Comparison of SRS Tank Closure Cesium Removal versus Hanford Tank Side Cesium Removal System – 21357

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ABSTRACT

Both the Savannah River Site and the Office of River Protection at the Hanford site will process millions of gallons of radioactive waste stored in underground tanks, and both sites are using pretreatment facilities for the removal of solids and cesium such that the resulting streams can be immobilized for on-site disposal as low activity waste. In addition to the planned baseline treatment facilities, Savannah River Site is using the Tank Closure Cesium Removal facility to supplement the Salt Waste Pretreatment Facility, and Hanford will use the Tank Side Cesium Removal facility until the Waste Treatment Plant Pretreatment facility comes on line. Both, Tank Closure Cesium Removal and Tank Side Cesium Removal are modular facilities which are similar in many respects. They use the same fundamental technology such as dead-end filtration of solids, ion exchange employing crystalline silicotitanate, and operate at the same nominal throughput of 5 gallons per minute; however, they are not identical designs. For example, the Hanford unit employs three columns in a lead-lag-polish carousel while the Savannah River Site unit employs four columns in series. The Department's strategy was not to have one design that might be applicable to both sites, instead have vendors bid on requirements and specifications needed at each site allowing vendors to create an appropriate design for specific site operation. The Tank Closure Cesium Removal unit was supplied by Columbia Energy & Environmental Services and the Tank Side Cesium Removal unit was supplied by AVANTech, LLC. A comparison is carried out in this study and some of the salient aspects are described in this paper.

INTRODUCTION

Approximately 344 ML (91 million gallons) of high activity mixed waste is currently stored in underground tanks at the United States Department of Energy's Savannah River Site and Hanford sites generated from our nation's defense program during the Manhattan Project and the Cold War [1]. The waste was created by the reprocessing of nuclear fuel where nuclear fuel was dissolved in solutions of sodium hydroxide (NaOH) and nitric acid (HNO_3). After recovering desirable constituents such as uranium and plutonium, NaOH and $NaNO_3$ were added to increase pH of the resulting liquid, called raffinate, in order to minimize carbon steel storage tank corrosion. These storage tanks contain a high concentration (> 5M Na+) of sodium nitrate ($NaNO_3$) in a mixture of sludge, saltcake and supernatant liquids. The insoluble sludge fraction of the waste consists of metal oxides and hydroxides and contains the bulk of many radionuclides such as the transuranic components, fissile material, and product isotope including cesium and strontium [2]. The saltcake, generated by evaporation of saturated aqueous solutions, consists primarily of crystallized sodium salts ($NaNO_3$, $Na_2(COO)_2$, etc.). The wastes from the tanks will be retrieved and processed in an environmentally safe manner for disposal in accordance with regulatory requirements for treatment and disposal.

The supernate, including dissolved saltcake, results in a waste stream that is much more voluminous and more easily treatable than the sludge.

To demonstrate the technical capability, both Savannah River and Hanford sites have deployed modular, mobile, and safe systems for treating supernate and dissolved saltcake. These systems are respectively known as the Tank Closure Cesium Removal (TCCR) and Tank Side Cesium Removal (TSCR) systems and have following commonalities:

Fig. 1. Delivery of Modular TSCR Enclosure

- Modular/ enclosure-based systems that were built and tested offsite prior to over-the-road transport (Fig. 1) and onsite installation (Fig. 2).
- Primary processes are dead-end filtration followed by cesium removal with a series of ion exchange columns loaded with an inorganic non-elutable adsorbent known as crystalline silicotitanate (CST).
- Spent ion exchange columns (IXC) are placed in an onsite interim safe storage facility.
- Remote operation from a nearby control facility.
- TCCR and TSCR are known as “pretreatment” systems because the low-level waste that they produce is sent to immobilization facilities for final processing.

