

**Enhanced Chemical Cleaning:
A New Process for Chemically Cleaning Savannah River Waste Tanks - 9100**

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ABSTRACT

At the Savannah River Site (SRS) there are 49 High Level Waste (HLW) tanks that eventually must be emptied, cleaned, and closed. The current method of chemically cleaning SRS HLW tanks, commonly referred to as Bulk Oxalic Acid Cleaning (BOAC), requires about a half million liters (130,000 gallons) of 8 weight percent (wt%) oxalic acid to clean a single tank. During the cleaning, the oxalic acid acts as the solvent to digest sludge solids and insoluble salt solids, such that they can be suspended and pumped out of the tank. Because of the volume and concentration of acid used, a significant quantity of oxalate is added to the HLW process. This added oxalate significantly impacts downstream processing. In addition to the oxalate, the volume of liquid added competes for the limited available tank space. A search, therefore, was initiated for a new cleaning process.

Using TRIZ (Teoriya Resheniya Izobretatelskikh Zadatch or roughly translated as the Theory of Inventive Problem Solving), Chemical Oxidation Reduction Decontamination with Ultraviolet Light (CORD-UV[®]), a mature technology used in the commercial nuclear power industry was identified as an alternate technology. Similar to BOAC, CORD-UV[®] also uses oxalic acid as the solvent to dissolve the metal (hydr)oxide solids. CORD-UV[®] is different, however, since it uses photo-oxidation (via peroxide/UV or ozone/UV to form hydroxyl radicals) to decompose the spent oxalate into carbon dioxide and water. Since the oxalate is decomposed and off-gassed, CORD-UV[®] would not have the negative downstream oxalate process impacts of BOAC. With the oxalate destruction occurring physically outside the HLW tank, re-precipitation and transfer of the solids, as well as regeneration of the cleaning solution can be performed without adding additional solids, or a significant volume of liquid to the process.

With a draft of the pre-conceptual Enhanced Chemical Cleaning (ECC) flowsheet, taking full advantage of the many CORD-UV[®] benefits, performance demonstration testing was initiated using available SRS sludge simulant. The demonstration testing confirmed that ECC is a viable technology, as it can dissolve greater than 90% of the sludge simulant and destroy greater than 90% of the oxalates. Additional simulant and real waste testing are planned.

INTRODUCTION

The Savannah River Site (SRS) currently has 49 High Level Waste (HLW) tanks. Approximately half were built in the 1950's, while the others were built in the 1970's. The tanks are flat-bottomed, 23- to 26-meters in diameter, 7- to 10-meters tall, and have a 2.8- to 4.9-million liter capacity. The walls and bottoms of the tanks are all made of commercial grade carbon steel. Typically, the tanks also contain kilometers of carbon steel cooling coils. Since the tanks are subsurface, access to the inside is limited through the typical 30- to 65- centimeter diameter risers. Each of these tanks eventually must be emptied of sludge, cleaned, and closed, as required by the Federal Facilities Agreement [1]. Some of the older tanks have developed leak sites, only further adding to the urgency to close the tanks [2].

Waste Types and Disposal Paths

Sludge at SRS can be grouped into two general types: F-Area sludge, and H-Area sludge. Each type is made up of both an aqueous fraction and a solids fraction. Assuming a volume of about 19,000 liters, representative mass quantities of the major constituents (i.e., accounting for about 90 to 95% of the mass) are shown in Table 1 [3].

Table I. Expected SRS Sludge Constituents

Constituent	F-Area Sludge		H-Area Sludge	
	Dry Solids	Aqueous	Dry Solid	Aqueous
	kg	kg	kg	kg
H ₂ O	0	17,600	0	17,600
Na ₂ CO ₃	0	7	0	1
NaCl	0	230	0	60
NaNO ₃	0	200	0	300
NaOH	0	650	0	330
Al(OH) ₃	770	0	2,940	0
NaAlO ₂	0	60	0	1
CaCO ₃	310	0	80	0
Ca(OH) ₂	0	5	0	1
Ce ₂ O ₃	0	30	0	50
Fe(OH) ³	2,910	1	1,270	0
Mn(OH) ₂	300	0	290	0
NiOH ₂	230	0	60	0
SiO ₂	0	230	0	390
UO ₂ (OH) ₂	500	0	150	0
ThO ₂	0	0	60	0
HgO	0	0	150	1

