Preliminary Documented Safety Analysis Assessment at the Hanford Site Capsule Storage Area

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Office of Enterprise Assessments
U.S. Department of Energy

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Acronyms

CFR	Code of Federal Regulations
CHPRC	CH2M HILL Plateau Remediation Company
CSA	Capsule Storage Area
CSP	Capsule Storage Pad
CSS	Cask Storage System
CW	Co-located Worker
DBA	Design Basis Accident
DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
EA	Office of Enterprise Assessments
MAR	Material at Risk
MCSC	Management of the Cesium and Strontium Capsules
MOI	Maximally Exposed Offsite Individual
NRC	U.S. Nuclear Regulatory Commission
PAC	Protective Action Criteria
PDSA	Preliminary Documented Safety Analysis
RL	Richland Operations Office
SAC	Specific Administrative Control
SBRT	Safety Basis Review Team
SER	Safety Evaluation Report
SS	Safety Significant
SSCs	Structures, Systems, and Components
TSC	Transportable Storage Canister
TSR	Technical Safety Requirement
UCS	Universal Capsule Sleeve
VCC	Vertical Concrete Cask
WESF	Waste Encapsulation and Storage Facility

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Summary

This assessment evaluated the preliminary documented safety analysis (PDSA) and safety evaluation report (SER) for the Capsule Storage Area (CSA) as part of the Management of the Cesium and Strontium Capsules (MCSC) Project at the Hanford Site. The MCSC Project includes retrieving cesium and strontium capsules from the Waste Encapsulation and Storage Facility (WESF), loading the capsules into cask storage systems (CSSs), and transferring the CSSs to a concrete capsule storage pad located at the CSA.

Significant Results for Key Areas of Interest
The CSA PDSA complies with DOE-STD-1189-2008, *Integration of Safety into the Design Process*, and the SER complies with DOE-STD-1104-2016, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents*. The assessment did not identify any best practices, findings, or deficiencies.

<u>Preliminary Documented Safety Analysis</u>
The PDSA adequately documents integration of safety into the design of the Hanford Site CSA as demonstrated by the following assessment results:

- The hazard evaluation includes an appropriately detailed, conservative hazard analysis and provides a sound basis for control selection.
- The selection of hazard controls follows the order of preference specified in DOE-STD-1189-2008 and provides adequate protection for workers and the public.
- The functional classification of safety structures, systems, and components (SSCs) is appropriate, and the safety functions, functional requirements, and performance criteria are adequate.
- Specific administrative controls are appropriately identified where safety SSCs are not practical.
- The descriptions of operating modes and design features are adequate to support future derivation of technical safety requirements.

<u>Federal Review and Approval</u>
The SER adequately documents the basis for approving the PDSA and appropriately concludes that the CSA design ensures adequate protection of the public, co-located and facility workers, and the environment. The SER identifies one condition of approval regarding development and implementation of a weld qualification program for the transportable storage canister.

Follow-up Actions
The Office of Enterprise Assessments will review the update to the WESF documented safety analysis in support of the MCSC Project.

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at the Hanford Site Capsule Storage Area

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 Capsule Storage Area (CSA) preliminary documented safety analysis (PDSA) and safety evaluation report (SER) as part of the Management of the Cesium and Strontium Capsules (MCSC) Project at the Hanford Site. The MCSC Project is managed by CH2M HILL Plateau Remediation Company (CHPRC) under the direction and oversight of the DOE Richland Operations Office (RL). NAC International is the design agent under subcontract to CHPRC. This assessment, conducted from May 2019 through September 2020, is part of an ongoing activity of independent oversight of new DOE nuclear facility projects to fulfill requirements specified in DOE appropriations legislation.

This assessment was conducted in accordance with the *Plan for the Office of Enterprise Assessments Assessment of the Waste Encapsulation and Storage Facility Capsule Storage Area Project Preliminary Documented Safety Analysis at the Hanford Site, Fiscal Year 2018*. The scope of this assessment included review of the hazard and accident analyses; hazard controls; beyond design basis accidents; safety structures, systems, and components (SSCs); and specific administrative controls (SACs) for the CSA PDSA. This assessment encompassed review of supporting documents, including the functional design criteria documents, final design reports, engineering design calculations and drawings, and the preliminary fire hazards analysis. This assessment also included review of the SER, which documents the RL approval basis for the PDSA. The loading operations of the cask storage system (CSS) are outside the scope of the CSA PDSA; these operations will be performed at the Waste Encapsulation and Storage Facility (WESF) and will be governed by an update to the WESF documented safety analysis (DSA). Acceptance criteria for the CSS ensure that the CSSs loaded at the WESF will meet required safety functions at the CSA.

