcine solids	
Al	13.9	14.3
Ba	0.14	0.13
Ca	1.2	1.2
Cr	0.19	0.2
Cu	0.12	0.1
Fe	21.6	22.2
K	0.26	0.25
Mg	0.85	0.95
Mn	6.72	7.1
Na	13.2	13.1
Ni	2.86	3.1
P	0.1	0.1
Pd	<0.010	<0.010
S	0.31	0.3
Si	1.49	1.3
Sn	0.07	not measured
Ti	0.05	<0.1
Zn	0.11	0.11
Zr	0.19	0.26

Table 3-3. Harrell SB6i SRAT Product Supernate Composition (mg/L)

Element	Supernate
Al	42.5
Ba	0.45
Ca	2730
Cr	0.88
Cu	58
Fe	0.64
K	1050
Mg	1970
Mn	9080
Na	33,900
Ni	1600
P	0.64
Pb	0.53
S	624
Si	260
Sn	6.08
Sr	4.90
Ti	<0.100
Zn	23.2
Zr	<0.100

Table 3-4. Harrell SB6i SRAT Product Anions and TOC (mg/kg)

Species	Measured Value
F	<500
Cl	450
NO_2	<500
NO_3	24,300
TOC	17,400

Species	Measured Value
SO_4	1080
C_2O_4	<500
HCO_2	60,100
PO_4	<500

3.2 Startup Cullet

The melter was loaded with ~111 kg of SB6-Frit 418 startup cullet at 36% waste loading from the 2010 campaign and its level in the vessel was approximately 17-19" from the site port seal surface. This glass was chosen since it was similar in composition to the material being fed to the CEF during Phase I testing, thus reducing the quantity of feed required for the test and the time involved to reach steady state conditions.

3.3 Sample Analysis

3.3.1 *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]

3.3.2 *Composition Measurements*

Melter feed, off-gas 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] for cations and potassium hydroxide[44] and aqua regia[45] for anions. Cations were measured with Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES) and anions were measured with Ion Chromatography (IC).[46,47] Total inorganic carbon (TIC) and TOC were measured by Analytical Development (AD) per procedure.[48]

3.3.3 *Glass Sample Reduction/Oxidation (REDOX) Measurements*

Glass samples were crushed, dissolved and analyzed by PSAL via Ultraviolet-visible (UV-Vis) spectroscopy according to procedure.[49]

4.0 Results and Discussion

A readiness assessment was conducted prior to testing and is summarized in SRNL-L3100-2013-00071.[50] The objectives and general operating conditions for Phase I testing were detailed in SRNL-L3100-2013-00045.[51]

Note that all data collected by the data acquisition system (DAS) every 30 seconds throughout testing is available in SRNL-L3100-2013-00189.[52] Plots of data collected throughout testing are shown in Figure A-1 through Figure A-12 and include:

- Bottom thermocouple temperatures
- Side thermocouple temperatures
- Vapor space thermocouple temperatures
- Glass pool thermocouple temperatures
- Air flows
- Argon bubbler flows
- Vapor space and off-gas line pressures
- Heater outputs
- Feed rate

4.1 Melter Heat-up

The melter was energized on May 29th, 2013 at approximately 09:30 and ramped to operating temperature in approximately 14 hours. The vapor space heaters were ramped in manual mode to a target temperature in the range of 700-750°C. The side and bottom heaters were operated in automatic ramp mode at 3ºC per minute until the temperature approached the target temperature of 1125°C, at which point manual 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 this time.[m] After control thermocouples[n] reached the target temperature of ~1125°C, approximately 1 hour was required for the melt pool to reach a temperature in the range of 1000-1050°C.

4.2 Turnover

The first feed addition occurred on May 30th, 2013 at approximately 01:15. Approximately 24 hours of feeding in the range of 189-357 g/min under argon bubbling (~0.1-0.5 scfm) were required to complete

[m] 16.2 scfm (AF1 – film cooler), 8.4 scfm (AF2 – camera 1), 8.2 scfm (AF3 – camera 2 inlet), 7.2 scfm (AF4 – camera 2 outlet) and 0.7 scfm (AF5 – melter stoke air).

[n] T1 – bottom, T3 through T10 – side (whichever thermocouple is reading the highest temperature) and T12 – vapor space.

one turnover of the melter volume. Approximately 115 kg of glass were poured from the melter.[o] This time was also used to monitor temperature and controller responses throughout the system. The average melt pool temperature during turnover was approximately 990°C, while the vapor space was maintained at an average temperature of 714°C. It should be noted that the relatively low average melt pool temperature can be attributed to the significant drops in temperature of thermocouple T13 throughout turnover. It is possible that the feed rate was far too high at times, which caused a buildup of cold cap or the thermocouple itself was faulty. The average melt pool temperature based off of T14 alone was 1012°C. Melter turnover was completed on May 31, 2013 at approximately 00:15.

4.3 Steady State Vapor Space Conditions

Multiple vapor space temperatures (approximately 700°C, 600º C, 500º C, 400º C, 350º C, and 300ºC) were evaluated during non-bubbled testing.[p] The goal was to maintain steady state conditions at reduced temperatures and monitor the off-gas composition. Steady state conditions were defined by three parameters, (i) vapor space temperature, (ii) feed rate and (iii) off-gas readings (H_2, CO_2 and NO_x). The values should fluctuate less than ±15% with no noticeable trend up or down. The vapor space temperature was incrementally lowered from the nominal 750°C in order to establish steady state feeding/pouring conditions at the target temperatures. The initial reductions in the vapor space temperature were achieved by lowering the set point on the vapor space heater control. The cold cap coverage was monitored and feed rate adjusted as necessary during the process. As lower temperatures were targeted (≤500°C), it also became necessary to add purge air followed by small increases in cooling air to the J.M. Canty, Inc. camera. As the vapor space temperatures were lowered, the air to the film cooler could be reduced since the exiting off-gas was also at a lower temperature. It should be noted that a discussion of steady state and the flammability model assessment is provided in a separate report.[9]

4.3.1 *Vapor Space Test Conditions*

Changes to heater outputs and air flows were the primary tools used to vary the conditions. When necessary, feed rate was also adjusted to provide constant cold cap coverage for different conditions. It was desired to have approximately 90% cold cap coverage with some small vent holes in the cold cap rather than having 100% cold cap coverage. The vent holes were monitored using the J.M. Canty, Inc. camera, which allowed viewing of the cold cap in an area above one of the bubblers.

A combination of heater output, air flow and feed rate adjustments were used to achieve the various vapor space temperatures. In some cases several hours were required to achieve steady state conditions. The average temperatures and vapor space heater outputs are shown in Table 4-1.

Table 4-1. Vapor Space Temperature Conditions

Target Vapor Space Temp (ºC)	Average Vapor Space Temp (ºC)	Average Melter Bottom Temp (ºC)	Average Glass Pool Temp (ºC)	Average Vapor Space Volts	Average Feed Rate (g/min)	Approximate Test Duration (minutes)
700	693	1124	1072	115	87	92
600	596	1118	1071	69	82	122
500	507	1117	1061	58	80	150
400	409	1123	1063	40	60	121
350	346	1125	1071	29	58	123
300	287	1120	1066	7	54	120

[o] Prior to testing the melter was filled with approximately 111 kg of SB6-Frit 418 cullet.
[p] During non-bubbled conditions, bubbling rate was maintained at 0.001 – 0.01 scfm per bubbler in order to reduce the risk of plugging the bubbler ports.

Maintaining consistent cold cap coverage was a primary goal for steady state conditions and ultimately the flammability model assessment. Images of the cold cap throughout vapor space testing are shown in Figure 4-1 and Figure 4-2. Feed rate adjustments were made to keep some small vent holes in the cold cap during most test conditions. The fact that vent holes occur randomly meant that no vents were available in the camera field of view for prolonged periods, especially during low temperature testing. Extended periods were required to verify overfeeding conditions rather than reduction in vent hole generation. Deviations in the melt pool thermocouple temperatures (T13 and T14) were an indicator of overfeeding; however, as previously mentioned, there was a substantial delay between overfeeding and the subsequent temperature deviation. As the vapor space temperature was reduced during the testing, feed rate reductions were required to prevent overfeeding of the melter. The average feed rates calculated during each of the test periods are shown in Table 4-1.

4.3.2 *Melter Inleakage*

The estimated air inleakage at the different vapor space test conditions is shown in Table 4-2. During Phase I runs at vapor space temperatures of 300-400°C, it became apparent that the melter pressure could not be maintained at the target value of -5 inwc under high purge air flow conditions. These additional air flows required testing at melter pressures approaching atmosphere when the vapor space temperature approached 300ºC. Table 4-3 shows the major sources of melter air and the corresponding melter pressure at each target vapor space temperature condition. The * on the final purge air value indicates a flow above the DAS programmed display range of the transmitter. The value observed on the transmitter was approximately 28 scfm.

Table 4-2. Estimated Melter Air Inleakage

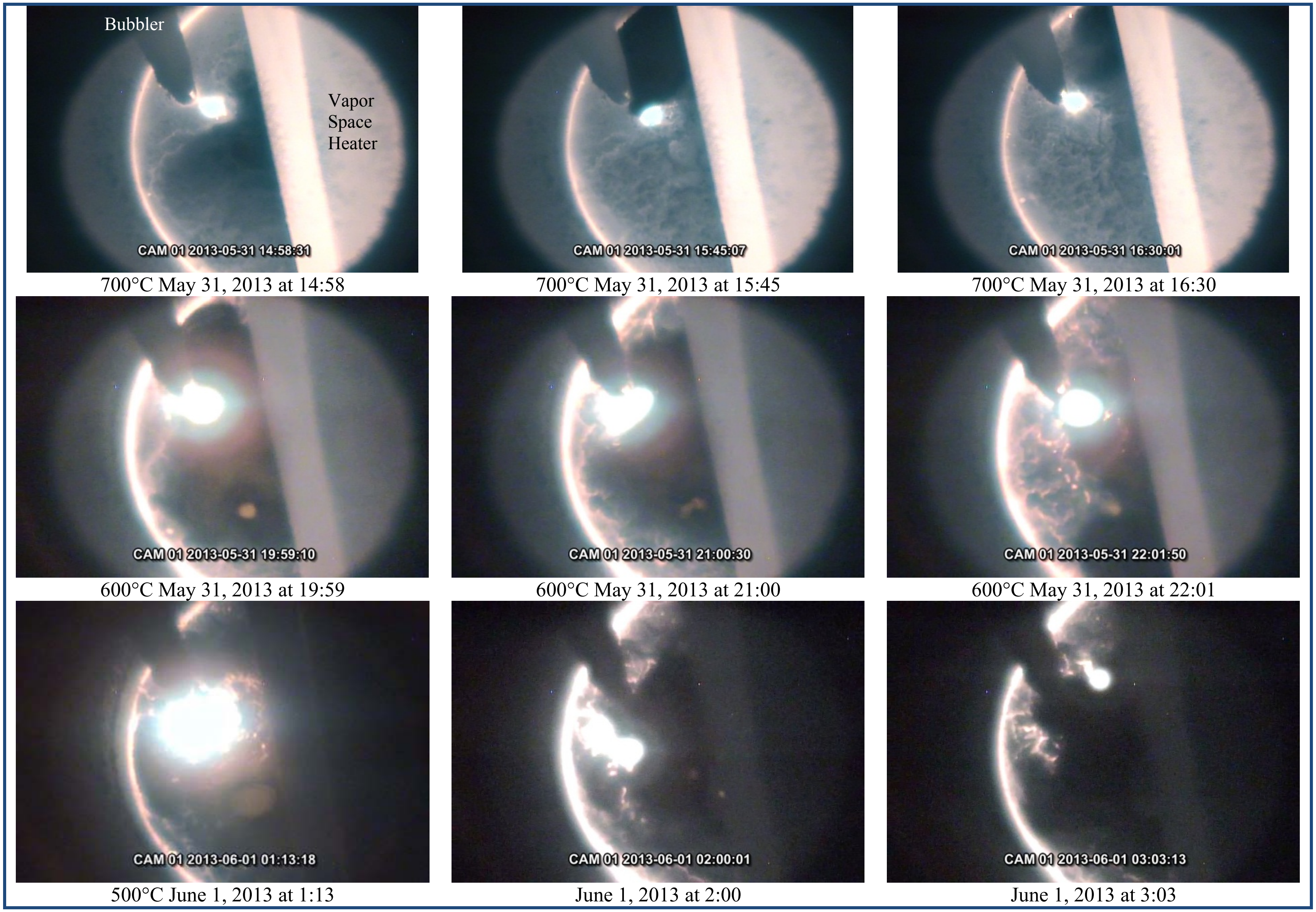
Average Vapor Space Temperature (ºC)	693	596	507	409	346	287
Calculated Air Inleakage (scfm)	8	8	9	11	10	8

Table 4-3. Melter Air Flows

Average Vapor Space Temp (ºC)	Film Cooler Air Flow (scfm)	Melter Purge Air Flow (scfm)	Canty Camera Air Flow (scfm)	Melter Pressure (inwc)
693	15	0.6	8	-5.0
596	15	0.6	8	-5.2
507	15	8	8	-4.7
409	8	19	8	-3.5
346	6	22	9	-3.1
287	6	24*	13	-0.5

4.4 Bubbled Testing

After completing the low vapor space steady state testing at approximately 300°C, the vapor space temperature was raised back up to the nominal operating average temperature of 725°C. Both bubblers were increased to approximately 0.5 scfm (total ~1 scfm). The system was operated with these conditions until feeding was stopped on June 3, 2013 at 12:03. During this time, the feed rate was in the range of 149 – 249 g/min, with an average value of 213 g/min. Significant drops of the T13 melt pool temperature were also observed; however, the exact cause is unknown. It is possible that the feed rate was far too high at times, which caused a buildup of cold cap or the thermocouple itself was faulty.



700°C May 31, 2013 at 14:58 | 700°C May 31, 2013 at 15:45 | 700°C May 31, 2013 at 16:30

600°C May 31, 2013 at 19:59 | 600°C May 31, 2013 at 21:00 | 600°C May 31, 2013 at 22:01

500°C June 1, 2013 at 1:13 | June 1, 2013 at 2:00 | June 1, 2013 at 3:03

Figure 4-1. Images of CEF cold cap (vapor space target temperatures of 500-700°C).

400°C June 1, 2013 at 10:21

400°C June 1, 2013 at 11:30

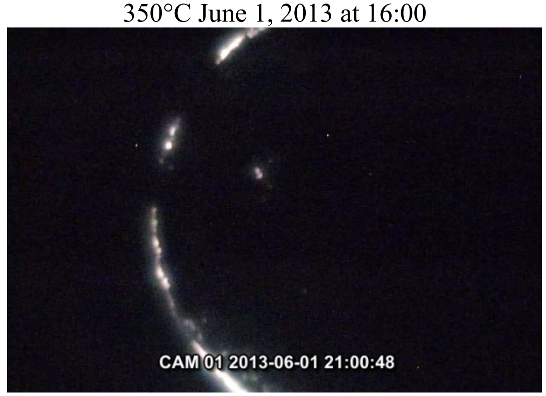
400°C June 1, 2013 at 12:22

350°C June 1, 2013 at 15:08

350°C June 1, 2013 at 16:00

350°C June 1, 2013 at 17:11

300°C June 1, 2013 at 20:06



300°C June 1, 2013 at 21:00

300°C June 1, 2013 at 22:06

Figure 4-2. Images of CEF cold cap (vapor space target temperatures of 300-400°C).

4.5 T13 Thermocouple Failure

Within the first few hours after startup on May 29, 2013, it was noticed that thermocouple T13 was not showing any signs of heating compared to thermocouple T14 as shown in Figure 4-3. At approximately 11:17, T13 was tested and the circuit appeared to work properly.

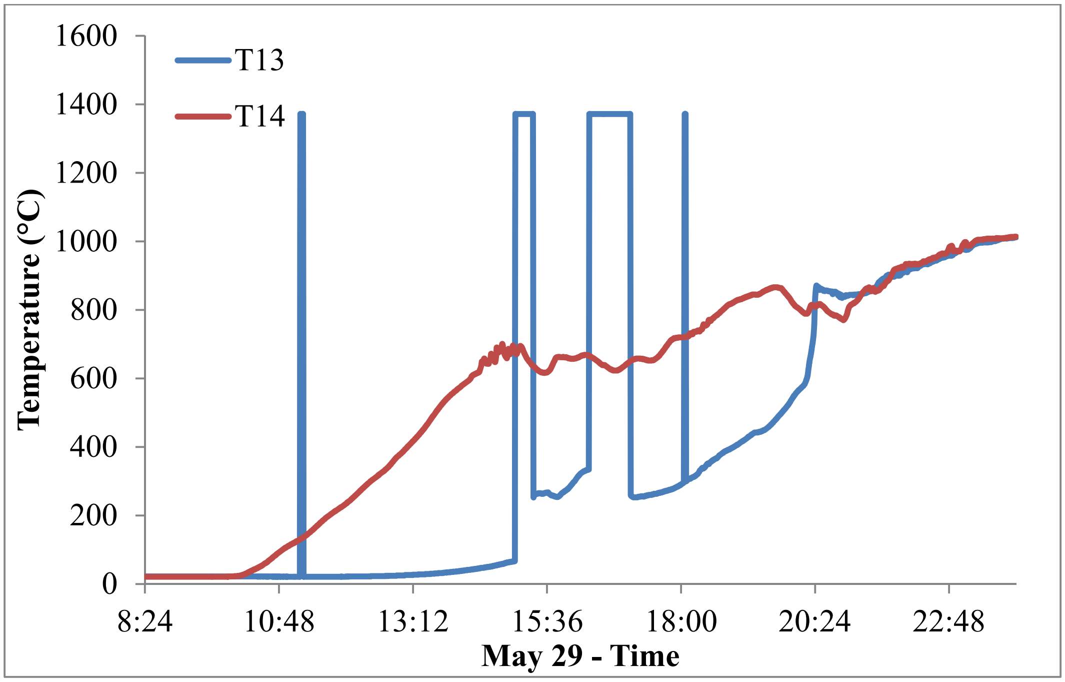


Figure 4-3. T13 thermocouple temperature as a function of time on May 29, 2013.

Based on the large temperature deviation observed between T13 and T14, it was decided to replace T13 (~15:00). At 16:31 T13 was completely removed from the melter and a replacement was lowered into the glass pool at 17:10 and verified at 18:04. Within a few hours, comparable temperature readings were observed between T13 and T14. An immediate cause for the failure could not be determined. It was later determined that the connection was loose, which caused contact between the two thermocouple wires. Thus, the recorded temperatures were actually of the ambient conditions outside of the melter.

