Plan for Resolution of Technical Issues at the Hanford Waste Treatment and Immobilization Plant Project – 15596

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ABSTRACT

The Waste Treatment and Immobilization Plant (WTP) Project has a number of first-of-a-kind technical challenges that have necessitated expert analysis and testing activities to resolve. Since 2006, the U.S. Department of Energy (DOE) chartered two major WTP technical reviews. Most recently, in 2012, a number of top scientists and engineers conducted a review focused on the design and operability of WTP black cell and hard-to-reach areas.

To provide leadership and oversight for resolution of the technical issues, DOE assembled a Design Completion Team composed of personnel from the DOE Office of River Protection (ORP), DOE contractors, and the national laboratories. The Design Completion Team established five technical subteams to address specific focus areas. The work of these subteams has evolved such that the project is now focused on eight technical issues referred to as T1 to T8.

The WTP contractor has developed, and DOE has approved, plans for resolution of these issues. These plans form the basis for the Pretreatment (PT) Facility engineering work that will be performed over the coming years. This work, along with a corresponding update to the PT Facility safety basis, will result in an authorization to resume the engineering work necessary to complete the PT Facility design.

INTRODUCTION

Hanford waste tanks contain complex and diverse mixtures of radioactive and chemical wastes in the form of sludge, salts, and liquids, necessitating a variety of unique waste retrieval and treatment methods. While the radioactive nature of the waste requires unique, remotely operated equipment and shielded facilities, it is the uncertainty and diversity of the physical and chemical properties of the 211 983 m^3 (56 million gallons) of waste that makes the Hanford cleanup mission uniquely complex. Consequently, the Waste Treatment and Immobilization Plant (WTP) has a number of first-of-a-kind technical challenges that have required additional expert analysis and testing activities to address.

In 2006, an External Flowsheet Review Team identified 28 technical vulnerabilities with the plant design or future operability. In 2012, a number of top scientists and engineers conducted a review of the major technical issues associated with the design and operability of the WTP. In late 2012, the U.S. Department of Energy (DOE) assembled a WTP Design Completion Team, composed of personnel from the DOE Office of River Protection (ORP), DOE contractors, and the national laboratories to provide leadership and oversight for resolution of the technical issues. The Design Completion Team established five technical subteams whose work focused on specific areas. The work of these teams has evolved such that the WTP Project is now focused on eight remaining technical issues for the Pretreatment (PT) Facility and, where applicable, the High-Level Waste (HLW) Facility as depicted in Table I.

TABLE I. Waste Treatment and Immobilization Plant Project technical issues by facility

Technical Issue	Pretreatment Facility	High-Level Waste Facility
(T1) Hydrogen Gas Release from Vessel Solids	X	
(T2) Criticality in Pretreatment Facility Vessels	X	
(T3) Hydrogen in Piping and Ancillary Vessels	X	X
(T4) Pulse Jet Mixing and Control	X	X
(T5) Erosion and Localized Corrosion in WTP Vessels and Piping	X	X
(T6) Design Redundancy in Black Cells/In-Service Inspection	X	X
(T7) Black Cell Vessel Structural Integrity	X	X
(T8) Facility Ventilation	X	X

DISCUSSION

The DOE restricted certain engineering, procurement, and construction work on the PT Facility, and to a lesser degree the HLW Facility in 2012 and early 2013 because of the impact of unresolved technical issues on the facility design, and a misalignment between the facility design and nuclear safety basis. Since then, the WTP contractor has developed, and DOE has approved, plans for resolution of the eight remaining PT Facility technical issues. These plans form the basis for the PT Facility engineering work to be performed in the coming years. This work, along with a corresponding update to the PT Facility safety basis, will result in an authorization to resume the engineering work necessary to complete the design of the PT Facility. In August 2014, DOE authorized the WTP contractor to resume engineering work needed to complete the design of the HLW Facility.