The MCSC Project includes retrieving the cesium and strontium capsules from the WESF pool, loading the capsules into CSSs, and transferring the CSSs to the CSA concrete capsule storage pad (CSP). A CSS consists of a universal capsule sleeve (UCS) that holds up to six capsules in two layers, a transportable storage canister (TSC) basket that holds 22 UCSs in two layers placed into a TSC, and a vertical concrete cask (VCC). The CSA will include between 17 and 20 CSSs for an initial service life of 40 years, with anticipated extensions up to 300 years. Figure 1 illustrates the various CSS components.

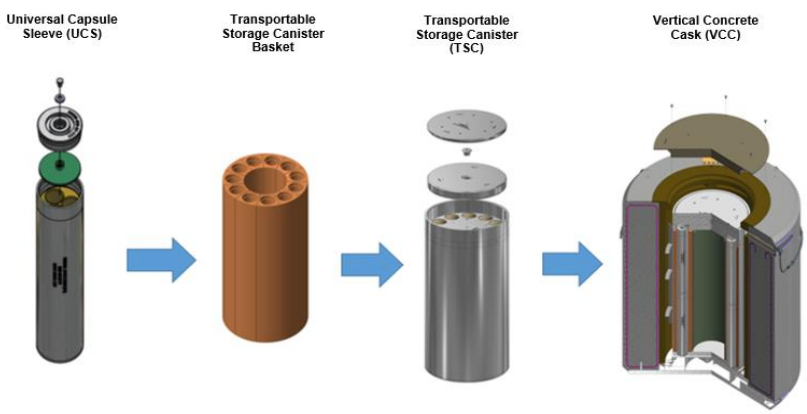

Figure 1. Cask Storage System Components

The cesium and strontium capsules will not be commingled (i.e., each CSS will contain either cesium or strontium). The CSS is similar to U.S. Nuclear Regulatory Commission (NRC)-licensed designs for dry storage of commercial spent nuclear fuel. The TSC design is compatible with NAC International's NRC-licensed transportation cask to facilitate potential offsite transportation. The UCSs are sized with permanent geologic disposal considerations, including deep borehole disposal concepts.

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 DOE Order 227.1A.

This assessment uses the requirements of 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*. Key aspects of these requirements are included in the objectives and criteria of EA Criteria and Review Approach Document 31-29, Rev. 0, *Review of Nuclear Facility Preliminary Safety Basis Development*. In accordance with the safety design strategy approved for this project, the 2008 version of the DOE standard was used to develop the PDSA.

The assessment team reviewed the PDSA Revision 0 submittal and subsequent revisions, examined primary supporting documents, and conducted meetings with key RL and CHPRC personnel responsible for developing and reviewing the safety basis documents. The assessment team also reviewed the SER issued by RL approving the PDSA. Appendix A lists the members of the assessment team, the Quality Review Board, and EA management responsible for this assessment.

There were no items for follow-up during this assessment.

3.0 RESULTS

3.1 Preliminary Documented Safety Analysis

The PDSA was developed over a span of almost two years. The assessment team was engaged throughout the development process, attending design reviews, conducting in-process reviews of interim drafts, and providing input on NRC regulations and nuclear industry practice for dry storage of spent nuclear fuel. The assessment team provided perspective on issues related to facility design life, aging management to support life extensions, consistency with NRC regulations and guidance, and compliance with industry codes and standards. All issues identified by the assessment team were addressed by changes to the CSA PDSA or will be addressed in the update to the WESF DSA. The results of the assessment are summarized in the following subsections.

3.1.1 Hazard and Accident Analyses (Chapter 3)

The objective of the assessment of Chapter 3 of the CSA PDSA was to evaluate hazard identification, hazard evaluation, and hazard controls. The review included events related to loss of passive cooling, fires, loss of confinement, natural phenomena hazards, and human-initiated external events. Criticality events are not credible because there is no fissile material. The CSA hazard categorization of hazard category 2 is appropriate per DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*.

