Tank Side Cesium Removal System Project and Technology Testing Activities – 22048

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ABSTRACT

Washington River Protection Solutions (WRPS) is the Tank Operating Contractor (TOC) for the U.S. Department of Energy-Office of River Protection (DOE-ORP) on the Hanford Site. The Hanford Site stores an estimated 56 million gallons of mixed radioactive and chemically hazardous waste in large underground tanks. WRPS has contracted with AVANTech to design and fabricate the Tank Side Cesium Removal (TSCR) system to produce a Low Activity Waste (LAW) feed from Hanford tank waste. The LAW will be transferred to the Waste Treatment and Immobilization Plant (WTP) LAW Vitrification Facility, where the hazardous constituents in the LAW will be immobilized in a durable glass waste form for disposal.

The TSCR Project demonstrates a tank-side treatment system for providing feed to the WTP LAW Vitrification Facility. The TSCR system is a modular design that removes undissolved solids and Cesium (Cs) from tank waste supernate prior to feeding it directly from Tank Farms to the WTP LAW Facility. The TSCR system will be deployed as a two-phased demonstration project. The first phase will monitor system performance and demonstrate the ability to safely operate and maintain the TSCR system in support of feed production for WTP hot commissioning and early operations. The second phase will demonstrate the ability to reliably and efficiently treat tank waste for an extended operating period. TSCR has utilized the experience of commercial equipment suppliers to design and build a treatment system, thus providing a lower cost quick-to-deployment process. The two key technologies utilized by the system are filtration to remove undissolved solids and ion exchange to remove Cs.

Technology testing has been performed to support successful deployment of the TSCR system. Recent testing activities include maximum ion exchange media loading, high solids filtration and ion exchange, and flammable gas detonation evaluations. In addition to the recent technology testing efforts that were completed, the project is nearing the final stages of deployment in the field. The project progress and current technology testing activities are presented.

INTRODUCTION

Radioactive and chemical wastes from nuclear weapon production are stored in underground tanks at the Hanford Site, located in the state of Washington. The waste tanks contain a complex and diverse mix of radioactive and chemical waste in the form of sludge, salts, and liquids, necessitating a variety of unique waste retrieval, treatment, and disposition methods.

In order to begin immobilization of tank waste as soon as practicable, the Department of Energy (DOE) is focusing on Direct Feed Low Activity Waste (DFLAW).

In this approach, the areas of the Waste Treatment and Immobilization Plant (WTP) which are ready to begin operations will be brought online ahead of full plant operations. This includes the Low-Activity Waste (LAW) Facility, the Analytical Laboratory and the Balance of Facilities support facilities. DFLAW allows treatment of the LAW portion of tank waste to begin. Part of WRPS' responsibility in support of DFLAW is to provide a qualified LAW feed for the Low-Activity Waste Facility, by separating the High Level Waste (HLW) and Low Activity Waste (LAW) fractions of tank waste.

The Tank Side Cesium Removal (TSCR) system has been developed to provide the feed for the LAW Facility. TSCR is a modular system that removes undissolved solids and Cesium (Cs) from tank waste supernate prior to feeding it directly from Tank Farms to the WTP LAW Facility. The TSCR system will be deployed as a two-phased demonstration project. The first phase will monitor system performance and demonstrate the ability to safely operate and maintain the TSCR system in support of feed production for WTP hot commissioning and early operations. The second phase will demonstrate the ability to reliably and efficiently treat tank waste for an extended operating period. TSCR has utilized the experience of commercial equipment suppliers to design and build a treatment system, thus providing a lower cost quick-to-deployment process. The TSCR system is located adjacent to the AP Tank Farm facility. A facility diagram is shown in Fig. 1.

