

**Implementation of Next Generation Solvent in the Caustic-Side Solvent Extraction Process for Increased Removal of Cesium at Savannah River Site – 14266**

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**ABSTRACT**

Caustic Side Solvent Extraction (CSSX) is currently used at the Department of Energy Savannah River Site (DOE SRS) for removal of cesium from the high-level salt-wastes stored in underground tanks. Currently, the actinide removal process (ARP) and the CSSX process are deployed in the ARP/Modular CSSX Unit (MCU), to process salt waste for permanent disposition. The CSSX technology utilizes a multi-component organic solvent and annular centrifugal contactors to extract cesium from alkaline salt waste. The original plant was permitted for a three year operating life; however, given the successful operation of the plant, a life extension program was completed to continue operations. As part of the life extension program, a new solvent called Next Generation Solvent (NGS), which was developed by Oak Ridge National Laboratory (ORNL) with funding provided by EM Technology Development, will be implemented at MCU to decrease the curies of cesium going to grout in the Saltstone Production Facility (SPF). NGS is an engineered solvent designed to increase the extraction performance of cesium from salt waste and with cold feed chemical changes increase the corresponding cesium stripping performance, resulting in a salt waste effluent with substantially lower cesium concentration. Implementation of NGS in the MCU at SRS is being performed to maintain previous commitments to the state of South Carolina with regard to the curies of cesium going into cementitious grout being left in the state, which could be impacted under the original CSSX flowsheet. In order to implement NGS in MCU, a technical maturation plan (TMP) was developed to identify technical maturity level gaps that required further evaluation, testing, or engineering work in order to bring the immature technology to the appropriate maturity level. The TMP was utilized as the guide to promote the Technical Readiness Level (TRL) from TRL-2 (i.e. technology concept and/or application formulated), with the corresponding activities necessary to reach a TRL-6 (i.e. engineering/pilot scale system in relevant environment). Critical technology maturation activities included full scale testing, combined hazards assessments for three SRS facilities, and Project/Facility documentation/modifications for incorporation of the NGS flow sheet.

**INTRODUCTION**

The SRS liquid waste system consists of multiple facilities to safely receive and store legacy radioactive waste, treat, and permanently dispose of waste. The large underground storage tanks and associated equipment, known as the 'tank farms', include a complex interconnected transfer system which includes underground transfer pipelines and ancillary equipment to direct the flow of waste. The waste in the tanks is present in three forms: supernatant, sludge, and

saltcake. The supernatant is an alkaline aqueous mixture, while sludge consists of insoluble solids and entrapped supernatant. The saltcake results from the evaporation (water removal) of the supernatant. The tank waste is retrieved and treated as sludge or salt solution. Saltcake is retrieved from the waste tanks by removing the interstitial liquid, dissolving the saltcake with water, and finally retrieving the dissolved salt solution for further processing [1]. The high level (radioactive) fraction (actinides, strontium, and cesium) of the waste is vitrified into a glass waste form, while the low-level waste is immobilized in cementitious grout waste called saltstone. Once the bulk of the waste is retrieved and processed, the tanks are closed via chemical cleaning, heel removal, stabilizing remaining residuals with tailored grout formulations and severing/sealing external penetrations. The comprehensive liquid waste disposition system, currently managed by Savannah River Remediation (SRR), consists of 1) safe storage and retrieval of the waste as it is prepared for permanent disposition; (2) definition of the waste processing techniques utilized to separate the high-level waste fraction/low-level waste fraction; (3) disposition of Low Level Waste (LLW) in saltstone; (4) disposition of the High Level Waste (HLW) in glass; and (5) closure state of the facilities, including tanks. This paper focuses on the technical maturation of a new solvent (i.e., NGS) for cesium extraction from high-level salt wastes for implementation in the MCU.

MCU was originally designed and permitted with a three year operating life and a five year design life, bridging the period before startup of the Salt Waste Processing Facility (SWPF). A life extension evaluation [2] was performed in 2009 and concluded that passive process components have a service life beyond year 2025. Active components designed to be replaced with existing spares includes process pumps. Major maintenance repairs are anticipated after 2015 which includes replacement of all contactor bearings and wiring in closed proximity to the strip effluent stream. With the extended operation of the MCU beyond its initial operating life forecast, previous commitments to the state of South Carolina with regard to the curies of cesium in the cementitious grout being left in the state, could be impacted under the current solvent flowsheet [3]. As a result, an improved flowsheet based on an improved solvent (NGS) developed by ORNL has been developed to improve the extraction and stripping of cesium from clarified salt solution (CSS). This new flowsheet employs a new extractant and suppressor in the solvent as well as new scrub and strip cold chemical feeds.

