WSRC-TR-2001-00288, Revision 1
SRT-RPP-2001-00014, Revision 1

KEYWORDS:
Hanford River Protection Project,
Low-Activity Waste, AN-102,
Envelope C, Evaporator

Sample Analysis Results for a Benchscale Evaporator Test Using a Hanford Tank 241-AN102 Sample

SAVANNAH RIVER TECHNOLOGY CENTER

Daro Ferrara
Mark Crowder
Charles Crawford
Bond Calloway

Publication Date: August 16, 2002

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy under Contract No. DE-AC09-96SR18500

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available for sale to the public, in paper, from: U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161,
phone: (800) 553-6847,
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/help/index.asp

Available electronically at http://www.osti.gov/bridge
Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from: U.S. Department of Energy, Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831-0062,
phone: (865)576-8401,
fax: (865)576-5728
email: reports@adonis.osti.gov

ACKNOWLEDGEMENTS

The results presented in this report are the product of the efforts of a task team made up of over twenty individuals at the Savannah River Site, Babcock and Wilcox, Southwest Research Institute, and Oak Ridge National Laboratory. The success of this program was only possible because of the ability of these individuals to work as a team. In particular, the authors would like to thank personnel at Oak Ridge National Laboratory, Babcock and Wilcox and Southwest Research Institute. Our primary contacts were Luther Gibson and Mark Burdette at Oak Ridge National Laboratory, Bill Stagg, Paul Macek and Les Hawthorne at Babcock and Wilcox, and Chee-Kai Tan at Southwest Research Institute. In addition, we are thankful for the effort put into the sample preparation and shipment by Robert Ray, Susan Jurgensen, Sarah Brown, Sherry Vissage, and Beverly Burch.

CONTENTS

1.0 EXECUTIVE SUMMARY

This report provides the analytical results of samples taken during the low-activity waste (LAW) evaporator process demonstration conducted at the Savannah River Technology Center with a 15-liter sample of Hanford tank 241-AN102 pretreated radioactive supernate. The objective of the task was to determine the concentration of various organic, inorganic and radionuclide constituents of potential concern (COPC) and physical properties of the evaporator feed, concentrate, condensate and off gas for the Hanford River Protection Project (RPP).

Over 150 samples and blanks were collected and analyzed in accordance with EPA SW-846 methods. The results from these analyses showed that

-One hundred nineteen target organic analyte concentrations were shown to be less than the minimum quantitatve limits in all samples (feed, concentrate, condensate, and off gas samples).
-Tetrahydrofuran (THF) was present in evaporator samples.
-THF was the most concentrated volatile compound detected in the off gas (290 µg/L).
-No pesticides or polychlorinated biphenyls (PCBs) were detected in any evaporator sample.
-Very low levels of some dioxins and furans were reported in the off-gas samples, but are thought to have been due to contamination.
-Total activity in the off gas was low (less than 17 pCi/L).
-Antifoam decomposition products were detected as tentatively-identified compounds during both analysis for volatile and semivolatile organic compounds.
-Condensate samples were shown to meet all waste acceptance criteria (WAC) for storage prior to processing at the Hanford 200-area Effluent Treatment Facility (ETF).

Most of the sample collection, sample preparation, and sample analyses provided results with sufficient pedigree to support the rigor associated with regulatory application of these results. In future studies, some alternative approaches should be taken to increase the number of target analytes that can be determined to this rigor. Five changes should be made to the approaches that were taken in this study:

-An alternative to the azeotropic distillation (EPA SW-846 Method 5031) needs to be developed. This method produced inconsistent results. Method 5031 was used for the determination of methanol and 2-butoxyethanol.
-Improvements need to be made in the method used to collect off-gas samples (EPA SW-846 Method 0031) for volatile organic analytes. Recoveries from one sorbent (Anasorb) were very low, and the other sorbent (Tenax) could not be used for some target analytes. Options may include application of EPA SW-846 Method 0030 or application of SUMMA canisters (EPA Method TO-14).
-The effect of the alkaline matrix on acid organic matrix spike recoveries needs to be addressed.
-Insufficient silver recoveries in these samples need to be addressed.
-Insufficient recoveries of other metals (e.g., platinum, tantalum, and uranium) need to be addressed perhaps simply by changing to a different digestion technique.

2.0 INTRODUCTION AND BACKGROUND

The baseline low activity waste (LAW) flow sheet for the River Protection Project (RPP) Waste Treatment Plant (WTP) includes pretreatment of Envelope A, B, and C supernate by removing strontium and transuranic ions via precipitation when appropriate (Envelope C supernate) and removing cesium and technetium ions via ion-exchange. This pretreated LAW is concentrated in the LAW Melter Feed Evaporator.

The U.S. Department of Energy provided Hanford tank samples to the RPP-WTP contractor during Part B1 for characterization, pretreatment and vitrification process tests. The DOE required the RPP-WTP contractor to characterize the Hanford tank samples and various pretreatment and vitrification process streams for organic, inorganic and radionuclide constituents of potential concern (COPCs)[1]. Characterization was conducted to provide a basis for RPP-WTP Dangerous Waste Permit Application. In addition, condensate analyses were also to be conducted to show compliance with the Hanford 200-Area Effluent Treatment Facility (ETF) waste acceptance criteria (WAC).[2] As a result, the RPP-WTP contractor directed the Savannah River Technology Center (SRTC) to characterize the LAW Melter Feed Evaporator feed, concentrate, condensate and off gas and the LAW and HLW glass and glass leachates using EPA's "Test Methods for Evaluating Solid Waste, Physical and Chemical Methods".[3] In response to the RPP-WTP request, SRTC personnel prepared a task plan[4] and together with BWXT Services performed the sample collection, preparation, and analyses.

This report provides the analytical results of samples taken during the LAW evaporator process demonstration conducted at SRTC with a sample of Hanford Tank 241-AN102 radioactive supernate. The LAW Melter Feed Evaporator process demonstration has been detailed by Crowder, et al in a previously issued document[5]. The evaporation was performed in a benchscale natural-convection thermosiphon vacuum evaporator with a 2.5-liter evaporator pot that was designed based on a natural-circulation calandria. At this scale, detection limits (most organic

---

[1] BNFL Letter No. 000183, "TWRS-P Contract No. DE-AC06-96RL13308 – W375 – Analysis of Evaporator Condensate, Non-Condensable Fraction, and Concentrate, Melter Off-Gas Condensate and Non-Condensable Fraction, ILAW Glass, and ILAW Glass Leachate", Michael E. Johnson to Steven T. Wach, Oct. 5 1998.

[2] Waste Mangement Federal Services of Hanford, Inc., "Hanford Site Liquid Waste Acceptance Criteria", **HNF-3172, Rev. 0**, September 1988.

[3] U.S. Environmental Protection Agency, "Test Methods for Evaluating Solid Waste, Physical and Chemical Methods", **EPA SW-846.**

[4] D. M. Ferrara, R. S. Groseclose, R. J. Ray, C. L. Crawford, and T. B. Calloway, Jr., "Task Technical, Analytical Study, and Quality Assurance Plan in Support of BNFL Part B: "Regulatory" Sample Analyses from A, B, C, LC, and HLW Studies at SRTC," **BNF-003-98-0082, Revision 0**, Westinghouse Savannah River Company, February 2000.

[5] M. L. Crowder, et al., "Bench-Scale Evaporation of a Large Hanford Envelope C Sample (Tank 241-AN-102)", **WSRC-TR-2000-00469 Rev. 1**, Westinghouse Savannah River Company, May 2001.

species-<10 µg/L in the off gas, most inorganic species-<1 mg/L in the off gas, and most radionuclides-<1 nCi/L in the off gas) were expected to be well below concentrations of regulatory significance for most target analytes that would be detectable using the off-gas sampling methods choosen.

Because this study was to be a process simulation, to the maximum extent practical, the experimental procedure was set up to mimic operation of a forced circulation evaporator. The volumetric air inleakage rate of the benchscale evaporator was scaled to the volumetric air inleakage rate of the RPP-WPT design basis evaporator on a system volume basis. As a result, analyte concentrations in the benchscale evaporator off gas are expected to be directly comparable with concentrations anticipated from the RPP-WPT design basis evaporator within the limitations normally associated with scaling from benchscale tests to fullscale operations.

Another air inleakage was installed between the evaporator and the off-gas sampling system to provide the minimum volumetric flow rate of the sampling equipment. Since all of the off gas was passed through the sampling systems (rather than sample the off gas isokinetically), essentially all of the target analytes were collected in the off-gas sampling system. The evaporator was heated with an Incoloy® heater rod. Steady-state operation of the evaporator was performed at 9.5 kPa and 51 °C. For a diagram of the apparatus and a more detailed description of the operating conditions, see Reference 4.

The objective of the task was to determine the physical properties and the concentrations of various organic, inorganic, and radionuclides in the evaporator feed, concentrate, condensate and off gas. The AN-102 Hanford tank sample was pretreated to remove strontium, transuranic elements, cesium and technetium using the reference RPP-WTP process. Samples of the resulting evaporator feed were collected and analyzed. The resulting 15-L AN-102 sample was then concentrated to 7.1 M Na. This concentration was identified by SRTC as the concentration that would meet the RPP customer's endpoint specification, 80 % of the bulk solubility at 25 °C.

Samples from the evaporator feed, concentrate, condensate and off gas system were taken using EPA SW-846 methods and submitted to an EPA certified laboratory, Babcock and Wilcox Services, Inc. (BWXT Services) for analysis using EPA SW-846 methods. The results from these analyses and the supporting documentation are being issued in a data package.[6] Because they were available several months before the evaporator study, the feed samples and associated blanks were collected and analyzed separately from the other samples.

---

[5] D. M. Ferrara, M. L. Crowder, H. Saito, "Data Package from Analysis of a Hanford Tank 241-AN102 Sample", in preparation.

The pretreated Hanford AN-102 radioactive supernate was evaporated in five phases.[5] For the initial phase, the evaporator pot was charged with 1.5 liters of feed. During the initial phase, the evaporator was brought to steady state. In the second, third, and fourth phases of this demonstration, the evaporator was continuously fed and operated at steady-state. During the last phase, the supernate was concentrated beyond the nominal endpoint of 7.1 M sodium.

Steady-state operation was performed such that the feed rate (nominally 8 mL/min) was equal to the sum of the rate at which condensate was collected (nominally 3 mL/min) and the rate at which concentrate was pumped from the evaporator pot (nominally 5 mL/min). Because the evaporator was continuously fed, because the heat flux into the evaporator pot was constant and because the total volume of concentrate in the system was constant, parameters such as vaporization rate, volatile release rates, and temperatures were essentially constant.

Samples were taken for volatile organic compound analysis, inorganic analysis (including radionuclides) and semivolatile organic compound analysis, respectively. Table 2.1 is a summary of some parameters associated with the second, third, and fourth phases of this demonstration. Note that the standard sampling methods indicated in Table 2.1 were designed for isokinetic sampling of stack off gases. The methods were adapted to the benchscale evaporator by Oak Ridge National Laboratory personnel who have several-years experience with such systems.

Table 2.1. Parameters Associated with Steady State Operation of the AN-102 Evaporator

	Volatile Organics	Metals and Radionuclides	Semivolatile Organics
	Phase 2	Phase 3	Phase 4
Sampling Method	EPA SW-846 #0031	EPA SW-846 #0060	EPA SW-846 #0010
Time (hr)	10.9	8.5	9.9
Feed Mass (g)	5214	3726	4700
Concentrate Mass (g)	4064	2405	3433
Condensate Mass (g)	1247	804	1251
Sample Air Volume (L)	7.5	5.9	6.8
Bleed Air Volume(L)	305.5	231.0	281.3
Total Air Volume(L)	313.0	236.9	288.1

Included in Table 2.1 is the volume of air that passed through the evaporator pot during each phase (sample air volume) and the volume of air that was bled into the system between the condenser and the off-gas sampling trains. The bleed air was passed through drierite prior to being pumped into the evaporator; however, no effort was made to remove potential contaminants. Prior to the Tank AN102 demonstration, the evaporator was operated with a sodium hydroxide solution to generate "process blanks." Results from process and field blank analyses were used to identify potential contaminants in the evaporator environment.

For calculations associated with this report, the sample air volume has been used since this is the volume that has been scaled from the full-scale evaporator. The resulting concentrations would be the most prototypic of those expected in the full-scale evaporator. Steady-state rates can be determined by dividing the mass and volumes given in Table 2.1 by the time each phase was performed.

Throughout this report, reference is made to the "minimum quantitative limit" (MQL) and to the "minimum detection limit" (MDL). The MQL is the lowest concentration at which the concentration of the analyte can be determined. The MDL is the lowest concentration at which the analyte can be determined to be present. At concentrations between the MDL and the MQL, the analyte can be determined to be present in the sample but the analyte concentration cannot be determined with acceptable reliability.

