Caustic Recycling Pilot Unit to Separate Sodium from LLW at Hanford Site - 12279

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ABSTRACT

As part of the Department of Energy (DOE) sponsored Advanced Remediation Technologies initiative, a scheme was developed to combine Continuous Sludge Leaching (CSL), Near-Tank Cesium Removal (NTCR), and Caustic Recycling Unit (CRU) using Ceramatec technology, into a single system known as the Pilot Near-Tank Treatment System (PNTTS). The Cesium (Cs) decontaminated effluent from the NTCR process will be sent to the caustic recycle process for recovery of the caustic which will be reused in another cycle of caustic leaching in the CSL process.

Such an integrated mobile technology demonstration will give DOE the option to insert this process for sodium management at various sites in Hanford, and will minimize the addition of further sodium into the waste tanks. This allows for recycling of the caustic used to remove aluminum during sludge washing as a pretreatment step in the vitrification of radioactive waste which will decrease the Low Level Waste (LLW) volume by as much as 39%.

The CRU pilot process was designed to recycle sodium in the form of pure sodium hydroxide. The basis for the design of the ¼th scale pilot caustic recycling unit was to demonstrate the efficient operation of a larger scale system to recycle caustic from the NTCR effluent stream from the Parsons process. The CRU was designed to process 0.28 liter/minute of NTCR effluent, and generate 10M concentration of “usable” sodium hydroxide. The proposed process operates at 40°C to provide additional aluminum solubility and then recover the sodium hydroxide to the point where the aluminum is saturated at 40°C. A system was developed to safely separate and vent the gases generated during operation of the CRU with the production of 10M sodium hydroxide. Caustic was produced at a rate between 1.9 to 9.3 kg/hr.

The CRU was located inside an ISO container to allow for moving of the unit close to tank locations to process the LLW stream. Actual tests were conducted with the NTCR effluent simulant from the Parsons process in the CRU. The modular CRU is easily scalable as a standalone system for caustic recycling, or for NTTS integration or for use as an In-Tank Treatment System to process sodium bearing waste to meet LLW processing needs at the HANFORD site. The standalone pilot operation of the CRU to recycle sodium from NTCR effluent places the technology demonstration at TRL level 6.

Multiple operations were performed with the CRU to process up to 500 gallons of the NTCR effluent and demonstrate an efficient separation of up to 70 % of the sodium without solids

precipitation while producing 10M caustic. Batch mode operation was conducted to study the effects of chemistry variation, establish the processing rate, and optimize the process operating conditions to recycle caustic from the NTCR effluent. The performance of the CRU was monitored by tracking the density parameter to control the concentration of caustic produced.

Different levels of sodium were separated in tests from the effluent at a fixed operating current density and temperature. The voltage of the modules remained stable during the unit operation which demonstrated steady operation to separate sodium from the NTCR effluent. The sodium transfer current efficiency was measured in testing based on the concentration of caustic produced. Measurements showed a current efficiency of 99.8% for sodium transfer from the NTCR effluent to make sodium hydroxide.

The sodium and hydroxide contents of the anolyte (NTCR feed) and catholyte (caustic product) were measured before and after each batch test. In two separate batch tests, samples were taken at different levels of sodium separation and analyzed to determine the stability of the NTCR effluent after sodium separation. The stability characteristics and changes in physical and chemical properties of the NTCR effluent chemistry after separation of sodium hydroxide as a function of storage time were evaluated. Parameters such as level of precipitated alumina, total alkalinity, analysis of Al, Na, K, Cs, Fe, OH, nitrate, nitrite, total dissolved and undissolved solids, viscosity, density, and other parameters of the NTCR effluent were measured. Changes in rheology and properties of NTCR stream to support downstream handling of the effluent after sodium separation was the basis for the analysis. The results show that the NTCR effluent is stable without the precipitation of aluminum hydroxide after 70% of the sodium was separated from the effluent.