One of the keys to resolving the WTP technical issues is the proposed Tank Waste Characterization and Staging capability in Hanford's tank farms. Tank waste feed mixing, sampling, and preconditioning are required to ensure the waste acceptance criteria for the PT Facility are met. Recent analysis demonstrates that, contrary to previous expectations, waste mixing and sampling cannot be accomplished effectively inside the double-shell tanks at Hanford. The Tank Waste Characterization and Staging capability would enable tank farm waste to be particle sized, mixed, sampled, characterized, and fed to the PT Facility predictably and consistently. It would also provide a method of managing waste projected to be more technically difficult to process. Finally, it would reduce the testing parameters required for full-scale vessel testing and support the PT Facility technical issue resolution activities.

A brief description of the eight technical issues and the plan for resolution of each of those issues follows.

(T1) Hydrogen Gas Release from Vessel Solids

High solids concentrations expected to be present in some waste feed could form a sediment layer on the PT Facility pulse-jet-mixed vessel bottoms as a result of incomplete mixing. This sediment layer may have the potential to retain hydrogen gas. A buildup of enough gas in the sediment could lead to a sudden episodic release of hydrogen into the vessel headspace in unacceptably high concentrations, creating a risk of combustion that could potentially damage internal or downstream components.

Resolution of this issue requires a combination of engineering studies, development of engineered and administrative safety controls, and vessel testing to ensure that any hydrogen gas release into the headspace of PT Facility vessels can be safely controlled to prevent a combustible event.
Managing hydrogen gas release from solids in PT Facility vessels would become less complex with the implementation of two potential initiatives: (1) replacing up to eight of the largest pulse-jet-mixed vessels with smaller, standardized vessel designs, and (2) implementing the Tank Waste Characterization and

Staging capability in the tank farms. Both of these potential initiatives would contribute to improved control of solids accumulation in PT Facility vessels.

(T2) Criticality in Pretreatment Facility Vessels

Up to 16 of the 149 underground single-shell tanks at Hanford may contain plutonium particles of a size and density that could settle on internal surfaces or bottoms of the pulse-jet-mixed vessels during pretreatment. If such settling was to occur, and the pulse-jet mixers were unable to resuspend the particles, plutonium could accumulate in a geometry that might initiate a criticality, resulting in localized heating and a release of gamma and neutron radiation.

The issue of an inadvertent criticality in PT Facility process vessels will be addressed by conducting engineering analyses, testing (if required), and peer reviews from nationally recognized nuclear safety experts. Similar to hydrogen gas release (T1), managing the potential for inadvertent criticality in process vessels would become much less complex by implementing the smaller, standardized, pulse-jet-mixed vessel design, and the Tank Waste Characterization and Staging capability in the tank farms, both of which would contribute to improved control of solids accumulation in PT Facility vessels. The approach for preventing an inadvertent criticality at the WTP will be documented in an update to the WTP Criticality Safety Evaluation Report. This report update and the WTP Documented Safety Analysis will provide authoritative documentation of the potential hazards and necessary controls to prevent an inadvertent criticality event at WTP.

(T3) Hydrogen in Piping and Ancillary Vessels

Highly radioactive liquid waste being processed in WTP vessels, piping systems, and components can generate hydrogen gas through radiolysis and thermolysis. If hydrogen accumulates and an ignition source is present, conditions could cause a deflagration and, in some cases, a detonation that could potentially damage the piping system or vessel. Hydrogen accumulation in piping and small ancillary vessels is an issue because it takes less time to reach hazardous concentrations than in larger vessels.

The DOE has approved (with conditions) the use of a quantitative risk assessment process for conducting design analyses of WTP process piping subject to hydrogen gas accumulation in both the HLW and PT Facilities. The quantitative risk assessment tools the WTP contractor is using for WTP process piping design have been reviewed and endorsed by an independent review team of nationally recognized piping design and nuclear safety experts. The WTP contractor has initiated piping design analyses using the hydrogen in piping and ancillary vessels (HPAV) quantitative risk assessment tools in the HLW Facility, and will conduct similar design activities for the PT Facility, subject to approval to proceed with PT Facility design activities at a future date.