DESCRIPTION

Goal of TCCR and TSCR

The goal of these modular treatment systems is to efficiently and safely produce low-activity waste that meets the waste acceptance criteria of downstream waste immobilization systems, which at Savannah River is the Salt Production Facility (SPF) and at Hanford is the Waste Treatment Plant LAW Vitrification Facility. Objectives associated with this goal are as follows:

- Demonstrate a cost-effective, simple, reliable at-tank treatment technology to filter solids and remove cesium from high-activity supernatant tank waste.
- Leverage commercial experience with the use of non-elutable CST ion exchange media from previous nuclear waste cleanup projects.
  - Incorporate previously utilized equipment designs to the maximum extent practicable.
  - Maximize fabrication, testing and operational preparedness at the vendor facility to minimize field work.

Fig. 2. TCCR Process Enclosure Assembly

- Reduction in cost and work scope as compared to previously proposed initiatives, such as the In-Tank Small Column Ion Exchange (SCIX) initiative at SRS and the spherical resorcinol formaldehyde based LAWPS at Hanford.

Although, both TCCR and TSCR have many common process features, their missions are not exactly the same. The TCCR operation supplements the Salt Waste Processing Facility (SWPF) at Savannah River, which is the primary means of waste pretreatment. With TCCR, the cesium is adsorbed on the IXC and treated low-activity waste effluent is sent to the SPF for immobilization in a cementitious grout. Meanwhile, TSCR is the primary means of high-activity liquid waste pretreatment at Hanford. TSCR is part of the Direct Feed Low Active Waste (DFLAW) initiative, which provides for early production of low-activity liquid waste that can be fed directly to the Waste Treatment Plant LAW Facility melter. Since work on the WTP Pretreatment Facility is paused [3], TSCR processing is the only current means of tank waste pretreatment at Hanford.

Feed Stream Characteristics

The feed streams to TCCR and TSCR are comprised of similar constituents. However, one major difference is the starting point of the waste feed. The single feed tank (10H) for TCCR, has been largely comprised of saltcake. Full dissolution of saltcake takes time and the liquid waste characteristics can vary during the dissolution operation, which causes instability in the waste stream. Conversely, the SWPF has dedicated tanks to blend and stage liquid waste to create a stable - well characterized waste stream that optimizes the caustic side solvent extraction (CSSX) process.

For TSCR, the planned AP-farm feed already exists in a liquid phase, so no salt dissolution is required. In addition, TSCR has a large staging/ blending tank (AP-105) that receives waste from various sources. The availability of large amounts of liquid and a designated staging tank is highly advantageous because it allows the feed stream to be attain chemical stability and be well characterized prior to treatment.

Operational Status

The TCCR has been operational since January 2019 [4]. Since the beginning, TCCR has processed just under 1,136,000 L (300,000 gal) of salt waste while reducing the starting waste level in Tank 10H by approximately 38 cm (15 in) [5, 6].

Over the course of the Tank 10H retrieval and treatment campaign large volumes of water and NaOH were added. Work is currently underway at Savannah River for a second TCCR campaign. This second campaign will transfer dissolved salt solution from Tank 9H to Tank 10H, for subsequent treatment through optimized filters and IXCs loaded with CST formed into a smaller bead size, in an effort to improve the dynamic capacity (kinetics) of the ion exchange process. [7, 8] The optimized TCCR used for treatment of waste originating from tank 9H will be referred to as Tank Closure Cesium Removal 1A (TCCR 1A) [4] to distinguish it from the originally configured TCCR used for treatment of Tank 10H wastes.

The contracts for TSCR design, manufacturing, testing and delivery were awarded in July 2018; TCCR preceded TSCR by almost 2 years. [9, 10] The TSCR final design was completed in 2019 and the factory acceptance test (FAT) was completed in March 2020.

During the FAT, the TSCR system underwent testing on all facets of operation including Hanford's 5.6M nominal sodium simulant run containing over 200 ppm of fine undissolved solids (UDS). [11] After completing the FAT, tank farm operators were trained on the operation of TSCR and tank farm craft-workers were trained on TSCR filter & IXC replacement.

