Contract No:

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Disclaimer:

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RSM Track #: 10560

TO: J. R. JACOBS, 241-152H

FROM: J. A. DYER, 773-42A

REVIEWER: J. A. PIKE, 703-41A

REEVALUATION OF THE RISK OF SOLIDS FORMATION IN THE 2H EVAPORATOR SYSTEM

Scope

Savannah River Remediation (SRR) Tank Farm Engineering requested further technical assistance from the Savannah River National Laboratory (SRNL) to reassess the risk of solids formation in the 2H Evaporator system following feed tank and drop tank blending operations conducted between 12/15/2018 and 1/6/2019. OLI aqueous electrolyte model simulations were completed for three variable-depth, post-blending liquid waste samples collected from Tank 43 on 1/27/2019. The purpose of the new simulations is to provide guidance to SRR on a recommended maximum overhead-to-feed volume ratio to avoid unwanted solids formation upon restart of the 2H Evaporator.

Summary and Recommendations

OLI simulations based on the current post-blend Tank 43 feed composition indicate that significant progress was made in blending the contents of Tank 43 and Tank 38 to lower the specific gravity and, hence, reduce the likelihood of solids precipitation in the evaporator pot and gravity drain line (GDL).

- Figure 1 shows the predicted total solids concentration in the evaporator pot at the bubble point temperature as a function of the overhead-to-feed volume ratio for the 2016 through 2019 Tank 43 samples. The curves for the 2016, 2017, and 2018 Tank 43 samples are based on previous OLI simulations summarized by Dyer (2018).

- Simulation results for Tank 43 samples HTF-43-19-2 (1” below liquid surface, 1.18 g/mL) and HTF-43-19-3 (90” below liquid surface, 1.18 g/mL) suggest that the 2H Evaporator can be operated at an overhead-to-feed volume ratio as high as 0.42 to 0.46

and avoid precipitation of sodium carbonate (green-shaded region to right in Figure 1). However, operation above a historical overhead-to-feed volume ratio of 0.35-0.38 (orange-shaded region in Figure 1) is not recommended to allow for some uncertainty associated with pump suction sample HTF-43-19-4 (below).

- OLI simulation results for sample HTF-43-19-4 (161" off the bottom, 1.28 g/mL), on the other hand, are more closely aligned with the unblended, higher-specific-gravity Tank 43 samples from 2018 (blue-shaded region in Figure 1). If sample HTF-43-19-4 is truly representative of the pump suction, then Figure 1 suggests that an overhead-to-feed volume ratio of 0.10 and above will lead to substantial sodium carbonate (Na_2CO_3) solids formation (thin green-shaded region to the left in Figure 1).

- Conversely, according to SRR Tank Farm Engineering, operating experience has shown that the specific gravity of samples collected near the pump suction (1.28 g/mL on 1/27/2019) is not necessarily representative of the specific gravity measured in the evaporator pot during operation. Figure 2 highlights that the specific gravity in the evaporator pot at the end of the recent three-week blending period was approximately 1.17 g/mL, which is in good agreement with the surface and midpoint samples (1.18 mg/L). One hypothesis is that the feed pump suction preferentially draws liquid from above the educator suction point where the specific gravity is lower. Another possible explanation is simply uncertainty in the actual sample collection depth relative to the actual depth of the pump suction (161" off the bottom).

- On a mass basis, Na_2CO_3 is the dominant solid predicted to form upon reaching saturation at typical evaporator operating conditions (108-115 ^oC bubble point and 1 atm total pressure) for all 2016-2019 samples. Unlike most solids, the solubility of Na_2CO_3 decreases with increasing temperature. The OLI model predicts that the evaporator system is undersaturated with respect to sodium nitrate, aluminum hydroxide, and sodium aluminum silicate (cancrinite) phases.

- The OLI simulations suggest that the preferred maximum liquid density in the evaporator pot is approximately 1.3 g/mL to avoid Na_2CO_3 precipitation, regardless of the maximum overhead-to-feed ratio.

Background

The 2H Evaporator GDL to Tank 38 plugged twice in 2018 within hours of startup, resulting in a one-month shutdown in both instances. SRNL was asked to simulate current and historic (2016

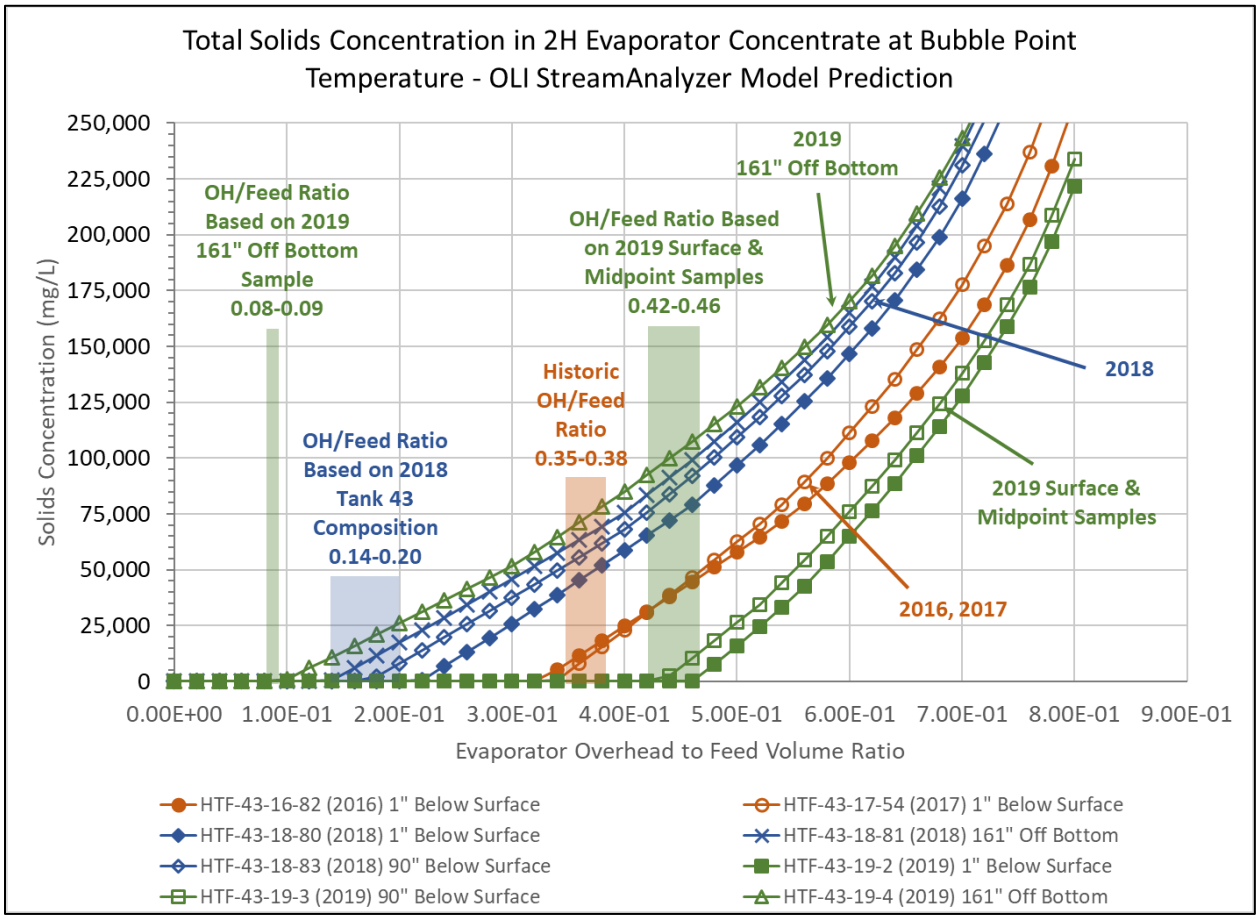

Figure 1. OLI Simulation of Total Solids Concentration in the 2H Evaporator Concentrate at the Bubble Point Temperature and 1 atm Total Pressure.

to 2017) aqueous feed chemistries in the Evaporator Feed Tank (currently Tank 43) using the OLI Systems software to determine the mass of precipitated salts that would be expected to form under 2H Evaporator operating conditions for a range of concentration factors (i.e., evaporator overhead-to-feed volume ratio). Based on the Tank 43 feed composition in November 2018, Dyer (2018) recommended operating the evaporator at an overhead-to-feed volume ratio of less than 0.2 (versus the recent historical ratio of 0.35-0.38) to avoid sodium carbonate precipitation and to extend the time between shutdowns.

From 12/15/2018 through 1/6/2019, Tank Farm Operations intentionally ran the 2H Evaporator with minimum steam input to the evaporator tube bundle to not generate an overhead vapor stream. During this three-week period, lower-specific-gravity salt solution from Tank 38 (drop tank) was periodically recycled to Tank 43 (feed tank) to blend the system and lower the specific gravity in Tank 43. Figure 2 (provided by Tank Farm Engineering) shows the change in

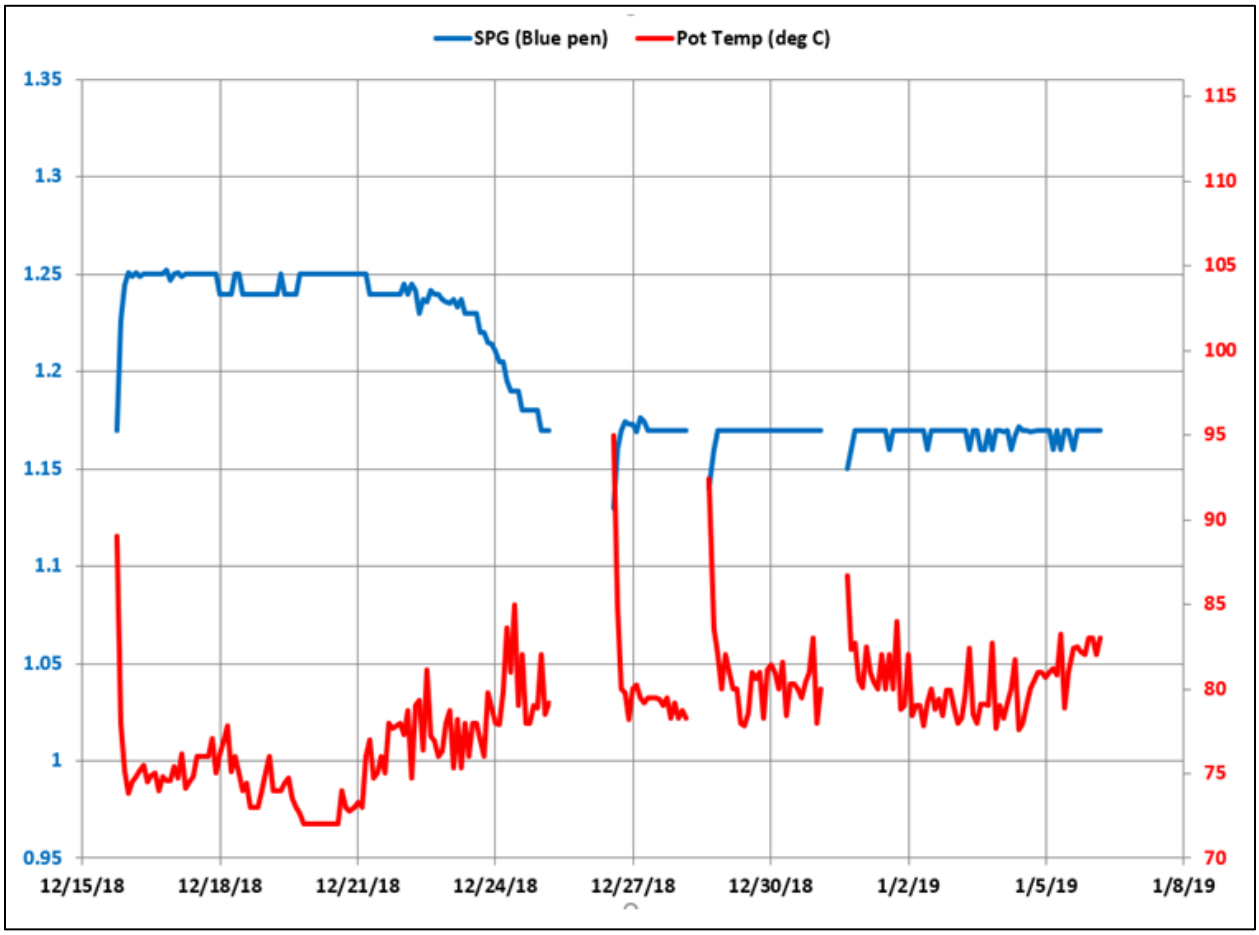

Figure 2. 2H Evaporator Pot Specific Gravity and Pot Temperature (deg C) from 12/15/2018 through 1/6/2019.

evaporator pot specific gravity and pot temperature with time from 12/15/2018 through 1/6/2019. As seen in Figure 2, the evaporator pot specific gravity decreases from approximately 1.25 to approximately 1.17 over 10 days. Recycle continued for an additional two weeks to further blend the feed tank and drop tank contents.