BACKGROUND

The Department of Energy's (DOE) Office of River Protection (ORP) was chartered to provide safe storage, retrieval, treatment and disposal of radioactive mixed waste at the DOE's Hanford site. The High Level Waste (HLW) treatment will require a processing step to remove non-radioactive hydrated aluminum oxides present in the form of either gibbsite or boehmite in the sludge phase. Removal of these non-radioactive components is necessary to reduce the number of HLW canisters produced during vitrification operations and improve overall processing efficiencies in that operation. The sludge is removed from the HLW by a leaching process that utilizes large amounts of sodium hydroxide (Caustic). The amount of caustic to leach the aluminum from the sludge is variable and new aluminum solubility models are being used to accurately predict the exact volume required. It was recognized that due to the large volume of caustic required to perform this caustic leaching step for the entire HLW inventory, it would be advantageous to develop a technology to allow for recovery and recycling of the available caustic inventory to reduce the overall sodium load to the Low Level Waste (LLW) vitrification process.

Ceramatec has developed a membrane based technology to recycle sodium from the LLW stream at the Hanford site. The proposed concept employs an electrochemical system that utilizes a sodium ion conducting NaSelect™ ceramic membrane to specifically remove sodium ions from a representative simulant from DOE waste tanks at Hanford. Removal of the sodium allows for clean caustic to be regenerated for reuse on-site for further waste pretreatment, or disposal. The NaSelect™ membrane based process has been demonstrated, both with a large range of simulants and the actual LLW, to recover sodium in the form of caustic very efficiently and safely. The technology has also been demonstrated to selectively remove sodium from a Hanford Pre Engineering Platform (PEP) simulant. As part of the DOE sponsored, Advanced Remediation Technologies initiative, a scheme was proposed to combine Caustic Sludge Leaching (CSL), Near-Tank Cesium Removal (NTCR) and Caustic Recycling using the Ceramatec Technology into a single system known as the Pilot-Near Tank Treatment System (PNTTS).

CAUSTIC RECYCLING UNIT DESIGN

A Process flow diagram (PFD) for the CRU was developed based on the NTTS scheme to treat the NTCR effluent from the Parsons processes, and to feed the produced caustic from the CRU to the CSL process. The NTTS flow sheet indicated a rate of 0.278 L/min of the NTCR effluent to be processed. Based on the flow rate specification and the requirement to remove 70% of sodium from the effluent, the amount of caustic that would be produced as a product was 9.33 Kg/hr at 10M concentration. The CRU was designed to be operated in an enclosed area with the specific equipment, electrical, and air handling systems meeting the National Fire Protection Association (NFPA) safety codes for: "Classification of Class I (Combustible Material) Areas". The equipment and electrical system were properly classified to make the system safe for integrated operation with the NTTS as specified in the PFD.

A standard high cube shipping container was selected as a means to transport, install and operate the CRU safely while complying with electrical code requirements for handling hydrogen. Modifications were made to the container to properly install the appropriate process and electrical equipment for operation, as well as to maintain the road worthiness of the shipping container. Piping and Instrumentation Diagrams (P&ID) were then developed from the PFD. The sections of the CRU during and after construction at the Ceramatec facility are presented in Figure 1.

The CRU was designed with the provision to include multiple process tanks and up to five modules. The size of the process tanks and the number of modules required were determined by the specified feed rate of NTCR effluent (from the Parsons process to the CRU) and the processing capacity of the modules. The CRU contains a number of instrumentation and control devices to facilitate automation as well as safe operation. The instrumentation and control devices were wired directly to various input and output Allen Bradley-modules, which were connected to the PLC, along with the Human Machine Interface (HMI) which has a touch screen panel