After the sludge is removed from a tank, it is prepared to become feed for the Defense Waste Processing Facility (DWPF), where it will be vitrified into a borosilicate glass matrix for eventual long-term disposal. As part of preparing the feed, the glass qualifications have a limited tolerance for salt, and therefore require that the sludge must be washed. Normally, during washing the sodium concentration must be reduced from greater than 6 molar to less than 1 molar. The remaining solids are disposed of through DWPF, while the spent wash water, containing the aqueous and solubilized salts are eventually processed through Salt Processing and ultimately disposed of through Saltstone. In Saltstone, the low curie liquid is combined with grout and solidified for long term disposal.

Cleaning the Tanks

Before the tanks can be closed, SRS prepares the HLW tanks for closure in three phases: bulk waste removal, heel removal, and chemical cleaning. The SRS HLW tanks must be very clean in order to support closure due to the high specific activity of the residual waste and the close proximity to the water table. For closure, an average allowed remaining residual volume has been estimated to be about 190 to 1,900 liters per tank, or if assumed to be spread-out evenly on a tank bottom, about 0.025 to 0.4 cm deep. Considering the size of the tanks and the internal cooling coils, the corrosion products alone would likely exceed the allowed residual.

For chemically cleaning SRS HLW tanks, the use of oxalic acid has been extensively evaluated [3]. In general, oxalic acid is preferred for cleaning metal surfaces, because of its combined cleaning and chelating effects. Other common acids used for cleaning metal surfaces include nitric acid and oxalic/citric acid blends. Since the SRS HLW tanks are made from carbon steel and the oxalic acid forms a passivation-layer on carbon steel surfaces, oxalic acid is preferred over nitric acid [4]. Pure oxalic acid solutions are preferred over oxalic/citric acid blends, since testing has concluded both are equally effective; however, the addition of citric acid, even if only a minor fraction of an acid blend, would require additional processing [5].

In the mid 1980's, SRS demonstrated the ability of oxalic acid to be used as a solvent to remove residual quantities of sludge by successfully cleaning Tank 16. Over 99% of the initial activity was removed using oxalic acid [3, 6, 7]. Currently, two other tanks are being cleaned based on a BOAC type process. The baseline process for BOAC includes the following [6,7]:

- The addition of 8 wt% oxalic acid solution to the treatment tank
- Mixing of the acid
- Transferring the spent acid/dissolved sludge to another HLW tank
- Restoring the pH of the spent acid solution to the corrosion control limits
- Transferring the resultant solids to an unqualified, yet to be washed Defense Waste Processing Facility (DWPF) feed batch
- As part of DWPF feed preparation, reducing the sodium concentration to within the 1 [M] sodium concentration limit imposed as part of the DWPF feed acceptance criteria
- Transferring the resultant and remaining liquids to an evaporator condensate drop tank, where most of the oxalate would precipitate out and be safely stored, as part of the sparingly-soluble salt heel
- Eventually, removing the salt heel via dissolution using significant volumes of water and generating significant quantities of additional feed to salt processing
- Feeding the dissolved salt solution as feed to salt processing

NEED FOR AN ALTERNATIVE CHEMICAL CLEANING TECHNOLOGY

BOAC requires about a half million liters of 8 wt% oxalic acid, to clean one HLW tank [6, 7] The additional liquid from BOAC will compete for the available limited tank space. Since most of the SRS HLW tanks will require chemical cleaning, without some regularly available excess evaporative capacity, the liquid added from BOAC could quickly consume operating ability. In addition to the liquid overwhelming the HLW process, there are significant process impacts from the oxalates. That is, even if the oxalate remains well managed and there are no process upsets, impacts occur. Four of the primary impacts are identified below.

- Increased number of wash cycles and overall duration to decrease the sodium concentration to within the allowed feed limits for DWPF (i.e., sodium limit currently equals 1 molar) [6,7]
- A significant increase in the volume of feed going to salt processing
- Additional waste vaults being required to handle the additional salt feed
- Additional years added to the overall HLW life-cycle

Because of the negative process impacts associated with BOAC, a search for an alternative was initiated.