4.6 Pour Tube Cartridge Heater Failure

The auxiliary heater contains a thermocouple that provides information about the glass temperature inside of the chimney surrounding the upper portion of the pour tube. This thermocouple can be used as input for control of the heater.

The output on the new auxiliary pour heater was gradually increased along with the other heater systems during startup. At an output of ~87% (~560 watts), the heater failed on May 29, 2013 at approximately 23:49. Figure 4-4 shows the heater temperature and output as a function of time leading up to the failure.[q] The failed heater was removed from the melt pool and replaced. It appears that the original heater failed near the start of the heated portion, which is slightly below the glass interface.

A wattage limit (~175 watts) was established for the new heater and it performed well throughout the remainder of the testing. The additional heater significantly improved the ability to maintain glass pool

[q] Note that the momentary drop in heater output at 15:04 was accidental.

temperature and pouring behavior, especially at the lower vapor space temperatures.

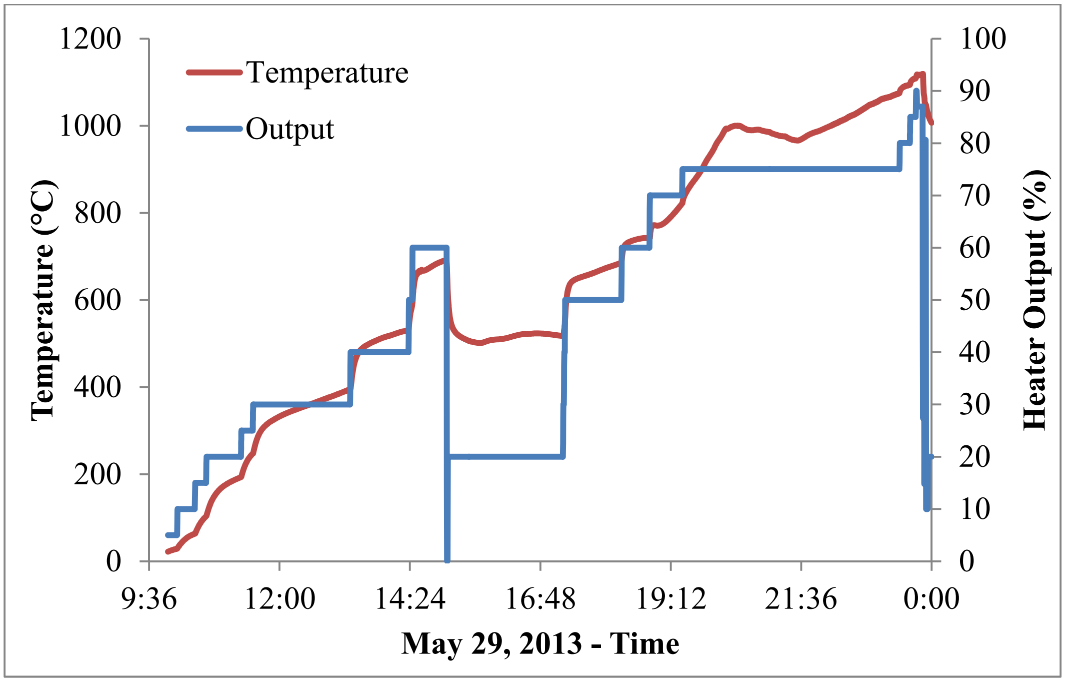


Figure 4-4. Pour tube heater output and temperature as a function of time prior to failure.

4.7 Vessel Dimensional Documentation

In support of future melter life assessments (see Section 2.1), the thermocouples that were welded to five of the six support blocks were monitored and recorded. Some support blocks were surrounded with reduced loose fill insulation in order to evaluate the possibility of additional cooling for creep reduction, if elevated temperatures were encountered. The remainder of the support blocks was surrounded by the normal method, which involves covering all exposed metal surfaces.

The average temperature for the different test conditions is shown in Table 4-4 and the recorded temperatures are shown in Figure 4-5. In general, support block temperature is approximately 50 degrees below the vapor space temperature during normal operating conditions. As the vapor space temperature decreases, the support temperatures also decrease and approach the actual temperature of the vapor space. It is important to note that all of the measured temperatures were well below the 1093°C value used to estimate the melter life based on creep concerns.

Table 4-4. Average Support Block Temperatures

Average Vapor Space Temperature (ºC)	**Average Support Block Temperature** (ºC)
693	657
596	546
507	466
409	378
346	334
287	292

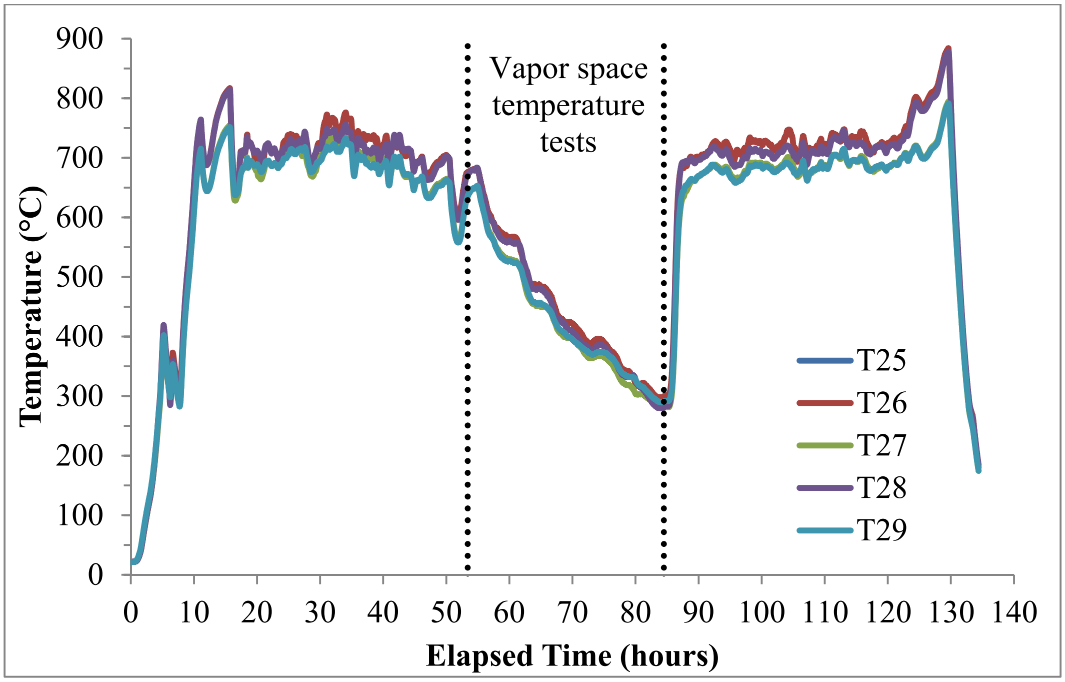


Figure 4-5. Support block temperatures throughout testing.

Prior to the start of Phase I testing, the melter vessel had been operated for approximately 250 hours during 2010 testing. Phase I testing resulted in an additional 135 hours, so the current total operational hours on the melter vessel is approximately 385 hours. Future Phase II testing will add 432 hours assuming a test duration of 18 days; however, the total operational hours will still be well below the recommended service life of 1250 hours (see Section 2.1 for more information).

4.8 Sampling

Samples were taken on a regular basis throughout the entire campaign. Feed samples were collected each time a new 55 gallon drum of melter feed was prepared. Glass samples were pulled from the pour stream at ~ 25 kg (glass poured) intervals. Condensate samples were taken from the overflow tank in the OGCT recirculation line hourly. The 25 µm bag filters[r] 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. The complete sets of sample results are shown in Appendix A Table A-1 through Table A-14. Dates and approximate times for the vapor space temperature tests are provided for reference in Table 4-5.

4.8.1 *Feed Analysis*

The measured compositions of all seven batches of melter feed are shown in Table 6-1 and Table 6-2.[s] 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 5%, which confirms that the melter feed was batched consistently. The measured TOC content of the melter feed was in the range of 14,400 – 16,900 µg/mL.

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[r] 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.

[s] Note that the increase in SO_4 concentration amongst the feed batches and %RSD of ~17% can most likely be attributed to the *analysis* rather than the samples themselves since the concentrations of the other detectable anions (Cl, NO_3 and HCO_2) are consistent with %RSD values less than 2%.

Table 4-5. Vapor Space Temperature Test Dates and Approximate Times

Vapor Space Temperature	Date	Start	End
700°C	5/31/2013	14:57	16:29
600°C	5/31/2013	19:58	22:00
500°C	6/1/2013	01:12	03:02
400°C	6/1/2013	10:20	12:21
350°C	6/1/2013	15:07	17:10
300°C	6/1/2013	20:05	22:05

4.8.2 *Condensate Analysis*

The pH values of all collected samples were in the range of 7.74 – 7.95 and densities were in the range of 0.9982 – 0.9985 g/cm^3. Solids were below the detection limit of 0.1%. The measured compositions of select condensate samples are shown in Table 6-3 and Table 6-4. A majority of these samples were collected during the vapor space tests (see Table 4-5). Note that F, NO_3, SO_4, PO_4, HCO_2 and C_2O_4 were below the detection limits for all measured samples and Cl and NO_2 were below the detection limits except for those samples shown in Table 6-4. In general, the concentration of components in the condensate increased with time, which is to be expected since the condensate system was closed and recirculated throughout the duration of the six-day test. Previous testing has shown that in condensate liquids with a pH greater than 7, the equilibria chemistry is shifted and nitrite concentration increases at the expense of nitrate concentration, which would account for the nitrite presence in the CEF condensate liquid.[53] The measured total carbon was in the range of 61.8 – 76.1 µg/mL (more details are provided in Appendix A Table A-9). TOC was in the range of 21.3 – 25.9 µg/mL and TIC was in the range of 40 – 51.1 µg/mL. The presence of TIC can be attributed to the atmospheric adsorption of CO_2 at pH greater than 7.

4.8.3 *Off-gas Filter Solids Analysis*

The measured compositions of each of the bag filters used during testing are shown in Table 6-5 and Table 6-6. Total solids content was in the range of 96-97.2%.

4.8.4 *Glass Analysis*

The measured glass compositions of select samples are shown in Table 6-7. Some of the analytes were below the detection limit of the instrument and are noted by a result preceded by a "<." %RSD values for the major glass components (> 0.5 wt%) are less than 10%, which confirms a consistent melter feed batching. A comparison of the expected glass composition, melter feed composition and measured glass composition is shown in Table 6-8. The calculated glass composition was determined by combining the measured SB6i SRAT product[39] received from Harrell Industries, Inc. with the target Frit 418 composition at a waste loading of 36%. No significant deviations are present between the calculated glass composition and the measured feed and glass compositions, which indicates that the melter feed was batched correctly. The $Fe^{2+}/\Sigma Fe$ ratios for all glass samples are in the range of 0.08 – 0.20 and are shown in Table 6-9. Compared to the REDOX crucible tests performed with the Harrell SB6i SRAT product prior to testing, these values are somewhat lower (more oxidized) than the measured $Fe^{2+}/\Sigma Fe$ crucible value of 0.26. A cause for the deviation is unknown at this time; however, it maybe be related to sources of air in the melter as opposed to a closed crucible system.

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 CO, CO_2, H_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 assessment is provided in a separate report.[9] Hydrogen generation during bubbled and non-bubbled conditions was an area of particular interest. A plot of the H_2 generation during both conditions is shown in Figure 6-1. Data for CO_2, CO, and NO_x are shown in Figure 6-2 through Figure 6-4. The decrease in gas concentrations between 35 hours and 70 hours is due to the increased air purges used during steady state vapor space temperature testing, which resulted in more air dilution.

5.0 Conclusions

Prior to startup, a number of improvements and modifications were made to the CEF, including addition of cameras, vessel support temperature measurement, and a heating element near the pour tube. After charging the CEF with cullet from a previous Sludge Batch 6 (SB6) run, the melter was slurry-fed with SB6-Frit 418 melter feed at 36% waste loading and was operated continuously for 6 days. Process data was collected throughout testing and included melter operation variables and off-gas chemistry. In order to satisfy the objective of Phase I testing, vapor space steady testing in the range of ~300°C-700°C was conducted without argon bubbling to baseline the melter data to the existing DWPF melter flammability model. Adjustments to heater outputs, air flows and feed rate were necessary in order to achieve the vapor space temperatures in this range.

The results of the Phase I testing demonstrated that the CEF is capable of operating under the low vapor space temperatures. A melter pressure of -5 inches of water was not sustained throughout the run, but the melter did remain slightly negative even with the maximum air flows required for the lowest temperature conditions were used. The auxiliary pour tube heater improved the pouring behavior at all test conditions, including reduced feed rates required for the low vapor space testing. Argon bubbling can be used to promote mixing and increase feed rate at multiple conditions. Improvements due to bubbling have been determined previously; however, the addition of the cameras to the CEF allows for visual observation during a range of bubbling configurations. The off-gas analysis system proved to be robust and capable of operating for long durations.

The total operational hours on the melter vessel are approximately 385 hours. After Phase II testing, the anticipated total is expected to be approximately 820 hours, which is still well below the recommended service life of 1250 hours. Dimensional measurements taken prior to Phase I testing and support block temperatures recorded during Phase I testing are available if an extension of service life beyond 1250 hours is desired in the future.

6.0 Recommendations

The additional cooling/purge air required during testing pushed the limits of both the off-gas system and the existing flow meters. Either expanding the calibration range of the air flow meters or replacement where necessary would enhance the run data. A larger blower could increase vacuum capabilities on both the OGCT and melter. Installation of the repaired SRNL camera should give an additional view of the cold cap, which will improve feeding control.

Table 6-1. Measured Melter Feed Composition (wt% calcined at 1100°C)

Sample ID	CEF1-F-059	CEF1-F-060	CEF1-F-061	CEF1-F-062	CEF1-F-063	CEF1-F-064	CEF1-F-065	Average	%RSD
Date	5/30/2013	5/30/2013	5/30/2013	5/31/2013	6/2/2013	6/2/2013	6/3/2013	---	---
Time	1:10	8:00	16:10	4:55	1:55	14:45	6:15	---	---
Al_2O_3	9.58	10.16	9.70	9.46	9.89	9.65	9.91	9.77	2.3
B_2O_3	5.28	5.01	4.98	5.00	4.75	4.95	5.00	5.00	3.0
BaO	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	2.4
CaO	0.51	0.53	0.53	0.51	0.54	0.52	0.51	0.52	2.7
Ce_2O_3	0.07	0.08	0.08	0.07	0.08	0.07	0.07	0.07	4.8
Cr_2O_3	0.09	0.10	0.10	0.09	0.09	0.09	0.10	0.10	2.6
Cu_2O	0.09	0.11	0.09	0.07	0.06	0.07	0.08	0.08	22.4
Fe_2O_3	11.08	11.54	11.05	10.75	10.99	10.95	11.19	11.08	2.3
K_2O	0.15	0.16	0.15	0.15	0.16	0.15	0.16	0.16	2.1
Li_2O	4.92	4.75	4.83	4.93	4.93	4.97	4.95	4.90	1.6
MgO	0.50	0.52	0.52	0.49	0.51	0.50	0.50	0.50	2.0
MnO_2	3.63	3.75	3.69	3.50	3.63	3.50	3.55	3.61	2.6
Na_2O	11.69	11.64	11.71	11.59	11.66	11.46	11.47	11.60	1.0
NiO	1.27	1.33	1.28	1.22	1.23	1.23	1.25	1.26	3.1
P_2O_5	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	---
PbO	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	---
PdO	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	---
SO_4	0.29	0.27	0.29	0.28	0.29	0.30	0.30	0.29	3.9
SnO_2	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	2.4
SiO_2	49.94	48.61	49.11	49.75	48.41	48.94	50.31	49.30	1.7
TiO_2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	2.7
ZnO	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	2.6
ZrO_2	0.13	0.14	0.14	0.13	0.13	0.13	0.14	0.13	2.6
TOTAL	99.39	98.86	98.42	98.18	97.51	97.65	99.66	---	---

Table 6-2. Measured Melter Feed Anions (mg/kg)

Sample ID	CEF1-F-059	CEF1-F-060	CEF1-F-061	CEF1-F-062	CEF1-F-063	CEF1-F-064	CEF1-F-065	Average	%RSD
Date	**5/30/2013**	**5/30/2013**	**5/30/2013**	**5/31/2013**	**6/2/2013**	**6/2/2013**	**6/3/2013**	---	---
Time	**1:10**	**8:00**	**16:10**	**4:55**	**1:55**	**14:45**	**6:15**	---	---
F	<500	<500	<500	<500	<500	<500	<500	<500	---
Cl	311	316	314	312	307.5	305	314.5	311	1.6
NO_2	<500	<500	<500	<500	<500	<500	<500	<500	---
NO_3	17200	17700	17900	17700	17700	17650	17100	17564	1.8
SO_4	445	568.5	633	701.5	701	736	750.5	648	16.6
C_2O_4	<500	<500	<500	<500	<500	<500	<500	<500	---
HCO_2	44600	46150	44950	45750	45750	45250	47200	45664	1.8
PO_4	<500	<500	<500	<500	<500	<500	<500	<500	---

Table 6-3. Measured Condensate Cations (mg/L)

