Hanford Tank Waste Treatment and Immobilization Plant (WTP) Waste Feed Qualification Program Development Approach – 13114

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ABSTRACT

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is a nuclear waste treatment facility being designed and constructed for the U.S. Department of Energy by Bechtel National, Inc. and subcontractor URS Corporation (under contract DE-AC27-01RV14136 [1]) to process and vitrify radioactive waste that is currently stored in underground tanks at the Hanford Site. A wide range of planning is in progress to prepare for safe start-up, commissioning, and operation.

The waste feed qualification program is being developed to protect the WTP design, safety basis, and technical basis by assuring acceptance requirements can be met before the transfer of waste. The WTP Project has partnered with Savannah River National Laboratory to develop the waste feed qualification program. The results of waste feed qualification activities will be implemented using a batch processing methodology, and will establish an acceptable range of operator-controllable parameters needed to treat the staged waste.

Waste feed qualification program development is being implemented in three separate phases. Phase 1 required identification of analytical methods and gaps. This activity has been completed, and provides the foundation for a technically defensible approach for waste feed qualification. Phase 2 of the program development is in progress. The activities in this phase include the closure of analytical methodology gaps identified during Phase 1, design and fabrication of laboratory-scale test apparatus, and determination of the waste feed qualification sample volume. Phase 3 will demonstrate waste feed qualification testing in support of Cold Commissioning.

INTRODUCTION

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is being designed and built to process and vitrify highly radioactive and mixed hazardous wastes stored in underground tanks at the Hanford Site. The tank waste is comprised of highly radioactive solids and liquid fractions in the form of sludge, salt cake, and supernatant liquid. Retrieval operations by the Tank Operations Contractor include staging the waste feed for transfer of supernatant and slurry fractions to WTP.

The waste feed qualification program is being developed to protect the WTP design, safety basis, and technical basis by assuring waste acceptance requirements are met before waste feed is transferred from the Tank Operations Contractor. During waste feed qualification, waste staged for transfer to the WTP is isolated, mixed, and sampled. The sample is then analyzed to

demonstrate compliance with the waste acceptance criteria (WAC). Waste processability is evaluated and the resulting waste treatment flowsheet is demonstrated laboratory- scale unit operations test apparatus.

The three components of waste feed qualification are described below, and are depicted in Fig. 1:

- Demonstrate compliance with the WAC: This demonstration is performed using standard and custom-developed laboratory instruments and techniques to quantify the acceptance parameters established in *Interface Control Document for Waste Feed* (ICD-19 [2]) and further defined in *Initial Data Quality Objectives for WTP Feed Acceptance Criteria* (WAC-DQO [3]).

- Evaluate waste processability: Once the WAC have been met, waste processability is then determined by evaluating the analytical results, and determining the process parameters needed to leach the waste [4], and other processing parameters. The outcome from the waste processability determination is a campaign-specific waste processing strategy.

- Demonstrate unit operations at laboratory scale: The waste processing strategy is then demonstrated using laboratory-scale unit operations test apparatus: waste concentration by evaporation, sludge washing and leaching, re-concentration by cross-flow ultrafiltration, ion exchange for Cs-137 removal, and glass formulation. A nominal recycle simulant may be used during specific unit operations tests that are affected by addition of recycles.

The results of waste feed qualification activities will be implemented using a batch processing methodology. Waste feed qualification results and the corresponding batch processing methodology will determine an acceptable range of operator-controllable parameters needed to treat the staged waste campaign. Specific parameters are then conveyed to operating staff in conjunction with system operating manuals to direct operational targets, limits, and action.