## **BACKGROUND**

### **SRS Salt Processing**

The existing ARP/MCU process has been operating at SRS since April 2008 as an interim salt treatment system to remove actinides and cesium from high level waste salt solutions. MCU is the first production-scale CSSX process for cesium separation. While the application of this solvent extraction process is unique, the process uses commercially available centrifugal contactors for the primary unit operation as well as other common methods of physical separation of immiscible liquids (i.e. coalescers and decanters). This process enables permanent disposal of the CSSX raffinate, Decontaminated Salt Solution (DSS), at the SPF as cementitious grout,

and the Strip Effluent (SE) containing cesium at the DWPF in a vitrified waste form. MCU is operated in series with ARP, where ARP first removes sludge solids, soluble strontium and actinides from the salt waste solution and then feeds the CSS to MCU for cesium extraction. Figure 1 provides an overview of the SRS Salt Processing Facilities that feed DWPF & SPF.

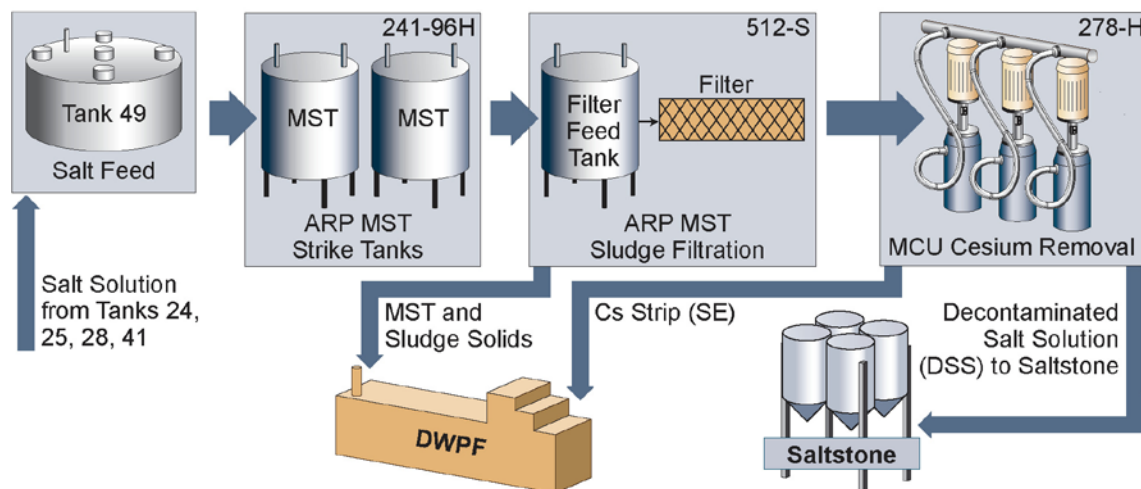


Figure 1. SRS Salt Processing Facilities

### MCU Process

MCU uses a four-part organic solvent developed by ORNL: 1) diluent/fluidic carrier; 2) calixarene extractant; 3) solubility modifier, and 4) suppressor, combined with the operation of multiple centrifugal contactors. The solvent is used to extract cesium from the aqueous feed solution in the extraction contactor bank consisting of seven centrifugal contactors. The DSS raffinate is sent to a coalescer and decanter to remove any entrained solvent before transfer to Tank 50. The cesium laden solvent from the extraction bank is scrubbed in the scrub contactor bank consisting of two centrifugal contactors. The scrub solution removes ionic impurities in the solvent, and also ensures that the anion pair associated with the Cs<sup>+</sup> in the solvent is in the optimal anion form for stripping. Cesium is then stripped from the solvent to an aqueous strip solution in the strip contactor bank consisting of seven centrifugal contactors. This concentrated cesium SE is then sent to a coalescer and decanter to remove solvent carried over into the strip effluent. The cesium laden SE is sent to DWPF to be vitrified. The solvent stream exits the strip contactor bank and is sent to the wash contactor bank consisting of two centrifugal contactors to clean the solvent of any impurities. The solvent is then recycled into the system for further use. As of the end of fiscal year 2013, MCU has successfully processed more than 3.9 million gallons of salt waste utilizing the BOBCalixC6 based solvent flowsheet.