Sample ID	Date	Time	Al	B	Ca	Cr	Fe	K	Li	Mg	Na	Si
CEF1-C-023	5/31/2013	1:15	0.38	13.71	7.36	0.29	0.03	1.77	1.28	0.61	63.03	4.63
CEF1-C-036	5/31/2013	14:30	0.43	17.81	7.71	0.32	0.03	1.94	1.65	0.68	75.89	4.85
CEF1-C-037	5/31/2013	15:30	0.40	17.35	7.54	0.31	0.03	1.92	1.62	0.66	75.96	4.74
CEF1-C-038	5/31/2013	16:30	0.36	17.38	7.63	0.32	0.03	1.95	1.65	0.68	79.18	4.92
CEF1-C-041	5/31/2013	19:30	0.43	18.62	7.77	0.32	0.03	2.00	1.71	0.71	80.27	4.98
CEF1-C-042	5/31/2013	20:30	0.51	18.50	7.72	0.32	0.03	2.01	1.70	0.70	79.17	5.02
CEF1-C-043	5/31/2013	21:30	0.42	18.18	7.65	0.31	0.03	1.99	1.68	0.70	79.37	5.01
CEF1-C-044	5/31/2013	22:03	0.49	18.88	7.71	0.32	0.03	2.06	1.70	0.71	82.04	5.15
CEF1-C-048	6/1/2013	1:30	0.45	19.38	7.95	0.32	0.03	2.11	1.78	0.74	81.82	5.77
CEF1-C-049	6/1/2013	2:30	0.42	19.21	7.81	0.32	0.03	2.09	1.76	0.74	84.11	5.96
CEF1-C-050	6/1/2013	3:06	0.49	19.06	7.69	0.32	0.03	2.10	1.75	0.73	84.62	5.94
CEF1-C-058	6/1/2013	10:30	0.49	19.25	7.81	0.32	0.03	2.14	1.80	0.76	84.74	6.51
CEF1-C-059	6/1/2013	11:30	0.47	19.11	7.71	0.32	0.03	2.11	1.78	0.75	85.97	6.55
CEF1-C-060	6/1/2013	12:20	0.53	18.69	7.52	0.31	0.03	2.06	1.74	0.73	84.95	6.31
CEF1-C-063	6/1/2013	15:30	0.51	19.94	7.92	0.33	0.03	2.17	1.84	0.78	86.89	6.86
CEF1-C-064	6/1/2013	16:30	0.53	19.14	7.66	0.31	0.03	2.19	1.78	0.75	87.05	6.64
CEF1-C-065	6/1/2013	17:25	0.51	19.61	7.87	0.32	0.03	2.14	1.82	0.77	88.16	6.63
CEF1-C-068	6/1/2013	20:30	0.54	18.98	7.57	0.31	0.03	2.08	1.77	0.74	86.75	6.29
CEF1-C-069	6/1/2013	21:30	0.53	20.15	8.02	0.33	0.03	2.19	1.86	0.79	86.80	6.74
CEF1-C-070	6/1/2013	22:30	0.55	19.75	7.82	0.32	0.03	2.14	1.82	0.76	87.76	6.53
CEF1-C-076	6/2/2013	4:30	0.57	20.28	8.06	0.33	0.03	2.20	1.87	0.80	87.40	7.14
CEF1-C-082	6/2/2013	10:30	0.61	18.87	7.60	0.31	0.03	2.08	1.77	0.75	87.24	6.61
CEF1-C-088	6/2/2013	16:00	0.45	25.49	7.97	0.34	0.03	2.66	2.43	0.91	111.67	5.82
CEF1-C-094	6/2/2013	22:00	0.48	27.62	7.79	0.34	0.03	2.73	2.53	0.90	115.59	5.97
CEF1-C-100	6/3/2013	4:00	0.43	30.06	7.87	0.35	0.03	2.84	2.67	0.92	123.69	6.23
CEF1-C-108	6/3/2013	12:00	0.43	34.19	8.24	0.37	0.03	3.15	2.98	0.98	129.10	6.52

Table 6-4. Measured Condensate Anions (mg/L)

Sample ID	Date	Time	Cl	NO_2
CEF1-C-088	6/2/2013	16:00	1.07	1.24
CEF1-C-094	6/2/2013	22:00	1.11	1.315
CEF1-C-100	6/3/2013	4:00	1.18	1.4
CEF1-C-108	6/3/2013	12:00	1.27	1.5

Note that F, NO_3, SO_4, PO_4, HCO_2 and C_2O_4 were below the detection limits for all measured samples.

Table 6-5. Measured Off-gas System Filter Solids Cations (wt% elemental at 105°C)

Sample ID	CEF1-FL-A	CEF1-FL-M	CEF1-FL-Q	CEF1-FL-B
Service Dates	5/29 - 5/30/2013	5/30 - 6/2/2013	6/2 - 6/2/2013	6/2 - 6/3/2013
Al	9.86	8.22	8.64	8.77
B	0.75	0.85	0.57	0.71
Ba	0.10	0.08	0.09	0.10
Ca	0.62	0.54	0.75	0.65
Ce	0.11	0.10	0.11	0.11
Cr	0.14	0.17	0.17	1.27
Cu	0.13	0.11	0.13	0.11
Fe	19.81	16.84	20.00	19.24
K	0.04	0.04	0.05	0.05
Li	0.81	1.04	0.52	0.74
Mg	0.66	0.58	0.72	0.65
Mn	6.07	5.14	6.50	5.86
Na	2.98	3.23	2.34	2.82
Ni	2.56	2.20	2.66	2.56
Pb	<0.1	<0.1	<0.1	<0.1
Si	10.83	13.01	10.44	10.95
Ti	0.04	0.05	0.05	0.06
Zn	0.09	0.08	0.09	0.09
Zr	0.11	0.11	0.09	0.09

Table 6-6. Measured Off-gas System Filter Solids Anions (wt%)

Sample ID	CEF1-FL-A	CEF1-FL-M	CEF1-FL-Q	CEF1-FL-B
Service Dates	5/29 - 5/30/2013	5/30 - 6/2/2013	6/2 - 6/2/2013	6/2 - 6/3/2013
F	<0.05	<0.05	<0.05	<0.05
Cl	<0.05	0.24	0.21	0.07
NO_2	<0.05	<0.05	<0.05	<0.05
NO_3	<0.05	<0.05	<0.05	<0.05
SO_4	0.15	0.12	0.17	0.21
C_2O_4	0.14	0.59	0.62	0.26
HCO_2	<0.05	<0.05	<0.05	<0.05
PO_4	<0.05	<0.05	<0.05	<0.05

Table 6-7. Measured Glass Composition Data (wt%)

Sample ID	CEF1-GL-005	CEF1-GL-007	CEF1-GL-008	CEF1-GL-009	CEF1-GL-014	CEF1-GL-016	Average	%RSD
Date	5/30/2013	5/31/2013	5/31/2013	6/1/2013	6/2/2013	6/3/2013	---	---
Time	21:40	11:17	22:17	11:11	22:08	9:53	---	---
Al_2O_3	10.17	9.97	9.89	9.68	9.69	9.60	9.83	2.2
B_2O_3	4.79	5.03	4.99	4.44	5.01	5.11	4.90	5.7
BaO	0.04	0.04	0.05	0.05	0.05	0.06	0.05	13.0
CaO	0.57	0.59	0.59	0.59	0.58	0.59	0.58	1.6
Ce_2O_3	0.05	0.06	0.06	0.06	0.07	0.07	0.06	13.8
Cr_2O_3	0.08	0.08	0.09	0.09	0.10	0.10	0.09	11.5
CuO	0.07	0.07	0.06	0.06	0.06	0.06	0.06	7.2
Fe_2O_3	10.51	10.51	10.60	10.50	10.73	10.70	10.59	1.1
K_2O	0.10	0.12	0.12	0.12	0.13	0.13	0.12	7.9
Li_2O	4.73	4.88	4.86	4.61	4.84	4.87	4.80	2.5
MgO	0.47	0.52	0.53	0.53	0.57	0.58	0.53	6.8
MnO_2	3.79	3.83	3.84	3.78	3.87	3.86	3.83	1.0
Na_2O	12.26	12.05	11.99	11.79	11.72	11.77	11.93	1.7
NiO	1.22	1.20	1.23	1.22	1.25	1.27	1.23	1.9
PbO	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	---
SiO_2	49.82	50.84	50.47	48.80	50.83	50.33	50.18	1.8
TiO_2	0.04	0.04	0.04	0.04	0.04	0.04	0.04	7.8
ZnO	0.04	0.04	0.05	0.05	0.06	0.06	0.05	15.4
ZrO_2	0.14	0.15	0.15	0.16	0.14	0.15	0.15	6.6
TOTAL	98.89	100.02	99.61	96.57	99.74	99.34	---	---

Table 6-8. Comparison of Calculated and Measured Compositions (wt%)

Component	Calculated Glass Composition	Average Measured Melter Feed Composition	Average Measured Glass Composition
Al_2O_3	9.48	9.77	9.83
B_2O_3	5.12	5.00	4.90
CaO	0.60	0.52	0.58
Fe_2O_3	11.09	11.08	10.59
Li_2O	5.12	4.90	4.80
MgO	0.51	0.50	0.53
MnO_2	3.83	3.61	3.83
Na_2O	11.53	11.60	11.93
NiO	1.31	1.26	1.23
SiO_2	49.79	49.30	50.18

Table 6-9. Measured REDOX Data

Sample	Date	Time	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
CEF1-GL-001	5/30/2013	3:35	0.08	0.08
CEF1-GL-002	5/30/2013	5:35	0.11	0.10
CEF1-GL-003	5/30/2013	10:50	0.15	0.13
CEF1-GL-004	5/30/2013	18:28	0.20	0.17
CEF1-GL-005	5/30/2013	21:40	0.20	0.17
CEF1-GL-006	5/31/2013	2:12	0.22	0.18
CEF1-GL-007	5/31/2013	11:17	0.20	0.17
CEF1-GL-008	5/31/2013	22:17	0.16	0.13
CEF1-GL-009	6/1/2013	11:11	0.13	0.11
CEF1-GL-010	6/2/2013	1:35	0.10	0.09
CEF1-GL-011	6/2/2013	7:20	0.14	0.12
CEF1-GL-012	6/2/2013	12:10	0.18	0.15
CEF1-GL-013	6/2/2013	17:11	0.20	0.16
CEF1-GL-014	6/2/2013	22:08	0.25	0.20
CEF1-GL-015	6/3/2013	4:36	0.23	0.19
CEF1-GL-016	6/3/2013	9:53	0.22	0.18

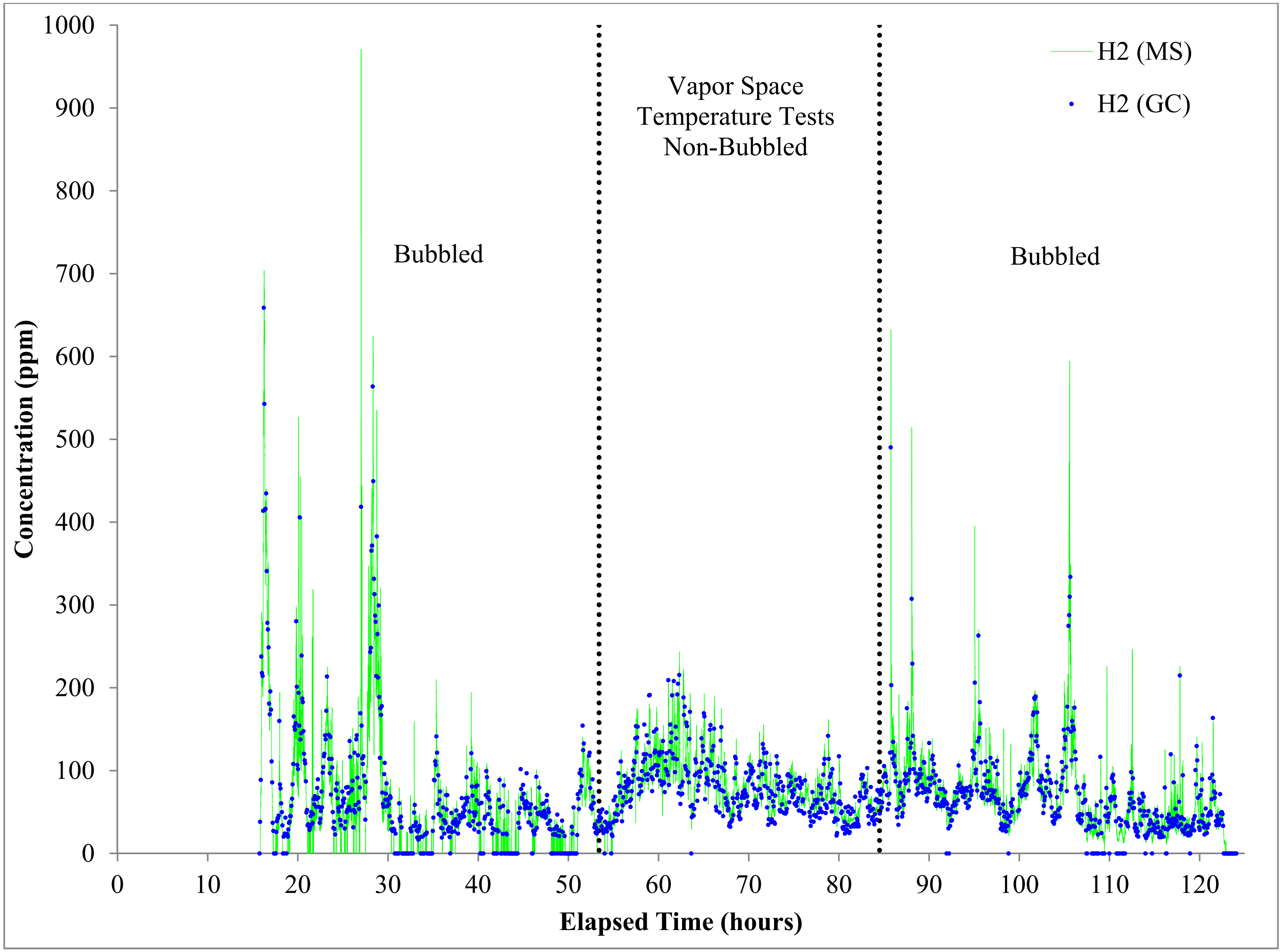

Figure 6-1. Hydrogen generation during bubbled and non-bubbled runs (Elapsed time=0 at 09:34 May 29, 2013).

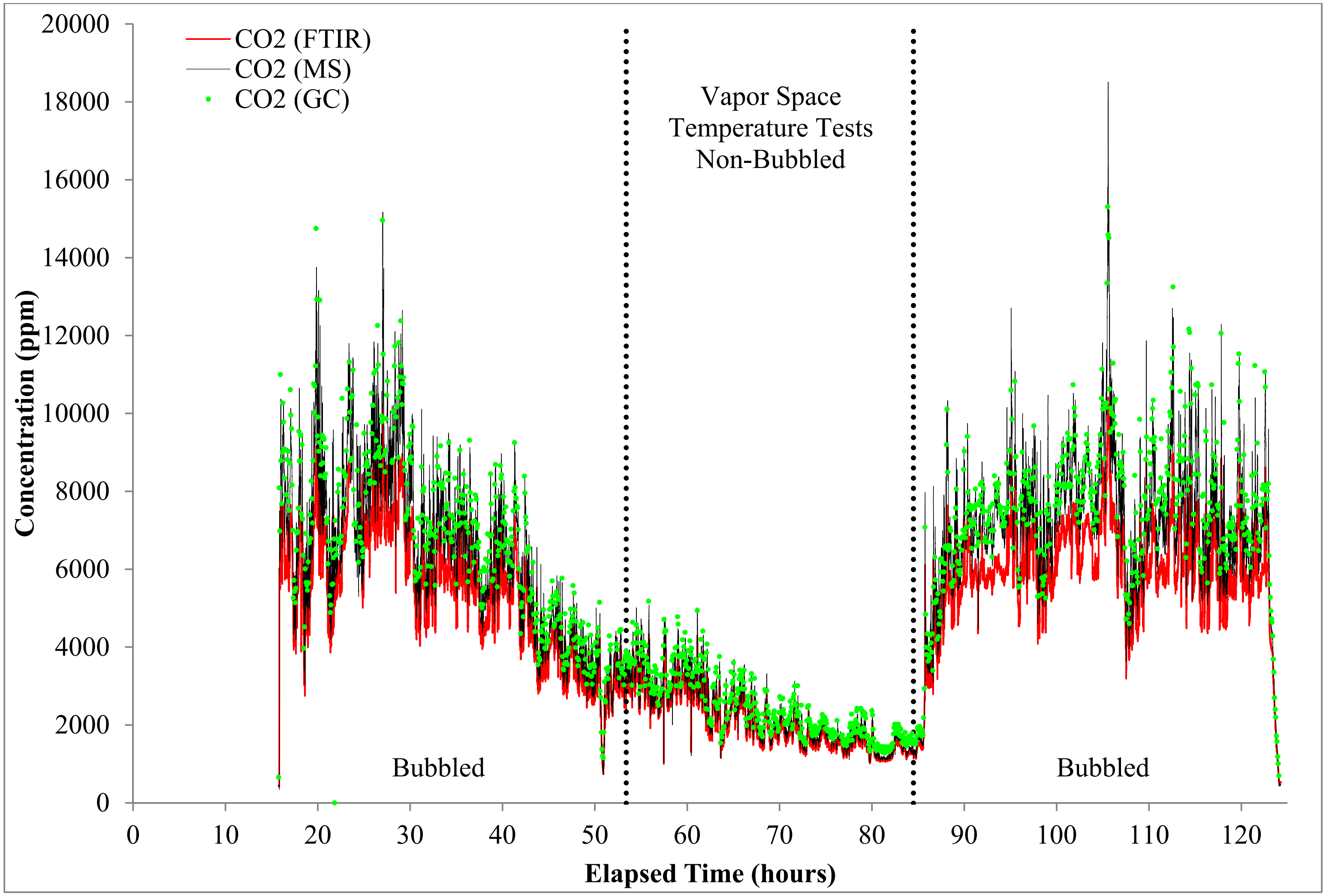

Figure 6-2. CO_2 generation (Elapsed time=0 at 09:34 May 29, 2013).

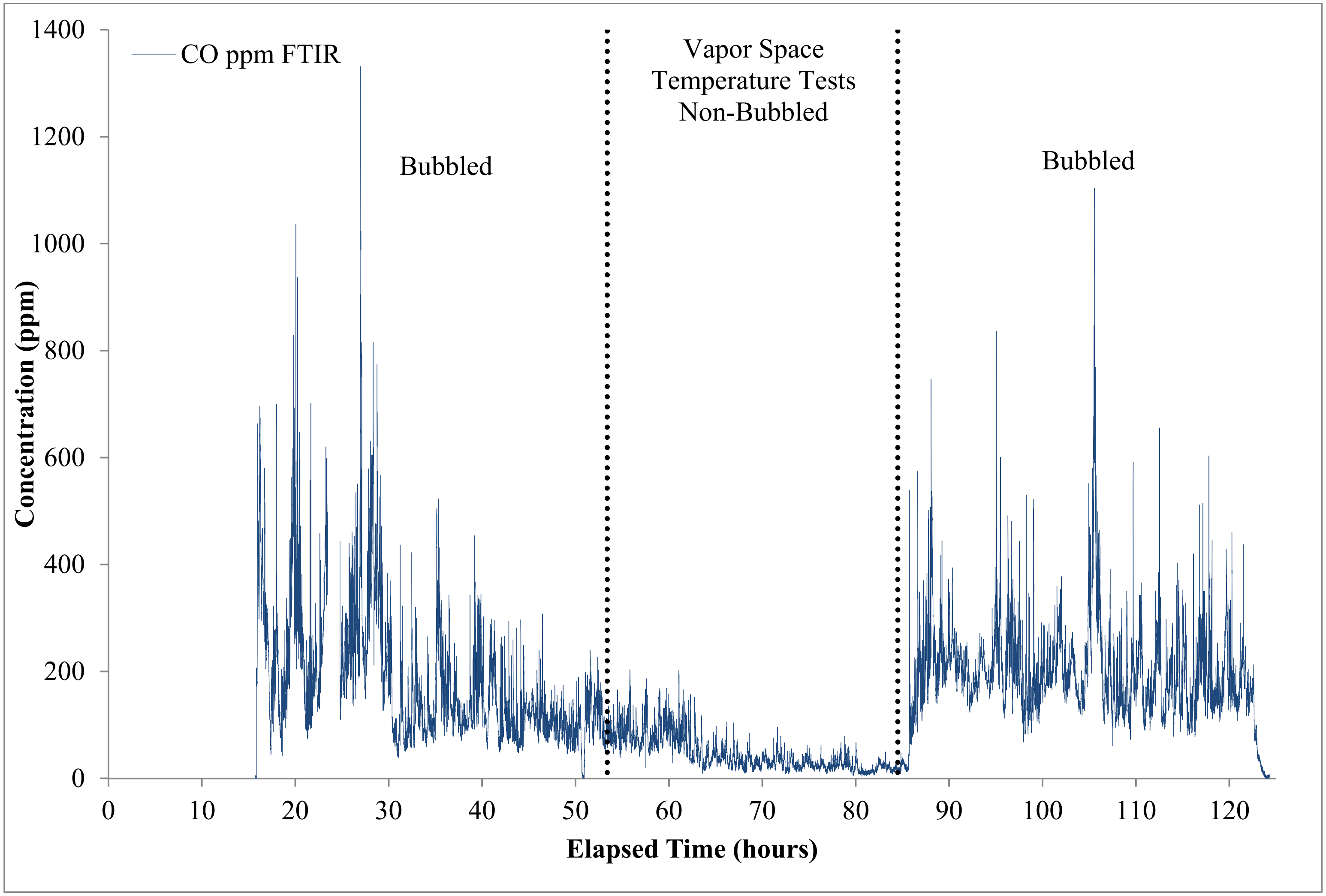

Figure 6-3. CO generation (Elapsed time=0 at 09:34 May 29, 2013).