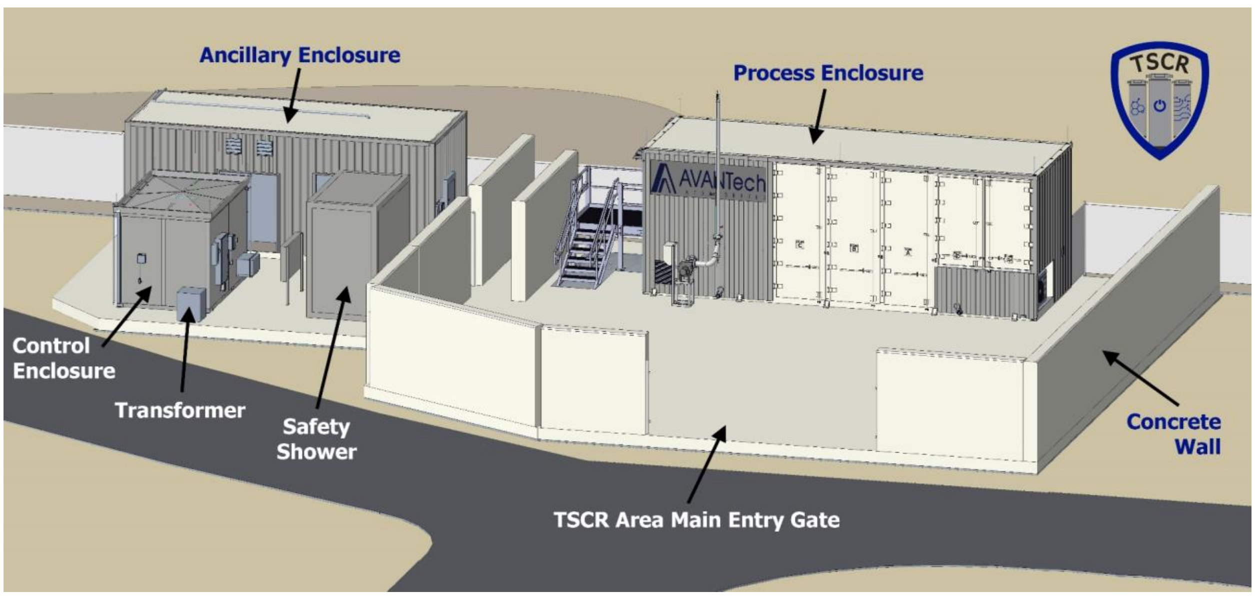

Fig. 1. TSCR Facility Diagram

TECHNOLOGY TESTING TAILORING APPROACH

In accordance with DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, the technologies utilized in the TSCR system need to be at a Technology Readiness Level (TRL) of seven (7) prior to approval of critical decision two (CD-2) [1]. The TSCR project achieved CD-2 with confirmation of TRL-7 in March 2020 [2]. The key aspect of TRL-7 is operation of the technology in a full-scale, similar system demonstrated in a relevant environment [3, 4]. TSCR is a technology demonstration project where a tailored approach to technology should be utilized. The key component of the tailoring approach utilized includes a review of applications where the technologies utilized by TSCR have previously been deployed thus helping to establish the TRL. Additionally, the planned processing parameters were evaluated through testing.

The following sections describe the key TSCR technologies, previous deployments, and test efforts performed to reduce risk and help ensure a successful demonstration.

KEY TSCR TECHNOLOGIES

The TSCR system utilizes commercially available components and technologies. The two key process technologies are filtration and IX. The primary purpose of the filtration is to remove solids and help prevent plugging of the IX columns. Filtration is performed using a 316 stainless steel (SS) Mott Media Grade 5 material in the dead-end filtration (DEF) configuration. The assembly consists of 98 filter tubes and approximately 77 ft^2 (7.2 m^2) of surface area per filter. There are two filter assemblies in the TSCR system which allows for backwashing of one filter while continued waste processing operation occurs in the other. These filters are configured in in a modular form such that they can be readily changed. A diagram of the filter configuration is shown in Fig. 2. The IX system removes Cs from the waste stream to meet the waste acceptance criteria of the WTP. The IX process utilizes the Crystalline Silicotitanate (CST) IX media produced by UOP Honeywell under the product name IONSIV R9140-B in a lead-lag-polish column configuration. Approximately 157 gal. (594 L) of CST IX media is contained within each column. Each IX column is self-shielded such that after the column has been loaded with sufficient Cs it can be removed and relocated to a spent IX column storage pad. A diagram of the IX column configuration is shown in Fig. 3.

