Safety Basis Assessment at the Hanford Site Tank Farms Tank Side Cesium Removal Facility

June 2021

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
IXC	Ion-Exchange Column
LCO	Limiting Condition for Operation
MAR	Material at Risk
MOI	Maximally Exposed Offsite Individual
ORP	Office of River Protection
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

Safety Basis Assessment at the Hanford Site Tank Farms
Tank Side Cesium Removal Facility
August 2020 through February 2021

Summary

Scope
This assessment evaluated the safety basis amendment and corresponding safety evaluation report for incorporating the Tank Side Cesium Removal (TSCR) Facility into tank farm operations at the Hanford Site. The tank farm safety basis has been amended to include the TSCR Facility and operations, which will provide an ion-exchange process to separate 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 documented safety analysis (DSA) and technical safety requirements (TSRs) comply with DOE-STD-3009-94 Change Notice No. 3, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, and the safety evaluation report complies with DOE-STD-1104-2016, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents*.

Documented Safety Analysis
The DSA amendment provides reasonable assurance that the TSCR Facility can be operated in a manner that adequately protects workers, the public, and the environment, as demonstrated by the following:

- 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-3009-94 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 derivation of TSRs.

Technical Safety Requirements
The TSRs provide reasonable assurance that the TSCR Facility can be operated in a manner that adequately protects workers, the public, and the environment, as demonstrated by the following:

- The TSRs are sufficient to ensure that safety systems and specific administrative controls meet their safety functions and functional requirements.
- The TSRs appropriately reflect the identified control safety functions, functional requirements, and performance criteria developed in the DSA.
- Limiting conditions for operation, surveillance requirements, and associated bases are consistent with the control development and evaluation in the DSA.
- Specific administrative controls and design features are adequately described.

Federal Review and Approval
The safety evaluation report meets the requirements of DOE-STD-1104-2016; adequately documents the basis for approving the tank farms safety basis amendment; and appropriately concludes that there is reasonable assurance that the health and safety of the public, workers, and environment will not be adversely affected by TSCR operations or associated changes to tank farm operations.

Best Practices and Findings
There were no best practices identified in this assessment.

There were no findings or deficiencies identified in this assessment.

Follow-up Actions
The Office of Enterprise Assessments plans no follow-up actions.

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Office of Nuclear Engineering and Safety Basis Assessments, within the independent Office of Enterprise Assessments (EA), conducted an assessment of the safety basis amendment and safety evaluation report (SER) for incorporating the Tank Side Cesium Removal (TSCR) Facility into tank farm operations at the Hanford Site. The safety basis includes HNF-SD-WM-TSR-006, *Tank Farms Technical Safety Requirements*, and RPP-13033, *Tank Farms Documented Safety Analysis*, which have been amended to integrate the control changes required for TSCR operations. This assessment, conducted from August 2020 through February 2021, is a follow-on activity to the EA assessment of the TSCR safety design basis documents completed in early 2020, as documented in *Preliminary Documented Safety Analysis Assessment at the Hanford Site Tank Farms Tank Side Cesium Removal Project*, April 2020.

This assessment was conducted in accordance with the *Plan for the Office of Enterprise Assessments Assessment of the Tank Farms Documented Safety Analysis Addendum at the Hanford Site, Fiscal Years 2019 – 2020*. The scope of this assessment included reviewing the hazard analysis; accident analysis; hazard controls including safety structures, systems, and components (SSCs) and specific administrative controls (SACs); and derivation of technical safety requirements (TSRs) associated with the TSCR Facility. The safety basis amendment consists of changes in the descriptions to reflect the TSCR Facility and operations, an addendum incorporating the hazard and accident analysis, and TSCR-specific additions to the TSRs. This assessment was limited to these changes; the assessment team did not review unchanged portions of the documented safety analysis (DSA) and 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 Facility 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 (LAW) Facility for vitrification. Commissioning of the TSCR Facility in 2021 is essential for the LAW Facility to begin vitrifying low-activity waste in 2023. The TSCR process involves pumping liquid waste (supernate) from Tank 241-AP-107 to the TSCR process enclosure, waste filtering, cesium removal via ion-exchange columns (IXCs), and delivery of the treated low-activity waste to Tank 241-AP-106. 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.

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 from DOE-STD-3009-94 Change Notice No. 3, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, for changes made to the tank farms safety basis to include the TSCR Facility and operations. The assessment team evaluated the Federal SER for compliance with DOE-STD-1104-2016, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents*.

For the safety basis amendment and SER review, the assessment team used the relevant sections from EA Criteria and Review Approach Document 31-3, Rev. 0, *Safety Basis Upgrade Review Criteria Review and Approach Document*, to guide the assessment.

The assessment team focused on selected aspects of nuclear safety essential to ensuring effective protection of workers and the public. The assessment team examined key supporting documents, including the process hazard analysis (PrHA), the preliminary fire hazards analysis, accident analysis calculations, design calculations, and engineering drawings. The assessment team conducted meetings with key WRPS personnel responsible for developing the safety basis documents and the ORP Safety Basis Review Team (SBRT) members responsible for reviewing them. 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 to ORP on the in-process review draft 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 DSA, SER, and supporting documents.

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

3.0 RESULTS

3.1 Documented Safety Analysis

3.1.1 Hazard and Accident Analyses (Chapter 3)

The objective of the assessment of Chapter 3 of the DSA addendum was to evaluate hazard identification and evaluation for the TSCR Facility, including the designation of hazard controls.