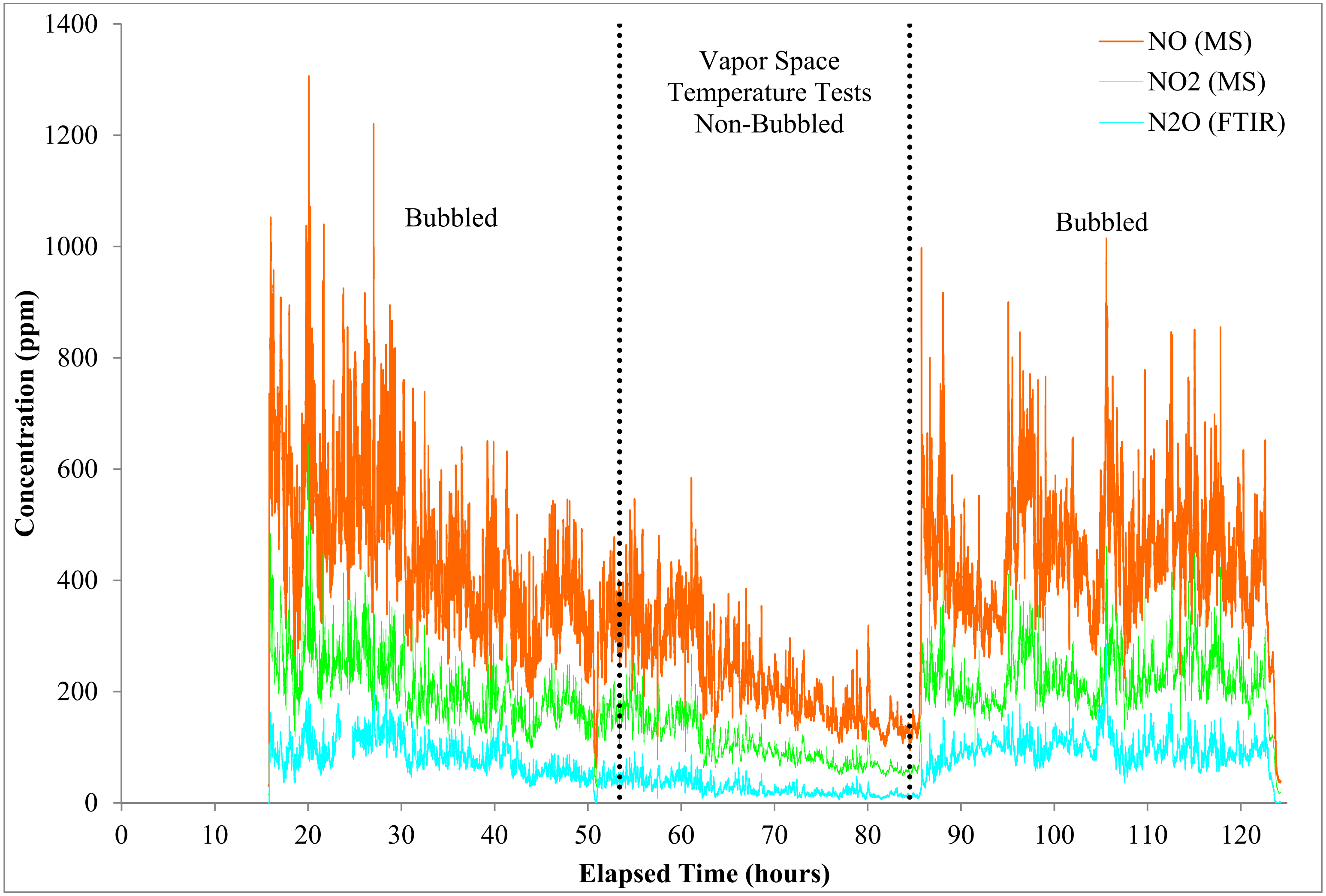

Figure 6-4. NO, NO_2 and N_2O generation (Elapsed time=0 at 09:34 May 29, 2013).

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47. "Anion Analysis Using the Dionex DX-500 and ICS-5000 Ion Chromatograph," Savannah River National Laboratory, Aiken, SC, ITS-0027, current revision.

48. "Operation of OI Analytical 1030 W Carbon Analyzer: Wet Oxidation Method," Savannah River National Laboratory, Aiken, SC, ADS-1209, current revision.

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50. F.C. Johnson, “Cold Cap Evaluation Furnace (CEF) Testing Readiness Assessment,” Savannah River National Laboratory, Aiken, SC, SRNL-L3100-2013-00071, May 2013.

51. F.C. Johnson and D.H. Miller, “Nitric-Formic Acid Flowsheet Melter Flammability Testing: 2013 Phase 1 CEF Run R&D Directions,” Savannah River National Laboratory, Aiken, SC SRNL-L3100-2013-00045, May 2013.

52. F.C. Johnson, “Alternate Reductant Cold Cap Evaluation Furnace (CEF) Phase I Data,” Savannah River National Laboratory, Aiken, SC, SRNL-L3100-2013-00189, 2013.

53. A.S. Choi, M.E. Smith, K.R. Crow, M.R. Baron, G.F. Rabon, S.L. Goudelock, and A.M. Wehner, “Summary of Campaigns Sgm-9 and Sgm-10 of the DWPF Scale Glass Melter,” Savannah River Laboratory, Aiken, SC, DPST-88-626, 1988.

Appendix A. Supplementary Figures and Tables

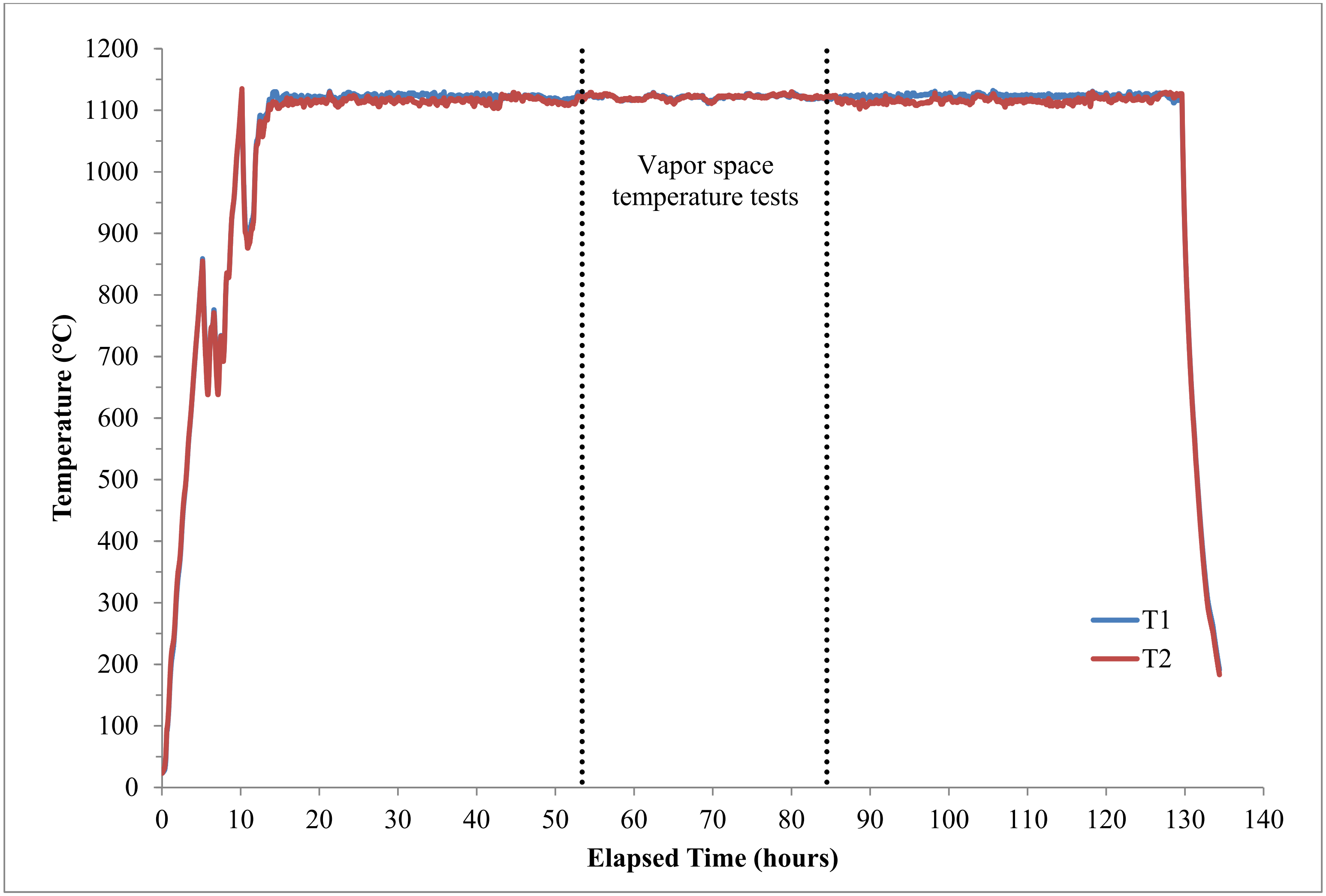

Figure A-1. Melter bottom thermocouple temperatures (Elapsed time=0 at 09:34 May 29, 2013).

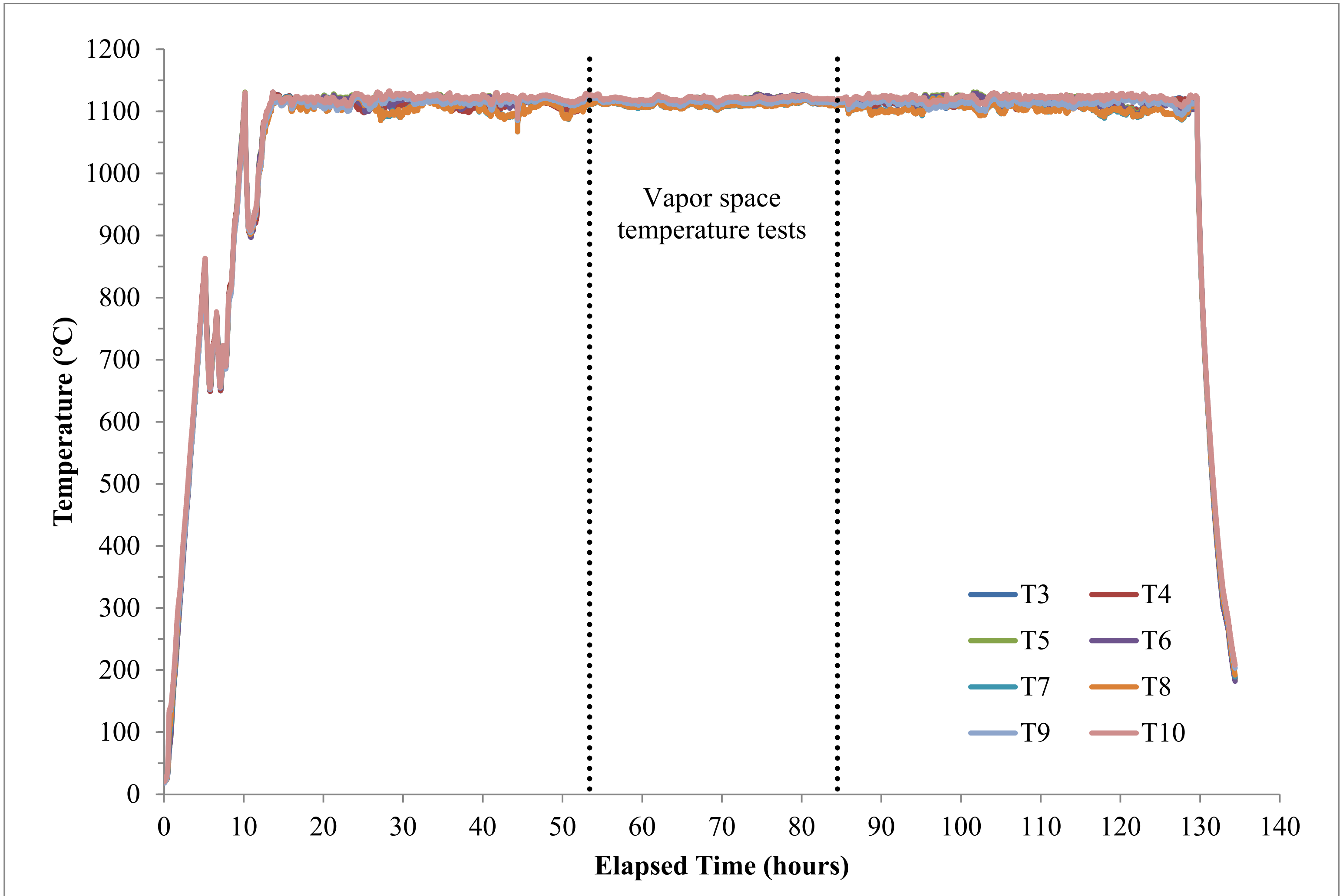

Figure A-2. Melter side thermocouple temperatures (Elapsed time=0 at 09:34 May 29, 2013).

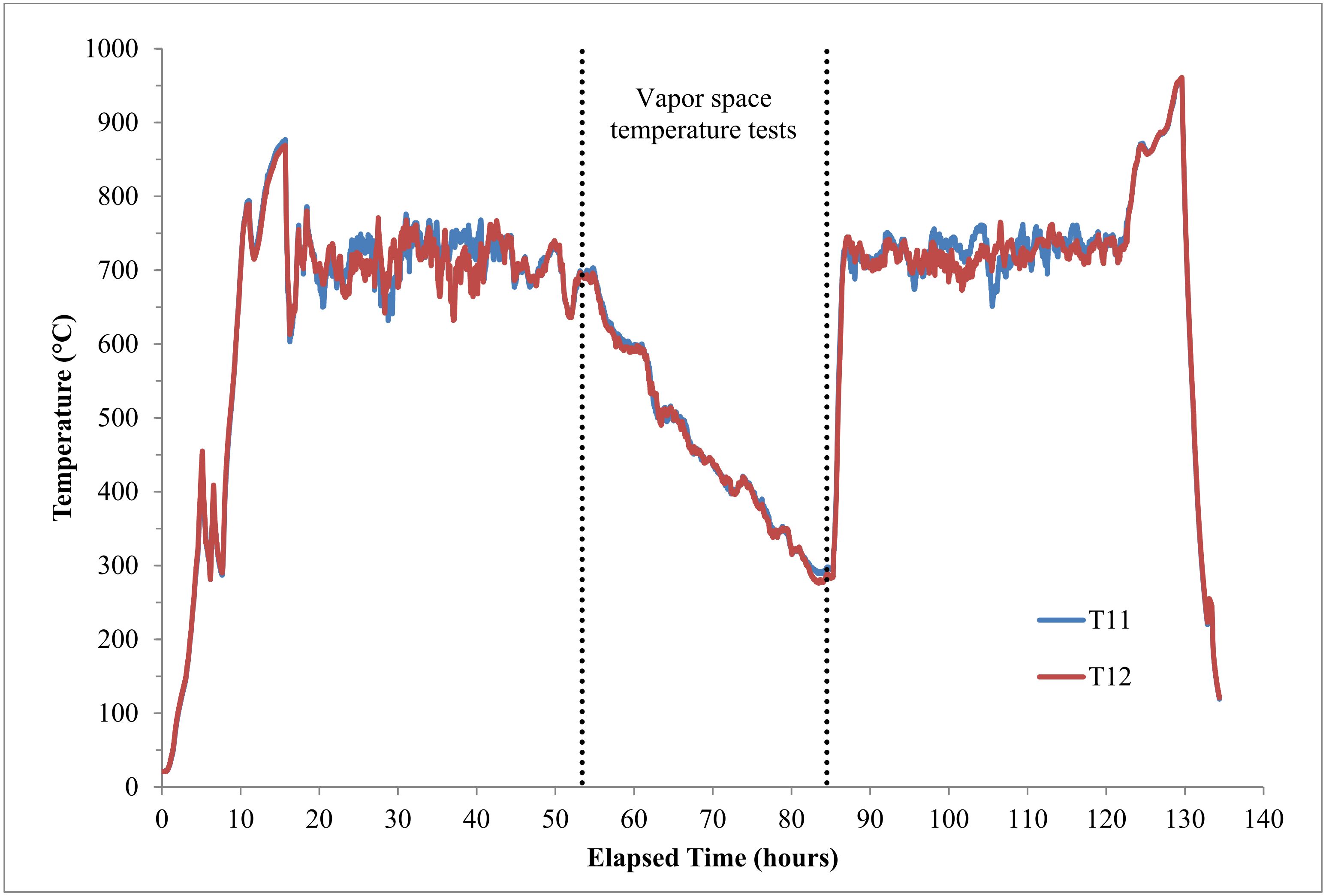

Figure A-3. Vapor space thermocouple temperatures (Elapsed time=0 at 09:34 May 29, 2013).