3.0 VOLATILE ORGANIC COMPOUNDS

Analysis of the samples for volatile organic compounds showed that most of the target analytes were not present in any of the samples at concentrations above the minimum quantitative limit (MQL). Of the purgable volatile organic compounds, tetrahydrofuran was the only target analyte that was detected in the evaporator feed. Several other target analytes were detected in the off gas samples but at very low concentrations. Results have been presented in Table 3.5. In addition to the target analytes, a limited number of tentatively-identified compounds (TICs) were detected, most of which appear to be decomposition products from antifoam that was added during the evaporator study. Difficulties were encountered with the method (azeotropic distillation by EPA SW-846 Method 5031) used to prepare the samples for analysis of the non-purgable volatile organic analytes. Difficulties were also encountered with some of the sorbents used to sample the off gas.

A. Experimental

Samples analyzed for volatile organic compounds were collected during the first ten-hour portion of the evaporator demonstration. These samples included duplicate evaporator feed samples, duplicate condensate samples, duplicate concentrate samples, duplicate pump trap samples, duplicate moisture trap samples, a pair of Tenax cartridges, an Anasorb cartridge and the associated blanks. Because they were available several months before the evaporator study, the feed samples and the associated blanks were collected and analyzed separately from the other samples.

1. Aqueous Samples

Aqueous samples included the evaporator feed, condensate, and concentrate samples. These samples were handled according to EPA SW-846 protocol for handling samples to be analyzed for volatile organic compounds. Bottles were filled to assure the sample had "zero headspace." A 1.2 N sodium hydroxide solution was used to prepare field blanks. This was used instead of ASTM Type II water to more closely simulate the highly caustic samples.

Methods used to analyze the feed, concentrate, and condensate samples for volatile organic compounds are given in Table 3.1. These methods were also used to analyze the pump trap and off-gas system moisture trap samples. All methods were performed according to SW-846 protocol except where noted in this section. Analytical methods were implemented by BWXT Services as Standard Operating Procedures.

Table 3.1. Methods Used to Measure Volatile Organic Compounds in Aqueous Samples

	Analytical Method
General Volatiles	SW-846 #5030B, 8260B
Nonpurgables	SW-846 #5031, 8260B
Organic Anions	SW-846 #9056

Most of the target volatile organic compounds were determined by Method 5030B (purge and trap) and 8260B (GC-MS). Matrix spike and matrix spike duplicate recoveries were within the specified range and met the reproducibility requirements given in the Quality Assurance Project Plan (QAPjP).[6] Although not specified by Method 5030B, alkaline samples are sometimes acidified to improve analyses. No such step was applied to these samples. Recoveries seemed to indicate that this approach was successful.

Methanol, ethanol, and 2-butoxyethanol were determined by Method 5031 (azeotropic distillation) and 8260B. Another option for this determination would have been Method 5021. Although Method 5021 (equilibrium headspace) does not include these compounds in the list of the method target analytes, experience at Pacific Northwest National Laboratory has shown the methods to be adequate for these determinations. Method 5031 was chosen over Method 5021 because SW-846 refers to Method 5021 as a "means for screening samples for volatile organics".

Method 5031 calls for analysis of a 300-μL distillate fraction. Preliminary studies showed that a large fraction of the target analytes were not being collected in this fraction. Increasing the amount of distillate collected increased the amount of sample that could be used for the analysis. Method 5031 was modified so that 1000 μL of distillate was collected and analyzed instead of 300 μL. In addition, an ice pack was used to provide additional cooling of the condenser. Even with these modifications, responses were low for the internal standards. Matrix spike and matrix spike duplicate recoveries were within the specified range but did not always meet the reproducibility requirements given in the QAPjP.[7] Therefore, results for methanol, ethanol, and 2-butoxyethanol should be considered estimates.

Acetate and formate were determined by Method 9056. Although oxalate does not meet the EPA SW-846 definition of a volatile compound, it is reported along with acetate and formate in this report since all three were determined from the same sample using the same method. Matrix spike and matrix spike duplicate recoveries were within the specified range and met the reproducibility requirements given in the QAPjP.[7] Method 9056 is not capable of separating acetate and formate.[8]

2. Off Gas System Samples

During operation of the evaporator, off gas was passed through an EPA SW-846 Method 0031 sampling train. This produced a pump trap sample, a moisture trap sample, two Tenax samples, and an Anasorb-747 sample. Tenax is an ion exchange resin used for sampling nonpolar organic compounds with boiling points between 80 and 200 °C. Anasorb-747 is an SKC Inc. proprietary beaded active carbon sorbant used for sampling a wide range of organic compounds. These samples were collected according to Method 0031 and shipped to BWXT Services for analysis. In addition to the field blanks and trip blanks required by this method, a set of process blanks was also generated by passing a sodium hydroxide solution through the evaporator under vacuum at ambient conditions. The purpose of the process blanks was to monitor for sources of the analytes other than the AN102 supernate.

Methods used to analyze the pump trap and moisture trap samples were the same as those given previously for aqueous samples. Methods used to analyze the Tenax and Anasorb samples for volatile organic compounds are given in Table 3.2. These methods were performed according to SW-846 protocol except where noted in this section. Analytical methods were implemented by BWXT Services as Standard Operating Procedures. Results from the pump trap, moisture trap, the two Tenax, and the Anasorb samples were combined according to EPA SW-846 Method 0031 and have been presented according to this method as a minimum value and a maximum value.

---

[7] J. S. Coker, "Quality Assurance Project Plan for Testing Programs: Savannah River Technology Center (SRTC), Pacific Northwest National Laboratory (PNNL)", **QP-W375-EN00002, Rev. 0**, June 7, 1999.

[8] EPA SW-846 Method 9056 is an ion chromatography method that is most often used for determination of inorganic ions. The specifications used for this method are such that formate and acetate co-elute. Results given in the report for formate and acetate are conservative. Formate results were determined by assuming no acetate was present. Similarly, acetate results were determined by assuming no formate was present. These assumptions will overestimate the concentration of both analytes.

Table 3.2. Methods Used to Determine Volatiles in Tenax and Anasorb Samples

	Analytical Method
Tenax	SW-846 # 5041A, 8260B
Anasorb	SW-846 # 5035,5030B,8260B

Some of the volatile target analytes could not be determined by this approach. EPA SW-846 Method 0031 specifically states that this method is not applicable to some of these analytes. Method 0031 states, "Method 0031 is generally not applicable to polar water-soluble and reactive volatile organic compounds." In the Results section, a list of these analytes is given. Off-gas results for these compounds have been noted to show that these compounds could not be determined from the Tenax sorbant. Options are being discussed for future analyses to assure as many of these analytes as possible are determined. In addition, other analytes (the ketones in particular) behaved "erratically". Acetone results should therefore be used with caution.

The Anasorb samples could not be desorbed using Method 5041B (thermal desorption). Even at higher temperatures these analytes would not desorb from the Anasorb. Therefore, these samples were extracted using EPA Method 5035, and the resulting methanol extract was analyzed using Method 8260B. Laboratory control sample, surrogate and internal standard recoveries were below the range that was specified in the QAPjP.[7] Conversations with laboratories where Anasorb is routinely used indicated that low recoveries are common. In addition, because of the analytical difficulties, the two field blanks and one of the process blanks were extracted one day after the specified fourteen-day sample shelflife.

B. Results from Volatile Organic Compound Analyses

With the following exceptions, all quality assurance specifications were met. Acetone and tetrahydrofuran (THF) were detected in most of the blanks but, in some cases, at concentrations below those measured in the samples. Quality Assurance Project Plan (QAPjP)[7] specifications were not met for the azeotropic distillation recoveries. This affected results for methanol and 2-butoxyethanol. In addition, acetate and formate were not separated during anion analyses. This was expected prior to the analyses.

1. Target Analytes Not Detected

Most of the target volatile organic compounds were not detected in any of the samples at the method minimum quantitative limit (MQLs). MQLs have been given in Table 3.3 for the volatile target analytes. The target compounds that were below the MQLs in all samples have been noted in Table 3.3. As indicated previously, some of the target analytes could not be determined from the Tenax cartridges. These analytes have also been noted in Table 3.3.

Table 3.3. Target Volatile Analytes Not Detected in AN-102 Evaporator Samples

Feed (µg/L)	**$<2.1x10^2$**		**Feed (µg/L)**	**$<2.1x10^3$**
Concentrate (µg/L)	**<38**		**Concentrate (µg/L)**	**$<3.8x10^2$**
Condensate (µg/L)	**<20**		**Condensate (µg/L)**	**$<2.0x10^2$**
Off Gas (µg/L air)	**<1.4**		**Offgas (µg/L air)**	**<14**
Analyte	**CAS Number**		**Analyte**	**CAS Number**
cis-1,3-Dichloropropene	10061-01-5		Acrolein	107-02-8
trans-1,3-Dichloropropene	10061-02-6		Propionitrile	107-12-0
*3-Heptanone	106-35-4		Acrylonitrile	107-13-1
1,2-Dibromoethane	106-93-4		*Butyl Acetate	123-86-4
Butane	106-97-8		*1,4-Dioxane	123-91-1
1,3-Butadiene	106-99-0		*Ethanol	64-17-5
3-Chloropropene	107-05-1		*1-Propanol	71-23-8
*4-Methyl-2-Pentanone	108-10-1		*n-Butanol	71-36-3
n-Pentane	108-66-0		*Acetonitrile	75-05-8
*Cyclohexanone	108-94-1			
5-Methyl-2-Hexanone	110-12-3			
*2-Heptanone	110-43-0			
n-Hexane	110-54-3			
Cyclohexane	110-82-7			
Cylcohexene	110-83-8			
n-Octane	111-65-9			
*4-Heptanone	123-19-3			
**n-Propionaldehyde	123-38-6			
Methacrylonitrile	126-98-7			
n-Heptane	142-82-5			
cis-1,2-Dichloroethene	156-59-2			
trans-1,2-Dichloroethene	156-60-5			
Cyclopentane	287-92-3			
Carbon Tetrachloride	56-23-5			
*3-Methyl-2-Butanone	563-80-4			
Chloroform	67-66-3			
1,1,1-Trichloroethane	71-55-6			
Bromomethane	74-83-9			
Chloroethane	75-00-3			
1,1-Dichloroethane	75-34-3			
1,1-Dichloroethene	75-35-4			
Dichlorofluoromethane	75-43-4			
Dichlorodifluoromethane	75-71-8			
Freon 113	76-13-1			
s-Dichlorotetrafluoromethane	76-14-2			
1,2-Dichloropropane	78-87-5			
1,1,2-Trichloroethane	79-00-5			
*1,1,2,2-tetrachloroethane	79-34-5			

*This analyte could not be determined on the Tenax cartridges.

**The MQL for n-propionaldehyde in the feed samples was $2x10^3$ µg/L.

< This indicates a result that was below the MDL. The value following this designation is the MDL.

2. Target Volatile Analytes Detected in at Least One of the Evaporator Samples

Thirty of the target volatile analytes were detected in at least one evaporator sample. Most of these were only detected in the off gas and many were detected at concentrations below the MQL. These results have been included in Table 3.4. These results have been determined according to EPA SW-846 protocol and are therefore being reported accordingly. Matrix spike recoveries and blank contamination are discussed where appropriate; however, in compliance with SW-846, the values have not been adjusted for recoveries or concentrations determined in the blanks.

a. Target Analyte Concentrations in the Feed Samples

As indicated in Table 3.4, all target analytes were below the method MQLs in the feed samples except tetrahydrofuran (THF), oxalate, formate, and acetate. THF was also present in the blanks at concentrations ranging from 5.7 μg/L in the laboratory's method blanks to 1.4×10^2 and 1.5×10^2 μg/L in the field and trip blanks respectively. As shown in Table 3.4, the THF results for the feed samples were more than an order of magnitude higher than any of the blank concentrations. Oxalate, formate, and acetate concentrations are also given in Table 3.4 for the feed samples. Note that EPA SW-846 Method 9056 is not capable of resolving formate and acetate. The value given for formate was the concentration that would have been present in the sample if no acetate were present. Similarly, the value for acetate is the concentration that would have been present in the sample if no formate were present.

b. Target Analyte Concentrations in the Concentrate Samples

As indicated in Table 3.4, all target analytes were below the method MQLs in the concentrate samples except ethylene oxide, 1,2-dichloroethane, chloromethane, THF, acetone, oxalate, formate, and acetate. MQLs were lower for the concentrate analyses than for the feed analyses because more of the concentrate was available for sampling.

Ethylene oxide was detected in the concentrate at levels well above the method MQL (38 μg/L). As indicated, the value reported in Table 3.4 (5.9×10^2 μg/L) was from one of the duplicate samples. The other sample result was reported at a significantly higher concentration (1.6×10^3 μg/L). This concentration (1.6×10^3 μg/L) was above the concentration at which the method had been calibrated. No ethylene oxide was detected in the feed samples. Therefore, the higher value was thought to be in error.