An MCU process flow schematic is shown in Figure 2.

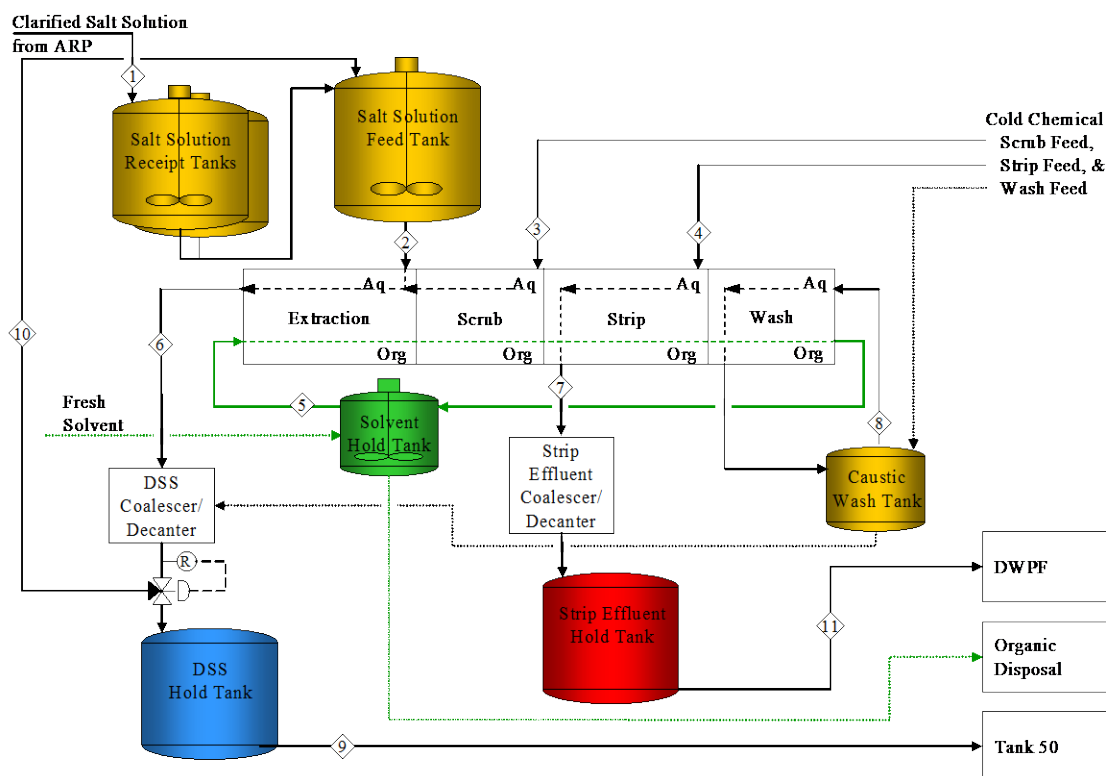


Figure 2. MCU Process Flow Schematic

## NGS IMPLEMENTATION CHEMICAL CHANGES

### Solvent

NGS utilizes the new extractant MaxCalix, more formally known as 1,3-alt-25,27-Bis(3,7-dimethyloctyloxy)calix[4]arene-benzocrown-6. Like BOBCalixC6, MaxCalix is a highly selective calixarene extractant which has a high affinity for cesium ions and a low affinity for sodium ions. The cesium affinity for both extractants is roughly the same; however, MaxCalix has a significantly increased solubility over BOBCalixC6 in the diluent Isopar™ L, thus enabling the extractant concentration to be increased from 7 mM to 50 mM (i.e., a 7x increase).

Both solvent systems use the modifier Cs-7SB, also known as 2-Propanol, 1-(2,2,3,3-Tetrafluoropropoxy)-3-(4-sec-butylphenoxy). The modifier is designed to increase the solubility of the extractant in the diluent to increase cesium extraction. However, with the increased solubility of MaxCalix in the diluent, less modifier is required in the NGS system (a reduction of 0.75 M to 0.5 M [4]). This reduction in modifier has an additional benefit of reducing the solvent viscosity and density, which is anticipated to further improve hydraulics in the centrifugal contactor banks and efficiency in the coalescers and decanters.