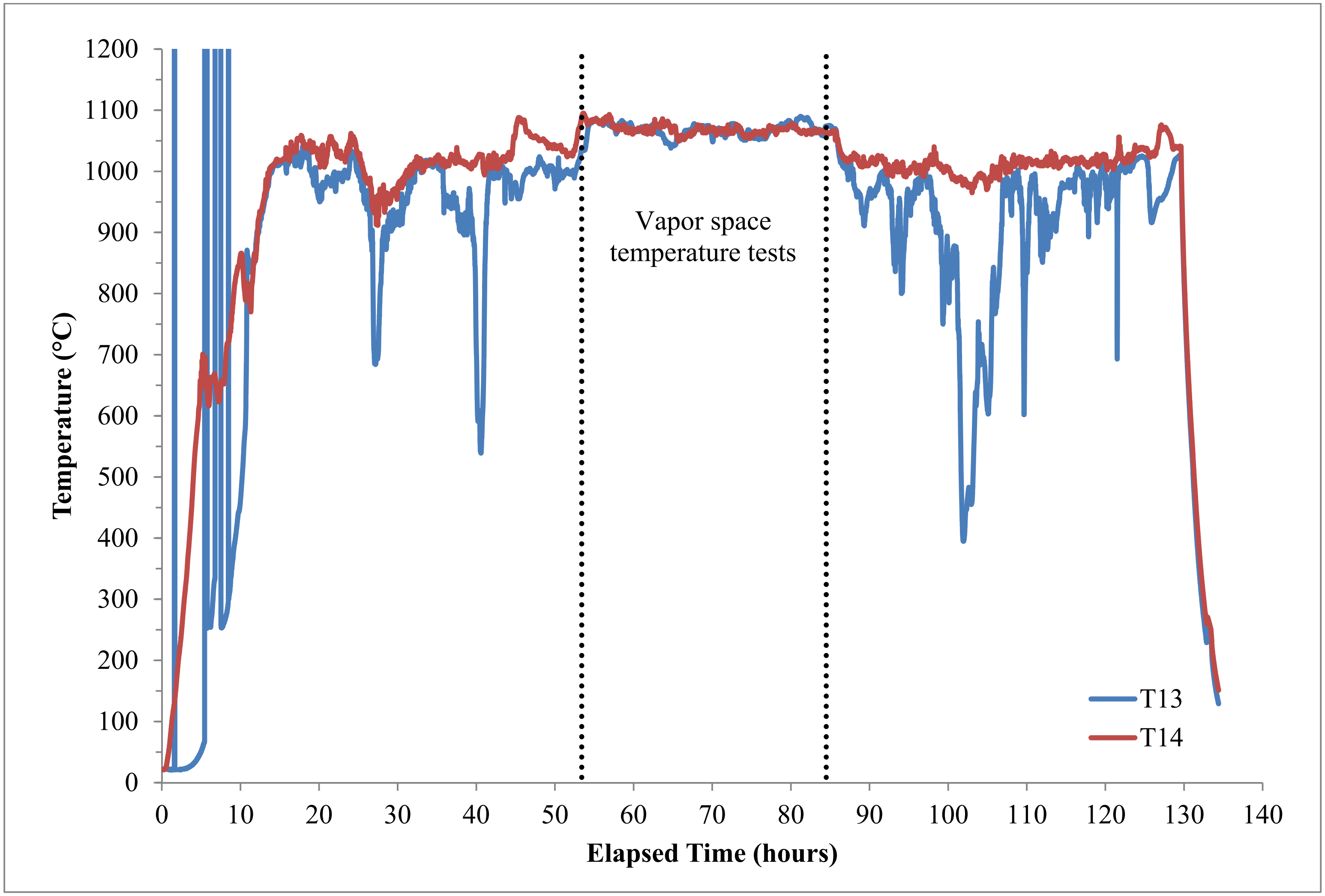

Figure A-4. Glass pool thermocouple temperatures (Elapsed time=0 at 09:34 May 29, 2013).

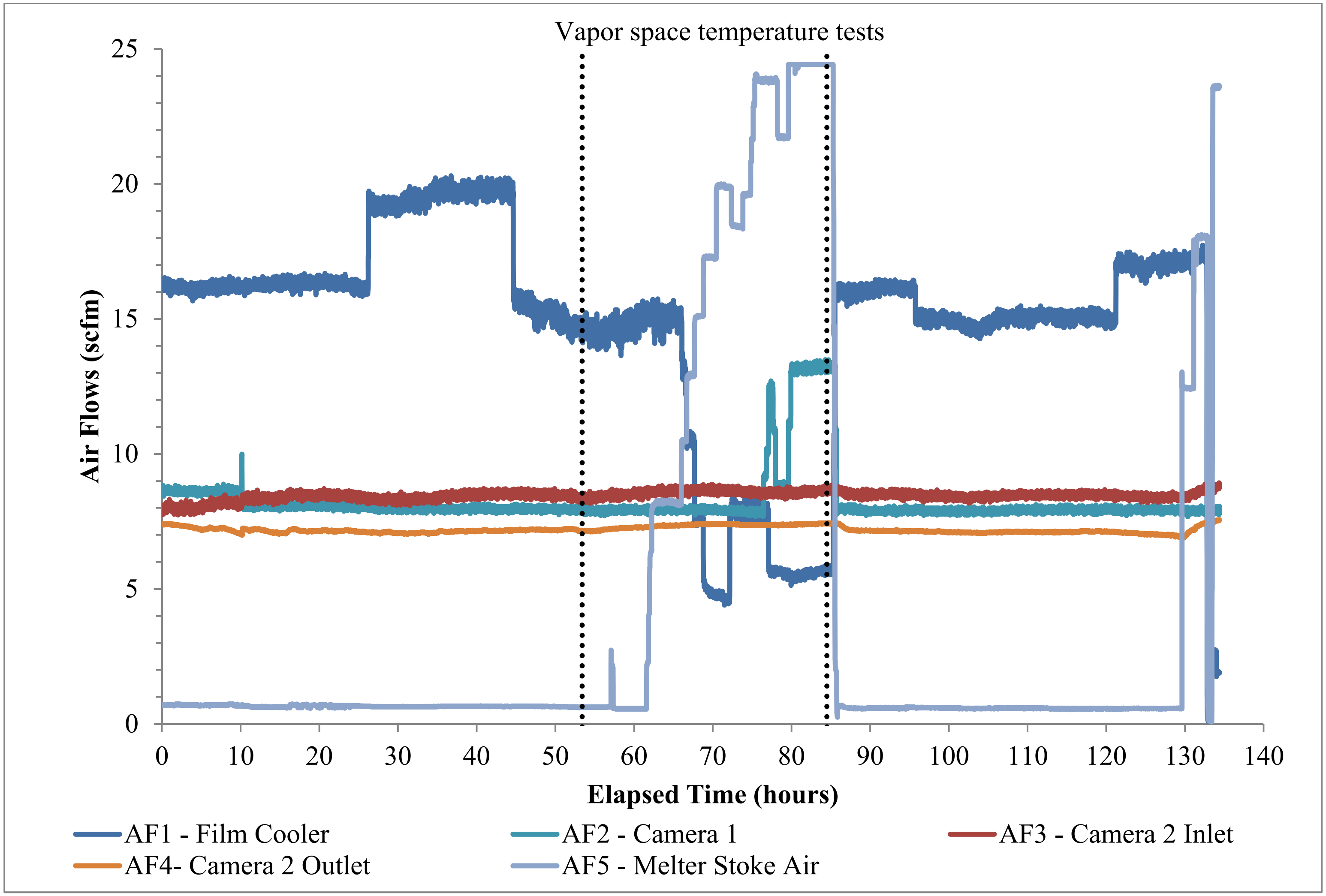

Figure A-5. Air flows (Elapsed time=0 at 09:34 May 29, 2013).

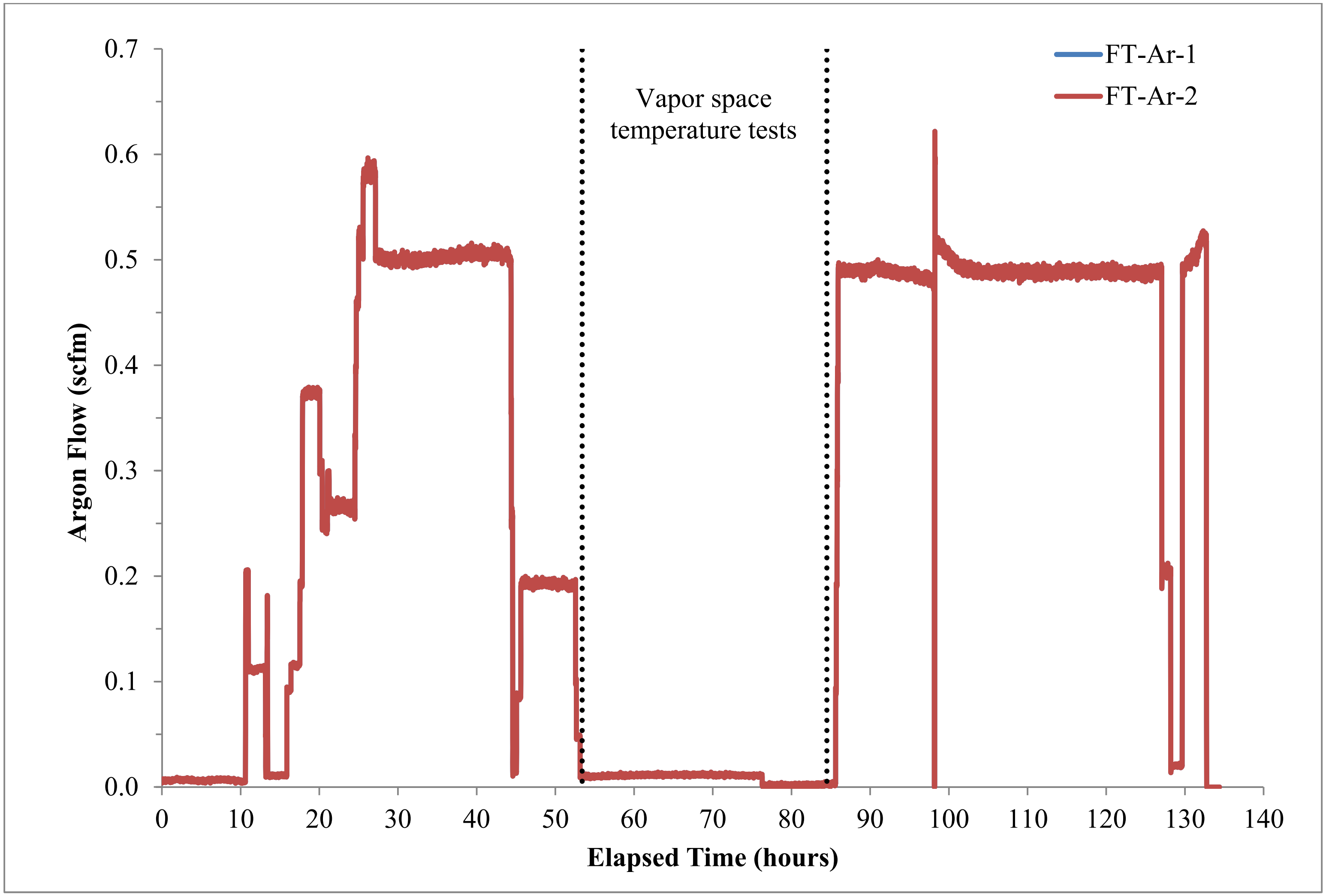

Figure A-6. Argon bubbler flows (Elapsed time=0 at 09:34 May 29, 2013).

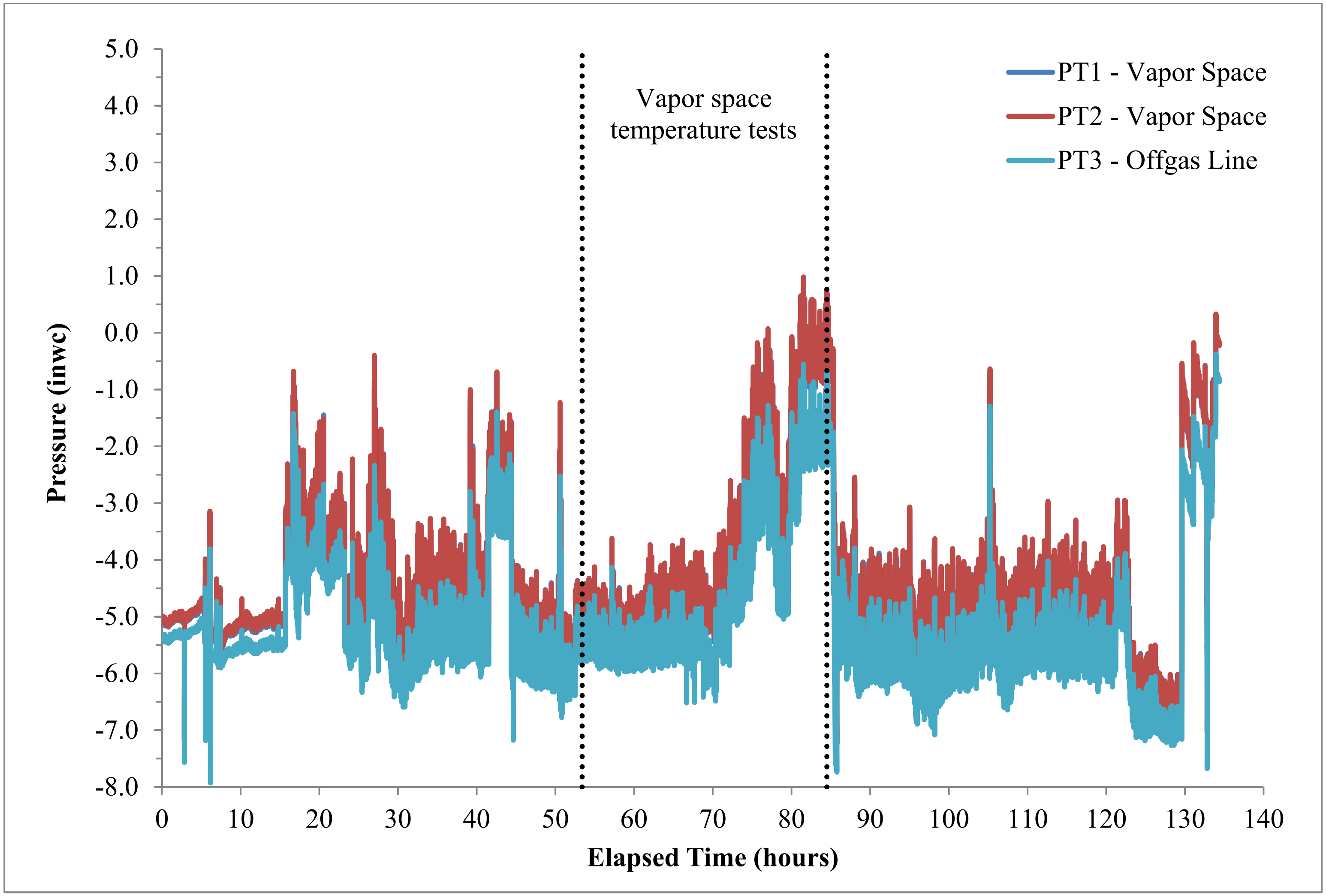

Figure A-7. Vapor space and off-gas line pressures (Elapsed time=0 at 09:34 May 29, 2013).

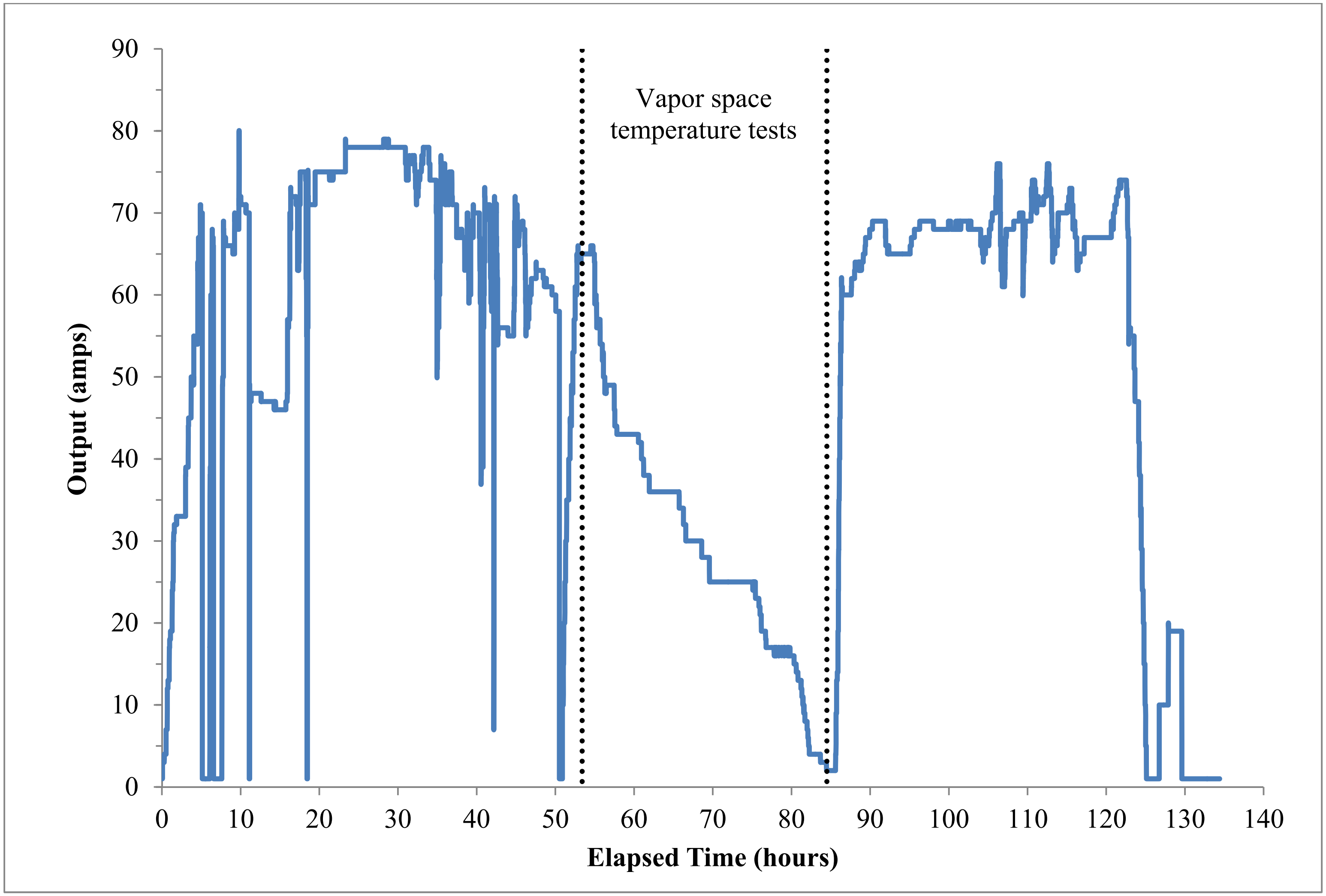

Figure A-8. Vapor space heater output (Elapsed time=0 at 09:34 May 29, 2013).