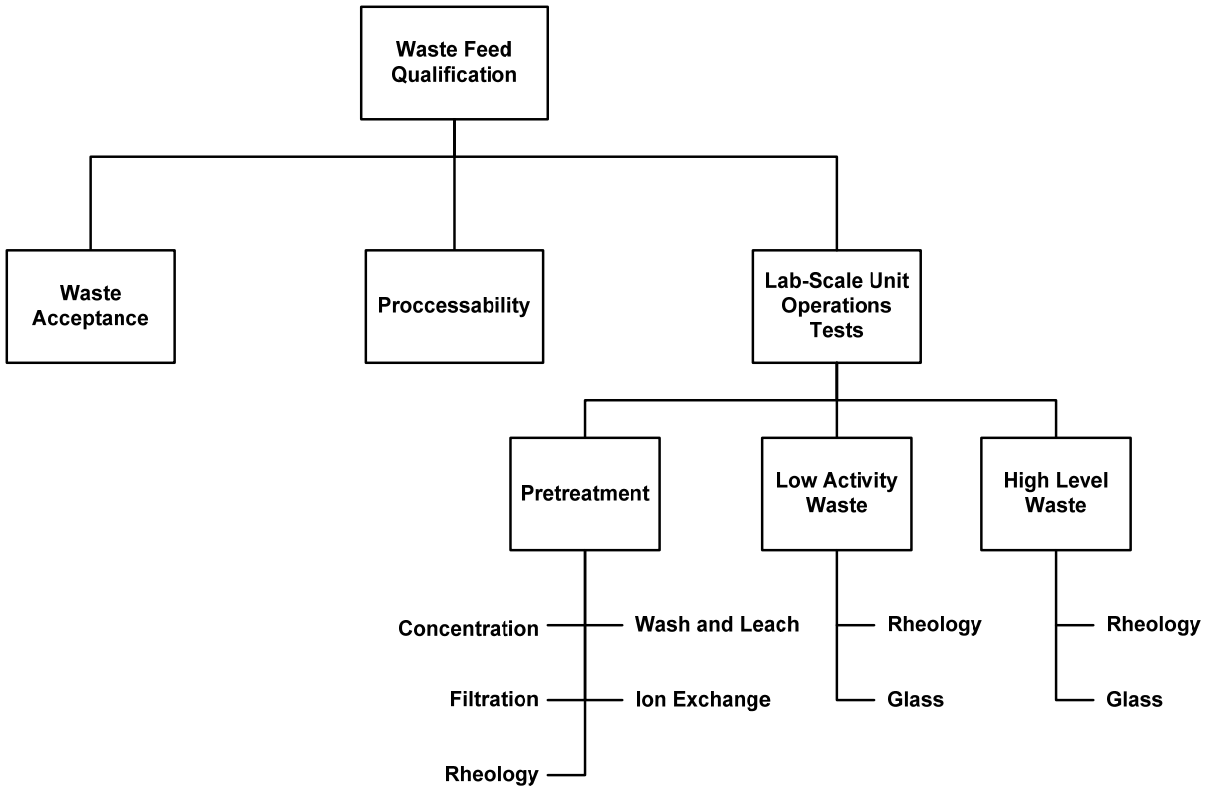

Fig. 1 Waste feed qualification program overview

WASTE FEED QUALIFICATION PROGRAM DEVELOPMENT

Waste feed qualification program development is being implemented in three separate phases in collaboration with Savannah River National Laboratory (SRNL) [5, 6]. Phase 1 is complete, and identified analytical methods needed to perform the WAC analysis as well as four analytical gaps. In addition, a series of recommendations were developed to support maturation of the waste feed qualification program. Phase 2 is in its early stages, and consists of: closure of analytical methodology gaps, design and fabrication of laboratory-scale unit operations apparatus, finalization of parameters to be measured and observed, and determination of the required sample volume. Phase 3 will demonstrate waste feed qualification testing in support of Cold Commissioning.

Phase 1 Development: Identify Methods to Demonstrate Compliance with Waste Acceptance Criteria

Demonstration of WAC compliance is performed on staged tank waste feed samples using standard and custom-developed laboratory instruments and techniques. This demonstration is required to characterize the staged waste feed through analysis of action limits parameters and processability parameters identified in the WAC-DQO [3]. The WAC compliance demonstration is to be performed before the first batch of a staged waste campaign is transferred from the Tank Operations Contractor to the WTP; subsequent batch transfers from the same characterized waste campaign do not require this demonstration.