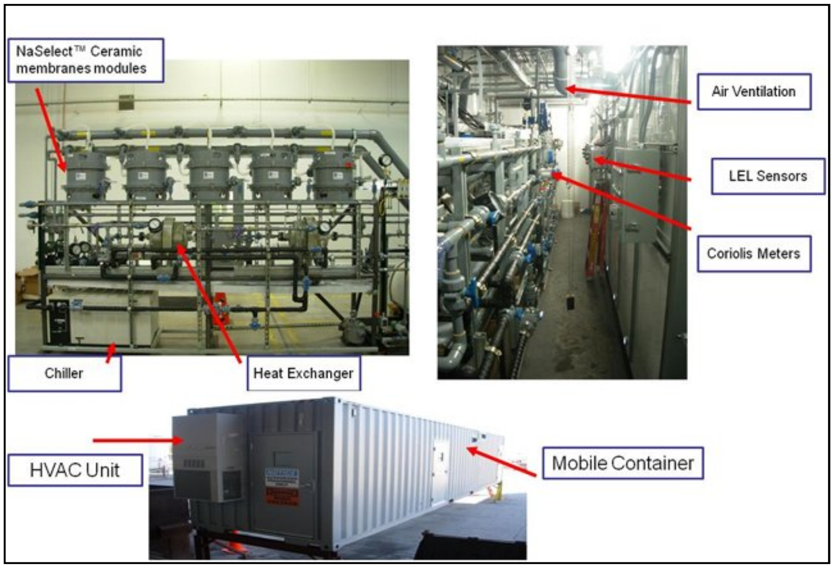

Figure 1: Sections of CRU during and after assembly

ELECTROLYTIC CELL LINE

Basis for the module design

It was required that the CRU be able to process 0.278 L/min of the NTCR effluent, with the ability to recycle 70% of the sodium, resulting in the production of 10M caustic at the rate of 9.33 Kg/hr. The size of the module was defined by the footprint requirement of the CRU. The present design of the module and its performance were previously qualified for recycling of caustic from multiple simulant chemistries as a part of the technology demonstration phase. The qualification results indicated that 5 electrochemical modules were required to meet the stipulated processing requirements.

Module design

A multi membrane based electrochemical module was designed similar to a tube and shell type heat exchanger configuration to handle the processing throughput, and with the aim to develop a prototypical modular design, having the ability to be scaled up linearly to meet production demands for a full size process. The module was designed to hold multiple tubular membranes in a vertical configuration to provide a $0.5m^2$ footprint. Each membrane was configured with a cathode rod housed inside the tubular membrane, with a separation gap for fluid flow, and an anode mesh outside the membrane. Figure 2 shows the cross-sectional view of the module and the flow path of solutions for both the anolyte and the catholyte through the module.

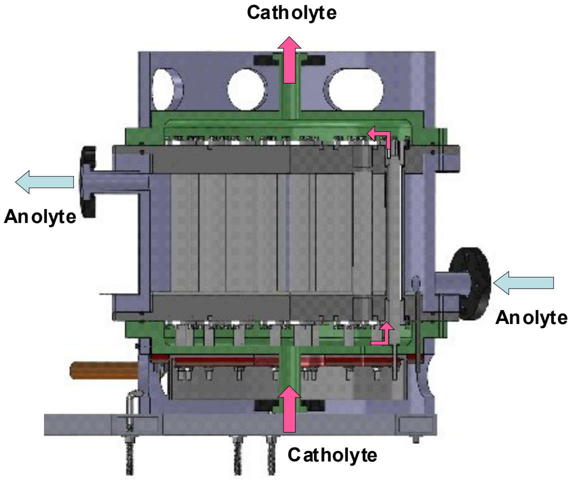

Figure 2: Module cross section and solution flow path.

The electrolytic cell line in the CRU will allow for operation of up to five individual modules. The anolyte and the catholyte are fed to the individual modules in parallel. Valves are installed in line to shut off the flow to any of the modules as required. Each module is connected to its own DC power supply to allow independent operation from the other modules.

Each module has anode and cathode compartment. The anode compartment receives the anolyte solution (NTCR effluent) and the cathode compartment receives the catholyte solution (10 M NaOH). The anolyte enters the module at the side bottom inlet and exists from the side top outlet. The anolyte flow is perpendicular to the flow of the catholyte solution with respect to the membranes. The reciculation flow rates for each solution to flow in and out of the module are about 7.57 liters per minute which facilitates efficient mass transfer by supplying the Na^+ for transfer across the membranes. As direct current is applied, the Na^+ is transferred from the anolyte, across the membrane, to the catholyte solution.

CRU OPERATION TO RECYCLE SODIUM FROM NTCR EFFLUENT

Ten independent tests were performed at Ceramatec's facility as part of the distributed pilot testing to recycle sodium from the NTCR effluent received from the Parsons process as part of the NTTS testing. The CRU testing was focused on optimization testing to establish process operating conditions and to demonstrate the ability of the CRU to meet or exceed required processing rate of the NTCR effluent feed. Additionally, the impact of chemistry changes in the NTCR effluent on performance characteristics of the CRU process was evaluated.