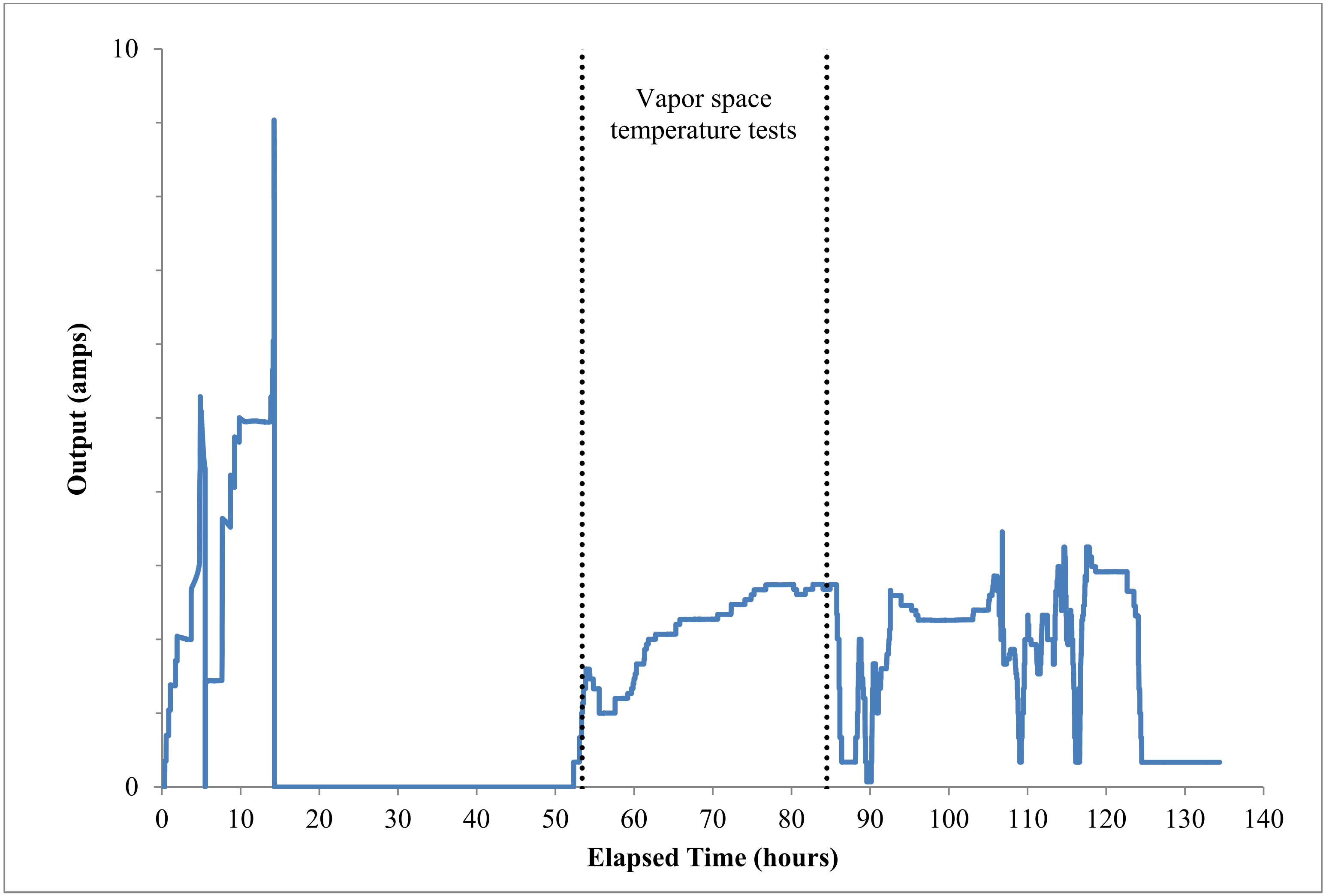

Figure A-9. Auxiliary pour tube heater output (Elapsed time=0 at 09:34 May 29, 2013).

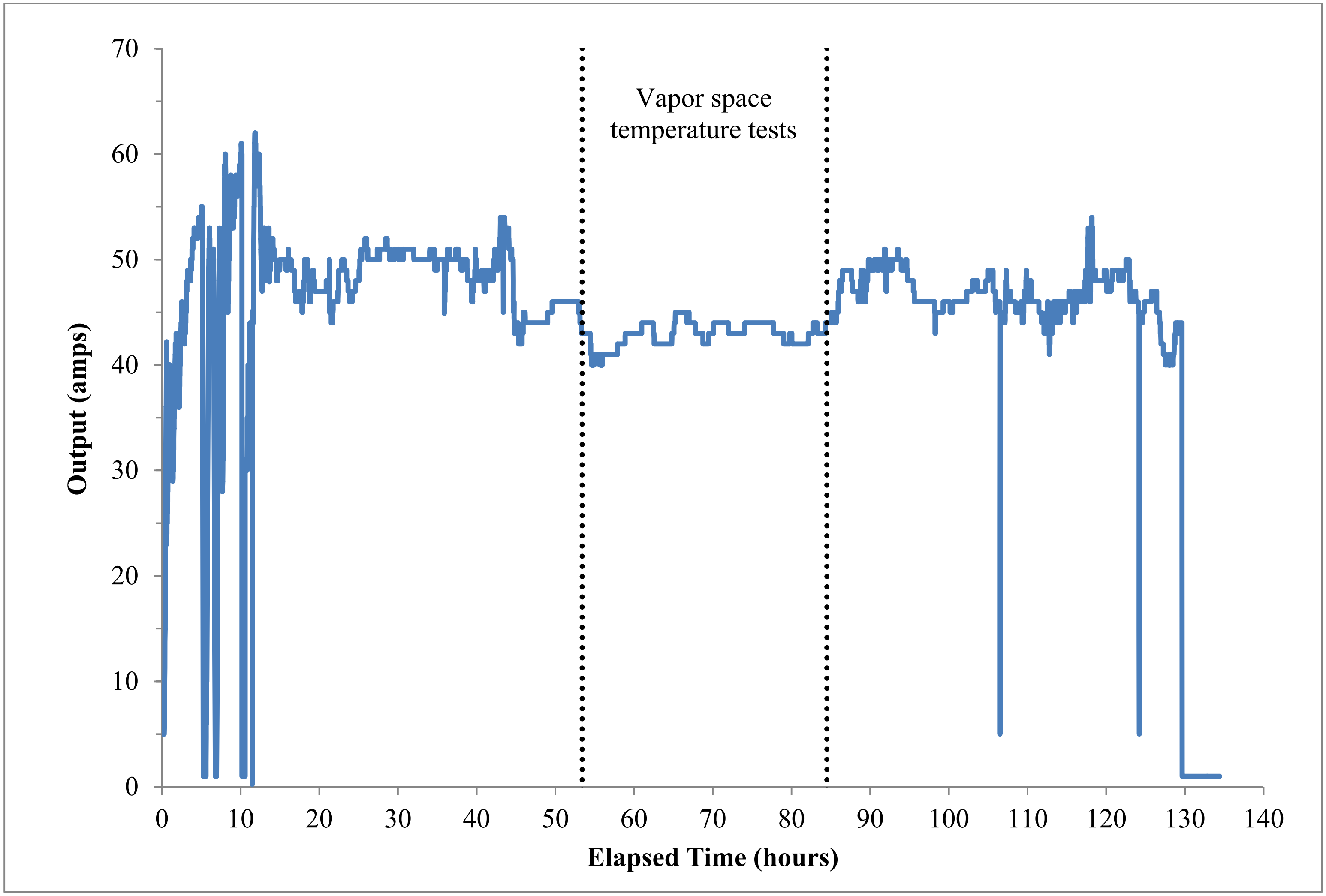

Figure A-10. Bottom heater output (Elapsed time=0 at 09:34 May 29, 2013).

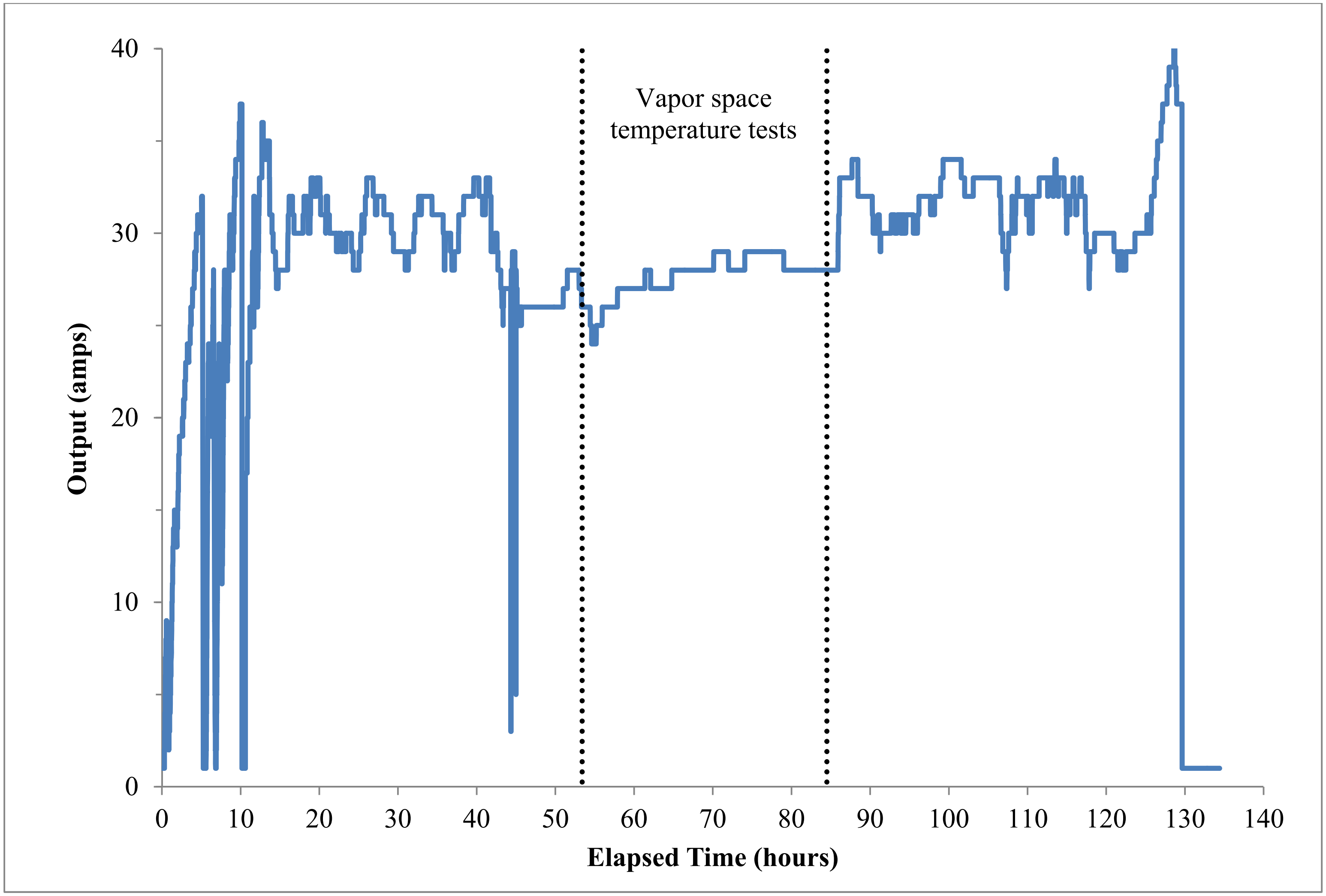

Figure A-11. Side heater output (Elapsed time=0 at 09:34 May 29, 2013).

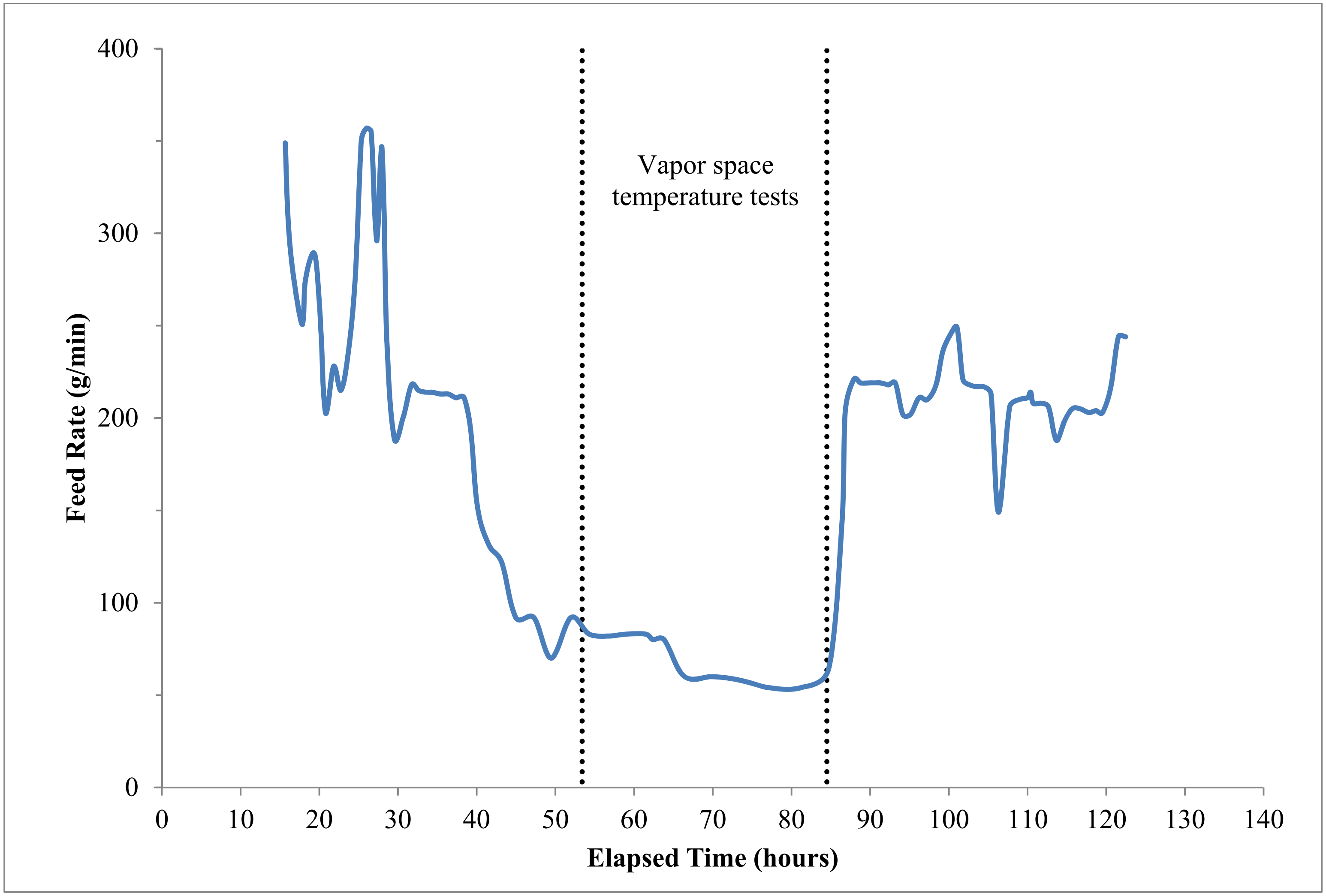

Figure A-12. Feed rate (Elapsed time=0 at 09:34 May 29, 2013).