3.1.1.1 Hazard Identification

The hazard identification process in the CSA PDSA is based on a preliminary hazards analysis using the What-if/Checklist process to identify potential abnormal conditions and accidents. The material at risk (MAR) is conservatively based on bounding values of the cesium and strontium capsule inventories. The MAR is appropriately described in terms of quantity and form. Worker safety hazards are included in the PDSA and, in some cases, worker action/inaction is considered as an initiating event. Initial conditions are identified for the CSS and CSP configurations; appropriately designated safety significant (SS) SSCs and a SAC (for CSS acceptance) protect these initial conditions. The PDSA adequately identifies and categorizes the hazards associated with the CSA.

3.1.1.2 Hazard Evaluation

The PDSA describes the CSS, the CSA design, and operational processes; provides the methodology for identifying and evaluating potential hazards; and includes the inputs and assumptions on which the hazard evaluation was based. The hazard evaluation considers normal, abnormal, and accident conditions. The evaluation includes natural phenomena hazards (e.g., seismic and ashfall) and human-initiated external events (e.g., aircraft crash).

The PDSA describes risk bins based on qualitative estimates for initiating event frequencies and conservative quantitative consequences to the public and co-located worker (CW). Initiating event frequencies are conservatively estimated. Radiological hazard consequences are evaluated against a radiological consequence threshold of 100 rem to the CW and the evaluation guideline of 25 rem to the maximally exposed offsite individual (MOI). Chemical hazard consequences are evaluated against the respective toxicological protective action criteria (PAC) for the CW (PAC-3) and for the MOI (PAC-2).

The PDSA provides a summary of the design basis accidents (DBAs) with unmitigated frequencies and consequences. The DBAs are based on representative and unique accident scenarios that include fires, drops, impacts, seismic events, and blocked vents (i.e., thermal stress due to loss of convective cooling). For each DBA scenario, the accident analysis provides a detailed discussion of scenario development, the source term, radiological consequences, chemical consequences, a comparison to thresholds, design requirements, and selected controls.

The limiting accident is a fire on the CSP resulting in failure of all the TSCs and UCSs and evaporation of the cesium salt. The bounding radiological dose consequences for this event, based on the entire cesium inventory, are 8.2 rem for the MOI and greater than 10,000 rem for the CW. Safety class controls were considered for this event but were deemed unnecessary due to the conservatism in the analysis parameters (i.e., maximum MAR, cesium salt temperature, and dispersion assumptions with no lofting) and the reliability of the passive design features of the CSS. The bounding toxicological dose consequences for this event are less than PAC-3 for the CW and less than PAC-2 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 conservatively evaluates an appropriate set of representative and unique accident scenarios as derived from the hazard evaluation. The consequence analysis methodology and associated parameters are conservative. SS SSCs and SACs are appropriately identified and functionally classified for each DBA based on the consequences.

3.1.1.3 Hazard Controls

Chapter 3 of the PDSA identifies controls for the protection of workers from potential hazard events, exclusive of standard industrial hazards. No safety class controls are identified because either the estimated dose consequences of the bounding accident do not challenge the evaluation guideline or adequate justification is provided for their exclusion from consideration. SS SSCs and SACs are identified to protect the facility worker and to prevent accidents with potential consequences exceeding 100 rem to the CW. All selected SS SSCs are passive preventive controls; no active or mitigative controls are required.

The PDSA includes four planned design and operational safety improvements, the most significant of which is related to the development of an aging management program. The aging management program is anticipated to adapt applicable NRC guidance with a focus on ensuring the safe storage of the capsules beyond the initial service life of 40 years (potentially up to 300 years).

Safety controls are properly identified, with clear traceability to the hazard events, and descriptions include the safety functions, functional requirements, and performance criteria. With the identification of only passive preventive controls (i.e., no active or mitigative controls), the selection of hazard controls follows the order of preference specified in DOE-STD-1189-2008. These controls should adequately prevent the analyzed accidents.

