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Test Specification
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Test Plan WSRC-TR-2001-00183,
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R&T Focus Area Evaporation
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WTP PILOT-SCALE EVAPORATION TESTS (U)

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LIST OF ACRONYMS

ADS	Analytical Development Section
DAS	Data Acquisition System
DF	Decontamination Factor
DOE	Department of Energy
EDL	Engineering Development Laboratory
FEP	Feed Evaporation Process
HLW	High Level Waste
RPP	River Protection Project
SBS	Submerged Bed Scrubber
TLP	Treated LAW Evaporation Process
UF	Ultra Filtration
WTP	Waste Treatment Plant

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ABSTRACT

This report documents the design, assembly, and operation of a Pilot-Scale Evaporator built and operated by SRTC in support of Waste Treatment Plant (WTP) Project at the DOE's Hanford Site. The WTP employs three identical evaporators- two for the Waste Feed and one for the Treated LAW. The Pilot-Scale Evaporator was designed to test simulants for both of these waste streams.

The Pilot-Scale Evaporator is 1/76th scale in terms of evaporation rates. The basic configuration of forced circulation vacuum evaporator was employed. A detailed scaling analysis was performed to preserve key operating parameters such as basic loop configuration, system vacuum, boiling temperature, recirculation rates, vertical distances between important hardware pieces, reboiler heat transfer characteristics, vapor flux, configuration of demisters and water spray rings.

Three evaporation test campaigns were completed. The first evaporation run used water in order to shake down the system. The water runs were important in identifying a design flaw that inhibited mixing in the evaporator vessel, thus resulting in unstable boiling operation. As a result the loop configuration was modified and the remaining runs were completed successfully.

Two simulant runs followed the water runs. Test 1: Simulated Ultrafiltration Recycles with HLW SBS, and Test 2: Treated AN102 with Envelop C LAW). Several liquid and offgas samples were drawn from the evaporator facility for regulatory and non-regulatory analyses. During Test 2, the feed and the concentrate were spiked with organics to determine organic partitioning. The decontamination factor (DF) for Test 1 was measured to be 110,000 (more than the expected value of 100,000).

Dow Corning Q2-3183A antifoam agent was tested during both Tests1 & 2. It was determined that 500 ppm of this antifoam agent was sufficient to control the foaminess to less than 5% of the liquid height.

The long-term testing (around 100 hours of operation) did not show any fouling of reboiler or other loop piping.

The Pilot-Scale Evaporator will be used in the Semi-Integrated Pilot Plant tests. Additionally, the Pilot-Scale design can easily accommodate hardware changes that result from the development of the full-scale evaporator to resolve any issues arising from the startup or operation of the full-scale facility.

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1.0 TESTING SUMMARY

The Engineering Development Lab (EDL) of Savannah River Technology Center (SRTC) designed, built, and operated a Pilot-Scale Evaporator in support of RPP's Waste Treatment Plant (WTP). The following sections provide a summary of pilot scale evaporation testing.

1.1 OBJECTIVES

The Pilot-Scale Evaporator was designed and operated to meet the following objectives as stated in the Test Specification.

Objective 1: Design, procure, and construct a forced circulating vacuum evaporator to be used for pilot scale evaporations tests at the SRTC. The pilot-scale evaporation system will be designed to pilot the Waste Feed and the Treated LAW Evaporators.

Discussion: Objective 1 was met and a 1/76th scale (based upon evaporation rate) evaporator was designed, fabricated, and successfully operated to run the prescribed evaporation campaigns.

Objective 2: Conduct at least three simulant tests using approved simulants of Envelope A, B, and/or C wastes with appropriate simulants of the WPT recycle streams. An additional Cesium (Cs) or Technetium (Tc) eluate evaporation test may also be conducted if deemed necessary by the WTP project.

Discussion: The third campaign was not required since Envelope C was expected to bound the performance of the other two waste types. Consequently, the test matrix was reduced to run only two simulant runs (Test 1: Simulated Ultrafiltration Recycles with HLW SBS, and Test 2: Treated AN102 with Envelop C LAW). Additionally, water runs were added to shake down the system and test hardware configuration. All three evaporation runs were completed successfully.

Objective 3: Determine the fate of separable organics (both tributyl phosphate and normal paraffin hydrocarbon) in the evaporator system.

Discussion: This objective was met by spiking the concentrate with separable organics during Test 2. Both liquid and offgas samples were analyzed for regulatory purposes.

Objective 4: Measure and analyze the simulant pilot scale test data.

Discussion: The Pilot-Scale Test Facility is fully instrumented to indicate and record flow rates of various streams system parameters such as pressure, temperature, and density. Several sample ports provided necessary samples for analyses.

Objective 5: Sample and analyze the composition of the Feed, Concentrate, Condensate, and Offgas for target constituents of regulatory concern by EPA SW-846 methods.

Discussion: In addition to in-house analyses, select samples were drawn and analyzed for regulatory purposes following the prescribed methods.

Objective 6: Report test results.

Discussion: This final report documents the results of all testing. Additionally, results of scaling analysis and preliminary assessment of Test 1 results were communicated during the course of the test program.

1.2 TEST EXCEPTIONS

The Test Specification specified three evaporation test campaigns using approved simulants of Envelope A, B, and/or C wastes with appropriate simulants of the WPT recycle streams. Additionally, Cs or Tc eluate evaporation test was also projected if deemed necessary by the WTP project. Once the test facility design and fabrication was complete, WTP project reduced the test matrix to run only two simulant runs (Simulated Ultrafiltration Recycles with HLW SBS and Treated AN102 with Envelop C LAW). Additionally, water runs were added to shake down the system and test hardware configuration.

1.3 RESULTS AND PERFORMANCE AGAINST SUCCESS CRITERIA

The results of the evaporator tests are compared below against the success criteria provided in the Test Specification.

Success Criteria	Discussion
1. Demonstrate that the Decontamination Factor (DF) is acceptable.	The DF for Test 1 was found to be 111,000 which was found to be acceptable for the 2-demisters design configuration.
2. Test antifoam agent (recommended by bench-scale tests) performance to ensure that the foam level to be less than 5% of the liquid height in the evaporator vessel	The recommended antifoam agent (Dow Corning Q2-3183A) was used for both Tests 1 & 2. The recommended concentration was 1400 ppm. Both Tests 1 & 2 showed that around 500 ppm of antifoam was effective to control the foam level to less than 1 ft for a liquid height of 22 ft (<5% foam height). Since only two simulants were evaporated under this report, the antifoam concentrations for the full-scale operation must be guided by the bench scale tests covering a wider variety of waste simulants.

Success Criteria	Discussion
3. Are operating parameters achievable?	The Pilot-Scale evaporator tests demonstrated that the operating parameters such as system vacuum, steady boiling, feed and concentrate removal are achievable. The water tests identified an earlier design flaw that resulted in unsteady boiling. The modified design resulted in steady and stable operation

1.4 QUALITY REQUIREMENTS

This work was conducted in accordance with the RPP-WTP QA requirements specified for work conducted by SRTC as identified in DOE IWO M0SRLE60. SRTC has provided matrices to WTP demonstrating compliance of the SRTC QA program with the requirements specified by WTP. Specific information regarding the compliance of the SRTC QA program with RW-0333P, Revision 10, NQA-1 1989, Part 1, Basic and Supplementary Requirements and NQA-2a 1990, Subpart 2.7 is contained in these matrices.

1.5 R&T TEST CONDITIONS

R&T Test Conditions	Discussion
1. Design, fabricate and operate a forced circulation vacuum evaporator rig.	Based upon the available design information, SRTC successfully designed and operated a forced circulation vacuum evaporator rig. A scaling analysis was performed and approved by R&T customer.
2. Consult vendor on mist eliminator design.	SRTC contracted Otto York to design and supply mist eliminators for the Pilot-Scale evaporator.
3. Conduct three evaporation test campaigns using approved simulants of Envelope A, B, and/or C wastes with appropriate simulants of the WPT recycle streams. Additionally, perform Cs or Tc eluate evaporation test if deemed necessary by the WTP project.	Once the test facility design and fabrication was complete, WTP project reduced the test matrix to run only two simulant runs (Simulated Ultrafiltration Recycles with HLW SBS and Treated AN102 with Envelop C LAW). The third campaign was not required since Envelop C was expected to bound the performance of the other two waste types. Additionally, water runs were added to shakedown the system and test hardware configuration.

R&T Test Conditions	Discussion
4. Test antifoam agent performance.	The antifoam agent was able to control the foaminess within the specified limit of 5%.
5. Confirm that operating parameters are achievable.	The Pilot-Scale evaporator successfully achieved all the specified operating parameters such as vacuum, temperatures, flow rates, and vapor flux.
6. Spike the feed/concentrate with organics and analyze various stream for analyses.	The feed/concentrate was spiked and samples were analyzed for regulatory and non-regulatory purposes.
7. Be prepared to operate the pilot scale evaporator with a simulant of Cs or Tc eluate to confirm bench scale results and model development.	The pilot-scale evaporator stands ready for any simulant feed. However, Cs simulant or Tc eluate runs were not requested to be made.

1.6 SIMULANT USE

WTP customer approved all simulants used in the evaporation task. These simulants were either prepared at the Engineering Development Lab or acquired from other RPP programs as described below. The following three evaporation test campaigns were successfully completed.

- **Water runs.** The water runs were added to the original test matrix in order to shake down the system and test hardware configuration.
- **Test 1**. Simulated Ultrafiltration Recycles with HLW SBS. The simulants for ultrafiltration recycles were prepared in the Engineering Development Lab (EDL) following an approved recipe and mixing protocol. Duratek supplied the HLW SBS.
- **Test 2.** Treated AN-102 with Envelop C LAW SBS. The Treated AN-102 was generated by the precipitation and filtration processes completed earlier in the EDL. Duratek supplied the Envelop C LAW SBS.

1.7 DISCREPANCIES AND FOLLOW-ON TESTS

The full-scale evaporator designs (both for Waste Feed and Treated LAW) were not available when the Pilot-Scale evaporator design was underway. WTP customer advised SRTC to proceed with the Pilot-Scale design based upon the available information. Later, WTP customer provided SRTC a copy of the Engineering Specification prepared for full-scale evaporator vendor. The operating parameters such as system pressure, temperatures, and concentration factors for the Pilot-Scale are similar to those for the full-scale ones. However, the system hardware discrepancies will be identified only after the full-scale design by the vendor is complete and available. The Pilot-Scale evaporator yielded lower values of decontamination factors. This would require hardware modifications in the vapor space of the evaporator vessel. The Pilot-Scale evaporator hardware can be easily modified once the full-scale design is finalized and available.

It is planned to use the existing evaporator setup during the upcoming integrated tests.

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2.0 DISCUSSION

2.1 TEST PROGRAM OBJECTIVES

The Pilot-Scale Evaporator was designed and operated to meet the following objectives as stated in the Test Specification.

- Design, procurement, and construction of a pilot LAW forced circulating vacuum evaporator that will be used for pilot scale evaporations tests at the SRTC Thermal Fluids Laboratory. The pilot-scale evaporation system will be designed to pilot the LAW Feed and Melter Feed Evaporators.
- Conduct at least three simulant tests using approved simulants of Envelope A, B, and/or C wastes with appropriate simulants of the WPT recycle streams. An additional Cs or Tc eluate evaporation test may also be conducted if deemed necessary by the WTP project.
- Determine the fate of separable organics (both tributyl phosphate and normal paraffin hydrocarbon) in the evaporator system.
- Measure and analyze the simulant pilot scale test data.
- Sample and analyze the composition of the Feed, Concentrate, Condensate, and Offgas for target constituents of regulatory concern by EPA SW-846 methods.
- Report test results.

2.2 BACKGROUND AND PREVIOUS WORK

The objective of the River Protection Project Waste Treatment Plant (RPP-WTP) is to build a vitrification plant at the Hanford Site to stabilize the radioactive waste currently stored in large tanks at that site. Prior to the vitrification process, the stored waste undergoes various waste treatment processes including evaporation. The process flowsheet includes two separate evaporators –Low Activity Waste (LAW) Feed Evaporator and LAW Melter Feed Evaporator. The pilot-scale evaporation tests will be conducted at EDL to provide operational and regulatory compliance test data simulating the LAW Feed and Melter Feed Evaporator process conditions.

Low Activity Waste (LAW) solutions have been evaporated at the Hanford site using forced circulation evaporators since the 1960s. Many of the LAW solutions stored in the double-shell tanks were evaporated in the 242-A evaporator / crystallizer, which is a forced circulation evaporator. The WTP LAW Feed Evaporator and LAW Melter Feed Evaporator are of a design similar to that of the 242-A evaporator. As such, a large set of data is available in Hanford site records concerning the evaporation of LAW solutions. However, the WTP will mix recycle waste solutions from the HLW and LAW vitrification processes with the LAW feed solutions. Evaporation of these mixtures is likely to differ from the evaporation of only LAW solutions. Additionally, the WTP must evaluate the expected discharges from the Waste Feed Evaporator and the Treated LAW Evaporator to an offgas treatment system and the 200-East Area Liquid Effluent Treatment Facility in support of regulatory permit applications.

During the previous phase of the project, the WTP began a process to collect information on the evaporation characteristics (e.g., tendency to foam, solubility) of LAW solutions, (Monson 2000) and (Calloway 2000), as well as provide information to assess compliance of non-condensable and condensate waste streams with regulatory permits. This information was used to prepare an initial model of the LAW melter feed evaporator system using the OLI Corporation Environmental Simulation Program (ESP) (Choi 1999).

SRTC also conducted bench scale evaporation experiments using simulants and radioactive samples (Calloway et al 2000), (Calloway 2000), and (Crawford et al 2001). Envelope C simulated evaporator feed was spiked with a group of organic chemicals that chemically represent the various volatile and semi-volatile organics found in Hanford waste (Saito 2001). The evaporator concentrate, condensate, and offgas were sampled using EPA SW-846 sampling and analysis methods. Additionally, SRTC evaporated a radioactive sample of Hanford waste from tank 241-AN102 (Crowder et al 2001) (Ferrara et al 2001). The radioactive evaporator feed, concentrate, and condensate were also sampled using EPA SW-846 methods and analyzed for volatile, semi-volatile, radionuclides and metals. The purpose of both experiments was to determine the expected distribution of hazardous species throughout the evaporator system. The distribution of volatile and semi-volatile organics in the evaporator offgas is a function of both vapor pressure of the chemical species and the physical entrainment associated with the evaporator. Entrainment is dependent on the scale and physical arrangement of the evaporator system scale and was at best only partially approximated in the B1 tests conducted at SRTC.

Since this data will be used to support risk assessment and air permit preparation activities for WPT, pilot-scale testing is needed to support the modeling efforts conducted by SRTC during Part B1. It is expected that a pilot-scale system will more closely approximate the expected entrainment of a full-scale evaporator system. The WPT environmental team will use the SRTC model and pilot-scale data developed by this test specification to support risk assessment and air permit preparation activities.

SRTC conducted evaporation studies using both simulants and actual Hanford tank samples. The WPT LAW evaporators will process actual Hanford tank waste plus a combination of recycle stream that will be generated from the WPT Vitrification (HLW and LAW Submerged Bed Scrubber Condensate) and Pretreatment (e.g., HLW/LAW Ultrafiltration Permeate, Ion Exchange Recycle flush liquors) Plants. The SRTC testing conducted in Part B1 did not include the expected WPT recycle streams. The pilot evaporator system will be used to conduct integrated testing in which expected recycle streams will be added to simulated LAW feed. The ratio of recycle to feed volume will be varied over the expected range of operations.

Envelope C simulants of 241-AN-107 and radioactive samples of 241-AN-102 were found to foam significantly during atmospheric and vacuum evaporation bench scale tests (Crowder et al 2001). Bench-scale vacuum evaporation tests conducted with Envelope A (241-AN-105) and B (241-AZ-101) simulants did not show any significant foaming. Radioactive and bench evaporation tests conducted by SRTC and PNNL were not conducted at the design basis vaporization flux (kg vapor/s/boiling surface area) Therefore, these tests only provided a qualitative means of determining the foaming potential of the waste and the effectiveness of the antifoam agents employed during the experiments. Foaming studies conducted for the DWPF have shown that the design basis vaporization flux is required to fully characterize the foaming in waste evaporators (Koopman 2000). Anti-foam reagent screening studies are presently in progress at the Illinois Institute of Technology, a subcontractor to SRTC. Conformation testing of these reagents will be performed at SRTC.

2.3 QA REQUIREMENTS

This work was conducted in accordance with the RPP-WTP QA requirements specified for work conducted by SRTC as identified in DOE IWO M0SRLE60. SRTC has provided matrices to WTP demonstrating compliance of the SRTC QA program with the requirements specified by WTP. Specific information regarding the compliance of the SRTC QA program with RW-0333P, Revision 10, NQA-1 1989, Part 1, Basic and Supplementary Requirements and NQA-2a 1990, Subpart 2.7 is contained in these matrices.

2.4 TEST APPARATUS

The Pilot-Scale Evaporator was designed to establish evaporation conditions similar to those of the full-scale system. In order to achieve this, it is important to identify key operating parameters in the full-scale process and then duplicate these conditions in the Pilot-Scale as closely as possible. At the time when the Pilot Scale Evaporator was in design planning stages, the full-scale evaporator design was not available. Only some preliminary design information was available based upon experience with the existing evaporators. In fact, the full-scale evaporator was identified as a procured system from a vendor and the vendor's procurement package was under preparation when the Pilot-Scale was being designed. RPP customer advised SRTC to initiate the Pilot-Scale based upon the available information at that time.

The RPP customer provided the following preliminary drawings for the full-scale system.

- SK-W375-PT-M00021 V11002 Recirculation Vessel, System PT-120
- SK-W375-PT-M00016 E11001 Reboiler, System PT-120
- SK-W375-PT-M00006 E11003 After-Condenser, System PT-120
- SK-W375-PT-M00025 Equipment Envelope/Hydraulic Profile, Single Pass Reboiler

The operating parameters such as pressure, temperature, evaporation rates and flow rates were guided by the Engineering Specification for Forced Circulation Vacuum Evaporator Systems (Spec. No. 24590-PTF-3PS-MEVV-T0001).

2.4.1 Scaling Considerations

Based upon the information provided in the drawings and the Test Specification, a scaling analysis was conducted to determine key design parameters for the Pilot-Scale Evaporator. Key process conditions that influence the evaporation process were identified. These are listed and discussed in this section.

2.4.1.1 System Pressure

The boiling temperature of aqueous solutions is a strong function of the system pressure. As the pressure decreases, the boiling temperature also decreases. Water that boils at 100 °C at 14.7 psia, boils at only 38.4 °C at 1 psia. Note that the waste simulants have higher boiling temperatures than water at a given pressure, however, the temperature-pressure relationship is similar. The waste simulants used in this study boiled around 45 °C at 1 psia. The difference between this temperature and the water boiling temperature at the same pressure is commonly known as the boiling point elevation. The boiling point elevation is somewhat influenced by the chemical composition of the solution.

In order to achieve prototypic evaporation conditions, it is important to preserve the pressure levels at the boiling interface. The system was designed to achieve 1 psia nominal pressure in the vapor space of the evaporator vessel. Additionally, in order to preclude any premature flashing, the balance of the system must be kept at a higher pressure. This was achieved by placing all the recirculation loop piping, reboiler, and the recirculation pump well below the boiling surface. The exit of the reboiler was specified to be 10 ft below the minimum liquid level in the evaporator vessel.

Another consequence of the low system pressure is the placement of the primary condenser. In order to gravity draw condensate out of the primary condenser at low pressure of 1 psia, the condenser must be placed at barometric heights. Consequently, the lowest point of the condenser was placed about 32 ft above the primary condensate tank level and the condensate was collected through a constant level dip tube arrangement in the condensate catch tanks.

2.4.1.2 Vapor Flux

Vapor flux is the rate of evaporation per unit area of the boiling surface (mass rate per unit surface area). When divided by the vapor density at the operating pressure, it yields the vapor velocity at the boiling interface. Entrainment of liquid droplets by the vapor stream is strongly influenced by the vapor velocity at the interface. Higher vapor velocities result in higher liquid entrainment that in turn may lead to lower values of decontamination factor (DF). The DF for a certain chemical species is defined as its concentration in the concentrate divided by its concentration in the vapor (as measured in its condensate).

The full-scale design has vapor velocities around 10 ft/s. Since one of the main objectives of the pilot-scale testing was to determine the decontamination factors (DF) for various boiling campaigns, it was necessary to preserve these velocity levels in the pilot scale design.

2.4.1.3 Disengagement Zone and Demisters

The liquid-vapor interface is not a well defined surface. Only under non-boiling conditions, one can expect a clear interface. Under boiling conditions, the region where water vapor disengages from the liquid can be divided into two distinct zones. The first zone is like froth where vapor bubbles and saturated liquid coexist in a very turbulent mixed zone. As soon as boiling ceases, this zone collapses to a well defined liquid-vapor interface. Note that this froth is different from foam that exists even as boiling ceases. The second zone exists just above the froth zone where smaller liquid droplets are entrained by the vapor and the larger droplets fall down under gravity. This zone is termed as the disengagement zone.