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

Sample ID	Lab ID	Al	B	Ba	Ca	Ce	Cr	Cu	Fe	K	Li	Mg
CEF1-F-059 (A)	13-0919	5.09	1.65	0.045	0.360	0.060	0.063	0.060	7.90	0.125	2.29	0.297
CEF1-F-059 (B)	13-0919	5.05	1.62	0.046	0.365	0.060	0.065	0.094	7.60	0.129	2.28	0.301
CEF1-F-060 (A)	13-0920	5.35	1.56	0.049	0.376	0.068	0.068	0.091	7.96	0.133	2.20	0.309
CEF1-F-060 (B)	13-0920	5.40	1.55	0.049	0.384	0.068	0.068	0.103	8.18	0.133	2.22	0.311
CEF1-F-061 (A)	13-0921	5.16	1.56	0.047	0.376	0.067	0.066	0.082	7.77	0.127	2.26	0.310
CEF1-F-061 (B)	13-0921	5.11	1.53	0.047	0.386	0.068	0.067	0.081	7.69	0.130	2.23	0.312
CEF1-F-062 (A)	13-0922	4.99	1.54	0.045	0.361	0.063	0.064	0.065	7.47	0.129	2.28	0.296
CEF1-F-062 (B)	13-0922	5.03	1.56	0.045	0.362	0.064	0.063	0.054	7.57	0.129	2.31	0.296
CEF1-F-063 (A)	13-0923	5.21	1.49	0.047	0.385	0.065	0.064	0.048	7.72	0.131	2.30	0.307
CEF1-F-063 (B)	13-0923	5.25	1.47	0.046	0.384	0.065	0.064	0.060	7.64	0.129	2.29	0.306
CEF1-F-064 (A)	13-0924	5.11	1.54	0.046	0.367	0.060	0.064	0.062	7.66	0.128	2.31	0.298
CEF1-F-064 (B)	13-0924	5.10	1.53	0.046	0.370	0.061	0.065	0.069	7.65	0.129	2.31	0.300
CEF1-F-065 (A)	13-0925	5.24	1.55	0.046	0.361	0.063	0.066	0.068	7.82	0.131	2.31	0.300
CEF1-F-065 (B)	13-0925	5.25	1.56	0.047	0.368	0.064	0.066	0.072	7.83	0.136	2.30	0.303

Sample ID	Lab ID	Mn	Na	Ni	P	Pb	Pd	S	Sn	Si	Ti	Zn	Zr
CEF1-F-059 (A)	13-0919	2.33	8.73	1.00	<0.100	<0.100	<0.100	0.098	0.028	23.4	0.020	0.041	0.096
CEF1-F-059 (B)	13-0919	2.26	8.59	1.00	<0.100	<0.100	<0.100	0.098	0.029	23.3	0.020	0.042	0.097
CEF1-F-060 (A)	13-0920	2.38	8.64	1.06	<0.100	<0.100	<0.100	0.088	0.031	22.7	0.022	0.044	0.104
CEF1-F-060 (B)	13-0920	2.37	8.60	1.05	<0.100	<0.100	<0.100	0.090	0.030	22.7	0.021	0.044	0.104
CEF1-F-061 (A)	13-0921	2.34	8.64	1.01	<0.100	<0.100	<0.100	0.094	0.030	23.2	0.021	0.041	0.100
CEF1-F-061 (B)	13-0921	2.33	8.70	1.01	<0.100	<0.100	<0.100	0.101	0.030	22.7	0.021	0.042	0.101
CEF1-F-062 (A)	13-0922	2.22	8.55	0.977	<0.100	<0.100	<0.100	0.095	0.029	23.2	0.020	0.042	0.098
CEF1-F-062 (B)	13-0922	2.21	8.63	0.946	<0.100	<0.100	<0.100	0.094	0.029	23.3	0.021	0.041	0.098
CEF1-F-063 (A)	13-0923	2.30	8.66	0.971	<0.100	<0.100	<0.100	0.097	0.029	23.0	0.020	0.042	0.099
CEF1-F-063 (B)	13-0923	2.29	8.61	0.970	<0.100	<0.100	<0.100	0.096	0.029	22.3	0.020	0.041	0.099
CEF1-F-064 (A)	13-0924	2.20	8.47	0.963	<0.100	<0.100	<0.100	0.101	0.030	22.5	0.020	0.041	0.097
CEF1-F-064 (B)	13-0924	2.23	8.50	0.973	<0.100	<0.100	<0.100	0.097	0.030	23.2	0.020	0.041	0.098
CEF1-F-065 (A)	13-0925	2.24	8.45	0.982	<0.100	<0.100	<0.100	0.101	0.031	23.5	0.020	0.042	0.100
CEF1-F-065 (B)	13-0925	2.25	8.54	0.986	<0.100	<0.100	<0.100	0.099	0.030	23.5	0.021	0.043	0.102

Table A-2. IC Analysis of Feed (mg/kg)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	SO_4	C_2O_4	HCO_2	PO_4
CEF1-F-059 (A)	13-0919	<500	315	<500	17200	402	<500	44600	<500
CEF1-F-059 (B)	13-0919	<500	307	<500	17200	488	<500	44600	<500
CEF1-F-060 (A)	13-0920	<500	314	<500	17700	539	<500	46000	<500
CEF1-F-060 (B)	13-0920	<500	318	<500	17700	598	<500	46300	<500
CEF1-F-061 (A)	13-0921	<500	313	<500	17900	610	<500	44900	<500
CEF1-F-061 (B)	13-0921	<500	315	<500	17900	656	<500	45000	<500
CEF1-F-062 (A)	13-0922	<500	312	<500	17900	701	<500	45800	<500
CEF1-F-062 (B)	13-0922	<500	312	<500	17500	702	<500	45700	<500
CEF1-F-063 (A)	13-0923	<500	310	<500	17800	689	<500	45600	<500
CEF1-F-063 (B)	13-0923	<500	305	<500	17600	713	<500	45900	<500
CEF1-F-064 (A)	13-0924	<500	307	<500	17900	728	<500	45300	<500
CEF1-F-064 (B)	13-0924	<500	303	<500	17400	744	<500	45200	<500
CEF1-F-065 (A)	13-0925	<500	321	<500	17100	731	<500	47200	<500
CEF1-F-065 (B)	13-0925	<500	308	<500	17100	770	<500	47200	<500

Table A-3. Feed Solids and Density

Sample	Lab ID	Total Solids	Insoluble Solids	Wt % Calcined	Soluble Solids	pH	Density (g/cc)	Density Supernate (g/cc)
CEF1-F-059 (A)	13-0919	42.4%	34.3%	34.8%	53.42%	6.01	1.3263	1.08079
CEF1-F-059 (B)	13-0919	42.4%	34.3%	34.8%	53.33%		1.3262	1.08079
CEF1-F-060 (A)	13-0920	41.6%	33.2%	33.8%	50.99%	5.99	1.3160	1.08243
CEF1-F-060 (B)	13-0920	41.7%	32.9%	33.8%	51.16%		1.3161	1.08243
CEF1-F-061 (A)	13-0921	42.1%	33.5%	34.4%	52.40%	5.97	1.3073	1.08177
CEF1-F-061 (B)	13-0921	41.9%	33.8%	34.2%	52.02%		1.3072	1.08177
CEF1-F-062 (A)	13-0922	42.9%	34.6%	35.1%	54.04%	5.99	1.3145	1.08211
CEF1-F-062 (B)	13-0922	42.8%	34.6%	35.0%	53.79%		1.3147	1.08210
CEF1-F-063 (A)	13-0923	42.1%	33.2%	34.3%	52.15%	5.99	1.3126	1.08315
CEF1-F-063 (B)	13-0923	41.9%	33.4%	34.1%	51.82%		1.3125	1.08314
CEF1-F-064 (A)	13-0924	42.3%	33.8%	34.6%	52.91%	5.99	1.3115	1.08217
CEF1-F-064 (B)	13-0924	42.3%	33.5%	34.5%	52.72%		1.3114	1.08214
CEF1-F-065 (A)	13-0925	42.0%	33.7%	34.2%	51.99%	6.02	1.3154	1.08131
CEF1-F-065 (B)	13-0925	41.7%	33.7%	33.8%	51.12%		1.3154	1.08129

Table A-4. Feed Carbon Content

Sample ID	Lab ID	Total Carbon ug/mL	Organic Carbon ug/mL	Inorganic Carbon ug/mL
CEF1-F-059	300305064	<15100	15000	<80
CEF1-F-060	300305065	<14500	14400	<80
CEF1-F-061	300305066	<15700	15600	<80
CEF1-F-062	300305067	<15000	14900	<80
CEF1-F-063	300305068	<15400	15300	<80
CEF1-F-064	300305069	<15200	15100	<80
CEF1-F-065	300305070	<17000	16900	<80

Note: Since inorganic carbon levels are below detection limits, the total carbon value must be reported as “<” since total carbon is the sum of organic and inorganic carbon.

Table A-5. Condensate Cations Set 1 (mg/L)

Sample ID	Lab ID	Al	B	Ba	Ca	Ce	Cr	Cu	Fe	K	Li	Mg	Mn	Na	Ni	Pb	Si	Ti	Zn	Zr
CEF1-C-023 (A)	13-0891	0.363	13.6	<0.010	7.24	<0.010	0.282	<0.010	0.028	1.75	1.26	0.596	<0.010	63.7	<0.010	<0.010	4.58	<0.010	<0.010	<0.010
CEF1-C-023 (B)	13-0891	0.396	13.9	<0.010	7.48	<0.010	0.289	<0.010	0.028	1.79	1.29	0.615	<0.010	62.3	<0.010	<0.010	4.68	<0.010	<0.010	<0.010
CEF1-C-036 (A)	13-0892	0.435	17.6	<0.010	7.70	<0.010	0.316	<0.010	0.029	1.93	1.64	0.682	<0.010	76.0	<0.010	<0.010	4.84	<0.010	<0.010	<0.010
CEF1-C-036 (B)	13-0892	0.421	18.0	<0.010	7.72	<0.010	0.315	<0.010	0.029	1.94	1.65	0.683	<0.010	75.8	<0.010	<0.010	4.86	<0.010	<0.010	<0.010
CEF1-C-037 (A)	13-0893	0.409	17.1	<0.010	7.49	<0.010	0.307	<0.010	0.028	1.90	1.61	0.659	<0.010	76.7	<0.010	<0.010	4.70	<0.010	<0.010	<0.010
CEF1-C-037 (B)	13-0893	0.389	17.6	<0.010	7.59	<0.010	0.311	<0.010	0.028	1.93	1.63	0.670	<0.010	75.2	<0.010	<0.010	4.77	<0.010	<0.010	<0.010
CEF1-C-038 (A)	13-0894	0.367	17.4	<0.010	7.67	<0.010	0.316	<0.010	0.028	1.96	1.66	0.687	<0.010	78.5	<0.010	<0.010	4.96	<0.010	<0.010	<0.010
CEF1-C-038 (B)	13-0894	0.360	17.4	<0.010	7.59	<0.010	0.314	<0.010	0.028	1.94	1.64	0.675	<0.010	79.9	<0.010	<0.010	4.89	<0.010	<0.010	<0.010
CEF1-C-041 (A)	13-0895	0.439	18.3	<0.010	7.69	<0.010	0.316	<0.010	0.028	1.98	1.69	0.699	<0.010	80.4	<0.010	<0.010	4.94	<0.010	<0.010	<0.010
CEF1-C-041 (B)	13-0895	0.429	18.9	<0.010	7.86	<0.010	0.322	<0.010	0.028	2.03	1.72	0.715	<0.010	80.1	<0.010	<0.010	5.02	<0.010	<0.010	<0.010
CEF1-C-042 (A)	13-0896	0.507	18.6	<0.010	7.72	<0.010	0.317	<0.010	0.028	2.01	1.70	0.704	<0.010	79.5	<0.010	<0.010	5.02	<0.010	<0.010	<0.010
CEF1-C-042 (B)	13-0896	0.504	18.4	<0.010	7.73	<0.010	0.319	<0.010	0.028	2.01	1.70	0.704	<0.010	78.8	<0.010	<0.010	5.02	<0.010	<0.010	<0.010
CEF1-C-043 (A)	13-0897	0.430	18.1	<0.010	7.63	<0.010	0.312	<0.010	0.028	1.98	1.67	0.695	<0.010	79.4	<0.010	<0.010	4.98	<0.010	<0.010	<0.010
CEF1-C-043 (B)	13-0897	0.416	18.3	<0.010	7.68	<0.010	0.313	<0.010	0.028	2.00	1.69	0.700	<0.010	79.4	<0.010	<0.010	5.04	<0.010	<0.010	<0.010
CEF1-C-044 (A)	13-0898	0.490	18.8	<0.010	7.70	<0.010	0.316	<0.010	0.029	2.05	1.70	0.708	<0.010	81.7	<0.010	<0.010	5.16	<0.010	<0.010	<0.010
CEF1-C-044 (B)	13-0898	0.481	19.0	<0.010	7.73	<0.010	0.315	<0.010	0.028	2.07	1.70	0.705	<0.010	82.4	<0.010	<0.010	5.13	<0.010	<0.010	<0.010
CEF1-C-048 (A)	13-0899	0.451	19.2	<0.010	7.92	<0.010	0.322	<0.010	0.029	2.11	1.78	0.741	<0.010	82.6	<0.010	<0.010	5.75	<0.010	<0.010	<0.010
CEF1-C-048 (B)	13-0899	0.443	19.5	<0.010	7.98	<0.010	0.328	<0.010	0.028	2.11	1.78	0.749	<0.010	81.1	<0.010	<0.010	5.79	<0.010	<0.010	<0.010
CEF1-C-049 (A)	13-0900	0.427	19.1	<0.010	7.78	<0.010	0.321	<0.010	0.029	2.09	1.76	0.737	<0.010	84.2	<0.010	<0.010	5.95	<0.010	<0.010	<0.010
CEF1-C-049 (B)	13-0900	0.421	19.4	<0.010	7.85	<0.010	0.326	<0.010	0.029	2.10	1.77	0.741	<0.010	84.0	<0.010	<0.010	5.97	<0.010	<0.010	<0.010
CEF1-C-050 (A)	13-0901	0.486	19.3	<0.010	7.65	<0.010	0.318	<0.010	0.029	2.10	1.75	0.727	<0.010	84.9	<0.010	<0.010	5.93	<0.010	<0.010	<0.010
CEF1-C-050 (B)	13-0901	0.484	18.8	<0.010	7.72	<0.010	0.317	<0.010	0.030	2.11	1.75	0.728	<0.010	84.4	<0.010	<0.010	5.95	<0.010	<0.010	<0.010
CEF1-C-058 (A)	13-0902	0.484	19.2	<0.010	7.82	<0.010	0.323	<0.010	0.029	2.14	1.80	0.759	<0.010	84.3	<0.010	<0.010	6.50	<0.010	<0.010	<0.010
CEF1-C-058 (B)	13-0902	0.503	19.3	<0.010	7.81	<0.010	0.322	<0.010	0.029	2.14	1.80	0.757	<0.010	85.2	<0.010	<0.010	6.52	<0.010	<0.010	<0.010
CEF1-C-059 (A)	13-0903	0.459	19.2	<0.010	7.69	<0.010	0.317	<0.010	0.029	2.11	1.77	0.746	<0.010	85.6	<0.010	<0.010	6.54	<0.010	<0.010	<0.010
CEF1-C-059 (B)	13-0903	0.491	19.0	<0.010	7.74	<0.010	0.315	<0.010	0.029	2.12	1.78	0.748	<0.010	86.4	<0.010	<0.010	6.57	<0.010	<0.010	<0.010

Table A-6. Condensate Cations Set 2 (mg/L)

Sample ID	Lab ID	Al	B	Ba	Ca	Ce	Cr	Cu	Fe	K	Li	Mg	Mn	Na	Ni	Pb	Si	Ti	Zn	Zr
CEF1-C-060 (A)	13-0904	0.54	18.70	<0.010	7.54	<0.010	0.31	<0.010	0.03	2.07	1.75	0.73	<0.010	84.25	<0.010	<0.010	6.35	<0.010	<0.010	<0.010
CEF1-C-060 (B)	13-0904	0.52	18.69	<0.010	7.50	<0.010	0.31	<0.010	0.03	2.06	1.74	0.73	<0.010	85.64	<0.010	<0.010	6.27	<0.010	<0.010	<0.010
CEF1-C-063 (A)	13-0905	0.50	20.03	<0.010	7.97	<0.010	0.33	<0.010	0.03	2.19	1.86	0.79	<0.010	86.55	<0.010	<0.010	6.88	<0.010	<0.010	<0.010
CEF1-C-063 (B)	13-0905	0.52	19.84	<0.010	7.86	<0.010	0.33	<0.010	0.03	2.15	1.83	0.78	<0.010	87.23	<0.010	<0.010	6.83	<0.010	<0.010	<0.010
CEF1-C-064 (A)	13-0906	0.52	18.99	<0.010	7.60	<0.010	0.31	<0.010	0.03	2.18	1.76	0.74	<0.010	86.69	<0.010	<0.010	6.59	<0.010	<0.010	<0.010
CEF1-C-064 (B)	13-0906	0.53	19.29	<0.010	7.73	<0.010	0.31	<0.010	0.03	2.21	1.79	0.75	<0.010	87.42	<0.010	<0.010	6.69	<0.010	<0.010	<0.010
CEF1-C-065 (A)	13-0907	0.52	19.22	<0.010	7.76	<0.010	0.32	<0.010	0.03	2.10	1.80	0.75	<0.010	87.00	<0.010	<0.010	6.57	<0.010	<0.010	<0.010
CEF1-C-065 (B)	13-0907	0.51	20.00	<0.010	7.99	<0.010	0.33	<0.010	0.03	2.17	1.85	0.78	<0.010	89.31	<0.010	<0.010	6.69	<0.010	<0.010	<0.010
CEF1-C-068 (A)	13-0908	0.53	18.82	<0.010	7.53	<0.010	0.31	<0.010	0.03	2.07	1.76	0.73	<0.010	86.67	<0.010	<0.010	6.25	<0.010	<0.010	<0.010
CEF1-C-068 (B)	13-0908	0.54	19.15	<0.010	7.61	<0.010	0.31	<0.010	0.03	2.09	1.78	0.74	<0.010	86.82	<0.010	<0.010	6.33	<0.010	<0.010	<0.010
CEF1-C-069 (A)	13-0909	0.51	20.04	<0.010	8.01	<0.010	0.33	<0.010	0.03	2.19	1.87	0.79	<0.010	86.44	<0.010	<0.010	6.75	<0.010	<0.010	<0.010
CEF1-C-069 (B)	13-0909	0.55	20.25	<0.010	8.02	<0.010	0.33	<0.010	0.03	2.19	1.86	0.79	<0.010	87.16	<0.010	<0.010	6.72	<0.010	<0.010	<0.010
CEF1-C-070 (A)	13-0910	0.55	19.69	<0.010	7.78	<0.010	0.32	<0.010	0.03	2.13	1.81	0.76	<0.010	88.59	<0.010	<0.010	6.52	<0.010	<0.010	<0.010
CEF1-C-070 (B)	13-0910	0.54	19.81	<0.010	7.86	<0.010	0.32	<0.010	0.03	2.16	1.82	0.76	<0.010	86.93	<0.010	<0.010	6.54	<0.010	<0.010	<0.010
CEF1-C-076 (A)	13-0911	0.57	20.46	<0.010	8.09	<0.010	0.34	<0.010	0.03	2.21	1.88	0.80	<0.010	86.56	<0.010	<0.010	7.16	<0.010	<0.010	<0.010
CEF1-C-076 (B)	13-0911	0.57	20.10	<0.010	8.04	<0.010	0.33	<0.010	0.03	2.19	1.87	0.80	<0.010	88.24	<0.010	<0.010	7.12	<0.010	<0.010	<0.010
CEF1-C-082 (A)	13-0912	0.63	18.97	<0.010	7.63	<0.010	0.32	<0.010	0.03	2.09	1.78	0.75	<0.010	86.93	<0.010	<0.010	6.70	<0.010	<0.010	<0.010
CEF1-C-082 (B)	13-0912	0.59	18.77	<0.010	7.56	<0.010	0.31	<0.010	0.03	2.07	1.76	0.74	<0.010	87.54	<0.010	<0.010	6.52	<0.010	<0.010	<0.010
CEF1-C-088 (A)	13-0913	0.45	25.69	<0.010	8.03	<0.010	0.35	<0.010	0.03	2.69	2.46	0.93	<0.010	111.26	<0.010	<0.010	5.89	<0.010	<0.010	<0.010
CEF1-C-088 (B)	13-0913	0.45	25.29	<0.010	7.90	<0.010	0.34	<0.010	0.03	2.64	2.40	0.90	<0.010	112.08	<0.010	<0.010	5.74	<0.010	<0.010	<0.010
CEF1-C-094 (A)	13-0914	0.48	27.95	<0.010	7.82	<0.010	0.34	<0.010	0.03	2.74	2.54	0.91	<0.010	115.96	<0.010	<0.010	5.99	<0.010	<0.010	<0.010
CEF1-C-094 (B)	13-0914	0.48	27.30	<0.010	7.75	<0.010	0.34	<0.010	0.03	2.71	2.52	0.90	<0.010	115.23	<0.010	<0.010	5.95	<0.010	<0.010	<0.010
CEF1-C-100 (A)	13-0915	0.43	30.34	<0.010	7.93	<0.010	0.35	<0.010	0.03	2.86	2.69	0.93	<0.010	122.82	<0.010	<0.010	6.29	<0.010	<0.010	<0.010
CEF1-C-100 (B)	13-0915	0.44	29.78	<0.010	7.82	<0.010	0.35	<0.010	0.03	2.82	2.66	0.91	<0.010	124.57	<0.010	<0.010	6.17	<0.010	<0.010	<0.010
CEF1-C-108 (A)	13-0916	0.43	34.42	<0.010	8.29	<0.010	0.38	<0.010	0.03	3.16	2.98	0.99	<0.010	129.33	<0.010	<0.010	6.56	<0.010	<0.010	<0.010
CEF1-C-108 (B)	13-0916	0.42	33.95	<0.010	8.19	<0.010	0.37	<0.010	0.03	3.15	2.97	0.97	<0.010	128.87	<0.010	<0.010	6.47	<0.010	<0.010	<0.010