Table 1 presents the matrix of the tests planned to recycle caustic from the NTCR effluent received at the Ceramatec’s facility and to demonstrate the operational reliability of the CRU.

Table 1: Tests to recycle sodium from NTCR waste effluent from Parsons process.

Test #	Test Variables
1 & 2	Up to 70% Na^+ Removed (123.02 liters NTCR effluent)
3 & 4	50% Na^+ Removed (170.34 liters NTCR effluent)
5 & 6	60% Na^+ Removed (141.96 liters NTCR effluent)
7	70% Na^+ Removed with 3.79 lpm flow rate to modules (123.02 liters NTCR effluent)
8	70% Na^+ Removed with 7.57 lpm flow rate to modules (123.02 liters NTCR effluent)
9	70% Na^+ Removed with 11.36 lpm flow rate to modules (123.02 liters NTCR effluent)
10	70% Na^+ Removed with 15.14 lpm flow rate to modules (123.02 liters NTCR effluent)

Testing summary

Two, 1040 liter totes of NTCR effluent from the Parsons NTCR process were received at Ceramatec's facility. Each tote contained different concentrations of sodium and had slightly differing overall chemistry. The selected tote for feeding the CRU was positioned outside the CRU for pumping the specified amount into the Holding Tank located inside the CRU. The material in the NTCR Holding Tank was then transferred to the Anolyte Caustic Tank for processing.

Operational results

The testing with the CRU was performed at a current density of 750 A/m^2 and at a process temperature of 40^oC. The concentration of the caustic product was maintained at 10M. Figure 3 shows the summary of results for the modules operating voltage vs. sodium removed for the 10 tests performed with the CRU at Ceramatec's facility. The performance represents the average steady voltage of the modules obtained during the batch testing cycle to separate sodium.

The results demonstrate the effect of the sodium concentration in the anolyte on module operating voltage. The voltage of the modules in each test follow a similar trend versus the sodium concentration, indicating that as the sodium concentration in the anolyte NTCR effluent is reduced by separation of sodium, the voltage of the electrolytic cell modules increases. The variance in voltage between individual tests generally depends on the differing chemistry of the two totes received from the Parsons process. The two totes had slightly different levels of sodium. The solution from tote #2 was used for test # 6 thru 10, and the solution from tote #1 was used for tests # 1 thru 6. The higher sodium content in tote #2 resulted in lower operating voltages of the modules during the associated tests.

The performance results from the multiple batch testing of the NTCR effluent to recycle caustic is presented in Table 2. Samples were taken at different intervals during each batch test while the NTCR effluent was being processed. The sodium mass balance analysis was performed on samples to determine the concentration of sodium in the NTCR effluent and the amount of caustic produced.

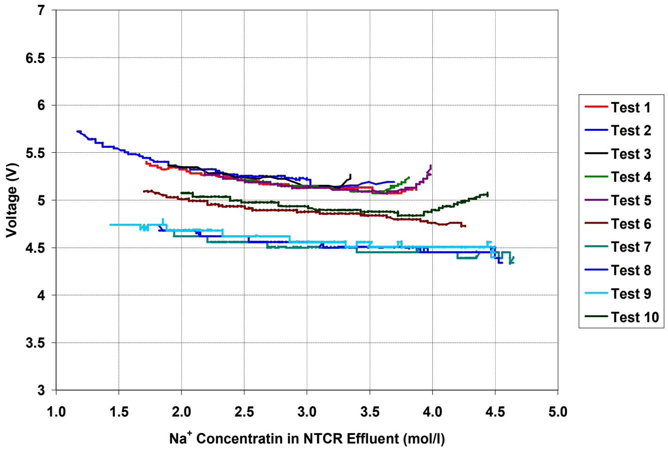

Figure 3: Voltage vs. sodium concentration of NTCR effluent

Table 2: Average initial and final voltages compared to sodium concentration.

