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Volume I

Technology Maturation Plan for the Waste Treatment and Immobilization Plant

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Office of River Protection
U.S. Department of Energy
Richland, Washington 99352

SUMMARY

The U.S. Department of Energy (DOE), Office of River Protection (ORP) and the DOE Office of Environmental Management (EM), Office of Project Recovery have completed three Technology Readiness Assessments (TRA) for the Hanford Waste Treatment and Immobilization Plant (WTP) facilities. The methodology and concepts used in these assessments were adapted from detailed guidance contained in the Department of Defense (DoD) *Technology Readiness Assessment Deskbook*[1]. The purpose of these assessments was to evaluate the maturity of WTP critical technology elements (CTE). The WTP TRAs are provided in Volume II.

In addition, the WTP Contractor completed an independent assessment of the process flowsheet technology readiness of the WTP. This review was conducted by an External Flowsheet Review Team (EFRT).

The results from these two separate assessments have been evaluated using a risk and value engineering approach to ensure that the planned technology maturation work will reduce the technology risk and result in a life-cycle cost benefit to DOE. The results from the evaluation of these two separate assessments have been used to prepare this Technology Maturation Plan (TMP).

This TMP identifies eight technologies that require further maturation based on the results of the TRAs. These are identified below along with the associated WTP facility.

- Rapid Analysis of Radioactive Waste Samples (Analytical Laboratory)
- Waste Solids Separation and Treatment (Pretreatment)
- Radioactive Cesium Removal (Pretreatment)
- Cesium and Nitric Acid Management (Pretreatment)
- Waste Slurry Mixing (Pretreatment and High-Level Waste [HLW] Vitrification)
- HLW Melter Offgas Treatment (HLW Vitrification)
- Low-Activity Waste (LAW) Container Closure (LAW Vitrification)
- LAW Container Decontamination (LAW Vitrification)

This TMP:

- Presents an overview of planned technology development and engineering activities to mature CTEs identified in the DOE completed TRAs, which have not received a Technology Readiness Level of 6.
- Describes the approach to manage the closure of the technology maturity issues.
- Presents and reconciles the technology issues identified in the TRAs with those identified by the EFRT assessment.

The estimated budgets to close the EFRT and the TRA identified technology maturity requirements are $224 million and $32 million, respectively. The technology maturation activities are to be managed to complete the closure of the EFRT and TRA technology issues within the DOE approved WTP cost baseline.

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[1] DoD 2005, *Technology Readiness Assessment (TRA) Deskbook*, Department of Defense, prepared by the Deputy Undersecretary of Defense for Science and Technology, May 2005.

ACRONYMS

AHL	Analytical Hotcell Laboratory Equipment System
CD	Critical Decision
CNP	Cesium Nitric Acid Recovery Process System
CO_2	carbon dioxide
CTE	Critical Technology Element
CXP	Cesium Ion Exchange Process System
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DWPF	Savannah River Defense Waste Processing Facility
EFRT	External Flowsheet Review Team
EM	Office of Environmental Management
FEP	Waste Feed Evaporation Process System
FRP	Waste Feed Receipt Process System
HEME	high-efficiency mist eliminator
HLP	HLW Lag Storage and Feed Blending Process System
HLW	High-Level Waste [Vitrification Facility]
HOP	HLW Melter Offgas Treatment Process System
IHLW	immobilized high-level waste
ILAW	immobilized low-activity waste
IRP	issue response plan
LA-ICP-AES	Laser Ablation-Inductively Coupled Plasma-Atomic Emission Spectrometer
LAW	Low-Activity Waste [Vitrification Facility]
LFH	LAW Container Finishing Handling System
Mo	molybdenum
NASA	National Aeronautics and Space Administration
ORP	Office of River Protection
PJM	pulse jet mixer
PT	Pretreatment [Facility]
PUREX	Plutonium-Uranium Extraction Plant
PVV	Process Vessel Vent Exhaust System
PWD	Plant Wash and Disposal System
RCRA	*Resource Conservation and Recovery Act of 1976*
RF	resorcinol-formaldehyde
RLD	Radioactive Liquid Waste Disposal System
SEWG	Science and Engineering Working Group
SIC	sulfur-impregnated carbon
TLP	Treated LAW Evaporation Process System
TMP	Technology Maturation Plan
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
UFP	Ultrafiltration Process System
WESP	Wet Electrostatic Precipitator
WTP	Waste Treatment and Immobilization Plant
WVDP	West Valley Demonstration Project

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1.0 Introduction

The U.S Department of Energy (DOE), Office of River Protection (ORP) is constructing a Waste Treatment and Immobilization Plant (WTP) for the treatment and vitrification of the underground tank wastes stored at the Hanford Site in Washington State. Hanford tank waste consists of approximately 190 million curies of radioactivity in 53 million gallons of waste. The tank waste includes solids (sludge), liquids (supernatant), and saltcake (dried salts that will dissolve in water forming supernatant). The tank waste will be treated and immobilized to protect the environment and meet regulatory requirements.

1.1 Purpose of the Waste Treatment and Immobilization Plant

The WTP is being constructed to remediate Hanford Site tank waste by:

- Pretreating the waste to separate it into two fractions, Low-Activity Waste (LAW) and High-Level Waste (HLW);
- Immobilizing the LAW as a vitreous waste form for onsite disposal; and
- Immobilizing the HLW as a vitreous waste form for ultimate disposal in the national repository.

The first tank waste fraction, LAW, is comprised of the tank waste liquids (and dissolved saltcake) and contains the bulk of the tank waste chemicals and certain radionuclides (e.g., cesium, strontium, and transuranics) that must be removed prior to immobilizing the waste. LAW is a mixed, characteristic, and listed waste regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA), and must meet certain treatment standards and performance standards for onsite disposal of the final waste form.

The second tank waste fraction, HLW, is comprised of the long half-life radioactive tank waste solids and the radionuclides separated from the LAW fraction. HLW must meet specific treatment and performance standards for storage and repository disposal of the final waste form.

The WTP is comprised of five major facilities:

- Pretreatment (PT) Facility to prequalify the waste feeds and separate the tank waste into HLW and LAW process streams
- LAW Vitrification Facility to immobilize the LAW fraction
- HLW Vitrification Facility to immobilize the HLW fraction
- Analytical Laboratory to support the operation of the treatment facilities
- Balance of Facilities that provide utilities and other support services to the treatment facilities

The WTP Project is DOE’s largest capital construction project with an estimated cost of $12.263 billion and a project completion date of November 2019.

1.2 Purpose of the Technology Maturation Plan

The purpose of this Technology Maturation Plan (TMP) is to describe:

- Activities and schedules to resolve the WTP technology maturity issues
- Relationship of the Technology Readiness Assessments (TRA) and External Flowsheet Review Team (EFRT) issues
- Plan to manage the closure of the WTP technology issues

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2.0 Technology Assessments of the WTP

The maturity of the WTP process flowsheet and technologies have been assessed by the WTP Contractor (Bechtel National, Inc.), independent WTP contractor review teams and the DOE in design review and oversight processes. The most notable assessments were the:

- *Comprehensive External Review of the Hanford Waste Treatment Plant Flowsheet and Throughput*[1] completed in March 2006. This assessment, termed the "External Process Flowsheet Review," identified 28 separate issues. These issues included technology, design, operational and programmatic topics. A number of these issues originated from the immature state of the technologies that comprise the WTP flowsheet.
- Three separate TRAs were conducted by the DOE. These TRAs were patterned after guidance established in the U.S. Department of Defense (DoD) *Technology Readiness Assessment Deskbook*[2] (DoD 2005).

Major results from these assessments are summarized below. A crosswalk of the issues identified in these separate assessments is provided in Appendix A.

2.1 External Process Flowsheet Review

An independent External Process Flowsheet Review Team (EFRT), reporting to the WTP Contractor, conducted a review to determine if the design of the WTP will achieve its waste treatment capacity requirements. The EFRT was comprised of technical experts from industry, academia, and scientific laboratories.

The EFRT conducted a comprehensive review of the entire WTP process flowsheet to address three principal questions:

1. Are there any major issues that will prevent the WTP from operating?
2. Are there any major issues that will prevent the WTP from achieving contract-specified treatment rates with commissioning and future feeds?
3. Are there any potential issues that could prevent the WTP from achieving contract-specified treatment rates with commissioning and future feeds?

From their assessment, the EFRT concluded:

- Plugging of process piping from solids and precipitation could result in unplanned outages that prevent the WTP from operating consistently. If this major issue is corrected, there are no other issues that will keep the WTP from operating.
- Sixteen other major issues were identified that could prevent the WTP from achieving contract treatment rates with commissioning and future feeds. These issues include mixing vessel erosion, mixing system adequacy, process operating limit definition, and design issues with the PT Facility Ultrafiltration Process System (UFP). Fixing these major issues will ensure the WTP will achieve the design treatment rates for all presently identified waste feeds.

[1] CCN 132846, *Comprehensive External Review of the Hanford Waste Treatment Plant Flowsheet and Throughput,* March 2006, Bechtel National Inc. Richland, Washington, 99352
[2] DoD 2005, *Technology Readiness Assessment (TRA) Deskbook*, Department of Defense, prepared by the Deputy Undersecretary of Defense for Science and Technology, May 2005.

- Eleven potential issues were identified that could also prevent the WTP from achieving contract treatment rates with commissioning and future feeds. The potential issues included undemonstrated decontamination factors for the evaporators, process recycle management, and process control system design adequacy. Fixing these potential issues provides additional assurance in achieving design treatment rates.

The EFRT concluded that all of the issues identified have solutions and do not require development of new technologies. However, maturation of selected WTP technologies (e.g., ultrafiltration and cesium ion exchange) is required.

2.2 WTP Technical Readiness Assessments

The DOE has independently completed three separate TRAs for the WTP. These TRAs are identified below and are included in Volume II of this TMP.