SEARCH FOR AN ALTERNATIVE

Not to replicate previous work searching for an alternative to BOAC [3], a recent search for an alternative deployed a modified TRIZ approach. TRIZ is a Russian acronym for "Teoriya Resheniya Izobretatelskikh Zadatch," which roughly translates as the Theory of Solving Inventive Problems. TRIZ is different from most other approaches in that it is based on the underlying principle that "Inventing is the removal of technical contradictions." A key advantage associated with TRIZ is that it looks for analogous, but already solved, problem and adapts the solution.

Using the TRIZ approach, the need for an alternative to BOAC was restated as: "Remove 90% of 19,000 liters of mostly radioactive metal oxides and hydroxides from a HLW tank within approximately 6 months, while minimizing the creation of secondary waste, disposing of spent cleaning solution with minimal impacts to tank space, and disposing of spent cleaning solution with minimal impact to downstream facilities." The cleaning effectiveness for the alternative, 90% of 19,000 liters, was simply based on the scaled laboratory effectiveness seen for BOAC [5].

A review of current industrial practices was undertaken to find an analogous, but solved, recent problem where the solution could be adapted for SRS HLW tank cleaning. Using the TRIZ approach, scale removal from the primary coolant loop of nuclear power plants was identified to be an analogous, but already solved problem. The six primary dilute Decontamination Regenerative Technologies (DRTs) that are commercially used in nuclear power plants were identified as being potentially capable of meeting the need. Summary assessments for each of the DRTs are contained in the following six sub-sections [8, 9,10].

Low Oxidation Metal Ion

The Low Oxidation Metal Ion (LOMI) technology uses the vanadous ion, V^{+2} , as a reducing agent and picolinic acid, $C_6H_5NO_2$, as a chelating agent [8]. The technology is novel in that it uses the V^{+2} ions to quickly reduce the ferric ion to ferrous ions. During decontamination, a sodium picolinate solution is prepared in a mix tank. Once the sodium picolinate is well mixed in the decontamination volume, vanadous formate is injected directly into the system to be cleaned. The vanadous formate is injected directly into the system to prevent an almost immediate air oxidation of the vanadous ion [8]. Since the

LOMI technology cannot be used in open-air systems, such as in HLW tanks, the technology was quickly discounted from further consideration.

Canadian Depleted Uranium Decontamination

The Canadian Depleted Uranium Decontamination (CAN-DECON) technology uses oxalic acid, $H_2C_2O_4$, as both the reducing and chelating agent, and ethylene diaminetetracetic acid, EDTA, $C_{10}H_{16}N_2O_8$, as a complexation agent [8]. Citric acid, $C_6H_8O_7$, may also be used as a chelating agent. With this technology, mixed bed ion exchange resins are utilized to remove the chemical cleaning agents from the product stream [8].

Citric Acid/Oxalic Acid

The Citric Acid/Oxalic Acid (CITROX) technology uses oxalic acid, $H_2C_2O_4$, as the reducing agent and citric acid, $C_6H_8O_7$, as a chelating agent [8]. The CITROX blend was developed primarily to minimize iron oxalate precipitation when using oxalic acid to remove scale. The cleaning solution is made using dry organic acids added in a dry powder form. Typically, the dry acid is dissolved in a mixing tank, heated, and injected into the preheated system to be decontaminated. The dissolution occurs rapidly even at room temperatures. As the chelating agent, citric acid helps keep the metal in solution, until they are removed via cation exchange. Being a regenerative process, the solvent is continuously circulated through the resin bed, removing the dissolved metals, including radionuclides, while returning the organic acids to their original form [8].

The use of CITROX to clean HLW tanks will create a significant quantity of spent ion exchange resin. Although the use of citric acid/oxalic acid blends have been shown to work well for scale removal in nuclear power plants, based on laboratory testing [5] the use of pure oxalic acid solution has been determined equally effective as the CITROX blend in dissolving HLW sludge.

Decontamination for Decommissioning

The Decontamination for Decommissioning (DfD) technology uses fluoroboric acid, HF_4 , as both the reducing and chelating agents [8]. The DfD technology has been applied to a wide range of efforts, ranging in size from the primary loop in nuclear power plant to a small positive displacement pump. With DfD being a regenerative process, the solvent is regenerated by passing it through a cation exchange resin. Eventually, when the cleaning is complete the HF_4 is neutralized and prepared for disposal [8]. The potential downstream HLW process impacts from fluoroboric acid to Salt Processing and DWPF are not well understood.