The suppressor is present in the solvent to improve stripping performance by suppressing the effects of anion impurities and lipophilic surfactants. The BOBCalixC6 based solvent system utilizes TOA as the suppressor. During the development of the NGS flowsheet it was determined that TOA would not successfully function in the NGS system with the new strip chemistry. An initial improved flowsheet was developed with DCiTG, also known as N,N'-Dicyclohexyl-N"-isotridecylguanidine, as the suppressor in the NGS system. DCiTG is a generic version of the active guanidine reagent in the Cognis extractant LIX™79. DCiTG was initially considered an attractive candidate for suppressor because of its effectiveness and availability. However, DCiTG was ultimately rejected because in testing it was found to partition too readily to the aqueous phase [5]. Partitioning of the suppressor to the strip aqueous phase poses potential downstream processing impacts. An alternative suppressor, TiDG, also known as (tris(3,7-dimethyloctyl)guanidine hydrochloride), was chosen for the NGS system because of its effectiveness, stability, and lipophilic characteristics. The working suppressor will remain the same concentration in both solvent systems (0.003 M).

NGS and BOBCalixC6 solvent systems utilize the same isoparaffinic diluent, Isopar™ L. The concentration of Isopar™ L will increase in the NGS system (from 69 wt. % to 74 wt. %). This increase in diluent is also anticipated to improve hydraulics by reducing solvent density and viscosity.

#### Cold Feeds

The MCU system uses scrub, strip, and wash cold chemicals in order to remove cesium and impurities from the solvent. The BOBCalixC6 based solvent system operates under a nitrate swing principle, which drives the transfer of ions between the aqueous and solvent phases depending on the concentration of nitrate in the aqueous phase. The NGS system operates under a pH-swing principle, which drives the transfer of ions between the aqueous and solvent phases depending on the pH of the aqueous phase.

After extraction the cesium laden solvent is sent to the scrub hydraulic bank [6]. Scrubbing removes soluble salts, such as sodium and potassium from the solvent. These salts would be stripped in the first strip stage and negatively affect the stripping process by altering the aqueous phase concentrations for all subsequent strip contactor stages. In the BOBCalixC6 based solvent system the scrub solution is 0.05 M nitric acid. This ensures that the anion associated with Cs<sup>+</sup> in the solvent is nitrate, which promotes stripping in the BOBCalixC6 based solvent system [7]. The NGS flowsheet changes the scrub solution to 0.025 M sodium hydroxide, which ensures that the anion associated with Cs<sup>+</sup> in the solvent is hydroxide, which promotes stripping in the NGS system [8,9]. The change in the scrub solution results in the suppressor being in a neutral form after it contacts the scrub so the suppressor can then subsequently protonate in the strip bank. The aqueous product of the scrub contactor bank is sent back to the extraction bank, and the solvent product is sent forward to the strip bank.

In the BOBCalixC6 based solvent system the strip solution is 0.001 M nitric acid. This low concentration forces the migration of the concentrated cesium nitrates in the solvent to the more dilute aqueous nitric acid [7]. However, any effort to improve the stripping of cesium in the BOBCalixC6 based solvent system would be limited by the ability to lower the concentration of nitrate in the strip solution. The NGS system utilizes a 0.01 M boric acid as the strip solution. The boric acid strip was chosen for the NGS system because improved cesium stripping could be

achieved by employing a pH swing rather than a nitrate swing in either system. The boric acid strip was determined to be more effective when nitrate ions were removed from the solvent; hence the change from a nitrate based scrub to a hydroxide based scrub. Investigation of alternatives suggested that replacement of the nitrate anion with a much more hydrophilic anion, such as borate, would substantially decrease the cesium distribution coefficients associated with the stripping [8]. Testing confirmed that replacing the nitric acid strip with boric acid would result in increased stripping. The combination of MaxCalix as the extractant, TiDG as the suppressor, and the use of boric acid strip provide a dramatic increase in the removal of cesium from the salt waste. The aqueous effluent from the strip bank containing the concentrated cesium is sent forward to DWPF for borosilicate vitrification while the stripped solvent is sent to the wash contactor bank.