- *Technology Readiness Assessment for the Waste Treatment and Immobilization Plant (WTP) Analytical Laboratory, Balance of Facilities and LAW Waste Vitrification Facilities*, 07-DESIGN-042, U.S. Department of Energy, Richland, Washington
- *Technology Readiness Assessment for the Waste Treatment and Immobilization Plant (WTP) HLW Waste Vitrification Facility*, 07-DESIGN-046, U.S. Department of Energy, Richland, Washington
- *Technology Readiness Assessment for the Waste Treatment and Immobilization Plant (WTP) Pretreatment Facility*, 07-DESIGN-047, U.S. Department of Energy, Richland, Washington

The methodology used for conducting the WTP TRAs was based upon detailed guidance contained in the DoD *Technology Readiness Assessment Deskbook*. The assessments utilized a slightly modified version of the Technology Readiness Level (TRL) Calculator[3] originally developed by Nolte et al. (2003) to determine the TRL for the critical technology elements (CTE). The three TRAs consisted of three parts:

1. Identifying the CTEs.
2. Assessing the TRLs of each CTE using the technical readiness scale used by DoD and the National Aeronautics and Space Administration (NASA) and adapted by the assessment team for use by DOE.
3. Recommendations for required work to bring immature technologies to appropriate maturity levels. This third part is the subject of this TMP.

A TRA and CTE summary shown below identifies the number of WTP systems considered in the TRAs, number of systems determined to be CTEs, and the number of CTEs determined to have a TRL less than 6.

[3] Nolte, William L., et al., *Technology Readiness Level Calculator*, Air Force Research Laboratory, presented at the National Defense Industrial Association Systems Engineering Conference, October 20, 2003.

WTP Area	Number of Systems considered in TRA as Potential CTEs	Number of CTEs selected for Detailed Maturity Assessment	Number of CTEs with a Technology Maturity Level less than 6
Pretreatment	33	9	9 (4 [a])
Analytical Laboratory	20	1	1
Balance of Facilities	20	1	0
LAW Vitrification	32	5	2
HLW Vitrification	30	5	1
WTP Common	50	0	0
Total	185	21	14 (8 [a])

[a.] Common mixing issues were identified for the following systems: Cesium Ion Exchange Process System (CXP), Waste Feed Evaporation Process System (FEP), Waste Feed Receipt Process System (FRP), HLW Melter Offgas Treatment Process System (HOP), HLW Lag Storage and Feed Blending Process System (HLP), , Treated LAW Evaporation Process System (TLP), and Plant Wash and Disposal System (PWD)/Radioactive Liquid Waste Disposal System (RLD). The mixing issues are combined in this TMP.

2.3 Definition of TRL Levels

The TRL scale used in the TRAs is based on the DoD and NASA scales. Minor modifications have been made to reflect the chemical processing function of the WTP.

Testing is recommended in this plan to assure that the eight identified technologies will be matured to a TRL 6. To achieve a TRL 6, testing must be completed at an engineering- or pilot-scale, with a testing system fidelity that is similar to the actual application and with a range of simulated wastes and/or limited range of actual waste, if applicable.

Obtaining additional information and understanding of the behavior of the tank wastes and process stream compositions is critical to defining the operational environment and evaluating the WTP technologies. This information requirement is being addressed by detailed activities being conducted to resolve the EFRT issues.

Technology Readiness Levels used in WTP Assessments			
Relative Level of Technology Development	**Technology Readiness Level**	**TRL Definition**	**Description**
System Operations	**TRL 9**	Actual system operated over the full range of expected conditions.	Actual operation of the technology in its final form, under the full range of operating conditions. Examples include using the actual system with the full range of wastes.
System Commissioning	**TRL8**	Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system with real waste in hot commissioning.
	TRL 7	Full-scale, similar (prototypical) system demonstrated in a relevant environment.	Prototype full-scale system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing the prototype in the field with a range of simulants and/or real waste and cold commissioning.
Technology Demonstration	**TRL 6**	Engineering/pilot-scale, similar (prototypical) system validation in a relevant environment.	Representative engineering-scale model or prototype system, which is well beyond the lab-scale tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype with real waste and a range of simulants.
	TRL 5	Laboratory-scale, similar system validation in relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity system in a simulated environment and/or with a range of real waste and simulants.
Technology Development	**TRL 4**	Component and/or system validation in laboratory environment	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in a laboratory and testing with a range of simulants.
Research to Prove Feasibility	**TRL 3**	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development is initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative. Components may be tested with simulants.
	TRL 2	Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies.
Basic Technology Research	**TRL 1**	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.

2.4 Technology Heritage

One of the primary missions of the DOE and its predecessor agencies is to conduct waste treatment operations for waste generated from nuclear research and the production of nuclear materials. To support this mission, DOE has an active technology development program to test and evaluate candidate technologies for nuclear waste treatment. This development program provided the basis for establishing the technical requirements and identification of candidate technologies for the WTP. The technologies that comprise the WTP process flowsheet have either been previously used in nuclear waste treatment operations in DOE facilities or are adaptations of commercial technologies.

The technology maturation activities described in this TMP comprise only a part of the technology development required to support the final WTP design. A significant technology development and testing effort has already been completed by DOE and the WTP Contractor to provide the basis for the WTP design and to support operational planning. The results of this existing program have resulted in the maturation of a majority of the technologies required for the WTP. These technologies include the glass melters in the LAW Vitrification and HLW Vitrification facilities and the waste feed evaporators in the Pretreatment facility. The WTP Project is also taking advantage of other sources of technology from other DOE funded technology programs and private industry to support the development of the WTP flowsheet.

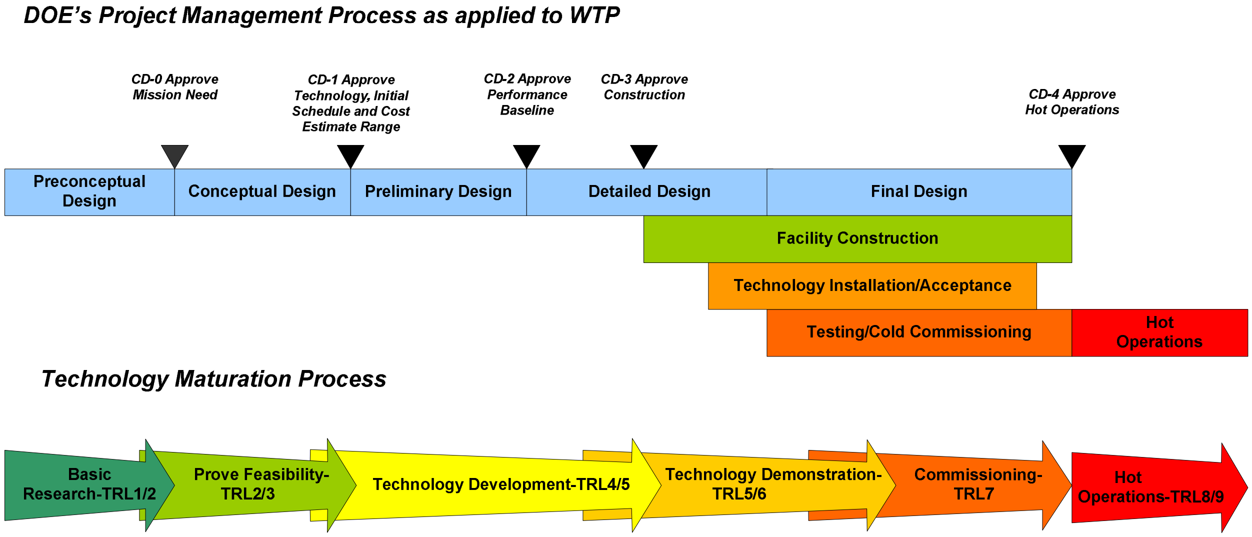
2.5 WTP Project Activities and Technology Maturation

The WTP facility design is comprised of a facility structure with supporting services and utilities, and installed technologies (e.g., equipment systems) located within the facility structure. The purpose of the WTP facility structure is to provide shielding for personnel from the radioactive material being processed, and containment and confinement of radioactive materials. Based on design concepts for radiochemical facilities, including the WTP, the design of the facility is developed in parallel with the initial selection of technologies. This design process results in the specification of the physical interfaces between the facility and the technologies. This design approach provides an opportunity to mature and insert technologies during construction, and provides the flexibility to accommodate modified and alternative technologies at a future date. This approach was used in the WTP to reduce the overall project completion schedule.

The figure below shows the DOE Order 413.3[4] project management process, as applied to the WTP, and the technology maturation process. This figure shows the relationship of the Critical Decision (CD) process with major project activities (e.g., design, construction, commissioning, and operations) and the desired maturity level of critical technologies. This figure illustrates that technology demonstration (e.g., testing to achieve a TRL 5 or 6) can be in progress during the final design and facility construction phase. However, technologies that have not achieved a TRL 6 represent a risk to the facility design. This risk was evaluated in the development of the TMP. Where required, the need to develop alternative technologies has been specified.

Technology performance risks also exist during the cold and hot commissioning phases of the WTP project. These risks will be identified and mitigated during technology installation and acceptance, and cold and hot commissioning, of the actual plant equipment systems.

[4] DOE Order 413.3, *Program Management and Project Management for the Acquisition of Capital Assets*, January 3, 2006, U.S. Department of Energy, Washington D.C.



2.6 Management of Technology Maturity

Oversight of technology maturation will be conducted by a Science and Engineering Working Group (SEWG) comprised of staff from the DOE and the WTP Contractor. The SEWG will:

- Oversee the planning and completion of the technology testing and engineering work identified in this TMP associated with closure of the EFRT and TRA issues.
- Identify and evaluate additional WTP technology development requirements using a risk assessment and value engineering process.
- Approve the closure of technology issues.
- Recommend the budget for WTP technology maturation.

New technology opportunities will be identified and evaluated, and approaches to evaluate and consider them will be defined. Technology opportunities will be identified through value engineering analysis. Technology development requirements will be recommended where required.