Decontamination for Decommissioning-Improved

As a successor to DfD, the primary chemical used with the Decontamination for Decommissioning-Improved (DfDx) technology is also fluoroboric acid, HF_4 [9]. Since DfD uses ion exchange resin, in which disposal can prove difficult, an enhancement to DfD replaced the ion exchange column with an electrochemical cell. The new technology is termed DfDx [9].

The potential downstream process impacts from fluoroboric acid to salt processing and DWPF are not well understood. Additionally, because of the use of an electrochemical cell, the technology's use has been considered restricted to the decontamination of small components, such as the decontamination of a single pump. The DfDx technology, therefore, was considered not to have a proven throughput capable of potentially cleaning the assumed representative HLW tank within about 6 months.

Chemical Oxidation Reduction Decontamination with Ultraviolet Light

The Chemical Oxidation Reduction Decontamination with Ultraviolet Light (CORD-UV) technology uses oxalic acid, $H_2C_2O_4$, as a reducing agent [10]. CORD-UV treatment steps typically include [10]:

- A series of customized chemical oxidation and/or reduction steps optimized for the unique surface of the contaminant to be removed,
- Decomposition of the solvent (in this case oxalic acid) to carbon dioxide and water utilizing a patented photo-oxidation treatment process, which uses ozone/UV, such that the oxalate is removed.

Normally within a reactor, the whole cleaning effort is performed with only one system full of demineralized water. Exposure to oxalic acid results in dissolution of metal hydroxides and oxides to give soluble metal oxalate. The oxalates are then decomposed via photo-oxidation [10].

The envisioned adaptation of the CORD-UV process would minimize the volume of liquid added to the HLW process by delivering the removed sludge as a precipitate slurry, and continually regenerating and reusing the solvent, thereby minimizing the amount of total liquid added to the process. Another advantage of CORD-UV is that no new chemicals are introduced to the HLW process, minimizing the potential for downstream impacts. As for flammability concerns, no volatile organics are used.

DOWN SELECT

With all six of the technologies being DRTs, all were considered to add only minimal amounts of liquid to the HLW process. When performing the TRIZ operation of “trading the contradictions,” LOMI could not be applied in the air atmosphere, and was therefore, the only technology which could not potentially obtain the desired 90% dissolution. With most DRTs, the use of ion exchange technology is fundamental to a dilute regenerative nature, with DfDx and CORD-UV being two positive exceptions. All of the DRTs were considered to have a well-proven throughput, except for DfDx. Except for CORD-UV, each of the DRTs negatively require the introduction of a new chemical to the HLW process, hence potentially causing significant downstream impacts. A summary of the TRIZ evaluation is shown in Table II.

Table II. Contradiction Table for the Dilute Decontamination Regenerative Technologies

Technology	Dissolution (i.e., about 90%)	Secondary Waste	Downstream Impacts	Throughput
LOMI	Contradiction - will not work in air	Contradiction - creates used ion exchange resin	Not evaluated	Proven
CAN-DECON	Proven	Contradiction - creates used ion exchange resin	Potential contradiction - uses EDTA; downstream impacts on DWPF are not	Proven

CITROX	Proven	Contradiction-creates used ion exchange resin	Potential contradiction - uses citric acid; downstream impacts on DWPF are not	Proven
DfD	Proven	Contradiction-creates used ion exchange resin	Potential contradiction – adds fluoroboric acid; downstream impacts are not	Proven
DfDx	Proven	Contradiction–does not use resin, smaller volume of carbon media used to collect	Potential contradiction – adds fluoroboric acid; downstream impacts are not	Potential contradiction – not proven
CORD-UV	Proven	Can be modified such that it does not use ion exchange resin	Uses oxalic acid	Proven

Although the CORD-UV[®] process in nuclear power plant applications commonly uses ion exchange, its use is not fundamental to the base technology [10]. The base technology of CORD-UV[®] is that it uses photo-oxidation as a destructive dilute regenerative method [10]. In the SRS application, an evaporator would be used to partially de-water the slurry. Ultimately it was agreed that the CORD-UV technology was the only DRT which did not have any contradictions. Since the CORD-UV technology did not have any contradictions, contradiction trading was not required, and CORD-UV became the TRIZ identified alternative.