Test #	Initial Voltage	Initial Na+ effluent Feed Concentration (mol/liter)	Final Voltage	Final Na+ effluent Feed Concentration (mol/liter)	Caustic Produced wt%
1	5.11	3.87	5.40	1.83	22.5
2	5.19	3.65	5.66	1.22	26.2
3	5.26	3.39	5.37	1.83	26.0
4	5.24	4.05	5.21	2.52	23.8
5	5.37	4.00	5.30	2.13	21.2
6	4.72	4.26	5.09	1.74	24.8
7	4.40	4.78	4.68	1.96	25.6
8	4.34	4.78	4.74	1.83	26.9
9	4.40	4.78	4.74	1.96	25.6
10	4.64	4.31	4.56	2.00	24.8

As observed in Table 2, the concentration of caustic maintained in the catholyte in all tests was lower than the targeted value of 10M or 30 wt%. Upon review, this was found to be a result of an offset indication in solution density of the catholyte by the Coriolis mass flow meter.

Table 3 shows the percentage of sodium that was removed from the NTCR effluent in each batch test as compared to the proposed objectives for that test. During the operation of the CRU, several samples of the anolyte and catholyte solutions from each test were obtained and sent to Energy Northwest Laboratories in Richland, WA for Inductive Coupling Plasma (ICP) and other analysis. The turnaround time from the sample submission to receipt of the results was one week. This delay resulted in nine of the ten batch tests being completed before any sample analysis results were made available. Finally, when the analysis results from the nine batch tests were compared against the calculated results for sodium concentration in the anolyte and catholyte solutions as indicated by the CRU process instruments, a discrepancy was observed between the indicated and actual concentration of caustic in the catholyte solution.

Table 3: Mole percent of sodium removed.

Test #	Test Plan	Mole % of Caustic Removed
1, 2	Up to 70 % Caustic Removal (32.14 gal NTCR effluent)	Test 1 - 53% Test 2 - 67%
3 & 4	50% Caustic Removal (45 gal NTCR effluent)	Test 3 - 46% Test 4 - 38%
5 & 6	60% Caustic Removal (37.5 gal NTCR effluent)	Test 5 - 47% Test 6 - 59%
7	70% Caustic Removal - 1 gpm flow rate to modules (32.14 gal NTCR effluent)	60%
8	70% Caustic Removal - 2 gpm flow rate to modules (32.14 gal NTCR effluent)	62%
9	70% Caustic Removal - 3 gpm flow rate to modules (32.14 gal NTCR effluent)	68%
10	70% Caustic Removal - 4 gpm flow rate to modules (32.14 gal NTCR effluent)	54%

The offset indication of the Coriolis mass flow meter was corrected prior to conducting the last test in the series (Test #9), and the CRU subsequently obtained 68% removal of sodium based on the target of 70%. A quicker turnaround of sample analysis results would have allowed for the instruments to be fine tuned for more accurate monitoring of the sodium separation from the NTCR effluent.

Analysis of samples to determine CRU performance

The sodium and the hydroxide contents of the anolyte and catholyte were measured before and after each batch test. Results showed that sodium in the range of 38% to 68% was recycled from the NTCR effluent. In the case of two batch tests, samples were taken from the anolyte and catholyte at different levels of sodium separation, and then analyzed to evaluate the expected chemical stability of the NTCR effluent after processing in the CRU. The stability characteristics and changes in the physical and chemical properties of the processed NTCR effluent as a function of storage time were evaluated. Parameters such as: level of precipitated alumina, total alkalinity, analysis of ions (i.e. Al^{+3}, Na^{+}, K^{+}, Cs+, $Fe^{+2,+3}$, OH^{-}, NO_3^{-}, NO_2^{-}), total dissolved and undissolved solids, viscosity and density were measured.

Analysis of samples from batch operation of the CRU

The analytical results and conclusions on specific parameters for test #9 are shown in Table 4.

Table 4: Analytical results of the anolyte and catholyte samples from batch test # 9 obtained during processing in the CRU.

Parameter	Test # 9 Anolyte pre-test	Test # 9 Anolyte post-test	% change	Test # 9 Catholyte pre-test	Test # 9 Catholyte post-test	% change	Inference
Density (g/ml)	**1.19**	1.08	-9.244				anolyte density decreased
Al (mg/L)	**10000**	9900	-1.000	1.2	1.1	-8.333	Al content in catholyte slightly declined. anolyte stayed constant
Sodium (mg/L)	**110000**	35000	-68.182	190000	200000	5.263	% sodium removed: anolyte: 68.2. catholyte has slightly increased
Hydroxide (as $CaCO_3$) (mg/L)	**210000**	82000	-60.952	420000	420000	0.000	% hydroxide removed: 61.
Total Suspended solids (mg/L)	**310**	220	-29.032				TSS in anolyte decreased

Analysis of the as-received NTCR effluent and processed NTCR samples from CRU testing.