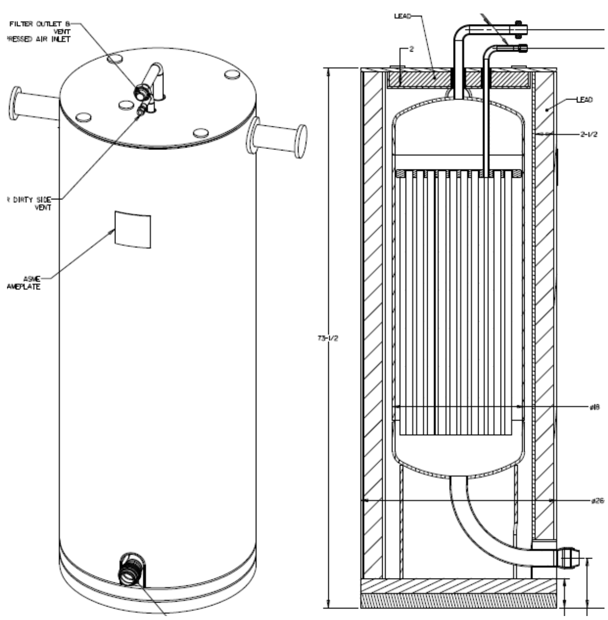

Fig. 2. General Filter Configuration

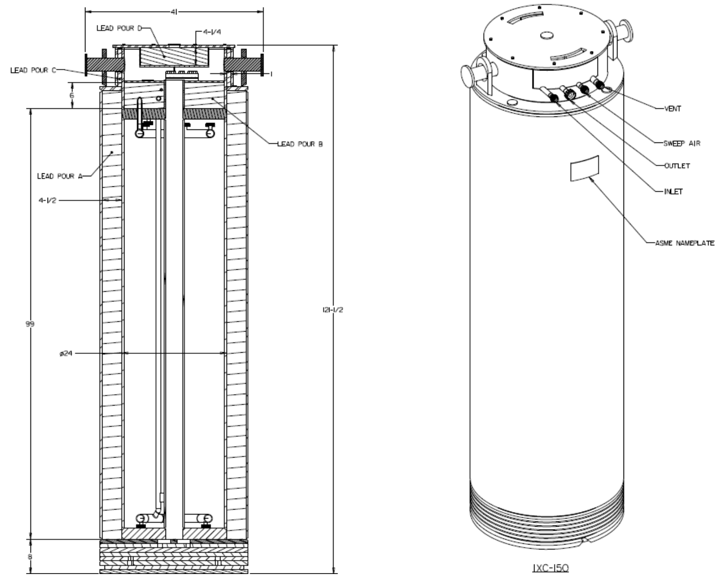

Fig. 3. General Ion Exchange Column Configuration

PREVIOUS TECHNOLOGY DEPLOYMENTS

As described previously, a key part of the tailored approach of establishing the TRL level included a review of applications where the technologies utilized by TSCR have previously been deployed. Both DEF and IX are considered commercially mature technologies and have been used in varied environments.

A recent application of DEF in a relevant environment was found in the DOE Savannah River Site (SRS) accelerated tank closure initiative. The Tank Closure Cesium Removal (TCCR) project has successfully operated to treat waste from Tank 10H preparing it for immobilization. TCCR has successfully treated over 200,000 gallons of tank waste [6, 7]. The TCCR filter successfully performed its function of protecting the IX columns during operation. The operation of the TCCR system represented a full-scale deployment of DEF in a relevant waste stream.