The entrained liquid droplets are removed by the downstream demisters. The distances between the liquid-vapor interface and the first demister and between the two demisters are important dimensions to be preserved in a pilot-scale test. Additionally, the thickness of the demister pads and their construction details must be prototypic for a pilot-scale facility. At the time of pilot-scale design, the demister details for the full-scale evaporator were not available. Otto York (well-known manufacturer of demister material) designed and supplied the demister pads for the pilot scale test facility.

Based upon the above considerations and other known geometrical information available, it was decided to preserve all important vertical dimensions in the Pilot-Scale design. The lateral dimensions such as vessel diameter, number or reboiler tubes, and piping diameters were selected to yield the prototypic vapor flux rates. Table 2-1 lists pertinent dimensions and flow parameters for both the full-scale evaporator and the pilot-scale test facility as yielded by the scaling analysis. The percentage of full-scale values is also listed in the table. The final Pilot-Scale design provided a nominal boil-off rate of 0.4 gpm of primary condensate with a maximum boil-off rate of 0.5 gpm. Although the nominal system pressure is 1 psia, the Pilot-Scale facility is capable of achieving pressures as low as 0.6 psia.

2.4.2 Test Apparatus Description

Figure 2-1 shows the Process and Instrumentation Diagram (P&ID). The Pilot-Scale Evaporator System consists of many sub-systems provided alphabetically.

- Antifoam System
- Concentrate Loop
- Evaporator Recirculation
- Feed Loop
- House Air
- Jet Pump
- Primary Condensate
- Process Water
- Secondary Condensate
- Steam Generator
- Spray Water

Table 2-1. Comparison of Full-Scale vs. Pilot-Scale Design Parameters

Parameter	Units	Full Scale Evap	Pilot scale	% of Full Scale
Evaporator vessel dia	ft	13.00	1.49	11.47
Liquid level range in evap vessel	ft	2.92	2.92	100.00
Min liquid vol. in evap vessel	gal	11003.31	144.78	1.32
Max liquid vol. in evap vessel	gal	13899.13	182.88	1.32
Min residence time in evap vessel	min	1.50	1.50	100.00
Max recirculation flow rate	gpm	7335.54	96.52	1.32
Max residence time in evap vessel	min	1.89	1.89	100.00
Evaporation rate in gpm	gpm	30.00	0.39	1.32
Evaporation rate in lbm/sec	lbm/s	4.17	0.05	1.32
Enthalpy of evaporation	kW	4540.03	59.74	1.32
Evap vessel x-sectional area	ft2	132.73	1.75	1.32
Evap vessel opererating pressure	psia	1.00	1.00	100.00
Vapor flux	lbm/s-ft2	0.03	0.03	100.00
Vapor velocity at boiling interface	ft/s	10.15	10.15	100.00
Reboiler tube OD	in	1.50	1.50	100.00
Reboiler tube ID	in	1.33	1.33	100.00
Flow area/tube	in2	1.40	1.40	100.00
Number of tubes		228.00	3.00	1.32
Total flow area	ft2	2.21	0.03	1.32
Tube height	ft	7.00	7.00	100.00
Recirculation flow rate	gpm	7335.54	96.52	1.32
Recirculation flow rate	ft3/s	16.34	0.22	1.32
Sp gravity		1.33	1.33	100.00
Receir mass flow rate	lbm/s	1356.49	17.85	1.32
Liquid velocity in tubes	ft/s	7.39	7.39	100.00
Recirculation loop piping ID	in	19.50	2.25	11.51
Recirculation loop piping x section area	ft^2	2.07	0.03	1.33
Velocity in recirculation loop piping	ft/s	7.88	7.82	99.27

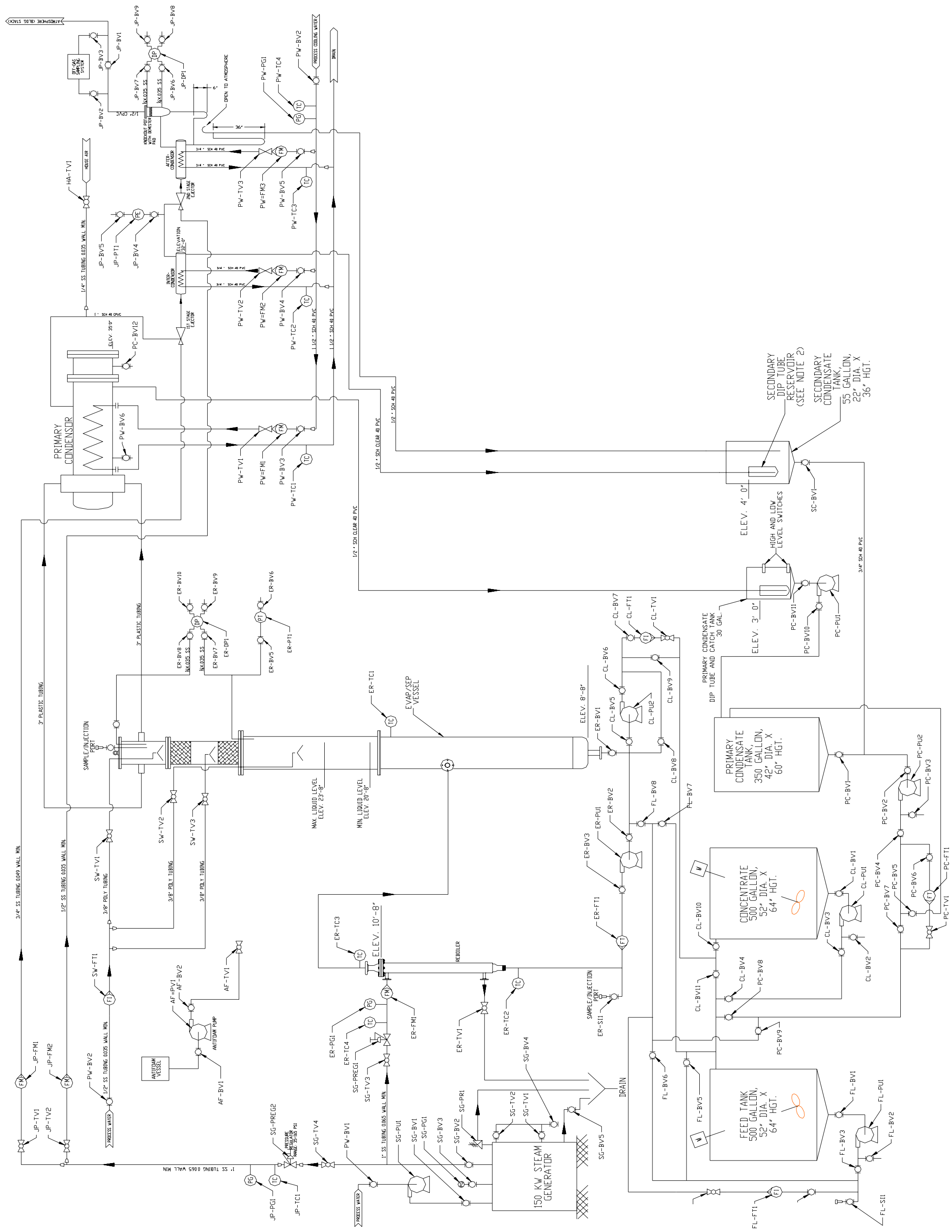

Figure 2-1. Process Diagram for Pilot-Scale Evaporator System

Typically, each campaign would evaporate about 300 gallons of working fluid (water or waste simulant). The evaporator is a forced circulation evaporator where heat is added in the reboiler that is essentially a shell-and-tube heat exchanger with steam on the shell side. No evaporation occurs in the reboiler due to hydrostatic pressure head. The evaporator vessel is kept under vacuum (~ 1 psia) and the boiling temperature for water is about 104 °F (40 °C) at this pressure. The simulant has a boiling point elevation of about 11 °F. Thus the entire evaporation process occurs at moderate temperatures (100 - 120 °F).

Figure 2-2 shows the details of the evaporator vessel location with respect to the primary condenser, reboiler, and recirculation pump. The evaporator vessel is about 27 feet tall with a nominal inside diameter of 17". The bottom 12 feet of the vessel is stainless steel and the top 15 feet is acrylic. The boiling surface will be maintained in the lower part of the acrylic section. The minimum and maximum liquid levels in the acrylic section are 5" and 40", respectively. The designed capacity of evaporator vessel and the recirculation piping is about 100 gallons. Feed tank supplies the simulant to the evaporator. The evaporator is designed to evaporate 0.4 gpm of water.

The water vapor is condensed in the primary condenser. Under steady conditions, the concentrate is removed from the recirculation line and collected in the concentrate tank (Figure 2-1). The condensate from the primary condenser is collected in the primary condensate tank. A two-stage steam-driven jet pump maintains desired vacuum in the evaporator vessel. The jet pump has its own set of condensers, an inter and after condenser. A separate tank catches the condensate from the jet pump. The system can be operated under either a batch mode or a continuous (reflux) mode. Several sample and injection ports are provided to draw samples and inject tracers as needed. Key equipment in each sub-system is listed in Table 2-2.

2.5 TEST OPERATING CONDITIONS

The Pilot-Scale Evaporator can be operated under batch mode or recirculation mode as described in this section.

2.5.1 Batch Mode of Operation

In the batch mode, fresh feed is supplied to the evaporator and the condensate is removed from the evaporator. The evaporator inventory (approx. 100 gallons) keeps on concentrating due to evaporation. Once the target concentration is reached in the evaporator vessel, the concentrate is continuously removed from it to maintain a nominal level in the evaporator vessel. The first phase at the beginning of a particular campaign is then initial concentration phase, followed by the steady operation phase. During the later phase, fresh feed is supplied and concentrate and condensate are removed on a steady basis. At a nominal boil-off rate of 0.4 gpm, about 200 gallons of primary condensate is collected in an 8 hr-per-day operation. Thus several hundred gallons of fresh feed is needed every day to operated under this mode of operation.

Table 2-2. Equipment Designation

CL=CONCENTRATE LOOP

ITEM	DESCRIPTION
CL-BV1	BALL VALVE 1½" SPEARS 2329-015C
CL-BV2	BALL VALVE ½" WHITEY SS-45S8
CL-BV3	BALL VALVE 1" SPEARS 2329-010C
CL-BV4	BALL VALVE ¾" SPEARS 2329-007C
CL-BV5	BALL VALVE ¾" SPEARS 2329-007C
CL-BV6	BALL VALVE ¾" SPEARS 2329-007C
CL-BV7	BALL VALVE ¼" SWAGELOK SS-43-S4
CL-BV8	BALL VALVE ¾" SPEARS 2329-007C
CL-BV9	BALL VALVE ¾" SPEARS 2329-007C
CL-BV10	BALL VALVE ¾" SPEARS 2329-007C
CL-BV11	BALL VALVE ¾" SPEARS 2329-007C
CL-BV12	⅜" PLUG VALVE PARKER #18HB
CL-BV13	⅜" PLUG VALVE PARKER #18HB
CL-FT1	MAGNETIC FLOWMETER TR-3703
CL-PU1	PUMP ¾ HP TEEL MODEL #1P701B
CL-PU2	PUMP ½ HP TEEL MODEL #1P799B
CL-TV1	THROTTLE VALVE ¼" WHITEY SS-1VS4

ER=EVAPORATOR RECIRCULATION

ITEM	DESCRIPTION
ER-AP1	ROSEMONT PRESSURE TRANSDUCER TR-3718
ER-AP2	ROSEMONT PRESSURE TRANSDUCER TR-3717
ER-BV1	BALL VALVE 2½" SPEARS 2322-025C
ER-BV2	BALL VALVE 2" SPEARS 2329-020C
ER-BV3	BALL VALVE 1½" SPEARS 2329-015C
ER-BV4	BALL VALVE 2½" SPEARS 2322-025C
ER-BV5	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV6	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV7	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV8	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV9	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV10	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV11	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV12	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV13	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV14	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV15	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV16	BALL VALVE ¼" SWAGELOK SS-43S4
ER-BV17	BALL VALVE ¼" SWAGELOK SS-43S4
ER-DP1	ROSEMONT PRESSURE TRANSDUCER TR-2150
ER-DP2	ROSEMONT PRESSURE TRANSDUCER TR-3720
ER-DP3	ROSEMONT PRESSURE TRANSDUCER TR-3554
ER-FM1	ROTOMETER
ER-FT1	MAGNETIC FLOWMETER TR-3278
ER-PG1	PRESSURE GUAGE
ER-PT1	ROSEMONT PRESSURE TRANSDUCER TR-3554
ER-PU1	PUMP 3 HP TEEL MODEL #2P392
ER-SI1	SAMPLE/INJECTION PORT ¼" SWAGELOK SS-42S4
ER-TC1	"E" TYPE THERMOCOUPLE TR-1520
ER-TC2	"E" TYPE THERMOCOUPLE TR-1523
ER-TC3	"E" TYPE THERMOCOUPLE TR-1525
ER-TC4	"E" TYPE THERMOCOUPLE TR-1505
ER-TV1	1" GLOBE VALVE McMASTER CARR #4889K15

FL=FEED LOOP

ITEM	DESCRIPTION
FL-BV1	BALL VALVE 1" SPEARS 2329-010C
FL-BV2	BALL VALVE ½" WHITEY SS-45S8
FL-BV3	BALL VALVE ¾" SPEARS 2329-007C
FL-BV4	BALL VALVE ⅜" SWAGELOK SS-44S6
FL-BV5	BALL VALVE ¾" SPEARS 2329-007C
FL-BV6	BALL VALVE ¾" SPEARS 2329-007C
FL-BV7	THIS NO. NOT USED
FL-BV8	BALL VALVE 1" SPEARS 2329-010C
FL-FT1	MAGNETIC FLOWMETER TR-3702
FL-PU1	TEEL ½ HP MODEL:1P799B PUMP
FL-TV1	THROTTLE VALVE ⅜"SWAGELOK SS-1VS6

HA=HOUSE AIR

ITEM	DESCRIPTION
HA-TV1	THROTTLE VALVE ¼" WHITEY SS-1VS4
HA-TV2	BUILT INTO ROTOMETER HA-FM1
HA-FM1	ROTOMETER

JP=JET PUMP

ITEM	DESCRIPTION
JP-BV1	BALL VALVE ½" SPEARS 2329-005C
JP-BV2	BALL VALVE ½" SPEARS 2329-005C
JP-BV3	BALL VALVE ½" SPEARS 2329-005C
JP-BV4	BALL VALVE ¼" SWAGELOK SS-43S4
JP-BV5	BALL VALVE ¼" SWAGELOK SS-43S4
JP-BV6	BALL VALVE ¼" SWAGELOK SS-43S4
JP-BV7	BALL VALVE ¼" SWAGELOK SS-43S4
JP-BV8	BALL VALVE ¼" SWAGELOK SS-43S4
JP-BV9	BALL VALVE ¼" SWAGELOK SS-43S4
JP-BV10	BALL VALVE ¼" SWAGELOK SS-43S4
JP-DP1	ROSEMONT PRESSURE TRANSDUCER TR-02151
JP-SI1	SAMPLE/INJECTION PORT ¼" SWAGELOK SS-42S4
JP-TC1	THERMOCOUPLE TR-1509
JP-TV1	1" GLOBE VALVE McMASTER CARR #4889K15
JP-TV2	1" GLOBE VALVE McMASTER CARR #4889K15
JP-PT1	ROSEMONT PRESSURE TRANSDUCER TR-1381

PC=PRIMARY CONDENSATE

ITEM	DESCRIPTION
PC-BV1	BALL VALVE 1" SPEARS 2329-010C
PC-BV2	BALL VALVE 1" SPEARS 2329-010C
PC-BV3	BALL VALVE ½" WHITEY SS-45S8
PC-BV4	BALL VALVE ¾" SPEARS 2329-007C
PC-BV5	BALL VALVE ¾" SPEARS 2329-007C
PC-BV6	BALL VALVE ⅜" SWAGELOK SS-44S6
PC-BV7	BALL VALVE ¾" SPEARS 2329-007C
PC-BV8	BALL VALVE ¾" SPEARS 2329-007C
PC-BV9	BALL VALVE ¾" SPEARS 2329-007C
PC-BV10	BALL VALVE ¾" SPEARS 2329-007C
PC-BV11	BALL VALVE ½" WHITEY SS-45S8
PC-BV12	BALL VALVE ½" WHITEY SS-45S8
PC-BV131	BALL VALVE ½" WHITEY SS-45S8
PC-FT1	MAGNETIC FLOWMETER TR-3705
PC-FT2	MAGNETIC FLOWMETER TR-03562
PC-PU1	PUMP MARCH MFG. MODEL MDX
PC-PU2	3/4 H.P. TEEL MODEL 1P701B PUMP

PW=PROCESS WATER

ITEM	DESCRIPTION
PW-BV1	BALL VALVE ¾" SPEARS 2329-007C
PW-BV2	BALL VALVE 2" SPEARS 2329-020C
PW-BV3	BALL VALVE 1 ½" SPEARS 2329-015C
PW-BV4	BALL VALVE 1" SPEARS 2329-010C
PW-BV5	BALL VALVE 1" SPEARS 2329-010C
PW-BV6	BALL VALVE ½" SPEARS 2329-005C
PW-BV7	BALL VALVE ¾" SPEARS 2329-007C
PW-FM1	ROTOMETER TR-3684
PW-FM2	ROTOMETER TR-3682
PW-FM3	ROTOMETER TR-3683
PW-PG1	PRESSURE GUAGE 0-200 PSIG ASHCROFT
PW-PG2	PRESSURE GUAGE 0-200 PSIG ASHCROFT
PW-PG3	PRESSURE GUAGE 0-200 PSIG ASHCROFT
PW-TC1	THERMOCOUPLE TR-1514
PW-TC2	THERMOCOUPLE TR-1515
PW-TC3	THERMOCOUPLE TR-1519
PW-TC4	THERMOCOUPLE TR-1544
PW-TV1	1 1/2" GATE VALVE McMASTER CARR #4599K47
PW-TV2	1" GATE VALVE McMASTER CARR #4599K45
PW-TV3	1" GATE VALVE McMASTER CARR #4599K45

SC=SECONDARY CONDENSATE

ITEM	DESCRIPTION
SC-BV1	BALL VALVE 1" SPEARS 2329-010C

SG= STEAM GENERATOR

ITEM	DESCRIPTION
SG-BV1	BALL VALVE 3/4" BRASS FNPT
SG-BV2	BALL VALVE 3/4" BRASS FNPT
SG-BV3	BALL VALVE 3/4" BRASS FNPT
SG-BV4	BALL VALVE 3/4" BRASS FNPT
SG-BV5	BALL VALVE 3/4" BRASS FNPT
SG-PG1	PRESSURE GUAGE 0-300 PSIG WIKA
SG-PR1	PRESSURE RELIEF PSU-6160
SG-PREG1	JORDON PRESSURE REGULATOR
SG-PREG2	JORDON PRESSURE REGULATOR
SG-PU1	1/2 H.P. EMERSON MOD. C55JXGNF-3728 PUMP
SG-TV1	SIGHT GLASS VALVE
SG-TV2	SIGHT GLASWS VALVE
SG-TV3	1" GLOBE VALVE McMASTER CARR #4889K15
SG-TV4	1" GLOBE VALVE McMASTER CARR #4889K15

SW=SPRAY WATER

ITEM	DESCRIPTION
SW-BV1	BALL VALVE 1/2" WHITEY SS- 45S8
SW-FI1	ROTOMETER TR-20210
SW-FT1	MAGNETIC FLOWMETER TR-3704
SW-TV1	THROTTLE VALVE 1/4" SWAGELOK SS-1VS4
SW-TV2	THROTTLE VALVE 3/8" SWAGELOK SS-1VS6
SW-TV3	THROTTLE VALVE 1/4" SWAGELOK SS-1VS4

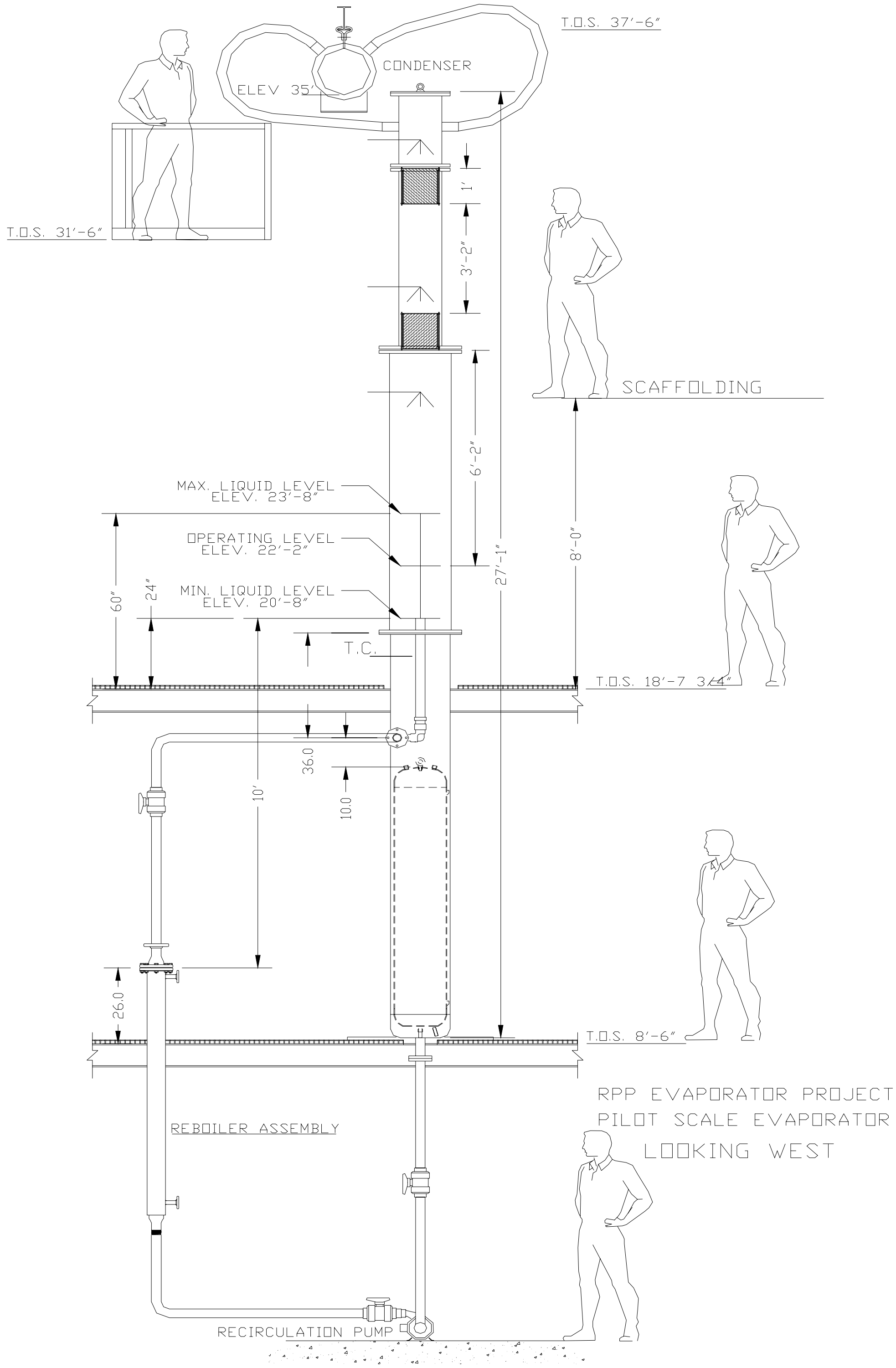

Figure 2-2. Pilot-Scale Evaporator Elevations Details

2.5.2 Recirculation Mode of Operation

In this mode the initial concentration phase is the same as described above. Once fresh feed runs out, the concentrate and the primary condensate stream are combined in the feed tank to reconstitute feed. The liquid levels in the evaporator vessel, feed tank, and the condensate tank are kept at a constant level to assure that the recycled feed is representative of the fresh feed. Thus, the recycled feed never runs out and the evaporator can be operated for long-term tests without having thousands of gallons of fresh feed.