Tank Compositions for OLI Simulations

The OLI simulations were based on cation and anion data generated by the SRNL Analytical Development group. Appendix A provides the three sample results reports for samples HTF-43-19-2, HTF-43-19-3, and HTF-43-19-4 collected from Tank 43 on 1/27/2019. Hay (2016), Hay et al. (2017), and Hay et al. (2018) were the source of the water analysis data for the 2016, 2017,

and 2018 Tank 43 samples, respectively. Specific data from Appendix A used as inputs to the OLI model are summarized in Appendix B in Table B-1, Table B-2, and Table B-3.

OLI Studio Model Formulation

The Water Analyzer and Stream Analyzer modules, respectively, within OLI Studio (ver. 9.6.1) were used to reconcile the analyte data from Appendix A and then to generate the evaporation profiles for the Tank 43 samples. The Mixed Solvent Electrolyte (MSE) thermodynamic framework and associated MSE public database were employed. The default was to include redox chemistry in the MSE chemistry model (Wilmarth et al., 2013); however, redox chemistry had to be deselected in some cases to enable model convergence at the bubble point temperature. This did not impact the dominant Na/Al/Si/O/CO_3 precipitation reactions.

Analytes from the sample results reports in Appendix A were first transformed to an OLI molecular input species as indicated in the third column of Table B-1, Table B-2, and Table B-3. Both molar concentration (mole/L) and mass concentration (mg/L) data for specific analytes from the sample results reports were transformed to the equivalent mass concentration (mg/L) for the specified OLI input species. The OLI input species were chosen based on recommendations by Wilmarth et al. (2013) and Martino et al. (2014) when using the OLI Systems software to simulate liquid waste systems.

The Water Analyzer module was used to reconcile each tank sample for electroneutrality (i.e., charge balance) at 103 ^oC (close to the bubble point temperature) by adding/subtracting Na^+ ion. Samples were not reconciled for pH because the free OH^- concentration [OH^-] results in a pH greater than 14 at 25 ^oC. Instead, model-predicted [OH^-] was compared to measured [OH^-] for each tank waste sample to ensure reasonable agreement within the analytical (up to 10%) and tank sampling (unknown, but likely >10%) uncertainties. Each charge-balanced sample was then exported as a molecular stream for further evaluation using the OLI Stream Analyzer. Figure C-1, Figure C-2, and Figure C-3 in Appendix C show the charge-balanced OLI feed streams for samples HTF-43-19-2, HTF-43-19-3, and HTF-43-19-4, respectively.

OLI Stream Analyzer simulations of the Tank 43 samples were executed at 1 atm total pressure and the model-predicted bubble point temperature. An isobaric “vapor fraction (vapor/inflow) survey” was conducted to model precipitation (scaling tendency) as a function of the vapor-to-feed mole fraction (0.00 to 0.80 mol/mol in steps of 0.02) as shown in Figure 3. Post-processing calculations transformed the OLI vapor-to-feed fraction in mol/mol to the desired overhead-to-feed volume ratio at 25 ^oC. In this instance, the differences between the mol/mol and vol/vol fractions at 25 ^oC for all three samples were less than 2 percent. Bubble point temperatures for the 2019 Tank 43 samples ranged from 105 to 108 ^oC at the feed concentration and increased to

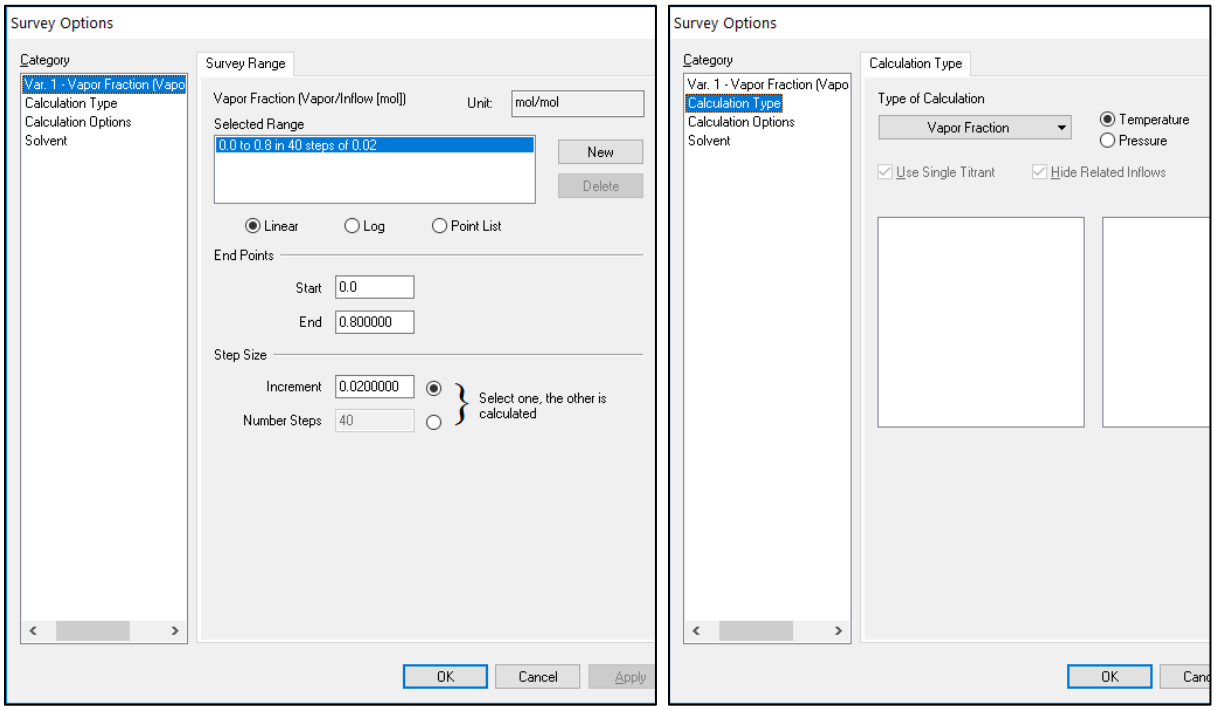

Figure 3. Selection of "Vapor Fraction (Vapor/Inflow) Survey" in OLI Stream Analyzer to Simulate Evaporation at Constant Pressure.

108 to 116 ºC as water was evaporated overhead to the historic overhead-to-feed volume ratios of 0.35 to 0.38.

Density Results

Reported liquid densities for the evaporator pot from OLI Stream Analyzer are shown in Table 1 and Table 2. As highlighted in Table 1, OLI-predicted densities for samples HTF-43-19-2 (surface) and HTF-43-19-3 (midpoint), assuming an overhead-to-feed ratio of 0.36, are lower than OLI-predicted densities for the 2016 though 2018 Tank 43 samples (1.35-1.38 g/mL in 2018; 1.31-1.32 g/mL in 2016 and 2017). Conversely, the OLI-predicted density of 1.41 g/mL for sample HTF-43-19-4 (pump suction), assuming an overhead-to-feed ratio of 0.36, is more closely aligned with 2018 pump suction sample HTF-43-18-81 (1.38 g/mL). Interestingly, Table 2 suggests that the preferred maximum liquid density in the evaporator pot is approximately 1.3 g/mL to avoid Na_2CO_3 precipitation, regardless of the maximum overhead-to-feed ratio.

Results of the vapor fraction (vapor/inflow) surveys using OLI Stream Analyzer for 2019 Tank 43 samples HTF-43-19-2 (surface), HTF-43-19-3 (midpoint), and HTF-43-19-4 (pump suction) are included in Appendix D. The summary table for each of the three samples includes the solids scaling tendencies and the mass concentrations for each solid that is predicted to form at the

Table 1. OLI Liquid Density of Evaporator Concentrate for Tank 43 Samples at an Overhead-to-Feed Ratio of 0.36.

Density at Overhead/Feed Ratio = 0.36		
Sample	Calendar Year	Density (g/cc) @ Bubble Point
HTF-43-16-82	2016	1.32
HTF-43-17-54	2017	1.31
HTF-43-18-80	2018	1.35
HTF-43-18-81	2018	1.38
HTF-43-18-83	2018	1.37
HTF-43-19-2	2019	1.26
HTF-43-19-3	2019	1.28
HTF-43-19-4	2019	1.41

Table 2. OLI Liquid Density of Evaporator Concentrate for Tank 43 Samples at Maximum Overhead-to-Feed Ratio to Avoid Na_2CO_3 Precipitation.

Sample	Calendar Year	Maximum OH/Feed to Avoid Na_2CO_3 Precipitation	Density (g/cc) at Maximum OH/Feed
HTF-43-18-80	2018	0.20	1.29
HTF-43-18-81	2018	0.14	1.30
HTF-43-18-83	2018	0.16	1.30
HTF-43-19-2	2019	0.46	1.31
HTF-43-19-3	2019	0.42	1.31
HTF-43-19-4	2019	0.08	1.31

evaporator bubble point temperature. A scaling tendency equal to 1.0 signifies that the solution is saturated with respect to that solid. A scaling tendency much less than 1.0 means that the solution is undersaturated with respect to that solid.

References

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Appendix A. Tank 43 Sample Analyses

HTF-43-19-2: Surface Sample (1” below liquid surface)

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Sample Results Report
08-February-2019 12:02:43PM
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LIMS Project ID	LW-AD-PROJ-190116-2	**Sampled On**	1/27/2019 12:00:00AM
Sample ID	LW12885	**Logged On**	1/28/2019 7:33:44AM
Sample Number	12885	**Received On**	1/31/2019 2:17:07PM
Sample Status	AUTHORIZED	**Approved By**	WILLIAMS, MATTHEW S
User Sample ID	HTF-43-19-2		

Analysis	Rep	Description	Result (one sigma % unc)	Units
FREE_OH_OTHER_BASE_EXCLUDE_CO3	1	FREE OH	1.38 (10)	Molar
FREE_OH_OTHER_BASE_EXCLUDE_CO3	1	COMMENT	corrected for HLC DF 10.16	-
GAMMA_SPEC	1	GAMMA SPEC COMMENTS	NA	-
GAMMA_SPEC	1	Cs-137	1.60E08 (5.00%)	DPM/mL
HLC-DILUTION	1	SOLIDS (YES/NO)	No	-
HLC-DILUTION	1	DENSITY AVERAGE	1.176	g/mL
HLC-DILUTION	1	DENSITY RSD	0.290	%
IC_ANIONS	1	CHLORIDE	0.00389 (10)	M
IC_ANIONS	1	NITRITE	1.58 (10)	M
IC_ANIONS	1	NITRATE	0.82 (10)	M
IC_ANIONS	1	SULFATE	0.0581 (10)	M
RAD_ICPES_LEEMAN	2	Al	0.049 (10 %RSD)	M
RAD_ICPES_LEEMAN	2	Ca	<8.78E-06 (N/A %RSD)	M
RAD_ICPES_LEEMAN	2	Fe	4.23E-05 (12.3 %RSD)	M
RAD_ICPES_LEEMAN	2	K	4.99E-03 (11.2 %RSD)	M
RAD_ICPES_LEEMAN	2	Na	4.05 (10 %RSD)	M
RAD_ICPES_LEEMAN	2	P	3.06E-03 (20 %RSD)	M
RAD_ICPES_LEEMAN	2	Si	2.76E-03 (11.9 %RSD)	M
TIC_TOC	1	TOTAL CARBON (ug C/mL)	4380 (10)	µg C/mL
TIC_TOC	1	INORGANIC CARBON (ug C/mL)	4060 (10)	µg C/mL
TIC_TOC	1	ORGANIC CARBON (ug C/mL)	325 (10)	µg C/mL