During Phase 1, analytical methodologies for analyzing the physical, inorganic and organic, and radiochemical properties listed in the WAC-DQO [3] were proposed by the WTP. These methodologies were then reviewed by SRNL for technical adequacy and unit processing applicability. Based on the review, SRNL either concurred with the proposed methodology, recommended an alternative methodology, or confirmed that a methodology gap existed [7]. Closure of methodology gaps is discussed later in this paper. In addition, SRNL performed an assessment of the approach to perform waste feed qualification and acceptance [8]. These results provided the foundation for a technically defensible approach to performing waste feed qualification at the WTP.

Phase 2 Development: Develop Laboratory-Scale Apparatus to Evaluate Waste Processability and Demonstrate Unit Operations

The Phase 2 scope of work is the specification, fabrication, configuration, and demonstration of unit operations test apparatus used to perform the leaching determination and to demonstrate the campaign-specific waste feed treatment strategy. Additional activities include: closure of the analytical methodology gaps identified during Phase 1 and determination of the required sample volume.

Unit operations to be demonstrated include the following:

- Waste concentration by evaporation: Perform boil-down evaluations to monitor changes in physical properties and observe any occurrence of foaming within waste feed evaporation process (FEP) system (including recycles) and treated LAW evaporation process (TLP) system operational limits.

- Sludge leaching, washing, and cross-flow ultrafiltration: Demonstrate the leaching parameters selected during the leaching determination. Additionally: evaluate ultrafilter performance using a cell unit filter (CUF) apparatus, evaluate rheology and weight percent solids at selected intervals, obtain permeate necessary for ion exchange testing, and obtain the slurry phase for HLW glass production.

- Ion exchange for Cs-137 removal: Obtain ion exchange effluent for treated LAW glass production, obtain ion exchange regeneration eluant for HLW glass production, and evaluate spent resin to support determination of the spent resin disposal path in the Pretreatment Facility.

- HLW and LAW glass formulation: Using the appropriate glass formulation algorithms [9, 10] determine and add the required glass former chemicals to produce HLW and LAW glasses. Evaluate rheology of each feed stream after addition of the glass former chemicals, and fabricate LAW and HLW glasses.

During the demonstration of the campaign-specific waste treatment strategy, unit-specific parameters are to be measured along with measurements of hydrogen generation rate, rheology, and visual observations for the presence of foaming.

Waste Feed Concentration by Evaporation

WTP unit operations include two waste evaporation processes: FEP on the front end of process before other treatment, and TLP on the back end of the treatment sequence for treated LAW. The objective of LAW waste feed concentration is to adjust the sodium molarity and the solids concentration of some waste streams using scaled evaporator system apparatus. During these demonstrations, evaluations are performed to analyze changes in the waste's physical properties and as well as to observe for the occurrence of foaming. The evaluations are required to ensure waste concentrations are within the operational limits of the evaporator systems.

The following analyses are expected to be performed on concentrated FEP unit operations samples: sodium concentration (molarity), density; viscosity, and percent total solids including both total dissolved solids and undissolved solids.

The following analyses are expected to be performed on concentrated TLP unit operations samples: sodium concentration (molarity), density, viscosity, percent total solids including both total dissolved solids and undissolved solids, cool down curve (observation of samples for precipitation at different temperature and time intervals), chemical composition, and hydrogen generation rate.

Sludge Leaching, Washing, and Ultrafiltration

WTP unit operations include oxidative and caustic leaching and cross-flow ultrafiltration to create the HLW and LAW feed streams intended for vitrification. A scaled CUF system is to be used to perform the sludge leaching, washing, and cross-flow ultrafiltration unit operations demonstration. The parameters established during the leaching determination are confirmed through unit operations testing.