Currently, the TSCR system is onsite and work is underway to complete onsite installation and acceptance testing. The TSCR baseline scheduled to commence tank waste treatment operations is July 2022.

Modular Technology Benefits

The modular technology for both TCCR and TSCR came about from experiences at SRS with the Small Column Ion Exchange initiative and recovery efforts at Fukushima. Work performed by the DOE to develop CST [13] and underpin the Small Column Ion Exchange initiative was applied at Fukushima and formed the basis for the Simplified Active Water Retrieval and Recovery (SARRY) system, which has treated a majority of the liquid waste resulting from the 2011 Fukushima accident. [14]

Modularity has renewed momentum because it offers major cost savings, optimized schedules, decreases onsite worker risks, occupies a smaller footprint, provides flexibility to disposition design alternatives that arise during final design & fabrication and supports effective Deactivation and Decommissioning (D&D) at end of mission. Flexibility is especially important with regards to new design configurations, wherein design changes are often made after the final design is approved. The modular approach affords many benefits as described below:

1. Systems are sized so that major components can be placed inside a modular enclosure that can be transported by highway.

2. Compact arrangement facilitates placement of the treatment systems very near the waste source and multiple units if needed.

3. Supports the ready-made approach. Enclosures with process equipment and controls are fully assembled and thoroughly tested under simulated conditions offsite, then transported onsite where they are placed on a pad and connected to interfacing structures and systems.

4. Modular IXCs can accommodate multiple types of ion exchange media and adsorbents to selectively remove other contaminants of interest such as strontium, technetium and iodine.

TCCR/TSCR PHYSICAL COMPARISONS

TCCR and TSCR are quite similar as each are comprised of 3 enclosures or skids. Both have a Process Enclosure with all the waste wetted components and a Control Enclosure. They differ in the third skid/ enclosure, TCCR has a ventilation skid and TSCR has an Ancillary Enclosure. Each of the TSCR enclosures are complete with HVAC systems. TCCR and TSCR are designed to treat waste at a nominal 5 gpm; this flow rate balances size, limited life cycle, cost and schedule. [15, 16] A comparison of various system features is provided in Table I.

TABLE I. System Feature Comparison

Enclosure/ Skid Description	TCCR	TSCR
Process Enclosure	Footprint: ~3 m (10’) W × ~12 m (40’) L	Footprint: ~3.6 m (11’-11”) W × ~12.8 m (42’) L
Pre-Filtration	Duplex filters	Duplex filters
Ion Exchange	4 IXCs in series	3 IXCs in series with lead-lag-polish carousel

Enclosure/ Skid Description	TCCR	TSCR
Post-Filtration	Media trap	Media trap
Ba-137m Decay	No short-lived isotope decay capability	Delay tank with 1-hour residence time
Control Enclosure	Footprint: ~2.6 m (8'-6") W × ~6.1 m (20') L Human machine interface (HMI), Process Enclosure video monitors	Footprint: ~2.7 m (9') W × ~4 m (13') L Human machine interface (HMI) and Process Enclosure video monitors. Interfaces with Tank Farm Monitoring and Control System central control room.
Ventilation Skid	Prefilter, Heater, HEPA filter, blower, sampling ports.	No Ventilation Skid. Same components as TCCR are built into the Process Enclosure.
Water	Well water and domestic water are provided from SRS utilities.	Potable water is pumped from tanker into the Ancillary Enclosure Reagent Water Tank and then purified by filtration and ion exchange equipment.
Sodium Hydroxide	Externally connect with concentrated NaOH (via chemical totes) with water for filling, flushing and rinsing.	Reagents, pumps and tanks in the Ancillary Enclosure are used to create 0.1 M NaOH for filling, flushing and rinsing.
Air	Compressed air is provided from SRS utilities	Service and instrument air are provided from compressor, dryer and receivers in the Ancillary Enclosure.
Fire Suppression	No fire suppression system.	Pressurized water mist system

