Preliminary Documented Safety Analysis Assessment at the Hanford Site Tank Farms Tank Side Cesium Removal Project

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Office of Enterprise Assessments
U.S. Department of Energy

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Acronyms

CW	Co-located Worker
DBA	Design Basis Accident
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
EA	Office of Enterprise Assessments
FRED	Functions and Requirements Evaluation Document
IRED	Instrument Requirements Evaluation Document
IXC	Ion-Exchange Column
LCO	Limiting Condition for Operation
MAR	Material at Risk
MOI	Maximally Exposed Offsite Individual
NPH	Natural Phenomena Hazards
ORP	Office of River Protection
PDSA	Preliminary Documented Safety Analysis
PrHA	Process Hazard Analysis
SAC	Specific Administrative Control
SBRT	Safety Basis Review Team
SER	Safety Evaluation Report
SSCs	Structures, Systems, and Components
TSCR	Tank Side Cesium Removal
TSR	Technical Safety Requirement
WRPS	Washington River Protection Solutions

Preliminary Documented Safety Analysis Assessment at the Hanford Site Tank Farms Tank Side Cesium Removal Project July 2019 through January 2020

Summary

Scope
This assessment evaluated the preliminary documented safety analysis (PDSA) and safety evaluation report for the Tank Side Cesium Removal (TSCR) Project at the Hanford Site tank farms. The TSCR Project will provide the tank farms with a temporary ion-exchange process to separate approximately 15 million curies of cesium-137 from tank waste and store the spent ion-exchange columns above ground for up to the 50-year design life of the storage pad.

Significant Results for Key Areas of Interest
The TSCR PDSA complies with DOE-STD-1189-2008, *Integration of Safety into the Design Process,* and the safety evaluation report complies with DOE-STD-1104-2016, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents*.

Preliminary Documented Safety Analysis

- The hazard evaluation includes an appropriately detailed, conservative process hazard analysis and provides a sound basis for control selection and functional classification.
- The selection of hazard controls follows the DOE-STD-1189-2008 preferred control hierarchy and provides adequate protection for workers and the public.
- The functional classification of safety structures, systems and components is appropriate, and the safety functions, functional requirements, and performance criteria are adequate.
- The specific administrative control evaluations demonstrate that safety functions will be met.
- The descriptions of operating modes, limiting conditions for operation, and design features are adequate to support future derivation of technical safety requirements.

Federal Review and Approval

The safety evaluation report meets the requirements of DOE-STD-1104-2016, adequately documents the basis for approving the PDSA, and appropriately concludes that there is reasonable assurance the health and safety of the public, workers, and environment will not be adversely affected by TSCR operations.

Best Practices and Findings

The assessment team identified a best practice implemented by Washington River Protection Solutions (WRPS). Using an integrated project team, WRPS develops documents to support safety basis system evaluation of safety significant equipment. These documents also support design, procurement, commercial grade dedication, startup, and operations by specifying key design attributes and critical characteristics through systematic and comprehensive failure analysis.

There were no findings or deficiencies identified in this assessment.

Follow-up Actions
EA will review the Hanford Tank Farms documented safety analysis addendum authorizing TSCR operations.

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Tank Side Cesium Removal Project

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Office of Nuclear Safety and Environmental Assessments, within the independent Office of Enterprise Assessments (EA), conducted an assessment of the preliminary documented safety analysis (PDSA) and safety evaluation report (SER) for the Tank Side Cesium Removal (TSCR) Project at the Hanford Site tank farms. This assessment, conducted from July through December 2019, is part of ongoing targeted assessments of new DOE nuclear facility projects focusing on the adequacy of the safety design basis documents.

This assessment was conducted in accordance with the *Plan for the Office of Enterprise Assessments Targeted Review of the Hanford Site Low Activity Waste Pretreatment System Preliminary Safety Basis.* The scope of this assessment encompassed review of the hazard and accident analyses, including hazard controls, design basis accidents (DBAs), and beyond design basis accidents; safety structures, systems, and components (SSCs) and specific administrative controls (SACs); and the preliminary derivation of technical safety requirements (TSRs).