Chloromethane and 1,2-dichloroethane were detected in the concentrate. As indicated, values reported in Table 3.4 were from one of the duplicate samples. Although the method did indicate that these analytes were present in the second samples, the measured concentrations (35 and 8.6 μg/L for chloromethane and 1,2-dichloroethane respectively) were below the method MQL. The higher concentrations have been conservatively reported in Table 3.4.

Table 3.4. Concentrations of Target Volatile Analytes

Analyte	CAS #	Feed (µg/L)	Concentrate (µg/L)	Condensate (µg/L)	[$]Off Gas (µg/L)	
					Min	Max
[+]Ethylbenzene	100-41-4	$<2.1\times10^{2}$	<38	<20	0.015	1.3
[+]Styrene	100-42-5	$<2.1\times10^{2}$	<38	<20	0.034	1.3
[+]1,2-Dichloroethane	107-06-2	$<2.1\times10^{2}$	[*]5.7×10^{2}	<20	<1.4	
[+]2-Pentanone	107-87-9	$<2.1\times10^{2}$	<38	<20	[*]0.16	1.4
[+]Methylcyclohexane	108-87-2	$<2.1\times10^{2}$	<38	<20	[J]0.0015	1.3
[+]Toluene	108-88-3	$<2.1\times10^{2}$	<38	<20	0.049	1.3
[+]Chlorobenzene	108-90-7	$<2.1\times10^{2}$	<38	<20	[J]0.00099	1.3
[++]Tetrahydrofuran	109-99-9	[B]2.9×10^{3}	[BJ]$<1.7\times10^{2}$	[B]2.81×10^{2}	2.9×10^{2}	
[+]n-Nonane	111-84-2	$<2.1\times10^{2}$	<38	<20	0.10	1.4
[+]Tetrachloroethene	127-18-4	$<2.1\times10^{2}$	<38	<20	0.015	1.3
Ethylacetate	141-78-6	$<2.1\times10^{3}$	$<3.8\times10^{2}$	$<2.0\times10^{2}$	[J]0.0070	13
[+]2-Hexanone	591-78-6	$<2.1\times10^{2}$	<38	<20	0.58	1.9
[++]Isopropanol	67-63-0	$<2.1\times10^{3}$	$<3.8\times10^{2}$	243	88	89
[+]Acetone	67-64-1	$<2.1\times10^{2}$	[BJ]<47	[B]<47	[***]10	
[+]Benzene	71-43-2	$<2.1\times10^{2}$	<38	<20	0.012	1.3
[+]Chloromethane	74-87-3	$<2.1\times10^{2}$	[*]1.4×10^{2}	<20	[*]0.080	0.70
[+]Methylene Chloride	75-09-2	$<2.1\times10^{2}$	[*]<38	<20	[J]0.056	0.90
[+]Carbon Disulfide	75-15-0	$<2.1\times10^{2}$	<38	<20	0.048	1.3
[+]Ethylene Oxide	75-21-8	$<2.1\times10^{2}$	[**]5.9×10^{2}	<20	<1.3	
[+]Chlorodifluoromethane	75-45-6	$<2.1\times10^{2}$	<38	<20	0.25	1.4
[++]2-Methyl-2-propanol	75-65-0	$<2.1\times10^{3}$	$<3.8\times10^{2}$	$<2.0\times10^{2}$	[J]3.7	5.3
[+]Trichlorofluoromethane	75-69-4	$<2.1\times10^{2}$	<38	<20	[J]0.0049	1.3
[++]2-Butanol	78-92-2	$<2.1\times10^{3}$	$<3.8\times10^{2}$	$<2.0\times10^{2}$	[J]2.0	8.7
[+]2-Butanone	78-93-3	$<2.1\times10^{2}$	<38	<20	[J]0.13	0.44
[+]Trichloroethene	79-01-6	$<2.1\times10^{2}$	<38	<20	[J]0.011	1.3
[+]m,p-Xylenes	-	$<2.1\times10^{2}$	<38	<20	0.042	1.3
[+]o-Xylene	95-47-6	$<2.1\times10^{2}$	<38	<20	0.041	1.3
[+]3-Pentanone	96-22-0	$<2.1\times10^{2}$	<38	<20	0.067	1.3
[+++]2-Butoxyethanol	111-76-2	$<5.9\times10^{3}$	$<4.7\times10^{3}$	$<6.0\times10^{2}$	-	-
[+++]Ethanol	64-17-5	$<5.9\times10^{3}$	$<4.7\times10^{3}$	$<6.0\times10^{2}$	-	-
[+++]Methanol	67-56-1	$<5.9\times10^{3}$	$<4.7\times10^{3}$	[RJ]64	-	-
[#]Oxalate	144-62-7	1.13×10^{6}	2.8×10^{5}	<28	-	-
[@##]Formate	64-18-6	3.72×10^{6}	[J]1.3×10^{7}	$<2.5\times10^{2}$	-	-
[@###]Acetate	64-19-7	3.8×10^{6}	4.4×10^{7}	[J]3.0×10^{2}	-	-

[B] This analyte was detected in one or more of the analytical laboratory's method blanks.

[J] This analyte detected at a concentration below the minimum quantitative limit (MQL).

[R] This result was rejected during data validation because the calibration check deviated by more than 30%.

[$] Units for off gas results are micrograms of analyte per liter of air at 1 atm and 25 °C.

[*] This is from a single sample. The result from the duplicate was below the MQL.

[**] This is from a single sample. The result from the duplicate was not considered credible.

[+] MQLs: feed 2.1×10^{2} µg/L, concentrate 38 µg/L, condensate 20 µg/L, off gas 1.4 µg/L air.

[++] MQLs: feed 2.1×10^{3}µg/L, concentrate 3.8×10^{2}µg/L, condensate 2.0×10^{2}µg/L, off gas 14µg/L air.

[+++] Consider these results to be estimates. Surrogate recoveries were high, and internals standard responses were low. MQLs: feed 6.2×10^{3}µg/L, concentrate 4.7×10^{3}µg/L, condensate 6.0×10^{2}µg/L.

[#] Oxalate MQLs: feed 4.7×10^{4}µg/L, concentrate 1.4×10^{4}µg/L, condensate 28µg/L.

[##] Formate MQLs: feed 2.5×10^{5}µg/L, concentrate 2.5×10^{6}µg/L, condensate 2.5×10^{2}µg/L.

[###] Acetate MQLs: feed 3.7×10^{4}µg/L, concentrate 3.7×10^{6}µg/L, condensate 37µg/L.

[@] Formate and acetate results should be consider as upper limits. See report footnote 8.

[***] This should be considered to be "nondetect" based on application of the CLP 10x rule.

< This analyte was not detected at or above the concentration given. Unless noted, the concentration given is the MDL.

In addition, THF and acetone were detected in the concentrate at levels close to the method MQLs (4×10^2 µg/L and 40 µg/L for THF and acetone respectively). These analytes were also present in the blanks at concentrations given in Table 3.5. The field, trip and process blank concentrations are such that application of the EPA Contract Laboratory Program (CLP) 10x rule would suggest that these results be considered "nondetects" for acetone and THF. The EPA CLP guidelines state, "Positive sample results should be reported unless the concentration of the compound in the sample is less than or equal to 10 times (10x) the amount in any blank for the common volatile laboratory contaminants (methylene chloride, acetone, 2-butanone, and cyclohexane), or 5 times (5x) the amount for other volatile target compounds."[9] Acetone and THF have been indicated in Table 3.4 as a "nondect" at a concentration of 10x the laboratory method blank. THF has been indicated in Table 3.4 as a "nondetect" for the concentrate samples at a concentration of 10x the laboratory method blank.

Table 3.5. Acetone and THF Concentrations in Concentrate Samples and Blanks

	Acetone	**Tetrahydrofuran (THF)**
Concentrate Samples (µg/L)	28±9	$*1.3\pm0.1\times10^2$
Process Blank (µg/L)	10	25
Field Blank (µg/L)	9.8	28
Trip Blank (µg/L)	7.4	23
Method Blank (µg/L)	4.7	17

*This was the measured concentrate result. During validation, the CLP 10x rule indicated the THF concentrate result should be considered as less than 10x the reported method blank value.

Oxalate, formate, and acetate concentrations are also given in Table 3.4 for the concentrate samples. Note that EPA SW-846 Method 9056 is not capable of resolving formate and acetate.[8] The value given for formate is the concentration that would have been present in the sample if no acetate was present. Similarly, the value for acetate is the concentration that would have been present in the sample if no formate was present. The formate concentration was close to the method MQL (3×10^6 µg/L).

c. Target Analyte Concentrations in the Condensate Samples

As indicated in Table 3.4, all target analytes were below the method MQLs in the condensate samples except THF, isopropanol, acetone, methanol, and acetate. MQLs were lower for the condensate analyses than for the feed or concentrate analyses because the condensate samples were much more dilute than the other aqueous samples.

---

[9] U.S. Environmental Protection Agency, "USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review",OSWER 9240.1-05A-P, October 1999.

Isopropanol was detected in the condensate at levels close to the method MQL ($2x10^2$ µg/L). Isopropanol was not detected in any of the blanks or in any of the other samples. Because this analyte was detected at such low concentrations in the condensate, it was probably in the feed at a concentration that was below the method MQL.

In addition, THF and acetone were detected in the condensate at levels close to the method MQL ($2x10^2$ µg/L and 20 µg/L for THF and acetone respectively). Although no process blanks were available for these samples, the trip, field and laboratory method blanks were the same as those used with the concentrate samples (Table 3.5). The acetone field, trip and process blank concentrations were such that application of the CLP 10x rule would make the acetone results "nondetects".

As indicated in Table 3.4, methanol was detected in the condensate samples. Although the method did show methanol to be present in the samples, concentrations were below the established method MQL ($6x10^2$ µg/L). Methanol was not detected in any blanks or in any of the other samples. Because this analyte was detected at such low concentrations in the condensate, it may have been present in the feed at a concentration that was below the method MQL.

The acetate concentration was also given in Table 3.4 for the condensate samples. As discussed previously,[8] the value given for acetate is the concentration that would have been present in the sample if no formate was present. The acetate concentration was close to the method MQL ($3x10^2$ µg/L).

During operation of the actual evaporator, condensate will be sent to the 200-Area Effluent Treatment Facility (ETF) at Hanford. Therefore, this stream must meet the ETF waste acceptance criteria (WAC). These limits are given in Appendix C of the ETF WAC[2] expressed in terms of an upper limit on eight chemical families of which five are limited to 2000 mg/L. This is the lowest of the limits on organic compounds. This is almost four orders of magnitude higher than any of the target analytes. Therefore, the volatile organic species would not have caused the condensate to exceed the WAC for the controlled families of organic compounds.

d. Target Analyte Concentrations in the Off-Gas Samples

In addition to results from the aqueous samples, Table 3.4 includes results from analysis of the off-gas system samples. These values were determined according to EPA SW-846 Method 0031 and are given in terms of micrograms of each analyte per liter of air at standard conditions. The off-gas concentrations given in Table 3.4 were determined by adding the masses in the pump trap samples, the moisture trap samples, the first Tenax sample, the second Tenax sample and the Anasorb sample and dividing by the volume of gas sampled. Equation 1 show how these calculations were performed.

$$C = (m_{tenax1}+m_{tenax2}+m_{anasorb}+C_{pump}V_{pump}+C_{moisture}V_{moisture})/(KYV_mP/T) \qquad \text{(Eq.1)}$$

where C was the concentration of the analyte in µg/L air,
m_{tenax1} was the measure mass of the analyte on the first tenax cartridge in µg,
m_{tenax2} was the measure mass of the analyte on the seconde tenax cartridge in µg,
$m_{anasorb}$ was the measured mass of the analyte on the ansorb cartridge in µg,
C_{pump} was the concentration of the analyte in the pump trap sample in µg/L,
V_{pump} was the volume of the pump trap condensate collected in L,
$C_{moisture}$ was the concentration of the analyte in the moisture trap sample in µg/L,
$V_{moisture}$ was the volume of condensate in the moisuture trap in L,
K was a constant (0.3858 °K/mm Hg) for converting to standard conditions (20 °C and 1 atm),
Y was the dry gas meter calibration factor,
V_m was the dry gas volume in L,
P was the barometric pressure in mm Hg, and
T was the average temperature in °K.

Equation 1 was applied to each analyte in Table 3.4 twice. First, the concentration was determined only for the samples in which the analyte was detected. For example, if none of the analyte was detected on the Anasorb sample, $m_{anasorb}$ was assumed to be zero for this application of Equation 1. This provided the minimum value in Table 3.4. Second, the MQLs were used for the samples in which no analyte was detected. In the example given above, the MQL for the Anasorb sample would be used in the calculation. This provided the maximum value in Table 3.4. For some analytes (e.g. 1,2-dichloroethane) the only value given in Table 3.4 is an upper limit. In these cases the analyte was not detected in any of the samples. For some cases (e.g. THF) the only value given in Table 3.4 is a measured value. In these cases, the analyte was measured in all of the off-gas samples.