Process Enclosure Access

The Process Enclosures for TCCR and TSCR both have an airlock and "process space" where the waste-wetted components are located, and personnel normally access the Process Enclosure through the airlock entry door. The Process Enclosures differ in the way that filtration and ion exchange components are accessed for maintenance/ replacement: TCCR has hatches on the roof of the enclosure for access by crane while TSCR has hinged doors on the side of the enclosure for access by a forklift. (Fig. 3a/3b) Other details are delineated below in Table II:

TABLE II. System Access Comparison

Component	TCCR	TSCR
Doors/ Hatches	1 man-door 4 hatches over the IXCs Separate hatch for prefilter access	1 man-door. 2 hinged side doors for filter access 3 hinged side double-doors for IXC access and accessing ventilation and HVAC components.

<table>
<tr><th>Component</th><th>TCCR</th><th>TSCR</th></tr>
<tr><td>Filter Replacement</td><td>The filters have a shielded one-piece filter “module” that is connected to the process piping with flanged hoses.</td><td rowspan="2">The shielded filter modules and ion exchange columns are removed through hinged side doors and replaced using a forklift. The forklift is compatible with both the filters and ion exchange columns.</td></tr>
<tr><td>Ion Exchange replacement</td><td>The IXC column is lifted through the roof hatch of process enclosure with a crane for replacement.</td></tr>
</table>

Fig. 3a. TCCR IXC Installation

Fig. 3b. TSCR IXC Installation

Filtration

The TCCR and TSCR filtration systems are somewhat similar. They share the following features:

- Duplex arranged wherein one filter is online and the other is in backwash or standby.
- Dead-end filtration with backwash capability.

Table III delineates some of the filtration differences:

TABLE III. Filter Comparison

Feature	TCCR	TSCR
DP setpoint for backwash	24.1 kPa (3.5 psid), design/ 34.5 (5.0 psid), actual, adjusted remotely	13.8 kPa (2.0 psid) or 24 hours of operation
Source of backwash	Filtrate from the online filter flows backwards through offline filter. *Note: Flow through the IXCs is stopped during a backwash*	Compressed air accumulator is used to force stored filtrate and 0.1 M NaOH backwards through the filter. *Note: Enables continuous operation without disrupting flow to the IXCs*

Feature	TCCR	TSCR
Backwash receiver	Backwash is returned to the feed tank (10H). *Note that undissolved solids (UDS) concentrations increase over the treatment campaign*	Backwash is returned to AP-108 (TSCR Drain Tank). *Note that undissolved solids (UDS) concentrations remains constant over the treatment campaign*
Shielding configuration	Filter housings are located inside a shield assembly. (Fig. 4a)	Filter housing and integral shielding create a filtration module. (Fig. 4b)

Fig. 4a. TCCR Filter Housings & Shield Assembly

Fig. 4b. TSCR Filter Modules

Ion Exchange Columns

The TCCR and TSCR ion exchange columns have a relatively similar geometry – being tall and narrow with a high length to diameter ratio. This geometry aids in dissipating the decay heat associated with high Cs-137 loading. Both columns have top entry nozzles with down flow operation from top to bottom. The main differences are associated with shielding and the method of heat dissipation (i.e. cooling). As shown in Fig. 5, the TCCR IXC fits inside a two-piece shield container assembly and uses a water jacket for heat dissipation. The TSCR IXC, known as the IXC-150, has integral shielding (creating a one-piece module) and an open center core that reduces the center-line temperature and dissipates decay heat by convection.

