K-Basins Sludge Treatment and Packaging at the Hanford Site – 13585

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ABSTRACT

Highly radioactive sludge resulting from the storage of degraded spent nuclear fuel has been consolidated in Engineered Containers (ECs) in the 105-K West Storage Basin located on the Hanford site near the Columbia River in Washington State. CH2M Hill Plateau Remediation Company (CHPRC) is proceeding with a project to retrieve the sludge, place it in Sludge Transport and Storage Containers (STSCs) and store those filled containers within the T Plant Canyon facility on the Hanford Site Central Plateau (Phase 1). Retrieval and transfer of the sludge material will enable removal of the 105-K West Basin and allow remediation of the subsurface contamination plumes under the basin.

The U.S. Department of Energy (DOE) plans to treat and dispose of this K Basins sludge (Phase 2) as Remote Handled Transuranic Waste (RH TRU) at the Waste Isolation Pilot Plant (WIPP) located in New Mexico. The K Basin sludge currently contains uranium metal which reacts with water present in the stored slurry, generating hydrogen and other byproducts. The established transportation and disposal requirements require the transformation of the K Basins sludge to a chemically stable, liquid-free, packaged waste form. The Treatment and Packaging Project includes removal of the containerized sludge from T Plant, the treatment of the sludge as required, and packaging of all the sludge into a form that is certifiable for transportation to and disposal at WIPP. Completion of this scope will require construction and operation of a Sludge Treatment and Packaging Facility (STPF), which could be either a completely new facility or a modification of an existing Hanford Site facility.

A Technology Evaluation and Alternatives Analysis (TEAA) for the STP Phase 2 was completed in 2011. A Request for Technology Information (RFI) had been issued in October 2009 to solicit candidate technologies for use in Phase 2. The RFI also included a preliminary definition of Phase 2 functions and requirements. Potentially applicable technologies were identified through a commercial procurement process, technical workshops, and review of the numerous previous sludge treatment technology studies. The identified technology approaches were screened using the criteria established in the Decision Plan, and focused bench top feasibility testing was conducted. Engineering evaluations of the costs, schedules, and technical maturity were developed and evaluated. Recommendations were developed based on technical evaluations. The criteria used in the evaluation process were as follows: (1) Safety, (2) Regulatory/stakeholder acceptance, (3) Technical maturity, (4) Operability and maintainability, (5) Life-cycle cost and schedule, (6) Potential for beneficial integration with ongoing STP-Phase 1 activities, and (7) Integration with Site-wide RH-TRU processing/packaging, planning, schedule, and approach.

The TEAA recommended Warm Water Oxidation (WWO) as the baseline treatment technology and two risk reduction enhancement options for further consideration during development of the process – size reduction and chemical oxidation (Fenton's reagent). The enhancement options would potentially allow a useful reduction in the total operating time required to process the K Basins sludge. The U.S. Department

of Energy's Richland Field Office (DOE-RL) has approved this recommended technical approach. The baseline process can be broken down into the following main process steps: (1) STSC transfer from T Plant to the Sludge Treatment and Packaging Facility (STPF). (2) Retrieval of sludge from the STSCs and transfer to the Receipt and Reaction Tank (RRT). (3) Preparation for immobilization by oxidation using heated water (i.e., WWO) for those batches that require it and concentration by evaporating water at about atmospheric pressure in the RRT. (4) Immobilization by using additives to eliminate free liquids and packaging of the treated sludge into drums. (5) Inspection and handling of the filled drums prior to transfer to a separate storage and shipping facility. (6) Handling of vapor, condensate, and other waste streams generated by the process. Each of these steps is discussed in the paper, together with the current state of progress in developing the technology and requirements for continued development. A schematic of the recommended baseline WWO treatment process is given below.

INTRODUCTION

K Basins Sludge Description

The K West Basin, where sludge materials are stored, is one of the last facilities in the Columbia River corridor containing stored nuclear material. Once these sludge materials are removed, the remaining structures will be demolished and removed by the 100K Project. Completion of K Basins sludge material removal will enable demolition of the K West Basin, 100 K Area remediation, and, ultimately, conversion of the K West (KW) reactor to interim safe storage – the last of the eight reactors to be placed in interim safe storage.

