Resolution of Technical Issues at the Waste Treatment and Immobilization Plant Pretreatment Facility – 17281

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ABSTRACT

The U.S. Department of Energy's (DOE) Waste Treatment and Immobilization Plant (WTP) Pretreatment (PT) Facility has a number of first-of-a-kind technical challenges that have required additional expert analysis and testing activities to resolve. In 2006, an External Flowsheet Review Team identified 28 technical vulnerabilities with the plant design or future operability. Over a period of three months starting in September 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. These experts also provided independent advice on some of the broader challenges associated with completing the Hanford tank waste mission – highlighting the linkage between the physical and chemical properties of the tank waste and the PT Facility technical issues.

In 2012 and early 2013, DOE's Office of River Protection (ORP) directed the WTP contractor to suspend production work on the PT Facility until the outstanding technical issues could be resolved and the nuclear safety basis could be updated and brought into alignment with any updates to the facility design and/or process flowsheet.

By late 2016, DOE and the WTP contractor resolved three of the eight outstanding technical issues:

- (T1) Hydrogen Gas in Vessels
- (T2) Criticality in PT Facility Vessels
- (T3) Hydrogen in Piping and Ancillary Vessels (HPAV).

Resolving all three of these issues required a combination of engineering studies and updates to foundational PT Facility safety basis documents to ensure both the design features and safety control strategies were adequately developed and fully supportable.

The five remaining unresolved technical issues are Pulse-Jet Mixing (PJM) of Vessels (T4), Erosion and Corrosion in WTP Vessels and Piping (T5), PT Facility Optimization (T6), Black Cell Vessel Structural Integrity (T7), and Facility Ventilation (T8).

Specific plans for resolving each of the five remaining technical issues have been developed by the WTP contractor. This paper provides a synopsis of the status of PT Facility technical issue resolution, and how resolution of the issues will enable DOE to make an informed decision to establish a new performance baseline for the PT Facility at a future date.

INTRODUCTION

The Hanford WTP will cover 65 acres and consist of four nuclear facilities – PT Facility, High-Level Waste (HLW) Facility, Low-Activity Waste (LAW) Facility, and an Analytical Laboratory – as well as operations and maintenance buildings, utilities and office space.

The PT Facility is the first step in the process of vitrifying Hanford's tank waste. The PT Facility is the largest of the four major nuclear facilities that compose WTP. It is 165 m (540 ft) long and 66 m (215 ft) wide, the size of nearly four football fields, and 36 m (120 ft) tall, or 12 stories, high. When complete, its total area will be more than 45 500 m^2 (490,000 ft^2).

Waste will be pumped from the Hanford tanks via underground pipes to feed receipt vessels in the PT Facility. From the feed receipt vessels, the waste will undergo treatment processes to separate the low-activity fraction from the high-level waste. The treatment processes include evaporation to concentrate the waste, filtration to partition the solids to high-level waste, and ion-exchange to partition the soluble, highly radioactive isotopes to high-level waste.

The high-level solids and highly radioactive isotopes will be sent to the HLW Facility, while the low-activity liquids will be sent to the LAW Facility for immobilization. The PT Facility is shown in its current construction state on Figure 1.

Fig. 1. Pretreatment Facility Construction.

DISCUSSION

The Hanford tank wastes are a complex mixture of radioactive and chemical constituents in the form of sludge, salt cake, and supernate. The variety of generation processes and waste storage methods have necessitated the development of a range of 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 so complex. Consequently, the WTP has a number of first-of-a-kind technical challenges that have required additional expert analysis and testing activities to address. 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 designs.

Technical Issues Description

A brief description of the eight technical issue areas is provided below:

- (T1) Hydrogen Gas Events in Vessels – Hydrogen gas is generated from the waste through radiolysis and thermolysis. Excessive amounts could be retained in sediment layers and be episodically released resulting in accumulation of hydrogen in the vessel headspace. This accumulation increases the risk of combustion that could potentially damage internal or downstream components.
- (T2) Criticality in Pretreatment Facility Vessels – Up to 16 of the Hanford tanks may contain plutonium particles of a size and density that could settle and not be easily resuspended by the pulse-jet mixers. Accumulation of plutonium could occur in a geometry that might initiate a criticality.
- (T3) Hydrogen in Piping and Ancillary Vessels – As discussed above, hydrogen gas can be generated during processing of the wastes. 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 ancillary vessel.
- (T4) Pulse-Jet Mixing and Control – Pulse-jet mixers must be controlled so they pull waste in and push waste out in a carefully-calibrated stroke designed to avoid forcing pressurized air into the vessel. Forcing pressurized air into a vessel, known as an “overblow,” could create excessive stresses on components in the vessel that can fatigue the vessel and cause structural damage. The pulse-jet mixers must also keep waste slurries with high-solids concentrations adequately mixed to prevent solids from accumulating on the bottom of the vessels and creating potential safety hazards such as hydrogen gas accumulation and inadvertent criticality.
- (T5) Erosion and Localized Corrosion in WTP Vessels and Piping – Given the uncertainties in waste feed characteristics and the need for a 40-year design life, the existing erosion and localized corrosion design basis for vessels and piping may not have sufficient margin resulting in unexpected wall thinning and/or piping or vessel failure.
- (T6) Design Redundancy in Black Cells and In-Service Inspection – The potential exists for major equipment to fail before the end of its 40-year design life because of material defects, fabrication errors, installation deficiencies, or other unforeseen reasons. The baseline design for the piping and equipment in the black cells and hard-to-reach areas did not include accessibility for monitoring or repair.
- (T7) Black Cell Vessel Structural Integrity – Changes to seismic criteria and analysis methodology over the years has resulted in the need for potential modifications to the vessel designs coupled with updated structural analysis. With the potential redesign of the PJM vessels, these criteria would be

factored into the design. For existing installed vessels, implementing complex modifications could potentially introduce additional technical risks and/or hazards that must be evaluated and balanced with the benefits of making the modifications.