The wash is a 0.03 M sodium hydroxide solution for both solvent systems. The wash is designed to eliminate impurities and degradation products built up in the solvent over time. This ensures that the solvent can be effectively recycled.

### Solvent Blending

The NGS Blend (mixture of BOBCalixC6 and NGS) was developed by ORNL, specifically as a strategy [4] for introducing NGS to MCU, as it removes the hazards and risks associated with the need to de-inventory the BOBCalixC6 based solvent out of MCU, as such an effort would be prohibitively complex, generate significant waste, and create significant risk of potential personnel radiological exposure. Through testing ORNL has shown the NGS Blend to be equally effective as pure NGS.

The NGS solvent components were introduced to the MCU solvent system in a “concentrate” and blended with the existing BOBCalixC6 based solvent to create the NGS Blend. Following blending of the solvent, the MCU entered into a maintenance outage to replace system active components (i.e., pumps and pumps variable frequency drives). MCU deliberate operations with NGS will be initiated following the completion of the maintenance outage. After NGS implementation with the NGS Blend, all solvent additions/adjustments will consist of only NGS constituents. Therefore, the operating solvent will gradually approach the final Pure NGS concentrations. The concentrations of the various solvents are shown in Table I.

TABLE I: MCU Solvent Concentrations

Solvent	Constituent Concentrations (Nominal)
BOBCalixC6 Based Solvent	BOBCalixC6 = 0.007 M Cs-7SB = 0.750 M TOA = 0.003 M Isopar-L balance (69 wt. %)
NGS Blend	MaxCalix = 0.0465 M Cs-7SB = 0.500 M BOBCalixC6 = 0.0035 M TiDG = 0.003 M TOA = 0.0015 M Isopar-L balance (74 wt. %)
Pure NGS	MaxCalix = 0.050 M Cs-7SB = 0.500 M TiDG = 0.003 M Isopar-L balance (74 wt. %)

## TECHNICAL MATURATION PLAN

MCU with NGS process maturation was performed utilizing the methodologies described in the United States Department of Energy (DOE) Technology Readiness Assessment (TRA) Guide [10], which outlines three primary steps:

- Establish the principal technology elements (TEs) for the proposed process, and subsequently assess each TE with respect to its potential designation as a critical technology element (CTE).
- Determine the associated technology readiness levels (TRLs) for each CTE.
- Ascertain potential technology gaps that might hinder technology deployment and document strategies for closing the gaps, and maturing the technology.

The TRA provides a snapshot of the technology readiness of each CTE and demonstrates that a TRL of 6 has been reached and the program is ready for implementation in the facility. The various TRA levels and definitions are defined in Table II.

TABLE II: Technology Readiness Levels [10]

Relative Level of Technology Development	TRL	TRL Definition
System Operations	9	Actual system operated over the full range of expected conditions
System Commissioning	8	Actual system completed & qualified through test & validation
	7	Full scale, similar (prototypical) system demonstrated in relevant environment
Technology Demonstration	6	Engineering/ pilot scale, similar (prototypical) system validation in relevant environment
	5	Lab scale similar system validation in relevant environment
Technology Development	4	Component and/or system validation in laboratory environment
	3	Analytical and experimental critical function and/or characteristic proof of concept
Research to Prove Feasibility	2	Technology concept and/or application formulated
	1	Basic principles observed and repeated

### Critical Technology Elements

Two CTEs were identified by the assessment team: the contactor banks and the coalescer/decanter [11,12]. The contactor banks, the first CTE (CTE 1), have two objectives critical to the MCU process. The first objective is to extract cesium from CSS to produce DSS. The second objective is to strip cesium from the solvent, so the solvent can be recirculated and re-used. The second CTE (CTE 2) is the coalescer/decanter combination. The objective of this technology is to sufficiently reduce organic carryover in the aqueous product streams. The coalescer increases the size of entrained organic droplets. The decanter separates the organic and aqueous streams. Coalescers are the key to minimizing loss of organic traces to downstream processing, minimizing downstream flammability problems therein, and recovering valuable solvent components.