Highly radioactive sludge (containing up to 120,000 curies of actinides and fission products) resulting from the storage of degraded Spent Nuclear Fuel (SNF) has been consolidated in Engineered Containers (ECs) located in the 105-K West Storage basin near the Columbia River. This K Basin sludge material resulted from extended storage of excess N-Reactor fuel in both the KE and KW Basins. A significant fraction of the N Reactor SNF degraded during the lengthy underwater storage period due to damage to the Zircaloy cladding sustained during reactor discharge and the subsequent corrosion of the metallic uranium, along with basin water chemistry issues in the KE Basin. The SNF corrosion products, together with other debris, accumulated in the K Basins over the years. That portion which passed through a screen with a 0.64 cm (0.25 inch) opening is collectively referred to as sludge [1]. Most of the sludge on the KE Basin floor and in its adjacent pits has been transferred to KW Basin and consolidated into large (~5 ft. x ~12 ft. x 13 ft. tall) ECs for underwater storage. Most of the sludge on the KW Basin floor and in its adjacent pits has also been consolidated into ECs for underwater storage on the floor of the KW Basin. A small amount of sludge remains on the floor of the KW Basin which will be disposed as part of the decontamination and decommissioning of the basin.

Spent fuel cleaning and packaging operations were conducted in the KW Basin. SNF canisters from KE Basin were transferred to KW for cleaning and repackaging. The Integrated Water Treatment System (IWTS) was installed in the KW Basin to maintain water clarity during the fuel cleaning operations. Much of the material smaller than 0.25 inch that had been in the KE and KW canisters was captured either in IWTS Knock-Out Pots (KOP)/Strainers (particles larger than 600 microns), or in settler tanks or on garnet filters (particles smaller than 600 microns). Sludge previously contained in the settler tanks has been transferred to EC-230 and will remain segregated from the other EC sludge. The EC and settler tank sludge inventory are to be disposed as remote-handled transuranic (RH-TRU) waste in the Waste

Isolation Pilot Plant (WIPP) disposal facility. The KOP material is specifically excluded as a waste stream in this treatment process and has another route for its disposal and is outside the scope of this report.

The US Department of Energy's (DOE's) efforts to identify and implement an effective treatment and packaging system for the K Basin sludge have a long and difficult history. A number of disposition approaches have been initiated, but were abandoned for a variety of technical and programmatic reasons. Some 39 different alternatives analyses of varying depth and rigor have been documented over the last 10-15 years. In 2007, DOE reset the Sludge Treatment Project (STP) back to "between Critical Decision (CD)-0 and CD-1" [2]. DOE also directed that an updated alternative analysis be conducted, including compliance with DOE Order 413.3 (now DOE Order 413.3b) and utilization of DOE Standard 1189 and the Technology Readiness Assessment (TRA) process defined in the DOE TRA guide (now DOE Guide 413.3-4). DOE's primary objective was to reduce the technical and programmatic risk of the STP by utilizing the formal project management tools that DOE has established to assure successful project delivery.

In January 2009, CH2M Hill Plateau Remediation Company (CHPRC) issued an alternatives analysis report for the removal and treatment of the sludge contained in the K West Basin ECs and settler tanks [3]. The report documented the screening of hundreds of technology and implementation options and documented the detailed evaluation of seven retrieval and treatment strategy options. A key finding of the report was that DOE's expressed objective to meet a 2015 date to remove all waste materials from the Columbia River corridor with a high certainty resulted in a recommendation to divide the mission into two phases. Phase 1 was defined as the efforts to retrieve, transfer and interim store the K Basin sludge material on the 200 Area Plateau. The report concluded that "Commitment to final treatment technology is not required until Phase 2; this allows adequate time to develop and establish robust treatment and immobilization technologies and resolve any outstanding disposal pathway issues."

CHPRC is proceeding with a subproject to develop and demonstrate the retrieval process, install retrieval equipment in the KW Basin, and modify an existing annex to support loading of the sludge into Sludge Transport and Storage Containers (STSCs). The loaded STSCs will be shipped to the 200 Area plateau for interim storage in the T Plant Canyon facility. This subproject is defined as the Engineered Container Retrieval and Transfer System (ECRTS), and is also referred to as Phase 1 of the STP.