Process Flowsheet and Technology Gaps

To show continuity with BOAC, but also show an improvement, the new process was termed Enhanced Chemical Cleaning (ECC). After determining the CORD-UV technology to be the TRIZ identified alternative, an initial pre-conceptual process flowsheet was drafted. Refer to Figure 1.

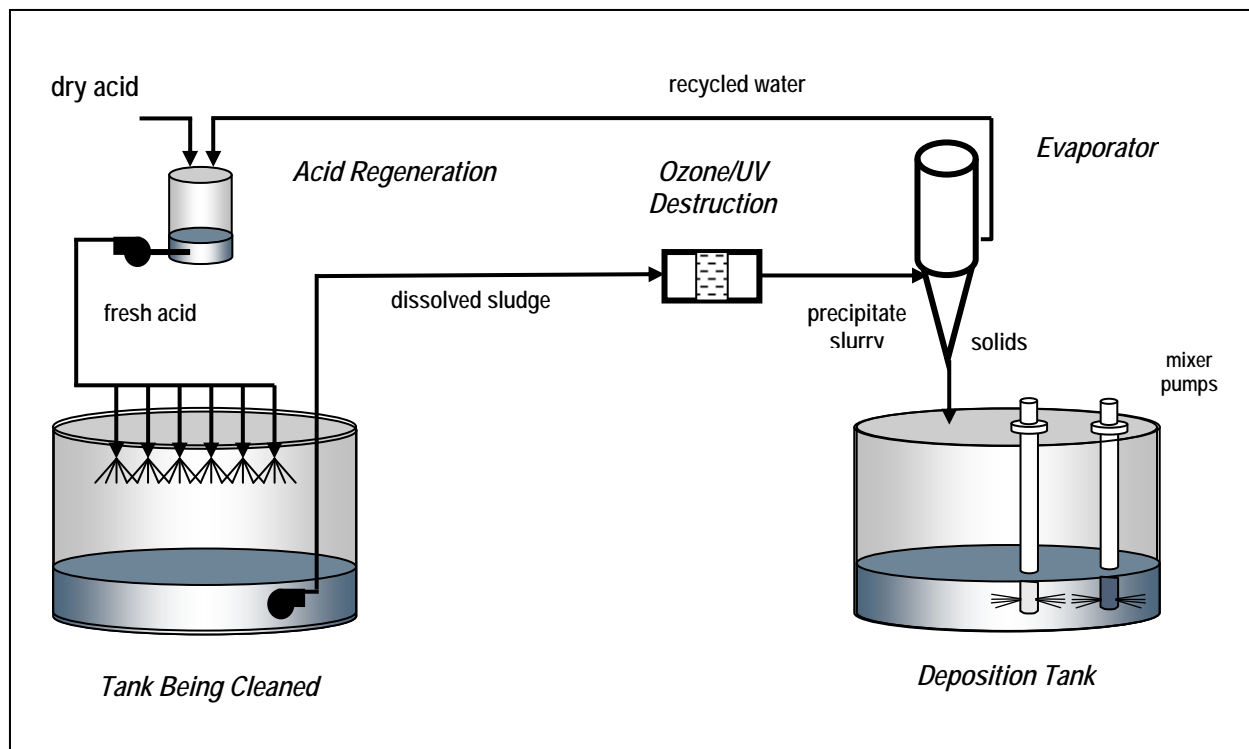


Fig. 1. “Pre-Conceptual” ECC flowsheet.

After the sludge dissolves and is suspended and transferred out of the tank, the spent acid/ dissolved solids will be treated with ozone/UV, where the oxalate will decompose causing the sludge to re-precipitate. The solids will be separated from the waste stream, and as a slurry, will be transferred to the deposition tank, while the liquid will be recycled back towards the treatment tank. Dry oxalic acid will then be added back to the liquid. The refreshed dilute oxalic acid cleaning solution will be added back into the treatment tank for further dissolution of the sludge [10].