3.1.1.4 Defense in Depth

The PDSA effectively incorporates the principles of defense in depth described in DOE-STD-1189-2008. SSCs and administrative controls provide preventive functions so that multiple independent barriers are available for the protection of workers and the public. The barriers include credited and non-credited controls. For example, confinement of the cesium and strontium salts is provided by the non-credited inner and outer capsules and credited TSC and UCS. Safety management programs, which provide sufficient assurance of abnormal condition detection and notification, response processes, procedures, and training for facility workers and the CW, are identified in the PDSA.

3.1.1.5 Beyond Design Basis Accidents

The PDSA analyzes a beyond design basis seismic event resulting in the collapse and failure of all the CSSs. The conservative release assumptions take into account shock and vibration, free-fall spill, and air turbulence caused by collapsing debris. The estimated dose consequences for this event were marginally higher than the seismic DBA; therefore, no additional safety controls or evaluation of improvements were warranted.

3.1.2 Safety Structures, Systems, and Components and Specific Administrative Controls (Chapter 4)

The objective of the assessment of Chapter 4 of the PDSA was to assess whether the functional requirements and performance criteria are sufficient to ensure that the safety functions can be met. The PDSA clearly identifies the safety functions for credited controls and provides the criteria to ensure that the controls can prevent the postulated accidents. Chapter 4 of the PDSA describes key attributes of the controls required to support the safety functions identified in the hazard and accident analyses and to support subsequent derivation of the technical safety requirements (TSRs) in Chapter 5. Chapter 4 includes descriptions of the safety functions, functional requirements, and performance criteria, as well as references to the applicable sections in Chapters 3 and 5 of the PDSA.

The CSS, including the UCS, TSC, and VCC, is the primary SS preventive passive engineered control. Confinement is provided by the welded TSC, which prevents release of cesium or strontium during normal, off-normal, and accident conditions, including fires, drops, impacts, seismic events, and blocked vents (i.e., loss of cooling). The TSC is protected by the VCC, which provides for passive cooling, shielding, and physical protection of the TSC. The UCS is identified as a design feature that confines solid or liquid salts during normal storage and provides geometry control of the capsules to preserve the thermal modeling and DBA analysis assumptions. The SS CSP prevents failure of the CSS for emplacement operations and storage by maintaining structural integrity during natural phenomena hazard DBAs.

The safety functions, functional requirements, and performance criteria of safety SSCs, identified as preventive controls or initial conditions, are clearly described. The functional requirements adequately address the nuclear safety hazards, and the system evaluations provide required information to assess control performance. 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 their safety function.

Chapter 4 of the PDSA appropriately identifies four SACs to protect initial conditions, preserve analysis assumptions, or prevent hazard events. For each SAC, the PDSA provides its safety function, description, and functional requirements. The PDSA also includes an evaluation section, with performance criteria, that assesses the ability of the SAC to meet the safety functions. A key SAC is the CSS acceptance criteria SAC to ensure that the CSS was loaded, sealed, and transported in accordance with applicable requirements and limits, including thermal loading, heat transfer components, welding, and helium backfilling. Another key SAC is the CSS passive cooling operability SAC to ensure that the passive cooling vents remain open with unrestricted airflow during normal conditions and after natural events (e.g., snow, ashfall). The SACs are sufficiently developed to support the PDSA and final CSS design. The safety functions of the SACs are consistent with those identified in the hazard and accident analyses. The functional requirements and SAC evaluations sufficiently describe how the SACs meet their safety functions.

3.1.3 Preliminary Documented Safety Analysis Conclusion

The PDSA meets the requirements of DOE-STD-1189-2008 and comprehensively identifies and evaluates the hazards associated with the CSA. The hazard analysis appropriately addresses hazardous materials and energy sources and postulates an adequate set of hazard events. The identified controls are adequate to reasonably 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 from the hazard analysis. The evaluation of the SSCs and SACs identifies sufficient performance criteria to ensure that safety functions will be met.

3.2 Preliminary Derivation of Technical Safety Requirements

The objective of the assessment of Chapter 5 of the PDSA was to evaluate the TSRs, their bases, and the associated preliminary derivation to verify the accurate translation of credited SSCs and performance requirements into a set of formal and implementable requirements. These requirements preserve the identified safety functions, functional requirements, and performance criteria developed in Chapters 3 and 4 of the PDSA. The CSA TSRs meet the requirements of DOE-STD-1189-2008. Design features and SACs are adequately described. Performance of routine operational and maintenance activities (e.g., surveillances, inspections, repairs) is identified.