Phase 2 of the STP is defined as the treatment (stabilization) and packaging of the sludge such that it can be transported to and disposed at WIPP as RH-TRU waste [3]. Phase 2 is assumed to begin after the successful completion of Phase 1 sludge retrieval, transfer and placement in interim storage; commencing operations after an indefinite interim storage period. Phase 1 is well underway and is expected to complete its operations on schedule. Phase 2 work performed to date is limited to development of a Phase 2 Technology Evaluation and Alternatives Analysis (TEAA) and a Preliminary Technology Maturation Plan (PTMP). The primary purpose of the TEAA is to recommend to DOE a technical approach for Phase 2 treatment and packaging that represents a high certainty of successful deployment and completion of the STP treatment and packaging mission. The primary purpose of the PTMP is to recommend to DOE a plan for the development of the technology selected during the TEAA evaluation process. A Request for Technology Information (RFI) was issued in October 2009 to solicit candidate technologies for use in Phase 2. The RFI also include a preliminary definition of Phase 2 functions and requirements [4].

The *Preliminary STP Container and Settler Sludge Process System Description and Material Balance* (i.e. flowsheet) [5] defines the Phase 1 project flowsheet and estimated radionuclide and chemical compositions for the EC and settler tank sludge that will be loaded into the STSCs. The loaded STSCs represent both the product of the Phase 1 project and the starting material for the Phase 2 project. The original flowsheet estimates from this document for ^{239}Pu fissile gram equivalent (FGE) concentrations and volumes of primary sludge types to be packaged (on which the original TEAA was based but since revised) are found in Table I. In addition to the sludges listed in Table I below, three STSCs are estimated to be filled with sludge and garnet filter media from the KW Basin IWTS and one STSC filled with material from the ECRTS subproject sand filter media. The STP Phase 1 baseline assumed a total of 30 STSCs will be used to package sludge, garnet and sand filter materials for interim storage at T Plant, which provides allowance for uncertainties relative to flowsheet estimated quantities.

Table I. Quantities and composition of K Basin sludge (circa 2009)

	KE Engineered Containers	KW Engineered Containers	Settler	Total
Total Volume of Sludge (m^3)	18.4	5.1	5.4	28.9
FGE (g/m^3) [sludge concentration]	702	1,560	7,340	-

Sludge Treatment Requirements

An RFI was issued in October 2009 to solicit candidate technologies for evaluation [4]. The RFI specified that the sludge would be hydraulically removed from the STSCs and transferred to the treatment facility. As a result of this transfer process, it is assumed that the slurry would be diluted to 5% by volume solids and delivered for treatment and packaging at 70 gallons per minute (GPM) through a 1-1/2” diameter hose. The proposed treatment process is required to remove the excess water, treat the sludge to eliminate or reduce hydrogen gas production to acceptable levels, and eliminate free liquids in order to be in compliance with the requirements of the Remote Handled Transuranic Waste Authorized Methods for Payload Control (RH-TRAMPAC) [6] and the WIPP waste acceptance criteria (WAC) [7]. The treated sludge would then be packaged for transportation to WIPP for disposal as RH-TRU. It is anticipated that lag storage on the Central Plateau will be required before shipment to WIPP is completed, since the rate of packaging is likely to exceed WIPP’s ability to transport the certified packages to the repository in the same timeframe. The details of exactly how compliance will be measured and monitored has yet to be determined.

TECHNOLOGY EVALUATIONS

Technology Solicitations

CHPRC reviewed vendor responses to the RFI, the results of previous alternatives analyses, and information on additional technology options identified by the project; and conducted a technical workshop with knowledgeable staff from the project and PNNL. On the basis of this review CHPRC selected 8 candidate treatment processes for feasibility evaluation:

- Warm Water Oxidation (WWO)
- Fenton's Reagent Oxidation Process (FROP)
- Size Reduction Water Oxidation Process (SRWOP)
- Phosphate Ceramic Hydrogen Inhibitor Process (PCIP) using Borobond™[1]
- Peroxide Carbonate Oxidation Process (PCOP)
- In-Container Vitrification (ICV™)[2]
- Inductively Heated In-Container Vitrification System (IVS)
- Nitrate Chemical Inhibitor Process (NCIP)

Proof-of-concept testing was completed for key elements of all candidate technology approaches except IVS. IVS was at an early stage of development and was not advanced sufficiently to complete a feasibility demonstration in the time frame of TEAA study, so an engineering report was prepared to provide additional descriptive information for the evaluation process. Testing was carried out by five vendors and PNNL.