The apparatus is to be specified, fabricated, and configured to perform ultrafiltration and to confirm the leaching determination parameters, including: initial concentration by cross-flow ultrafiltration, caustic leaching, post caustic leach re-concentration by cross-flow ultrafiltration, first solids washing, oxidative leaching, second solids washing, and final concentration by cross-flow ultrafiltration.

The following analyses and observations are expected to be performed during this testing: foaming, slurry and permeate chemical composition, slurry rheology, slurry hydrogen generation rate, and permeate precipitation.

The leaching vessel is to be fabricated to allow for temperatures of up to 90 °C, to have the capability to add leaching reagents and dilution water (to represent collapsed steam), and to observe foaming. The cross-flow ultrafiltration assembly is expected to be a single, two-foot Mott filter element with a 0.1 μm pore size, a 1.27 cm (0.5 inch) inner diameter, and to have an effective filtration area of approximately 243 square cm (0.262 square feet). However, the exact specifications of the apparatus are an outcome of the equipment design phase.

Ion Exchange for Cs-137 Removal

WTP unit operations include ion exchange to remove Cs from the LAW waste. The ion exchange resin is elutable to transfer the removed Cs to the HLW waste stream. Ultrafiltration permeate produced during CUF system runs undergoes ion exchange in order to prepare treated LAW feed for vitrification. Prior to introduction into the ion exchange column, the CUF permeate is to be observed for signs of precipitation. The objectives of the ion exchange unit operation are to:

- Produce ion exchange effluent: The ion exchange effluent is sampled, concentrated through TLP boil-down, and used as feed for treated LAW glass formulation.

- Produce acid regeneration eluate: The eluate is analyzed for Pu and neutron absorbers (i.e., Cd, Mn, Ni, and Fe). The remainder of the eluate is combined with the final CUF system slurry sample to formulate HLW glass.

- Produce spent resin: The spent resin is to be dried and analyzed for radiological content and metals to support determining the spent resin disposal path in the Pretreatment Facility.

The ion exchange test apparatus is expected to be a scaled version of the ion exchange columns designed for the Pretreatment Facility. Cs-137 breakthrough is not expected to be measured. It is expected that the spherical resorcinol formaldehyde ion resin will be single use, such that it is used to qualify a single waste campaign. However, the exact specifications of the apparatus will be an outcome of the equipment design phase.

HLW and LAW Glass Formulation

The final step of unit operations testing is the formulation of glass. The types and quantities of glass forming materials to be mixed with the LAW and HLW feeds are determined using the appropriate glass formulation algorithm [9, 10], One the glass formers are added, rheological measurements are made and the mixtures are then vitrified at the crucible scale using a nominal melt temperature of 1150°C.

Selection of glass forming material types and quantities used during waste qualification support rheological measurements and preparation of HLW and LAW glasses. Glass forming material types and quantities selected for use during actual waste processing are determined through evaluation of process sample results and the use of the appropriate glass formulation algorithm.

The following steps are expected to be performed during glass formulation and analysis:

- Sample and analyze the treated HLW and LAW feed streams for constituents identified in the appropriate glass formulation algorithms, rheology (Bingham yield stress and consistency), and hydrogen generation rate.

- Use the appropriate glass formulation algorithm to determine the types and quantities of glass forming materials to be added to comply with glass product and processability constraints.

- Add the glass forming materials specified by the appropriate glass formulation algorithms.

- Sample and analyze the feed streams to confirm addition of glass forming materials and rheology (Bingham yield stress and consistency).

- Use the current glass formulation algorithm to confirm that the projected glass processability and product constraints are achieved before vitrifying the sample.

- Vitrify the feed streams and inspect the vitrified product for phase homogeneity or crystalline phase separation.

Phase 3 Development: Implementation During Cold Commissioning

Phase 3 is the implementation of the waste qualification program to support Cold Commissioning.

PHASE 1 RESULTS

Two reports were prepared during Phase 1. *SRNL Phase 1 Assessment of the WTP Waste Qualification Program* [8] summarizes SRNL's perspective of the WTP waste feed qualification program, including detailed insight into specific WTP unit operations. This report also provides a general overview of the Defense Waste Processing Facility waste qualification program in order to serve as a basis for comparison to WTP, as well as lessons learned. The report concludes with recommendations to promote the maturation of the WTP waste feed qualification program.