These design activities will result in a technical report that specifies the HPAV design features in PT Facility hot cells containing high-solids vessels, and a conceptual design for HPAV-affected piping routes throughout the facility. Representative HPAV quantitative risk assessment model runs completed for the HLW Facility will support PT Facility piping design decisions. The testing of remote piping connectors and other components (e.g., valves, instruments) to determine integrity from vibration, seismic, and hydrogen events also will be completed, and impacts to the designs determined and resolved. These activities will align the safety control strategy with the piping design criteria and result in a design basis that will permit completion of HPAV piping designs in both the HLW and PT Facilities.

(T4) Pulse-Jet Mixing and Control

WTP will use pulse-jet mixers to mix liquids and slurries in 38 of its process vessels. Pulse-jet mixers are cylindrical tanks internal to process vessels that mix the vessel contents by drawing the liquids or slurries into the cylinders by a vacuum, and then pressurizing the cylinder to eject the liquid or slurry back into the vessel via discharge nozzles, much like a turkey baster. Pulse-jet mixers have been used in nuclear applications worldwide for mixing radioactive liquids, slurries, and sludges. The pulse-jet-mixing systems have no moving parts and do not require maintenance.

Additional testing and analyses are required to support design verification of pulse-jet-mixed vessels. Accumulation of solids in the pulse-jet-mixed vessels resulting from inadequate mixing could lead to safety concerns, such as episodic hydrogen gas release or inadvertent criticality. Solids accumulation also could interfere with waste-level measurements in vessels, which could lead to overblow events (i.e., air discharged out of the mixers into the vessel).

The general plan for vessel selection and testing is provided in the report *U.S. Department of Energy Approach for Resolution of Pulse-Jet Mixed Vessel Technical Issues in the Waste Treatment and Immobilization Plant* [1]. As previously noted, DOE is pursuing a design solution that will replace up to 8 large vessels with varying designs in the PT Facility with a smaller standardized pulse-jet-mixed vessel design capable of mixing high solids. This strategy has the potential to substantially reduce the testing cost and schedule duration.

Two vessels will be tested using full-scale prototypes to obtain the required information to resolve the issues on pulse-jet-vessel mixing and control. These vessel prototypes represent vessel designs, or vessel design features, that previously have been tested at smaller scales and demonstrated to mix a wide variety of solids concentrations. Full-scale testing with the first vessel was initiated in July 2014 at the Full-Scale Vessel Test Facility. The primary purpose of this first phase of testing is to demonstrate the pulse-jet mixing control system design and operating concepts. The second vessel, which will be a replacement standardized vessel design, will be tested first at a small scale in a laboratory environment, followed by testing at full-scale in the Full-Scale Vessel Test Facility. The purpose of this second phase of vessel testing is to demonstrate pulse-jet mixing performance and control system testing over the complete range of fluids and slurries planned to be processed in the PT Facility.

(T5) Erosion and Localized Corrosion in WTP Vessels and Piping

Given the uncertainties in waste feed characteristics, the existing erosion and localized corrosion design basis for WTP vessels and piping may not have established conservative margins to account for localized erosive wear expected over a 40-year service life. The potential for excessive erosion and localized corrosion could result in unexpected wall thinning, an extended work stoppage for repairs, and, in a worst case scenario, the potential for piping or vessel failure.

The WTP contractor has initiated a series of comprehensive erosion, corrosion, and synergistic erosion/corrosion tests to establish a basis for erosion and localized corrosion design criteria specific to WTP process conditions. The test program will cover process conditions applicable to both the HLW and PT Facilities. Required chemistry controls will be identified in the PT Facility flowsheet and incorporated into corrosion evaluations. When the analyses and testing activities are completed, the erosion and localized corrosion design bases for vessels and piping can be validated as input to the HLW and PT Facility design completion. Before the erosion and corrosion test program is completed, an erosion and corrosion risk assessment will be conducted for both facilities (completed in early 2014 for HLW) to allow for a risk-based decision to proceed with production engineering and design activities.

(T6) Design Redundancy in Black Cells and In-Service Inspection

The current design for equipment/components located in black cells and hard-to-reach areas may not account for redundancy or in-service inspection to support a 40-year service life. Black cells are rooms that are not accessible during operation; hence, no monitoring or maintenance could be performed. The potential exists for major equipment to fail before the end of its design life because of material defects, fabrication errors, installation deficiencies, or other unforeseen reasons. The piping and equipment in these areas is not accessible for monitoring of potential signs of degradation, and is not accessible for repair or recovery, should it become necessary.