With the following exceptions, all quality assurance specifications were met. The Tenax sorbent could not be used to determine the volatile compounds given in Table 3.6. In addition, some of the analyte (THF in particular) concentrations were high enough to saturate the detector. Therefore, concentrations for these analytes may be slightly higher than those reported. Anasorb recoveries were low. This affected all of the off gas results for the volatile organic compounds.

THF and acetone were detected in all of the off-gas samples. THF and acetone were also detected in the blanks associated with these samples. The acetone concentrations were such that the concentration reported in Table 3.4 could be considered as a "nondetect" by application of the CLP 10x rule. The acetone result has been flagged in Table 3.4 with the appropriate footnote. THF concentrations in the analytical samples were much higher than the blanks and should be considered present in the sample.

Table 3.6. Compounds that Could Not Be Determined on the Tenax Sorbant

Analyte	CAS Number
3-Heptanone	106-35-4
4-Methyl-2-Pentanone	108-10-1
Cyclohexanone	108-94-1
2-Heptanone	110-43-0
4-Heptanone	123-19-3
Butyl Acetate	123-86-4
1,4-Dioxane	123-91-1
2-Butenal	4170-30-3
3-Methyl-2-Butanone	563-80-4

Analyte	CAS Number
Ethanol	64-17-5
Isopropanol	67-63-0
1-Propanol	71-23-8
n-Butanol	71-36-3
Acetonitrile	75-05-8
Ethylene Oxide	75-21-8
2-Methyl-2-Propanol	75-65-0
2-Butanol	78-92-2
1,1,2,2-Tetrachloroethane	79-34-5

3. Tentatively-Identified Compounds

During analysis for the target compounds several tentatively-identified compounds (TICs) were identified in these samples. These compounds have been given in Table 3.7. The concentrations should be used with caution since no steps were taken to calibrate for these analytes. Additional peaks were reported, but per discussions with RPP personnel, no attempt was made to identify these compounds.

Table 3.7. Concentrations of Volatile Tentatively-Identified Compounds

Analyte	CAS #	Feed (μg/L)	Condensate (μg/L)	Off Gas (μg/L)
Octamethyltrisiloxane	107-51-7	-	-	0.091
Trimethyl Ester Boric Acid	121-43-7	-	-	0.14
Carbon Dioxide	124-38-9	[B]7×10^{2}	-	[B]21
(2-Methyloxyethyl) Trimethyl Silane	18173-63-2	-	-	0.20
tert-Butyldimethylsilanol	18173-64-3	-	-	0.0047
Hexamethylcyclotrisiloxane	541-05-9	-	-	0.55
Octamethylcyclotetrasiloxane	556-67-2	-	[*]43	0.94
D-Limonene	5989-27-5	-	-	0.16
Bis (2-Trimethyl) Malonic Acid	90744-45-9	-	-	0.15
(E)-2-Butenal	-	-	-	0.056

[*] This is from a single sample. The result from the duplicate was below the MQL.

[B] This analyte was detected in the laboratory method blanks.

Most of the TICs appear to be methyl siloxane compounds from the antifoam that was used in this study. Although no specific data was available to show the expected decomposition products of the antifoam, the vendor indicated that decomposition should be expected in caustic solutions to produce methylated siloxanes. Carbon dioxide was seen in several of the off-gas samples but most predominantly on the Anasorb samples; however these concentrations were similar to the concentrations reported for the field and trip blanks.

C. Conclusions from Volatile Organic Compound Analyses

Analyses of the evaporator samples showed that the concentrations of volatile compounds in the samples were very low. With some exceptions, these analyses met the requirements given in the QAPjP.[7] Significant difficulties were encountered in applying the azeotropic distillation to these samples and in recovering analytes from the Anasorb sorbant. In addition, some of the analytes could not be determined from the Tenax sorbant. The following conclusions can be made from these determinations:

-Except for THF, none of the volatile organic target analytes were detected in the feed.
-THF was detected at concentrations above the method MQL in all streams except the concentrate.
-Low concentrations of several volatile organic analytes were detected in the off gas. These may have been present in the feed samples at concentrations that could not be detected. The target analytes that were detected in the off gas samples were THF, acetone, and the compounds for which minimum concentrations have been given in Table 3.4. Table 3.8 is a summary of the target analytes that were detected in the AN-102 evaporator samples.
-The condensate sample easily met the 200-Area ETF WAC for organic compounds.
-TICs were identified primarily as being from the antifoam used in the evaporator study. Currently, alternative antifoams are being investigated.

4.0 SEMIVOLATILES, PESTICIDES, PCBs, DIOXINS AND FURANS

Analysis of the samples for semivolatile organic compounds, pesticides, polychlorinated biphenyls (PCBs), dioxins and furans showed that most of the target analytes were not present in any of the samples at concentrations above the minimum quantitative limit (MQL). No target analyte was detected in the evaporator feed. Only four of the semivolatile organic compounds and four of the dioxins and furans were detected in at least one of the other samples.

A. Experimental

Samples that were analyzed for semivolatile organic compounds were collected during the third ten-hour portion of the evaporator demonstration. These samples included duplicate evaporator feed samples, duplicate condensate samples, duplicate concentrate samples, duplicate pump trap samples, an XAD cartridge, and the associated blanks.

Table 3.8. Summary of Target Volatile Analytes Detected above the Method MQLs

Analyte	CAS #	Feed	Concentrate	Condensate	[$]Off Gas (µg/L)	
		(µg/L)	(µg/L)	(µg/L)	Min	Max
[+]Ethylbenzene	100-41-4	-	-	-	0.015	1.3
[+]Styrene	100-42-5	-	-	-	0.034	1.3
[+]Toluene	108-88-3	-	-	-	0.049	1.3
[++]Tetrahydrofuran	109-99-9	[B]$2.9x10^{3}$	-	[B]$2.81x10^{2}$	$2.9x10^{2}$	
[+]n-Nonane	111-84-2	-	-	-	0.10	1.4
[+]Tetrachloroethene	127-18-4	-	-	-	0.015	1.3
[+]2-Hexanone	591-78-6	-	-	-	0.58	1.9
[++]Isopropanol	67-63-0	-	-	243	88	89
[+]Benzene	71-43-2	-	-	-	0.012	1.3
[+]Carbon Disulfide	75-15-0	-	-	-	0.048	1.3
[+]Ethylene Oxide	75-21-8	-	[**]$5.9x10^{2}$	-	-	
[+]Chlorodifluoromethane	75-45-6	-	-	-	0.27	1.5
[+]m,p-Xylenes	-	-	-	-	0.042	1.3
[+]o-Xylene	95-47-6	-	-	-	0.041	1.3
[+]3-Pentanone	96-22-0	-	-	-	0.067	1.3
[#]Oxalate	144-62-7	$1.13x10^{6}$	$2.8x10^{5}$	-	-	-
[@##]Formate	64-18-6	$3.72x10^{6}$	[J]$1.3x10^{7}$	-	-	-
[@###]Acetate	64-19-7	$3.8x10^{6}$	$4.4x10^{7}$	[J]$3.0x10^{2}$	-	-

[J] This analyte detected at a concentration below the minimum quantitative limit (MQL).

[B] This analyte was detected in the laboratory method blanks.

[$] Units for off gas results are micrograms of analyte per liter of air at 1 atm and 25 °C.

[+] MQLs: feed $2.1x10^{2}$ µg/L, concentrate 38 µg/L, condensate 20 µg/L, off gas 1.4 µg/L air

[++] MQLs: feed $2.1x10^{3}$µg/L, concentrate $3.8x10^{2}$µg/L, condensate $2.0x10^{2}$µg/L, off gas 14µg/L air

[#] Oxalate MQLs: feed $4.7x10^{4}$µg/L, concentrate $1.4x10^{4}$µg/L, condensate 28µg/L

[##] Formate MQLs: feed $2.5x10^{5}$µg/L, concentrate $2.5x10^{6}$µg/L, condensate $2.5x10^{2}$µg/L

[###] Acetate MQLs: feed $3.7x10^{4}$µg/L, concentrate $3.7x10^{6}$µg/L, condensate 37µg/L

[@] Formate and acetate results should be consider as upper limits. See report footnote 8.

[**] This result is from a single sample. The value from the 2nd duplicate exceeded the high calibrated concentration.

1. Aqueous Samples

Aqueous samples included the evaporator feed, condensate, and concentrate samples. These samples were handled according to EPA SW-846 protocol for handling samples to be analyzed for semivolatile organic compounds. A 0.01 N sodium hydroxide solution was used to prepare trip blanks and field blanks. This was used instead of ASTM Type II water to more closely simulate the highly caustic samples.

Methods used to analyze these samples have been listed in Table 4.1. These methods were also used to analyze the pump trap samples from the off-gas system. All methods were performed according to SW-846 protocol except where noted in this section. Analytical methods were implemented by BWXT Services and Triangle Laboratories, Inc. as Standard Operating Procedures.

Table 4.1. Methods Used to Determine Semivolatile Compounds in Aqueous Samples

	Analytical Method
General Semivolatiles	SW-846 #3510C, 8270C
Triethylamine	SW-846 #3510C, GC-MS
Pesticides and PCBs	SW-846 #3510C, 8082C
Dioxins and Furans	SW-846 #8290

Most semivolatile organic compounds were determined by Method 3510C (extraction) and 8260B (GC-MS). Because of the high pHs, Method 3510C was modified. For feed samples, the basic extraction was performed first. Based on subsequent experience with a set of samples from a nonradioactive evaporator study, BWXT Services determined that results were improved if the pHs were adjusted, and Method 3510C was then performed. For aqueous samples other than the feed samples, pHs were lowered prior to the acid extraction. No target semivolatiles were detected in the blanks. For some feed and concentrate analytes, matrix spike and duplicate recoveries did not meet the QAPjP requirements.[7] Recovery values are discussed along with the sample results.

Triethylamine (TEA) was determined by Method 3510C (modified as discussed in the previous paragraph) and Gas Chromatography-Mass Spectrometry (GC-MS). TEA was determined using a GC column (RTx-5 Amine) that was deactivated for amines. This column appeared to cause degradation of the compound that is used to tune the mass spectrometer. Since the response to TEA was within other specifications, the samples were analyzed. Because of questions associated with the instrument tune, tentatively-identified compounds were not reported.

Pesticides and polychlorinated biphenyls (PCBs) were determined by Method 3510C (modified as discussed previously) and 8082 (GC-MS). Recoveries were within the specified range and met the reproducibility requirements given in QAPjP. None of the pesticides or PCBs was detected in the blanks. During the analyses, continuing calibrations indicated that the instrument response had drifted such that reported concentrations would have been higher than the actual values. EPA SW-846 protocol did not require these analyses be repeated because all analytes were determined to be below the method MQL. This type of failure shows a drift in the method toward higher sensitivity.

Dioxins and furans were determined by Method 8290. BWXT Services performed the extractions, and Triangle Laboratories, Inc analyzed the extract. Feed sample recoveries were within the range specified in the QAPjP.[7] The duplicate appears to have been spiked twice. Accounting for this, the recoveries also met the precision requirements. Concentrate and condensate recoveries also met the QAPjP requirements[7] except for the 2,3,4,7,8-pentachlorodibenzofuran (23478PeCDF) duplicate recovery (140%) and 1,2,3,7,8,9-heptachlorodibenzofuran (123789HpCDF) precision (26.5%).

2. Off Gas System Samples

During operation of the evaporator, off gas was passed through an EPA SW-846 Method 0010 sampling train. This produced a pump trap sample, a rinse sample, and an XAD sorbant sample. These samples were collected according to Method 0010 and shipped to BWXT Services for analysis. In addition to the field blanks required by this method, a set of process blanks was also generated by operating the evaporator with a sodium hydroxide solution.

Methods used to analyze the pump trap and rinse samples were the same as those given previously for aqueous samples. Methods used to analyze the XAD samples have been given in Table 4.2. These methods were performed according to SW846 protocol except where noted in this section. Analytical methods were implemented by BWXT Services and Triangle Laboratories, Inc. as Standard Operating Procedures.

For the pesticide analyses, surrogate recoveries were well outside of the range specified in the QAPjP for the matrix spike recoveries.[7] These recoveries were 210 % and 190 % for decachlorobiphenyl and 170 % for tetrachloro-m-xylene. The pesticide matrix spike and duplicate recoveries were within the specified range. For the dioxin and furan analyses, the 1,2,3,4,6,7,8,9-octachlorodibenzop-Dioxin (OCDD) recoveries were biased high (138 and 133 % for the matrix spike and duplicate respectively). All semivolatile and PCB recoveries were within the range specifed in the QAPjP.[7]

Table 4.2. Methods Used to Determine Semivolatile Compounds in XAD Samples

	Analytical Method
General Semivolatiles	SW-846 #3542, 8270C
Triethylamine	SW-846 #3542, GC-MS
Pesticides and PCBs	SW-846 #3542, 8082C
Dioxins and Furans	SW-846 #3542, 8290

B. Results from Semivolatile Organic Compound Analyses

Most of the target analytes were not detected in any of the samples. As discussed in the previous section, matrix spike, surrogate, and some of the internal standard recoveries were outside of the ranges given in the QAPjP.[7] This was expected to have been caused by the high pHs of these samples. This conclusion was supported by an observed color change when the internal standard was added to the samples and by the successful recovery of the internal standards in the other samples and blanks. Results are given in Table 4.5.