Washington River Protection Solutions (WRPS) manages the tank farms under the direction and oversight of the DOE Office of River Protection (ORP). The TSCR Project is a capital asset project for the tank farms, the purpose of which is to provide the capability to remove undissolved solids and cesium from tank waste. The treated waste will be fed into the Hanford Waste Treatment and Immobilization Plant Low-Activity Waste facility for vitrification. Completion of TSCR construction and commissioning in 2021 is essential for the Low-Activity Waste facility to begin vitrifying low-activity waste in 2023. The TSCR process involves pumping low-activity liquid waste (supernate) from Tank 241-AP-106 to the TSCR process enclosure; waste filtering; cesium removal via ion-exchange columns (IXCs); and delivery of the treated supernate to Tank 241-AP-107. Up to 160 spent IXCs, each with a maximum loading of 141,600 curies of cesium-137 (the radioactive isotope of concern), could be stored on the spent IXC storage pad for up to the 50-year design life of the storage pad. AVANTech, Inc. is the design agent under contract to WRPS for the TSCR design and process equipment fabrication.

2.0 METHODOLOGY

The DOE independent oversight program is described in and governed by DOE Order 227.1A, *Independent Oversight Program*, which is implemented through a comprehensive set of internal protocols, operating practices, assessment guides, and process guides. This report uses the terms "best practices, deficiencies, findings, and opportunities for improvement" as defined in the order.

As identified in the approved plan, this assessment considered requirements for the TSCR Project safety design basis documents from DOE-STD-1189-2008, *Integration of Safety into the Design Process*, and DOE-STD-1104-2016, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents*. For the PDSA and SER review, the assessment team used the relevant sections from EA Criteria and Review Approach Document 31-29, Rev. 0, *Review of Nuclear Facility Preliminary Safety Basis Development*, to guide the assessment.

The assessment team focused strategically on selected aspects of nuclear safety essential to ensuring effective protection of workers and the public. With a review of the PDSA and supporting hazard analysis, the assessment indirectly addressed the line management preparation, review, and approval processes. The assessment team examined key supporting documents, including the Safety Design

Strategy, the process hazard analysis (PrHA), the preliminary fire hazards analysis, Functions and Requirements Evaluation Documents (FREDs), Instrument Requirements Evaluation Documents (IREDs), accident analysis calculations, design calculations, procurement specifications, and engineering drawings. The assessment team conducted meetings with key WRPS personnel and ORP safety basis review team (SBRT) members responsible for developing and reviewing the safety basis documents. The members of the assessment team, the Quality Review Board, and EA management responsible for this assessment are identified in Appendix A.

The assessment team used a comment and response process to address issues identified during its review. The team provided comments on the PDSA to ORP at the in-process review draft and final submittal stages and received written responses. When necessary, follow-on discussions among the assessment team, ORP, and WRPS were conducted to resolve issues. Comments were resolved by either adequate comment responses or by changes incorporated into the resubmitted final PDSA, SER, and supporting documents.

No items from previous assessments required follow-up in this assessment.

3.0 RESULTS

3.1 Preliminary Documented Safety Analysis

3.1.1 Hazard and Accident Analyses (Chapter 3)

The objective of the assessment of Chapter 3 of the PDSA was to evaluate hazard identification and evaluation, including the designation of hazard controls.

The assessment team reviewed hazard events related to explosions, fires, loss of confinement, direct radiation exposure, and natural phenomena and man-made external events. Criticality events are not credible for the initial supernate waste processing campaigns because the waste is below the single parameter limits of American National Standards Institute/American Nuclear Society (ANSI/ANS)-8.1-2014, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside of Reactors*. The hazard categorization of the TSCR process is appropriately identified as hazard category 2 in accordance with DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, based on the inventory of cesium-137 in a single spent IXC.

3.1.1.1 Hazard Identification

The hazard identification in the TSCR PDSA is based on a PrHA using hazard and operability analysis to identify potential hazards and subsequent abnormal and accident events. The material at risk (MAR) calculation is conservatively based on the design basis cesium-137 loading capacity of the IXC and is protected as an initial condition by the TSCR Waste Acceptance SAC. The MAR is appropriately described in terms of quantity and form. Energy sources are appropriately identified for events. Worker safety hazards are included in the PDSA, and in some cases, worker action/inaction is considered as an initiating event. The PDSA adequately identifies and characterizes the TSCR hazards.