HTF-43-19-3: Midpoint Sample (90” below liquid surface)

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Sample Results Report
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LIMS Project ID	LW-AD-PROJ-190116-2	**Sampled On**	1/27/2019 12:00:00AM
Sample ID	LW12886	**Logged On**	1/28/2019 7:33:45AM
Sample Number	12886	**Received On**	1/31/2019 2:17:07PM
Sample Status	AUTHORIZED	**Approved By**	WILLIAMS, MATTHEW S
User Sample ID	HTF-43-19-3		

Analysis	Rep	Description	Result (one sigma % unc)	Units
FREE_OH_OTHER_BASE_EXCLUDE_CO3	1	FREE OH	1.48 (10)	Molar
FREE_OH_OTHER_BASE_EXCLUDE_CO3	1	COMMENT	corrected for HLC DF 10.11	-
GAMMA_SPEC	1	GAMMA SPEC COMMENTS	NA	-
GAMMA_SPEC	1	Cs-137	1.31E08 (5.00%)	DPM/mL
HLC-DILUTION	1	SOLIDS (YES/NO)	No	-
HLC-DILUTION	1	DENSITY AVERAGE	1.176	g/mL
HLC-DILUTION	1	DENSITY RSD	0.193	%
IC_ANIONS	1	CHLORIDE	0.00413 (10)	M
IC_ANIONS	1	NITRITE	1.65 (10)	M
IC_ANIONS	1	NITRATE	0.86 (10)	M
IC_ANIONS	1	SULFATE	0.0613 (10)	M
RAD_ICPES_LEEMAN	2	Al	0.053 (10 %RSD)	M
RAD_ICPES_LEEMAN	2	Ca	<8.73E-06 (N/A %RSD)	M
RAD_ICPES_LEEMAN	2	Fe	4.49E-05 (14.5 %RSD)	M
RAD_ICPES_LEEMAN	2	K	5.42E-03 (10.3 %RSD)	M
RAD_ICPES_LEEMAN	2	Na	4.26 (10 %RSD)	M
RAD_ICPES_LEEMAN	2	P	3.26E-03 (20 %RSD)	M
RAD_ICPES_LEEMAN	2	Si	3.23E-03 (10.3 %RSD)	M
TIC_TOC	1	TOTAL CARBON (ug C/mL)	4570 (10)	µg C/mL
TIC_TOC	1	INORGANIC CARBON (ug C/mL)	4220 (10)	µg C/mL
TIC_TOC	1	ORGANIC CARBON (ug C/mL)	352 (10)	µg C/mL

HTF-43-19-4: Pump Suction Sample (161” off tank bottom)

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Sample Results Report
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LIMS Project ID	LW-AD-PROJ-190116-2	**Sampled On**	1/27/2019 12:00:00AM
Sample ID	LW12887	**Logged On**	1/28/2019 7:33:45AM
Sample Number	12887	**Received On**	1/31/2019 2:17:07PM
Sample Status	AUTHORIZED	**Approved By**	WILLIAMS, MATTHEW S
User Sample ID	HTF-43-19-4		

Analysis	Rep	Description	Result (one sigma % unc)	Units
FREE_OH_OTHER_BASE_EXCLUDE_CO3	1	FREE OH	2.47 (10)	Molar
FREE_OH_OTHER_BASE_EXCLUDE_CO3	1	COMMENT	corrected for HLC DF 10.21	-
GAMMA_SPEC	1	GAMMA SPEC COMMENTS	NA	-
GAMMA_SPEC	1	Cs-137	2.27E08 (5.00%)	DPM/mL
HLC-DILUTION	1	SOLIDS (YES/NO)	No	-
HLC-DILUTION	1	DENSITY AVERAGE	1.280	g/mL
HLC-DILUTION	1	DENSITY RSD	0.255	%
IC_ANIONS	1	CHLORIDE	0.00645 (10)	M
IC_ANIONS	1	NITRITE	2.49 (10)	M
IC_ANIONS	1	NITRATE	1.33 (10)	M
IC_ANIONS	1	SULFATE	0.0754 (10)	M
RAD_ICPES_LEEMAN	2	Al	0.077 (10 %RSD)	M
RAD_ICPES_LEEMAN	2	Ca	<8.83E-06 (N/A %RSD)	M
RAD_ICPES_LEEMAN	2	Fe	5.01E-05 (17.9 %RSD)	M
RAD_ICPES_LEEMAN	2	K	9.05E-03 (10.1 %RSD)	M
RAD_ICPES_LEEMAN	2	Na	7 (10 %RSD)	M
RAD_ICPES_LEEMAN	2	P	6.04E-03 (20 %RSD)	M
RAD_ICPES_LEEMAN	2	Si	2.41E-03 (11.6 %RSD)	M
TIC_TOC	1	TOTAL CARBON (ug C/mL)	7170 (10)	µg C/mL
TIC_TOC	1	INORGANIC CARBON (ug C/mL)	6710 (10)	µg C/mL
TIC_TOC	1	ORGANIC CARBON (ug C/mL)	462 (10)	µg C/mL

Appendix B. OLI Studio Model Input Data

Table B-1. Tank 43 Input Data for OLI Studio Model (1" Below Liquid Surface).

				Analytical Result		OLI Input
Ion/Element	MW Ion (g/mole)	OLI Input Species	MW OLI Species	2019 HTF-43-19-2	Analytical Data Units	2019 HTF-43-19-2 (mg/L)
Si	28.085	Na2SiO3	122.06	2.76E-03	M	3.37E+02
Fe	55.845	Fe(OH)3	106.87	4.23E-05	M	4.52E+00
Ca	40.078	Ca+2	40.078	8.78E-06	M	0.00E+00
K	39.10	K+	39.10	4.99E-03	M	1.95E+02
Li	6.94	Li+	6.94		M	
Na	22.99	Na+	22.99	4.05E+00	M	9.31E+04
Zn	65.38	Zn+2	65.38		M	
OH-	17.01	OH-	17.01	1.38E+00	M	2.35E+04
F-	19.00	F-	19.00		M	
Cl-	35.45	Cl-	35.45	3.89E-03	M	1.38E+02
NO2-	46.01	NO2-	46.01	1.58E+00	M	7.27E+04
Br-	79.90	Br-	79.90		M	
NO3-	62.00	NO3-	62.00	8.20E-01	M	5.08E+04
P	30.97	PO4-3	94.97	3.06E-03	M	2.91E+02
SO4-2	96.06	SO4-2	96.06	5.81E-02	M	5.58E+03
CO3-2	60.01	CO3-2	60.01		M	0.00E+00
TIC	12.01	CO3-2	60.01	4.06E+03	mg/L	2.03E+04
Al	26.98	Al(OH)4-1	95.01	4.90E-02	M	4.66E+03
B	10.81	B(OH)4-1	78.84		mg/L	
Cr	52.00	CrO4-2	115.99		mg/L	
C2O4-2	88.03	C2O4-2	88.03		M	
CHO2-	44.03	HCOO-1	44.03		M	
CO3-2/NO3-				4.12E-01		
CO3-2/Na				8.35E-02		
Si/Na				6.81E-04		
	Below quantification limit; therefore, assumed zero					

Table B-2. Tank 43 Input Data for OLI Studio Model (90" Below Liquid Surface).

				Analytical Result		OLI Input
Ion/Element	MW Ion (g/mole)	OLI Input Species	MW OLI Species	2019 HTF-43-19-3	Analytical Data Units	2019 HTF-43-19-3 (mg/L)
Si	28.085	Na2SiO3	122.06	3.23E-03	M	3.94E+02
Fe	55.845	Fe(OH)3	106.87	4.49E-05	M	4.80E+00
Ca	40.078	Ca+2	40.078	8.73E-06	M	0.00E+00
K	39.10	K+	39.10	5.42E-03	M	2.12E+02
Li	6.94	Li+	6.94		M	
Na	22.99	Na+	22.99	4.26E+00	M	9.79E+04
Zn	65.38	Zn+2	65.38		M	
OH-	17.01	OH-	17.01	1.48E+00	M	2.52E+04
F-	19.00	F-	19.00		M	
Cl-	35.45	Cl-	35.45	4.13E-03	M	1.46E+02
NO2-	46.01	NO2-	46.01	1.65E+00	M	7.59E+04
Br-	79.90	Br-	79.90		M	
NO3-	62.00	NO3-	62.00	8.60E-01	M	5.33E+04
P	30.97	PO4-3	94.97	3.26E-03	M	3.10E+02
SO4-2	96.06	SO4-2	96.06	6.13E-02	M	5.89E+03
CO3-2	60.01	CO3-2	60.01		M	0.00E+00
TIC	12.01	CO3-2	60.01	4.22E+03	mg/L	2.11E+04
Al	26.98	Al(OH)4-1	95.01	5.30E-02	M	5.04E+03
B	10.81	B(OH)4-1	78.84		mg/L	
Cr	52.00	CrO4-2	115.99		mg/L	
C2O4-2	88.03	C2O4-2	88.03		M	
CHO2-	44.03	HCOO-1	44.03		M	
CO3-2/NO3-				4.09E-01		
CO3-2/Na				8.25E-02		
Si/Na				7.58E-04		
	Below quantification limit; therefore, assumed zero					

Table B-3. Tank 43 Input Data for OLI Studio Model (161" Off Tank Bottom).

				Analytical Result		OLI Input
Ion/Element	MW Ion (g/mole)	OLI Input Species	MW OLI Species	2019 HTF-43-19-4	Analytical Data Units	2019 HTF-43-19-4 (mg/L)
Si	28.085	Na2SiO3	122.06	2.41E-03	M	2.94E+02
Fe	55.845	Fe(OH)3	106.87	5.01E-05	M	5.35E+00
Ca	40.078	Ca+2	40.078	8.83E-06	M	0.00E+00
K	39.10	K+	39.10	9.05E-03	M	3.54E+02
Li	6.94	Li+	6.94		M	
Na	22.99	Na+	22.99	7.00E+00	M	1.61E+05
Zn	65.38	Zn+2	65.38		M	
OH-	17.01	OH-	17.01	2.47E+00	M	4.20E+04
F-	19.00	F-	19.00		M	
Cl-	35.45	Cl-	35.45	6.45E-03	M	2.29E+02
NO2-	46.01	NO2-	46.01	2.49E+00	M	1.15E+05
Br-	79.90	Br-	79.90		M	
NO3-	62.00	NO3-	62.00	1.33E+00	M	8.25E+04
P	30.97	PO4-3	94.97	6.04E-03	M	5.74E+02
SO4-2	96.06	SO4-2	96.06	7.54E-02	M	7.24E+03
CO3-2	60.01	CO3-2	60.01		M	0.00E+00
TIC	12.01	CO3-2	60.01	6.71E+03	mg/L	3.35E+04
Al	26.98	Al(OH)4-1	95.01	7.70E-02	M	7.32E+03
B	10.81	B(OH)4-1	78.84		mg/L	
Cr	52.00	CrO4-2	115.99		mg/L	
C2O4-2	88.03	C2O4-2	88.03		M	
CHO2-	44.03	HCOO-1	44.03		M	
CO3-2/NO3-				4.20E-01		
CO3-2/Na				7.98E-02		
Si/Na				3.44E-04		
	Below quantification limit; therefore, assumed zero					