Table 4.3. Semivolatile Recoveries for Method 8270C on Aqueous Samples

	Feed (%)			Concentrate (%)		
	Spike	Duplicate	Deviation	Spike	Duplicate	Deviation
Phenol	*0	*0	-	*0	*0	-
1,4-Dichlorobenzene	52	57	9	57	64	12
1,2,4-Trichlorobenzene	65	67	3	55	64	15
2,4-Dinitrotoluene	*733	100	*152	*307	*3267	*166
Pentachlorophenol	*8	*9	12	*8	*11	*32

*These values did not meet the requirements of QAPjP (apparently due to high pHs).

With the following exceptions, all quality assurance specifications were met. Recoveries were low in the aqueous samples for three of the five compounds used for the matrix spikes and duplicates. These values are given in Table 4.3. Poor recoveries were probably due to the sample alkalinity. XAD sample recoveries met specifications. TEA recoveries also met specifications; however, the mass spectrometer could not be tuned because of incompatibilities between the TEA method and the compound used for tuning.

1. Target Analytes Not Detected

Most of the target semivolatile organic compounds were below the method MQLs. The target compounds that were below the method MQLs in all samples are listed in Table 4.4. The minimum quantitative limits for the semivolatile organic compounds were $1x10^2$ µg/L for the feed samples, $3x10^2$ µg/L for the concentrate samples, 20 µg/L for the condensate samples, and 20 µg/L air for the off gas.

2. Target Semivolatile Analytes Detected in at Least One of the Evaporator Samples

Four of the target analytes were detected in at least one of the samples. Most of these were detected in only one of the duplicate samples and at concentrations below the method MQL. These results have been included in Table 4.4. These results have been determined according to EPA SW-846 protocol and are therefore being reported accordingly. Matrix spike recoveries and blank contamination are discussed where appropriate.

Table 4.4. Target Semi-Volatile Analytes Not Detected* in AN-102 Evaporator Samples

Analyte	CAS No.		Analyte	CAS No.
p-Nitrochlorobenzene	100-00-5		Dibenzo (a,h) anthracene	53-70-3
1,4-Dintrobenezene	100-25-4		1,3-Diclhorobenzene	541-73-1
BenzylAlcohol	100-51-6		Propyl Nitrate	627-13-4
4-Methylphenol	106-44-5		N-Nitrosodimethylamine	62-75-9
1,4-Dichlorobenzene	106-46-7		Hexachloroethane	67-72-1
Phenol	108-95-2		2-Propenoic Acid	79-10-7
Pyridine	110-86-1		PCNB	82-68-8
bis (2-Ethylhexyl) Phthalate	117-81-7		Hexachlorobutadiene	87-68-3
Di-n-Octylphthalate	117-84-0		Pentachlorophenol	87-86-5
1,2,4-Trichlorobenzene	120-82-1		Dinoseb	88-85-7
2,4-Dinitrotoluene	121-14-2		Naphthalene	91-20-3
Triethylamine	121-44-8		1,1-Biphenyl	92-52-4
Diphenylamine	122-39-4		2-Methylphenol	95-48-7
Tributyl Phosphate	126-73-8		1,2-Dichlorobenzene	95-50-1
BHT	128-37-0		Actophenone	98-86-2
Tetrachloronaphthalene	1335-88-2		Nitrobenzene	98-95-3
Benxo (a) Pyrene	50-32-8			

*Quantitative limits: Feed $1x10^2$ µg/L Concentrate $3x10^2$ µg/L
Condensate 20 µg/L Off Gas 20 µg/L air

a. Target Analyte Concentrations in the Feed Samples

As indicated in Table 4.4 and Table 4.5, all target analytes were below the method MQLs in the feed samples. As discussed previously, the matrix spike and matrix spike duplicate recoveries did not meet the specifications of the QAPjP.[7] This is thought to be due to the high pH of the samples. Because of these recovery problems, validation indicated that the feed sample results should be rejected.[10] In reality, the affected analytes are not expected to be stable in the alkaline samples.

---

[10] Walt Kubilius, "Report of Analytical Data Validation of Regulatory Analyses for SRTC Contract WFO-98-003: LC Evaporator Samples; Rev.0," **ESH-EMS-20010125**, January 10, 2001.

Table 4.5. Concentrations of Target Semivolatile Analytes Detected

Analyte	CAS #	Feed	Concentrate	Condensate	Off Gas (µg/L)	
		(µg/L)	(µg/L)	(µg/L)	Min	Max
1,4-Dintrobenzene	100-25-4	$<1\text{x}10^2$	$<3\text{x}10^2$	*<22	<34	
Benzyl Alcohol	100-51-6	$<1\text{x}10^2$	*$<3\text{x}10^2$	31	0.0097	34
Propyl Nitrate	627-13-4	$<1\text{x}10^2$	*$<3\text{x}10^2$	<22	<34	
N-Nitrosodimethylamine	62-75-9	$<1\text{x}10^2$	$<3\text{x}10^2$	$1.7\text{x}10^2$	6.3	12

< This indicates analytes that were not present at concentrations above the given MQL.
*This is from a single sample. The duplicate was below this MQL but above the MDL.

b. Target Analyte Concentrations in the Concentrate Samples

Only benzyl alcohol and propyl nitrate were detected in the concentrate samples. As discussed previously, validation indicated the results should be rejected for values below the MQLs. In reality, the affected analytes are not expected to be stable in the alkaline samples. Values reported in Table 4.5 were from one sample. Although the analysis indicated these analytes were present in the other duplicate, the measured concentrations (67 and 47 µg/L for benzyl alcohol and propyl nitrate respectively) were below the MQL.

c. Target Analyte Concentrations in the Condensate Samples

As indicated in Table 4.5, propyl nitrate was below the MQLs in the condensate samples, 1,4-dinitrobenzene was detected in one of the duplicates (at a concentration below the MQL), and benzyl alcohol and N-nitrosodimethylamine were detected in both duplicates. As discussed previously, validation indicated the MQLs should be rejected and the reported concentrations for the other analytes should be considered qualitative.

d. Target Analyte Concentrations in the Off-Gas Samples

In addition to results from the aqueous samples, Table 4.5 includes results from analysis of the off-gas system samples. These values were determined according to EPA SW-846 Method 0010 and are given in terms of micrograms of each analyte per liter of air. The off-gas concentrations given in Table 4.5 were determined by adding the results from the pump trap samples, rinse samples, and an XAD cartridge sample. Issues discussed with analyte recoveries are applicable to these samples.

Because 1,4-dinitrobenzene and propyl nitrate were not detected in any of the off-gas samples, no minimum value was reported for these analytes in Table 4.5. The minimum values were determined to be the sum of off-gas concentrations from the samples with detected analytes. Because 1,4-dinitrobenzene and propyl nitrate were not detected in any of the samples, the minimum value could be as low as 0.

3. Tentatively-Identified Compounds

During analysis for the target compounds several tentatively-identified compounds (TICs) were identified in these samples. These compounds are given in Table 4.6. The results should be used with caution. Concentrations are thought to be accurate to within 100 %; however, no attempt was made to verify this. In addition, steps were taken to verify that the TICs were properly identified. Additional peaks were reported as "unknown", but per discussions with RPP personel, no attempt was made to identify these compounds. The four siloxanes given in Table 4.6 are thought to be degradation products from the antifoam used during the evaporator study.

Table 4.6. Concentrations of Semivolatile Tentatively-Identified Compounds

Analyte	CAS #	Feed	Concentrate	Condensate	Off Gas
		(µg/L)	(µg/L)	(µg/L)	(µg/L)
1-Nitro-2-Propanone	10230-68-9	7×10^{2}	-	-	-
Butanoic Acid	107-92-6	3.4×10^{3}	-	-	-
Toluene	108-88-3	-	-	-	0.0026
Nonane	111-84-2	-	-	-	2.5
5-Methyldecane	13151-35-4	-	-	-	0.019
1,4-Dintrosopiperazine	140-79-4	1×10^{3}	-	-	-
3-Chloro-Cyclohexene	2441-97-6	4.2×10^{2}	-	-	-
4-Ethyl-2-Methyl Hexane	3074-75-7	-	-	-	0.0039
cis and trans-4-Methyl-2-Hexene	3404-55-5	4.6×10^{3}	-	-	-
2,2-Dimethyl-3-Pentanol	3970-62-5	-	7.1×10^{4}	-	-
Dodecamethylcyclohexasiloxane	540-97-6	-	-	-	0.0032
Decamethylecyclopentasiloxane	541-02-6	-	-	-	0.0084
Hexamethylcyclotrisiloxane	541-05-9	-	-	-	0.0023
Octamethylcyclotetrasiloxane	556-67-2	-	-	-	0.017
3,3-Dimethyl-1-Butene	558-37-2	2.4×10^{3}	-	-	-
n-Hexadecanoic Acid	57-10-3	-	1.5×10^{3}	-	-
Octadecanoic Acid	57-11-4	-	1.9×10^{3}	-	-
4-Nitrosomorpholine	59-89-2	1.2×10^{3}	-	17	-
(E)-2-Nonene	6434-78-2	-	-	-	0.0039
Benzoic Acid	65-85-0	1.9×10^{2}	-	-	-
1-Docosanol	661-19-8	-	-	-	0.0090
Methylene Chloride	75-09-2	-	1.7×10^{4}	-	4.8
1,2-Dichlorocyclohexane	822-86-6	2×10^{3}	-	-	-

C. Results from Pesticide and Polychlorinated Biphenyl (PCB) Analyses

None of the target pesticides or PCBs were detected in any of the samples. These results have been included in Table 4.7. These results have been determined according to EPA SW-846 protocol and are therefore being reported accordingly. The results have not been adjusted for recoveries. As indicated previously, the continuing calibration for the pesticides showed a 15% increase in the instrument sensitivity. Because none of the analytes were detected, EPA SW-846 protocol did not require corrective action.

Table 4.7. Concentrations of Pesticides and Polychlorinated Biphenyls

Analyte	CAS #	Feed	Concentrate	Condensate	Off Gas
		(µg/L)	(µg/L)	(µg/L)	(µg/L)
Hexachlorobenzene	118-74-1	<3	<3	<0.9	<0.4
Octachloronaphthalene	2234-13-1	<3	<3	<0.9	<0.4
Toxaphene	3001-35-2	<2x10^2	<2x10^2	<5x10	<1x10
Aldrin	309-00-2	<2	<2	<0.5	<0.2
alpha-BHC	319-84-6	<2	<2	<0.5	<0.2
beta-BHC	319-85-7	<2	<2	<0.5	<0.2
Isodrin	465-73-6	<3	<3	<0.9	<0.4
4,4'-DDT	50-29-3	<3	<3	<0.9	<0.4
Gamma-BHC (Lindane)	58-89-9	<2	<2	<0.5	<0.2
Dieldrin	60-57-1	<3	<3	<0.9	<0.4
Endrin	72-20-8	<3	<3	<0.9	<0.4
4,4'-DDD	72-54-8	<3	<3	<0.9	<0.4
Heptachlor	76-44-8	<2	<2	<0.5	<0.2
Aroclor-1260	11096-82-5	<3x10	<3x10	<9	<3
Aroclor-1254	11097-69-5	<3x10	<3x10	<9	<3
Aroclor-1268	11100-14-4	<3x10	*ND	*ND	*ND
Aroclor-1221	11104-28-2	<6x10	<6x10	<2x10	<7
Aroclor-1232	11141-16-5	<3x10	<3x10	<9	<3
Aroclor-1248	12672-29-6	<3x10	<3x10	<9	<3
Aroclor-1016	12674-11-2	<3x10	<3x10	<9	<3
Aroclor-1262	37327-23-5	<3x10	*ND	*ND	*ND
Aroclor-1242	53469-21-9	<3x10	<3x10	<9	<3

*This PCB set is not specified by Method 8082 and was not determined in this samples.
< This indicates analytes that were not detected at the given MDL.

With the following exceptions, all quality assurance specifications were met. Aqueous sample recoveries met specifications. Continuing calibration indicated that the instrument sensitivity had increased by more than 15 %. In such cases, EPA SW-846 allows for the MQLs to be used. Result validation identified the MQLs to be estimates. XAD sample recoveries were above the specified range. Both the calibration drift and the high XAD recoveries would cause results to be over-reported.

D. Results from Dioxin and Furan Analyses

Most of the samples were determined to be free of dioxins and furans at the method MQLs. These results have been included in Table 4.8. As indicated in Table 4.8, OCDD and the associated total (HxCDD) were detected in some of the off gas samples and in the associated blanks. Application of the CLP 5x rule indicates that these results should be considered as "nondetects". The other detected analytes were reported at concentrations that were either below or close to the MQL (within a factor of 3).