Detailed issue response plans (IRP) will be prepared to provide the planning basis to resolve technology issues identified in this TMP. The IRPs will provide the detailed activities, schedule, budget, and technology maturation and issue closure criteria. IRPs were also prepared to document the plan, schedule, and budget for closure of the EFRT issues.

3.0 Technology Maturation Plan

3.1 Development of Technology Maturation Requirements

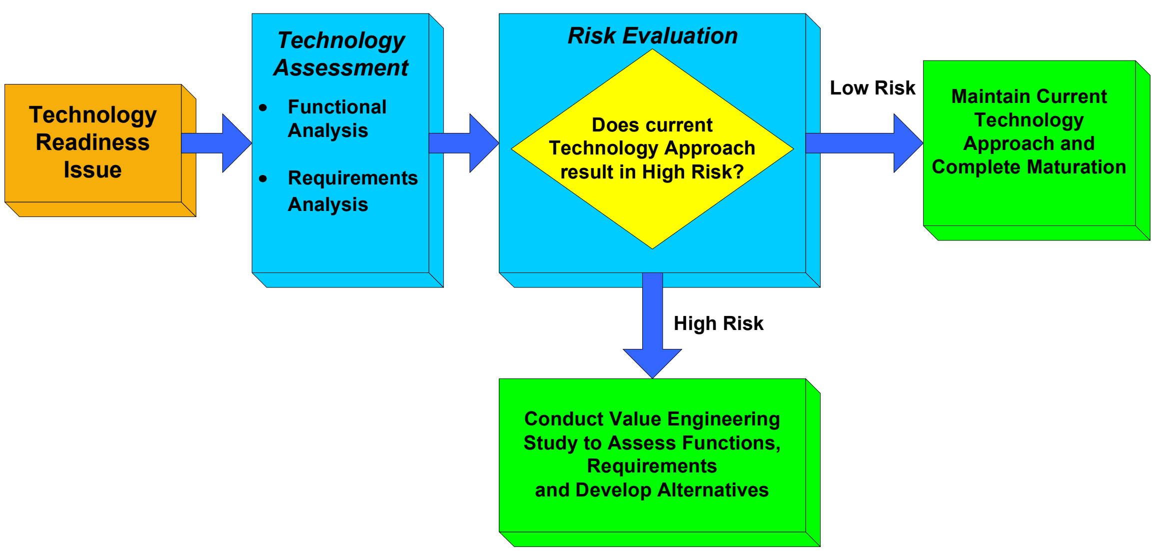
The development of the maturation plan for the CTEs used qualitative risk assessment and value engineering techniques to ensure that:

- Maturation plans for the CTEs were developed using a systematic approach.
- WTP project-specific and life cycle implications of maturing the CTEs were understood.
- The current plan, and potential alternative strategies, for closing the technology risks considered the requirements, system functions, cost, and life cycle operations.
- Opportunities for improving operational performance, reducing cost, or simplifying the system were identified and considered.

The approach used to establish the maturation plans for the CTEs involved a re-assessment of their functions and critical design requirements, an evaluation of the risk of technology failure and a determination of the acceptability of the current development plan. . This approach provided an understanding of the uncertainties and assumptions used in the CTE requirements, the design and operational interfaces within the WTP. It also provided the background for a "first order" risk evaluation of the CTE.

The risk evaluation was designed to determine the qualitative probability and consequences of not maturing the CTE to a TRL 6 prior to completion of WTP Project construction. The outcome of the analysis, either a low or high risk, was used to determine the preference for maintaining the current development plan or the identification and examination of an alternative plan based on potential impacts.

If determined necessary, based on a high risk, a more detailed value engineering study was identified in the TMP. The purpose of the value engineering study is to determine more completely if the current technology plan is acceptable and identify and select an alternative for development.



3.2 Life-Cycle Benefit

The use of the TRA approach to assess and plan technology maturation for the WTP results in:

- Reduced overall project costs by resolving technology maturity issues and avoiding engineering re-work and potential delays in WTP commissioning.
- Higher confidence that the WTP design will achieve program mission operating requirements by the assessment of technology readiness and the completion of required technology maturation activities.
- Higher confidence that the WTP will meet its operating goals at a reduced life-cycle operating cost.

Technology maturation costs are small compared to impacts from design re-work and potential delays in the WTP operating schedule (estimated at over $1 billion per year). The TRA process is also designed to ensure that future performance issues associated with the technology systems are identified and resolved before operations.

3.3 Specific Technology Maturation Plans

3.3.1 Rapid Analysis of Radioactive Waste Samples – Analytical Laboratory

Key Technology Addressed

Laser Ablation-Inductively Coupled Plasma-Atomic Emission Spectrometer (CTE: LA-ICP-AES)

Objectives

Achieving the waste treatment capacities of the WTP requires the development of the LA-ICP-AES technology to support the analysis of waste treatment process samples. The LA-ICP-AES uses a laser to ablate and analyze particulates from the surface of a prepared glass coupon (which will be prepared from waste stream samples) for elemental species in the waste streams. The laser ablation sample preparation and analysis technique was selected for application in the WTP because the analysis turnaround time associated with LA-ICP-AES technology (less that 10 hours) is significantly shorter than traditional wet chemistry techniques (range from 22 to 55 hours). These wet chemistry techniques are used in current and previous DOE waste processing plants (West Valley Demonstration Project [WVDP] and Savannah River Defense Waste Processing Facility [DWPF]), where chemical sample analysis of melter feeds was completed by dissolving the slurry by acid dissolution, converting the slurry to glass or dissolving the glass with a caustic fusion (both potassium and sodium), and analyzing the dilute fusion solutions using LA-ICP-AES technologies.

Approach

Based on WTP method development work and previous testing at DOE national laboratories, sufficient information was available to proceed with prototype LA-ICP-AES specifications for testing to optimize the final design of the laser ablation sample preparation system. The WTP Project has initiated a full-scale test in the Hanford 222-S Laboratory to verify and validate LA-ICP-AES analytical method for hot samples. The task involves installation and testing of a WTP-procured LA-ICP-AES glovebox system properly configured in the adjacent hot cell for remotely ablating HLW samples and adaptation of the developed LA-ICP-AES method to routine operational requirements. This system will be a full-scale prototype of the WTP Project system to analyze actual tank waste.

Scope

- Construct prototype LA-ICP-AES test system
- Test prototype LA-ICP-AES test system
- Develop calibration and operating procedures for WTP LA-ICP-AES

Current State of the Art TRL 5

Initial feasibility tests of the LA-ICP-AES system were completed in two independent studies conducted at Savannah River National Laboratory and Battelle's Pacific Northwest National Laboratory.
The studies supported rapid turnaround time requirements; and evaluated the capability of the LA-ICP-AES to provide sufficient sample turnaround time, accuracy, and precision for waste processing within the WTP.

	Milestones	Performance Targets	TRL Achieved at Milestone
2007	Construct and asemble LA-ICP-AES prototype	Plant-scale prototype of LA-ICP-AES assembled in radiochemical facility at the Hanford Site (e.g., 222-S Laboratory)	5
2008	Demonstrate LA-ICP-AES on actual tank waste samples in prototypic operating environment	LA-ICP-AES exceeds accuracy and reliability of traditional radiochemical analysis methods	6

3.3.2 Waste Solids Separation and Treatment – Pretreatment Facility

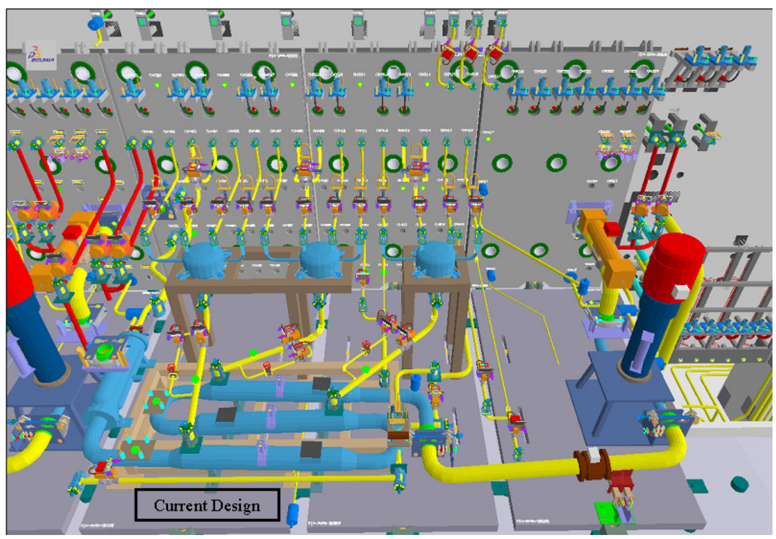
Key Technology Addressed

Separation of HLW Solids and Liquids, Treatment of Solids to Remove Non-Radioactive Components (CTE: UFP)

Objective

The purpose of the Ultrafiltration Process System (UFP) is to separate Hanford Site tank HLW solids from the liquids, and treat the solids by caustic and oxidative leaching processes. The production rate and quality of the downstream operations of both the LAW Vitrification Facility and the HLW Vitrification Facility are directly related to the performance of UFP.

The purpose of the caustic and oxidative leaching processes is to wash and dissolve materials (aluminum, chromium, and other components) that would affect the performance of the HLW Vitrification system. High solids slurry feed (~20 % solids) to the HLW melter is desired to reduce volatiles and increase throughput. While testing has shown it is possible to maintain HLW vitrification melt rates with lower concentration feeds, this mode of operation could lead to offgas system plugging, especially in the film cooler.



Optimum leaching conditions for the HLW solids are not known without testing. The HLW glass canister production can be minimized by increasing the effectiveness of the leaching processes. If the HLW sludge is not effectively leached, an excessive number of immobilized high-level waste (IHLW) canisters will be produced; or, if extra leaching chemicals are required to support leaching, an excessive number of LAW glass containers could be produced. The ability to meet WTP Project throughput, and shorten the WTP mission duration will be enhanced by understanding the leaching processes.