2.6 EVAPORATOR CAMPAIGNS

Three evaporation campaigns were completed under this test program as described in this section. The Pilot-Scale startup and operation followed EDL Work Instructions I-EDL-0151, SRT-RPP-2003-00078, 6-11-2003.

2.6.1 Evaporator Operation

All the desired feed simulants were first transferred from mixing vessels/drums to the feed tank. The feed was agitated on a continuous basis to preclude any settling. Using the main feed pump and 3/4" transfer line, the evaporator vessel was filled with fresh feed up to the nominal operating level (~100 gallons). The evaporator was then started in the following sequence.

1. Start steam generator.
2. Ensure adequate cooling water to the primary condenser and the two jet pump condensers.
3. Start two-stage jet pump (second stage is started first) to start pulling the vacuum on the system.
4. Start the main recirculation pump to establish recirculation rates of 90 - 100 gpm.
5. Start supplying steam to the reboiler.
6. Once the concentrate starts boiling, adjust the reboiler heat input, feed rate, concentrate removal rate and system pressure. The system pressure was adjusted to 1 psia by varying the air bleed on the suction side of the first stage of the jet pump. Steam supply rate to the reboiler was adjusted to maintain the cold side temperature rise around 2.7 °C. At 90 gpm recirculation rate this translates to energy required to boil-off 0.4 gpm of water.
7. Pull desired samples from the sample ports as needed.
8. Inject antifoam agent through the recirculation loop injection port as needed.

2.6.2 Sampling Methods

The Pilot-Scale Evaporator System was designed with several sample/injection ports to draw samples or to inject spiking material as needed. Throughout the test program, a large number of samples were collected and archived. The idea was to select a small subset of these samples for analyses as needed. The liquid samples were drawn for two separate analytical labs. Most of the liquid samples were drawn for archival and analyses by SRTC's analytical labs. A small set of liquid and all offgas samples were drawn for the regulatory analyses by offsite vendors. SRTC contracted BWXT to perform regulatory analyses of liquid samples. Air Tech. performed offgas sampling and analyses for regulatory purposes.

Note that the entire system is designed to operate under vacuum. The vapor space in nominally kept at 1 psia. The boiling surface was nominally 20 ft above the main circulation pump. Thus with the hydrostatic head of 20 ft of concentrate (at 88.4 lbm/ft3), the pump inlet pressure is 13.3 psia. For water, the pump inlet pressure is 9.7 psia. The sample port for the concentrate is located downstream of the pump. The pump outlet pressure is the function of the system pressure loss that varies depending upon the rheology of the working fluid.

For water runs, pressure throughout the circulation loop remained below atmospheric pressure. For the simulant runs, the pressure at the sample port was slightly negative (below atmospheric) at the beginning of the concentration period. As the concentrate in the evaporator vessel became denser, the sample port pressure became positive. In view of these considerations, sometimes the sample was sucked out using a syringe and then transferred to a vial. For most of the time the sample port pressure was positive and the sample was collected in a vial/bottle by opening the sample port valve.

The feed sample port was always under positive pressure and the samples were collected in a vial/bottle. Both the feed sample port and the concentrate sample port were allowed to run for at least 10 volumes of the dead space in the sample lines. After this flush-out the samples were collected. Typically 60-ml samples were collected for all liquid streams. For the concentrate, a small amount (~15-20 ml) was filtered through a filter paper to collect insoluble solids. The filtrate was then filtered again through another filter paper to prepare blanks. Both filter papers were dried in a desiccator. The blanks provided information above the solubles.

The primary and the secondary condensate samples were drawn from the respective tank dip tubes using a syringe. The syringe was flushed out twice with the respective condensate before collecting the sample. The last liquid sample was the knockout pot drain loop (KDL) sample. The KDL sample amount was usually very small and at the end of each day of operation about 30-40 ml of sample was collected in a vial. Liquid samples for regulatory analyses were drawn from the same ports using the same techniques. However, the samples were drawn in 1-liter bottles.

The offgas sampling was performed by Air-Tech Environmental, LLC. Air-Tech followed the protocol of EPA Method 0010. Details of their setup and sampling procedure are documented in a separate report [9].

2.6.3 Water Tests

The first evaporation campaign used water as the working fluid. The purpose of this campaign was to shake down the test facility and identify any problems with the hardware or the operating conditions.

This campaign turned out to be very useful in identifying a major shortcoming in the recirculation loop configuration. In the initial design used for the Pilot-Scale evaporator, the concentrate enters the evaporator vessel tangentially at about 4 ft below the boiling surface. This configuration had two shortcomings - a swirling motion due to tangential entry at about 8 ft/s and poor mixing due to excessive submergence of 4 ft. The result was large temperature fluctuations in the boiling region and unstable boiling operation. Due to poor vertical mixing, large chunks of supersaturated water would flash violently causing excessive vapor generation thus overwhelming the steam jet pump. The pump was designed to handle nominal evaporation rate of 0.4 gpm with minor fluctuations.

Since the saturation temperature follows the system pressure, large-scale oscillations in evaporator temperature and pressure were observed. Consequently, the concentrate return line was reconfigured to allow the returning fluid jet in a vertical direction. The jet was discharged at about 1 ft below and up towards the boiling surface at a fluid velocity of about 2 ft/s (Figure 2-2). This modification resulted in a well-mixed boiling region and stable operation. All subsequent testing was done with the modified configuration.

2.6.4 Test 1- Simulated Ultrafiltration Recycles with HLW SBS from Duratek

Test 1 was performed using Ultrafiltration Recycles Simulant with HLW SBS in the following quantities.

Simulant	**Volume (Liters)**
First Wash (see Appendix A for recipe)	448.4
Second Wash (see Appendix B for recipe)	448.4
Leach (see Appendix C for recipe)	62.32
Acid Cleaning Solution (see Appendix D for recipe)	335.92
Caustic Solution (0.1 Molar NaOH)	224.96
HLW SBS from Duratek	1520.00
Total	**3040 liters (803 gallons)**

The simulant quantities (except for HLW SBS) were prepared in Engineering Development Lab of SRTC according to the procedure: WTP Pilot Scale Evaporator Mixing Procedure, EES Field Procedure FP-955, 5-29-03.

Table 2-3 gives a chronology of events for Test 1. Note that the Pilot-Scale Evaporator was not operated round the clock. Instead it was normally started in the morning and shut down at the end of the working day. No runs were made over the weekends. Thus the actual elapsed time for the chemicals in the evaporator was much larger than the actual run time.

Table 2-3. Evaporator Test 1 Chronology

Date	Day	Time	Daily Boil Time hrs:min	Comm Boil Time hrs:min	Event Time hrs:min	Sp. Gr.	Event
6/11/03	Wed	13:00			13:00		System Started, Pulled Feed Samples
		14:00			13:00		Heat added to reboiler
		15:00					
		16:00					
		17:00	4:00	4:00:00	17:00		Pulled samples Feed, CT, PCT, SCT Shut Down
6/12/03	Thur	7:00			7:15		System Started
		8:00					
		9:00					
		10:00			10:35		Pulled Feed Sample
		11:00					
		12:00			12:00		Pulled samples Feed, CT, PCT, SCT
		13:00					
		14:00			14:18	1.095	Sp Gr by Process Inst. 1.0916
		15:00			15:23	1.107	
		16:00			16:00	1.118	Pulled samples Feed, CT, PCT, SCT, KDL
		17:00	10:00	14:00:00	17:15		Shut Down
6/16/03	Mon	7:00			7:30		System Started
		8:00			8:05		Added heat to reboiler
		9:00			9:45		Pulled Feed Sample
		10:00	3:05	17:05:00	10:35		System shut down for replacement of 3" flex tubes to primary condenser
6/18/03	Wed	12:00			12:00		Flex tubes installed
		13:00			13:30	1.138	Heat added to reboiler after starting the system
		14:00					
		15:00			15:23	1.107	
		15:00					
		16:00	3:00	20:05:00	16:30		System shut down
6/19/03	Thur	8:00			8:35		System started
		9:00					
		10:00					
		11:00					
		12:00					
		13:00					
		14:00			14:00		Pulled sample SCT
		15:00					
		16:00	7:35	27:40:00	16:10	1.218	System shut down
6/20/03	Fri	9:00			9:30		Added 6 gal of feed to achieve mid level
		10:00			10:00	1.204	System started
		11:00					
		12:00					
		13:00					
		14:00	4:55	32:35:00	14:55	1.216	System shut down
6/23/03	Mon	8:00			8:45		System started
		9:00					
		10:00					
		11:00			11:04		Performed addition of antifoam test @ 500. 1000, 1400 ppm
		12:00					
		13:00			13:15		The concentrate and recirculation pumps developed leaks, System shut down
6/24/03	Tue	14:00			14:35		System started again after rebuilding concentrate and recirculation pumps
		15:00					
		16:00	7:45	40:20:00	16:30		System shut down

Table 2-3. Evaporator Test 1 Chronology - continued

Date	Day	Time	Daily Boil Time hrs:min	Comm Boil Time hrs:min	Event Time hrs:min	Sp. Gr.	Event
6/25/03	Wed	7:00			7:15		System started
		8:00					
		9:00			9:30		Pulled samples Feed, CT, PCT, SCT
		10:00					
		11:00					
		12:00					
		13:00					
		14:00					
		15:00			15:50		Pulled samples Feed, CT, PCT, SCT
		16:00	9:00	49:20:00	16:15		System shut down
6/26/03	Thur	7:00			7:15		System started
		8:00			8:00		Pulled samples Feed, CT, PCT, SCT
		9:00					
		10:00					
		11:00					
		12:00			12:55	1.211	
		13:00					
		14:00			14:25		Sp. Gr. Of concentrate filtrate = 1.21
		15:00			15:50		Pulled samples Feed, CT, PCT, SCT
		16:00	9:00	58:20:00	16:15		System shut down
6/27/03	Fri	7:00			7:20		System started
		8:00					
		9:00			9:15		Pulled samples Feed, CT, PCT, SCT
		10:00	3:25	61:45:00	10:45		System shut down
6/30/03	Mon	8:00			8:35		System started
		9:00					
		10:00			10:30	1.216	Pulled samples Feed, CT, PCT, SCT
		11:00					
		12:00					
		13:00					
		14:00					
		15:00			15:00		Pulled samples Feed, CT, PCT, SCT
		16:00	6:40	68:25:00	15:15		System shut down
7/1/03	Tue	10:00			10:45		System started
		11:00					
		12:00					
		13:00					
		14:00			14:00		Pulled samples Feed, CT, PCT, SCT, 0.4 cfm air bleed to evap.
		15:00	4:50	73:15:00	15:35		System shut down
7/2/03	Wed	8:00			8:00		System started
		9:00			9:35		Pulled samples Feed, CT
		10:00					
		11:00					
		12:00					
		13:00					
		14:00			14:00		Pulled samples Feed, CT, PCT, SCT
		15:00	6:30	79:45:00	14:30		System shut down
7/9/03	Wed	12:00			12:00		System started, 0.2 cfm air bleed to evap.
		13:00			12:30		Pulled Feed samples
		14:00					
		15:00					
		16:00			16:40		Pulled CT, PCT, SCT and KDL samples
		17:00	5:00	84:45:00	17:00		System shut down

2.6.5 Test 2 - Treated AN102 & Envelope C LAW SBS from Duratek

Test 2 was performed using Treated AN-102 R2 Filtrate with LAW SBS in the following quantities.

Simulant	**Volume (Liters)**
Treated AN102R2 Filtrate	1575
LAW SBS from Duratek	1575
Total	**3150 liters (830 gallons)**

Table 3.4 gives a chronology of events for Test 2. As noted on **Table 3.4**, Test 2 had the following three distinct phases of operations.

- **Initial Concentration Phase.** In this phase fresh feed was boiled off in the evaporator without removing any concentrate. The fresh feed had a specific gravity of 1.145. The target concentrate Sp. Gr. was1.43 (88.44 lbm/ft3 density at 111 F). Of the total feed inventory of 830 gallons, this phase used about 345 gallons to yield 100 gallons of concentrate in the evaporator vessel.
- **Steady Operation with Fresh Feed.** In this phase another 345 gallons of fresh feed was fed to the evaporator and 100 gallons of concentrate was removed.
- **Long Term Test with Recycled Feed.** For this phase of testing, the concentrate and the primary condensate were transferred back to the feed tank to reconstitute the feed.

Table 2-4. Evaporator Test 2 Chronology

Date	Event Time hrs:min	Daily Boil Time hrs:min	Comm Boil Time hrs:min	Density lbm/ft3	Event
Initial Concentration Starts					
9/15/03	10:45				Started filling up the evaporator vessel with feed from feed tank
Mon	11:15			71.5	100 gallons of feed transferred from feed tank to evap vessel
	15:00				Started steam generator
	15:30				Started jet pump and reboiler
	16:15			71.92	Vigorous boiling, froth height ~ 4 ft
	17:30			74.84	
9/16/03	7:50				Started jet pump and reboiler
Tue	9:10				Steam generator pressure dropped, shut down
	9:40				Checked steam generator fuses, system started again
	11:00				Pulled Feed, CT, PCT & SCT Samples
	14:38			88.4	Reached target concentration, Pulled Feed, CT, PCT, SCT & KDL Samples, System shut down
Steady Operation with Fresh Feed					
9/17/03	9:15			88.25	Started steam generator
Wed	9:45				Boiling started. Combined 54 spiking ampules
	10:49				Injected 56 grams of antifoam to the evap recirculation loop (100 ppm)
	10:56				Injected 56 grams of more antifoam to the evap recirculation loop (total 200 ppm)
	12:00				Pulled Feed, CT, PCT & SCT Samples
	13:15				Pulled baseline samples for regulatory analyses
	13:18				Began addition of 540 mL of organic spike
	14:10				Pulled Feed, CT, PCT & SCT Samples, Also pulled all regulatory liquid samples
	15:05				Pulled Feed, CT, PCT & SCT Samples
	16:05				Pulled Feed, CT, PCT, SCT and KDL samples for ADS
	17:20	7:35	7:35		System shut down
9/18/03	9:45				Concentrate pump leaky seal was replaced
Thu	10:05				Started jet pump and reboiler
	10:20				Boiling started
	11:00				Pulled Feed, CT, PCT & SCT Samples
	12:00				Pulled Feed, CT, PCT & SCT Samples
	13:00				Pulled Feed, CT, PCT & SCT Samples
	14:00				Pulled Feed, CT, PCT & SCT Samples
	14:15	3:55	11:30		System shut down
9/25/03	9:55				Started steam generator
Thu	10:00				Started jet pump and reboiler
Start of Long-Term Test with Recycled Feed					
	10:50				Concentrate and primary condensate were combined in the feed tank
	13:00				Pulled Feed, CT, PCT & SCT Samples
	15:52				Injected 56 grams of more antifoam to the evap recirculation loop (total 300 ppm)
	16:50				Pulled Feed, CT, PCT, SCT & KDL Samples
	17:00	6:10	17:40		System shut down
9/26/03	10:10				Steam generator started
Fri	10:18				Started jet pump and reboiler
	10:40				Boiling vigorously
	11:15				Pulled Feed, CT, PCT & SCT Samples
	15:50				Pulled Feed, CT, PCT & SCT Samples
	16:05	5:25	23:05		System shut down. Noticed a scale in the clear section of evap. Vessel upto ~20" level

Table 2-4. Evaporator Test 2 Chronology - continued

Date	Event Time hrs:min	Daily Boil Time hrs:min	Comm Boil Time hrs:min	Density lbm/ft3	Event
Start of Long-Term Test with Recycled Feed - continued					
9/30/03	13:00				Steam generator started
Tue	13:10				Started jet pump and reboiler
	13:30				Pulled Feed, CT, PCT & SCT Samples
	13:35				Boiling started
	16:50				Pulled Feed, CT, PCT & SCT Samples
	16:55	3:20	26:25		System shut down
10/1/03	8:10				Started steam generator
Wed	8:15				Started jet pump and reboiler
	8:35				Boiling started
	8:50				System shut down, concentrate pump leaking
	10:30				Started the system again after installing a new seal for concentrate pump
	11:00				Pulled Feed, CT, PCT & SCT Samples
	11:30	1:00	27:25		System shut down
10/6/03	13:00				Started steam generator
Mon	13:20				Started jet pump and reboiler
	13:50				Boiling started
	14:50				Concentrate line plugged
	15:25	1:35	29:00		System shut down
10/7/03	9:45				Started steam generator, jet pump and reboiler
Tue	10:00				Boiling started
	11:20				Pulled Feed, CT, PCT & SCT Samples
	16:40				Pulled Feed, CT, PCT, SCT & KDL Samples
	16:45	6:45	35:45		System shut down
10/9/03	9:30				Started steam generator, jet pump and reboiler
Thu	10:00				Boiling started
	10:25				Shut down, leakage in steam generator sight glass
	14:00				Leak fixed, system started again
	14:20				Boiling started. Added 100 ppm of antifoam added at 15:40 (300 ppm total)
	16:40				Pulled Feed, CT, PCT, SCT & KDL Samples
	16:55	3:00	38:45	88.3	System shut down
10/10/03	10:00				Started steam generator
Fri	10:05				Started jet pump and reboiler
	10:20				Boiling started
	16:00				Pulled Feed, CT, PCT, SCT & KDL Samples
	16:05	5:15	44:00		System shut down
10/13/03	9:30				Started steam generator
Mon	9:37				Started jet pump and reboiler
	9:55				Boiling started
	10:00				Pulled Feed, CT, PCT & SCT Samples
	15:00			89.6	
	16:40				Pulled Feed, CT, PCT, SCT & KDL Samples
	16:45	6:50	50:50		System shut down
10/14/03	9:15				Started steam generator
Tue	9:25				Started jet pump and reboiler
	9:39				Boiling started
	10:00				Pulled Feed, CT, PCT & SCT Samples
	16:40				Pulled Feed, CT, PCT, SCT & KDL Samples
	16:49	7:10	58:00		System shut down
10/15/03	7:50				Started steam generator
Wed	7:55				Started jet pump and reboiler
	8:10				Boiling started
	12:45	4:35	62:35		System sht down, concentrate pump leaking

Table 2-4. Evaporator Test 2 Chronology - continued

Date	Event Time hrs:min	Daily Boil Time hrs:min	Comm Boil Time hrs:min	Density lbm/ft3	Event
Start of Long-Term Test with Recycled Feed - continued					
10/20/03	10:10				Started steam generator
Mon	10:15				Started jet pump and reboiler
	10:30				Boiling started
	16:50				Pulled Feed, CT, PCT, SCT & KDL Samples
	17:00	6:30	69:05		System shut down
10/21/03	8:20				Started steam generator
Tue	9:30				Leakage in cooling water line, system shut down
	10:00				System started again
	10:20				Boiling started
	16:50				Pulled Feed, CT, PCT, SCT & KDL Samples
	17:00	6:40	75:45		System shut down
10/22/03	8:00				Started steam generator
Wed	8:15				Started jet pump and reboiler
	8:30				Boiling started
	16:00				Pulled Feed, CT, PCT, SCT & KDL Samples
	16:20	7:50	83:35		System shut down
10/23/03	9:15				Started steam generator
Thu	9:20				Started jet pump and reboiler
	9:45				Boiling started
	16:45	7:00	90:35		Pulled Feed, CT, PCT, SCT & KDL Samples, System shut down
10/24/03	8:20				Started steam generator
Fri	8:30				Started jet pump and reboiler
	8:50				Boiling started
	15:45				Pulled Feed, CT, PCT, SCT & KDL Samples
	15:50	7:00	97:35		System shut down
10/27/03	9:55				Started steam generator
Mon	10:00				Started jet pump and reboiler
	10:15				Boiling started
	13:15				Pulled Feed, CT, PCT, SCT & KDL Samples
	14:15	4:00	101:35		System shut down
10/28/03	8:15				Started steam generator
Tue	8:20				Started jet pump and reboiler
	8:35				Boiling started
	14:00				System shut down
	15:50				System started again, boiling started
	16:20				Pulled Feed, CT, PCT, SCT & KDL Samples
	16:25	6:00	107:35		System shut down
Fri	8:30				Started jet pump and reboiler
	8:50				Boiling started
	15:45				Pulled Feed, CT, PCT, SCT & KDL Samples
	15:50	7:00	97:35		System shut down
10/27/03	9:55				Started steam generator
Mon	10:00				Started jet pump and reboiler
	10:15				Boiling started
	13:15				Pulled Feed, CT, PCT, SCT & KDL Samples
	14:15	4:00	101:35		System shut down
10/28/03	8:15				Started steam generator
Tue	8:20				Started jet pump and reboiler
	8:35				Boiling started
	14:00				System shut down
	15:50				System started again, boiling started
	16:20				Pulled Feed, CT, PCT, SCT & KDL Samples
	16:25	6:00	107:35		System shut down

2.7 TEST RESULTS

2.7.1 Foaming/Antifoam Results

One of the Pilot-Scale Evaporator test program objectives was to determine any foaming issues associated with different evaporation campaigns. Additionally, the test program was designed to test the effectiveness of an antifoam agent (Dow Corning Q2-3183A).