With the following exceptions, all quality assurance specifications were met. Aqueous sample recoveries met specifications except that the 23478-PeCDF recoveries were above the specified range and the 123789-HxCDF recovery deviations were above the specified limit. For the XAD sorbents, the laboratory control sample recoveries were above the specified range. The LCS and LCSD were used for the ending calibration for the XAD samples because the actual ending calibration check was outside of the twelve-hour limit.

E. Conclusions from Semivolatile, Pesticide, PCB, and Dioxins and Furans Analyses

Analyses of the evaporator samples showed that the concentrations of target semivolatile compounds, pesticides, PCBs, and dioxins and furans in the samples were very low. Semiquantitative results of the TIC semivolatile compounds suggested these concentrations may be significantly higher. With some exceptions, these analyses met the requirements given in QAPjP. Recoveries were poor for several of the matrix spike, internal standard, and surrogate recoveries because of matrix effects associated with the feed and concentrate samples. The following conclusions can be made from these determinations:

-No target semivolatile, pesticide, PCB or dioxin or furan was detected in the feed.
-Four semivolatile target analytes were detected in at least one of the condensate, concentrate, or off-gas samples. The values that were above the MQL have been presented in Table 4.9.
-Very low dioxin and furan concentrations were reported in some of the off-gas samples.
-The condensate sample easily met the 200-Area ETF WAC for organic compounds.
-No pesticide or PCB was detected in any of the samples.

5.0 INORGANIC SPECIES AND RADIONUCLIDES

Analysis of the samples for inorganic species and radionuclides showed the samples to be primarily sodium nitrate. Slightly more than half of the radioactivity in the feed and concentrate samples was due to strontium-90. The radioactivity in the condensate and off gas samples was four orders of magnitude less than the radioactivity in the feed. Although the radioactivity associated with the condensate and off-gas samples was very low, the most abundant radionuclide in these samples appears to have been tritium. Results have been given in Table 5.2.

Table 4.8. Concentrations of Dioxins and Furans

Analyte	CAS #	Feed	Concentrate	Condensate	Off Gas (µg/L)	
		(µg/L)	(µg/L)	(µg/L)	Min.	Max.
2378-TCDD	1746-01-6	$<2x10^{-5}$	$<2x10^{-6}$	$<2x10^{-6}$	$<1x10^{-6}$	
12378-PeCDD	40321-76-4	$<2x10^{-5}$	$<1x10^{-6}$	$<2x10^{-6}$	$<1x10^{-6}$	
123478-HxCDD	57653-85-7	$<2x10^{-5}$	$<1x10^{-6}$	$<2x10^{-6}$	$<3x10^{-6}$	
123678-HxCDD	39227-28-6	$<2x10^{-5}$	$<1x10^{-6}$	$<2x10^{-6}$	$<2x10^{-6}$	
123789-HxCDD	19408-74-3	$<2x10^{-5}$	$<1x10^{-6}$	$<2x10^{-6}$	$<2x10^{-6}$	
1234678-HpCDD	35822-39-4	$<3x10^{-5}$	$<2x10^{-6}$	$<2x10^{-6}$	$<3x10^{-6}$	
OCDD	3268-87-9	$<5x10^{-5}$	$<3x10^{-6}$	$<3x10^{-6}$	$^{JB}5.2x10^{-6}$	$^{JB}7.0x10^{-6}$
2378-TCDF	51207-31-9	$<1x10^{-5}$	$<1x10^{-6}$	$<8x10^{-7}$	$<1x10^{-6}$	
12378-PeCDF	57117-41-6	$<1x10^{-5}$	$<8x10^{-7}$	$<2x10^{-6}$	$^{J}7.2x10^{-7}$	$^{J}1.4x10^{-6}$
23478-PeCDF	57117-31-4	$<1x10^{-5}$	$<8x10^{-7}$	$<2x10^{-6}$	$<1x10^{-6}$	
123478-HxCDF	57117-44-9	$<2x10^{-5}$	$<8x10^{-7}$	$<2x10^{-6}$	$<1x10^{-6}$	
123678-HxCDF	72918-21-9	$<2x10^{-5}$	$<8x10^{-7}$	$<8x10^{-7}$	$<1x10^{-6}$	
234678-HxCDF	70648-26-9	$<2x10^{-5}$	$<8x10^{-7}$	$<8x10^{-7}$	$<1x10^{-6}$	
123789-HxCDF	60851-34-5	$<2x10^{-5}$	$<1x10^{-6}$	$<2x10^{-6}$	$<2x10^{-6}$	
1234678-HpCDF	67562-39-4	$<2x10^{-5}$	$<1x10^{-6}$	$<2x10^{-6}$	$<1x10^{-6}$	
1234789-HpCDF	55673-89-7	$<3x10^{-5}$	$<1x10^{-6}$	$<2x10^{-6}$	$<2x10^{-6}$	
OCDF	39001-02-0	$<3x10^{-5}$	$<2x10^{-6}$	$<2x10^{-6}$	$<3x10^{-6}$	
Total TCDD	-	$<2x10^{-5}$	$<2x10^{-6}$	$<2x10^{-6}$	$<1x10^{-6}$	
Total PeCDD	-	$<2x10^{-5}$	$3.2x10^{-6}$	$<2x10^{-6}$	$8.7x10^{-7}$	$2.0x10^{-6}$
Total HxCDD	-	$<2x10^{-5}$	$<1x10^{-6}$	$<2x10^{-6}$	$^{B}4.3x10^{-6}$	$^{B}6.2x10^{-6}$
Total HpCDD	-	$<3x10^{-5}$	$<2x10^{-6}$	$<2x10^{-6}$	$<3x10^{-6}$	
Total TCDF	-	$<1x10^{-5}$	$<1x10^{-6}$	$<8x10^{-7}$	$1.4x10^{-7}$	$1.3x10^{-6}$
Total PeCDF	-	$<1x10^{-5}$	$<8x10^{-7}$	$<2x10^{-6}$	$^{J}7.2x10^{-7}$	$^{J}1.4x10^{-6}$
Total HxCDF	-	$<2x10^{-5}$	$<8x10^{-7}$	$<2x10^{-6}$	$<1x10^{-6}$	
Total HpCDF	-	$<2x10^{-5}$	$<1x10^{-6}$	$<2x10^{-6}$	$<2x10^{-6}$	

[J] This analyte detected at a concentration below the minimum quantitative limit (MQL).

[B] This analyte was detected in one or more of the analytical laboratory's method blanks.

< This indicates an analyte that was not detected at the given MDL.

Table 4.9. Summary of Target Semi Volatile Analytes Detected above the Method MQLs

Analyte	CAS #	Feed	Concentrate	Condensate	Off Gas (µg/L)	
		(µg/L)	(µg/L)	(µg/L)	Min	Max
Benzyl Alcohol	100-51-6	-	-	31	0.0097	34
N-Nitrosodimethylamine	62-75-9	-	-	1.7×10^{2}	6.3	12
Total PeCDD		-	-	-	8.7×10^{-7}	2.0×10^{-6}
Total HxCDD		-	-	-	[B]4.3×10^{-6}	[B]6.2×10^{-6}
Total TCDF		-	-	-	1.4×10^{-7}	1.3×10^{-6}

[B] This analyte was detected in one or more of the analytical laboratory's method blanks.

A. Experimental

Samples that were analyzed for inorganic species and for radionuclides were collected during the second ten-hour portion of the evaporator demonstration. These samples included duplicate evaporator feed samples, duplicate condensate samples, duplicate concentrate samples, duplicate pump trap samples, a set of samples from an EPA SW-846 sampling train, and the associated blanks.

1. Aqueous Samples

Aqueous samples included the evaporator feed, condensate, and concentrate samples. These samples were handled according to EPA SW-846 protocol for handling samples to be analyzed for inorganic compounds. A 0.01 N sodium hydroxide solution was used to prepare field blanks. This was used instead of ASTM Type II water to more closely simulate the highly caustic samples.

Methods used to analyze these samples for inorganic species and for radionuclides have been given in Table 5.1. These methods were also used to analyze the off-gas samples. All methods were performed according to EPA SW-846 protocol except where noted in this section. Analytical methods were implemented by BWXT Services as Standard Operating Procedures.

Most of the elemental analyses were performed by Method 3015 (acid digestion) and 6010B (ICP-AES). Matrix spike, matrix spike duplicate, and laboratory control sample recoveries were within the specified range and met the reproducibility requirements given in QAPjP except for platinum, silver, tantalum, and uranium recoveries. Platinum matrix spike and matrix spike duplicates were high (152 and 204%). Silver, tantalum, and uranium recoveries were low (less than 20%).

Arsenic and selenium analyses were performed by Method 3015 and one of the graphite furnace atomic absorption methods (Method 7060A for arsenic and Method 7740 for selenium). Recoveries were within the specified range and met the reproducibility requirements given in QAPjP. Arsenic and selenium concentrations were below the method MQLs for all blanks associated with these samples.

Table 5.1. Methods Used to Determine Inorganic Species and Radionuclides

	Analytical Method
General Metals	SW-846 #3015, 6010B
Arsenic	SW-846 #3015, 7060A
Selenium	SW-846 #3015, 7740
Mercury	SW-846 #7470A
Anions	SW-846 #9056A
Ammonia	Ion-selective Electrode
Cyanide	SW-846 #9014
Hydroxide	Titration
Most γ-Emitters	Gamma Spectroscopy
C-14, Se-79, Pu-241, I-129, Sr-90, Tc-99, H-3	Beta Liquid Scintillation
Most α-Emitters	Separation and Alpha PHA
Gross Alpha and Gross Beta	SW-846 #9310

2. Off-Gas Samples

During operation of the evaporator, off gas was passed through an EPA SW-846 Method 0060 sampling train. This produced a pump trap sample, a probe rinse sample, and four impinger samples (three of which were only used for mercury analysis). These samples were collected according to Method 0060 and shipped to BWXT Services for analysis. Equation 2 was used to determine the concentration of the analyte in the off gas system. For mercury analyses, Equation 2 was modified to include three additional impinger terms.

$$C=(C_pV_p-C_{pb}V_{pb}+C_rV_r-C_{rb}V_{rb}+C_iV_i-C_{ib}V_{ib})/(KYV_mP/T) \qquad \text{(Eq. 2)}$$

where C was the concentration of the analyte in μg/L air,
C_p was the concentration of the analyte in the pump trap sample in μg/L or pCi/L,
V_p was the volume of the pump trap condensate collected in L,
C_{pb} was the concentration of the analyte in the pump trap blank in μg/L or pCi/L,
V_{pb} was the volume of the condensate in the pump trap blank in L,
C_r was the concentration of the analyte in the rinse sample in μg/L or pCi/L,
V_r was the volume of the rinse collected in L,
C_{rb} was the concentration of the analyte in the rinse blank in μg/L or pCi/L,
V_{rb} was the volume of the rinse blank in L,
C_i was the concentration of the analyte in the impinger sample in μg/L,
V_i was the volume of condensate in the impinger sample in L,
C_{ib} was the concentration of the analyte in the impinger blank in μg/L,
V_{ib} was the volume of condensate in the impinger blank in L,
K was a constant (0.3858 °K/mm Hg) for converting to standard conditions (20 °C and 1 atm),
Y was the dry gas meter calibration factor,

V_m was the dry gas volume in L (L),
P was the barometric pressure in mm Hg , and
T was the average temperature in °K.

B. Results from Elemental Analyses

Results from the elemental analyses have been presented in Table 5.2. These results have been determined according to EPA SW-846 protocol and are being reported accordingly. Matrix spike recoveries and blank contamination are discussed where appropriate; however, in compliance with SW-846, the results have not been adjusted. In addition to concentrations, a concentration factor has been given in Table 5.2. This concentration factor is the concentrate concentration divided by the feed concentration.

Values given in Table 5.2 were for duplicate samples unless otherwise indicated. Uncertainties were expressed in terms of the standard deviation of these duplicates. An attempt was made to retain the EPA SW-846 nomenclature for data qualifiers. As such, a "B" qualification has a different meaning for the results in Table 5.2 than it had in previous sections.

Results given in Table 5.2 for boron, bismuth, cadmium, palladium, and platinum indicated that these elements were present at measurable concentrations in one or more of the samples. Initial and continuing calibration blanks indicated that these results should be considered to be below the method minimum quantitative limits. These results should therefore be considered to be "nondetects".

Concentration factors for most of the major species were between 1.5 and 1.9. The concentration factor for potassium was slightly higher (2.0). Concentration factors reported previously[5] are consistent with a value of 1.5. For the feed samples, the phosphorous matrix spike recovery was high (139 %) while the matrix spike recovery for the concentrate samples was easily within the specified range (104 %). If one were to adjust the feed concentrations for the high phosphorous bias, the phosphorous concentration factor would be 1.3.