Appendix C. OLI Studio Model Charge-Balanced OLI Feed Streams

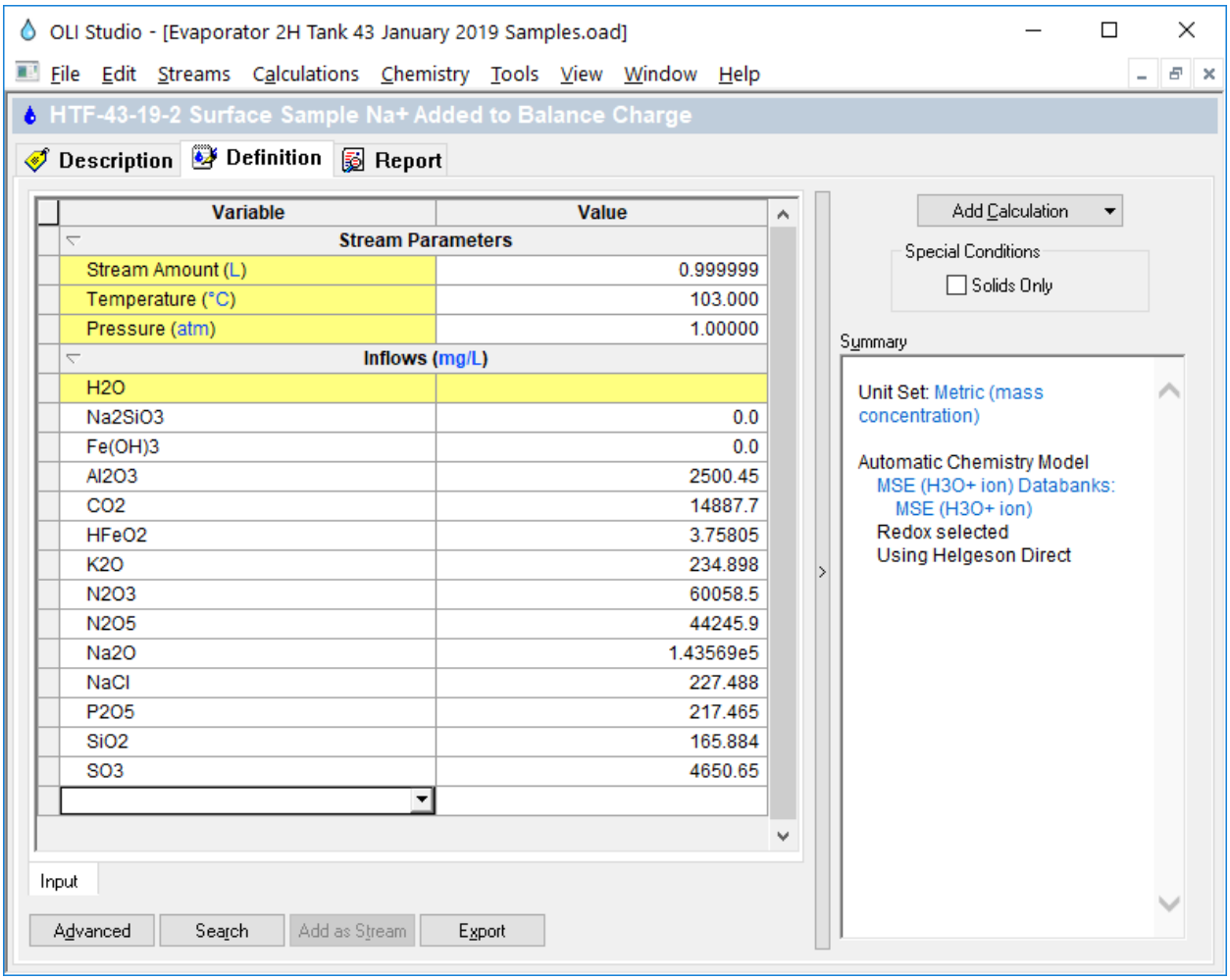

Figure C-1. Charge-Balanced OLI Feed Stream for Sample HTF-43-19-2 (1” below liquid surface).

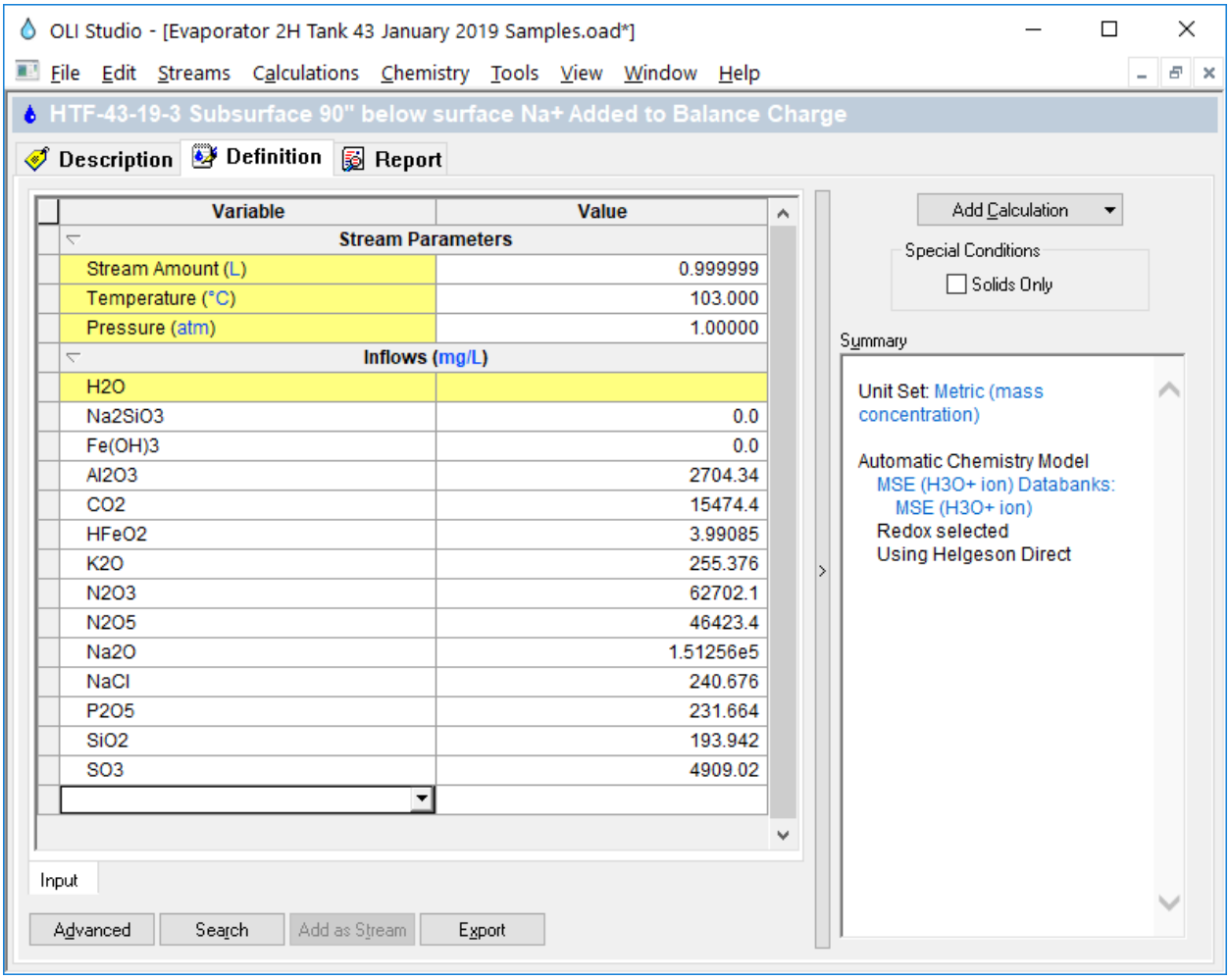

Figure C-2. Charge-Balanced OLI Feed Stream for Sample HTF-43-19-3 (90” below liquid surface).

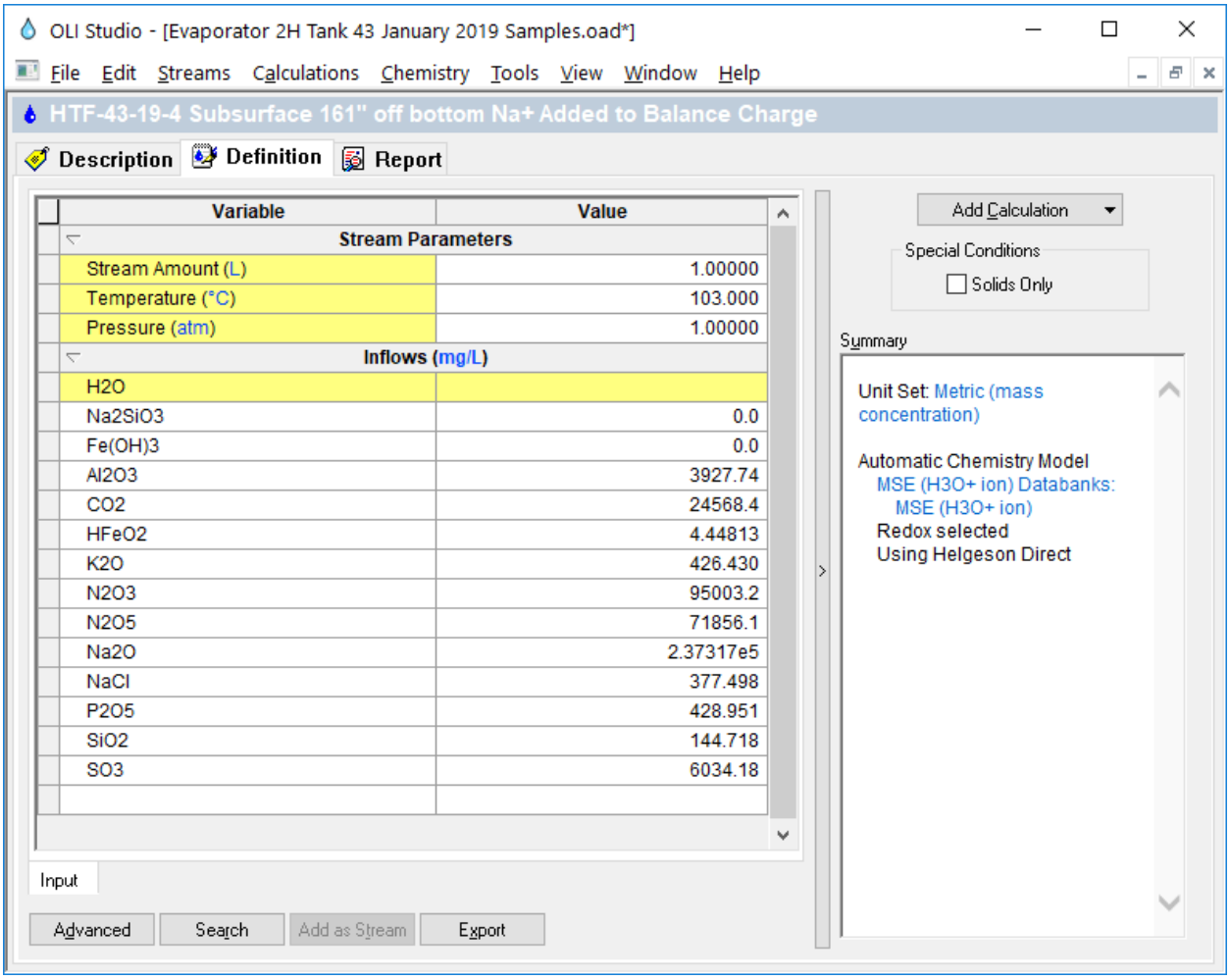

Figure C-3. Charge-Balanced OLI Feed Stream for Sample HTF-43-19-4 (161” off tank bottom).