3.1.1.2 Hazard Evaluation

The assessment team reviewed the hazard analysis to determine whether it appropriately evaluates the TSCR processes under normal, abnormal, and accident conditions. The assessment team examined the analyzed hazard scenarios and potential effects of postulated events to verify that the estimated unmitigated consequences for workers and the public are conservative.

The TSCR PrHA is divided into a series of study nodes to allow for a systematic approach to developing accident scenarios, identifying boundaries and interfaces, and establishing the applicable MAR. The hazard evaluation analyzes normal operations and maintenance processes, as well as abnormal and accident conditions (e.g., flammable gas deflagrations, waste transfer leaks, above-ground tank failure). The evaluation includes natural phenomena hazards (NPH) events (e.g., seismic, lightning, wind, ashfall) and man-made external events (e.g., aircraft crash, external fires, vehicle impacts).

The hazard evaluation process appropriately includes hazard screening, hazard evaluation, unmitigated and mitigated consequence/frequency estimation, and hazard control selection. For each hazard event, qualitative estimates are assigned for initiating-event frequencies and consequences. Hazard event consequences are evaluated against a radiological consequence threshold of 100 rem to the co-located worker (CW) and the Evaluation Guideline of 25 rem to the maximally exposed offsite individual (MOI) for the selection of safety SSCs. Radiological consequences do not challenge the Evaluation Guideline, and, appropriately, there are no safety class controls identified for protection of the MOI. Chemical consequences are evaluated against toxicological Protective Action Criteria level 3 values for the CW and Protective Action Criteria level 2 values for the MOI for the selection of safety SSCs. Selection of safety SSCs for worker safety is adequate based on the criteria in DOE-STD-1189-2008, Appendix A, *Safety System Design Criteria*.

The PDSA uses the DOE-STD-1189-2008 § A.2 specified onsite atmospheric dispersion factor of 3.5×10^{-3} sec/m^3 at 100 meters, a value that takes into account building wake effects from a significant structure. The PDSA demonstrates that this value is sufficiently conservative through the use of ARCON96, a U.S. Nuclear Regulatory Commission-approved computer code that calculates near-field atmospheric dispersion coefficients. The worst-case dispersion factor calculated by ARCON96 under any atmospheric dispersion condition is 1.06×10^{-3} sec/m^3, which confirms the conservatism of the DOE-STD-1189-2008 § A.2 specified factor.

For each DBA, the accident analysis provides an adequate discussion of scenario development, source term, initiating frequency, radiological consequences, chemical consequences, comparison to thresholds, and controls selection, including identification of safety function and defense-in-depth features. The bounding radiological consequence DBA is a seismic event resulting in simultaneous multiple IXC drops. The radiological consequences for this event are less than 5 rem for the MOI.

The hazard evaluation addresses an appropriate range of hazardous materials and energy sources and addresses a thorough set of hazard events. Initiating event frequencies and consequences are conservatively estimated. The accident analysis adequately evaluates an appropriate set of representative and unique DBAs derived from the hazard evaluation. The consequence analysis methodology and associated parameters are conservative. Safety significant SSCs and SACs are appropriately identified and functionally classified for each DBA based on the consequences.

3.1.1.3 Hazard Controls

The assessment team reviewed the accident analysis in Chapter 3 of the PDSA to evaluate the selection and classification of safety controls. Chapter 3 identifies controls for the protection of workers from potential hazard events, exclusive of standard industrial hazards. Safety SSCs and SACs are identified to prevent or mitigate DBAs with potential consequences exceeding 100 rem to the CW and to protect the facility worker. Selected safety significant SSCs primarily include passive preventive and mitigative controls.

The IXC and associated shielding is the primary passive preventive control for the direct radiation hazard of cesium-137. The TSCR process enclosure is the primary passive mitigative control during supernate processing, mitigating the release of cesium during normal, off-normal, and accident conditions, including sprays, leaks, and seismic events. During long-term storage, the IXC provides passive ventilation and confinement, which prevent release of cesium during normal, off-normal, and accident conditions except for vehicle impact and seismic events. The mitigated consequences of vehicle impact and seismic events are less than 100 rem to the CW.