Some of the feeds to the leaching operation will contain significant amounts of alumina, oxalates, and other materials that could precipitate. There is the possibility that aluminum solids will form in the leach tank itself or in other streams from the leaching operation if unfavorable conditions occur.

Approach

The maturation approach for the UFP is to demonstrate through testing of the prototypic design and process flowsheet. An engineering scale test system is being designed and built and will begin operation in early 2008. Laboratory testing with actual radioactive tank waste samples is also required to demonstrate the process flowsheet. The testing activities will be supported by process modeling using chemistry-based computer codes.

Alternative technologies will be identified, evaluated, and developed to perform the functions of the UFP due to the low maturity of this technology and the current risk to WTP performance.

Scope

- Radioactive testing of sludge treatment process at laboratory scale
- Prototypic testing of UFP pilot plant to confirm design and process
- Process modeling to simulate operation and performance of plant scale UFP
- Identify, evaluate, and develop an alternative technology for the UFP

Current State of the Art TRL 3

The UFP was determined to be a TRL 3 because the WTP ultrafiltration technology design has only been conceptualized on paper; integrated caustic/oxidative leaching has not been completed; there is very little data on the filtration of caustic leached waste and no filtration data on oxidatively leached waste; and prototypic integrated system equipment testing to demonstrate process feasibility has not been completed.

	Milestones	Performance Targets	TRL Achieved at Milestone
2007	Complete radioactive laboratory-scale leaching and filtering tests	Demonstrate leaching and filtering with actual tank waste at laboratory scale	4
2008	Develop representative non-radioactive simulants for use in pilot-scale testing	Representative simulants for pilot-scale mixing, leaching, and filtering tests developed	5
2008	Complete initial pilot scale testing of ultrafiltration system using nonradioactive simulants	Demonstrate ultrafiltration and leaching design concept with prototypic process flowsheet and pilot-scale testing system	6
2008	Complete a value engineering study to identify and evaluate an alternative technology for the UFP	Identify an alternative technology to perform the same functional requirements as specified for the UFP	4
2009	Complete initial testing of an alternative technology to perform the functions of the UFP	Demonstrate an alternative leaching and ultrafiltration design concept with prototypic process flowsheet and pilot-scale testing system	6

3.3.3 Radioactive Cesium Removal – Pretreatment Facility

Key Technology Addressed

Cesium Removal from Filtered Liquid Wastes using Ion Exchange System (CTE: CXP)

Objective

The primary purpose of the Cesium Ion Exchange Process System (CXP) is to remove radioactive cesium (Cs-137) from the UFP permeate using an ion exchange process prior to immobilization of the permeate (e.g., treated LAW) as LAW glass.

Approach

Current activities to demonstrate adequacy of the CXP technology are divided into an ongoing effort to develop and qualify ion exchange media (resin) for use in the system, and physical design of the WTP system.

The maturation approach for the CXP will include a combination of additional design review, value engineering, flowsheet modeling, laboratory-scale testing, and prototype testing to confirm design concepts. Further maturation of the technology is needed to test and evaluate: column head space inerting and flammable (e.g., hydrogen) gas removal; removal of 99% of spent resin from columns; and additional assessments of cesium ion exchange resin (spherical resorcinol formaldehyde) resin for physical degradation due to radiation damage, allowable Cs-137 concentrations in the nitric acid eluate, impact of organics species on performance and impact of precipitates on ion exchanger, and ion exchanger column performance.

Scope

- Assess design and technology concepts for the hydrogen venting subsystem, select reference
- Conduct prototypic testing of hydrogen venting subsystem
- Demonstrate 99% removal of spent ion exchange resin
- Assess solids precipitation in ion exchange feed
- Assess impact of solids and organics on ion exchanger performance
- Complete radiation stability testing on ion exchange resin
- Establish detailed cesium ion exchange column design features

Current State of the Art TRL 5

Significant testing of the CXP technology to demonstrate adequacy has included an ongoing effort to develop and qualify ion exchange media (resin) for use in the system, and physical design of the equipment system. The CXP was determined to be a TRL 5 due to incomplete demonstration of the process and equipment technology and incomplete testing of the cesium ion exchange resin. Technology testing will include the nitrogen inerting collection piping and controls for removing hydrogen and other gases from the ion exchange columns, the capability to remove 99% by volume of the spherical ion exchange resin from a prototypic column, and evaluating the potential for formation and management of solids in the CXP.

	Milestones	**Performance Targets**	**TRL Achieved at Milestone**
2008	Complete value engineering assessment of hydrogen removal system design concept	Select design concept for hydrogen removal system	5
2009	Test prototypic hydrogen removal system	Verify hydrogen concentration levels can be maintained below flammability levels in ion exchange system	5
2008	Complete radiation stability testing of cesium ion exchange resin	Determine if performance of resin is adequate following anticipated radiation dose	5
2008	Assess solids precipitation and mitigation approaches in ion exchange feed	Demonstrate solids management is adequate in ion exchange system	5
2008	Determine allowable Cs-137 concentration in nitric acid used for elution (Note: tied to Cesium Nitric Acid Recovery Process System (CNP) issue resolution)	Demonstrate maximum Cs-137 level in nitric acid used for ion exchanger elution	5
2009	Test ability of ion exchange system to process UFP permeate containing solids and organic materials	Demonstrate maximum capability of ion exchange system to process permeate containing solids and organics	6

3.3.4 Cesium and Nitric Acid Management – Pretreatment Facility

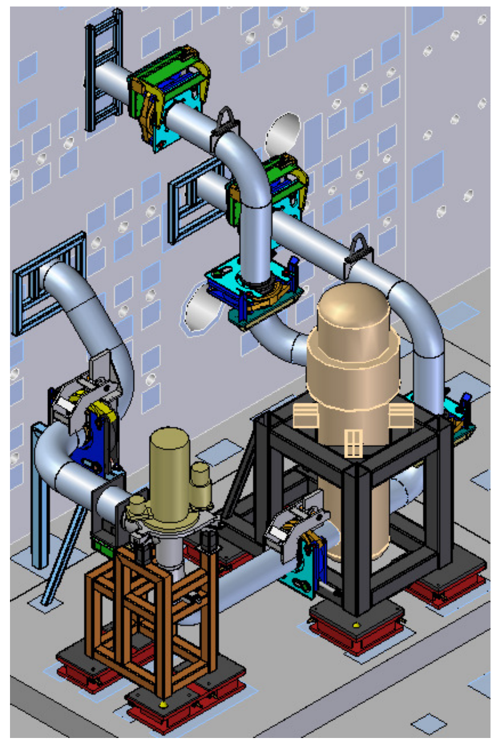
Key Technology Addressed

Treatment of Cesium Ion Exchange Eluate to Separate Cesium-137 and Nitric Acid (CTE: CNP)

Objective

The purpose of the Cesium Nitric Acid Recovery Process System (CNP) is to support uninterrupted and continuous operation of the CXP by receipt and vacuum concentration of as-produced eluate from the CXP, by recovery of (~ 0.5M, essentially cesium-free) nitric acid for reuse as CXP eluent, and by transfer of concentrated (cesium-rich) eluate to the process used to make HLW melter feed.

Approach



The current design for the CNP is supported by material and energy balances, engineering calculations, limited lab-scale testing, vendor recommendations, past Hanford Site evaporator experience from B Plant and Plutonium-Uranium Extraction (PUREX) Plant operations, plus general industrial experience with nitric acid concentration and rectification. The CNP equipment (evaporator vessel including demisters, reboiler, reboiler pump, rectifier, condensers, and vacuum system) is designed and supplied by the vendor, based on engineering specifications prepared by the WTP Contractor. Vendor shop tests include limited testing of fabricated equipment only. Removal (but not replacement) of demisters will be demonstrated. Integrated system acceptance tests are planned after installation, during cold commissioning of the PT Facility.

The technology maturation activities include a comprehensive CNP design review, pilot testing of the integrated CNP process to support final design specification, fabrication and testing, followed by installation, and commissioning. Alternative operating modes for the CNP will also be evaluated.

The design review will evaluate the current design including the control system, and level and entrainment control. If warranted, following the design review, pilot testing will be completed to confirm the CNP equipment concepts, management of foaming in the evaporator, achievable decontamination factors for Cs in the rectifier, use of specific gravity process control and upcomer design adequacy. The current surge tankage may be adequate if pilot testing shows that flow variations necessary to accommodate the batch/continuous CNP operations are comfortably within the capacity of supporting vessels. If not, addition of CNP feedstock vessels and/or recovered acid storage may be required.

Maintenance of evaporator internals will also be demonstrated. Testing at larger scale than pilot (10% full-scale) is probably not justified since the features to be demonstrated (integrated operations, control system, surge volumes, etc.) are not particularly scale-sensitive. Review of commercially available pilot facilities would be prudent, since the individual equipment items to be tested are standard process equipment. Test equipment and test conditions should be specified which closely match the planned CNP design and operations, in order to provide a test environment very close to the anticipated operational environment.

Scope

- Complete computer simulation of control system to establish control requirements
- Assess alternative operating modes and design concepts for the CNP
- Complete design assessment of the CNP and proposed integration into PT Facility processes
- Complete prototypic testing of CNP

Current State of the Art TRL 3

The CNP was determined to be a TRL 3 because testing has only been completed on a laboratory scale to measure the physical properties of the anticipated process solutions to provide information for thermodynamic modeling. Confirmation testing of the CNP equipment components (reboiler, separator vessel, and condenser; demisters and rectifier column) has not been completed. Computer simulation of the CNP operation has not included the full composition range of feed solutions. Proposed changes to the CNP flowsheet including the neutralization of the cesium concentrate product and impacts of the change to the use of resorcinol-formaldehyde (RF) resin have not been evaluated.