A failure modes, effects, and criticality analysis is being implemented to identify the probability and consequences of equipment and piping failures in HLW and PT Facility black cells and hard-to-reach areas. This process will identify potential single-point failure vulnerabilities, inspections or other monitoring that is needed to provide the requisite confidence of achieving predicted design life, and the design and operational contingencies needed to ensure timely recovery and completion of the WTP Project's mission should an unforeseen failure of a component occur. In addition, the WTP contractor is conducting conceptual design studies for PT Facility black cells to determine the changes required to PT Facility equipment and flowsheet if DOE adopts a standardized design for the PT Facility high-solids pulse-jet-mixed vessels. The conceptual design studies will support the advancement of the PT Facility design and provide input to the decision on use of the standardized vessels.

(T7) Black Cell Vessel Structural Integrity

Changes in the loadings for structural analyses of fabricated and installed black cell vessels, especially pulse-jet-mixed vessels, have identified the potential need for structural modifications to support internal components. The need for the modifications is driven primarily by changes to seismic criteria and analysis methodology. The seismic ground motion criteria for WTP changed around 2005—after the vessels were fabricated and installed. The current seismic categorization of these vessels may not be appropriate considering the safety function of the vessels and the overall mission risk. Implementing complex modifications to vessels that have been fabricated and installed potentially could introduce additional technical risks and/or hazards that must be evaluated and balanced with the benefits of making the modifications.

The WTP Project is using an expert review panel to assess the degree of conservatism in the existing design criteria, analytical methodology, and design configuration, and identify potential changes in criteria and methodology. Once the expert review panel has completed their assessment, the project will develop a plan for implementing criteria changes in design and safety basis documents. Assuming a change is warranted and approved, the vessels in black cells will be reanalyzed using a seismic category that is consistent with the safety classification. In addition, an assessment will be conducted for each of the HLW and PT Facilities to determine the cost, schedule, and technical risk associated with making internal modifications to installed vessels versus the benefit of making the modifications. The risk assessments will be used to inform the decision on final vessel configuration and seismic/safety classification.

(T8) Facility Ventilation

Several normal, off-normal, and post-design basis event operational conditions have the potential to cause the HEPA filters to fail due to higher than anticipated aerosol loading onto the filters. In contaminated facilities, air-handling units are designed and installed to ensure air always flows from less contaminated areas to more contaminated areas. The report from a recent project design review of the HLW Facility

concluded that airflow in the required directions and required volumes within the facility may not be adequate. This could result in the spread of contamination within the facility and put the workers at risk.

Resolution of the issues related to HEPA filter performance requires a combination of testing, design, and safety control strategy development. The WTP Project is currently working with industry on a redesign of the radial HEPA filter media, after which the filters will be retested at Mississippi State University. Additional complementary solutions being considered include alternate safety control strategies and operating procedures. A design study and alternatives analysis is being conducted to consider physical changes to the HLW Facility ventilation systems to ensure adequate and cascading airflows can be achieved during all potential off-normal operational and accident scenarios. A design and operability review will be performed on the PT Facility ventilation systems and any required design modifications will be evaluated and implemented as appropriate.

CONCLUSIONS

The WTP contractor has established plans for resolving each of the eight remaining technical issues for the WTP's PT Facility, and proceeded to update their near-term project execution baseline to implement the technical activities needed to resolve the issues. Resolution of the technical issues is expected to continue over a period of several years. DOE will closely monitor progress on resolving the technical issues. DOE also will review and approve the WTP contractor's Safety Design Strategy, which will provide the basis for updating the PT Facility safety basis, and establish a process by which the design and safety basis will be aligned. Resolution of the technical issues and establishment of a revised safety basis will be key prerequisites to resuming engineering, procurement, and construction activities for the PT Facility.

REFERENCES

1. DOE/ORP-2014-03, 2014, *U.S. Department of Energy Approach for Resolution of Pulse-Jet Mixed Vessel Technical Issues in the Waste Treatment and Immobilization Plant*, U.S. Department of Energy, Office of River Protection, Richland, Washington.