The front-end of the flowsheet focuses on the dissolution of the residual solids with dilute oxalic acid. The tail-end focuses on oxalate destruction and metal oxide separation, as a slurry, from the spent acid stream. Based on Figure 1, ten potential technology gaps were identified. Six were applicable to the front end of the process and nine were applicable to the tail-end. A testing matrix was developed to identify which of the technology gaps should be evaluated with simulate and which required real waste testing. As part of the testing, the simulant tests were further divided into two groups, those which would be required to show the initial efficacy of the process, and those which be performed only after process details were better defined. The early simulant tests are termed “demonstration,” while the latter will be termed “integrated,” since the scope of the integrated includes testing the entire operability of the ECC process. Appropriately, the integrated simulant test will use hazardous simulant, containing a more complete list of the applicable metals. It should be noted that many of the technology gaps tested for as part of the demonstration test, may be further tested and evaluated during the integrated test. The testing matrix is shown in Table III.

Table III. Testing Matrix

Technology Gap	Process Segment
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		Front End	Tail End
1	Dissolution using low concentration of oxalic acid	Simulant - demonstration	NA
2	Oxalate destruction	NA	Simulant - demonstration
3	Corrosion	Simulant - demonstration	Simulant - demonstration
4	Temperature	Simulant - demonstration	Simulant - demonstration
5	Gas generation, overpressurization & flammability	Simulant - integrated	Simulant - integrated
6	Actinide solubility & kinetics	Real Waste	Real Waste
7	Solids separation technology (evaporator)	NA	Simulant - integrated
8	Effect of aluminum	NA	Simulant - integrated
9	Effect of mercury and secondary oxidizers	NA	Simulant - integrated
10	Operability of the process, including effect/cleaning of UV lights	Simulant - integrated	Simulant - integrated

DEMONSTRATION TESTING WITH SRS HLW SIMULANT

Three key performance indicators, based on BOAC, were selected to demonstrate the potential effectiveness of the CORD UV technology for cleaning of the SRS HLW tanks [3, 5]:

- 1) Dissolution of greater than 90% of the sludge simulant
- 2) Destruction of greater than 90% of the dissolution organics (i.e., the oxalic acid)
- 3) Solids resulting from oxalic acid decomposition contain less than 10% organics.

Demonstration that these indicators were met was performed using a two-part demonstration test that included separate dissolution and decomposition process loops. The dissolution loop is shown in Figure 2. It includes a pump, a heating chamber and a sludge dissolution chamber, and holds 18 liters of solution. The flow rate through the dissolution loop is a constant 3.8 liters per minute with a resulting velocity in the dissolution chamber of 0.6 cm per minute.



Fig. 2. Dissolution demonstration loop.

The recirculating pump is in the lower right corner. The dissolution screen rack, on which the sludge is loaded for dissolution testing, is loaded into the stainless steel vessel on the left-center of the figure. The inset shows the dissolution loop screen rack loaded with wet sludge simulant, although both wet and dried simulant runs were performed. The center vessel covered with insulation is the heating vessel. The recirculation flow path is from the pump to the dissolution vessel, then into the heating chamber, then back to the pump.

A sludge simulant, based on the same recipe for the BOAC simulant, was obtained from Savannah River National Laboratory (SRNL) [5]. The composition of this simulant was verified by the AREVA laboratory prior to demonstration loop runs.

Extent of dissolution was determined by measuring the level of dissolved iron and aluminum in samples of the circulating fluid at various time points after the pump was engaged. Dissolved iron and aluminum were analyzed by atomic absorption spectroscopy utilizing standard methods. The sampling point was on the discharge side of the recirculation pump. The dependence of dissolution extent and rate on temperature was determined by conducting runs at 25°C, 50°C and 70°C.

To determine whether the key performance indicator for dissolution had been met, mass balance calculations were performed based upon the known composition of the sludge simulant compared to the levels of dissolved iron and aluminum in the process fluid. Additionally, the dissolution loop screens were weighed and the entire loop visually inspected before and after the dissolution runs. Figure 3A shows the dissolution screens after a typical run, while Figure 3B shows the interior of the dissolution loop screen chamber. The dissolution screens (Figure 3A) contain a light film of less than 1 mm in thickness which is likely a metallic oxide or hydroxide. The film on the screen chamber wall (Figure 3B) is less than 1 mm thick, is easily mobilized by scraping when air dried. However, both weighing and

visual inspection clearly show that all sludge simulant has been dissolved or mobilized in the process. Taken together, these results demonstrated that the dissolution process had met the key performance indicator of dissolution of greater than 90% of the sludge simulant.