	Milestones	Performance Targets	TRL Achieved at Milestone
2008	Complete value engineering design assessment of the CNP, and alternative design concept, with proposed integration into PT Facility processes	Develop clear performance requirements for CNP design and operations concept	4
2008	Complete computer simulation of CNP control system and alternative CNP operating modes	Confirm control system concept for concentration of cesium and separation of nitric acid	4
2009	Complete prototypic testing of CNP design concept	Demonstrate the design of the CNP and characterize performance of the CNP in all anticipated operating modes	6

3.3.5 Waste Slurry Mixing – Pretreatment and HLW Vitrification Facility

Key Technology Addressed

Mixing of Process Waste Streams Using Pulse Jet Mixer (PJM) and other Mixing Devices (CTEs: PJM, CXP, FEP, FRP, HOP, HLP, PWD, TCP, TLP, RLD, UFP)

Objective

The function of the PJM system is to mix waste streams comprised of liquid and solids in specially designed vessels to dissipate gases, blend liquids and solids, and suspend solids for sampling and transport.

PJM devices are long cylindrical vessels that draw in fluid by a vacuum and then pressurize to partially eject the fluid to cause mixing; much like a syringe draws in and expels fluid. These devices have been shown to be reliable and have no moving parts that require maintenance. Thus, the PJM was selected to be used in vessel systems that were designed to have no maintenance over the 40-year operational design life of the WTP.

Approach

PJM technology maturation is divided into two activities: (1) an ongoing development effort to develop and qualify PJMs for use in WTP vessels and (2) physical design of the PJM systems.

The mixing system design will be addressed by testing in scaled prototypes to verify the ability to resuspend settled waste following a mixing system shutdown with bounding conditions of waste characteristics and PJM performance factors. Data from these tests will be used to determine mixing times associated with the various mixing functions of each Newtonian vessel, and production model runs, including confirmed mixing times demonstrating required plant throughput. Testing will also be done to confirm that the post-design basis event mixing adequately disturbs settled solids to release hydrogen from a settled solids layer. Testing will confirm that Newtonian vessel mixing systems are sufficient to produce the degree of waste homogeneity required by mixing success criterion.

Vessels located in black cells that do not have mixing and have the potential for solids formation will be evaluated to establish a technology solution. This includes evaluating the definition of conditions that lead to solids formation; process flowsheet options to preclude solids formation; physical changes that will preclude solids formation (e.g., operating solvent-rich or at higher temperature to prevent precipitation); and selection of design features (flowsheet changes, operating changes, and equipment changes) that mitigate solids formation.

Scope

- Confirm mixing requirements for WTP process vessels
- Confirm the mixing system design of PJM vessels containing Newtonian and non-Newtonian fluids to resuspend settled waste following a mixing system shutdown
- Develop testing information that allows accurate prediction of required mixing time for various vessel-mixing functions
- Confirm that post-design basis event mixing of vessels that use one-half of the PJMs for mixing adequately releases hydrogen
- Demonstrate that normal process PJM mixing successfully meets mixing requirements for vessels containing Newtonian and non-Newtonian fluids
- Identify and confirm mixing requirements for vessels that do not currently have mixing requirements.

Current State of the Art TRL 4

Confirmatory testing to validate the mixing performance of PJM mixed vessels containing low solid concentrations (e.g., Newtonian solutions), has not been completed. Specific, quantifiable design requirements for the PJM technology have not been established to support testing evaluation and design confirmation. The mixing requirements will consider the functional requirements (e.g., safety, environmental, and process control) of the vessels and the anticipated waste characteristics in the vessel.

	Milestones	Performance Targets	TRL Achieved at Milestone
2008	Complete value engineering process to confirm mixing requirements for PJMs	Develop clear performance requirements for PJM mixed vessels based on safety, functional requirements and waste compositions	5
2008	Complete prototypic testing on PJM design configurations	Prototypic testing complete	5
2008	Confirm adequacy of mixing in PJM mixed vessels	Confirm adequacy of PJM vessel design concepts to meet mixing requirements based on prototypic testing and engineering analysis	6
2008	Identify and confirm mixing requirements for vessels that do not have mixing capability using value engineering	Establish and demonstrate mixing system design for vessels that do not currently have mixing capability	6

3.3.6 HLW Melter Offgas Treatment – HLW Vitrification Facility

Key Technology Addressed

Treatment of Melter Offgas to Remove Contaminants (CTE: HOP/PVV)

Objective

The function of HLW Melter Offgas Treatment Process System (HOP) is to remove hazardous particulates, aerosols, and gases from the HLW melter offgas and vessel ventilation process offgas.
The function of the Process Vessel Vent Exhaust System (PVV) is to provide a pathway for vessel offgas to the HOP for treatment. Confinement barriers are provided by maintaining a vacuum on vessels and associated piping for the safety of plant staff.
The combined primary and vessel ventilation offgas stream is discharged to the secondary offgas system, and then exhausted to the atmosphere from the facility stack. These systems treat the HLW melter offgas so that it conforms to relevant federal, state, and local air emissions requirements at the point of discharge from the facility stack.

Approach

The development and testing activities for the HLW offgas system are divided into two activities: (1) an ongoing development effort to develop and qualify equipment and (2) physical design of the components currently undergoing detailed design and procurement. Specific details for the three technology maturation activities, film cooler cleaning, carbon sulfur bed qualification, and material corrosion issues with the Wet Electrostatic Precipitator (WESP), are described below.

Film cooler operating ranges will be determined based on analysis of existing experimental data. The design criteria for the film cooler cleanout device will be established and a prototypic film cooler cleaner designed and tested to confirm the final design of the film cooler cleanout device.

Prototype testing will be performed for the sulfur-impregnated carbon (SIC) bed material using HLW gas simulant and prototypic adsorbent materials. Testing is planned to encompass: removal efficiency for elemental mercury, breakthrough time, and loading profile throughout the adsorbent bed; and removal efficiency, breakthrough time, and loading profile for mercury, naphthalene, and allyl alcohol; as well as temperature increases associated with nitric oxide (NO_x) and allyl alcohol.

A revised corrosion evaluation will be completed to demonstrate the viability of 6% molybdenum (Mo) stainless steels for WESP internals and vessels in the WTP offgas environment. Selection of corrosion resistant alloy for WESP vessels and internals is of critical importance to support the 40-year design life. In addition, piping and valving arrangements will be completed to allow direction of offgas directly from the melter to the high-efficiency mist eliminator (HEME) or to the HEME through the WESP in the event of premature failure of the WESP.

Scope

- Design, test, and confirm design for HLW melter film cooler cleaner
- Qualify the carbon-sulfur absorbent for mercury removal
- Complete corrosion assessment for the WESP
- Identify alternative operating approach in the event of premature WESP failure

Current State of the Art TRL 5

Extensive testing of a prototypic HLW offgas system was completed to support development of the HLW melter. Technology risks remain with the HLW melter film coolers, submerged bed scubber, carbon-sulfur bed columns, and the WESP design.

	Milestones	Performance Targets	TRL Achieved at Milestone
2008	Develop and test a prototypic film cooler cleaner	Demonstrate film cooler design concept	5
2008	Complete testing of candidate SIC bed material to demonstrate adequacy for mercury removal.	Testing results that confirm adequacy of SIC bed material and HOP design	5
2008	Complete evaluation of the WESP materials of construction, complete testing if required	Confirm adequacy of materials of construction for WESP	5
2008	Complete value engineering assessment of alternative operating concept in event of premature WESP failure	Design assessment report identifying an alternative design/operating configuration	6

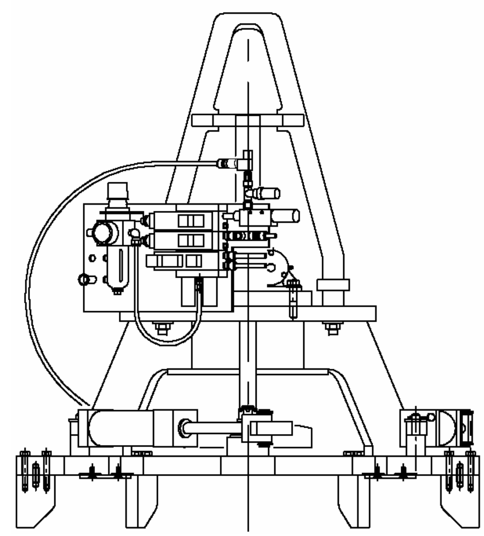
3.3.7 LAW Container Sealing – LAW Vitrification Facility

Key Technology Addressed

Closure of the LAW Container to Prevent Radioactive Contamination Spread (CTE: LFH Container Sealing Subsystem)

Objective

The LAW Container Finishing Handling System (LFH) container sealing subsystem, located in the LAW Vitrification Facility, is used to provide container closure. The closure allows handling and transportation to the Hanford disposal site, maintains void fill requirements, and supports decontamination.



Approach

The technology maturation activities include a re-assessment of the closure requirements and remote mockup testing.

Value engineering studies will be completed to re-assess the LAW container closure requirements. This will consider: traditional leak rate estimates for shipping (considering the physical properties of the glass source term); defining the Hanford Site shipping requirements; Hanford Site burial ground requirements; container integrity requirements; ability to prove closure qualification over the 40-year lifetime of the plant (repair of the lidding equipment; modification or new equipment, human error); and the ability to control canister contamination. The source and type of expected contamination will be identified as part of the work identified in the LAW Container Decontamination section (Section 3.3.8).

Assuming canister closure leak test criteria is specified; consideration should then be given to determine whether some additional testing during commissioning and operation is required. The WTP will have to prove the closure technique (special process) meets or exceeds the leak criteria and does not require periodic testing or a method of sampling the lid seal leak rate.

Additional testing in a mockup will be required to mature the technology to a TRL 6 (if the existing technology remains or an alternative technology is selected that has not been demonstrated).
An integrated prototypic testing of the closure system will be performed, including the inert fill, seal cleanliness, lidding machine operation (retrieving a lid from the lid magazine, installing, visual verification of closure, and leak test of the closure).

Scope

- Complete value engineering assessment on requirements and design solution for LAW container sealing subsystem
- Complete prototypic testing of LAW container sealing subsystem

Current State of the Art TRL 5

The design of the LFH container sealing subsystem has been completed. High-fidelity prototype testing of the sealing system and interfacing subsystems (e.g., glass level measurement, inert filling, inspection design) has not been completed.