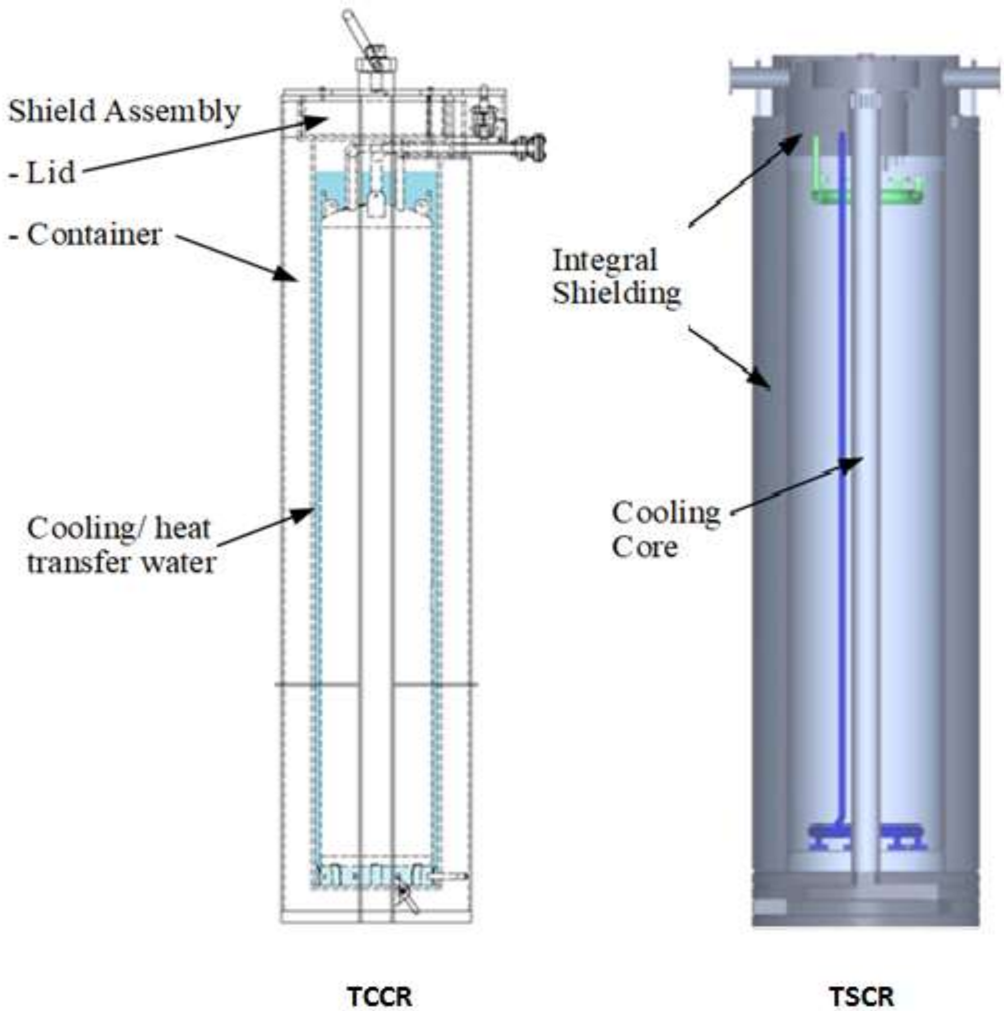

Fig. 5. Ion Exchange Column Section View

Additional metrics for the TCCR and TSCR IXCs are provided in Table IV:

TABLE IV. Ion Exchange Column Comparison

IXC Feature	TCCR	TSCR
Cross Sectional Area	1,687 cm^2 (261.5 in^2), TCCR 1A	2,578 cm^2 (399.6 in^2), IXC-150
IXC Media Bed Volume	452.4 L (119.5 gal)	596.2 L (157.5 gal)
Cesium-137 Capacity	175,000 Ci – 211,000 Ci	141,600 Ci
Weight, operating (w/ media, water & shielding)	16,363.6 kg (36,000 lbs.)	12,181.8 kg (26,800 lbs.)
Pressure Rating	1,655 kPa (240 psig)	2758 kPa (400 psig)
Maximized Analyzed Lift Height	NA	91.5 cm (36 inches)

Ion Exchange Storage Pad (Interim Safe Storage)

Spent ion exchange columns need to be replaced periodically. The spent ion exchange media is flushed with dilute NaOH (~ 0.1 M) and water, and then dried to remove any free-standing liquid. Spent IXCs are then disconnected from the process piping and removed from the process enclosure. A crane and transporter are used for moving the IXCs at Savannah River while a forklift is used for all IXC handling and movement at Hanford. The IXC storage pad at Savannah River originally held 4 IXCs, but it is being increased to 20 IXCs in support of the TCCR 1A initiative for Tank 9H. The TSCR storage pad is designed for 150 IXCs.