- (T8) Facility Ventilation – Several normal, off-normal, and post-design basis event operational conditions have the potential to cause the HEPA (high-efficiency particulate air) filters to fail due to higher than anticipated aerosol loading onto the filters. Additionally, concern exists over the proper air balance of the ventilation system based on a recent project design review of the HLW Facility.

Technical Issue Resolution

The WTP contractor has developed, and DOE has approved, plans for resolution of each of the technical issues. The plans require a combination of engineering studies and analysis; modeling; and test programs associated with vessel mixing, erosion and corrosion, and ventilation system HEPA filters. This work, along with a corresponding update to the PT Facility safety basis, will result in a future DOE decision to authorize resuming the engineering work necessary to complete the design of the PT Facility.

Significant progress has been made on resolution of the technical issues with the implementation of a revised approach that includes consideration of potential vessel design changes, the most significant being the use of a smaller, standardized high-solids vessel (SHSV) design. Implementation of this concept has allowed T1, T2, and T3 to be resolved through design and operational changes that can be implemented with the necessary safety controls. By resolving T1 through T3, DOE determined the WTP Project is ready to resume PT Facility design work in areas related to these three issues.

For technical issue T1 (hydrogen gas events in vessels), the WTP contractor prepared an engineering study with supporting calculations to document the revised hydrogen control strategy for PT Facility vessels, consisting of both preventive and mitigative controls. Analysis included the impact of decay heat, process changes, and assumptions on hydrogen generation rate and consequences. Results of the engineering study, combined with planned actions to control WTP waste feed and utilize the SHSV, provided the basis for resolution of the T1 issue.

For technical issue T2 (criticality in vessels), the WTP contractor performed engineering studies, calculations, and criticality safety evaluations to assess the criticality safety concerns and to identify WTP operating and control strategies to safely treat Hanford tank waste materials. DOE convened the DOE Office of Environmental Management Criticality Safety Support Group to provide an independent review of the completed documentation. After extensive investigations, DOE concluded the criticality issue does not represent a credible hazard based on the proposed controls in the completed safety evaluations and engineering studies.

For technical issue T3 (HPAV), the WTP contractor updated and DOE approved a change to the PT Facility preliminary documented safety analysis with supporting calculations, and changes to the Safety Requirements Document and Basis of Design to clarify requirements for design of piping to prevent or control potential hydrogen explosions in WTP process piping. This approach presents a clear distinction in the application of nuclear safety analysis for functional classification of hydrogen controls, and the design of piping using HPAV design criteria.

A simplified PJM vessel testing program has been developed over the last year to resolve T4 using the SHSV design. Qualification of the SHSV for mixing will be achieved through full-scale testing with a prototypic SHSV under a set of most adverse design conditions in conjunction with additional engineering analyses. An Integrated Technical Team consisting of DOE, the WTP contractor, and independent experts was established to accelerate and provide oversight and direction to the test program and SHSV qualification. The prototype SHSV has been installed in the full-scale vessel test facility in Richland, Washington. Vessel testing started in December 2016 is planned to be completed by the end of 2017.

Erosion and corrosion design basis testing for T5 resolution has been defined for the vessels and piping systems in the PT Facility. The defined corrosion testing will validate the basis and limits for both general corrosion and localized corrosion and will include the most adverse processing chemistries for the PT Facility. Erosion testing will consider the wear to vessels due to the PJM impingement and to the piping from erosion. Due to the synergistic nature of corrosion with erosion, the test plans for both programs will include a chemical and physical component to ascertain the total corrosion and wear from these components. Test plans have been finalized and initial testing is underway.

For T6, engineering studies are being performed to address the major challenges with remote operations over a 40-year design life. The potential need for redundancy of major equipment has been evaluated through process utilization studies to identify the throughput limiting equipment or vessel. The studies have been coupled with an evaluation of potential process flowsheet changes to eliminate some of the contributing causes to the other technical issues (e.g., lowering caustic dissolution temperatures to mitigate the potential for stress corrosion cracking in vessels). In parallel, the vessels, systems, and piping are being evaluated to determine the potential areas more prone to failure and the locations where limited access may be gained for in-service inspections to support a reliability integrity management program. Finally, the general lay-out for planning areas 2, 3, and 4 is being re-evaluated to mitigate identified configuration concerns and address the Defense Nuclear Facilities Safety Board issues such as aerosol, spray, and leak impacts to the ventilation system.

With the redesign of the PJM vessels, the latest seismic criteria are being used to support the structural analysis necessary for input to the design to ensure closure of T7. The criteria have influenced the bottom and top heads of the vessel design, as well as the structural internals for supporting the PJMs. Evaluation of the existing installed vessels has also begun.

Finally, resolution of T8 for the PT Facility is being worked in parallel with resolution for the HLW Facility. Filter testing is being performed to support all of the WTP facilities and the results will be available by the end of 2016 to incorporate any changes in the design. The ventilation system for the HLW Facility is being independently reviewed and lessons learned or design changes from that review will be incorporated into the review of the PT Facility. Given the close tie of the ventilation system to the PJM and sparger systems for mixing, the ventilation system design cannot be finalized without this final design input.

CONCLUSIONS

Working with DOE, the WTP contractor has resolved three of the eight technical issues for the PT Facility, and significant progress has been made in the last year with establishing and simplifying the necessary test plan for vessel mixing. The WTP contractor is actively working the remaining four technical issues with established plans. DOE continues to closely monitor progress on resolving the technical issues. 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.