Note that the evaporator system operates under vacuum. After the initial boil-off, the system is essentially degassed. Typically, within 20-30 minutes of the startup, target vacuum level (1 psia) was achieved and stable boiling conditions were established with ~ 1 - 2 feet of froth/foam zone. Any small addition of air for a few seconds into the recirculation loop resulted in a dramatic increase in the froth height, up to the lower demister. This was observed due to the recirculation pump seal failure. Since the entire system is under vacuum, the failed seal allowed atmospheric air to be entrained into the evaporator vessel. No effort was made to measure the air in-leakage rate. This effect is independent of addition of antifoam agent. All evaporator tests were performed without any air in-leakage into the evaporator vessel.

Dow Corning Q2-3183A antifoam agent was used for both Test 1 and Test 2. Contents plus CAS numbers of this antifoam agent are listed below.

1. Polypropylene glycol	25322-69-4
2. Polydimethylsiloxane	63148-62-9
3. Treated Silica	NJ TSRN 14962700-5005P
4. Octylphenoxy polyethoxy ethanol	9036-19-5
5. Polyether polyol	9082-00-2
6. Treated amorphous silica	
7. Treated Silica	NJ TSRN 14962700-5149P

2.7.1.1 Foaming/Antifoam Addition for Test 1

It is important to note at the outset that the boiling surface/zone undergoes a fairly turbulent and violent flashing of superheated fluid. This active zone contains vapor bubbles and liquid droplets of various sizes. This zone is more or less like froth since it collapses as soon as the boiling process ceases. No significant stable foam was observed when the boiling stopped. However, the froth zone can be as high as ~ 5-6 feet with occasional splattering of liquid droplets hitting the lower demister pad. In this report, the words 'froth' and 'foam' are used interchangeably.

Foaming was noted during the waste feed evaporation run, as shown in Figure 2-3. The foaming was highest (~5 feet) during initial concentration of the feed from the dilute (<1M Na) initial concentration to a specific gravity of 1.22. The foam was vigorously buffeted by the escaping vapors resulting in a significant amount of splatter. The demister pads were routinely hit by the splatter during initial boil-off. After the initial boil-off, the foam region stabilizes to about 24 inches high.

Figure 2-3. Foaming during Initial Concentration

The addition of 500 ppm of Dow Corning Q2 3183A antifoam significantly reduced the amount of foam noted, but did not eliminate the foam entirely, however, the height of the foam was reduced by approximately one half (~ 10" - 12"). Then another dose of 500 ppm antifoam was injected with minor impact on the foam height (~8"). Finally the last dose of 400 ppm was added to achieve the target value of 1400 ppm. No additional decrease in foam height was observed. No degradation of the antifoam was noted during subsequent steady-state operation.

The fluctuations in vacuum increased the foaming and splattering during the test by causing short term increases in flux rate. When the vacuum is decreased, the boiling temperature rises and flux rate is decreased while the bulk slurry in the evaporator is heated until the new boiling temperature is reached. When the vacuum is increased, the boiling temperature is reduced and flux rate is significantly increased as the slurry in the evaporator is now in a superheated condition. Thus any pressure fluctuations in the system result in large fluctuations in instantaneous boil-off rates and associated foaming action.

2.7.1.2 Foaming/Antifoam Addition for Test 2

As described above, the total target concentration of antifoam agent was 1400 ppm. for Test 1, this target was reached by adding 500 ppm, 500 ppm and 400 ppm. During Test 1 antifoam addition, it was observed that the first dose of 500 ppm was effective to reduce the froth/foam height and additional doses had only marginal effect. In view of this, for Test 2, it was decided to add the antifoam agent in 100 ppm increments and observe the effect on foam height.

For Test 2, three doses of 100 ppm of antifoam agent were found to be sufficient in minimizing the foam height. Figure 2-4 shows the foam height before any antifoam addition. The black triangular marks on the vessel are 1 ft apart. Lower and upper yellow/black lines on left the measuring tape represent nominal liquid level and maximum liquid levels, respectively. The froth zone was nominally between 3 - 4 ft high under stable boiling conditions. Liquid height in the evaporator was nominally 22 ft. Thus the froth/foam height was around 15 - 20%. Note that the lower demister pad is about 6 ft above the liquid level.

Figure 2-5 represents the foam after the first dose of 100 ppm. A significant reduction in foam height was observed. Nominally, the froth height reduced to 1 - 2 ft range (5 - 10%). Figure 2-6 shows the foam after the second dose of 100 ppm (total 200 ppm antifoam). The froth height dropped to less than 1 ft (< 5%). Later, another dose of 100 ppm was added after 36 hours of operation since the froth height was getting slightly more than 1 ft. Minor reduction of foam height was observed and no further antifoam agent was added beyond the total 300 ppm value. A stable froth/foam region remained around 8" high (~ 3%) for balance of the test duration as shown in Figure 2-7.

Note that in both tests, around 500ppm dose of antifoam agent was effective to control the foaminess. However, the Pilot-Scale tests were not designed to optimize the antifoam agent concentration levels. A more comprehensive bench scale study covering a wider range of waste simulants recommended 1400 ppm. The Pilot-Scale tests demonstrated that the recommended value is effective in controlling the foaminess.

Figure 2-4. Foam Height Before Antifoam Addition

Figure 2-5. Foam Height After 100 ppm Antifoam Addition

Figure 2-6. Foam Height After 200 ppm Antifoam Addition

Figure 2-7. Foam Height After 300 ppm Antifoam Addition

2.7.2 Decontamination Factors (DF) for Cesium

2.7.2.1 Cesium DF for Test 1

Samples of the evaporator feed, concentrate, and condensate were pulled and analyzed for cesium content. The cesium decontamination factor was determined by dividing the Cs concentration in the concentrate by the Cs concentration in the primary condensate. The secondary condensate volume is an order of magnitude lower than the primary condensate volume, therefore it was not included in the calculation. The concentrate value was utilized for the Cs concentration due to the length of time that the vessel boiled under steady-state conditions. The final sample results are shown in Table 2-5along with the calculated decontamination factors and amounts of cesium removed by the primary and secondary condensate from the evaporation system.

Table 2-5. Cesium Results and Decontamination Factor

Cs in Feed	Cs in Concentrate	Cs in Primary Condensate	Cs in Secondary Condensate	Cs in Knockout Pot Drain Loop	Cs DF Factor
μg/g	μg/g	μg/L	μg/L	μg/L	
87.82	567	5.1	5.7	0.03	111,000

2.7.3 Composition Changes During Long Term Testing

During the initial concentration phase of the Evaporator Test 2 from 9/15/03 to 9/16/03, the Na molarity of the evaporator concentrate went from about 3 M to 12.5 M as shown in Figure 2-8. The Na molarity of the concentrate then dropped to an average value of 10.8 M. The variance in the measured values is most likely due to changes in the feed as well as condensate rates as shown in Figure 2-9. Note that during the long term run, nominal feed rate and concentrate removal rates were adjusted to maintain a 100-gallon level in the evaporator at any given time. Sometimes to correct the concentrate level, large amounts of feed and concentrate were transferred using a 3/4" transfer line. The target density value was 88.4 lbm/ft3. The concentrate density in the evaporator vessel was maintained in the 88 - 89 lbm/ft3 range.

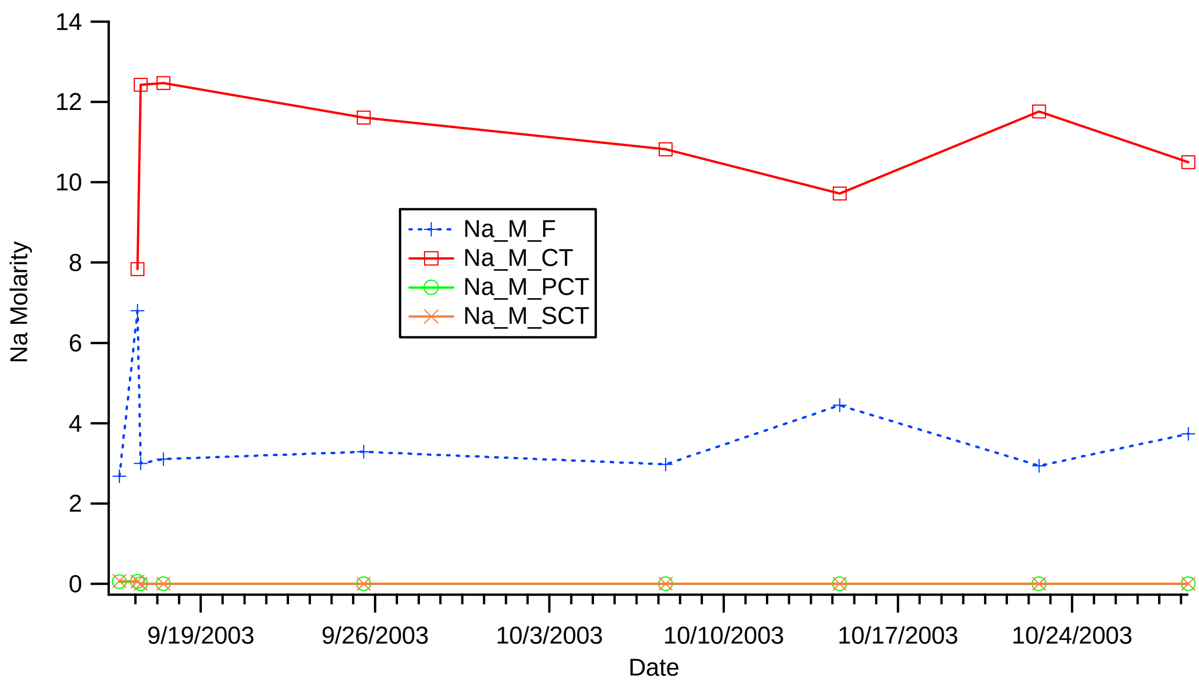

Figure 2-8. Na Molarity of Evaporator Feed (F), Concentrate Tank (CT), Primary Condensate Tank (PCT), and Secondary Condensate Tank (SCT) during Test 2

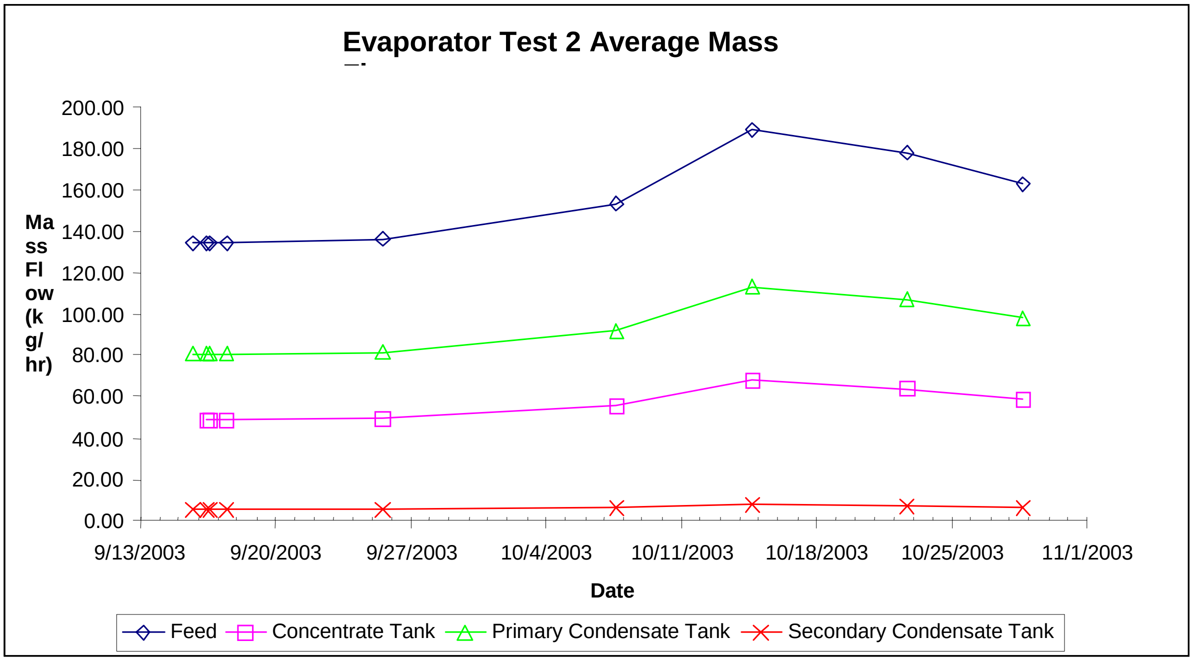

Figure 2-9. Evaporator Test 2 Average Mass Flow Rates

The concentration changes for all the elementals during Evaporator Test 2 can be categorized into multiple groups based on how much they changed over the course of the run. For the cations there were four changing groups: negligible, small, medium, and large. Small changes were observed for the cations Ca, Cd, Cr, Li, Ni, Pb, Si, Sn, W, and Zn on the order of 100 ppm as shown in Figure 2-10 through Figure 2-13 for the various evaporator streams. Medium changes were observed for the cations Al, B, K, P, and S on the order of 5000 ppm as shown in Figure 2-14 through Figure 2-17. Large changes were observed for the cation Na on the order of 50000 ppm as shown in Figure 2-18 through Figure 2-21. The other cations (As, Ba, Ce, Co, Cu, La, Mg, Mn, Mo, Nd, Sr, Ti, Tl, V) had low concentrations or concentration changes less than 100 ppm.

The anions changed in a similar manner. There were three anion change groups: small, medium, and large. Of course, the magnitude of the changes was different from the cations. Small changes were observed for HCOO, CL, PO4, SO4, and C2O4 on the order of 5000 ppm as shown in Figure 2-22. Medium changes were noted for the anion NO2 (nitrite) on the order of 24000 ppm as shown in Figure 2-24. Large changes were seen for the anion NO3 (nitrate) on the order of 60000 ppm as shown in Figure 2-26. The anion changes in the Primary Condensate and the Secondary Condensate were not detectable or concentrations fell below detection limits.

Other than sodium, aluminum changes concentration more than the other cations. Some of this variance is due to changes in the feed and condensate rates. Some of the variance is also due to analytical error. The largest changing anion was NO3 followed by NO2 as expected in this nitrate rich system. Table 2-6 through Table 2-8 show the raw concentrations for the cations and anions.

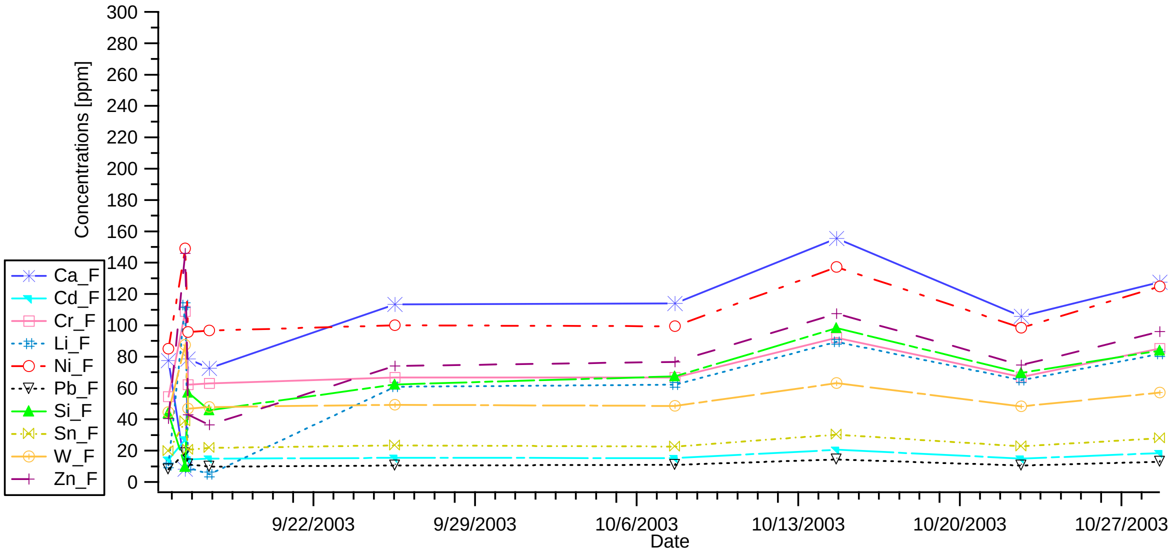

Figure 2-10. Evaporator Run 2 Feed (F) Concentrations in ppm for Small Changing Cations

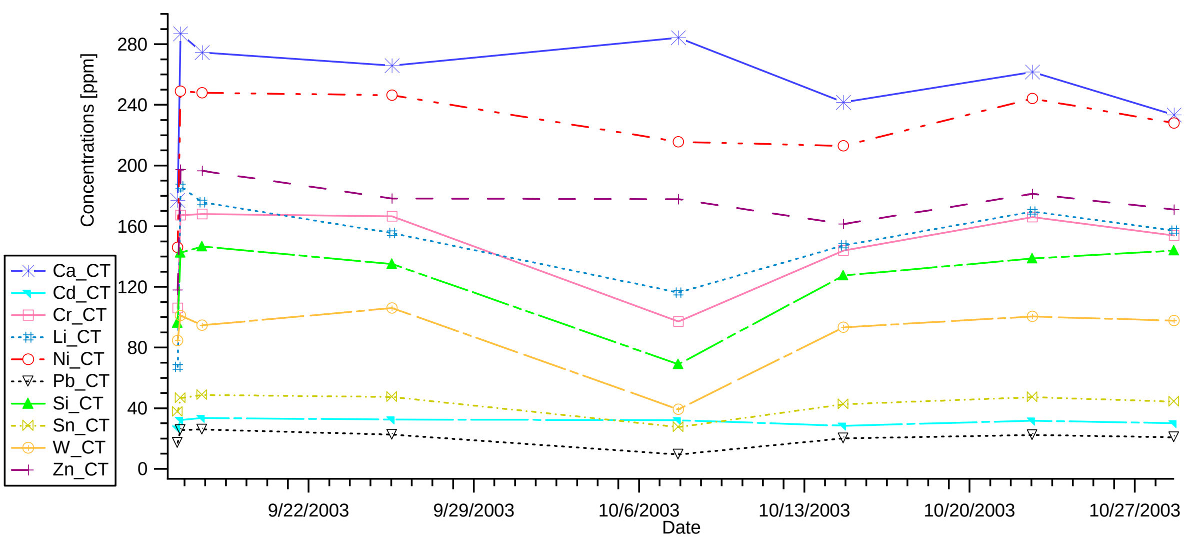

Figure 2-11. Evaporator Run 2 Concentrate Tank (CT) Concentrations in ppm for Small Changing Cations