Appendix D. OLI Studio Model Evaporator Simulation Results

Table D-1. OLI Studio Model Evaporator Simulation Results for 2019 Tank 43 Sample HTF-43-19-2 (1” below liquid surface).

					Scaling Tendency									Solids Concentration (mg/L)				
Condensed Vapor/Feed [vol/vol] 25 °C	Volume - Liquid-1 [L]	Temperature [°C]	Pressure [atm]	Density (g/cc)	Na8Al6Si6O24CO3.2H2O (Cancrinite) Scaling Tendency	Na8Al6Si6O24CO3.1H2O (Cancrinite monohydrate) Scaling Tendency	Na8Al6Si6O24(OH)2.2H2O (Hydroxycancrinite) Scaling Tendency	Na6Al6Si6O24.12H2O (hydrated zeolite A) Scaling Tendency	Fe3O4 (Magnetite) - Sol Scaling Tendency	Na2CO3 (Natrite) - Sol Scaling Tendency	Na2CO3.1H2O (Thermonatrite) Scaling Tendency	2Na2SO4.Na2CO3 - Sol Scaling Tendency	Al(OH)3 (Gibbsite) - Scaling Tendency	Na3PO4 - Sol [mg/L]	Na2CO3 (Natrite) - Sol [mg/L]	Fe3O4 (Magnetite) - Sol [mg/L]	2Na2SO4.Na2CO3 - Sol [mg/L]	Total Solids (mg/L)
0.00E+00	1.00E+00	1.05E+02	1.00E+00	1.16E+00	4.70E-02	4.96E-01	1.51E-03	2.66E-07	1.00E+00	1.37E-01	1.43E-01	1.76E-03	6.86E-03	0.00E+00	0.00E+00	3.16E+00	0.00E+00	3.16E+00
2.00E-02	9.81E-01	1.05E+02	1.00E+00	1.17E+00	3.24E-02	3.44E-01	1.09E-03	1.66E-07	1.00E+00	1.46E-01	1.51E-01	2.06E-03	6.36E-03	0.00E+00	0.00E+00	3.06E+00	0.00E+00	3.06E+00
4.00E-02	9.61E-01	1.05E+02	1.00E+00	1.17E+00	2.25E-02	2.41E-01	7.96E-04	1.04E-07	1.00E+00	1.55E-01	1.59E-01	2.43E-03	5.90E-03	0.00E+00	0.00E+00	3.09E+00	0.00E+00	3.09E+00
6.00E-02	9.42E-01	1.05E+02	1.00E+00	1.17E+00	1.53E-02	1.64E-01	5.67E-04	6.39E-08	1.00E+00	1.65E-01	1.69E-01	2.86E-03	5.46E-03	0.00E+00	0.00E+00	3.13E+00	0.00E+00	3.13E+00
8.00E-02	9.22E-01	1.05E+02	1.00E+00	1.18E+00	1.01E-02	1.09E-01	3.95E-04	3.80E-08	1.00E+00	1.76E-01	1.79E-01	3.39E-03	5.02E-03	0.00E+00	0.00E+00	3.18E+00	0.00E+00	3.18E+00
1.00E-01	9.02E-01	1.05E+02	1.00E+00	1.18E+00	6.54E-03	7.09E-02	2.68E-04	2.19E-08	1.00E+00	1.88E-01	1.90E-01	4.05E-03	4.60E-03	0.00E+00	0.00E+00	3.23E+00	0.00E+00	3.23E+00
1.20E-01	8.82E-01	1.06E+02	1.00E+00	1.19E+00	4.09E-03	4.46E-02	1.77E-04	1.22E-08	1.00E+00	2.02E-01	2.02E-01	4.85E-03	4.19E-03	0.00E+00	0.00E+00	3.29E+00	0.00E+00	3.29E+00
1.40E-01	8.63E-01	1.06E+02	1.00E+00	1.19E+00	2.48E-03	2.72E-02	1.13E-04	6.54E-09	1.00E+00	2.16E-01	2.15E-01	5.84E-03	3.80E-03	0.00E+00	0.00E+00	3.35E+00	0.00E+00	3.35E+00
1.60E-01	8.43E-01	1.06E+02	1.00E+00	1.20E+00	1.45E-03	1.60E-02	7.02E-05	3.37E-09	1.00E+00	2.32E-01	2.29E-01	7.08E-03	3.42E-03	0.00E+00	0.00E+00	3.42E+00	0.00E+00	3.42E+00
1.80E-01	8.23E-01	1.06E+02	1.00E+00	1.20E+00	8.17E-04	9.09E-03	4.20E-05	1.66E-09	1.00E+00	2.50E-01	2.44E-01	8.64E-03	3.06E-03	0.00E+00	0.00E+00	3.49E+00	0.00E+00	3.49E+00
2.00E-01	8.03E-01	1.06E+02	1.00E+00	1.21E+00	4.42E-04	4.95E-03	2.42E-05	7.85E-10	1.00E+00	2.70E-01	2.61E-01	1.06E-02	2.72E-03	0.00E+00	0.00E+00	3.56E+00	0.00E+00	3.56E+00
2.20E-01	7.84E-01	1.06E+02	1.00E+00	1.21E+00	2.29E-04	2.58E-03	1.34E-05	3.52E-10	1.00E+00	2.93E-01	2.80E-01	1.31E-02	2.40E-03	0.00E+00	0.00E+00	3.63E+00	0.00E+00	3.63E+00
2.40E-01	7.64E-01	1.07E+02	1.00E+00	1.22E+00	1.13E-04	1.28E-03	7.07E-06	1.49E-10	1.00E+00	3.18E-01	3.01E-01	1.64E-02	2.10E-03	0.00E+00	0.00E+00	3.71E+00	0.00E+00	3.71E+00
2.60E-01	7.44E-01	1.07E+02	1.00E+00	1.23E+00	5.27E-05	6.05E-04	3.56E-06	5.97E-11	1.00E+00	3.46E-01	3.24E-01	2.06E-02	1.82E-03	0.00E+00	0.00E+00	3.79E+00	0.00E+00	3.79E+00
2.80E-01	7.25E-01	1.07E+02	1.00E+00	1.23E+00	2.32E-05	2.70E-04	1.69E-06	2.23E-11	1.00E+00	3.78E-01	3.50E-01	2.62E-02	1.56E-03	0.00E+00	0.00E+00	3.88E+00	0.00E+00	3.88E+00
3.00E-01	7.05E-01	1.07E+02	1.00E+00	1.24E+00	9.63E-06	1.13E-04	7.60E-07	7.78E-12	1.00E+00	4.14E-01	3.79E-01	3.35E-02	1.33E-03	0.00E+00	0.00E+00	3.97E+00	0.00E+00	3.97E+00
3.20E-01	6.85E-01	1.08E+02	1.00E+00	1.25E+00	3.72E-06	4.40E-05	3.19E-07	2.50E-12	1.00E+00	4.55E-01	4.11E-01	4.34E-02	1.11E-03	0.00E+00	0.00E+00	4.07E+00	0.00E+00	4.07E+00
3.40E-01	6.66E-01	1.08E+02	1.00E+00	1.26E+00	1.33E-06	1.59E-05	1.25E-07	7.38E-13	1.00E+00	5.02E-01	4.46E-01	5.68E-02	9.21E-04	0.00E+00	0.00E+00	4.16E+00	0.00E+00	4.16E+00
3.60E-01	6.46E-01	1.08E+02	1.00E+00	1.26E+00	4.36E-07	5.28E-06	4.50E-08	1.98E-13	1.00E+00	5.56E-01	4.87E-01	7.52E-02	7.50E-04	0.00E+00	0.00E+00	4.27E+00	0.00E+00	4.27E+00
3.80E-01	6.26E-01	1.09E+02	1.00E+00	1.27E+00	1.30E-07	1.60E-06	1.48E-08	4.75E-14	1.00E+00	6.18E-01	5.32E-01	1.01E-01	6.01E-04	0.00E+00	0.00E+00	4.37E+00	0.00E+00	4.37E+00
4.00E-01	6.07E-01	1.09E+02	1.00E+00	1.28E+00	3.48E-08	4.34E-07	4.41E-09	1.01E-14	1.00E+00	6.90E-01	5.84E-01	1.37E-01	4.73E-04	0.00E+00	0.00E+00	4.48E+00	0.00E+00	4.48E+00
4.20E-01	5.87E-01	1.09E+02	1.00E+00	1.29E+00	8.29E-09	1.05E-07	1.17E-09	1.89E-15	1.00E+00	7.74E-01	6.43E-01	1.90E-01	3.64E-04	0.00E+00	0.00E+00	4.60E+00	0.00E+00	4.60E+00
4.40E-01	5.67E-01	1.10E+02	1.00E+00	1.30E+00	1.72E-09	2.22E-08	2.75E-10	3.04E-16	1.00E+00	8.74E-01	7.10E-01	2.67E-01	2.74E-04	0.00E+00	0.00E+00	4.72E+00	0.00E+00	4.72E+00
4.60E-01	**5.48E-01**	**1.10E+02**	**1.00E+00**	**1.31E+00**	**3.08E-10**	**4.04E-09**	**5.58E-11**	**4.12E-17**	**1.00E+00**	**9.91E-01**	**7.87E-01**	**3.82E-01**	**2.01E-04**	**0.00E+00**	**0.00E+00**	**4.84E+00**	**0.00E+00**	**4.84E+00**
4.80E-01	5.27E-01	1.11E+02	1.00E+00	1.32E+00	7.13E-11	9.48E-10	1.58E-11	8.38E-18	1.00E+00	1.00E+00	7.80E-01	4.63E-01	1.54E-04	0.00E+00	7.68E+03	5.00E+00	0.00E+00	7.68E+03
5.00E-01	5.06E-01	1.11E+02	1.00E+00	1.33E+00	1.40E-11	1.89E-10	3.91E-12	1.45E-18	1.00E+00	1.00E+00	7.64E-01	5.64E-01	1.15E-04	0.00E+00	1.60E+04	5.18E+00	0.00E+00	1.60E+04
5.20E-01	4.85E-01	1.12E+02	1.00E+00	1.34E+00	2.19E-12	3.02E-11	7.82E-13	1.95E-19	1.00E+00	1.00E+00	7.47E-01	7.00E-01	8.31E-05	0.00E+00	2.45E+04	5.36E+00	0.00E+00	2.45E+04
5.40E-01	4.64E-01	1.12E+02	1.00E+00	1.35E+00	2.63E-13	3.69E-12	1.23E-13	1.98E-20	1.00E+00	1.00E+00	7.28E-01	8.88E-01	5.73E-05	0.00E+00	3.30E+04	5.55E+00	0.00E+00	3.30E+04
5.60E-01	4.43E-01	1.13E+02	1.00E+00	1.37E+00	2.42E-14	3.48E-13	1.51E-14	1.51E-21	1.00E+00	1.00E+00	7.08E-01	1.00E+00	3.78E-05	0.00E+00	4.10E+04	5.75E+00	1.68E+03	4.27E+04
5.80E-01	4.22E-01	1.13E+02	1.00E+00	1.38E+00	1.63E-15	2.41E-14	1.39E-15	8.32E-23	1.00E+00	1.00E+00	6.86E-01	1.00E+00	2.36E-05	0.00E+00	4.86E+04	5.96E+00	4.97E+03	5.36E+04
6.00E-01	4.01E-01	1.14E+02	1.00E+00	1.40E+00	7.25E-17	1.10E-15	8.71E-17	2.92E-24	1.00E+00	1.00E+00	6.61E-01	1.00E+00	1.38E-05	0.00E+00	5.64E+04	6.17E+00	8.45E+03	6.48E+04
6.20E-01	3.80E-01	1.15E+02	1.00E+00	1.41E+00	1.94E-18	3.05E-17	3.41E-18	5.98E-26	1.00E+00	1.00E+00	6.35E-01	1.00E+00	7.38E-06	0.00E+00	6.43E+04	6.38E+00	1.21E+04	7.64E+04
6.40E-01	3.59E-01	1.16E+02	1.00E+00	1.43E+00	2.84E-20	4.62E-19	7.54E-20	6.40E-28	1.00E+00	1.00E+00	6.05E-01	1.00E+00	3.57E-06	0.00E+00	7.25E+04	6.58E+00	1.60E+04	8.85E+04
6.60E-01	3.38E-01	1.17E+02	1.00E+00	1.46E+00	1.98E-22	3.36E-21	8.30E-22	3.11E-30	1.00E+00	1.00E+00	5.72E-01	1.00E+00	1.53E-06	0.00E+00	8.09E+04	6.75E+00	2.01E+04	1.01E+05
6.80E-01	3.18E-01	1.19E+02	1.00E+00	1.48E+00	5.50E-25	9.84E-24	3.83E-24	4.59E-07	1.00E+00	1.00E+00	5.36E-01	1.00E+00	5.57E-07	0.00E+00	8.98E+04	6.88E+00	2.43E+04	1.14E+05
7.00E-01	2.97E-01	1.20E+02	1.00E+00	1.51E+00	4.83E-28	9.19E-27	5.92E-27	4.59E-07	1.00E+00	1.00E+00	4.96E-01	1.00E+00	1.68E-07	0.00E+00	9.93E+04	6.93E+00	2.87E+04	1.28E+05
7.20E-01	2.77E-01	1.22E+02	1.00E+00	1.55E+00	8.08E-02	2.01E-30	2.25E-30	4.59E-07	1.00E+00	1.00E+00	4.53E-01	1.00E+00	3.93E-08	0.00E+00	1.09E+05	6.84E+00	3.34E+04	1.43E+05
7.40E-01	2.57E-01	1.25E+02	1.00E+00	1.59E+00	8.08E-02	8.47E-01	2.55E-03	4.59E-07	1.00E+00	1.00E+00	4.06E-01	1.00E+00	6.67E-09	0.00E+00	1.21E+05	6.51E+00	3.82E+04	1.59E+05
7.60E-01	2.36E-01	1.27E+02	1.00E+00	1.65E+00	8.08E-02	8.47E-01	2.55E-03	4.59E-07	1.00E+00	1.00E+00	3.56E-01	1.00E+00	7.36E-10	0.00E+00	1.33E+05	5.75E+00	4.35E+04	1.77E+05
7.80E-01	2.16E-01	1.31E+02	1.00E+00	1.71E+00	8.08E-02	8.47E-01	2.55E-03	4.59E-07	1.00E+00	1.00E+00	3.03E-01	1.00E+00	4.56E-11	2.27E+02	1.48E+05	4.26E+00	4.91E+04	1.97E+05
8.00E-01	1.95E-01	1.36E+02	1.00E+00	1.79E+00	8.08E-02	8.47E-01	2.55E-03	4.59E-07	1.00E+00	1.00E+00	2.48E-01	1.00E+00	1.28E-12	1.64E+03	1.65E+05	1.48E+00	5.55E+04	2.22E+05