Off-gas sample results given in Table 5.2 were expressed in terms of EPA SW-846 Method 0060 protocol. In the cases in which the analyte was not detected in any off-gas sample, a maximum value was given. This maximum value was the sum of the analyte MQLs. This convention for presenting these results is defined in EPA SW-846 Method 0060. When the analyte was detected in one or more of the samples, the detected value was used in place of the MQL. In addition, when the analyte was detected, a minimum value was also given. This minimum value was the sum of the detected values. As indicated in Table 5.2, sodium was the only element detected at greater than 10 times the method detection limit in all of the off-gas samples.

Table 5.2. Inorganic Species in Streams from the Envelope C Evaporator

	Feed	**Concentrate**	****CF**	**Condensate**	**Off Gas**
	(µg/L)	(µg/L)		(µg/L)	(µg/L air)
Ag	^{N}<80	^{N}<4x10^{2}	-	^{*BN}960	^{BN}3.7-^{N}4.8
Al	5.73±0.02x10^{6}	1.03±0.05x10^{7}	1.8	*<1x10^{3}	<7.5
As	<4x10^{2}	<2x10^{3}	-	<2x10^{3}	<11
B	2.0±0.1x10^{4}	3.1±0.1x10^{4}	1.5	^{*B}5.6x10^{3}	^{B}3.0x10^{2}
Ba	*<20	*<1x10^{2}	-	*<1x10^{2}	^{B}0.67-0.93
Be	^{B}16	^{B}60	3.7	*<20	^{B}0.24
Bi	<1x10^{4}	*<5x10^{3}	-	4±1x10^{4}	^{BN}35-^{N}57
Ca	1.185±0.007x10^{5}	2.3±0.02x10^{5}	1.9	*<5x10^{3}	^{B}48-61
Cd	2.20±0.01x10^{4}	4.0±0.2x10^{4}	1.8	<1x10^{2}	^{B}0.44-0.86
Co	1.35±0.03x10^{3}	^{B}2.3±0.1x10^{3}	1.7	<3x10^{2}	<1.6
Cr	7.66±0.02x10^{4}	1.40±0.07x10^{5}	1.8	*<3x10^{2}	<1.5
Cu	3.8±0.2x10^{3}	9±3x10^{3}	2.4	<3x10^{2}	^{B}0.45-1.9
Fe	^{B}9±2x10^{2}	^{*B}4.6x10^{3}	5	*<3x10^{3}	^{N}<18
Hg	*<5	<3	-	<1	^{B}0.13-^{N}1.7x10^{-2}
K	8.72±0.01x10^{5}	1.71±0.08x10^{6}	2.0	<6x10^{3}	^{B}18-43
Li	^{N}<1x10^{2}	^{N}<6x10^{2}	-	<6x10^{2}	<3.7
Mg	<4x10^{2}	<2x10^{3}	-	<2x10^{3}	<12
Mn	7.36±0.03x10^{2}	1.2±0.3x10^{3}	1.7	<1x10^{2}	^{B}1.2-1.4
Mo	2.24±0.07x10^{4}	3.96±0.09x10^{4}	1.8	<6x10^{2}	<8.7
Na	1.185±0.007x10^{8}	1.60±0.06x10^{8}	1.4	9±1x10^{3}	^{B}1.3x10^{2}
Ni	1.295±0.007x10^{5}	2.5±0.1x10^{5}	1.9	<6x10^{2}	<4.0
P	^{N}7.96±0.08x10^{5}	7.6±0.8x10^{5}	^{N}0.95	<1x10^{4}	<61
Pb	4.12±0.03x10^{4}	7.8±0.9x10^{4}	1.9	<3x10^{3}	<17
Pd	^{N}<3x10^{3}	^{N}<1x10^{4}	-	^{BN}2.4±0.3x10^{4}	<91
Pt	<6x10^{2}	^{N}2.6±0.1x10^{6}	-	*8.2x10^{3}	^{B}51-^{N}56
Rh	^{N}<1x10^{4}	^{N}<5x10^{4}	-	<5x10^{4}	<3.0x10^{2}
S	2.29±0.02x10^{6}	3.6±0.2x10^{6}	1.6	<2x10^{3}	^{B}3.5-14
Sb	<4x10^{2}	<2x10^{3}	-	<2x10^{3}	<12
Se	^{B}6.5±0.6x10^{2}	<1x10^{3}	-	<1x10^{3}	<9.1
Si	^{B}8.91±0.04x10^{3}	<2x10^{5}	-	<2x10^{4}	<5.0x10^{3}
Sn	^{B}3.00±0.03x10^{3}	<4x10^{3}	-	<4x10^{3}	<26
Ta	^{N}<3x10^{3}	^{N}<2x10^{4}	-	^{N}<1x10^{4}	^{N}<94
Tl	^{B}1.7±0.1x10^{3}	*<6x10^{3}	-	*<6x10^{3}	<37
U	<1x10^{4}	^{N}<7x10^{4}		^{N}<7x10^{4}	<4.0x10^{2}
V	2.3±0.5x10^{2}	<4x10^{2}	-	<4x10^{2}	<2.7
W	^{N}6.685±0.007x10^{4}	^{N}1.11±0.01x10^{5}	^{N}1.7	^{N}<7x10^{3}	^{N}<41
Y	^{B}4.10±0.08x10^{2}	^{B}1.0±0.1x10^{2}	2.3	<8x10^{2}	<4.9
Zn	7±1x10^{2}	^{B}2.2±0.8x10^{3}	3	8±1x10^{2}	^{B}13
Zr	^{N}<2x10^{3}	^{N}<1x10^{4}	-	<1x10^{4}	<74

^{B}Analyte present at concentrations greater than the MDL but less than 10 times the MDL.

^{N}Matrix spike recovery was not within the specified range of 75 to 125 percent.

*This is the result from a single sample.

**CF (concentration factor) is concentrate concentration divided by feed concentration.

< This indicates an analyte that was not detected at the given MDL.

C. Results from Anion Analyses

Results from the anion analyses are presented in Table 5.3. These results meet all of the associated QA requirements. These results have been determined according to EPA SW-846 protocol and are being reported accordingly. Concentration factors have not been given in Table 5.3. Because of complicated equilibria associated with these concentrated solutions, the applicability of such factors has been questioned. For example, the calculated nitrate concentration factor would be higher than expected, while the value for nitrite would be lower. As expected, during evaporation, the equilibrium between these two anions was shifted.

Table 5.3. Anions in Streams from the Envelope C Evaporator

Analyte (units)	Feed	Concentrate	Condensate	Off Gas
Br (µg/L)	<2x10^{4}	<8x10^{5}	<20	<20
Cl (µg/L)	1.59±0.04x10^{6}	1.35±0.04x10^{7}	<20	3.7±0.1x10^{2}
CN (mg/L)	41±5	3.5±0.3	<0.05	<0.05
F (µg/L)	7.6±0.2x10^{5}	<6x10^{5}	70	70
OH (N)	0.437±0.004	2.99±0.01	0.011±0.001	-
NH4 (mg/L)	-	8.0	3.5	-
NO3 (µg/L)	9.0±0.3x10^{7}	1.61±0.08x10^{8}	<10	<10
NO2 (µg/L)	3.78±0.04x10^{7}	1.7±0.1x10^{7}	<20	<20
pH	13.06±0.04	-	9.0±0.1	-
PO4 (µg/L)	1.6±0.6x10^{6}	<1x10^{6}	<30	<30
SO4 (µg/L)	7.0±0.8x10^{6}	1.5±0.1x10^{7}	<30	<30

< This analyte was not detected at the MDL given.

Results for the condensate sample were compared to the 200-Area ETF WAC. All criteria were met. The condensate pH was easily within the required range (0.5 to 13.0), ammonium was shown to be below the WAC limit (100,000 mg/L), and no oxidizer was present above the WAC limit (1000 mg/L). In addition, determinations were made for all anionic species that would need to be determined for condensate to be transferred to the 200-area ETF.

D. Results from Radionuclide Analyses

Results from the radionuclide analyses are presented in Table 5.4. Although most of these were not determined by EPA SW-846 methods, where possible, they are being reported according to EPA SW-846 protocol. Recoveries and blank contamination are discussed where appropriate; however, the results have not been adjusted for these. In addition to radionuclide concentrations, a concentration factor is given in Table 5.4. This factor is the concentrate concentration divided by the feed concentration.

Table 5.4. Radionuclides in Streams from the Envelope C Evaporator

Analyte	Feed	Concentrate	Factor	Condensate	Off Gas
	(pCi/L)	(pCi/L)		(pCi/L)	(pCi/L air)
Am-241	$1.42\pm0.03\text{x}10^{7}$	$7.0\pm0.3\text{x}10^{6}$	0.49	$<1\text{x}10^{2}$	<60
C-14	$4.8\pm0.4\text{x}10^{5}$	$5\pm1\text{x}10^{5}$	0.95	$<4\text{x}10^{3}$	$<8.0\text{x}10^{2}$
Ce-144	$<4\text{x}10^{5}$	-	-	-	-
Cm-242	$8.4\pm0.1\text{x}10^{4}$	$3.5\pm0.1\text{x}10^{4}$	0.41	<60	<52
Cm-244	$1.04\pm0.01\text{x}10^{7}$	$5.2\pm0.3\text{x}10^{6}$	0.50	$<1\text{x}10^{2}$	22-33
Co-60	$3.66\pm0.03\text{x}10^{7}$	$5.6\pm0.2\text{x}10^{7}$	1.5	$<2\text{x}10^{2}$	$^{+}0.95\text{-}^{+}1.1\text{x}10^{2}$
Cs-134	$<8\text{x}10^{4}$	$<2\text{x}10^{5}$	-	$<2\text{x}10^{2}$	18-*30
Cs-137	$4.83\pm0.04\text{x}10^{7}$	$8.1\pm0.4\text{x}10^{7}$	1.7	$<2\text{x}10^{2}$	$1.1\text{-}1.2\text{x}10^{2}$
Eu-152	$6.23\pm0.3\text{x}10^{5}$	$6.8\pm0.9\text{x}10^{5}$	1.1	$<6\text{x}10^{2}$	<63
Eu-154	$3.65\pm0.04\text{x}10^{7}$	$5.6\pm0.1\text{x}10^{7}$	1.5	$<6\text{x}10^{2}$	<74
Eu-155	$2.10\pm0.07\text{x}10^{7}$	$3.3\pm0.2\text{x}10^{7}$	1.6	$<5\text{x}10^{2}$	**<42
Gross Alpha	$3.30\pm0.2\text{x}10^{7}$	$3.7\pm0.6\text{x}10^{7}$	1.1	$2.8\text{x}10^{3}$	$1.1\text{-}1.7\text{x}10^{2}$
Gross Beta	$2.78\pm0.03\text{x}10^{9}$	$4.4\pm0.5\text{x}10^{9}$	1.6	$2.7\text{x}10^{5}$	$*1.7\text{x}10^{4}$
H-3	$2.4\pm0.2\text{x}10^{5}$	$3.1\text{x}10^{5}$	1.3	$1.49\pm0.04\text{x}10^{5}$	$5.5\text{-}6.5\text{x}10^{3}$
I-129	$6\pm13\text{x}10^{4}$	$9\pm3\text{x}10^{4}$	1.5	$<2\text{x}10^{3}$	$<1.7\text{x}10^{3}$
Nb-94	$<8\text{x}10^{4}$	$<2\text{x}10^{5}$	-	$<2\text{x}10^{2}$	<22
$^{++}$Np-237	$1.2\pm0.3\text{x}10^{4}$	$1.6\text{x}10^{4}$	1.3	<4x10	5.0-21
Pu-238	$6.4\pm0.9\text{x}10^{5}$	$1.12\pm0.04\text{x}10^{6}$	1.7	<5x10	<49
Pu-239/240	$7.4\pm0.9\text{x}10^{5}$	$1.28\pm0.04\text{x}10^{6}$	1.7	<5x10	<26
Pu-241	$1.4\pm0.2\text{x}10^{6}$	$3\pm1\text{x}10^{6}$	1.9	$<1\text{x}10^{4}$	$<3.5\text{x}10^{3}$
Ra-226	$<2\text{x}10^{5}$	$<4\text{x}10^{5}$	-	$<4\text{x}10^{2}$	$^{+}50\text{-}^{+}58$
Ru-103	$<1\text{x}10^{5}$	$<2\text{x}10^{5}$	-	$<2\text{x}10^{2}$	<28
Ru-106	$<8\text{x}10^{5}$	$<2\text{x}10^{6}$	-	$<2\text{x}10^{3}$	$<2.1\text{x}10^{2}$
Sb-125	$<3\text{x}10^{5}$	-	-	-	-
Se-79	$3.2\pm0.6\text{x}10^{5}$	$<5\text{x}10^{6}$	-	$<5\text{x}10^{4}$	$<2.9\text{x}10^{3}$
Sn-113	$<1\text{x}10^{5}$	-	-	-	-
Sr-90	$1.43\pm0.09\text{x}10^{9}$	$2.11\pm0.06\text{x}10^{9}$	1.5	$<1\text{x}10^{3}$	$<4.3\text{x}10^{2}$
Tc-99	$3.7\pm0.2\text{x}10^{7}$	$3.60\pm0.09\text{x}10^{7}$	0.97	$<3\text{x}10^{3}$	$<5.0\text{x}10^{2}$
U-234	$3\pm1\text{x}10^{3}$	$1.2\text{x}10^{4}$	4.4	<80	<24
U-235	<80	$1.9\pm0.5\text{x}10^{2}$	-	<70	<18
U-236	$<1\text{x}10^{2}$	-	-	-	-
U-238	<80	$5.8\pm0.7\text{x}10^{2}$	1.6	<40	<16
Zn-65	$<2\text{x}10^{5}$	-	-	-	-

^{B}Analyte present at concentrations greater than the MDL but less than 10 times the MDL.
^{N}Matrix spike recovery was not within the specified range of 75 to 125 percent.
*This value was from a single detected pump trap value. The other duplicate was below the detection limit.
**Eu-155 in the probe rinse was assumed to be 0 because no value or detection limit was determined.
$^{+}$During validation, these results were determined to be "nondetects".
$^{++}$During validation, neptunium-237 results were rejected due to interferences with the tracer.
< This analyte was not detected at the MDA given.