SRNL Phase 1 Assessment of the WAC/DQO and Unit Operations for the WTP Waste Qualification Program [7] documents the review of proposed analytical methodologies and unit operations for WTP waste feed qualification. This review was conducted in three parts: (a) review of proposed analytical methodologies for WAC action limits parameters, (b) review of proposed analytical methodologies for WAC processability and regulatory information parameters, and (c) review of unit operation approaches to be used in the laboratory scale flowsheet demonstration.

The review of (a) and (b) resulted in SRNL subject matters experts providing (1) concurrence with, (2) an alternative methodology, or (3) identification of a methodology gap for each of the WAC parameters. The analytical method gaps identified are: hydrogen generation rate, abrasivity, critical velocity, and the trace radionuclide Pa-231.

The hydrogen generation rate and abrasivity gaps are being closed as part of the Phase 2 development work. Development of a field deployed critical velocity measurement capability is being addressed by the Tank Operations Contractor [11]. Closure of the Pa-231 methodology gap is in hold pending an evaluation of the basis for including this radionuclide in the immobilized high level waste form compliance documentation. Development of a methodology to measure Pa-231 will be initiated, if required, upon completion of the evaluation.

PHASE 2 PROGRESS

Methods to measure hydrogen generation rate and abrasivity of tank farm samples during waste feed qualification are being developed by SRNL [6]. Development activities include performance of literature searches, development of recommendations for measurement apparatus, specification and design of the measurement apparatus, fabrication and testing of the apparatus, and transfer of the apparatus to the WTP. Specification, design, fabrication, and transfer of the unit operations test apparatus described in the sections above is future work.

INTERFACE WITH ON-GOING WORK

Waste qualification activities interface with on-going work being performed by the WTP and the Tank Operations Contractor. This work is briefly described below.

Tank Operations Contractor Mixing and Sampling Program

The purpose of the Tank Operations Contractor Mixing and Sampling Program is to mitigate technical risks associated with the ability of the tank farms waste feed delivery systems to mix, sample, and transfer HLW feed to meet the WTP WAC [11]. The Program is focused on three areas: limits of performance. This work is ongoing. Results from this work that affect ICD-19 [2] and the WAC DQO [3] would be incorporated into the waste qualification program.

Closure of ICD-19 and WAC DQO Open Items

ICD-19 [2] and the WAC DQO [3] contain a number of issues, open items, and actions that require resolution. As these items are resolved, changes to these documents may be needed. Corresponding changes would be incorporated into the waste qualification program.

INTERFACE WITH BATCH PROCESSING METHODOLOGY

Waste feed qualification outcomes are implemented using the batch processing methodology. When completed, the batch processing methodology will define the use of waste feed qualification results, WTP process sampling and analysis results, and process knowledge to define an acceptable range of operator-controllable parameters used to treat the staged waste campaign within the requirements of nuclear safety, chemical processing, and glass formulation quality. The methodology is implemented through campaign sheets and supporting batch sheets, which when coupled with the system operations manual, enables the treatment of waste feeds through the WTP. This is depicted in Fig. 2.

A campaign consists of multiple batches that have similar physical and chemical properties. Campaign sheets forecast the batch treatment approach for a specific waste campaign, based on the outcomes from waste feed qualification. In addition, campaign sheets will contain process decisions, such as whether or not to leach which are also outcomes of the waste feed qualification program.

Batch sheets will be developed using inputs from campaign sheets, process sample results, and current process conditions such as vessel and heel volumes to identify the parameters necessary to treat waste in a specific batch operation. Batch sheets are used with the system operating manual to control batch processes where waste processing parameters change from batch to batch, based on waste composition. The key parameters in batch sheets are waste identification, waste process authorizations and conditions (such as time and temperature), and target transfer volumes for waste and chemical reagents.