Scaling tendency is a measure of the tendency of a solid species to form at the specified conditions. Solids with a scaling tendency > 1.0 will form if solid formation is governed by equilibrium and if no other solids with a common cation or anion are present which also have a scaling tendency > 1.0.

Mass concentration (mg/L) of solid species predicted to form.

Highlights cases with a historical overhead-to-feed volume ratio ranging between 0.34 and 0.38.

Highlights maximum overhead-to-feed volume ratio where no Na2CO3 is predicted to form.

Table D-2. OLI Studio Model Evaporator Simulation Results for 2019 Tank 43 Sample HTF-43-19-3 (90” below liquid surface).

					Scaling Tendency									Solids Concentration (mg/L)					
Condensed Vapor/Feed [vol/vol] 25 °C	Volume - Liquid-1 [L]	Temperature [°C]	Pressure [atm]	Density (g/cc)	Na8Al6Si6O24CO3.2H2O (Cancrinite) Scaling Tendency	Na8Al6Si6O24C O3.1H2O (Cancrinite monohydrate) Scaling Tendency	Na8Al6Si6O24(OH)2.2 H2O (Hydroxycancrinite) Scaling Tendency	Na6Al6Si6O24 .12H2O (hydrated zeolite A) Scaling Tendency	Fe3O4 (Magnetite) - Sol Scaling Tendency	Na2CO3 (Natrite) - Sol Scaling Tendency	Na2CO3.1H2O (Thermonatrite) Scaling Tendency	2Na2SO4.Na2 CO3 - Sol Scaling Tendency	Al(OH)3 (Gibbsite) - Scaling Tendency	NaFeO2 - Sol [mg/L]	Na3PO4 - Sol [mg/L]	Na2CO3 (Natrite) - Sol [mg/L]	Fe3O4 (Magnetite) - Sol [mg/L]	2Na2SO4.Na2 CO3 - Sol [mg/L]	Total Solids (mg/L)
0.00E+00	1.00E+00	1.05E+02	1.00E+00	1.17E+00	3.92E-02	4.20E-01	1.50E-03	1.73E-07	1.00E+00	1.59E-01	1.63E-01	2.62E-03	5.79E-03	0.00E+00	0.00E+00	0.00E+00	3.36E+00	0.00E+00	3.36E+00
2.00E-02	9.81E-01	1.05E+02	1.00E+00	1.18E+00	2.58E-02	2.78E-01	1.04E-03	1.03E-07	1.00E+00	1.69E-01	1.72E-01	3.08E-03	5.33E-03	0.00E+00	0.00E+00	0.00E+00	3.25E+00	0.00E+00	3.25E+00
4.00E-02	9.62E-01	1.05E+02	1.00E+00	1.18E+00	1.73E-02	1.87E-01	7.28E-04	6.20E-08	1.00E+00	1.80E-01	1.82E-01	3.64E-03	4.92E-03	0.00E+00	0.00E+00	0.00E+00	3.28E+00	0.00E+00	3.28E+00
6.00E-02	9.42E-01	1.06E+02	1.00E+00	1.18E+00	1.13E-02	1.23E-01	5.00E-04	3.63E-08	1.00E+00	1.92E-01	1.92E-01	4.31E-03	4.52E-03	0.00E+00	0.00E+00	0.00E+00	3.32E+00	0.00E+00	3.32E+00
8.00E-02	9.22E-01	1.06E+02	1.00E+00	1.19E+00	7.18E-03	7.85E-02	3.35E-04	2.06E-08	1.00E+00	2.05E-01	2.04E-01	5.12E-03	4.13E-03	0.00E+00	0.00E+00	0.00E+00	3.37E+00	0.00E+00	3.37E+00
1.00E-01	9.02E-01	1.06E+02	1.00E+00	1.19E+00	4.43E-03	4.87E-02	2.18E-04	1.13E-08	1.00E+00	2.19E-01	2.17E-01	6.13E-03	3.76E-03	0.00E+00	0.00E+00	0.00E+00	3.43E+00	0.00E+00	3.43E+00
1.20E-01	8.83E-01	1.06E+02	1.00E+00	1.20E+00	2.65E-03	2.93E-02	1.38E-04	5.99E-09	1.00E+00	2.35E-01	2.30E-01	7.37E-03	3.40E-03	0.00E+00	0.00E+00	0.00E+00	3.49E+00	0.00E+00	3.49E+00
1.40E-01	8.63E-01	1.06E+02	1.00E+00	1.20E+00	1.53E-03	1.70E-02	8.44E-05	3.05E-09	1.00E+00	2.52E-01	2.45E-01	8.92E-03	3.06E-03	0.00E+00	0.00E+00	0.00E+00	3.55E+00	0.00E+00	3.55E+00
1.60E-01	8.43E-01	1.06E+02	1.00E+00	1.21E+00	8.50E-04	9.55E-03	4.99E-05	1.49E-09	1.00E+00	2.71E-01	2.62E-01	1.09E-02	2.73E-03	0.00E+00	0.00E+00	0.00E+00	3.62E+00	0.00E+00	3.62E+00
1.80E-01	8.23E-01	1.06E+02	1.00E+00	1.21E+00	4.54E-04	5.14E-03	2.84E-05	6.93E-10	1.00E+00	2.93E-01	2.80E-01	1.33E-02	2.43E-03	0.00E+00	0.00E+00	0.00E+00	3.69E+00	0.00E+00	3.69E+00
2.00E-01	8.04E-01	1.07E+02	1.00E+00	1.22E+00	2.33E-04	2.65E-03	1.55E-05	3.07E-10	1.00E+00	3.17E-01	3.00E-01	1.64E-02	2.14E-03	0.00E+00	0.00E+00	0.00E+00	3.77E+00	0.00E+00	3.77E+00
2.20E-01	7.84E-01	1.07E+02	1.00E+00	1.23E+00	1.13E-04	1.30E-03	8.13E-06	1.29E-10	1.00E+00	3.43E-01	3.21E-01	2.04E-02	1.87E-03	0.00E+00	0.00E+00	0.00E+00	3.85E+00	0.00E+00	3.85E+00
2.40E-01	7.64E-01	1.07E+02	1.00E+00	1.23E+00	5.26E-05	6.09E-04	4.05E-06	5.12E-11	1.00E+00	3.73E-01	3.46E-01	2.56E-02	1.62E-03	0.00E+00	0.00E+00	0.00E+00	3.93E+00	0.00E+00	3.93E+00
2.60E-01	7.45E-01	1.07E+02	1.00E+00	1.24E+00	2.30E-05	2.69E-04	1.91E-06	1.90E-11	1.00E+00	4.07E-01	3.72E-01	3.24E-02	1.39E-03	0.00E+00	0.00E+00	0.00E+00	4.01E+00	0.00E+00	4.01E+00
2.80E-01	7.25E-01	1.08E+02	1.00E+00	1.25E+00	9.47E-06	1.12E-04	8.53E-07	6.58E-12	1.00E+00	4.45E-01	4.02E-01	4.13E-02	1.17E-03	0.00E+00	0.00E+00	0.00E+00	4.10E+00	0.00E+00	4.10E+00
3.00E-01	7.05E-01	1.08E+02	1.00E+00	1.25E+00	3.64E-06	4.35E-05	3.57E-07	2.11E-12	1.00E+00	4.88E-01	4.35E-01	5.33E-02	9.85E-04	0.00E+00	0.00E+00	0.00E+00	4.20E+00	0.00E+00	4.20E+00
3.20E-01	6.86E-01	1.08E+02	1.00E+00	1.26E+00	1.30E-06	1.57E-05	1.39E-07	6.22E-13	1.00E+00	5.37E-01	4.72E-01	6.94E-02	8.15E-04	0.00E+00	0.00E+00	0.00E+00	4.29E+00	0.00E+00	4.29E+00
3.40E-01	6.66E-01	1.09E+02	1.00E+00	1.27E+00	4.26E-07	5.21E-06	5.01E-08	1.67E-13	1.00E+00	5.93E-01	5.14E-01	9.15E-02	6.64E-04	0.00E+00	0.00E+00	0.00E+00	4.39E+00	0.00E+00	4.39E+00
3.60E-01	6.46E-01	1.09E+02	1.00E+00	1.28E+00	1.28E-07	1.58E-06	1.66E-08	4.04E-14	1.00E+00	6.58E-01	5.60E-01	1.22E-01	5.33E-04	0.00E+00	0.00E+00	0.00E+00	4.50E+00	0.00E+00	4.50E+00
3.80E-01	6.27E-01	1.09E+02	1.00E+00	1.29E+00	3.45E-08	4.34E-07	4.97E-09	8.72E-15	1.00E+00	7.33E-01	6.13E-01	1.65E-01	4.20E-04	0.00E+00	0.00E+00	0.00E+00	4.61E+00	0.00E+00	4.61E+00
4.00E-01	6.07E-01	1.10E+02	1.00E+00	1.30E+00	8.31E-09	1.06E-07	1.34E-09	1.65E-15	1.00E+00	8.20E-01	6.73E-01	2.26E-01	3.24E-04	0.00E+00	0.00E+00	0.00E+00	4.72E+00	0.00E+00	4.72E+00
4.20E-01	**5.87E-01**	**1.10E+02**	**1.00E+00**	**1.31E+00**	**1.76E-09**	**2.29E-08**	**3.19E-10**	**2.72E-16**	**1.00E+00**	**9.22E-01**	**7.41E-01**	**3.15E-01**	**2.45E-04**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**4.83E+00**	**0.00E+00**	**4.83E+00**
4.40E-01	5.67E-01	1.10E+02	1.00E+00	1.32E+00	3.74E-10	4.93E-09	7.85E-11	4.65E-17	1.00E+00	1.00E+00	7.87E-01	4.20E-01	1.85E-04	0.00E+00	0.00E+00	2.61E+03	4.96E+00	0.00E+00	2.61E+03
4.60E-01	5.46E-01	1.11E+02	1.00E+00	1.33E+00	8.99E-11	1.20E-09	2.32E-11	9.96E-18	1.00E+00	1.00E+00	7.73E-01	5.02E-01	1.43E-04	0.00E+00	0.00E+00	1.04E+04	5.13E+00	0.00E+00	1.04E+04
4.80E-01	5.25E-01	1.11E+02	1.00E+00	1.34E+00	1.80E-11	2.44E-10	5.79E-12	1.74E-18	1.00E+00	1.00E+00	7.57E-01	6.09E-01	1.07E-04	0.00E+00	0.00E+00	1.83E+04	5.30E+00	0.00E+00	1.83E+04
5.00E-01	5.04E-01	1.12E+02	1.00E+00	1.35E+00	2.89E-12	4.00E-11	1.19E-12	2.42E-19	1.00E+00	1.00E+00	7.41E-01	7.53E-01	7.77E-05	0.00E+00	0.00E+00	2.63E+04	5.47E+00	0.00E+00	2.63E+04
5.20E-01	4.83E-01	1.12E+02	1.00E+00	1.36E+00	3.62E-13	5.12E-12	1.94E-13	2.58E-20	1.00E+00	1.00E+00	7.22E-01	9.50E-01	5.40E-05	0.00E+00	0.00E+00	3.44E+04	5.66E+00	0.00E+00	3.44E+04
5.40E-01	4.62E-01	1.13E+02	1.00E+00	1.37E+00	3.65E-14	5.27E-13	2.58E-14	2.17E-21	1.00E+00	1.00E+00	7.02E-01	1.00E+00	3.61E-05	0.00E+00	0.00E+00	4.16E+04	5.85E+00	2.37E+03	4.40E+04
5.60E-01	4.41E-01	1.13E+02	1.00E+00	1.38E+00	2.70E-15	4.00E-14	2.59E-15	1.31E-22	1.00E+00	1.00E+00	6.81E-01	1.00E+00	2.30E-05	0.00E+00	0.00E+00	4.88E+04	6.05E+00	5.53E+03	5.43E+04
5.80E-01	4.20E-01	1.14E+02	1.00E+00	1.40E+00	1.36E-16	2.07E-15	1.82E-16	5.27E-24	1.00E+00	1.00E+00	6.58E-01	1.00E+00	1.37E-05	0.00E+00	0.00E+00	5.61E+04	6.25E+00	8.86E+03	6.50E+04
6.00E-01	3.99E-01	1.15E+02	1.00E+00	1.41E+00	4.34E-18	6.82E-17	8.32E-18	1.30E-25	1.00E+00	1.00E+00	6.32E-01	1.00E+00	7.56E-06	0.00E+00	0.00E+00	6.35E+04	6.45E+00	1.24E+04	7.59E+04
6.20E-01	3.79E-01	1.16E+02	1.00E+00	1.43E+00	8.02E-20	1.31E-18	2.29E-19	1.78E-27	1.00E+00	1.00E+00	6.03E-01	1.00E+00	3.80E-06	0.00E+00	0.00E+00	7.12E+04	6.63E+00	1.61E+04	8.72E+04
6.40E-01	3.58E-01	1.17E+02	1.00E+00	1.46E+00	7.66E-22	1.30E-20	3.37E-21	1.21E-29	1.00E+00	1.00E+00	5.72E-01	1.00E+00	1.71E-06	0.00E+00	0.00E+00	7.91E+04	6.80E+00	1.99E+04	9.90E+04
6.60E-01	3.37E-01	1.18E+02	1.00E+00	1.48E+00	3.26E-24	5.81E-23	2.32E-23	3.38E-07	1.00E+00	1.00E+00	5.38E-01	1.00E+00	6.72E-07	0.00E+00	0.00E+00	8.74E+04	6.92E+00	2.39E+04	1.11E+05
6.80E-01	3.17E-01	1.20E+02	1.00E+00	1.51E+00	5.11E-27	9.64E-26	6.16E-26	3.38E-07	1.00E+00	1.00E+00	5.01E-01	1.00E+00	2.23E-07	0.00E+00	0.00E+00	9.61E+04	6.98E+00	2.81E+04	1.24E+05
7.00E-01	2.97E-01	1.22E+02	1.00E+00	1.54E+00	2.28E-30	4.60E-29	4.95E-29	3.38E-07	1.00E+00	1.00E+00	4.61E-01	1.00E+00	5.96E-08	0.00E+00	0.00E+00	1.06E+05	6.91E+00	3.24E+04	1.38E+05
7.20E-01	2.76E-01	1.24E+02	1.00E+00	1.58E+00	7.64E-02	8.09E-01	2.86E-03	3.38E-07	1.00E+00	1.00E+00	4.17E-01	1.00E+00	1.22E-08	0.00E+00	0.00E+00	1.16E+05	6.65E+00	3.70E+04	1.53E+05
7.40E-01	2.56E-01	1.27E+02	1.00E+00	1.63E+00	7.64E-02	8.09E-01	2.86E-03	3.38E-07	1.00E+00	1.00E+00	3.71E-01	1.00E+00	1.74E-09	0.00E+00	0.00E+00	1.27E+05	6.05E+00	4.18E+04	1.69E+05
7.60E-01	2.36E-01	1.30E+02	1.00E+00	1.69E+00	7.64E-02	8.09E-01	2.86E-03	3.38E-07	1.00E+00	1.00E+00	3.21E-01	1.00E+00	1.56E-10	0.00E+00	0.00E+00	1.40E+05	4.88E+00	4.70E+04	1.87E+05
7.80E-01	2.15E-01	1.34E+02	1.00E+00	1.75E+00	7.64E-02	8.09E-01	2.86E-03	3.38E-07	1.00E+00	1.00E+00	2.70E-01	1.00E+00	7.55E-12	0.00E+00	1.13E+03	1.55E+05	2.76E+00	5.28E+04	2.09E+05
8.00E-01	1.94E-01	1.39E+02	1.00E+00	1.84E+00	7.64E-02	8.09E-01	2.86E-03	3.38E-07	3.12E-01	1.00E+00	2.17E-01	1.00E+00	1.50E-13	7.03E+00	2.17E+03	1.72E+05	0.00E+00	5.93E+04	2.34E+05