For IX a significant amount of research has previously been performed on CST. This media was initially deployed using real waste at Oak Ridge National Laboratory (ORNL) on the Melton Valley Storage Tank (MVST) mixed low-level waste to remove Cs for waste immobilization and disposal [5]. Additionally, CST has also been deployed for cleanup of contaminated sea water at the Fukushima Daiichi Power Plant in Japan as part of the Simplified Active water Retrieval and Recovery system. However, the most recent and relevant deployment of CST has been the TCCR project at SRS. As described earlier CST has been used to remove Cs from over 200,000 gallons of tank waste from Tank 10H [6, 7]. The use of CST in the TCCR system represented a full-scale deployment with a relevant waste stream.

TSCR TESTING PROGRAM

In addition to the previous deployment evaluation, testing was planned and performed to provide confirmation of TSCR process parameters and address specific waste conditions that were be anticipated.

Testing with simulant was performed to aid in the selection of the filter media used in DEF for TSCR and real waste filtration testing was performed to address potential differences as compared to previous deployments. IX with CST testing was performed with both simulant and real waste to confirm prototypic processing conditions. Additionally, hydrogen gas generation and media drying rates were evaluated to support project needs. The following sections describe the filtration, IX and confirmation test efforts conducted.

Filtration Evaluation

In support of DEF filter media selection for use in the TSCR system simulant testing was performed to evaluate three media types: 1) Pall pleated polypropylene, 2) Mott Media Grade 5 SS, and 3) Pall SS metal mesh filter. This test effort was conducted in two phases. The first phase performed a comparison of the three-filter media for solids loading and backwash recovery. The second phase addressed extended performance including repeated loading and backwash cycles [8]. The results of this effort demonstrated the Mott Media Grade 5 material performed better in both solids loading and recovery during backwash.

To further evaluate the Mott grade 5 filter media, real waste testing was performed using prototypic processing conditions utilizing multiple waste feeds and high solids loading simulant testing under off normal conditions.

Real waste testing was performed utilizing tank samples from AP-107 (TSCR Phase 1 feed), AP-105 and AW-102 [9, 10, 11, 12]. Prototypic filter flux rates were used during the testing. This real waste testing establishes a performance comparison that can be used to benchmark the simulant results. The test results for majority of the sampling events indicated no filter fouling and no solids were visibly present upon backwashing. One test utilizing AP-107 taken from a lower position in the tank demonstrated fouling that required more frequent backwashing [12]. Further evaluation of the solids provided insight that temperature effects may be the primary driver for the solid's formation.

Simulant testing with high solids content was also performed to evaluate the systems response to an off normal feed [13]. Although the system is not required to make through put under a high solids (off normal) conditions, this test effort provided insight into the response to different solids feed concentrations, varying filter differential pressure options and other information to support operational response to off normal feeds.

The results of the media selection, multiple real waste tests and off normal high solids evaluation provide confidence that the filtration system for the TSCR technology demonstration can be successful performed.

IX Media Evaluation

Column testing with simulants was performed to establish the expected loading and breakthrough profile. To support this, a full height column assembly was utilized to ensure prototypic flow velocities and residence time were matched to the planned TSCR process conditions. This test effort also addressed the anticipated impact of changing flow velocities, sodium levels, temperature, and the addition of organics [14]. One of the assemblies used in the testing is shown in Fig. 4.

Fig. 4. Tall Column IX Assembly

Other constituents in Hanford waste can compete with Cs resulting in impacts to loading on the CST. The use of Hanford related simulants and a range of temperatures was needed to aid in modeling future waste batches and column use predictions. Constituents including sodium, potassium, free hydroxide, nitrite, carbonate, sulfate, phosphate, and temperature were evaluated for their impact on Cs loading. The results from this test effort found that under conditions likely to be encountered during the operation of TSCR sodium, potassium, carbonate, and free hydroxide were the most influential variables [15].

Real waste testing was performed under prototypic residence time processing conditions. Waste samples from AP-107 (TSCR Phase 1 feed), AP-105 and AW-102 were utilized [9, 16, 17]. The real waste establishes a performance comparison that can be used to benchmark or qualify the simulant results.

Test results from the above efforts indicate that the planned processing conditions for TSCR are expected to meet the goals of the demonstration. Additionally, the results indicate good agreement between the real waste and simulant test efforts.