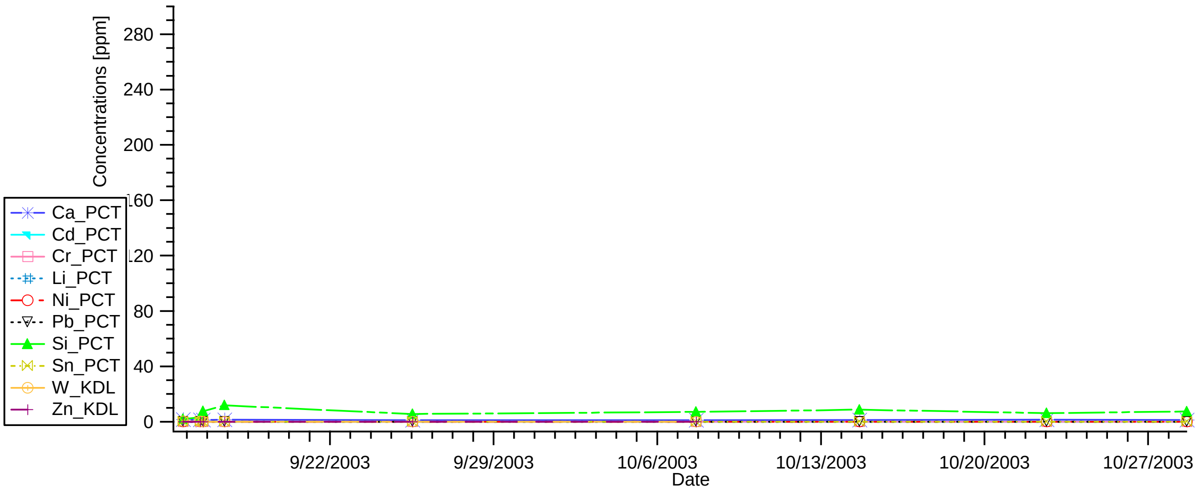

Figure 2-12. Evaporator Run 2 Primary Condensate Tank (PCT) Concentrations in ppm for Small Changing Cations

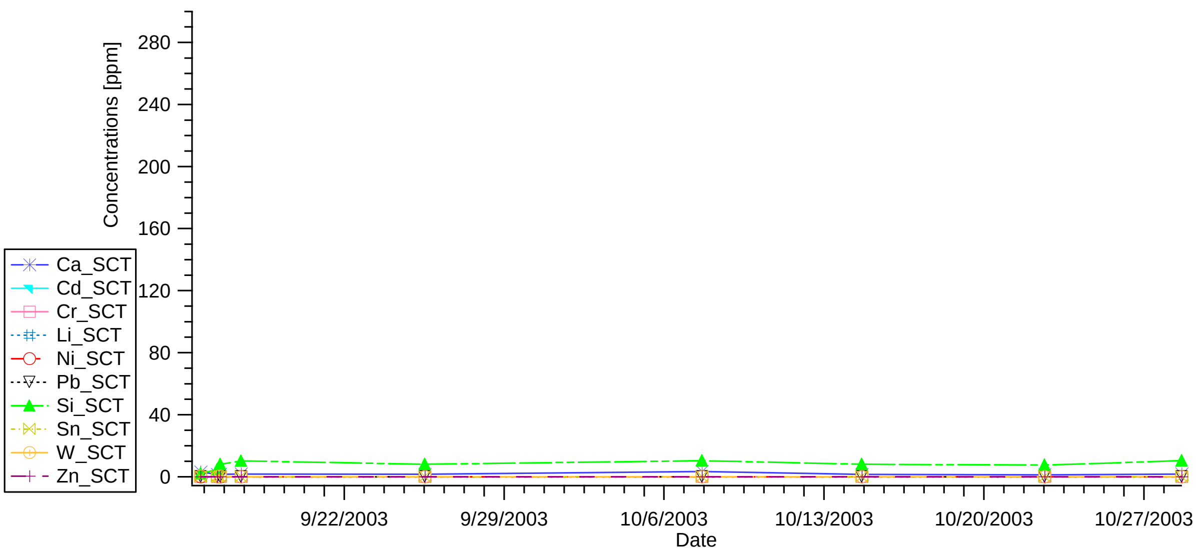

Figure 2-13. Evaporator Run 2 Secondary Condensate Tank (SCT) Concentrations in ppm for Small Changing Cations

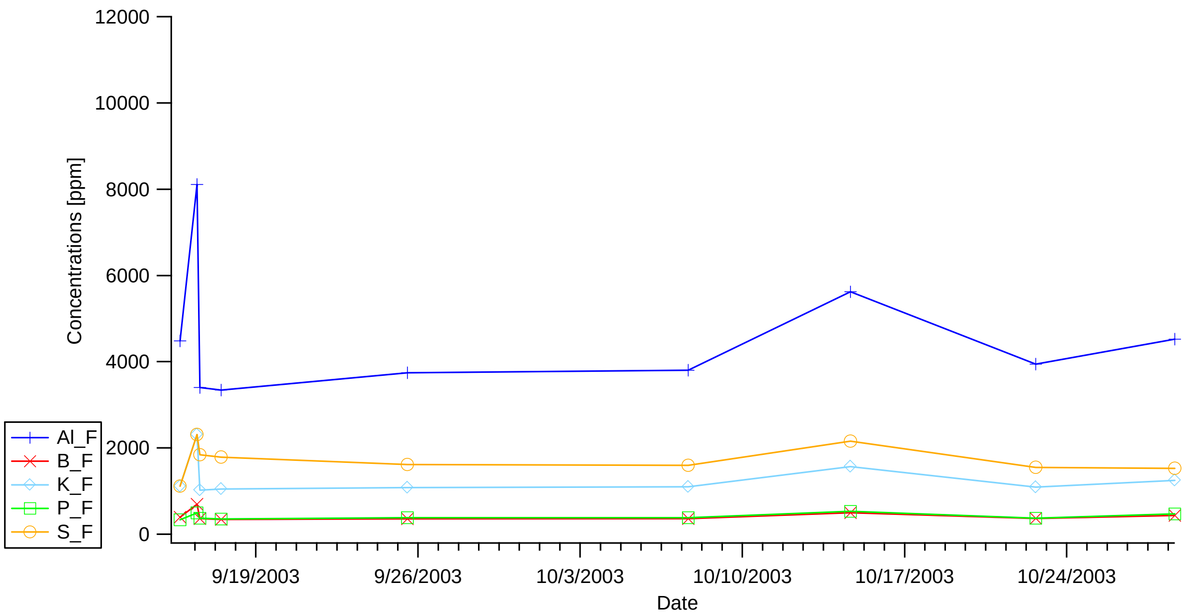

Figure 2-14. Evaporator Run 2 Feed (F) Concentrations in ppm for Medium Changing Cations

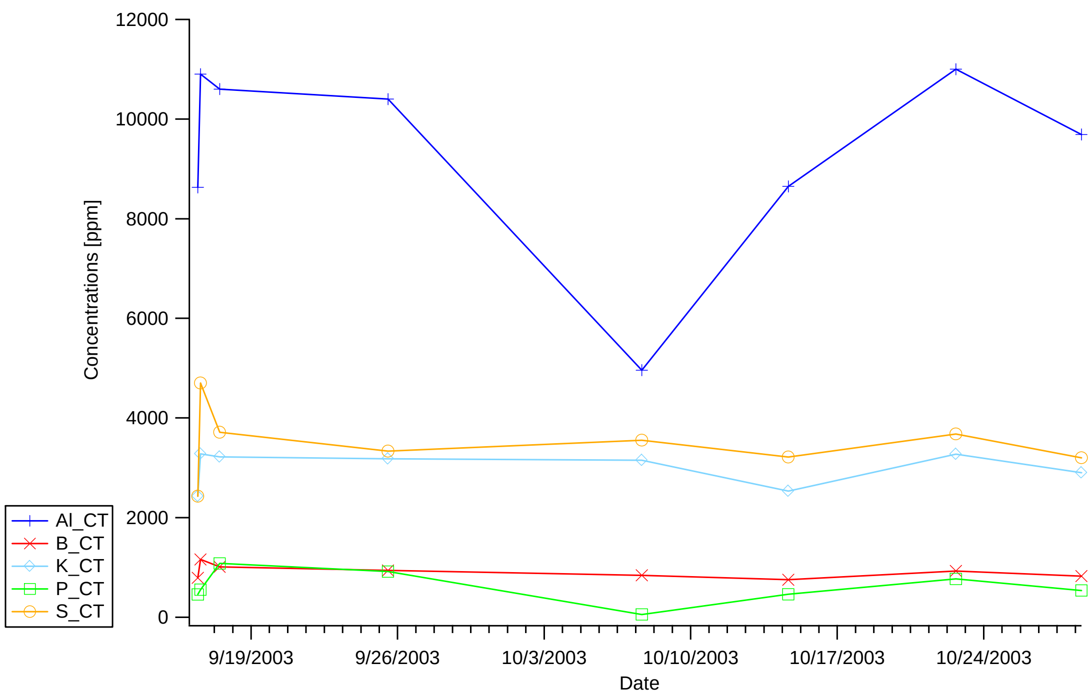

Figure 2-15. Evaporator Run 2 Concentrate Tank (CT) Concentrations in ppm for Medium Changing Cations

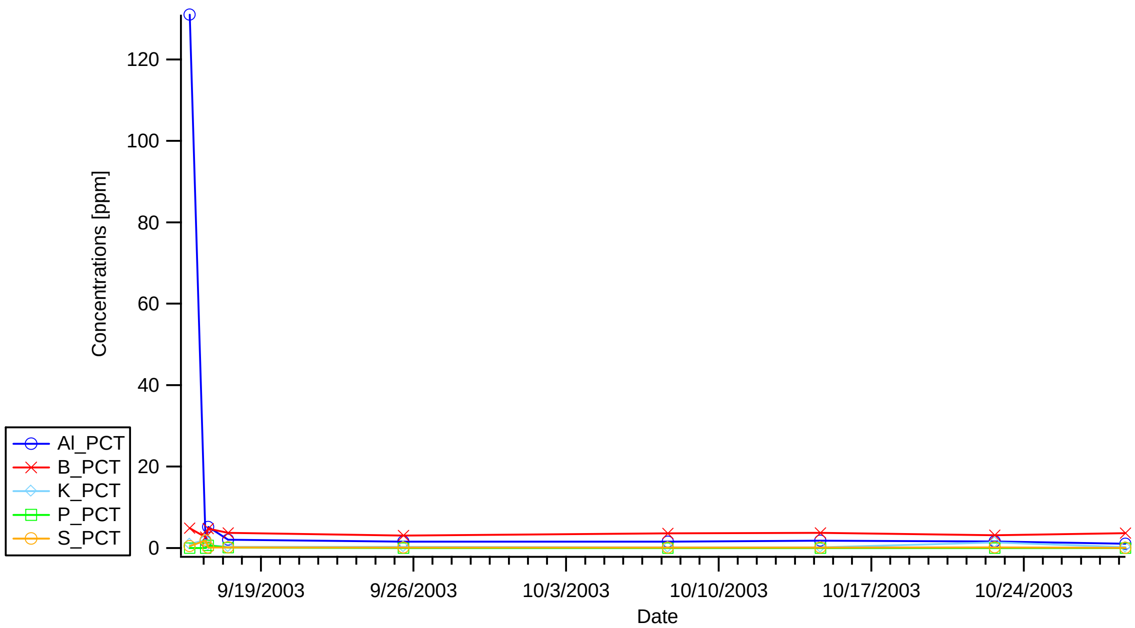

Figure 2-16. Evaporator Run 2 Primary Condensate Tank (PCT) Concentrations in ppm for Medium Changing Cations

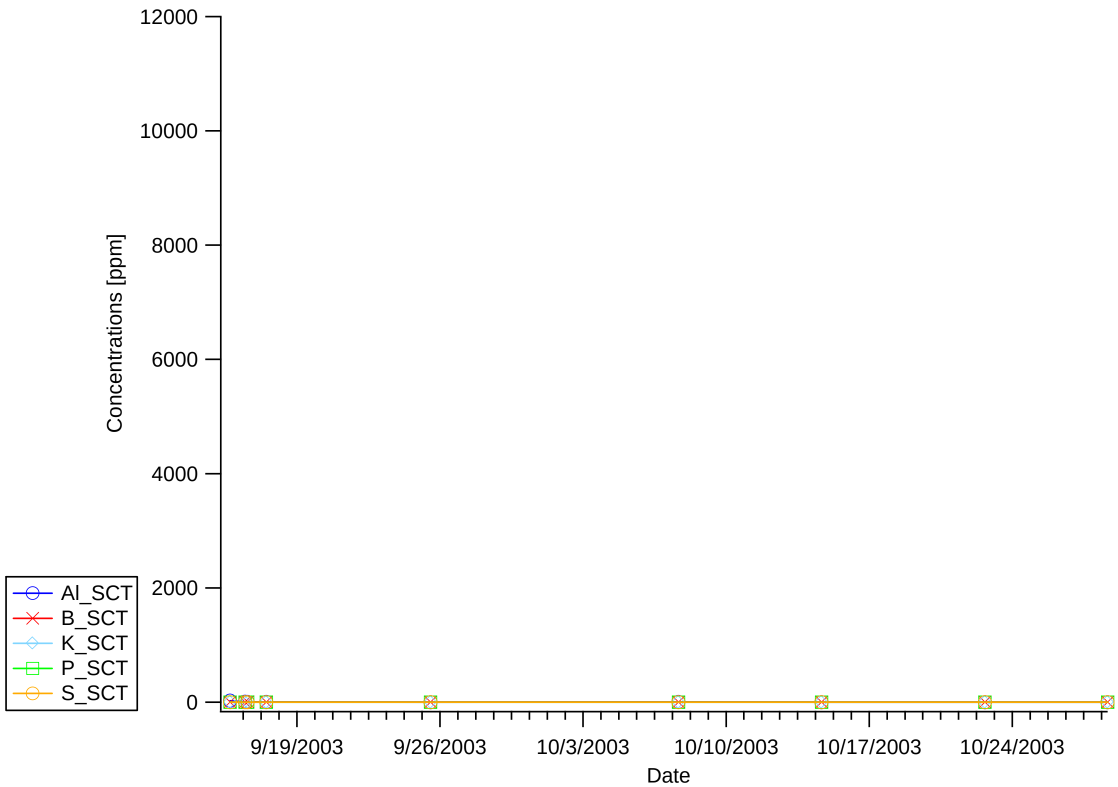

Figure 2-17. Evaporator Run 2 Secondary Condensate Tank (SCT) Concentrations in ppm for Medium Changing Cations

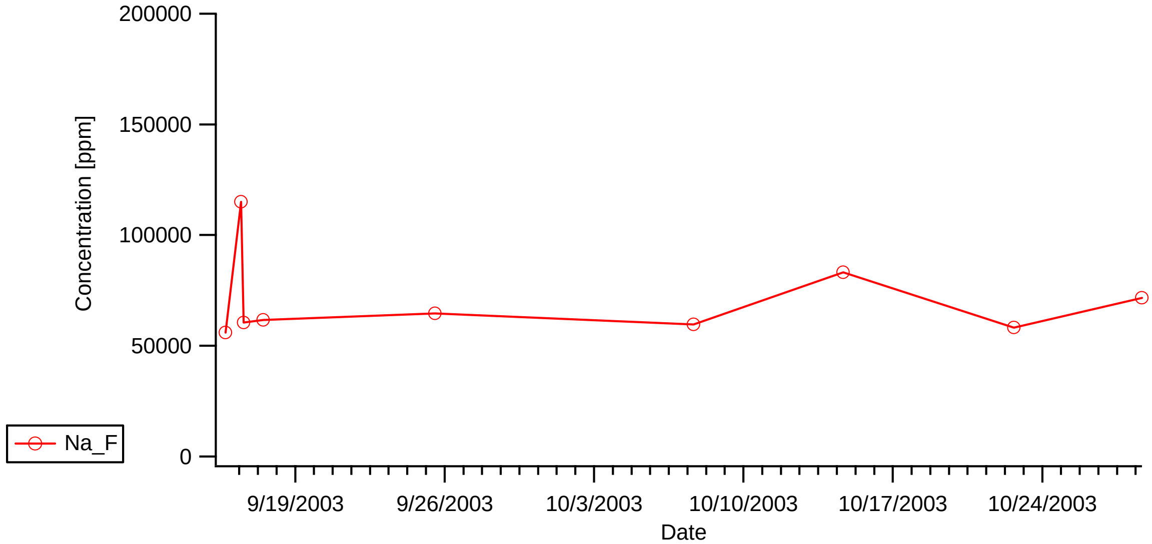

Figure 2-18. Evaporator Run 2 Feed (F) Concentrations in ppm for Large Changing Cations

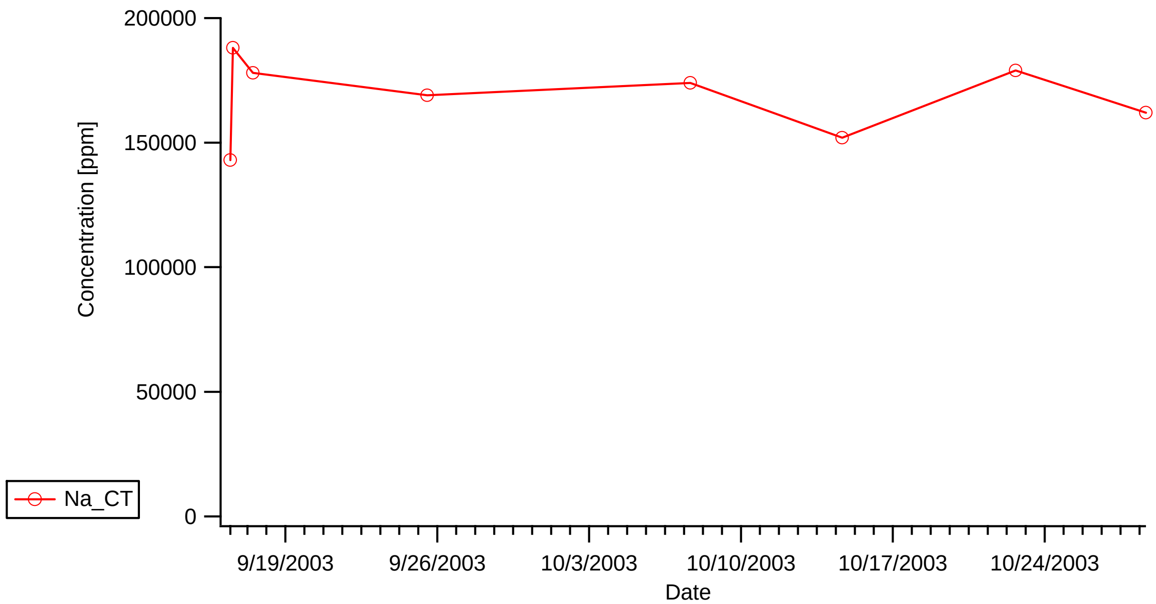

Figure 2-19. Evaporator Run 2 Concentrate Tank (CT) Concentrations in ppm for Large Changing Cations

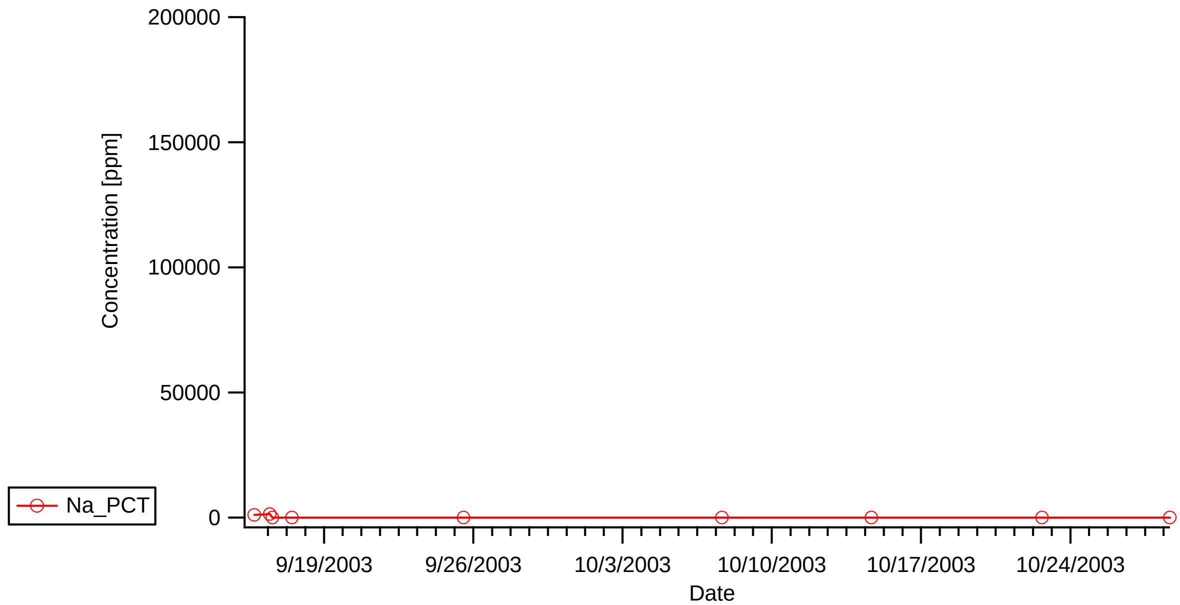

Figure 2-20. Evaporator Run 2 Primary Condensate Tank (PCT) Concentrations in ppm for Large Changing Cations