Scaling tendency is a measure of the tendency of a solid species to form at the specified conditions. Solids with a scaling tendency > 1.0 will form if solid formation is governed by equilibrium and if no other solids with a common cation or anion are present which also have a scaling tendency > 1.0.

Mass concentration (mg/L) of solid species predicted to form.

Highlights cases with a historical overhead-to-feed volume ratio ranging between 0.34 and 0.38.

Highlights maximum overhead-to-feed volume ratio where no Na2CO3 is predicted to form.

Table D-3. OLI Studio Model Evaporator Simulation Results for 2019 Tank 43 Sample HTF-43-19-4 (161" off tank bottom).

					Scaling Tendency										Solids Concentration (mg/L)					
Condensed Vapor/Feed [vol/vol] 25 °C	Volume - Liquid-1 [L]	Temperature [°C]	Pressure [atm]	Density (g/cc)	Na8Al6Si6O24CO3.2H2O (Cancrinite) Scaling Tendency	Na8Al6Si6O24CO3.1H2O (Cancrinite monohydrate) Scaling Tendency	Na8Al6Si6O24(OH)2.2H2O (Hydroxycancrinite) Scaling Tendency	Na6Al6Si6O24.12H2O (hydrated zeolite A) Scaling Tendency	Fe3O4 (Magnetite) - Sol Scaling Tendency	Na2CO3 (Natrite) - Sol Scaling Tendency	Na2CO3.1H2O (Thermonatrite) Scaling Tendency	2Na2SO4.Na2CO3 - Sol Scaling Tendency	Na3PO4 - Sol Scaling Tendency	Al(OH)3 (Gibbsite) - Scaling Tendency	NaFeO2 - Sol [mg/L]	Na3PO4 - Sol [mg/L]	Na2CO3 (Natrite) - Sol [mg/L]	Fe3O4 (Magnetite) - Sol [mg/L]	2Na2SO4.Na2CO3 - Sol [mg/L]	Total Solids (mg/L)
0.00E+00	1.00E+00	1.08E+02	1.00E+00	1.28E+00	1.19E-09	1.48E-08	1.88E-10	3.26E-16	1.00E+00	7.01E-01	5.96E-01	8.71E-02	2.40E-03	4.87E-04	0.00E+00	0.00E+00	0.00E+00	3.63E+00	0.00E+00	3.63E+00
2.00E-02	9.83E-01	1.09E+02	1.00E+00	1.29E+00	3.64E-10	4.59E-09	6.20E-11	8.66E-17	1.00E+00	7.56E-01	6.29E-01	1.05E-01	2.68E-03	3.99E-04	0.00E+00	0.00E+00	0.00E+00	3.40E+00	0.00E+00	3.40E+00
4.00E-02	9.63E-01	1.10E+02	1.00E+00	1.29E+00	1.53E-10	1.96E-09	2.81E-11	3.14E-17	1.00E+00	8.12E-01	6.67E-01	1.29E-01	2.93E-03	3.41E-04	0.00E+00	0.00E+00	0.00E+00	3.40E+00	0.00E+00	3.40E+00
6.00E-02	9.44E-01	1.10E+02	1.00E+00	1.30E+00	6.17E-11	7.95E-10	1.22E-11	1.08E-17	1.00E+00	8.73E-01	7.09E-01	1.58E-01	3.22E-03	2.88E-04	0.00E+00	0.00E+00	0.00E+00	3.41E+00	0.00E+00	3.41E+00
8.00E-02	**9.24E-01**	**1.10E+02**	**1.00E+00**	**1.31E+00**	**2.36E-11**	**3.07E-10**	**5.01E-12**	**3.50E-18**	**1.00E+00**	**9.41E-01**	**7.53E-01**	**1.95E-01**	**3.56E-03**	**2.42E-04**	**0.00E+00**	**0.00E+00**	**0.00E+00**	**3.44E+00**	**0.00E+00**	**3.44E+00**
1.00E-01	9.04E-01	1.10E+02	1.00E+00	1.31E+00	9.00E-12	1.18E-10	2.09E-12	1.15E-18	1.00E+00	1.00E+00	7.90E-01	2.37E-01	3.93E-03	2.03E-04	0.00E+00	0.00E+00	1.03E+03	3.47E+00	0.00E+00	1.03E+03
1.20E-01	8.83E-01	1.11E+02	1.00E+00	1.32E+00	4.01E-12	5.33E-11	1.06E-12	4.78E-19	1.00E+00	1.00E+00	7.81E-01	2.64E-01	4.31E-03	1.75E-04	0.00E+00	0.00E+00	5.96E+03	3.52E+00	0.00E+00	5.96E+03
1.40E-01	8.62E-01	1.11E+02	1.00E+00	1.32E+00	1.68E-12	2.25E-11	5.05E-13	1.85E-19	1.00E+00	1.00E+00	7.72E-01	2.96E-01	4.74E-03	1.49E-04	0.00E+00	0.00E+00	1.09E+04	3.57E+00	0.00E+00	1.09E+04
1.60E-01	8.41E-01	1.11E+02	1.00E+00	1.33E+00	6.53E-13	8.83E-12	2.26E-13	6.64E-20	1.00E+00	1.00E+00	7.63E-01	3.33E-01	5.24E-03	1.26E-04	0.00E+00	0.00E+00	1.59E+04	3.63E+00	0.00E+00	1.59E+04
1.80E-01	8.20E-01	1.11E+02	1.00E+00	1.33E+00	2.35E-13	3.21E-12	9.42E-14	2.19E-20	1.00E+00	1.00E+00	7.53E-01	3.78E-01	5.83E-03	1.05E-04	0.00E+00	0.00E+00	2.09E+04	3.69E+00	0.00E+00	2.09E+04
2.00E-01	7.99E-01	1.12E+02	1.00E+00	1.34E+00	7.77E-14	1.07E-12	3.63E-14	6.59E-21	1.00E+00	1.00E+00	7.42E-01	4.32E-01	6.53E-03	8.62E-05	0.00E+00	0.00E+00	2.60E+04	3.75E+00	0.00E+00	2.60E+04
2.20E-01	7.78E-01	1.12E+02	1.00E+00	1.35E+00	2.34E-14	3.27E-13	1.29E-14	1.79E-21	1.00E+00	1.00E+00	7.30E-01	4.98E-01	7.35E-03	6.96E-05	0.00E+00	0.00E+00	3.11E+04	3.81E+00	0.00E+00	3.11E+04
2.40E-01	7.58E-01	1.12E+02	1.00E+00	1.35E+00	6.35E-15	9.02E-14	4.15E-15	4.37E-22	1.00E+00	1.00E+00	7.18E-01	5.78E-01	8.34E-03	5.53E-05	0.00E+00	0.00E+00	3.62E+04	3.87E+00	0.00E+00	3.62E+04
2.60E-01	7.37E-01	1.13E+02	1.00E+00	1.36E+00	1.54E-15	2.22E-14	1.21E-15	9.42E-23	1.00E+00	1.00E+00	7.05E-01	6.78E-01	9.52E-03	4.32E-05	0.00E+00	0.00E+00	4.13E+04	3.93E+00	0.00E+00	4.13E+04
2.80E-01	7.16E-01	1.13E+02	1.00E+00	1.37E+00	3.30E-16	4.83E-15	3.13E-16	1.78E-23	1.00E+00	1.00E+00	6.92E-01	8.03E-01	1.10E-02	3.30E-05	0.00E+00	0.00E+00	4.65E+04	3.99E+00	0.00E+00	4.65E+04
3.00E-01	6.96E-01	1.14E+02	1.00E+00	1.38E+00	6.17E-17	9.18E-16	7.15E-17	2.89E-24	1.00E+00	1.00E+00	6.77E-01	9.60E-01	1.27E-02	2.46E-05	0.00E+00	0.00E+00	5.16E+04	4.05E+00	0.00E+00	5.16E+04
3.20E-01	6.75E-01	1.14E+02	1.00E+00	1.39E+00	1.04E-17	1.57E-16	1.48E-17	4.21E-25	1.00E+00	1.00E+00	6.62E-01	1.00E+00	1.48E-02	1.80E-05	0.00E+00	0.00E+00	5.64E+04	4.11E+00	1.49E+03	5.79E+04
3.40E-01	6.54E-01	1.15E+02	1.00E+00	1.40E+00	1.50E-18	2.31E-17	2.67E-18	5.21E-26	1.00E+00	1.00E+00	6.47E-01	1.00E+00	1.74E-02	1.29E-05	0.00E+00	0.00E+00	6.11E+04	4.17E+00	3.45E+03	6.45E+04
3.60E-01	6.34E-01	1.15E+02	1.00E+00	1.41E+00	1.80E-19	2.84E-18	4.05E-19	5.29E-27	1.00E+00	1.00E+00	6.30E-01	1.00E+00	2.07E-02	8.90E-06	0.00E+00	0.00E+00	6.58E+04	4.22E+00	5.46E+03	7.13E+04