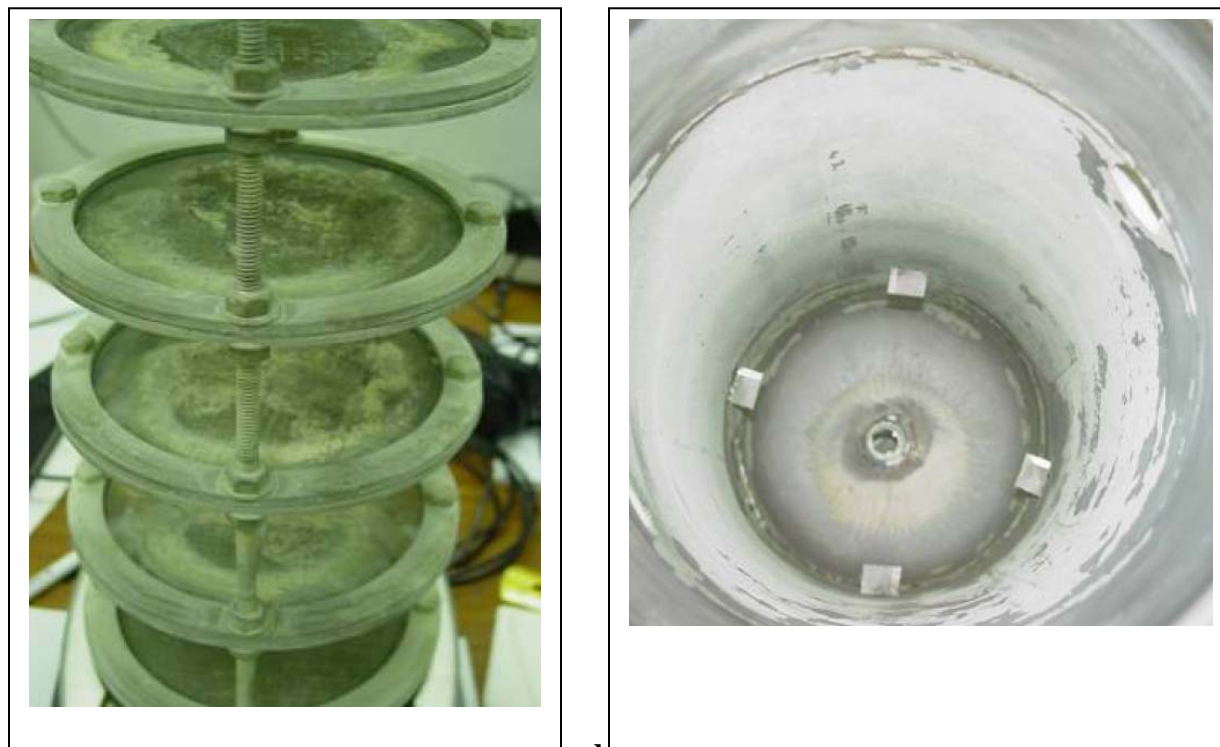


Fig. 5. Demonstration loop screens (A) and screen chamber interior (B) after process loop demonstration run.

As the next step, the extent of UV-induced decomposition of the oxalate was observed utilizing the decomposition loop of the system (Figure 4). When the color of the dissolved sludge simulant solution allowed satisfactory colorimetric analysis, decomposition of oxalic acid was monitored by titration with permanganate. However, when the dissolved sludge solution was too opaque for colorimetry, and filtration did not allow for sufficient reduction in turbidity, oxalic acid concentration was measured by ion chromatography.

After the dissolution loop was operated for at least 4 hours, cross-flow was initiated between the dissolution and decomposition loops, and the UV source was activated. Decomposition of oxalate, as well as iron concentrations and pH, were monitored from sampling ports at the inlet to the UV treatment module and at the outlet where the UV-irradiated solution is recirculated to the dissolution loop. Metallic precipitates in the decomposition loop were collected on an in-line one-micron filter (cyclone or centrifuge separators will be used for the actual full scale application to the SRS HLW tanks). Aluminum and iron concentrations could be reduced to below detectable levels in the decomposition loop (due to precipitation on the filter) when the oxalic acid concentration was decomposed to less than 100 ppm. These results demonstrated that the dissolution process had met the key performance indicator of decomposition of greater than 90% of the oxalic acid.



Fig. 4. Decomposition demonstration loop.