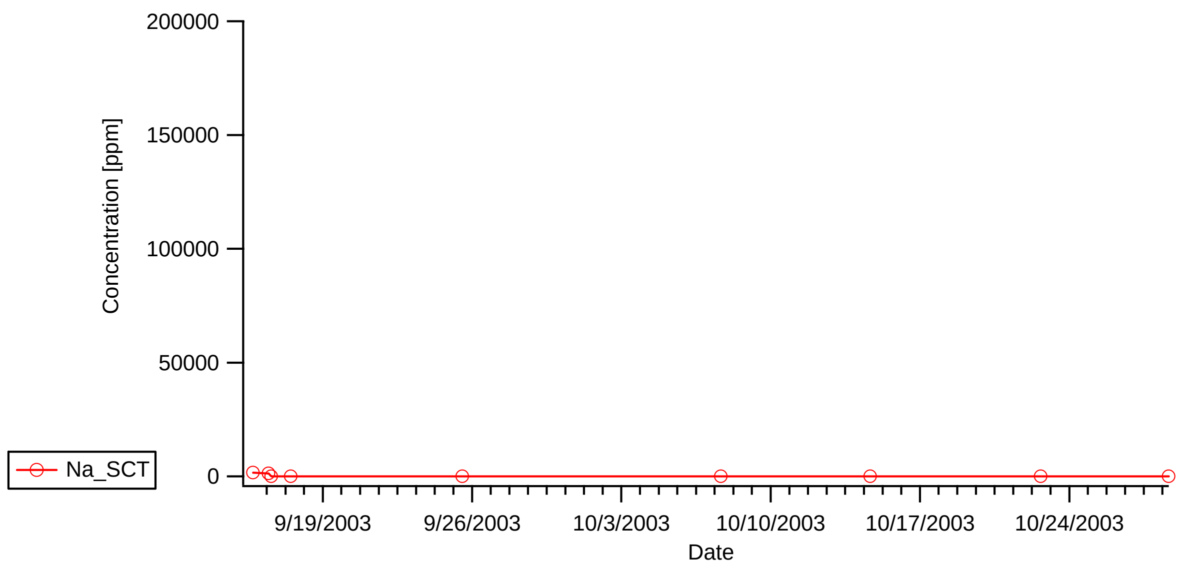

Figure 2-21. Evaporator Run 2 Secondary Condensate Tank (SCT) Concentrations in ppm for Large Changing Cations

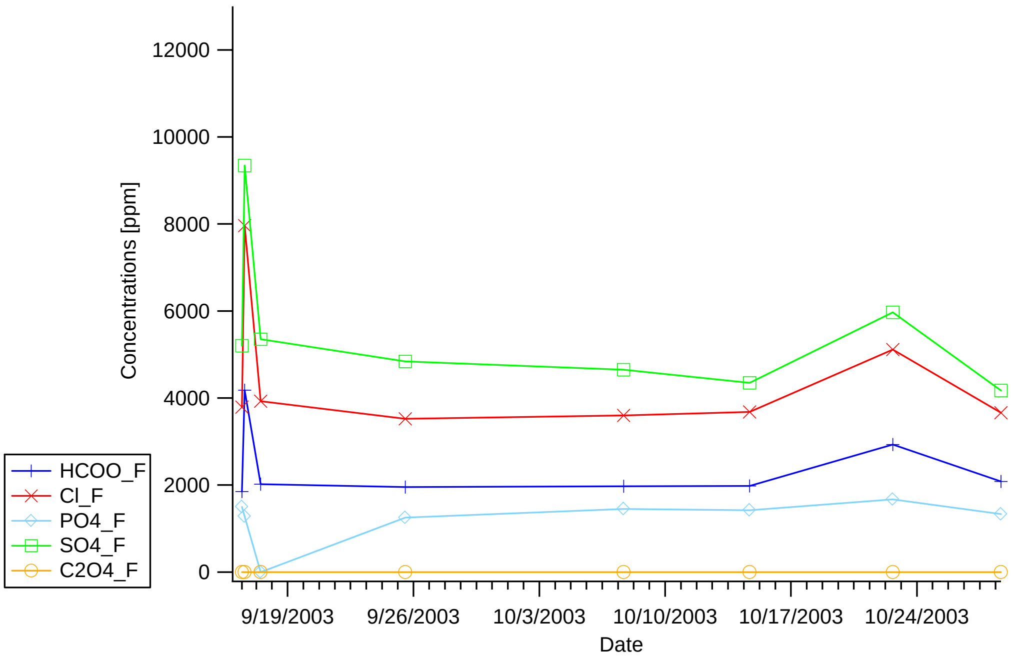

Figure 2-22. Evaporator Run 2 Feed Concentrations in ppm for Small Changing Anions

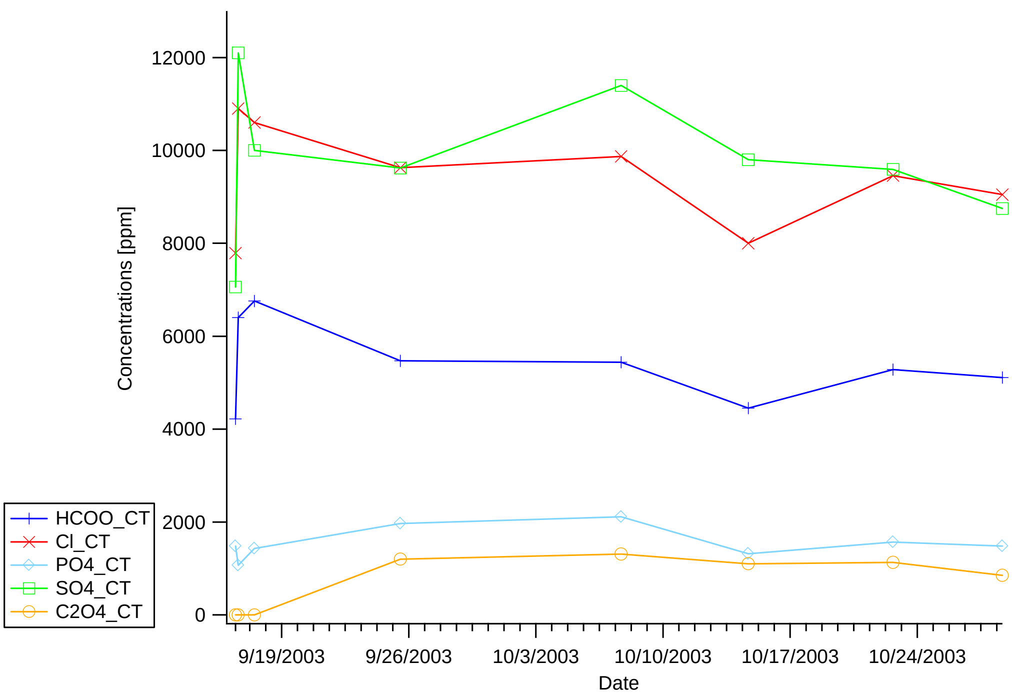

Figure 2-23. Evaporator Run 2 Concentrate Tank Concentrations in ppm for Small Changing Anions

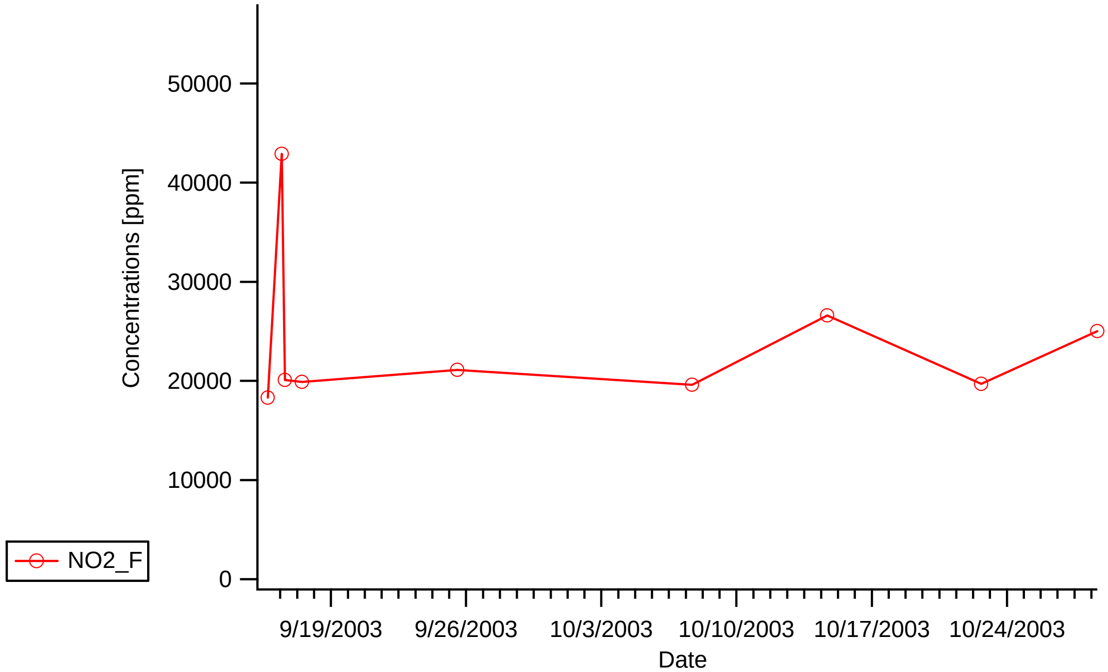

Figure 2-24. Evaporator Run 2 Feed Concentrations in ppm for Medium Changing Anions

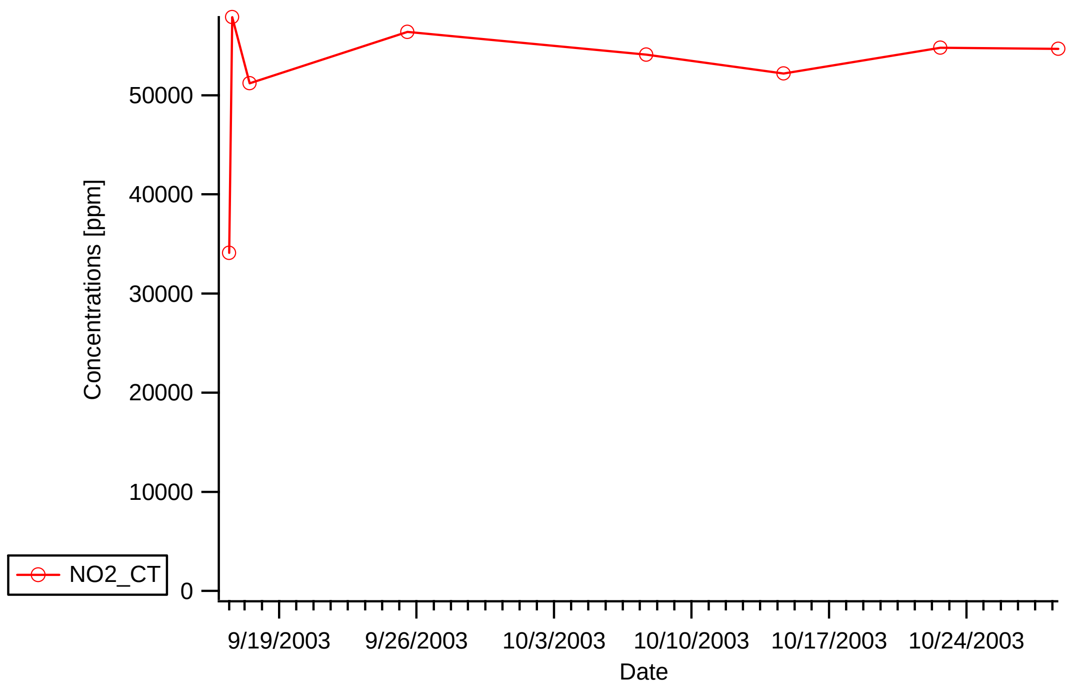

Figure 2-25. Evaporator Run 2 Concentrate Tank Concentrations in ppm for Medium Changing Anions

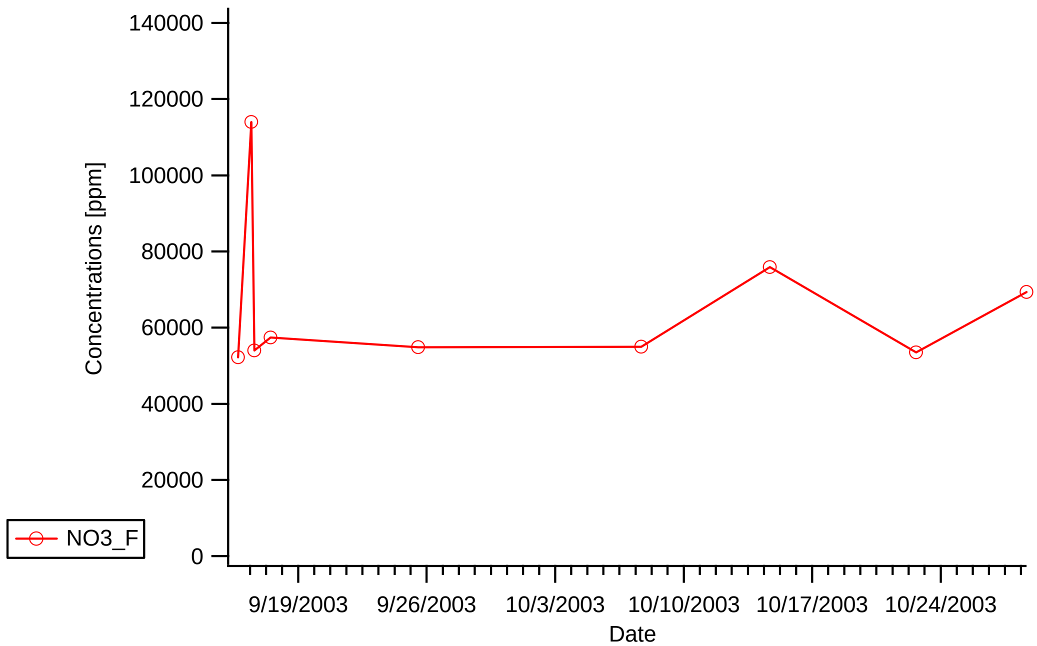

Figure 2-26. Evaporator Run 2 Feed Concentrations in ppm for Large Changing Anions

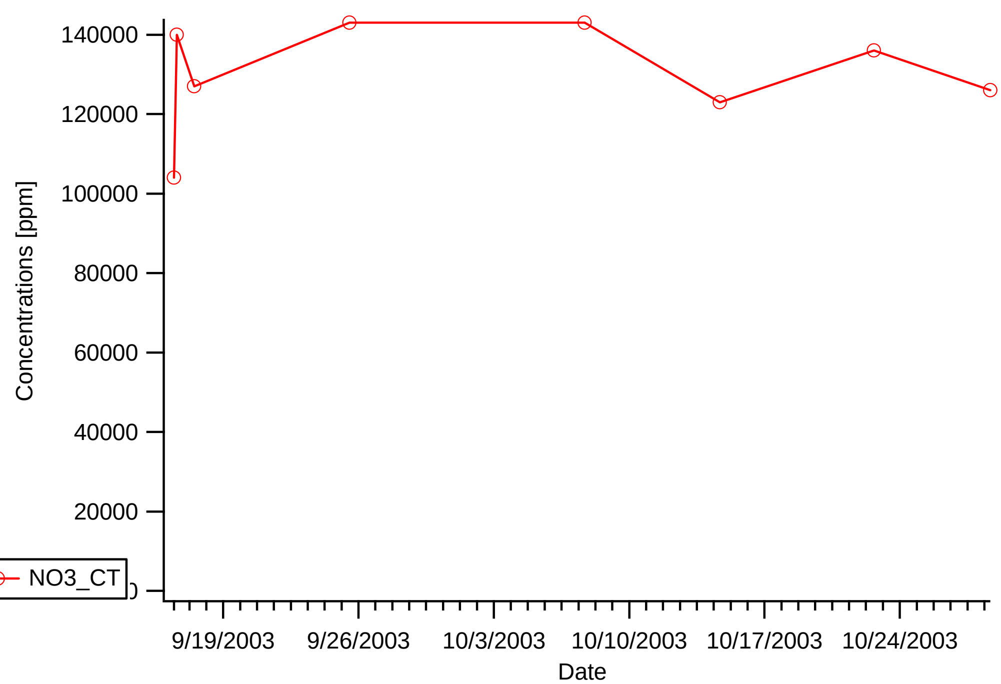

Figure 2-27. Evaporator Run 2 Concentrate Tank Concentrations in ppm for Large Changing Anions

Table 2-6. Evaporator Run 2 Cation Analyses for Feed and Concentrate Tank (CT)

Stream	Lab ID	Date Time	Density g/ml	pH	Al ppm	As ppm	B ppm	Ba ppm	Ca ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm	Fe ppm	K ppm	La ppm	Li ppm	Mg ppm
Feed	03-1861	9/15/2003 17:30	1.10	12.9	4480	<1.00	394	<0.010	77.5	14.3	0.554	<0.100	54.4	0.606	9.64	1110	0.383	10.6	<0.010
Feed	03-1864	9/16/2003 11:00	1.36	13.4	8110	<1.00	691	0.093	8.20	27.2	1.52	<0.100	109	1.44	3.36	2310	1.07	113	<0.010
Feed	03-1820	9/16/2003 14:00	1.14	13.3	3400	<1.00	361	<0.010	78.5	14.4	0.546	<0.100	62.2	0.88	12.3	1020	0.354	9.17	<0.010
Feed	03-1821	9/17/2003 12:00	1.16	13.4	3340	<1.00	340	<0.010	72.6	15.0	0.983	<0.100	62.9	1.03	6.72	1050	0.576	4.90	<0.010
Feed	03-1822	9/25/2003 13:00	1.17	13.4	3740	<1.00	356	<0.010	113	15.4	1.14	<0.100	66.8	1.33	7.22	1080	0.827	60.8	<0.010
Feed	03-1823	10/7/2003 16:00	1.15	13.5	3800	<1.00	361	<0.010	114	15.3	1.06	<0.100	66.7	1.33	10.9	1100	0.774	62.1	<0.010
Feed	03-1824	10/14/2003 16:00	1.23	13.7	5620	<1.00	497	<0.010	155	20.5	1.53	<0.100	92.0	1.88	18.1	1570	1.05	89.5	4.35
Feed	03-1825	10/22/2003 16:00	1.16	13.6	3940	<1.00	365	<0.010	106	14.9	1.06	<0.100	67.1	1.37	14.5	1090	0.703	65.0	<0.010
Feed	03-1826	10/28/2003 16:00	1.20	13.9	4520	<1.00	433	<0.010	127	18.5	1.35	<0.100	85.1	1.66	16.0	1250	0.826	81.7	3.30
CT	03-1865	9/16/2003 11:00	1.26	13.5	8630	<1.00	790	0.039	177	26.5	1.40	<0.100	106	1.10	10.5	2430	0.900	67.2	1.65
CT	03-1827	9/16/2003 14:00	1.52	13.5	10900	<1.00	1160	0.218	287	32.2	2.04	<0.100	167	3.35	13.2	3280	1.46	186.3	13.3
CT	03-1828	9/17/2003 12:00	1.61	13.5	10600	<1.00	1010	0.195	275	33.6	2.26	<0.100	168	3.47	20.1	3220	1.49	175.7	13.3
CT	03-1829	9/25/2003 13:00	1.58	13.6	10400	<1.00	938	0.166	266	32.5	2.78	<0.100	167	3.52	11.7	3180	1.84	155.4	12.8
CT	03-1830	10/7/2003 16:00	1.43	13.7	4960	<1.00	838	0.113	284	32.1	2.08	<0.100	97.2	2.97	7.60	3150	1.72	116.3	12.1
CT	03-1831	10/14/2003 16:00	1.47	13.6	8650	<1.00	752	0.085	242	28.5	2.43	<0.100	144	3.08	10.8	2530	1.67	147.2	11.7
CT	03-1832	10/22/2003 16:00	1.51	13.8	11000	<1.00	926	0.033	262	31.8	2.82	<0.100	166	3.83	12.6	3270	1.76	169.6	15.3
CT	03-1833	10/28/2003 16:00	1.49	13.7	9690	<1.00	825	<0.010	233	30.0	2.59	<0.100	154	3.39	16.5	2900	1.57	157.0	14.5