#### CTE 1

Centrifugal contactors boast ease of operation, rapid attainment of steady state, high mass-transfer rate, rapid coalescence, and compact size, making them the preferred device for solvent-extraction processing. The contactors were manufactured by Costner Industries Nevada Corporation (CINC). The contactors are of two sizes, a 10 inch rotor diameter (i.e., V-10), to accommodate high flow rates, and a smaller 5-inch rotor diameter (i.e., V-05), for lower flow rates. The extraction



bank consists of seven V-10 contactors. The cesium laden solvent is then sent to the scrub bank, which consists of two V-05 contactors. The cesium-enriched scrubbed solvent then passes into the strip bank, consisting of seven V-05 contactors, where the cesium is removed from the solvent phase (i.e., stripped) to the aqueous SE. Any acidic carryover from the strip bank, the solvent degradation products, and other contaminants will be neutralized/removed from the solvent using a dilute caustic solution wash with the two V-05 wash contactors.

## CTE 2

The two aqueous streams leaving MCU, the SE and DSS streams, contain small droplets of organic solvent which must be separated before the streams can be sent to downstream facilities. To achieve separation each stream passes through a coalescer and decanter in series.

Prior hydraulic testing of the V-10 contactors with BOBCalixC6 based solvent and simulated salt solution indicated that there could be up to 1,000 ppm carryover of the solvent in aqueous stream exiting the contactor with the majority of the droplets being less than 10  $\mu\text{m}$  in diameter [13]. If the DSS stream is sent to the downstream facility with this level of organic carryover, it could lead to flammability concerns to downstream processes as well as rapidly deplete the inventory of solvent in MCU. To remove the flammability potential and recover the solvent, a coalescer and decanter are installed in series downstream of the extraction contactors. Coalescers promote the merging of many small droplets to form fewer droplets with a larger diameter. The larger diameter increases the buoyant forces of the droplet (Stokes Law) requiring considerably less time to decant. The DSS coalescer media used is a 40 inch long, 20 micron polyphenylene sulfide type mesh. The DSS Decanter includes a baffle configuration to ensure the waste has sufficient time for the Cs-137 daughter product, Ba-137m, to decay at least 10 half-lives.

Prior hydraulic testing of the V-05 contactors indicated that there could be up to 400 ppm carryover of solvent in the aqueous SE stream exiting the contactors with the majority of the solvent droplets being less than 10  $\mu\text{m}$  in diameter [13]. If the SE stream is sent to the downstream facility with this level of organic carryover it would potentially cause a flammability concern in the DWPF facility, so a coalescer and decanter are installed downstream of the strip contactors to capture excess solvent carryover. The SE coalescer media used is a 20 inch long, 10 micron polyphenylene sulfide type mesh.

## **Technical Maturation Plan Progression**

Because MCU is an operational facility, the TRA process and TRL determination must be taken in context. The technology is in place and the flowsheet has been verified; a new component is simply being added to the system. The MCU with BOBCalix solvent has achieved a TRL of 9 with radiological operation. A self-conducted TMP performed for the “Pure NGS” with DCiTG as the suppressor identified the Technical category TRL to be 3, Programmatic category TRL to be 3, and the Manufacturing/Quality category TRL to be 6 [11,12]. Since issuance of the Pure NGS TMP, ORNL had further optimized NGS by replacing the suppressor with TiDG, and developed the Blend strategy as a way of introducing NGS, without assuming the risks associated with first

removing the BOBCalixC6 based solvent. Based on the change in suppressor and the strategy to blend the solvents, the assessment team issued a revision of the TMP [14] which identified the contactor banks CTE as an overall TRL-2 and the coalescer/decanter CTE as an overall TRL-2. The initial readiness levels in each of the assessment categories (Technology, Manufacturing and Quality, and Programmatic) for both CTEs after the change to TiDG and a blended solvent is shown in Table III.

**TABLE III: Initial Technical Readiness Levels for CTEs with Consideration of New Suppressor and Blend Strategy [14]**

	<b>Technology</b>	<b>Manufacturing &amp; Quality</b>	<b>Programmatic</b>
	<b>TRL</b>		
Contactactor Bank (CTE 1)	2	3	2
Coalescer & Decanter TRL (CTE 2)	2	3	2

The assessment team identified the tasks shown in Tables IV and V as being required to advance the TRL levels of the contactor banks CTE and coalescer/decanter CTE to TRL 6.