- Aluminum content in the anolyte remained constant in 8 of the 9 tests performed indicating that aluminum hydroxide precipitation had not occurred after sodium separation.

- The aluminum content in the catholyte did not change, indicating that the aluminum ions did not migrate from the anolyte to the catholyte. Based on the analysis results, it can be concluded that the modules were leak tight during operation and there was no mixing of anolyte with the catholyte solution.

- The concentration of sodium removed (mg/L) from the anolyte was in the range of 37.6% to 68.2% from the ten batch tests. The corresponding hydroxide removal was in the range of 42% to 70%. This indicates that Ceramatec has successfully demonstrated the CRU process by recycling a wide range of sodium hydroxide.

- The sodium content in the catholyte remained constant in majority of the tests, also in some cases increased because of temporary reduction in flow of dilution De-ionized water (D.I. water) added to maintain the concentration of the catholyte solution. This also indicates that sodium did not transfer from the catholyte back to the anolyte, which is a further confirmation that the modules were leak tight during operation.

- The iron content in the anolyte remained constant after the sodium removal tests.

- The values of density, viscosity and conductivity decreased after the NTCR effluent was processed by the CRU after the sodium removal step was completed. This is due to the reduction of the sodium hydroxide content in the processed NTCR effluent, which was expected to reduce the values of these parameters.

- The amount of nickel, potassium, nitrate and nitrite did not change significantly during the sodium removal process.

- The total suspended solids decreased in the NTCR effluent after processing in the CRU. This shows that dissolved solids such as aluminum hydroxide or alumina did not precipitate during the caustic removal process. It is probable that some of the dissolved iron initially present in the as-received NTCR effluent did precipitate.

- The maximum dissolved iron content measured was 11 ppm (test #10), which was observed to decrease to 9 ppm after processing by the CRU, which suggests that any suspended solids formed from iron precipitation would be minor after sodium removal in the NTCR effluent.

Stability analysis of CRU processed NTCR effluent

Evaluation of changes in the chemistry of the NTCR effluent after the target concentration of sodium hydroxide was recycled by processing in the CRU was critical to establish storage and handling of the processed NTCR effluent at the downstream level. The goal of this task was to study the stability (saturation and super saturation) and kinetics for solids precipitation, in the processed NTCR effluent and to determine the chemical stability during storage at ambient conditions. During processing in the CRU, the temperature of the NTCR effluent increases to the operating temperature of 40^{o}C; it became necessary to evaluate the stability of the effluent as it cools back to ambient or room temperature after the test. Samples of the processed NTCR effluent (target 70% Na removal) were stored at room temperature and the effects from storage were evaluated. The samples were analyzed after a storage period of 4 months. The representative stored samples from batch tests 1, 5, 6, 8, 9 and 10 were analyzed. The samples were shaken appropriately and then a representative amount from each sample was collected and sent to Energy Northwest Laboratory. Table 5 shows the analyses results of samples stored for 4 months from test # 9, compared to the analysis conducted on samples just after processing by the CRU.

Table 5: Analysis results of processed NTCR effluent samples from test # 9 after four months of storage.

Parameter	Test # 9 Anolyte pre-test	Test # 9-Anolyte post-test	% change	Inference
Density (g/ml)	1.08	1.08	0.000	Anolyte density constant
Viscosity (cP)	< 3	<3	-	
Al (mg/L)	9900	9700	-2.020	Al content in anolyte slightly declined.
Sodium (mg/L)	35000	36000	2.857	The sodium content increased dramatically
Hydroxide (as $CaCO_3$) (mg/L)	82000	59000	-28.049	The hydroxide content decreased significantly
Suspended solids (mg/L)	220	3000	1263.636	Significant increase in TSS (12x)

Summary: analysis of processed NTCR effluent.