Safety controls are properly identified and selected, with clear traceability to the hazard events, and include the safety functions and associated functional requirements. The selection of hazard controls follows the DOE-STD-1189-2008 preferred control hierarchy and is adequate to prevent or mitigate the analyzed DBAs.

3.1.1.4 Defense-in-Depth

The TSCR PDSA effectively incorporates the principles of defense-in-depth described in DOE-STD-1189-2008. SSCs and administrative controls provide multiple independent barriers for the protection of workers and the public for postulated hazard events. The barriers include credited and non-credited controls.

3.1.2 Preliminary Design – Safety Controls (Chapter 4)

3.1.2.1 Safety Structures, Systems, and Components

The objective of the assessment of Chapter 4 of the PDSA was to verify that the functional classification of safety controls is appropriate and to determine whether the safety functions, functional requirements, and performance criteria are adequate.

The safety functions, functional requirements, and performance criteria are clearly described and allow evaluation of whether the controls effectively prevent or mitigate DBAs. The safety functions are consistent with those identified in the hazard and accident analyses. The functional requirements and system evaluations support a sufficient understanding of how the SSCs meet the safety function.

Using an integrated project team, WRPS develops FREDs and IREDs to support safety basis system evaluation of safety significant equipment. These documents also support design, procurement, commercial grade dedication, startup, and operations by specifying key design attributes and critical characteristics through systematic and comprehensive failure analysis. This approach is identified as a **Best Practice.**

3.1.2.2 Specific Administrative Controls

Chapter 4 of the PDSA identifies 10 SACs to protect initial conditions, preserve analysis assumptions, or prevent hazardous events. For each SAC, the PDSA provides its safety functions, description, and functional requirements. The PDSA also includes an evaluation section that adequately assesses the ability of the SAC to meet its identified safety functions. SACs work in conjunction to control hazardous conditions; for example, two SACs (4.5.5 Unrestrained Spent Ion-Exchange Column, and 4.5.8 TSCR Enclosure Pad and TSCR Spent Ion-Exchange Column Storage Pad Vehicle Access Restriction) prevent vehicles from impacting an IXC during storage and movement by restricting vehicle access. The SACs are sufficiently established to support the PDSA and final design. The safety functions of the SACs are consistent with those identified in the hazard analysis and provide adequate worker protection. The functional requirements and SAC evaluations sufficiently describe how the SACs meet their safety functions.

The assessment team identified a concern in that the evaluation of the IXC Inlet and Outlet Stack Installation SAC is incomplete. This SAC description includes steps to verify that the IXC is vented during installation of the vent stacks, but no requirement verifies that the IXC vent connection outlet screen is clean enough to ensure adequate passive airflow. A wire filter on the vent line at the exit inside the IXC could become partially plugged during operation, significantly impacting passive airflow and rendering ineffective the stack's ability to purge hydrogen. WRPS committed to include in the documented safety analysis (DSA) addendum technical justification of how the filter design precludes plugging; EA will verify the change during review of the Hanford Tank Farms DSA addendum.

3.1.2.3 Nuclear Safety Design Criteria Implementation

The assessment team reviewed the Safety Design Strategy (RPP-RPT-60822, *Tank-Side Cesium Removal Demonstration and Tank Farm Upgrades/Waste Feed Delivery Project Safety Design Strategy*, Revision 1), the procurement specification (RPP-SPEC-61910, *Specification for the Tank-Side Cesium Removal Demonstration Project (Project TD101)*, Revision 1), and vertical slices of the final design documents, calculations, and drawings. The approach to meeting the nuclear safety design criteria of DOE Order 420.1C, *Facility Safety*, is adequately described in the Safety Design Strategy and project specification, with no identified exceptions to the order. Applicable design codes and standards are referenced in the TSCR Project code of record, procurement specification, and final design documents, and the applicable NPH design criteria are identified.