	Milestones	Performance Targets	TRL Achieved at Milestone
2008	Complete value engineering assessment of requirements and design solutions for LFH container sealing subsystem	Reassess and define performance requirements for sealing of the LAW containers	5
2009	Complete prototypic testing on of container	Prototypic testing complete	6

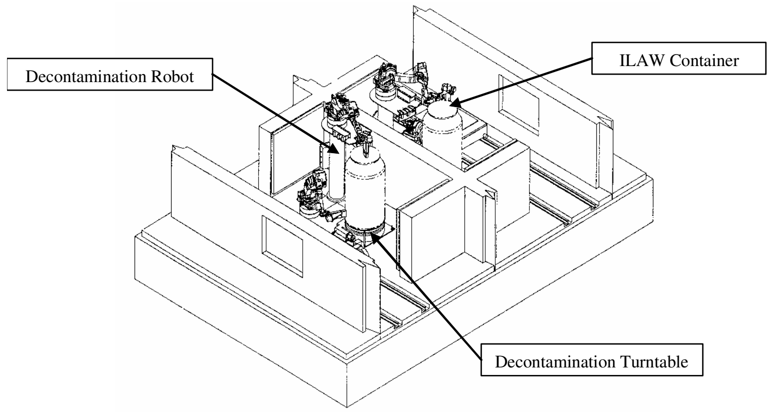
3.3.8 LAW Container Decontamination – LAW Vitrification Facility

Key Technology Addressed

Decontamination of LAW Container following Radioactive Glass Filling (CTE: LFH Container Decontamination Subsystem

Objective

The objective of the LFH container decontamination subsystem is to remove radioactive contamination from filled and sealed LAW containers to a smearable contamination level that allows movement of the containers to the Hanford Site burial ground.



The decontamination process uses abrasion to remove smearable radioactive contamination from the external surfaces of the sealed immobilized low-activity waste (ILAW) container. The abrasive media are solid carbon dioxide (CO_2) pellets. The CO_2 abrasion process uses a localized decontamination approach in which the CO_2 spray is applied through spray nozzles located inside a containment shroud. The shroud is designed to contain the CO_2 vapor (from sublimation of the solid CO_2) and the loose radioactive contamination. The CO_2 and the loose contamination are continuously removed from the shroud using a vacuum system. The contamination is packaged as solid waste.

Approach

The technology maturation activities include a reassessment of the decontamination requirements, a laboratory test or analysis to define the contamination basis, and prototypic (remote) mockup testing in a relevant environment to demonstrate technology. A value engineering evaluation will be completed to review the basis for the existing decontamination level requirements, methods of achieving the required smearable contamination levels (fixative in some or all places), and methods of responding to decontamination requirements failure, as well as provide recommendations on the testing scope to mature the technology

The LAW container decontamination system, as presently designed, will be prototypically tested to confirm vacuum shroud airflows and travel rates, and CO_2 nozzle velocities and offset distances with simulated operating conditions. Integrated testing will be done in a facility suitable for operators to run the equipment system as expected during production. Lessons learned will be fed back into the design, operation, and operating procedures.

Scope

- Identify expected contamination levels on the LAW containers (type, amount, and adherence mechanism)
- Assess requirements for decontamination of the LAW container
- Define scope of testing for prototypic testing
- Complete prototypic testing of LAW container decontamination system

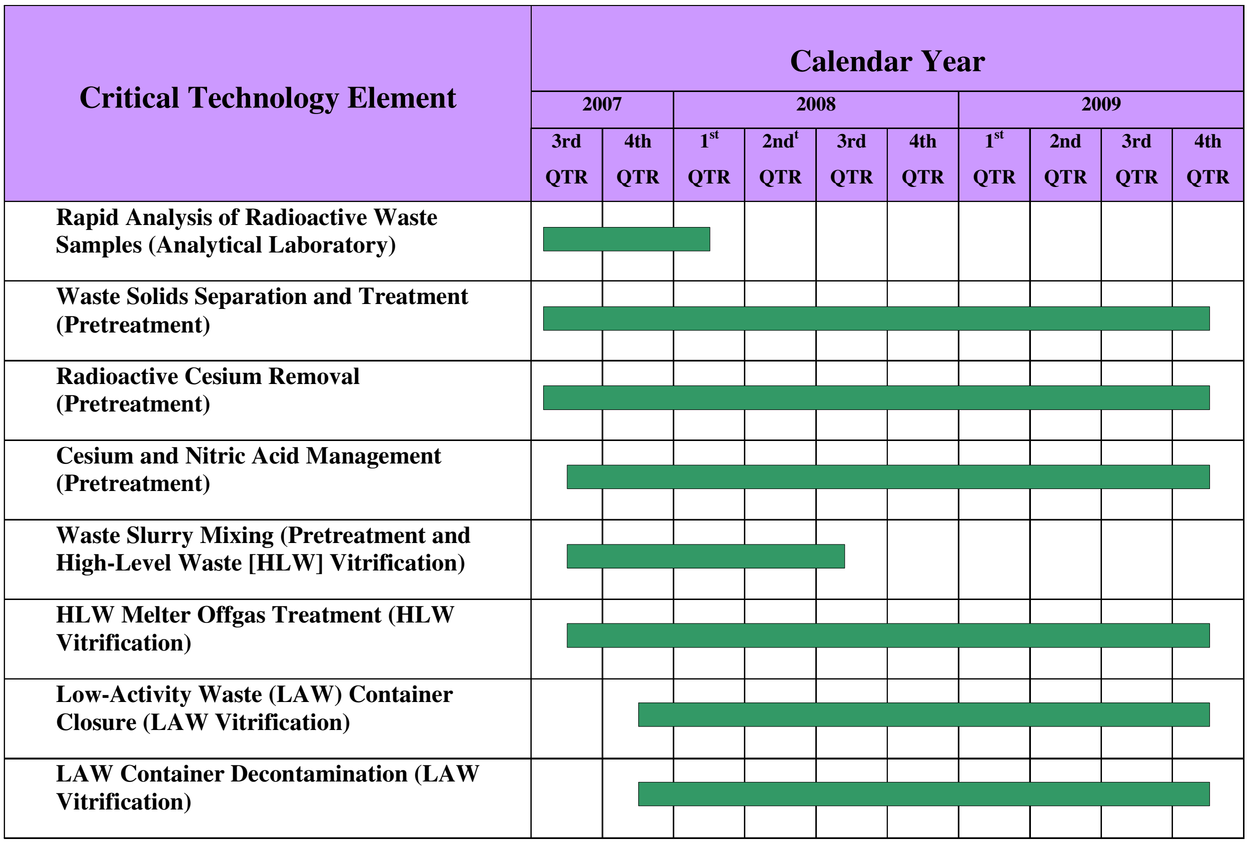
Current State of the Art TRL 4

The LAW container decontamination subsystem design is being finalized. Limited laboratory-scale testing has been completed to demonstrate proof of concept. Only pieces of the system tested have been tested on a laboratory scale.

	Milestones	Performance Targets	TRL Achieved at Milestone
2008	Reassess requirements for LAW container decontamination using a value engineering assessment; evaluate alternative technologies	Develop performance requirements for LAW container based on expected contamination levels and contamination mechanism; identify, evaluate and select preferred technology	4
2009	Complete prototypic testing of LAW container decontamination subsystem	Prototypic testing completed that demonstrated adequacy of technology	6

4.0 Technology Maturity Schedule

The Technology Maturity schedule for the activities described is shown below. The TMP activities are scheduled to demonstrate acceptable technology maturity required to support completion of construction and commissioning of the WTP on its current baseline schedule of February 2019.



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5.0 Technology Maturity Budget

The Technology Maturity budget for the activities described in this TMP is shown below as indicated by the heading "Additional TMP Cost". This budget is compared with the currently approved budget for resolution of respective technology maturity issues noted as "Current Technology Development Cost". A majority of the CTEs require additional technology maturity budget. All technology maturity costs for the "Rapid Analysis of Radioactive Waste Samples" are included in the current WTP approved budget.

Critical Technology Element	Current Technology Development Scope Cost ($K)[1]	Additional TMP Cost ($K)[2]
Rapid Analysis of Radioactive Waste Samples	$3,700	$0
Waste Solids Separation and Treatment	$57,100	$0
Radioactive Cesium Removal	$4,670	$7,240
Cesium and Nitric Acid Management	N/A[3]	$7,780
Waste Slurry Mixing	$17,700	$1,950
HLW Melter Offgas Treatment	$1,500	$2,210
LAW Container Closure	N/A[3]	$1,775
LAW Container Decontamination	N/A[3]	$4,025
Total	$84,670	$32,280

[1] Budget based on current IRPs. The estimated costs to resolve all EFRT issues is estimated to be $224M. See Appendix A for technology crosswalk between TRAs and EFRT recommendations.

[2] Additional TMP scope cost includes all identified potential activities to bring the CTE to a TRL 6.

[3] Does not apply. These technologies were not identified for technology development by EFRT.

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APPENDIX A. Crosswalk of WTP Technology Readiness Assessments and External Flowsheet Review Team Issues

Appendix A summarizes additional detail on the eight technology maturation issues discussed in the body of the Technology Maturation Plan (TMP). This discussion presents a summary from the U.S. Department of Energy (DOE)-conducted Technology Readiness Assessments (TRA) and External Flowsheet Review Team (EFRT)-conducted reviews of the technologies, maturity approach, and estimated maturation budget.

Included are two separate tables that list (1) the technology maturation topics that were identified by both the DOE completed TRAs and the EFRT assessment in which there was agreement, and (2) the EFRT issues that have been grouped as Design, Operations, and Programmatic.