Table 2-6. Evaporator Run 2 Cation Analyses for Feed and Concentrate Tank (CT) - continued

Stream	Date Time	Mn ppm	Mo ppm	Na ppm	Nd ppm	Ni ppm	P ppm	Pb ppm	S ppm	Si ppm	Sn ppm	Sr ppm	Ti ppm	Tl ppm	V ppm	W ppm	Zn ppm	Zr ppm	Na Mol/L
Feed	9/15/2003 17:30	0.077	11.7	56000	1.26	85.0	334	8.02	1110	43.8	19.7	6.93	0.23	<0.100	<0.100	44.5	40.5	0.708	2.7
Feed	9/16/2003 11:00	4.02	23.6	115000	3.39	149	492	18.4	2310	9.68	38.7	55.3	1.15	<0.100	<0.100	87.4	146	4.00	6.8
Feed	9/16/2003 14:00	0.009	12.5	60500	1.31	96	367	11.3	1839	57.0	20.7	7.89	0.121	<0.100	<0.100	46.9	42.9	0.550	3.0
Feed	9/17/2003 12:00	0.015	12.7	61700	1.70	97	350	9.7	1785	45.8	21.8	6.13	0.047	<0.100	<0.100	47.9	36.4	0.614	3.1
Feed	9/25/2003 13:00	2.97	13.1	64600	2.19	100	381	10.6	1614	62.2	23.3	28.1	0.580	<0.100	<0.100	49.2	74.0	1.56	3.3
Feed	10/7/2003 16:00	3.34	12.9	59600	2.09	99	383	10.9	1597	67.5	22.6	26.7	0.617	<0.100	<0.100	48.6	76.7	1.65	3.0
Feed	10/14/2003 16:00	4.65	17.3	83200	2.86	137	530	14.4	2156	98.2	30.2	28.6	0.780	<0.100	<0.100	63.1	108	2.40	4.5
Feed	10/22/2003 16:00	3.23	12.7	58200	1.90	98	371	10.6	1550	69.6	22.7	12.9	0.574	<0.100	<0.100	48.3	74.6	1.46	2.9
Feed	10/28/2003 16:00	4.33	15.6	71700	2.28	125	469	13.0	1525	83.9	28.0	12.5	0.905	<0.100	<0.100	57.1	96.0	2.38	3.7
CT	9/16/2003 11:00	2.74	23.0	143000	2.94	146	457	17.2	2430	96.2	37.7	46.2	0.582	<0.100	<0.100	84.6	118	1.98	7.8
CT	9/16/2003 14:00	5.59	28.5	188000	4.58	249	551	25.6	4700	142	46.7	84.8	1.01	<0.100	<0.100	101	197	3.52	12.4
CT	9/17/2003 12:00	5.90	28.8	178000	4.62	248	1079	26.0	3711	147	48.6	73.9	0.970	<0.100	<0.100	94.6	197	3.50	12.5
CT	9/25/2003 13:00	7.05	28.6	169000	5.08	246	917	22.7	3333	135	47.4	71.5	0.956	<0.100	<0.100	106	178	3.50	11.6
CT	10/7/2003 16:00	5.25	12.3	174000	4.65	216	54.9	9.5	3551	69.0	27.6	73.7	0.052	<0.100	<0.100	39.3	178	1.91	10.8
CT	10/14/2003 16:00	7.43	25.2	152000	4.54	213	461	20.2	3213	127	42.6	55.1	0.976	<0.100	<0.100	93.3	162	3.18	9.7
CT	10/22/2003 16:00	8.12	28.1	179000	4.91	244	766	22.3	3676	139	47.3	33.2	1.17	<0.100	<0.100	101	181	3.96	11.8
CT	10/28/2003 16:00	7.65	26.5	162000	4.35	228	535	20.9	3200	144	44.3	23.5	0.997	<0.100	<0.100	97.8	171	3.37	10.5

Table 2-7. Evaporator Run 2 Cation Analyses for Primary (PCT) and Secondary (SCT) Condensate Tanks

Stream	Lab ID	Date Time	Den. g/ml	pH	Al ppm	As ppm	B ppm	Ba ppm	Ca ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm	Fe ppm	K ppm	La ppm	Li ppm	Mg ppm
PCT	03-1862	9/15/03 17:30	1.00	10.4	131	<0.100	4.89	<0.001	1.52	<0.010	<0.010	<0.010	<0.010	<0.001	1.94	1.00	<0.001	<0.100	<0.001
PCT	03-1866	9/16/03 11:00	1.01	11.6	1.69	<0.100	2.68	<0.001	1.48	<0.010	<0.010	<0.010	<0.010	<0.001	2.95	1.98	<0.001	<0.100	<0.001
PCT	03-1834	9/16/03 14:00	1.01	10.8	5.16	<0.100	4.76	<0.001	1.25	<0.010	<0.010	<0.010	<0.010	<0.001	1.23	0.668	<0.001	<0.100	<0.001
PCT	03-1835	9/17/03 12:00	1.01	11.1	2.05	<0.100	3.75	<0.001	1.36	<0.010	<0.010	<0.010	<0.010	<0.001	2.24	0.289	<0.001	<0.100	<0.001
PCT	03-1836	9/25/03 13:00	1.01	10.7	1.55	<0.100	3.11	<0.001	1.13	<0.010	<0.010	<0.010	<0.010	<0.001	0.736	0.302	<0.001	<0.100	<0.001
PCT	03-1837	10/7/03 16:00	1.01	10.2	1.60	<0.100	3.59	<0.001	1.17	<0.010	<0.010	<0.010	<0.010	<0.001	0.925	0.178	<0.001	<0.100	<0.001
PCT	03-1838	10/14/03 16:00	1.02	9.89	1.82	<0.100	3.75	<0.001	1.21	<0.010	<0.010	<0.010	<0.010	<0.001	1.33	0.150	<0.001	<0.100	<0.001
PCT	03-1839	10/22/03 16:00	1.00	9.95	1.64	<0.100	3.17	<0.001	1.48	<0.010	<0.010	<0.010	<0.010	<0.001	1.21	1.390	<0.001	<0.100	<0.001
PCT	03-1840	10/28/03 16:00	1.01	9.56	1.02	<0.100	3.67	<0.001	1.21	<0.010	<0.010	<0.010	<0.010	<0.001	0.886	0.255	<0.001	<0.100	<0.001
SCT	03-1863	9/15/03 17:30	1.01	11.0	23.9	<0.100	3.10	<0.001	3.01	<0.010	<0.010	<0.010	<0.010	<0.001	1.38	0.934	<0.001	<0.100	<0.001
SCT	03-1867	9/16/03 11:00	1.01	11.9	6.55	<0.100	3.22	<0.001	1.48	<0.010	<0.010	<0.010	<0.010	<0.001	2.99	0.101	<0.001	<0.100	<0.001
SCT	03-1841	9/16/03 14:00	1.00	11.4	2.95	<0.100	5.58	<0.001	1.70	<0.010	<0.010	<0.010	<0.010	<0.001	1.76	0.199	<0.001	<0.100	<0.001
SCT	03-1842	9/17/03 12:00	1.00	11.2	2.08	<0.100	3.87	<0.001	1.83	<0.010	<0.010	<0.010	<0.010	<0.001	2.47	0.154	<0.001	<0.100	<0.001
SCT	03-1843	9/25/03 13:00	1.00	10.4	1.17	<0.100	3.96	<0.001	1.62	<0.010	<0.010	<0.010	<0.010	<0.001	0.845	0.267	<0.001	<0.100	<0.001
SCT	03-1844	10/7/03 16:00	1.00	11.2	3.21	<0.100	3.90	<0.001	3.43	<0.010	<0.010	<0.010	<0.010	<0.001	2.82	0.131	<0.001	<0.100	<0.001
SCT	03-1845	10/14/03 16:00	1.00	10.6	1.43	<0.100	3.72	<0.001	1.56	<0.010	<0.010	<0.010	<0.010	<0.001	2.01	0.148	<0.001	<0.100	<0.001
SCT	03-1846	10/22/03 16:00	1.01	10.2	1.06	<0.100	3.44	<0.001	1.20	<0.010	<0.010	<0.010	<0.010	<0.001	0.708	0.56	<0.001	<0.100	<0.001
SCT	03-1847	10/28/03 16:00	1.01	9.65	0.84	<0.100	3.53	<0.001	1.81	<0.010	<0.010	<0.010	<0.010	<0.001	1.95	0.501	<0.001	<0.100	<0.001
KDL	03-1848	9/16/03 14:00	1.01	9.31	1.37	<0.100	4.83	<0.001	3.24	<0.010	<0.010	<0.010	<0.010	1.89	14.6	0.546	<0.001	<0.100	<0.001
KDL	03-1849	9/25/03 13:00	1.02	9.77	1.39	<0.100	3.03	<0.001	2.20	<0.010	<0.010	<0.010	<0.010	2.11	2.39	0.198	<0.001	<0.100	<0.001
KDL	03-1850	10/7/03 16:00	1.00	10.9	2.06	<0.100	3.57	<0.001	6.76	<0.010	<0.010	<0.010	<0.010	<0.001	1.99	0.503	<0.001	<0.100	<0.001
KDL	03-1851	10/14/03 16:00	1.01	9.61	1.49	<0.100	3.42	<0.001	2.37	<0.010	<0.010	<0.010	<0.010	<0.001	0.981	0.346	<0.001	<0.100	<0.001
KDL	03-1852	10/22/03 16:00	1.01	8.27	1.66	<0.100	3.85	<0.001	2.38	<0.010	<0.010	<0.010	<0.010	<0.001	1.62	0.636	<0.001	<0.100	<0.001
KDL	03-1853	10/28/03 16:00	1.01	11.4	1.16	<0.100	3.21	<0.001	2.14	<0.010	<0.010	<0.010	<0.010	<0.001	0.636	5.69	<0.001	<0.100	<0.001

Table 2-7. Evaporator Run 2 Cation Analyses for Primary (PCT) and Secondary (SCT) Condensate Tanks - continued

Stream	Date Time	Mn ppm	Mo ppm	Na ppm	Nd ppm	Ni ppm	P ppm	Pb ppm	S ppm	Si ppm	Sn ppm	Sr ppm	Ti ppm	Tl ppm	V ppm	W ppm	Zn ppm	Zr ppm	Na Mol/L
PCT	9/15/2003 17:30	<0.001	<0.010	1060	<0.002	<0.030	<0.100	<0.050	0.46	1.95	<0.050	0.686	<0.001	<0.010	<0.010	2.77	<0.001	<0.001	0.0
PCT	9/16/2003 11:00	<0.001	<0.010	1410	<0.002	<0.030	<0.100	<0.050	1.87	3.15	<0.050	0.687	<0.001	<0.010	<0.010	0.326	<0.001	<0.001	0.1
PCT	9/16/2003 14:00	<0.001	<0.010	31.6	<0.002	<0.030	0.639	<0.050	0.092	7.53	<0.050	<0.100	<0.001	<0.010	<0.010	0.174	<0.001	<0.001	0.0
PCT	9/17/2003 12:00	<0.001	<0.010	11.8	<0.002	<0.030	0.132	<0.050	0.156	11.8	<0.050	<0.100	<0.001	<0.010	<0.010	0.041	<0.001	<0.001	0.0
PCT	9/25/2003 13:00	<0.001	<0.010	14.4	<0.002	<0.030	<0.100	<0.050	0.113	5.53	<0.050	<0.100	<0.001	<0.010	<0.010	0.024	<0.001	<0.001	0.0
PCT	10/7/2003 16:00	<0.001	<0.010	19.8	<0.002	<0.030	<0.100	<0.050	0.112	7.12	<0.050	<0.100	<0.001	<0.010	<0.010	0.021	<0.001	<0.001	0.0
PCT	10/14/2003 16:00	<0.001	<0.010	15.6	<0.002	<0.030	<0.100	<0.050	0.092	8.73	<0.050	<0.100	<0.001	<0.010	<0.010	0.020	<0.001	<0.001	0.0
PCT	10/22/2003 16:00	<0.001	<0.010	10.3	<0.002	<0.030	<0.100	<0.050	0.162	6.18	<0.050	<0.100	<0.001	<0.010	<0.010	0.019	<0.001	<0.001	0.0
PCT	10/28/2003 16:00	<0.001	<0.010	7.66	<0.002	<0.030	<0.100	<0.050	0.056	7.47	<0.050	<0.100	<0.001	<0.010	<0.010	0.019	<0.001	<0.001	0.0
SCT	9/15/2003 17:30	<0.001	<0.010	1570	<0.002	<0.030	<0.100	<0.050	0.415	2.02	<0.050	0.690	<0.001	<0.010	<0.010	0.384	<0.001	<0.001	0.1
SCT	9/16/2003 11:00	<0.001	<0.010	1260	<0.002	<0.030	<0.100	<0.050	0.086	4.76	<0.050	<0.100	<0.001	<0.010	<0.010	0.031	<0.001	<0.001	0.1
SCT	9/16/2003 14:00	<0.001	<0.010	7.03	<0.002	<0.030	<0.100	<0.050	0.130	8.10	<0.050	<0.100	<0.001	<0.010	<0.010	0.204	<0.001	<0.001	0.0
SCT	9/17/2003 12:00	<0.001	<0.010	9.01	<0.002	<0.030	<0.100	<0.050	0.127	10.3	<0.050	<0.100	<0.001	<0.010	<0.010	0.037	<0.001	<0.001	0.0
SCT	9/25/2003 13:00	<0.001	<0.010	32.7	<0.002	<0.030	<0.100	<0.050	0.162	8.14	<0.050	<0.100	<0.001	<0.010	<0.010	0.021	<0.001	<0.001	0.0
SCT	10/7/2003 16:00	<0.001	<0.010	13.5	<0.002	<0.030	<0.100	<0.050	0.119	10.3	<0.050	<0.100	<0.001	<0.010	<0.010	0.022	<0.001	<0.001	0.0
SCT	10/14/2003 16:00	<0.001	<0.010	8.05	<0.002	<0.030	<0.100	<0.050	0.103	8.14	<0.050	<0.100	<0.001	<0.010	<0.010	0.018	<0.001	<0.001	0.0
SCT	10/22/2003 16:00	<0.001	<0.010	13.6	<0.002	<0.030	<0.100	<0.050	0.152	7.55	<0.050	<0.100	<0.001	<0.010	<0.010	0.020	<0.001	<0.001	0.0
SCT	10/28/2003 16:00	<0.001	<0.010	24.0	<0.002	<0.030	<0.100	<0.050	0.366	10.3	<0.050	<0.100	<0.001	<0.010	<0.010	0.018	<0.001	<0.001	0.0
KDL	9/16/2003 14:00	<0.001	0.156	10.6	<0.002	<0.030	<0.100	<0.050	0.842	6.97	<0.050	<0.100	<0.001	<0.010	<0.010	0.342	<0.001	<0.001	0.0
KDL	9/25/2003 13:00	<0.001	0.100	7.57	<0.002	<0.030	<0.100	<0.050	0.379	5.53	<0.050	<0.100	<0.001	<0.010	<0.010	0.114	<0.001	<0.001	0.0
KDL	10/7/2003 16:00	<0.001	<0.010	14.6	<0.002	<0.030	<0.100	<0.050	0.133	7.49	<0.050	<0.100	<0.001	<0.010	<0.010	0.043	<0.001	<0.001	0.0
KDL	10/14/2003 16:00	<0.001	<0.010	22.4	<0.002	<0.030	<0.100	<0.050	0.281	7.59	<0.050	<0.100	<0.001	<0.010	<0.010	0.028	<0.001	<0.001	0.0
KDL	10/22/2003 16:00	<0.001	<0.010	30.6	<0.002	<0.030	<0.100	<0.050	0.526	11.1	<0.050	<0.100	<0.001	<0.010	<0.010	0.035	<0.001	<0.001	0.0
KDL	10/28/2003 16:00	<0.001	<0.010	203	<0.002	<0.030	<0.100	<0.050	4.02	55.9	<0.050	<0.100	<0.001	<0.010	<0.010	0.024	<0.001	<0.001	0.0

Table 2-8. Evaporator Run 2 Anion Analyses

Stream	Lab ID	Process Date	HCOO ppm	Cl ppm	NO2 ppm	NO3 ppm	PO4 ppm	SO4 ppm	C2O4 ppm
CT	03-1865	9/16/2003 11:00	4220	7790	34100	104000	1480	7060	<1000
CT	03-1827	9/16/2003 14:38	6400	10900	57900	140000	1070	12100	<1000
CT	03-1828	9/17/2003 12:00	6760	10600	51200	127000	1430	10000	<1000
CT	03-1829	9/25/2003 13:00	5470	9630	56400	143000	1970	9620	1200
CT	03-1830	10/7/2003 16:40	5440	9870	54100	143000	2110	11400	1310
CT	03-1831	10/14/2003 16:40	4450	8000	52200	123000	1320	9800	1100
CT	03-1832	10/22/2003 16:00	5280	9460	54800	136000	1570	9590	1130
CT	03-1833	10/28/2003 16:20	5110	9050	54700	126000	1480	8750	853
Feed	03-1861	9/15/2003 17:30	1850	3790	18300	52200	1500	5200	<1000
Feed	03-1864	9/16/2003 11:00	4180	7960	42900	114000	1280	9340	<1000
Feed	03-1820	9/16/2003 14:38	2020	3930	20100	54000	<1000	5350	<1000
Feed	03-1821	9/17/2003 12:00	1950	3520	19900	57400	1250	4840	<1000
Feed	03-1822	9/25/2003 13:00	1970	3600	21100	54800	1450	4650	<1000
Feed	03-1823	10/7/2003 16:40	1980	3680	19600	55000	1420	4350	<1000
Feed	03-1824	10/14/2003 16:40	2930	5110	26600	75900	1670	5970	<1000
Feed	03-1825	10/22/2003 16:00	2080	3660	19700	53500	1330	4170	<1000
Feed	03-1826	10/28/2003 16:20	2560	4740	25000	69300	1500	4570	<1000
KDL	03-1848	9/16/2003 14:38	<100	<100	<100	<100	<100	<100	<100
KDL	03-1849	9/25/2003 13:00	<100	<100	<100	<100	<100	<100	<100
KDL	03-1850	10/7/2003 16:40	<100	<100	<100	<100	<100	<100	<100
KDL	03-1851	10/14/2003 16:40	<100	<100	<100	<100	<100	<100	<100
KDL	03-1852	10/22/2003 16:00	<100	<100	<100	<100	<100	<100	<100
KDL	03-1853	10/28/2003 16:20	<100	<100	<100	<100	<100	<100	<100
PCT	03-1862	9/15/2003 17:30	<100	<100	<100	<100	<100	<100	<100
PCT	03-1866	9/16/2003 11:00	<100	<100	<100	<100	<100	<100	<100
PCT	03-1834	9/16/2003 14:38	<100	<100	<100	<100	<100	<100	<100
PCT	03-1835	9/17/2003 12:00	<100	<100	<100	<100	<100	<100	<100
PCT	03-1836	9/25/2003 13:00	<100	<100	<100	<100	<100	<100	<100
PCT	03-1837	10/7/2003 16:40	<100	<100	<100	<100	<100	<100	<100
PCT	03-1838	10/14/2003 16:40	<100	<100	<100	<100	<100	<100	<100
PCT	03-1839	10/22/2003 16:00	<100	<100	<100	<100	<100	<100	<100
PCT	03-1840	10/28/2003 16:20	<100	<100	<100	<100	<100	<100	<100
SCT	03-1863	9/15/2003 17:30	<100	<100	<100	<100	<100	<100	<100
SCT	03-1867	9/16/2003 11:00	<100	<100	<100	<100	<100	<100	<100
SCT	03-1841	9/16/2003 14:38	<100	<100	<100	<100	<100	<100	<100
SCT	03-1842	9/17/2003 12:00	<100	<100	<100	<100	<100	<100	<100
SCT	03-1843	9/25/2003 13:00	<100	<100	<100	<100	<100	<100	<100
SCT	03-1844	10/7/2003 16:40	<100	<100	<100	<100	<100	<100	<100
SCT	03-1845	10/14/2003 16:40	<100	<100	<100	<100	<100	<100	<100
SCT	03-1846	10/22/2003 16:00	<100	<100	<100	<100	<100	<100	<100
SCT	03-1847	10/28/2003 16:20	<100	<100	<100	<100	<100	<100	<100

2.7.4 Organic Partitioning

During Test 2, the evaporator pot was spiked with organics to examine the partitioning of volatile and semi-volatile organics across the evaporator. The organics were spiked into the evaporator pot in 10-ml ampoules each containing 0.01 g total organics in the portions as shown in Table 2-9. Initially 54 ampoules of the organics were added to 100 gallons in the evaporator pot on 9/16/03. After the initial charge, then the10-ml ampoules were added per 10 gallon of feed through 9/17/03. During the period of the organic spikes, liquid and offgas samples were pulled and analyzed. Liquid samples were taken for the feed, concentrate, primary and secondary condensates. Details of the liquid organic sampling are contained in the BWXT report [8] [*Westinghouse Savannah River Company BWXS Data reporting Package 0309037, BWXS-NELS Project Number 1199-011-23-70, SRTC Contract Number AB80151N (CO-7), Job 03477 – Evaporator Simulant, Characterization of Evaporator Simulant*, October 10, 2003, BWXT Services, Inc, Nuclear Environmental Laboratory Services, Lynchburg, VA.]. Offgas samples were taken coming off the primary condenser using the EPA Method 0010. Details of the offgas sampling are detailed in the Air Tech reportv[9] [Memo to Zafar Qureshi, October 27, 2003, Air-Tech Environmental, LLC, Research Triangle Park, NC.].