Development of the batch processing methodology is ongoing [12]. Further definition of the Plant's safety basis and technical basis as well as additional design activities will require evaluation and incorporation into the batch processing methodology as appropriate.

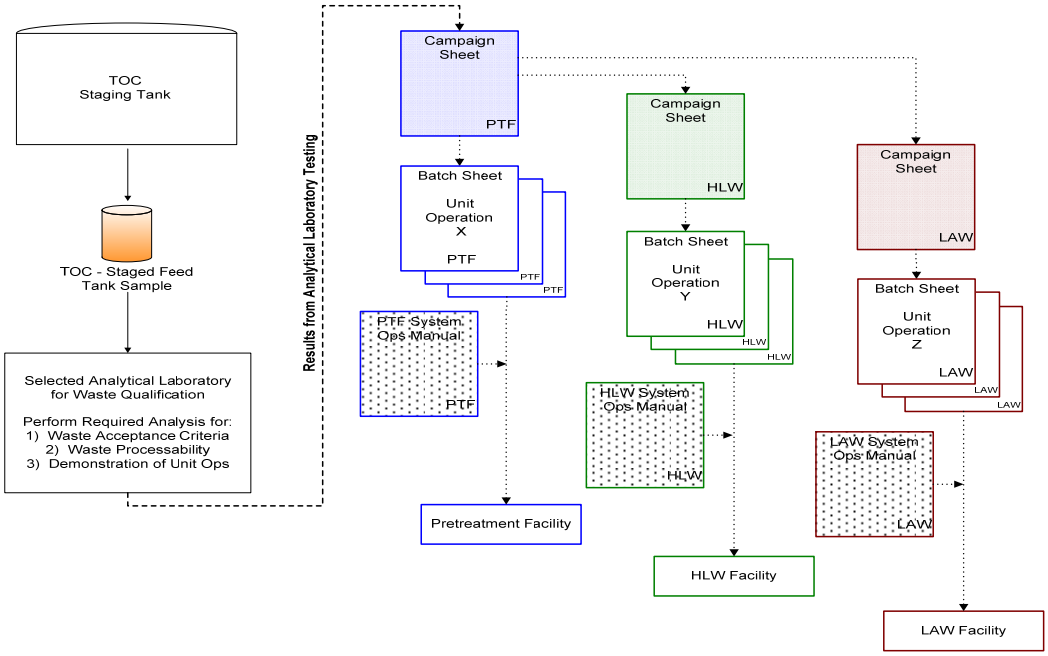

Fig. 2 Interaction between waste feed qualification and batch processing methodology

CONCLUSION

The WTP has established a framework for performing waste qualification using samples from each waste campaign staged by the Tank Operations Contractor. This framework has been reviewed and endorsed by SRNL, and consists of: demonstrating compliance with the waste acceptance criteria, evaluating waste processability, and demonstrating the selected waste processing strategy using laboratory-scale test apparatus. The approach is designed to protect the WTP design, safety basis, and technical basis by assuring waste acceptance requirements are met, and a campaign-specific waste treatment strategy is established before waste feed is transferred from the Tank Farm to the WTP.

Development of the waste feed qualification program capability is being performed in collaboration with SRNL, and consists of nine tasks:

1. Perform a literature search to identify unit operations test apparatus and protocol
2. Develop analytical methodology to measure abrasivity in a hot cell
3. Develop analytical methodology to measure hydrogen generation rate in a hot cell
4. Develop an integrated analytical and material flow diagram
5. Specify the LAW and HLW sample volumes required to perform waste feed qualification
6. Develop integrated work instructions for unit operations test apparatus, data collection and interpretation
7. Develop integrated work instructions for unit operations test apparatus, data collection and interpretation
8. Demonstrate the unit operations apparatus using representative simulants
9. Package and transfer custody of the unit operations apparatus

Completion of these nine tasks will enable the waste feed qualification laboratory, when selected, to successfully implement the waste feed qualification program for the WTP.

REFERENCES

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