Summary of Issues from Technology Readiness Level Assessment and EFRT Assessment		
Facility: Analytical Laboratory	**CTE:** LA-ICP-AES	**TRL**: 5
DOE TRA Assessment	The prototypical Laser Ablation-Inductively Coupled Plasma-Atomic Emission Spectrometer (LA-ICP-AES) system should be tested to demonstrate achievable detection limits for chemical elements of interest and satisfy turnaround time requirements on actual HLW sludge samples in a relevant environment to support the final design of the actual Analytical Laboratory subsystems. The LA-ICP-MS can be qualified in the Analytical Hotcell Laboratory Equipment System (AHL) after laser ablation technology has been implemented with ICP-AES in the AHL and is fully operational. Testing is recommended to confirm that the design of the LA-ICP-AES will meet its functional requirements. Design optimization for AHL implementation should continue following demonstration of the prototype. This testing is included in the Waste Treatment and Immobilization Plant (WTP) baseline.	
External Flowsheet Review Team (EFRT) Assessment	No related issues identified; part of baseline development plan.	
Maturity Approach	• Design prototype LA-ICP-AES test system • Test prototype LA-ICP-AES test system • Develop calibration and operating procedures for WTP LA-ICP-AES	
Budget Estimate	$3,700K included in WTP baseline	

Summary of Issues from Technology Readiness Level Assessment and EFRT Assessment		
Facility: Pretreatment	**CTE:** UFP, Ultrafiltration Process System	**TRL**: 4
DOE TRA Assessment	Development and testing at a laboratory scale with actual wastes, and at an engineering scale with simulants, should be completed in prototypical process and equipment testing systems to demonstrate all detailed flowsheets for the Ultrafiltration Process System (UFP) prior to final design. The testing should validate the scaling methodology for mixing, chemical reactions, and filter surface area sizing; determination of process limits; and recovery from off-normal operating events. Note: This planned testing work is in the WTP baseline as part of the testing identified in M-12, "Undemonstrated Leaching Process," and WTP baseline testing of the oxidative leaching process. Evaluation of a vertical modular equipment arrangement for the UFP filter elements for increasing the filter surface area should be continued. The design configuration (currently proposed horizontal or vertical orientation of the filters) that has the highest probability of successfully achieving performance requirements should be thoroughly tested in high-fidelity, prototypical engineering-scale tests using simulants that represent a range of tank waste compositions. Testing scope should include all filtration system operations, process flowsheets (caustic and oxidative leaching and strontium/transuranic precipitation), high-temperature filtration, and filter back pulsing, cleaning, draining, and replacement. Based on the results of this testing, a design concept (either the horizontal arrangement proposed by the Contractor or the vertical arrangement conceptualized by Energy*Solutions*) should be selected for final design. The strategy and method to scale the ultrafiltration processes (mixing, chemical reaction, and filter surface area) to predict performance of the ultrafiltration system should be established to ensure a high-fidelity UFP engineering-scale test platform and support useful interpretation of the testing results.	
External Flowsheet Review Team (EFRT) Assessment	*Undemonstrated Leaching Process* - Experiments to define the leaching steps have been carried out using only 50-250 ml samples. Scale-up of the processes using these data has not been demonstrated (M-12). *Inadequate Ultrafiltration (UF) Area and Flux* - For wastes requiring leaching, a combination of inadequate filter flux and area will likely limit throughput to the High-Level Waste (HLW) or Low-Activity Waste (LAW) Vitrification Facilities (M-13).	
Maturity Approach	• Radioactive testing of sludge treatment process at laboratory scale • Prototypic testing of UFP pilot plant to confirm design and process • Process modeling to simulate operation and performance of plant scale UFP • Identify, evaluate, and develop an alternative technology for the UFP	
Budget Estimate	$57,100K includes testing to mature current baseline technology and complete design changes for the WTP	

<table>
<tr><th colspan="3">Summary of Issues from Technology Readiness Level Assessment and EFRT Assessment</th></tr>
<tr><td>Facility: Pretreatment</td><td>CTE: CXP, Cesium Ion Exchange Process System</td><td>TRL: 5</td></tr>
<tr><td>DOE TRA Assessment</td><td colspan="2">Prototypic equipment testing should be completed, prior to continuing design of the hydrogen venting subsystem (nitrogen inerting and hydrogen gas collection piping system, control system) for removing hydrogen and other gases from the cesium ion exchange columns to demonstrate this design feature over the range of anticipated operating conditions.

The adequacy of the design concept for CXP-VSL-00001 should be re-evaluated and a determination made if this vessel should be modified to include mixing, chemical addition, and heating/cooling to mitigate anticipated process flowsheet issues with precipitation of solids in the CXP feeds (to be evaluated as part of the mixing system).

Testing of spherical resorcinol-formaldehyde (RF) resin should be conducted to: (1) assess physical degradation for irradiated resin samples; (2) assess effects from anti-foaming agent and separate organics present in the feed to the CXP; and (3) assess the impact of particulates on ion exchange column performance.

All currently planned testing and documentation of test results for spherical RF resin should be completed.
(Note: This planned work is in the WTP baseline.)

Additional research should be performed to attain a higher degree of understanding of the dissolution and precipitation kinetics for sodium oxalate.

The engineering specification for the ion exchange columns should be revised to incorporate the use of spherical RF resin and any design modifications resulting from closure of the EFRT recommendations for the CXP.</td></tr>
<tr><td>External Flowsheet Review Team (EFRT) Assessment</td><td colspan="2">Instability of Baseline IX Resin - The baseline ion exchange resin will not provide acceptable performance because of rapid degradation of its mechanical stability (M-14).

Questionable Column Design - In the preliminary drawings submitted by the vendor, the process fluid distribution/ collection piping for removing fluids from the column does not permit complete displacement of one process fluid by another. This may result in undesirable contamination/ mixing of the process fluids (M-10a).</td></tr>
<tr><td>Maturity Approach</td><td colspan="2">• Assess design and technology concepts for the hydrogen venting subsystem, select reference
• Conduct prototypic testing of hydrogen venting subsystem
• Demonstrate 99% removal of spent ion exchange resin
• Assess solids precipitation in ion exchange feed
• Assess impact of solids and organics on ion exchanger performance
• Complete radiation stability testing on ion exchange resin
• Establish detailed cesium ion exchange column design features</td></tr>
<tr><td>Budget Estimate</td><td colspan="2">Current budget for WTP baseline work $4,670K; additional TMP work scope $7,240K</td></tr>
</table>

Summary of Issues from Technology Readiness Level Assessment and EFRT Assessment		
Facility: Pretreatment	**CTE:** CNP, Cesium Nitric Acid Recovery Process System	**TRL**: 3
DOE TRA Assessment	The design of the Cesium Nitric Acid Recovery Process System (CNP) should be discontinued until: (1) a reassessment of the design and operational requirements for the CNP is completed; (2) the engineering specification for the CNP is revised to reflect operational conditions; and (3) the technology concept, which includes the process equipment and control system, is demonstrated through integrated prototypic testing. The CNP should be functionally tested prior to installation in the black cell. The testing should include: testing with representative process feed compositions; verification of the process control system concept; ability to control and monitor the composition of the nitric acid product; demonstrate the cesium decontamination factor of 5 million; and ability to adequately decontaminate the demister pads using the sprays installed in the separator vessel. The specific gravity operating limit for controlling the concentrated Cs eluate in the CNP separator to a maximum of 80% saturation should be re-evaluated. Based on the WTP Contractor's plan to neutralize Cs concentrate in the separator, and thereby create solids, this operating constraint may not be required. The engineering specification for the CNP should be modified to include: (1) the estimated variable feed composition; and (2) factory acceptance testing to demonstrate removal and installation of the demister pads from the separator vessel. The Contractor should reassess the corrosion evaluations for the CNP vessels and piping based the operating conditions of the system.	
External Flowsheet Review Team (EFRT) Assessment	No related issues identified.	
Maturity Approach	• Complete computer simulation of control system as establish control requirements • Assess alternative operating modes and design concepts for the CNP • Complete design assessment of the CNP and proposed integration into Pretreatment (PT) Facility processes • Complete prototypic testing of CNP	
Budget Estimate	TMP work scope $7,780K	

Summary of Issues from Technology Readiness Level Assessment and EFRT Assessment		
Facility: Pretreatment	**CTE:** PJM, Waste Slurry Mixing in Pretreatment and HLW Vitrification	**TRL**: 4
DOE TRA Assessment	Clear, quantitative, and documented mixing performance requirements for all pulse jet mixer (PJM)-mixed vessels in the PT Facility and HLW Vitrification Facility should be established. The requirements should be established for all vessel systems even though only those associated with Waste Feed Receipt Process System (FRP), HLW Lag Storage and Feed Blending Process System (HLP), Plant Wash and Disposal System (PWD), Treated LAW Evaporation Process System (TLP), and Waste Feed Evaporation Process System (FEP) were discussed in this assessment. PJM demonstration testing planned, as part of Issue Response Plan (IRP) M-3, "Inadequate Mixing System Design," should be completed. The testing information, supplemented with analysis, should be used to determine the design capability of each PJM mixed vessel and identify any required design changes. Process modeling to project the performance of the WTP and confirm design capability should use realistic assumptions on the effectiveness of mixing (both time and efficiency of mixing).	
External Flowsheet Review Team (EFRT) Assessment	*Inadequate Mixing System* – Current mixing system designs will result in insufficient mixing and/or extended mixing times (M-3).	
Maturity Approach	• Confirm mixing requirements for WTP process vessels • Confirm the mixing system design of PJM vessels containing Newtonian and non-Newtonian fluids to resuspend settled waste following a mixing system shutdown • Develop testing information that allows accurate prediction of required mixing time for various vessel-mixing functions • Confirm that post-design basis event mixing of vessels that use one-half of the PJMs for mixing adequately releases hydrogen • Demonstrate that normal process PJM mixing successfully meets mixing requirements for vessels containing Newtonian fluids and non-Newtonian • Identify and confirm mixing requirements for vessels that do not currently have mixing requirements.	
Budget Estimate	Current budget for WTP baseline work $17,700K, additional TMP work scope $1,950K	