The purpose of the testing was to clearly demonstrate whether a specific technology approach was feasible at a bench scale for the process steps not previously demonstrated at a bench scale. Testing data was supplemented with pre-conceptual engineering studies to allow the comparison of the technology approaches on a sufficiently even basis. This basis allowed for the selection of the most suitable technologies for further development consideration.

CHPRC assigned a technology advocate for each of the selected technologies. The technology advocates served as the liaison or interface between the vendor participants and CHPRC. The technology advocates continued to work with their respective participants throughout the performance of respondents' activities. The technology advocates provided support to the decision-making process. The advocates served as Subject Matter Experts (SMEs) for each technical approach and provided information and support to the Decision Support Board (DSB), as well as supported development of the CHPRC recommendations.

Technology Evaluation Process

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[1] Borobond is the registered trademark of Ceradyne, Inc., Boron Products LLC, 3250 South 614 Road, Quapaw, OK 74363; all rights reserved.

[2] In Container Vitrification and ICV are registered trademarks of the Geosafe Corporation, a wholly-owned subsidiary of Battelle Memorial Institute of Columbus, Ohio, whose ICV technology is exclusively licensed to Impact Services, Inc., 103 Palladium Way, Oak Ridge, TN 37830; all rights reserved.

The evaluation activities were based on the testing and engineering study results. Using Warm Water Oxidation (WWO) as a reference baseline, detailed technology maturity evaluations and facility deployment concepts were developed. For the other technologies, material balances and process equipment sizing were developed and compared to the more detailed information developed to support definition of the WWO process. It was concluded that all the technologies except the vitrification technologies were sufficiently similar to the WWO process (the base case) that WWO could be used as a basis for an integrated flowsheet that contained most of the required elements of the other technologies.

To provide a uniform basis for evaluation of technologies, a process basis document was prepared to summarize key process functions, requirements, and enabling assumptions to be used as the basis for the engineering evaluation phase of the STP Phase 2 TEAA. The process basis document was provided to each testing contractor as an attachment to their Statement of Work (SOW). With the exception of NCIP, the contractors developed summary process descriptions and preliminary sizing and processing rate estimates for the technology alternatives based the process basis document. The CHPRC technical team laid out similar information for the NCIP.

The contractor reports showed some variation in approach and level of detail. To get to an "apples to apples" comparison, it was necessary for the CHPRC technical team to develop a set of standardized flowsheets. These flowsheets were developed by starting with the contractor input and making adjustments to allow comparison of the alternative flowsheets on a reasonably consistent basis.

The TEAA base case standardized flowsheet analysis for each process was developed using bases and assumptions defined by the technical team. The following list summarizes key bases and assumptions:

- The process capacity must provide for complete processing of the sludge into WIPP compliant drums within 5 years or less based on an assumed 70 % total operating efficiency (TOE).
- The calculations assume receipt of up to 13.2 m^3 (3,500 gallons) of dilute sludge and flush water per STSC. The treatment system must be designed to accept the entire batch in one transfer at up to 70 gallons per minute (265 liters per minute). For the TEAA, utilization of the STSCs as part of slurry receipt and treatment system is not allowed (may be considered in later project optimization work).
- A total of 24 STSCs containing K-Basin Sludge material are to be processed (current estimate was 30 STSC's)
- The assumed sludge volume breakdown is 18.4, 5.1, and 5.4 m^3 of as-settled sludge (SS) volume each for KE EC, KW EC, and settler sludge. These values agree with the Phase 1 baseline at the time the TEAA was initiated in October, 2009.
- For the base case calculation of the number of product drums required, an average loading of 40 ^{239}Pu FGE per drum is assumed unless waste loading is limited by physical volume of the sludge.
- The maximum size of uranium (U) metal particles in the KE and KW sludge is 6,350 µm (0.25 inch). Maximum size of U metal particles in the settler sludge is 600 µm.
- Water oxidation calculations assume uranium particles are oxidized to extinction using water at temperatures near the boiling point. Reaction time is calculated per the equation provided in the Sludge Project Technical Databook [8] assuming anoxic water. The base case assumes an oxidation rate "enhancement factor" of 1.0. Sensitivity cases may consider oxidation rate enhancement factors between 3.0 and 1/3 per Sludge Project Technical Databook requirements.

- Sludge processing time cycle analyses do not consider ramp up at the start of hot operations or clean out after sludge processing is completed.