TABLE IV: Contactor Tasks to Advance to TRL-6 [14]

CTE 1 - Contactor
Task
NGS Risk and Opportunity Analysis Report
Safety Basis Strategy
Technical Requirements and Criteria Document (TR&C) update
Combined Hazards Assessment for Tank Farms, DWPF, and SPF
Tank Farms, DWPF, and SPF Waste Acceptance Criteria (WAC)/Waste Compliance Plan (WCP) Revisions
Salt Batch 6 ESS Test Report for NGS
Development of Analytical Method for TiDG
Downstream Impacts on Flammability/Material Compatibility Assessed
Material Balance Documented
New/Revised <i>Spreadsheet Algorithm for Stagewise Solvent Extraction (SASSE)</i> and <i>ROTOR</i> Models
Revised Process Flow Diagram
V-05/V-10 Contactor Testing using the Blend
Report on Guanidine Selection (TiDG)

TABLE V: Coalescer/Decanter Tasks to Advance to TRL-6 [14]

CTE 2 - Coalescer/ Decanter
Task
NGS Risk and Opportunity Analysis Report
Safety Basis Strategy
TR&C update
Combined Hazards Assessment for Tank Farms, DWPF and SPF
Tank Farms, DWPF, and SPF WAC/WCP Revisions
Development of Analytical Method for TiDG
Downstream Impacts on Flammability/Material Compatibility Assessed
Material Balance Documented
Revised Process Flow Diagram
V-05/V-10 Coalescer Testing using the Blended Solvent
Report on Guanidine Selection (TiDG)

The final revision of the TMP, Revision 3 [15], documented the completion of activities necessary to advance contactor banks CTE and the coalescer/decanter CTE to TRL-6. Revision 3 of the

TMP updated the internal snapshot of technology readiness demonstrating that a TRL-6 has been confirmed and the technology is ready for implementation.

The TMP accomplished the following:

- Summarized the technology development performed for implementing the technology
- Confirmed the current TRLs as TRL-6, using methodology based on the U.S. Department of Energy Technology Readiness Assessment Guide
- Documented that there are no current known gaps hindering deployment (i.e., all necessary testing/evaluations/studies have been completed to support implementation)
- Applied methodology based on the guide to demonstrate maturation of the technology

A timeline of the progression of the tasks is shown in Figure 3.

Since achieving TRL-6, the NGS “concentrate” has been introduced into the MCU solvent system solvent hold tank. The solvent mixture has been internally circulated from the solvent hold tank through the wash contactors to blend the BOBCalixC6 based solvent with the NGS “concentrate” to create the NGS Blend.