As shown in Fig. 6, Savannah River uses an upright post design to form a frame to ensure the IXCs don't topple over due to high winds or a seismic event. (Fig. 6a) IXCs will be lifted from the transporter with a crane and lowered into the steel support frame. This is similar to the SARRY storage frames at Fukushima. The IXC-150s at Hanford lock into an anchor base for long term storage. The anchor base is similar in design to those used for the High-Performance Advance Liquid Processing System and Subdrain IXCs at Fukushima. The anchor bases are installed one row at a time as IXCs are generated, which provides the forklift free and open access to each anchor base for placement of the IXC-150s. The low profile of the base enables workers to maintain the IXC-150s close to the ground, which minimizes the impacts of a dropped IXC scenario. (Fig. 6b)

Fig. 6a. TCCR Interim Safe Storage

Fig. 6b. TSCR IXC Anchor Base

Crystalline Silicotitanate (CST) Preparation and Loading

A lesson learned from the TCCR demonstration setup/startup is that CST can be subjected to abrasion during transport from the manufacturer and is inclined to be delivered with fines that must be removed prior to use. [17] Lessons learned will be applied to TCCR 1A (processing Tank 9 material) and TSCR. The design geometry of the TCCR IXC does not support upright transportation; therefore, additional IXCs needed to support processing of Tank 9H salt solution will be loaded with CST and pretreated in H-Tank Farm in a staging area next to TCCR. A vacuum pump assembly will load CST resin into the IXC. The IXCs will then be pretreated with a water backflush to level the CST bed and remove CST fines, which will be filtered and discarded.

If necessary, a sodium hydroxide wash of the CST will be completed prior to placing the IXCs into operation. With the IXC remaining in a vertical position, a crane will place the CST-loaded IXC into the TCCR Process Enclosure as shown in Fig. 3a.

CST for TSCR is prepared for use at a nearby facility in Richland, WA. All operations are performed with a 0.1M NaOH solution.

Fig. 7. Crystalline Silicotitanate Media

The media is first soaked to degas the pores, then backwashed in specially designed preparation tank, transferred into the IXC-150s, then rinsed with 0.1M NaOH to a turbidity endpoint. The IXC-150s are then loaded on a purpose-built transporter and delivered to the Hanford site, where no further media treatment is required.

Fig. 8. TSCR Ion Exchange Column Transporter

SITE REGULATORY DIFFERENCES

The DOE is following similar approaches with its regulatory outreach and approval for both TCCR (South Carolina) and TSCR (Washington). The formal processes for evaluation, determination, and execution of tank waste removal, disposal, and operational activities fully involves State Agency approval (both the Washington State Department of Ecology and Washington State Department of Health for TSCR, and the South Carolina Department of Health and Environmental Control for TCCR), the respective Environmental Protection Agency office for each region, and the Nuclear Regulatory Commission for its required 3116 regulatory role in South Carolina or the recommended regulatory consultation in Washington State under DOE O 435.1.

Hanford TSCR

From a permitting perspective, TSCR is included within the Low-Activity Waste Pretreatment System (LAWPS) Project.

The LAWPS facilities, including TSCR, will be considered a new treatment, storage, or disposal (TSD) unit (aka Operating Unit Group) and is required to be permitted in accordance with WAG 173-303-803. Permitted systems consists of mixed waste tank storage, treatment components and associated ancillary equipment subject to the standards of WAG 173-303-640, and mixed waste container storage areas for spent IXCs subject to the standards of WAG 173-303-630.