Table 2-9. Organic Spike in 10-ml Ampoules

Organic	Amount	Organic	Amount
1,4-Dinitrobenzene (100-25-4)	0.00125 g	Hexachloroethane (67-72-1)	0.00125 g
N-Nitrosodimethlyamine (62-75-9)	0.00125 g	Naphthalene (91-20-3)	0.00125 g
1,2-Dibromoethane (106-93-4)	0.00125 g	2-Chloronaphthalen (91-58-7)	0.00125 g
Quinoline (91-22-5)	0.00125 g	Diethylphthalate (84-66-2)	0.00125 g

Table 2-10 and Table 2-13 show how the spiked organics partitioned across the evaporator streams. The volatile organic dibromoethane all went out into the evaporator overheads, but 97% was condensed out in the primary and secondary condensers with only about 3% going up into the offgas. Hexachloroethane primarily escaped into the offgas (86%) with none coming out in the primary condenser and only 1% in the secondary condensers while the remainder (13%) stays in the evaporator concentrate. Naphthalene was the next biggest organic to make it to the offgas system (23%) with only 10% being captured by the primary and secondary condensers. A large portion of the Naphthalene (67%) did remain behind in the evaporator concentrate. Both Hexachloroethane and Naphthalene sublime at temperatures below their melting points so as these components escape into the offgas stream as a vapor and are cooled down below their melting points, they sublime back into the offgas rather than condensing into the liquid phase. The other components don't readily sublime and thus little makes into the offgas stream from the condensers. Of the remaining Semivolatile organics, most were captured in the primary and secondary condensate with little remaining in the evaporator concentrate ($\leq$ 5%).

Prior waste feed evaporator modeling [Daniel, W.E., Waste Feed Evaporator Off-Gas Emissions Modeling, Westinghouse Savannah River Co.: Aiken, SC 29808 (2002)] had looked at organic partitioning across the waste feed evaporator system. Unfortunately these earlier modeling results cannot be compared to the current pilot runs because the offgas model had a feed based on the Envelope B/D waste with Envelope C organic levels and a HAW SBS recycle where as the pilot work used an AN102 (Envelope C) waste and LAW SBS recycle. To try to compensate for these differences, the offgas model was re-run with a feed based on analyses of the AN-102 (Envelope C) waste and LAW SBS. Results from this modeling run are shown in Table 2-11.

For 1,2-Dibromoethane, naphthalene, and 2-Chloronaphthalene the model predicts more of these species goes up into the offgas than the pilot run. One reason for this difference is that the pilot run used a knock-out drum with demister pad, whereas the OLI model assumed only a 1% entrainment for its simulated demister. In the real world the knock-out drum may be more effective at reducing the offgas species than the simulated demister.

The model predictions for Hexachloroethane, Diethyl-phthalate, and Quinoline match more closely with the pilot values than for the other species. However there are still differences between the model predictions and the pilot run. The difference may be due to the pressure and temperature offsets between the OLI model and the actual pilot runs. The pilot runs were not instrumented to provide the necessary data required for proper modeling. Estimates of the various pressures used in the model may not match the actual pilot values. The offgas modeling parameters are shown in Table 2-12. By adjusting these model inputs, the organic splits could be made closer to the measured values. Without the necessary time and funding, the best estimates for the model inputs were chosen based on the limited information available.

Another reason for the discrepancy between the pilot work and OLI modeling is that the OLI model represents steady state simulation, i.e. not dynamic like the real process. The organic spiking and organic sampling occurred over a 2 hour period during which flow rates, temperature profiles, pressure profiles, and feed concentrations were changing. One more reason for the differences can be due to the solubility and sublimation characteristics of the species in OLI versus the real pilot work.

Table 2-10. Percent Organic Partitioning Across Pilot Evaporator

	1,2-Dibromo ethane (106-93-4)	Hexachlo roethane (67-72-1)	Naphth-alene (91-20-3)	2-Chloro-naphtha-len (91-58-7)	Diethylp hthalate (84-66-2)	N-Nitrosodi methlya mine (62-75-9)	Quinoline (91-22-5)	1,4-Dinitro-benzene (100-25-4)
	Volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics
Stream	%	%	%	%	%	%	%	%
Feed	0%	0%	0%	0%	0%	0%	0%	0%
Primary Condensate	57%	0%	6%	8%	100%	95%	98%	99%
Secondary Condensate	40%	1%	4%	1%	0%	0%	0%	0%
Offgas	3%	86%	23%	0%	0%	0%	0%	0%
Concentrate	0%	13%	67%	91%	0%	5%	2%	1%

Table 2-11. Percent Organic Partitioning Across OLI Modeled Evaporator

Stream	1,2-Dibromo-ethane	Hexachlo-roethane	Naph-thalene	2-Chloro-naphthalene	Diethyl - phthalate	Phenol (sub for N-Nitroso-dimethly-amine)	Quinoline	1,4-Dinitro-benzene	Ethanol
Feed									
Primary Condensate	7.50%	0.50%	4.54%	14.76%	85.23%	0.00%	79.49%	24.08%	92.73%
Secondary Condensate	11.87%	0.89%	7.49%	20.61%	0.13%	0.00%	18.85%	0.00%	6.96%
Offgas	80.62%	98.61%	87.96%	64.62%	0.00%	0.00%	1.41%	0.00%	0.07%
Concentrate	0.01%	0.00%	0.01%	0.01%	14.64%	100%	0.25%	75.92%	0.24%

Table 2-12. OLI Evaporator Modeling Parameters

Model Unit	Evaporator	Primary Condenser	PC Control Air Mixer	Steam Ejector 1	Inter-Condenser	Steam Ejector 2	After Condenser	After Condenser Demister
Temperature, °C	45	22	adiabatic	adiabatic	22	adiabatic	22	22
Pressure, psia	0.995	0.385	0.366	3.29	3.13	15.44	14.7	14.7

Table 2-13. Mass Organic Partitioning Across Pilot Evaporator

	1,2-Dibromoethane (106-93-4)	Hexachloroethane (67-72-1)	Naph-thalene (91-20-3)	2-Chloronaphthalen (91-58-7)	Diethylphthalate (84-66-2)	N-Nitrosodimethlyamine (62-75-9)	Quinoline (91-22-5)	1,4-Dinitrobenzene (100-25-4)
	Volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics	Semi-volatile Organics
Stream	μg/hr	μg/hr	μg/hr	μg/hr	μg/hr	μg/hr	μg/hr	μg/hr
Feed	0	0	0	0	0	636	609	0
Primary Condensate	2511	148	2681	2211	2230	150,040	325,288	160,931
Secondary Condensate	1753	375	1971	189	0	64	177	14
Offgas	115	48,000	10,560	0	0	0	0	0
Concentrate	0	7099	30,347	24,539	0	7812	6758	1268

2.7.5 Formation of Solids and Fouling

The formation of solids was examined due to concerns over a plug in the concentrate transfer line just upstream of valve CL-BV5. Consequently, fouling of the reboiler tubes due to materials in the evaporator pot was also of concern. Solids formation occurred during the blending of the individual recycle streams prior to Evaporation Test 1. Samples of the initial feed streams and the concentrated slurry were taken during Evaporation Test 1 to determine what solids formed during the evaporation of the recycles. Results indicate the formation of sodium alumino-silicates and other solids during Test 1, as shown in Table 2-14. In earlier bench-scale experiments [M. E. Stone et al, Waste Feed Evaporation: Physical Properties and Solubility Determination(U), WSRC-TR-2003-00212, Rev. 0, WSRC, Aiken, SC 29808] for Envelope A recycle evaporation with 50% SBS, gibbsite, bayerite, natrophosphate, and lithium aluminum hydroxide hydrate solids formed in the evaporator concentrate. The pilot evaporation concentrate also showed formation of bayerite and Lithium Aluminum Carbonate Hydroxide.

Table 2-14. Solids in the Evaporator Run 1 Samples

Solids in HLW Melter Offgas Condensate	Solids in UF Recycle	Solids in Evaporator Feed	Solids in Evaporator Concentrate
Hematite (Fe_2O_3)	N/A	Hematite (Fe_2O_3)	Hematite (Fe_2O_3)
Quartz (SiO_2)	N/A	Quartz (SiO_2)	Quartz (SiO_2)
N/A	Gibbsite ($Al(OH)_3$)	N/A	N/A
N/A	Bayerite ($Al(OH)_3$)	Bayerite ($Al(OH)_3$)	Bayerite ($Al(OH)_3$)
Maghemite-C (Fe_2O_3)	N/A	N/A	N/A
N/A	N/A	Nordstrandite ($Al(OH)_3$)	Nordstrandite ($Al(OH)_3$)
N/A	N/A	N/A	Nitratine ($NaNO_3$)
N/A	N/A	Sodium Nitrite ($NaNO_2$)	Sodium Nitrite ($NaNO_2$)
N/A	N/A	Lithium Aluminum Carbonate Hydroxide ($Li_2Al_4(CO_3)(OH)\cdot 3H_2O$)	Lithium Aluminum Carbonate Hydroxide ($Li_2Al_4(CO_3)(OH)\cdot 3H_2O$)
N/A	N/A	N/A	Sodium Alumino-silicate Hydrate ($Na_2Al_2Si_{15.7}O_{36.4}\cdot 8H_2O$)

The temperature of the reboiler (to maintain the desired boil-off rate) did not increase during Evaporator Test 1, indicating that very little fouling was occurring on the tubes. Visual observation of the interior of the heat exchanger tubes confirmed that very little fouling had occurred during Evaporator Test 1. The small amount of solids present on the tubes during Test 1 was easily removed by wiping. Visual examination indicates that the solids from Evaporator Run 1 are similar to the bulk solids in the concentrate stream. No other solids formation was observed in balance of the loop. This was checked by breaking the loop at the ball valve unions.

The splatter during Evaporator Test 1 led to a buildup of dried solids in the evaporator walls below the demister. These solids were very friable and easily removed by wiping. Antifoam was not added at the beginning of Test 1 to allow the foaming characteristics of the feed to be evaluated. The amount of splatter was significantly reduced by the antifoam addition. Therefore the amount of solids buildup in this area of the evaporator is not representative.

The solids that formed during Evaporator Test 2 are shown in Table 2-15. The solids were determined by first filtering the concentrate and submitting that filtered material for X-Ray Diffraction (XRD). This XRD was treated as representing the insoluble and some soluble species since it contained some interstitial supernate. The filtrate from the original concentrate sample was re-filtered, dried in a desiccator, and then submitted for XRD. This re-filtered desiccator sample was treated as a blank or representing the soluble solids. The difference between the original filtered sample and the re-filtered filtrate represented the insoluble species that actually formed. The only common solid between Evaporator Run 1 and 2 is Lithium Aluminum Carbonate Hydroxide Hydrate - $Al_2Li(OH)_6)_2CO_3 \cdot xH_2O$. Evaporator Run 2 also did not show any evidence of the formation of Sodium Alumino-silicate Hydrate ($Na_2Al_2Si_{15.7}O_{36.4} \cdot 8H_2O$) like Run 1. In earlier bench scale evaporation experiments with envelope AN-102 feed [M. L. Crowder et al, Bench-Scale Evaporation of a Large Hanford Envelope C Sample (Tank 241-AN-102), WSRC-TR-2000-00469, WSRC, Aiken, SC, 29808], natroxalate, silica, natrophosphate, sodium nitrate, sodium carbonate hydrogen hydrate, and thermonatrite formed. The pilot 2 run also showed evidence of the formation of natroxalate, natrophosphate, sodium carbonate hydrogen hydrate, and thermonatrite in the evaporator concentrate and on the reboiler walls.

The only evidence of fouling or scaling occurred on 10/6/03 about 29 hours into the 100-hour boil, when a plug occurred in the concentrate loop. A sample of this plug was sent off for XRD. The results are shown in Table 2-15. The plug contains a lot of solids like bayerite, kogarkoite, natrophosphate, nitratine, thermonatrite, trona, and lithium aluminum carbonate hydroxide hydrate. However, the plug did not contain any sodium alumino-silicate hydrate. The plug in the concentrate line was attributed to loop configuration where a low velocity/ dead zone existed under certain valve settings. The concentrate line was reconfigured and no further pluggage was observed.

When the heat exchanger tubes of the reboiler were examined at the end of Evaporator Test 2, a few solids were found on the inside heat exchanger walls. A sample of that material was submitted for XRD and the results are shown in Table 2-15. The common solids between the heat exchanger scale and Evaporator Run 1 were Lithium Aluminum Carbonate Hydroxide Hydrate - $(Al_2Li(OH)_6)_2CO_3 \cdot xH_2O$ and Nitratine $NANO_3$. This scale however was not significant.

Table 2-15. Solids in Evaporator Run 2 Samples

Solids in Evaporator Concentrate	Solids in Evaporator Loop Plug	Solids on Reboiler Walls at End of Run
N/A	Bayerite $(Al(OH)_3)$	N/A
Kogarkoite - Na_3FSO4	Kogarkoite - Na_3FSO4	Kogarkoite - Na_3FSO4
Natrophosphate $Na_7F(PO_4)_2(H_2O)_{19}$	Natrophosphate $Na_7F(PO_4)_2(H_2O)_{19}$	N/A
N/A	Nitratine $NANO_3$	Nitratine $NANO_3$
Thermonatrite $Na_2CO_3 \cdot H_2O$	Thermonatrite $Na_2CO_3 \cdot H_2O$	N/A
N/A	Trona - Na3H(CO3)2!2H2O	N/A
Lithium Aluminum Carbonate Hydroxide Hydrate - $(Al_2Li(OH)_6)_2CO_3{\cdot}xH_2O$	Lithium Aluminum Carbonate Hydroxide Hydrate - $(Al_2Li(OH)_6)_2CO_3{\cdot}xH_2O$	Lithium Aluminum Carbonate Hydroxide Hydrate - $(Al_2Li(OH)_6)_2CO_3{\cdot}xH_2O$
Natroxalate $C_2Na_2O_4$	N/A	N/A
N/A	N/A	N/A
N/A	N/A	Sodium Carbonate Hydrogen Hydrate $Na_2CO_3NaHCO_3(H_2O)_2$
N/A	N/A	Pirrsonite $Na_2Ca(CO_3)_2$!2H2O

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3.0 FUTURE WORK

The Pilot-Scale Evaporator was designed to concentrate a variety of waste streams under forced circulation and vacuum conditions. After completing three evaporation campaigns (one with water and two with simulated waste streams) described in this report, the evaporator is being prepared for use in the upcoming Hanford WTP Semi-Integrated Pilot Plant (SIPP) tests.

As the full-scale evaporator design/procurement is progressing, WTP can test or verify the performance of any of the evaporator subsystem such as demister, concentrate loop configuration, injection of antifoam agent etc. using the Pilot-Scale Evaporator. The Pilot-Scale Evaporator can also be used to address issues during the startup or normal operations of the full-scale facility.

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4.0 REFERENCES

1. BNFL-003-98-0189, Revision 0, Envelopes A, B, and C Shaker/ Bath Evaporation Saturation Studies, P. R. Monson January 4, 2000, Westinghouse Savannah River Company, Aiken, South Carolina.

2. BNFL-003-98-0166, Revision 0, Evaporation of Hanford Envelope B Simulant (AZ-101) Preliminary Report, T. B. Calloway, January 6, 2000, Westinghouse Savannah River Company, Aiken, South Carolina.

3. BNFL-003-98-0080, Revision 0, Preliminary Modeling Results of Pretreated LAW Evaporator, A. S. Choi, June 1, 1999, Westinghouse Savannah River Company, Aiken, South Carolina.

4. T. B. Calloway, Evaporation of Hanford Envelope A Simulant (AN-105), WSRC-TR-2000-00300, August 2000.

5. C. L. Crawford, et. al., Crucible-Scale Active Vitrification Testing Envelope A, Tank 241-AN103 (U), WSRC-TR-2000-00302, 9/15/2000.

6. H. H. Saito, et. al., AN-107 © Simulant Bench-Scale LAW Evaporation with Organic Regulatory Analysis, WSRC-TR-2000-00486, Feb 2001

7. M. L. Crowder, Bench-Scale Evaporation of a Large Hanford Envelope C Sample (Tank 241-AN-102), WSRC-TR-2000-00469, Feb 2001

8. *Westinghouse Savannah River Company BWXS Data reporting Package 0309037, BWXS-NELS Project Number 1199-011-23-70, SRTC Contract Number AB80151N (CO-7), Job 03477 – Evaporator Simulant, Characterization of Evaporator Simulant*, October 10, 2003, BWXT Services, Inc, Nuclear Environmental Laboratory Services, Lynchburg, VA.

9. Memo to Zafar Qureshi, October 27, 2003, Air-Tech Environmental, LLC, Research Triangle Park, NC.

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APPENDIX A. RECIPE FOR FIRST WASH

Total volume of 1st wash simulant 448.4 liters

	Compounds	Formula	Mass (Grams)
1	Sodium Chloride	NaCl	1572.85
2	Sodium Fluoride	NaF	1274.92
3	Sodium Sulfate	Na2SO4	1130.38
4	Sodium Hydroxide	NaOH	8955.68
5	Sodium Aluminate	Na2O.Al2O3.3H2O	13231.73
6	Sodium meta-silicate	Na2SiO3.9H2O	476.99
7	Sodium Oxalate	Na2C2O4	719.23
8	Sodium Phosphate	Na3PO4.12H2O	2658.96
9	Sodium Carbonate	Na2CO3	9939.10
10	Sodium Nitrate	NaNO3	32492.48
11	Sodium Nitrite	NaNO2	20721.33
12	Water	H2O	422486.35
		Final Mass	**515660.00**
		Density (g/ml)	**1.15**

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APPENDIX B. RECIPE FOR SECOND WASH

Total volume of 2nd. wash simulant 448.4 liters

	Compounds	Formula	Mass (Grams)
1	Sodium Chloride	NaCl	273.13
2	Sodium Sulfate	Na2SO4	72.93
3	Sodium Hydroxide	NaOH	11315.88
4	Sodium Aluminate	Na2O.Al2O3.3H2O	8887.72
5	Sodium meta-silicate	Na2SiO3.9H2O	258.06
6	Sodium Phosphate	Na3PO4.12H2O	287.03
7	Sodium Carbonate	Na2CO3	1357.24
8	Sodium Nitrate	NaNO3	61.47
9	Sodium Nitrite	NaNO2	121.07
10	Water	H2O	446024.19
		Final Mass	**468658.72**
		Density (g/ml)	**1.045**

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APPENDIX C. RECIPE FOR LEACH

Total volume of Leach simulant 62.32 liters

	Compounds	Formula	Mass (Grams)
1	Sodium Chloride	NaCl	91.30
2	Sodium Sulfate	Na2SO4	20.26
3	Sodium Hydroxide	NaOH	4400.11
4	Sodium Aluminate	Na2O.Al2O3.3H2O	2616.50
5	Sodium meta-silicate	Na2SiO3.9H2O	75.63
6	Sodium Phosphate	Na3PO4.12H2O	52.38
7	Sodium Carbonate	Na2CO3	495.40
8	Sodium Nitrate	NaNO3	13.67
9	Sodium Nitrite	NaNO2	39.26
10	Water	H2O	61682.29
		Final Mass	**69486.80**
		Density	**1.115**

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APPENDIX D. RECIPE FOR ACID CLEANING SOLUTION

Total volume Acid Cleaning Solution 335.92 liters

	Compounds	**Formula**	**Mass (Grams)**
1	Aluminum Hydroxide	Al(OH)3	899.93
2	Cadmium Nitrate	Cd(NO3)2.4H2O	264.37
3	Chromium Nitrate	Cr(NO3)3.9H2O	40.31
4	Ferric Nitrate	Fe(NO3)3.9H2O	2442.81
5	Magnesium Nitrate	Mg(NO3)2.6H2O	64.50
6	Manganese Nitrate	Mn (NO3)2.6H2O	86.67
7	Nickel Nitrate	Ni(NO3)2.6H2O	249.25
8	Nitric Acid	HNO3	40310.40
9	Phosphoric Acid	H3PO4	29.56
10	Silica	SiO2	54.75
11	Sodium Nitrate	NaNO3	493.80
12	Zirconyl Nitrate	Zr(NO3)2	244.55
13	Water	H2O	312909.14
		Final Mass	**358090.04**
		Density (g/ml)	**1.066**

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