3.3 Final Design

The objectives of the assessment of the final design and supporting design documentation was to verify that the nuclear safety design criteria of DOE Order 420.1C, *Facility Safety*, are adequately addressed and to evaluate implementation of the functional design criteria established for the MCSC Project. The assessment focused on the adequacy of the CSS design and loading processes to support the safety functions, functional requirements, and performance criteria of safety SSCs.

The CSS final design is summarized in the final design report, which provides a description of the CSS design basis, design modification options, and testing. The final design report describes the design and operational considerations in support of an initial service life of 40 years with extensions up to 300 years. These considerations include material selection (e.g., 316L stainless steel), fabrication specifications (e.g., cold spray of TSC welds), and aging management programs. The final design report includes a description of the CSS components, loading plans to manage thermal distributions, and operational processes for loading the capsules and transferring the CSS to the CSP. Detailed interfaces with existing WESF facilities and systems are provided. The final design report summarizes engineering design thermal, shielding, and structural calculations. These calculations take into consideration normal loading operations and storage conditions as well as off-normal conditions and accidents.

The approach to meeting the nuclear safety design criteria of DOE Order 420.1C is described in the final design report. Applicable DOE Order 420.1C requirements and applicable design codes and standards for safety SSCs are listed in the functional design criteria document and are reflected in the final design. The CSS design is adapted from proven NRC-licensed dry storage cask systems for commercial spent nuclear fuel. The CSS design complies with American Society of Mechanical Engineers (ASME) boiler and pressure vessel code and applies design criteria consistent with NRC guidance. The only exception is the use of an alternate means for inspecting closure welds. RL approved an equivalent approach for addressing compliance with the ASME code, consistent with DOE Order 420.1C requirements. The equivalent approach will use a weld qualification program that will be developed to establish parameters to ensure leak-tight closure and structural adequacy following remote visual inspection and acceptance.

The final design includes sufficient information to demonstrate compliance with the nuclear safety design criteria of DOE Order 420.1C and the established functional design criteria for the MCSC Project. The final design also provides adequate assurance that safety SSCs will provide their safety functions and that loading processes will preserve the initial conditions established in the PDSA.

3.4 Federal Review and Approval

The assessment team reviewed the SER for the CSA PDSA to determine its adequacy as the approval basis for the PDSA as required by DOE-STD-1104-2016. The Safety Basis Review Team (SBRT) reviewed the PDSA and developed the SER in accordance with RL procedure NSD-RL-PRO-SH-50251, *Safety Basis Review and Approval*.

The SBRT included members with appropriate subject matter expertise. The SBRT concluded that the PDSA meets the criteria for a compliant safety basis at the PDSA stage as required by 10 CFR 830, Subpart B, *Safety Basis Requirements*; DOE Order 420.1C; and DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*. The SBRT also concluded that the PDSA addresses each of the topics identified for PDSA inclusion in DOE-STD-1189-2008, including TSR coverage, derivation of facility modes, TSR derivation, and design features. The SBRT determined that the CSA design ensures adequate protection for the public, co-located and facility workers, and the environment. Based on its review, the SBRT recommended approval of the PDSA to support procurement and construction, as well as development of safety basis documents that will be required for CSA startup and operation.

The SER adequately addresses the approval bases identified in DOE-STD-1104-2016, including base information, hazard and accident analyses, safety SSCs, SACs, derivation of TSRs, defense in depth, and safety management programs. For each approval basis, the SER provides adequate justification for recommending approval of the PDSA. The SER closed all comments and the condition of approval (COA) remaining from the conceptual safety validation report (written for approval of the CSA conceptual safety design report). The SER appropriately identified one new COA for completion of the final closure welds for the TSC under a weld qualification program consistent with the approved equivalency request. This COA adequately addresses a comment identified by the assessment team.

The SER correctly concludes that the initial hazard categorization of the CSA as hazard category 2 is appropriate and consistent with the project hazards. The SER adequately documents review of the PDSA and provides an understanding of the DBA consequences and the controls incorporated into the CSA design to prevent significant hazard events. The SER appropriately concludes that the CSA design ensures adequate protection for the public, co-located and facility workers, 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

Document Review: May 2019 – September 2020
Comment Review and Responses/Discussion: June 2019, September 2019, January 2020

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