IX Media Drying Evaluation

Prior to moving a used IX column loaded with Cs to a storage pad the contents must meet a no free liquids criteria. Process confirmation was needed to identify the length of time that would be required for drying to meet the criteria. The initial planning estimate was 4 days of drying. Test efforts confirmed that the base design approach of 4 days was more than sufficient to dry the media and in addition, determined that the storage criteria could be met after 1 day of drying [18]. This results in a potential reduction in down time by three days thereby increasing operating efficiency.

IX Media Gas Generation Evaluation

Confirmation was needed to understand the gas generation rates, due to radiolysis, for the different temporary or long-term storage conditions of the CST. Gas generation tests were performed with CST under the following conditions [19].

- Dry CST – Long term storage type condition
- Wet CST – Initial dewatering prior to drying type condition
- CST in water – Water filled column condition (generally bounding)
- CST in simulant with organics – Evaluation of organic impact
- CST in simulant at elevated temperature – Evaluation of temperature impacts

A test assembly was configured that uses simulants and CST with a radiation source while monitoring for gas volume and chemical composition. This testing allowed for determination of the gas generation rate and composition expected to be evolved for the specific condition with CST present. The shielded assembly used for the irradiation of the samples is shown in Fig. 5. Test results indicated that the gas generation rates were within the design basis.

Fig. 5. Gas Generation Shielded Assembly

Vent Stack Assembly Detonation Evaluation

In addition to test efforts addressing Hanford specific process conditions, a unique test effort was performed to confirm analytical results related to flammable gas. This activity involved demonstrating the response of the IXC ventilation filter assembly to actual flammable gas detonation. A representative diagram of the IXC ventilation filter assembly is shown in Fig. 6. As noted previously CST that has been loaded with radioactive Cs produces hydrogen and other gases due to radiolysis. The gases produced are diffused through the ventilation filter assemblies attached to the used IXC. Detonation testing was conducted using a stoichiometric mixture of hydrogen and nitrous oxide which was flowed through a vent assembly and ignited [20]. This testing confirmed the ventilation assembly maintains structural integrity during a detonation and established the resulting over pressure values. A representative photo of the ventilation filter assembly utilized in testing is shown in Fig. 6.

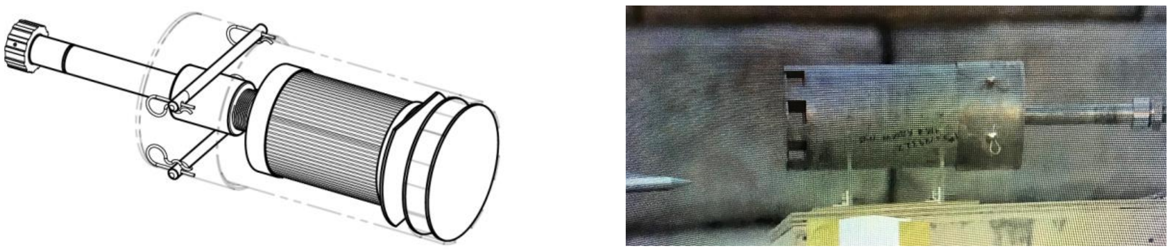

Fig. 6. IXC Ventilation Filter Assembly

CONCLUSION

WRPS utilized a tailored evaluation approach for the key technologies used in the TSCR system. The key component of the tailoring approach included a review of applications where the technologies utilized by TSCR have previously been deployed thus helping to establish the TRL. Both DEF and CST were considered commercially available technologies and were found to have been utilized in relevant environments at full scale in hot operations. In addition to previous deployments, Hanford specific testing was completed to confirm the TSCR process parameters with both simulants and real waste. Test results indicated that the planned processing conditions for TSCR can be expected to meet the goals of the demonstration and in some cases, opportunities for additional operational efficiency were found.

The combination of the DEF and CST full scale deployments in a relevant environment and the confirmation test efforts associated with the process parameters provided the risk reduction necessary to help ensure a successful technology demonstration at the Hanford site.

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