3.80E-01	6.13E-01	1.16E+02	1.00E+00	1.42E+00	1.77E-20	2.84E-19	5.07E-20	4.31E-28	1.00E+00	1.00E+00	6.12E-01	1.00E+00	2.48E-02	5.95E-06	0.00E+00	0.00E+00	7.06E+04	4.27E+00	7.53E+03	7.82E+04
4.00E-01	5.92E-01	1.16E+02	1.00E+00	1.43E+00	1.37E-21	2.27E-20	5.12E-21	2.75E-29	1.00E+00	1.00E+00	5.94E-01	1.00E+00	3.01E-02	3.83E-06	0.00E+00	0.00E+00	7.55E+04	4.30E+00	9.65E+03	8.52E+04
4.20E-01	5.72E-01	1.17E+02	1.00E+00	1.45E+00	8.23E-23	1.40E-21	4.04E-22	1.32E-30	1.00E+00	1.00E+00	5.74E-01	1.00E+00	3.71E-02	2.35E-06	0.00E+00	0.00E+00	8.06E+04	4.32E+00	1.18E+04	9.24E+04
4.40E-01	5.51E-01	1.18E+02	1.00E+00	1.46E+00	3.67E-24	6.41E-23	2.42E-23	5.70E-15	1.00E+00	1.00E+00	5.53E-01	1.00E+00	4.64E-02	1.38E-06	0.00E+00	0.00E+00	8.57E+04	4.32E+00	1.40E+04	9.98E+04
4.60E-01	5.31E-01	1.19E+02	1.00E+00	1.48E+00	1.17E-25	2.11E-24	1.05E-24	5.70E-15	1.00E+00	1.00E+00	5.31E-01	1.00E+00	5.91E-02	7.60E-07	0.00E+00	0.00E+00	9.11E+04	4.30E+00	1.63E+04	1.07E+05
4.80E-01	5.11E-01	1.20E+02	1.00E+00	1.50E+00	2.53E-27	4.73E-26	3.17E-26	5.70E-15	1.00E+00	1.00E+00	5.08E-01	1.00E+00	7.67E-02	3.93E-07	0.00E+00	0.00E+00	9.66E+04	4.24E+00	1.86E+04	1.15E+05
5.00E-01	4.90E-01	1.21E+02	1.00E+00	1.52E+00	3.52E-29	6.84E-28	6.27E-28	5.70E-15	1.00E+00	1.00E+00	4.83E-01	1.00E+00	1.01E-01	1.88E-07	0.00E+00	0.00E+00	1.02E+05	4.13E+00	2.09E+04	1.23E+05
5.20E-01	4.70E-01	1.22E+02	1.00E+00	1.54E+00	2.19E-08	5.94E-30	7.57E-30	5.70E-15	1.00E+00	1.00E+00	4.57E-01	1.00E+00	1.37E-01	8.27E-08	0.00E+00	0.00E+00	1.08E+05	3.96E+00	2.33E+04	1.32E+05
5.40E-01	4.50E-01	1.23E+02	1.00E+00	1.56E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	1.00E+00	1.00E+00	4.30E-01	1.00E+00	1.91E-01	3.28E-08	0.00E+00	0.00E+00	1.15E+05	3.70E+00	2.57E+04	1.41E+05
5.60E-01	4.29E-01	1.25E+02	1.00E+00	1.59E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	1.00E+00	1.00E+00	4.01E-01	1.00E+00	2.73E-01	1.15E-08	0.00E+00	0.00E+00	1.22E+05	3.33E+00	2.82E+04	1.50E+05
5.80E-01	4.09E-01	1.26E+02	1.00E+00	1.62E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	1.00E+00	1.00E+00	3.72E-01	1.00E+00	4.01E-01	3.51E-09	0.00E+00	0.00E+00	1.29E+05	2.81E+00	3.07E+04	1.60E+05
6.00E-01	3.89E-01	1.28E+02	1.00E+00	1.65E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	1.00E+00	1.00E+00	3.41E-01	1.00E+00	6.11E-01	9.02E-10	0.00E+00	0.00E+00	1.37E+05	2.06E+00	3.34E+04	1.70E+05
6.20E-01	3.68E-01	1.31E+02	1.00E+00	1.69E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	1.00E+00	1.00E+00	3.10E-01	1.00E+00	9.67E-01	1.89E-10	0.00E+00	0.00E+00	1.45E+05	1.01E+00	3.62E+04	1.82E+05
6.40E-01	3.48E-01	1.33E+02	1.00E+00	1.73E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	8.83E-01	1.00E+00	2.78E-01	1.00E+00	1.00E+00	3.15E-11	0.00E+00	1.04E+03	1.55E+05	0.00E+00	3.91E+04	1.95E+05
6.60E-01	3.27E-01	1.36E+02	1.00E+00	1.78E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	5.37E-01	1.00E+00	2.45E-01	1.00E+00	1.00E+00	3.86E-12	0.00E+00	1.91E+03	1.66E+05	0.00E+00	4.22E+04	2.10E+05
6.80E-01	3.07E-01	1.39E+02	1.00E+00	1.83E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	3.12E-01	1.00E+00	2.13E-01	1.00E+00	1.00E+00	3.22E-13	0.00E+00	2.57E+03	1.77E+05	0.00E+00	4.56E+04	2.26E+05
7.00E-01	2.86E-01	1.43E+02	1.00E+00	1.90E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	8.59E-02	1.00E+00	1.80E-01	1.00E+00	1.00E+00	1.65E-14	4.08E+00	3.10E+03	1.91E+05	0.00E+00	4.93E+04	2.43E+05
7.20E-01	2.65E-01	1.48E+02	1.00E+00	1.97E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	2.03E-02	1.00E+00	1.48E-01	1.00E+00	1.00E+00	4.51E-16	8.35E+00	3.54E+03	2.07E+05	0.00E+00	5.33E+04	2.63E+05
7.40E-01	2.45E-01	1.54E+02	1.00E+00	2.06E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	4.32E-03	1.00E+00	1.18E-01	1.00E+00	1.00E+00	5.37E-18	1.26E+01	3.95E+03	2.24E+05	0.00E+00	5.77E+04	2.86E+05
7.60E-01	2.25E-01	1.61E+02	1.00E+00	2.15E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	8.13E-04	1.00E+00	8.97E-02	1.00E+00	1.00E+00	2.02E-20	1.69E+01	4.37E+03	2.45E+05	0.00E+00	6.24E+04	3.12E+05
7.80E-01	2.06E-01	1.70E+02	1.00E+00	2.26E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	1.33E-04	1.00E+00	6.38E-02	1.00E+00	1.00E+00	1.41E-23	2.12E+01	4.80E+03	2.69E+05	0.00E+00	6.69E+04	3.41E+05
8.00E-01	1.88E-01	1.82E+02	1.00E+00	2.37E+00	2.19E-08	2.66E-07	3.33E-09	5.70E-15	1.81E-05	1.00E+00	4.09E-02	1.00E+00	1.00E+00	6.57E-28	2.56E+01	5.26E+03	2.95E+05	0.00E+00	6.96E+04	3.70E+05

Scaling tendency is a measure of the tendency of a solid species to form at the specified conditions. Solids with a scaling tendency > 1.0 will form if solid formation is governed by equilibrium and if no other solids with a common cation or anion are present which also have a scaling tendency > 1.0.

Mass concentration (mg/L) of solid species predicted to form.

Highlights cases with a historical overhead-to-feed volume ratio ranging between 0.34 and 0.38.

Highlights maximum overhead-to-feed volume ratio where no Na2CO3 is predicted to form.

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D. A. Crowley, 773-42A
J. A. Dyer, 773-42A
S. D. Fink, 773-A
N. V. Halverson, 773-42A
C. C. Herman, 773-A
J. R. Jacobs, 241-152H
J. S. Ledbetter, 704-56H
J. J. Mayer, 999-W
P. W. Norris, 241-152H
F. M. Pennebaker, 773-A
J. A. Pike, 703-41A
L. T. Reid, 773-A
B. J. Wiedenman, 773-42A
W. R. Wilmarth, 773-42A
Records Management (EDWS)
EM File, 773-42A – Rm. 243