Hanford has applied for a modification to the RCRA permit for Treatment, Storage, and Disposal of Dangerous Waste, Part III, Operating Unit Group 1 (WA7890008967), Low-Activity Waste Pretreatment System (LAWPS). The application follows the Class 3 modification process in WAC 173-303-830(4)(c), which governs the addition of an Operating Unit Group to the Hanford Site-Wide permit.

Work on TSCR installation, connection and related construction activities is currently being performed under Temporary Authorization approval from Washington State Ecology (Ecology). When installation and construction activities are completed, then Ecology will perform reviews and inspections to ensure construction was completed in accordance with the permit. The final LAWPS OUG 1 permit will replace this Temporary Authorization approval and be incorporated in the Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage and Disposal of Dangerous Waste, WA7890008967 (Site-Wide Permit). [18]

Savannah River TCCR

Under the South Carolina Pollution Control Act, S.C. Code Ann. §§ 48-1-10 *et seq*., SCDHEC is the delegated authority for air pollution control and water pollution control. The State has empowered SCDHEC to adopt standards for protection of water and air quality, and to issue permits for pollutant discharges. Further, SCDHEC is authorized to administer both the federal Clean Water Act and the Clean Air Act. Under South Carolina's Hazardous Waste Management Act, S.C. Code Ann. §§ 44-56-10 *et seq*., SCDHEC is granted the authority to manage hazardous wastes. With minor modifications, SCDHEC has promulgated the federal Resource Conservation and Recovery Act (RCRA) requirements, including essentially the same numbering system. The South Carolina Solid Waste Policy and Management Act, S.C. Code Ann. §§ 44-96-10 *et seq*., provides standards for the management of most solid wastes in the state.

Federal Facility Agreement (FFA)

Both Sites have respective Federal Facility Agreements with corresponding cleanup milestones for tank retrieval, closure, and tank waste treatment. The State of Washington also has a Court ordered Consent Decree requiring specific tank retrieval and tank waste treatment milestones.

National Environmental Policy Act

Both Savannah River and the Hanford Site have respective National Environmental Policy Act requirements for federal agencies to assess the potential environmental impacts of proposed actions.

National Defense Authorization Act

The State of South Carolina has chosen to be regulated under the *Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005,* Section 3116 allows determinations by the Secretary of Energy, in consultation with the NRC, that specific radioactive waste from reprocessing is non high-level waste and may be disposed of in South Carolina pursuant to a State-approved closure plan or a State-issued permit.

For salt waste, the DOE contemplates removing targeted fission products and actinides using a variety of technologies and combining the removed fission products and actinides with the metals being vitrified in DWPF. NDAA governs solidifying the remaining low-activity salt stream into saltstone for disposal in the SDF.

The State of Washington at this time has chosen not to be regulated under Section 3116 of the NDAA, and radioactive waste classification and management is done under the DOE O 435.1.

PROJECT MANAGEMENT (FOR COST AND SCHEDULE)

The TCCR is a demonstration project as determined by SRS Manual. S23, Procedure 1.1. Based on DOE protocol and cost, the TCCR Engineering, Procurement and Construction (EPC) activities are determined to be a Non-Routine, Lower Risk, and Projectized Operations Activity (POA). DOE Order 413.3B does not apply to POAs, however the tailored principles of the Order were utilized to manage TCCR EPC activities to provide structure, control, and visibility of cost, schedule and scope performance to meet contract requirements and DOE expectations.

The TSCR Demonstration Project is considered a capital project and managed in a phased manner to correspond with the startup of the Waste Treatment and Immobilization Plant (WTP), Low-Activity Waste (LAW) Facility as recommended by RPP RPT 60405 and follow DOE Order DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*.

TABLE V. Cost Comparison

Parameter	TCCR	TSCR
System Vendor Costs	$10.2M	<$10M
Schedule Baseline	February 15, 2018	2021-2022

CONCLUSION

The comparison of TCCR and TSCR will be presented during the 2021 Waste management Symposia.

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