For most of the primary radionuclides, the concentration factors were similar to the metal species concentration factors. Amercium-241, curium-242 and curium-244 concentration factors were very low, between 0.4 and 0.5. Because the concentration factors appear to be similar and because these three radionuclides are determined from the same sample aliquot using the same procedure, the deviation of these concentrations from the others appears to have occurred during the sample preparation and analysis. Similarly, the carbon-14 values were biased low. Carbon-14 measurements are subject to interference from other radionuclides that are present in the samples. Finally, the technetium-99 concentration factor was lower than expected. The cause of this discrepancy is not apparent; however, no technetium-99 was detected in the off-gas samples.

Most of the activity in the feed and concentrates was due to the presence of strontium-90. This radionuclide accounted for slightly more than half of the total activity in these samples. Most of the activity in the condensate and in the offgas samples appears to be due to tritium, although these activity levels were very low (less than 17 nCi/L of air for the off gas). Decontamination factors (concentration in the feed divided by concentration in the condensate) were 1.2 x 10^4 and 1.0 x 10^4 based on the gross alpha and gross beta results respectively.

The neptunium-237 results given in Table 5.4 were rejected during validation of the results. This was due to interference with this analyte by the Pu-242 that was used as a tracer. In addition, the radium-226 and cobalt-60 results for the off-gas samples were determined to be "nondetects". Review of the spectra showed no peaks to be present in the appropriate energy ranges.

The selenium-79 results given in Table 5.4 should be considered to be estimates. Recoveries were low for this analyte (22%). Although this is outside of the range given in the QAPjP[7], this type of recovery is typical for selenium-79 determinations. In addition, selenium-79 could not be located commercially. Therefore, a standard could not be prepared for this method.

E. Conclusions

Inorganic and radionuclide analyses of the evaporator samples showed the compositions to be essentially as expected. Table 5.5 is a summary of the inorganic and radionuclide analytes that were present at concentrations above the method MQLs. With some exceptions, these analyses met the requirements given in the QAPjP[7]. Silver, tantalum, uranium, and platinum recoveries were outside of the ranges given in Reference 7. In addition selenium-79 recoveries were low and neptunium-237 determination was hindered by interferences. The following conclusions can be made from these determinations:

-Concentration factors for most of the predominant species were from 1.4 to 1.9.
-Samples were predominantly sodium nitrate with high concentrations of sodium nitrite.
-Concentrate anion concentrations were not consistent with feed anion concentrations.
-Total activity in the off gas was low (less than 17 pCi/L). Thirty to forty percent of the total activity in the off-gas samples appears to have been due to tritium.
-Strontium-90 was the predominant radionuclide in the aqueous samples.
-The condensate samples easily met the ETF WAC for pH, ammonium, and oxidizers.

Table 5.5. Summary of Target Inorganic and Radionuclide Analytes Detected above the MQLs

	Feed	Concentrate	**CF	Condensate	Off Gas
	(µg/L)	(µg/L)		(µg/L)	(µg/L air)
Al	$5.73\pm0.02\text{x}10^{6}$	$1.03\pm0.05\text{x}10^{7}$	1.8	-	-
B	$2.0\pm0.1\text{x}10^{4}$	$3.1\pm0.1\text{x}10^{4}$	1.5	$^{*B}5.6\text{x}10^{3}$	$^{B}3.0\text{x}10^{2}$
Ca	$1.185\pm0.007\text{x}10^{5}$	$2.3\pm0.02\text{x}10^{5}$	1.9	-	^{B}48-61
Cd	$2.20\pm0.01\text{x}10^{4}$	$4.0\pm0.2\text{x}10^{4}$	1.8	-	^{B}0.44-0.86
Co	$1.35\pm0.03\text{x}10^{3}$	$^{B}2.3\pm0.1\text{x}10^{3}$	1.7	-	-
Cr	$7.66\pm0.02\text{x}10^{4}$	$1.40\pm0.07\text{x}10^{5}$	1.8	-	-
Cu	$3.8\pm0.2\text{x}10^{3}$	$9\pm3\text{x}10^{3}$	2.4	-	^{B}0.45-1.9
K	$8.72\pm0.01\text{x}10^{5}$	$1.71\pm0.08\text{x}10^{6}$	2.0	-	^{B}18-43
Mn	$7.36\pm0.03\text{x}10^{2}$	$1.2\pm0.3\text{x}10^{3}$	1.7	-	^{B}1.2-1.4
Mo	$2.24\pm0.07\text{x}10^{4}$	$3.96\pm0.09\text{x}10^{4}$	1.8	-	-
Na	$1.185\pm0.007\text{x}10^{8}$	$1.60\pm0.06\text{x}10^{8}$	1.4	$9\pm1\text{x}10^{3}$	$^{B}1.3\text{x}10^{2}$
Ni	$1.295\pm0.007\text{x}10^{5}$	$2.5\pm0.1\text{x}10^{5}$	1.9	-	-
S	$2.29\pm0.02\text{x}10^{6}$	$3.6\pm0.2\text{x}10^{6}$	1.6	-	^{B}3.5-14
Zn	$7\pm1\text{x}10^{2}$	$^{B}2.2\pm0.8\text{x}10^{3}$	3	$8\pm1\text{x}10^{2}$	^{B}13
Cl	$1.59\pm0.04\text{x}10^{6}$	$1.35\pm0.04\text{x}10^{7}$	-	-	$3.7\pm0.1\text{x}10^{2}$
CN	$41\pm5\ \text{x}10^{3}$	$3.5\pm0.3\ \text{x}10^{3}$	-	-	-
F	$7.6\pm0.2\text{x}10^{5}$	-	-	70	70
OH (N)	0.437 ± 0.004	2.99 ± 0.01	-	$1.1\pm0.1\ \text{x}10^{-2}$	-
NH4	-	$8.0\ \text{x}10^{3}$	-	$3.5\ \text{x}10^{3}$	-
NO3	$9.0\pm0.3\text{x}10^{7}$	$1.61\pm0.08\text{x}10^{8}$	-	-	-
NO2	$3.78\pm0.04\text{x}10^{7}$	$1.7\pm0.1\text{x}10^{7}$	-	-	-
pH	13.06 ± 0.04	-	-	9.0 ± 0.1	-
PO4	$1.6\pm0.6\text{x}10^{6}$	-	-	-	-
SO4	$7.0\pm0.8\text{x}10^{6}$	$1.5\pm0.1\text{x}10^{7}$	-	-	-
	(pCi/L)	(pCi/L)		(pCi/L)	(pCi/L air)
Am-241	$1.42\pm0.03\text{x}10^{7}$	$7.0\pm0.3\text{x}10^{6}$	0.49	-	-
Cm-242	$8.4\pm0.1\text{x}10^{4}$	$3.5\pm0.1\text{x}10^{4}$	0.41	-	-
Cm-244	$1.04\pm0.01\text{x}10^{7}$	$5.2\pm0.3\text{x}10^{6}$	0.50	-	22-33
Co-60	$3.66\pm0.03\text{x}10^{7}$	$5.6\pm0.2\text{x}10^{7}$	1.5	-	$^{+}0.95\text{-}^{+}1.1\text{x}10^{2}$
Cs-137	$4.83\pm0.04\text{x}10^{7}$	$8.1\pm0.4\text{x}10^{7}$	1.7	-	$1.1\text{-}1.2\text{x}10^{2}$
Eu-152	$6.23\pm0.3\text{x}10^{5}$	$6.8\pm0.9\text{x}10^{5}$	1.1	-	-
Eu-154	$3.65\pm0.04\text{x}10^{7}$	$5.6\pm0.1\text{x}10^{7}$	1.5	-	-
Eu-155	$2.10\pm0.07\text{x}10^{7}$	$3.3\pm0.2\text{x}10^{7}$	1.6	-	-
Gross Alpha	$3.30\pm0.2\text{x}10^{7}$	$3.7\pm0.6\text{x}10^{7}$	1.1	$2.8\text{x}10^{3}$	$1.1\text{-}1.7\text{x}10^{2}$
Gross Beta	$2.78\pm0.03\text{x}10^{9}$	$4.4\pm0.5\text{x}10^{9}$	1.6	$2.7\text{x}10^{5}$	$1.7\text{x}10^{4}$
H-3	$2.4\pm0.2\text{x}10^{5}$	$3.1\text{x}10^{5}$	1.3	$1.49\pm0.04\text{x}10^{5}$	$5.5\text{-}6.5\text{x}10^{3}$
Pu-238	$6.4\pm0.9\text{x}10^{5}$	$1.12\pm0.04\text{x}10^{6}$	1.7	-	-
Pu-239/240	$7.4\pm0.9\text{x}10^{5}$	$1.28\pm0.04\text{x}10^{6}$	1.7	-	-
Pu-241	$1.4\pm0.2\text{x}10^{6}$	$3\pm1\text{x}10^{6}$	1.9	-	-
Sr-90	$1.43\pm0.09\text{x}10^{9}$	$2.11\pm0.06\text{x}10^{9}$	1.5	-	-
Tc-99	$3.7\pm0.2\text{x}10^{7}$	$3.60\pm0.09\text{x}10^{7}$	0.97	-	-
U-234	$3\pm1\text{x}10^{3}$	$1.2\text{x}10^{4}$	4.4	-	-

*This value was from a single detected pump trap value. The other duplicate was below the detection limit.

$^{+}$During validation, these results were determined to be "nondetects".

6.0 PHYSICAL PROPERTIES

Physical properties were determined for the aqueous streams that will be generated by the evaporator. These streams were the feed, condensate, and concentrate. In addition, physical properties were determined for pump trap samples. Physical properties were not measured for the off-gas sampling system condensate because of very limited sample volume and because this will not be a stream that will be generated by the evaporator. Results are given in Table 6.2.

A. Experimental

Methods that were used to analyze aqueous samples for physical properties are given in Table 6.1. All methods were performed according to standard methods except where modified to accommodate limited sample sizes. Total solids and dissolved solids were measured according to standard methods given in Reference 7. Analytical methods were implemented by BWXT Services as Standard Operating Procedures.

Table 6.1. Methods Used to Determine Physical Properties for Aqueous Samples

	Analytical Method	**Notes**
Density	Pycnometry	Calibration performed with deionized water
Ignitability	SW-846 # 1010	Spoon/flame test used.
Total Solids	Filtration and Drying	Scaled to 1.00 mL instead of 10.0 mL.
Dissolved Solids	Drying	Scaled to 1.00 mL instead of 10.0 mL.
Conductivity	SW-846 #9050A	Method scaled to 5.00 mL instead of 50 mL.

B. Results and Conclusions from Physical Property Analyses

Results from the physical properties determinations have been presented in Table 6.2. These results can be summarized as follows:

-Density and solids measurements were in agreement with values measured at SRTC (1).
-As expected, none of the samples showed any evidence of ignitability or flash point.
-Condensate solids measurements met ETF WAC (dissolved solids $<2.5\times10^5$mg/L).[2]
-Conductivity was determined for the condensate as required by ETF WAC.[2]

Table 6.2. Physical Properties of Aqueous Samples from the Envelope C Evaporator

	Feed	Condensate	Pump Trap	Concentrate
Density (g/cc)	1.246±0.001	1.005±0.004	0.9986±0.0005	1.366±0.002
Ignitability	NI	NI	NI	NI
Total Solids (mg/L)	4.6±0.2x10^{5}	<1x10^{2}	*<1x10^{2}	6.6±0.1x10^{5}
Dissolved Solids(mg/L)	3.56±0.06x10^{5}	<1x10^{2}	**<1x10^{2}	5.6±0.2x10^{5}
Conductivity (mS/m)	-	9.7±0.2	-	-

*This is the result from one sample. Other sample total solids result was 2.8x10^{3} mg/L.

**This is the result from one sample. Other sample total solids result was 1x10^{2} mg/L.

< Solids were not detected at the MDL given.