Summary of Issues from Technology Readiness Level Assessment and EFRT Assessment		
Facility: HLW Vitrification	**CTE:** HOP/PVV Melter Offgas System	**TRL**: 5
DOE TRA Assessment	Testing of a prototypical HLW film cooler and film cooler cleaner should be completed to demonstrate the adequacy of the equipment concepts prior to cold commissioning. Note: This testing is part of the planned work to resolve the EFRT issue M-17, "HLW Film Cooler Plugging," dealing with film cooler blockages. Further testing of the WESP is recommended to address operational modes. The Vitreous State Laboratory of the Catholic University of America tests indicated difficulties restoring power to the Wet Electrostatic Precipitator (WESP) electrodes may be related to the melter feed composition (24590-101-TSA-W000-0009-174-00001). In some cases, the WESP electrodes could not be brought back up to full voltage after significant operation with low-activity waste (LAW) feeds. While no problems were observed with HLW simulants during DM1200 tests, operational information should be confirmed for the HLW feed to understand if feed properties caused the problems. Further evaluation is also recommended to prove the viability of 6% molybdenum (Mo) stainless steels for WESP internals and vessels in the WTP offgas environment. Selection of a corrosion resistant alloy for WESP vessels and internals is of critical importance, because the WESP vessel is not accessible for maintenance (except for the electrode connectors) or removable for the 40-year life of the HLW Vitrification Facility. The WESP vessel and internals are constructed of 6% Mo stainless steel (24590 HLW-N1D-HOP-00002). The article by Phull (2000) was the basis for the selection of the 6% Mo for the WTP in the WESP corrosion evaluation (24590-HLW-N1D-HOP-00002). Phull showed that even 6% Mo stainless steels exhibited very slight susceptibility to corrosion attack after 656 days of exposure to flue gases. Data from Phull implies that a 6% Mo alloy or greater stainless steel is needed in corrosive environments where long life is mandatory. Activated carbon vendor testing should be completed to confirm the behavior of organics, acids (nitrogen oxide [NO_x,] sulfur dioxide [SO_2], and halogen), sulfur, and mercury within the carbon bed. Note: Testing on the carbon bed material is scheduled to be completed as part of the WTP baseline within the next 12 months. Any problems identified by vendor testing of the activated carbon bed material may potentially impact the WTP design and the WTP environmental performance test plan (CCN:128559).	
External Flowsheet Review Team (EFRT) Assessment	*HLW Film Cooler Plugging* - Plugs will likely form in the melter film cooler or the transition line to the offgas system. These plugs will be difficult to remove and could constrain glass production (M-17).	
Maturity Approach	• Design, test and confirm design for HLW melter film cooler cleaner • Qualify the carbon-sulfur absorbent for mercury removal • Complete corrosion assessment for the WESP • Identify alternative operating approach in the event of premature WESP failure	
Budget Estimate	Current budget for WTP baseline work $1,500K; additional TMP work scope $2,210K	

Summary of Issues from Technology Readiness Level Assessment and EFRT Assessment		
Facility: LAW Vitrification	**CTE:** LFH, LAW Container Finishing Handling System Container Sealing Subsystem	**TRL**: 5
DOE TRA Assessment	Integrated prototypic testing of the actual immobilized low-activity waste (ILAW) container inert filling, flange cleaning, inspection, and lidding/delidding equipment system in a simulated remote environment should be completed prior to installation in the LAW Vitrification Facility to verify that the equipment system will perform as required.	
External Flowsheet Review Team (EFRT) Assessment	No related issues identified.	
Maturity Approach	• Complete Value Engineering assessment on requirements and design solution for LAW container sealing subsystem • Complete prototypic testing of LAW container sealing subsystem	
Budget Estimate	Additional TMP work scope $1,775K	

Summary of Issues from Technology Readiness Level Assessment and EFRT Assessment		
Facility: LAW Vitrification	**CTE:** LFH, LAW Container Finishing Handling System Container Decontamination Subsystem	**TRL**: 5
DOE TRA Assessment	Integrated prototypic testing of the actual ILAW container decontamination and smear testing systems in a simulated remote environment should be completed following fabrication of equipment components to verify the equipment system will perform as required and will achieve the WTP Project-specified surface decontamination levels (less than 100 dpm/100 cm^2 alpha and less than 1,000 dpm/100cm^2 beta-gamma). This testing program should be supplemented with laboratory scale testing to define the operational parameters for the carbon dioxide (CO_2) decontamination system.	
External Flowsheet Review Team (EFRT) Assessment	No related issues identified.	
Maturity Approach	• Identify expected contamination levels on the LAW containers (type, amount and adherence mechanism) • Assess requirements for decontamination of the LAW container • Define scope of testing for prototypic testing • Complete prototypic testing of LAW container decontamination system	
Budget Estimate	Additional TMP work scope $4,025K	

Technology Issues Identified by both the DOE TRAs and EFRT Assessments	**Issue Type**
Plugging in Process Piping – Piping that transports slurries will plug unless it is properly designed to minimize this risk. This design approach has not been followed consistently which will lead to frequent shutdowns due to line plugging.	Technology
Mixing Vessel Erosion – Large dense particles will accelerate erosive wear in mixing vessels. The effects of such particles on vessel life must be re-evaluated.	Technology
Designed for Commissioning Waste Rather Than Mission Needs – The WTP has not demonstrated that its design is sufficiently flexible to reliably process all of the Hanford Site tank farm wastes at design throughputs.	Technology
Must Have Feed Prequalification Capability – Without waste feed pre-qualification, each new batch of waste will require additional time for WTP to evaluate unit process responses and adjust operating parameters to define efficient processing. Bench-scale testing of unit operations with actual wastes would identify unexpected results and prevent potential plant problems.	Technology
Process Operating Limits Not Completely Defined – Many of the process operating limits have not been defined. Further testing is needed to define process limits for WTP unit operations. Without this more complete understanding of each process, it will be difficult or impossible to define a practical operating range for each unit operation.	Technology
Lack Of Comprehensive Feed Testing During Commissioning – The current plans for commissioning, which do not include leaching, do not adequately support WTP's future processing requirements.	Technology
Potential Gelation/ Precipitation – Some of the feeds to the leaching operation will contain significant amounts of aluminum and other materials that could precipitate. There is the possibility aluminum gel will form in the leach tank itself or in other streams from the leaching operation if unfavorable leaching conditions occur.	Technology
Inadequate Process Development – The effects of process variables, such as concentration of hydroxide, potassium, aluminum, and recycles along with flow rates and temperature, have not been determined experimentally.	Technology
Undemonstrated Sampling System – The sampling system may not prove adequate for handling slurries.	Technology

Design, Operational and Programmatic Issues Identified by the EFRT Assessment	**Issue Type**
Questionable Cross-Contamination Control – Elution utilizes the same piping as loading. Small quantity of trapped eluate can cause serious cross-contamination.	Design
Complexity of Valving – The design of the ion exchange system has >80 valves, many of which are interlocked to prevent processing in the event of incorrect valve line-up. This complexity increases the risks of processing outages and decreases expected availability.	Design
Cs-137 Breakthrough - The design of Cs-137 breakthrough monitoring is questionable.	Design
Pretreatment Facility Availability – The PT Facility will be difficult to reliably operate and maintain and may have less than desired availability.	Design
Inconsistent Short-Term vs. Long-Term Focus – DOE and the WTP Project have made design choices without consistently taking into account life-cycle costs. These decisions appear to be more focused on capital cost than on long-term operating cost and throughput.	Design
Incomplete Process Control Design – Adequacy of system performance due to documentation differences defining design basis, lack of agreed upon control strategy, and loss of experienced personnel needed to review system specifications.	Design
Inadequate Evaporator Control Scheme – Inadequate density measurement to control sodium concentration over the range of feeds.	Design
Misbatching of Melter Feed - There is a significant risk of mis-batching the LAW melter feed, leading to premature melter failure. This risk can best be eliminated through analysis of the melter feed.	Operational
Limited Remotability Demonstration - Planned remotability testing will not provide confidence that subcomponents in hot cells can be remotely changed out many years after commissioning.	Operational
Glass Formers Analysis at the Silos – Lack of analysis before unloading glass-forming chemicals (GFC) into silos.	Operational
Critical Equipment Purchases – Project must carefully evaluate critical material and equipment purchases (e.g., ion exchange columns and ultrafilters) to ensure the best equipment is purchased.	Programmatic
Loss of WTP Expertise Base – Loss of the WTP expertise base is already evident and likely to lead to a lengthy start-up and arduous operation. Because of the length of the WTP project and history of its funding, the continuity of the technical resources is impacted.	Programmatic
Lack of Spare LAW Melter – If a melter failure occurred, the WTP would have to operate at reduced throughput for an extended time (exceeding one year). This would severely impact completing the Hanford Site mission.	Programmatic
Lack of Spare HLW Melter – If a melter failure occurred, the WTP would have to operate at reduced throughput for an extended time (exceeding one year). This would severely impact completing the Hanford Site mission.	Programmatic

Appendix References

1. 24590-101-TSA-W000-0009-174-00001, Rev 00A, *Summary of DM1200 WESP History and Performance*, August 7, 2006, Bechtel National Inc., Richland, Washington.

2. 24590-HLW-N1D-HOP-00002, Rev. 2, *WESP Corrosion Evaluation*, December 22, 2005, Bechtel National, Inc., Richland, Washington.

3. Phull, B.S., W.L. Mathay, and R.W. Ross, 2000, "Corrosion Resistance of Duplex and 4-6% Mo-Containing Stainless Steels in FGD Scrubber Absorber Slurry Environments," presented at Corrosion 2000, Orlando, Florida, March 26-31, 2000, NACE International, Houston TX 77218.

4. CCN: 128559, "White paper on the Analysis of Naphthalene Destruction and Removal Efficiency (DRE) Testing at the Vitreous State Laboratory (VSL)," December 15, 2005, Bechtel National, Inc., Richland, Washington.