3.1.3 Technical Safety Requirements and Their Preliminary Derivation (Chapter 5)

The objective of the assessment of Chapter 5 of the PDSA was to verify accurate translation of credited SSCs and SAC performance requirements into a set of formal, implementable requirements. These requirements preserve the identified safety functions, functional requirements, and performance criteria developed in Chapters 3 and 4 of the PDSA. The TSCR preliminary TSR derivation meets the requirements of DOE-STD-1189-2008. Three facility modes—operations, maintenance, and standby—are established in Chapter 5 of the PDSA, and the descriptions are complete. Safety functions and associated surveillances for preliminary limiting conditions for operation (LCOs) are identified and adequately described. Design features are adequately described, and SACs are appropriately identified as either directed action administrative controls or LCOs.

3.1.4 Preliminary Documented Safety Analysis Conclusion

The PDSA meets the requirements of DOE-STD-1189-2008 and comprehensively identifies and evaluates the hazards associated with TSCR. The hazard analysis appropriately addresses hazardous materials and energy sources and postulates an adequate set of hazard events. The identified controls are adequate to ensure the safety of workers and the public. The safety functions and functional requirements for SSCs and SACs are sufficiently defined to meet the hazard control requirements derived in the hazard analysis. The system evaluation of the SSCs and SACs ensure that safety functions will be met. The identified operational modes, LCOs, and design features are adequate to support the derivation of TSRs.

3.2 Federal Review and Approval

The assessment team reviewed the SER to determine its adequacy as the approval basis for the PDSA as required by DOE-STD-1104-2016. The ORP SBRT followed the *Safety Basis Review Plan for Tank-Side Cesium Removal* and used the lines of inquiry to ensure the thoroughness of the review.

The SBRT included members with appropriate subject matter expertise in nuclear safety, criticality safety, and safety systems oversight. The SBRT concluded that the PDSA presents sufficient information for the final design, meets the format and content requirements of DOE-STD-1189-2008, and acceptably resolves SBRT (and EA) comments. Based on this assessment, the SBRT recommended approval of the TSCR PDSA.

The SER addresses the approval bases identified for review in DOE-STD-1104-2016, which include verification that the design requirements of DOE Order 420.1C are met, assessment that the PDSA final design is based on the safety functions identified in the hazard analysis, and confirmation that the appropriate design criteria are identified. For each approval basis, the SER provides a satisfactory basis for recommending approval of the PDSA.

The SBRT compared the content review of the PDSA with the requirements of DOE-STD-1189-2008. It concluded that the hazards analysis performed for the TSCR PDSA was developed consistent with DOE-STD-1189-2008 and that it follows an acceptable format provided in DOE-STD-3009-94. The SER also notes that all unmitigated offsite consequences for postulated events are low.

The SER adequately documents review of the PDSA and provides an understanding of the DBA consequences and the controls incorporated into the TSCR design to prevent significant hazard events. The SER correctly concludes that the initial hazard categorization of the TSCR Project as hazard category 2 is appropriate and consistent with the project hazards.

Overall, the PDSA and SER appropriately conclude that there is reasonable assurance the health and safety of the public, workers, and environment will not be adversely affected by the TSCR Project.

4.0 BEST PRACTICES

Best practices are safety-related practices, techniques, processes, or program attributes observed during an assessment that may merit consideration by other DOE and contractor organizations for implementation. The following **best practice** was identified as part of this assessment.

- Using an integrated project team, WRPS develops FREDs and IREDs to support safety basis system evaluation of safety significant equipment. These documents also support design, procurement, commercial grade dedication, startup, and operations by specifying key design attributes and critical characteristics through systematic and comprehensive failure analysis.

5.0 FINDINGS

There were no findings identified as part of this assessment.

6.0 DEFICIENCIES

There were no deficiencies identified as part of this assessment.

7.0 OPPORTUNITIES FOR IMPROVEMENT

There were no opportunities for improvement identified as part of this assessment.

8.0 ITEMS FOR FOLLOW-UP

Review the Hanford Tank Farms DSA addendum authorizing TSCR operations.

Appendix A
Supplemental Information

Dates of Assessment

July 2019 – January 2020

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