The assessment team reviewed hazard events related to explosions, fires, loss of confinement, direct radiation exposure, as well as natural phenomena and man-made external events. Criticality events are not credible for the waste processing campaigns using TSCR because the waste is below the single parameter limits of the invoked standard for nuclear criticality safety (ANSI/ANS-8.1-2014, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside of Reactors*). Correspondingly, the criticality safety determination does not identify the need for engineered or administrative controls due to the low fissile material inventory in the TSCR process enclosure and on the IXC storage pad.

The hazard categorization of the TSCR Facility 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. As allowed by DOE-STD-1027-92, tank farm facilities, which are independent (hazardous materials in one facility cannot interact with hazardous materials in another), are segmented, thus allowing their hazard categorization to be determined on an individual basis.

3.1.1.1 Hazard Identification

The hazard identification in the DSA addendum is based on a PrHA using a hazard and operability study 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 Waste Characteristics Controls as an administrative control key

element. 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 DSA, and in some cases, worker action/inaction is considered as an initiating event (e.g., valve misalignment). The DSA 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 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, IXC failure). The evaluation includes natural phenomena hazards 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 the protection of the MOI. Likewise, 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-3009-94.

The DSA uses the onsite atmospheric dispersion coefficient of 3.5×10^{-3} sec/m^3 at 100 meters as specified in DOE-STD-1189-2008, *Integration of Safety into the Design Process*, § A.2, which takes into account the building wake effects from a significant structure. The DSA demonstrates that this value is reasonably conservative.

For each design basis accident (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, resulting in 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 DSA addendum to evaluate the selection and classification of hazard 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 TSCR process enclosure is the primary passive mitigative control during supernate processing, mitigating the release of cesium from a spray leak during abnormal and accident conditions. The IXC and associated shielding is the primary passive preventive control for the direct radiation hazard of cesium-137. During storage, the IXC provides passive ventilation and confinement, which prevent release of cesium during normal, abnormal, and accident conditions. Seismic restraints and passive vehicle barriers, located on the IXC storage pad and around the TSCR yard, provide defense in depth for topples and vehicle impact events.

Hazard 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-3009-94 preferred control hierarchy and is adequate to prevent or mitigate the analyzed DBAs.

3.1.1.4 Defense in Depth

The DSA effectively incorporates the principles of defense in depth described in DOE-STD-3009-94. 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 Safety Controls (Chapter 4)

3.1.2.1 Safety Structures, Systems, and Components

The objective of the assessment of Chapter 4 of the DSA addendum 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 demonstrate how the SSCs meet the safety function.

3.1.2.2 Specific Administrative Controls

Chapter 4 of the DSA addendum identifies eight SACs to protect initial conditions, preserve analysis assumptions, or prevent hazardous events. For each SAC, the DSA provides its safety functions, description, and functional requirements. The DSA also evaluates the ability of the SAC to meet its identified safety functions. 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 to provide adequate worker protection.

3.1.3 Technical Safety Requirements (Chapter 5)

The objective of the assessment of Chapter 5 of the DSA addendum and the TSRs was to evaluate selected TSRs, their bases, and associated derivation to verify the accurate translation of credited SSCs and performance requirements into a set of formal and implementable requirements for the TSCR process. These requirements preserve the identified safety functions, functional requirements, and performance criteria developed in Chapters 3 and 4 of the DSA addendum. The TSCR TSRs and their derivation meet the requirements of DOE-STD-3009-94, and the format and content conform to DOE Guide 423.1-1B, *Implementation Guide for Use in Developing Technical Safety Requirements*. Modes and mode restrictions are clearly defined in Chapter 5 of the DSA addendum and are carried forward into the TSRs. Three facility modes—operations, maintenance, and shutdown—are established and are adequately defined. Limiting conditions for operation (LCOs) are consistent with the control development in the DSA. The LCO bases appropriately describe the conditions, surveillances, and required actions derived from the DSA. Design features are adequately described, with appropriate in-service inspection and configuration management requirements. SACs are adequately described, and administrative controls appropriately include commitments to the safety management programs. Surveillance requirements are consistent with the DOE guide and have justifiable frequencies.

3.1.4 Safety Basis Conclusion

The DSA and TSRs meet the requirements of DOE-STD-3009-94 and comprehensively identify and evaluate 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 ensures 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 DSA revision as required by DOE-STD-1104-2016. The ORP SBRT followed the *Safety Basis Review Plan for Tank Side Cesium Removal Facility Documented Safety Analysis Report and Technical Safety Requirement* 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 DSA and TSR document meet the format and content requirements of DOE-STD-3009-94 and provide reasonable assurance of protection from the hazards associated with tank farm operations involving the TSCR Facility. The SER notes that all unmitigated offsite consequences for postulated events are low. Based on this assessment, the SBRT recommended approval of the safety basis revisions.

The SER addresses the approval bases identified for review in DOE-STD-1104-2016, which include base information, hazard analysis, defense in depth, safety SSCs, SACs, derivation of TSRs, and safety management programs. For each approval basis, the SER provides a satisfactory basis for recommending approval of the safety basis amendment. The SER adequately documents the review of the safety basis amendment and provides an understanding of the DBA consequences and the controls to prevent or mitigate hazard events. The SER correctly concludes that the hazard categorization of the TSCR Facility as Hazard Category 2 is accurately presented.

Overall, the SER appropriately concludes that the safety basis amendment provides reasonable assurance that the TSCR Facility can be operated in a manner that adequately protects workers, the public, and the environment.

4.0 BEST PRACTICES

There were no best practices identified as part of this assessment.

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.

Appendix A
Supplemental Information

Dates of Assessment

August 2020 - February 2021

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