Solids collected on the in-line filters were then digested in a hydrochloric acid solution and analyzed for total organic carbon (TOC). Typical TOCs were in the range of 0.83 weight percent (wt%) TOC, confirming that the key performance indicator of less than 10% residual organics (i.e., oxalate) in the precipitated solids was met.

It was important to show that conditions which meet these key performance indicators are unlikely to damage the integrity of the SRS HLW tanks themselves during application of the CORD UV process. Galvanically coupled coupons representative of tank composition at SRS were supplied by SRNL. They were loaded into a dissolution loop and exposed to 10,000 ppm oxalic acid for 53 hours at 70°C and the extent of visible corrosion was examined. The coupons showed a light oxalate coating that generally functions as a passive layer. Coupons were then lightly brushed in soapy water, rinsed, dried and weighed, and compared to their pre-treatment weight. The weight differences extrapolated to a corrosion rate of 36 to 52 mm per year of continuous process treatment. This was well within the SRS-required corrosion allowance of 50 mm per 6 months. Treatment of each HLW tank is expected to occur over time frames significantly less than 6 months.

CONCLUSIONS

After a TRIZ search for an alternative technology for cleaning of the SRS HLW tanks, the CORD-UV technology was selected for further evaluation. A test rig consisting of a dissolution loop and an ozone/UV photo-oxidation decomposition loop based on the CORD-UV technology, was constructed and tested. Three key performance indicators were selected to demonstrate the test rig's effectiveness. In demonstration loop studies performed on a sludge simulant provided by SRNL, CORD-UV dissolved greater than 90% of the sludge simulant, destroyed greater than 90% of the dissolution organics (i.e., the oxalic acid), and generated solids which contained less than 10% organics. Additionally, the process did not result in appreciable corrosion of test coupons representative of SRS HLW tank walls.

REFERENCES

1. D.P. CHEW, M.J. MAHONEY, and J.R. VITALI, "Life-cycle Liquid Waste Disposition Plan: Liquid Waste Planning Process," LWO-PIT-2007-00062, Rev. 14, Washington Savannah River Company (2007).
2. J.B. ELDER, B.J. WIERSMA, and R.L. SINDELAR, "Remote Inspection of a High Level Radioactive Waste Storage Tank For Cracking, Thinning, and Pitting, WSRC-MS-2003-00477, Washington Savannah River Company (2003).
3. K. ADU-WUSU, M.J. BARNES, N.E. BIBLER, J.R. CANTRELL, F.F. FONDEUR, B.A. HAMM, D.T. HOBBS, E.T. KETUSKY, M. SINGLETON, M.E. STALLINGS, W.E. STEVENS, and B.J. WIERSMA, "Waste Tank Heel Chemical Cleaning Summary," WSRC-TR-2003-00401, Washington Savannah River Company (2003).
4. K.H. SUBRAMANIAN, "Review of Corrosion Inhibition in High Level Radioactive Waste Tanks in the DOE Complex," - NACE 2004, New Orleans, LA (US), March 28-April 1, (2004).
5. M.E. STALLINGS, D.T. HOBBS, and B.J. WIERSMA, "Dissolution of Simulated and Radioactive Savannah River Site High-Level Waste Sludges with Oxalic Acid and Citric Acid Solutions," WSRC-TR-2004-0042, Washington Savannah River Company (2004).
6. J.A. PIKE, N.P. BADHEKA, and E.T. KETUSKY, "Flowsheet for SRS Waste Tank Heel Removal Using Oxalic Acid," WSRC-TR-2004-00317, Washington Savannah River Company (2004).
7. E.T., KETUSKY, MTech Chemical Engineering Thesis, "High Level Waste System Impacts from acid Dissolution of Sludge," University of South Africa (2008).
8. D. BRADBURY, "Review of Decontamination Technology Development, 1977-2000", British Nuclear Energy Society, London, October 22-26, 2000, Water Chemistry of Nuclear Reactor Systems 8 (2000).
9. S. BUSHART, C. WOOD, D. BRADBURY, and G. ELDER, "The EPRI DFDx Chemical Decontamination Process, Proceedings from WM2003, February 23-27 (2003).
10. H. WILLE and H. BERTHOLDT, "Lessons Learned in Full System Decontamination by Application of the CORD Family Concept," British Nuclear Energy Society, London, October 22-26, 2000, Water Chemistry of Nuclear Reactor Systems 8 (2000).