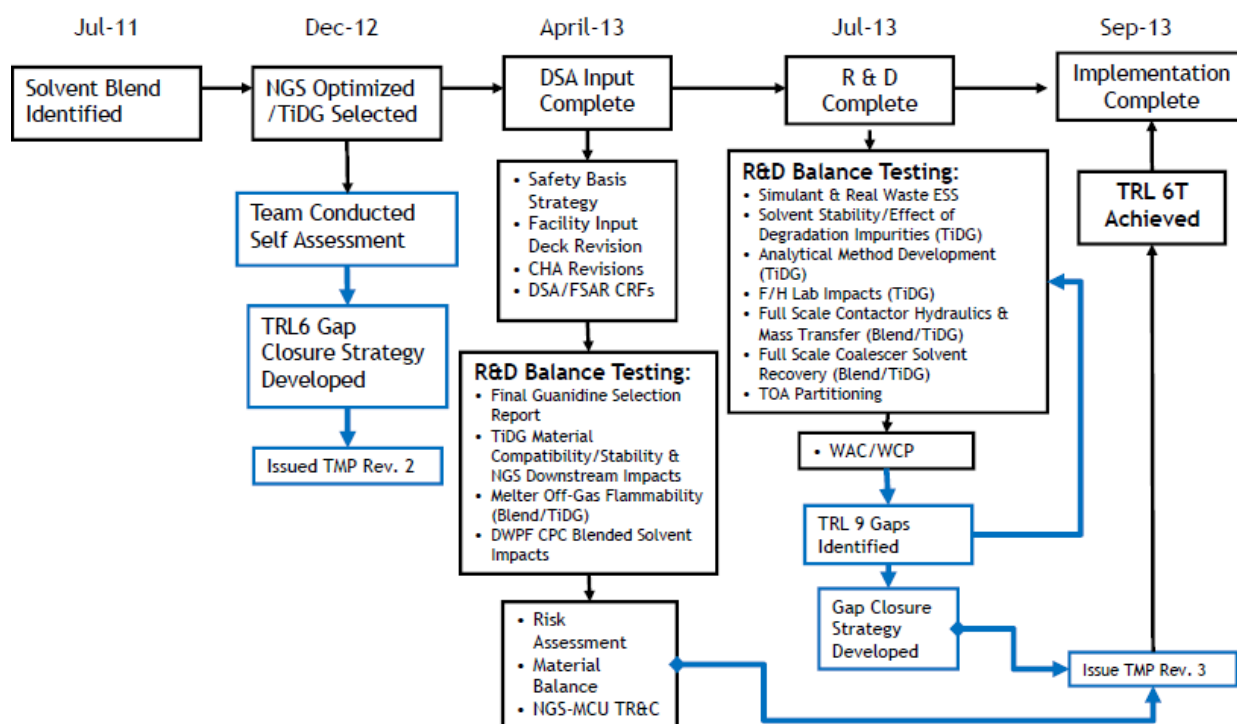


Figure 3. Timeline of Progression of Tasks to Achieve TRL 6

## **DELIBERATE OPERATIONS**

The MCU will undergo a period of deliberate operations under the oversight of the Management Control Plan [16] in order to ensure the performance of the MCU system is evaluated for startup and operation utilizing the improved solvent. Additional monitoring and evaluations will be performed during this demonstration period. The Management Control Plan will evaluate conduct of operations; procedure performance and adherence; process, system and equipment performance; and radiological monitoring.

The process, system, and equipment performance evaluation will be performed for micro-batch operations as outlined in the Demonstration Plan [17]. During this period of oversight a minimum of five micro-batches of CSS will be processed with the salt feed flow rate being incremented with each batch. The system will undergo a “sample and hold” period between each micro-batch, e.g. the strip effluent and DSS raffinate product stream hold tanks will be held until samples have been taken and key sample results are available and documented in an engineering evaluation. Each micro-batch will be supported by an Engineering Technical Evaluation, which will document key sample results and process parameter performance [18]. These engineering evaluations require Engineering, Operations, and Facility Management approval prior to transfer of the micro-batch to downstream facilities and start of a new micro-batch. Once all micro-batches and evaluations have been completed to acceptable standards, the MCU will be released to “sample and send” operations. “Sample and send” operations require sampling of each DSS and SE hold tank prior to transfer, but the hold tank contents may be sent to downstream facilities without requiring sample results or an engineering evaluation prior to transfer. A final engineering evaluation will be performed after completion of all micro-batches that will summarize all sample results, trends, and process parameters over the entire demonstration period. After successful performance of NGS in the MCU system and approval of the final engineering evaluation the MCU system will be released to normal operations. Future technology maturation opportunities include evaluation of higher salt solution feed flow rates (i.e. greater than 8.5 gpm) to achieve higher operational throughputs.

## **CONCLUSIONS**

MCU was permitted for a three year operating life; however, given the successful operation of the plant a life extension program was completed to extend operations beyond the original operating life. With the extended operation of the MCU beyond the initial operating life forecast, previous commitments to the state of South Carolina with regard to the total curies of cesium going into cementitious grout being left at the disposal facility in South Carolina could be impacted under the BOBCalixC6 flowsheet. The NGS flowsheet is being implemented at MCU to increase the cesium removal efficiency, allowing MCU to operate longer, processing more salt waste than initially anticipated, and without impacting the commitments to the state of South Carolina. A TMP was developed to implement NGS in MCU to identify technical maturity level gaps that

required further evaluation, testing, or engineering in order to bring the technology to TRL-6. Activities identified in the TMP have been completed and the CTEs have advanced to TRL-6. During the initial startup of MCU utilizing the NGS blended solvent, MCU will undergo a period of deliberate operations in order to ensure the performance of the MCU system is evaluated for startup and operation utilizing the improved NGS.

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