Table A-7. Condensate Supernate Anions (mg/L)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	SO_4	PO_4	HCO_2	C_2O_4
CEF1-C-023 (A)	13-0891	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-023 (B)	13-0891	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-036 (A)	13-0892	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-036 (B)	13-0892	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-037 (A)	13-0893	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-037 (B)	13-0893	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-038 (A)	13-0894	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-038 (B)	13-0894	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-041 (A)	13-0895	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-041 (B)	13-0895	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-042 (A)	13-0896	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-042 (B)	13-0896	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-043 (A)	13-0897	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-043 (B)	13-0897	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-044 (A)	13-0898	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-044 (B)	13-0898	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-048 (A)	13-0899	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-048 (B)	13-0899	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-049 (A)	13-0900	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-049 (B)	13-0900	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-050 (A)	13-0901	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-050 (B)	13-0901	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-058 (A)	13-0902	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-058 (B)	13-0902	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-059 (A)	13-0903	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-059 (B)	13-0903	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-060 (A)	13-0904	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-060 (B)	13-0904	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-063 (A)	13-0905	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-063 (B)	13-0905	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-064 (A)	13-0906	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-064 (B)	13-0906	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-065 (A)	13-0907	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-065 (B)	13-0907	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-068 (A)	13-0908	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-068 (B)	13-0908	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-069 (A)	13-0909	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-069 (B)	13-0909	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-070 (A)	13-0910	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-070 (B)	13-0910	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-076 (A)	13-0911	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-076 (B)	13-0911	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-082 (A)	13-0912	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-082 (B)	13-0912	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-088 (A)	13-0913	<1.00	1.07	1.24	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-088 (B)	13-0913	<1.00	1.07	1.24	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-094 (A)	13-0914	<1.00	1.11	1.32	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-094 (B)	13-0914	<1.00	1.11	1.31	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-100 (A)	13-0915	<1.00	1.18	1.40	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-100 (B)	13-0915	<1.00	1.18	1.40	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-108 (A)	13-0916	<1.00	1.27	1.50	<1.00	<1.00	<1.00	<1.00	<1.00
CEF1-C-108 (B)	13-0916	<1.00	1.27	1.50	<1.00	<1.00	<1.00	<1.00	<1.00

Table A-8. Condensate Density, Total Solids and pH

Sample ID	Lab ID	Density	Total Solids	pH
CEF1-C-023 (A)	13-0891	0.9982	<0.100	7.94
CEF1-C-023 (B)	13-0891	0.9982		
CEF1-C-036 (A)	13-0892	0.9982	<0.100	7.85
CEF1-C-036 (B)	13-0892	0.9982		
CEF1-C-037 (A)	13-0893	0.9982	<0.100	7.86
CEF1-C-037 (B)	13-0893	0.9982		
CEF1-C-038 (A)	13-0894	0.9982	<0.100	7.83
CEF1-C-038 (B)	13-0894	0.9982		
CEF1-C-041 (A)	13-0895	0.9982	<0.100	7.85
CEF1-C-041 (B)	13-0895	0.9982		
CEF1-C-042 (A)	13-0896	0.9982	<0.100	7.87
CEF1-C-042 (B)	13-0896	0.9982		
CEF1-C-043 (A)	13-0897	0.9982	<0.100	7.84
CEF1-C-043 (B)	13-0897	0.9982		
CEF1-C-044 (A)	13-0898	0.9982	<0.100	7.86
CEF1-C-044 (B)	13-0898	0.9982		
CEF1-C-048 (A)	13-0899	0.9983	<0.100	7.79
CEF1-C-048 (B)	13-0899	0.9983		
CEF1-C-049 (A)	13-0900	0.9983	<0.100	7.74
CEF1-C-049 (B)	13-0900	0.9983		
CEF1-C-050 (A)	13-0901	0.9983	<0.100	7.78
CEF1-C-050 (B)	13-0901	0.9983		
CEF1-C-058 (A)	13-0902	0.9983	<0.100	7.86
CEF1-C-058 (B)	13-0902	0.9983		
CEF1-C-059 (A)	13-0903	0.9983	<0.100	7.83
CEF1-C-059 (B)	13-0903	0.9983		
CEF1-C-060 (A)	13-0904	0.9983	<0.100	7.83
CEF1-C-060 (B)	13-0904	0.9983		
CEF1-C-063 (A)	13-0905	0.9983	<0.100	7.81
CEF1-C-063 (B)	13-0905	0.9983		
CEF1-C-064 (A)	13-0906	0.9983	<0.100	7.83
CEF1-C-064 (B)	13-0906	0.9983		
CEF1-C-065 (A)	13-0907	0.9983	<0.100	7.83
CEF1-C-065 (B)	13-0907	0.9983		
CEF1-C-068 (A)	13-0908	0.9983	<0.100	7.85
CEF1-C-068 (B)	13-0908	0.9983		
CEF1-C-069 (A)	13-0909	0.9983	<0.100	7.87
CEF1-C-069 (B)	13-0909	0.9983		
CEF1-C-070 (A)	13-0910	0.9983	<0.100	7.84
CEF1-C-070 (B)	13-0910	0.9983		
CEF1-C-076 (A)	13-0911	0.9983	<0.100	7.88
CEF1-C-076 (B)	13-0911	0.9983		
CEF1-C-082 (A)	13-0912	0.9983	<0.100	7.95
CEF1-C-082 (B)	13-0912	0.9983		
CEF1-C-088 (A)	13-0913	0.9985	<0.100	7.84
CEF1-C-088 (B)	13-0913	0.9985		
CEF1-C-094 (A)	13-0914	0.9985	<0.100	7.87
CEF1-C-094 (B)	13-0914	0.9985		
CEF1-C-100 (A)	13-0915	0.9985	<0.100	7.80
CEF1-C-100 (B)	13-0915	0.9985		
CEF1-C-108 (A)	13-0916	0.9985	<0.100	7.75
CEF1-C-108 (B)	13-0916	0.9985		

Table A-9. Condensate Carbon Content

Sample ID	Lab ID	Total Carbon (ug/mL)	Organic Carbon (ug/mL)	Inorganic Carbon (ug/mL)
CEF1-C-023	300305110	63.7	22.1	41.6
CEF1-C-036	300305111	62.3	21.9	40.4
CEF1-C-037	300305112	63.4	22	41.6
CEF1-C-038	300305113	62.5	21.3	41.2
CEF1-C-041	300305114	63.6	22	41.6
CEF1-C-042	300305115	61.9	21.9	40
CEF1-C-043	300305116	64.3	21.4	42.9
CEF1-C-044	300305117	61.8	21.8	40
CEF1-C-048	300305118	65.6	21.6	44
CEF1-C-049	300305119	67.8	22.3	45.5
CEF1-C-050	300305120	67.3	22.9	44.4
CEF1-C-058	300305121	74.7	25.2	49.5
CEF1-C-059	300305122	76.1	25	51.1
CEF1-C-060	300305123	75.2	25.9	49.3
CEF1-C-063	300305124	75.8	25.4	50.4

Table A-10. Filter Solids Cations (wt%)

Sample ID	Lab ID	Al	B	Ba	Ca	Ce	Cr	Cu	Fe	K	Li	Mg	Mn	Na	Ni	Pb	Si	Ti	Zn	Zr
CEF1-FL-A (A)	13-0931	9.90	0.754	0.101	0.614	0.109	0.141	0.115	20.0	0.044	0.800	0.658	6.10	2.98	2.58	<0.100	10.8	0.041	0.090	0.116
CEF1-FL-A (B)	13-0931	9.82	0.737	0.101	0.633	0.111	0.142	0.142	19.7	0.043	0.814	0.662	6.04	2.99	2.55	<0.100	10.9	0.041	0.091	0.107
CEF1-FL-M (A)	13-0932	8.21	0.855	0.085	0.543	0.098	0.175	0.124	16.9	0.046	1.04	0.597	5.16	3.27	2.20	<0.100	13.1	0.043	0.084	0.104
CEF1-FL-M (B)	13-0932	8.23	0.849	0.081	0.538	0.097	0.172	0.106	16.8	0.042	1.03	0.572	5.12	3.20	2.19	<0.100	12.9	0.059	0.080	0.115
CEF1-FL-Q (A)	13-0933	8.70	0.578	0.090	0.746	0.111	0.171	0.133	20.1	0.050	0.524	0.727	6.52	2.34	2.67	<0.100	10.6	0.046	0.096	0.090
CEF1-FL-Q (B)	13-0933	8.59	0.568	0.086	0.754	0.107	0.165	0.121	19.9	0.050	0.507	0.719	6.49	2.33	2.64	<0.100	10.3	0.055	0.094	0.093
CEF1-FL-B (A)	13-0934	8.82	0.713	0.099	0.655	0.104	1.26	0.115	19.2	0.052	0.735	0.647	5.87	2.88	2.55	<0.100	11.1	0.065	0.089	0.091
CEF1-FL-B (B)	13-0934	8.72	0.708	0.098	0.653	0.109	1.29	0.111	19.2	0.051	0.740	0.647	5.85	2.76	2.57	<0.100	10.8	0.064	0.087	0.083

Table A-11. Filter Solids Anions (wt%)

Sample ID	Lab ID	F	Cl	NO_2	NO_3	SO_4	C_2O_4	HCO_2	PO_4
CEF1-FL-A (A)	13-0931	<0.050	<0.050	<0.050	<0.050	0.148	0.168	<0.050	<0.050
CEF1-FL-A (B)	13-0931	<0.050	<0.050	<0.050	<0.050	0.145	0.120	<0.050	<0.050
CEF1-FL-M (A)	13-0932	<0.050	0.224	<0.050	<0.050	0.126	0.615	<0.050	<0.050
CEF1-FL-M (B)	13-0932	<0.050	0.254	<0.050	<0.050	0.122	0.565	<0.050	<0.050
CEF1-FL-Q (A)	13-0933	<0.050	0.201	<0.050	<0.050	0.177	0.610	<0.050	<0.050
CEF1-FL-Q (B)	13-0933	<0.050	0.213	<0.050	<0.050	0.169	0.635	<0.050	<0.050
CEF1-FL-B (A)	13-0934	<0.050	0.071	<0.050	<0.050	0.206	0.294	<0.050	<0.050
CEF1-FL-B (B)	13-0934	<0.050	0.071	<0.050	<0.050	0.205	0.230	<0.050	<0.050

Table A-12. Filter Solids

Sample ID	Lab ID	Total Solids
CEF1-FL-A (A)	13-0931	96.5%
CEF1-FL-A (B)	13-0931	96.6%
CEF1-FL-M (A)	13-0932	97.2%
CEF1-FL-M (B)	13-0932	97.2%
CEF1-FL-Q (A)	13-0933	96.0%
CEF1-FL-Q (B)	13-0933	96.0%
CEF1-FL-B (A)	13-0934	96.9%
CEF1-FL-B (B)	13-0934	96.8%

Table A-13. ICP-AES Glass Analysis (wt%)

Sample ID	Lab ID	Al	B	Ba	Ca	Ce	Cr	Cu	Fe	K
CEF1-GL-005 (A)	13-0859	5.40956	1.431	0.030209	0.404763	0.036845	0.053209	0.060378	7.35328	0.08405
CEF1-GL-005 (B)	13-0859	5.35599	1.547	0.044584	0.405513	0.040013	0.057211	0.060969	7.34148	0.087101
CEF1-GL-007 (A)	13-0860	5.32258	1.566	0.039042	0.420612	0.047583	0.054192	0.05406	7.39566	0.096357
CEF1-GL-007 (B)	13-0860	5.22755	1.56	0.038465	0.418896	0.04707	0.053003	0.061949	7.30665	0.098461
CEF1-GL-008 (A)	13-0861	5.22007	1.547	0.040333	0.423539	0.049585	0.059285	0.053275	7.40302	0.096784
CEF1-GL-008 (B)	13-0861	5.24782	1.553	0.040329	0.425068	0.049679	0.059841	0.052856	7.42605	0.09876
CEF1-GL-009 (A)	13-0862	5.09263	1.465	0.04183	0.420114	0.05072	0.060489	0.052595	7.24938	0.099095
CEF1-GL-009 (B)	13-0862	5.15232	1.294	0.041327	0.420428	0.050259	0.06016	0.049952	7.42986	0.095607
CEF1-GL-014 (A)	13-0863	5.13854	1.526	0.047641	0.414774	0.057319	0.06964	0.054505	7.53094	0.106703
CEF1-GL-014 (B)	13-0863	5.11352	1.583	0.047608	0.415383	0.057195	0.069433	0.057031	7.47859	0.105287
CEF1-GL-016 (A)	13-0864	5.07529	1.593	0.049154	0.420639	0.058123	0.071624	0.050933	7.45518	0.108126
CEF1-GL-016 (B)	13-0864	5.0831	1.581	0.049264	0.422427	0.058508	0.071442	0.053363	7.50899	0.108592

Sample ID	Lab ID	Li	Mg	Mn	Na	Ni	Pb	Si	Ti	Zn	Zr
CEF1-GL-005 (A)	13-0859	2.16	0.283	2.41	9.10	0.962	<0.100	23.3	0.021	0.031	0.100
CEF1-GL-005 (B)	13-0859	2.25	0.284	2.39	9.07	0.963	<0.100	23.3	0.021	0.031	0.101
CEF1-GL-007 (A)	13-0860	2.27	0.318	2.44	8.97	0.951	<0.100	23.7	0.025	0.036	0.118
CEF1-GL-007 (B)	13-0860	2.28	0.313	2.41	8.88	0.942	<0.100	23.8	0.022	0.035	0.106
CEF1-GL-008 (A)	13-0861	2.25	0.321	2.42	8.87	0.963	<0.100	23.7	0.025	0.037	0.105
CEF1-GL-008 (B)	13-0861	2.27	0.323	2.43	8.90	0.974	<0.100	23.5	0.027	0.037	0.120
CEF1-GL-009 (A)	13-0862	2.19	0.323	2.38	8.68	0.969	<0.100	22.8	0.026	0.037	0.121
CEF1-GL-009 (B)	13-0862	2.10	0.321	2.40	8.78	0.955	<0.100	22.8	0.026	0.037	0.116
CEF1-GL-014 (A)	13-0863	2.22	0.342	2.46	8.73	0.989	<0.100	23.4	0.023	0.046	0.107
CEF1-GL-014 (B)	13-0863	2.28	0.341	2.44	8.63	0.985	<0.100	24.1	0.023	0.047	0.106
CEF1-GL-016 (A)	13-0864	2.27	0.349	2.44	8.67	0.999	<0.100	23.1	0.023	0.045	0.108
CEF1-GL-016 (B)	13-0864	2.26	0.349	2.45	8.76	0.997	<0.100	23.9	0.024	0.046	0.108

Table A-14. Glass REDOX

Sample	Lab ID	Fe^{2+}	Fe^{3+}	∑Fe	Fe^{2+}/Fe^{3+}	$Fe^{2+}/\sum Fe$
EA	---	0.065	0.279	0.344	0.233	0.189
CEF1-GL-001 (A)	13-0865	0.038	0.467	0.505	0.081	0.075
CEF1-GL-001 (B)		0.039	0.467	0.506	0.084	0.077
CEF1-GL-002 (A)	13-0866	0.043	0.395	0.438	0.109	0.098
CEF1-GL-002 (B)		0.044	0.396	0.440	0.111	0.100
CEF1-GL-003 (A)	13-0867	0.058	0.380	0.438	0.153	0.132
CEF1-GL-003 (B)		0.058	0.383	0.441	0.151	0.132
CEF1-GL-004 (A)	13-0868	0.081	0.401	0.482	0.202	0.168
CEF1-GL-004 (B)		0.083	0.400	0.483	0.208	0.172
CEF1-GL-005 (A)	13-0869	0.084	0.426	0.510	0.197	0.165
CEF1-GL-005 (B)		0.084	0.423	0.507	0.199	0.166
CEF1-GL-006 (A)	13-0870	0.092	0.415	0.507	0.222	0.181
CEF1-GL-006 (B)		0.093	0.415	0.508	0.224	0.183
CEF1-GL-007 (A)	13-0871	0.083	0.418	0.501	0.199	0.166
CEF1-GL-007 (B)		0.084	0.417	0.501	0.201	0.168
CEF1-GL-008 (A)	13-0872	0.059	0.378	0.437	0.156	0.135
CEF1-GL-008 (B)		0.059	0.379	0.438	0.156	0.135
CEF1-GL-009 (A)	13-0873	0.053	0.422	0.475	0.126	0.112
CEF1-GL-009 (B)		0.054	0.423	0.477	0.128	0.113
CEF1-GL-010 (A)	13-0874	0.045	0.485	0.530	0.093	0.085
CEF1-GL-010 (B)		0.047	0.483	0.530	0.097	0.089
CEF1-GL-011 (A)	13-0875	0.057	0.398	0.455	0.143	0.125
CEF1-GL-011 (B)		0.057	0.401	0.458	0.142	0.124
CEF1-GL-012 (A)	13-0876	0.075	0.409	0.484	0.183	0.155
CEF1-GL-012 (B)		0.075	0.409	0.484	0.183	0.155
CEF1-GL-013 (A)	13-0877	0.076	0.385	0.461	0.197	0.165
CEF1-GL-013 (B)		0.075	0.388	0.463	0.193	0.162
CEF1-GL-014 (A)	13-0878	0.093	0.356	0.449	0.261	0.207
CEF1-GL-014 (B)		0.089	0.361	0.450	0.247	0.198
CEF1-GL-015 (A)	13-0879	0.091	0.395	0.486	0.230	0.187
CEF1-GL-015 (B)		0.092	0.397	0.489	0.232	0.188
CEF1-GL-016 (A)	13-0880	0.092	0.413	0.505	0.223	0.182
CEF1-GL-016 (B)		0.093	0.411	0.504	0.226	0.185

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