- An order of magnitude increase in the total suspended solids was observed as a result of the storage of samples after sodium removal. However, this increase still amounts to less than 0.6% of suspended solids in the stored samples. The suspended particles in the samples (dark brown in color) were collected and analyzed by Energy Dispersive Spectroscopy (EDS) and X-ray Diffraction (XRD). The data showed that the suspended particles were predominantly iron oxides (Fe_3O_4 and FeOCl) with small amount of Al and Na. The data confirms that the precipitation after sodium removal and storage was mainly from iron oxides present in the as received NTCR effluent from Parsons.

- The aluminum content declined slightly. The iron content was reduced by nearly half in concentration. The sodium content stayed constant in the stored sample compared to the sample taken right after the sodium separation test.

- The hydroxide content stayed constant except in the case of test # 9 where it reduced significantly.

- The density, viscosity and conductivity of the effluent remained constant.

CONCLUSIONS

1. The Caustic Recycling Unit (CRU) was designed to process the Parsons Near Tank Cesium Removal (NTCR) effluent stream with the defined target to recycle up to 70% of the free sodium hydroxide (caustic) in the NTCR effluent. The CRU was designed to operate at a current density of 75 mA/cm^2 based on a 100% sodium transfer efficiency. The size of the CRU pilot was defined by the process flow sheet specification developed by Parsons for integration and demonstration as part of the pilot scale Near Tank Treatment System (NTTS).

2. The Programmable Logic Controller (PLC) interlocks were tested and fine-tuned as required for system operation. The process equipment, instruments and controls with PLC automation and system interlocks were verified to separate the hydrogen and oxygen gases from the solutions during CRU operation and safely vent them to the environment.

3. The NaSelect™ (sodium ion conducting ceramic) membrane based electrolytic cell (module) was designed to efficiently package multiple membranes as required to process maximum throughput of the NTCR effluent. The prototypical modular design allows scaling the footprint linearly with addition of units to meet the processing demand for a full production size caustic recycling system at site. A cost effective method to make the NaSelect™ membranes at higher than 75% production yield was developed.

4. Distributed Pilot testing at Ceramatec, with the CRU, was performed to demonstrate the current efficiency of the NaSelect™ membranes near 100% for sodium transfer to separate sodium during the operation of the modules. The CRU was successfully tested in multiple batch tests to recycle sodium in the 35 to 70% range, from the NTCR effluent, without observing alumina precipitation based on the analysis of the post sodium separated NTCR effluent samples. The targeted caustic product concentration of close to 10 M was produced for reuse in the Caustic Sludge Leaching (CSL) process.

5. Efficient operation of a modular CRU system and its ability to handle and process higher throughput of feed to recycle sodium and make caustic was demonstrated. Safe operation of the system in tests totaling run time of over 200 hours was demonstrated in both manned and unmanned operations including overnight tests to process the NTCR effluent. Testing with a single module was performed prior to the operation of the CRU to study the impact of chemistry changes in the NTCR effluent on the performance characteristics of the caustic recycling process. The chemistry variation tests demonstrated the soundness of the module design, that houses the NaSelect™ membranes, to perform in a wide chemistry range of the feed.

6. The chemical and physical properties of the pre and post sodium separated NTCR effluent samples and the caustic product from multiple batch tests were analyzed by an independent analytical laboratory. The analysis results of samples stored for up to 4 months confirmed that the target of 70% of sodium removal from the NTCR effluent was achieved without the precipitation of alumina.

7. Overall, the Ceramatec CRU pilot system was successfully demonstrated to have a Technology Readiness Level (TRL) of 6 by processing the Parsons NTCR effluent.

8. The CRU technology is fully matured and ready for the DOE to use this technology for integration as a standalone process and at other insertion points at site for sodium management. Two of several insertion opportunities based on the process model developed by WRPS for the electrochemical caustic recycling process are, (i) supplemental treatment of the stream by the CRU system before being directed to the fluidized bed stream reformed (FBSR), the caustic recovery at this point would yield significant savings in the operation of the FBSR and disposal volume of Low Activity Waste (LAW), and (ii) the sodium rich liquid created from adding caustic to a single shell tank (SST) is routed to the CRU process to recycle caustic for use to retrieve the aluminum bearing hard heels from SST.