Note that available data has continued to evolve since the TEAA was initiated, and in some cases base case assumptions used for the TEAA normalized flowsheets differ from current STP Phase 1 project baseline values due to evolution of the Phase 1 project technical basis.

For the STP Phase 2 TEAA, testing using actual K Basin sludge was not practical since limited amounts of K Basin sludge was available and most of the vendors and their supporting laboratories could not process radioactive materials. Therefore, simulants were required. The STP has established a formal definition of simulants to be used for various aspects of K Basin sludge testing [9]. A KW Origin Container Sludge simulant recipe was selected as the primary basis for the Phase 2 proof-of-concept testing. There are two versions of the base recipe:

- Physical Simulant. The simulant referred to as "physical simulant" contains no uranium. Cerium oxide and steel grit are substituted for uranium oxides. In addition to the "base simulant" as defined in the STP Sludge Simulant Strategy and Design Basis [9], supplemental components that were identified as important were added to the base simulant for certain tests (e.g. graphoil, organic ion exchange resin, zeolite/mordenite, and flocculent). In some cases the base recipe was modified on a case by case basis to meet needs of specific tests.

- Uranium Containing KW Container Simulant. The Uranium Containing KW Container Simulant was prepared by PNNL per reference [10] and supplied as needed for all tests that utilized uranium containing simulant.

In Phase 1 of the STP, sludge is removed from the 105 KW Basin, placed in STSCs, and transported to T Plant for interim storage. The Phase 2 process starts with a sludge batch in an STSC in storage at T Plant and proceeds through the following overall process sequence (see Figure 1 below):

- Retrieval. This first step includes removal of an STSC from storage in T Plant, transport of the STSC to the treatment facility, retrieval of the sludge from the STSC, and transfer to the Treatment System. The current assumption is that some type of hydraulic approach (e.g. sluicing) would be used for sludge retrieval, resulting in a diluted sludge slurry delivered as a relatively large batch (up to 13.2 m^3 or 3,500 gallons including assumed line flush water) to Treatment. The retrieval process is developed and demonstrated as part of the Phase 1 system design and is outside the scope of the current sludge treatment technology evaluation. For purposes of the TEAA, CHPRC did not consider utilization of the STSCs themselves as part of slurry receipt and treatment system (this may be considered as a potential optimization alternative in future design phases).

- Receipt, Treatment, and Preparation for Immobilization. These systems act as a buffer to prepare each batch for transfer to the immobilization system. Process details vary depending on the specific alternative. However, all systems receive and interim store the STSC batch, concentrate the dilute sludge slurry by removing water, treat the sludge in some way, and deliver smaller batches of concentrated and treated sludge to the Immobilization and Packaging System.

- Immobilization and Packaging. The immobilization and packaging system accepts batches of concentrated sludge and packages it in drums that are sealed, decontaminated if needed, assayed to determine content of WIPP reportable isotopes, and transferred to on-site storage or shipping facilities. Details of the immobilization process vary by alternative. Key functions are to eliminate any free liquids, reduce hydrogen generation to acceptable rates, and determine content of WIPP reportable isotopes in each drum.

- Storage and Shipping. Finished drums will be stored on-site and eventually shipped to WIPP for disposal.

The retrieval, receipt, and storage functions are common to all the technology options. While not expressly discussed in the technology evaluation, cost allowances for retrieval are included in the cost estimates.

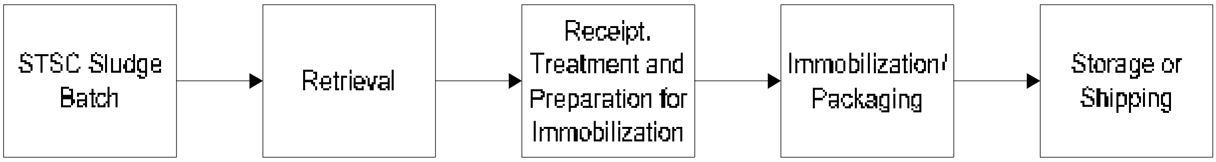

Figure 1. STP Phase 2 Overall Process Steps

All of the water-based processes (Warm Water Oxidation, Fenton's Reagent Oxidation Process, Peroxide Carbonate Oxidation Process, Phosphate Ceramic Hydrogen Inhibitor Process, and Nitrate Chemical Inhibitor Process) follow the same general process flow diagram with minor differences. Figure 2 illustrates the general process for these technologies.

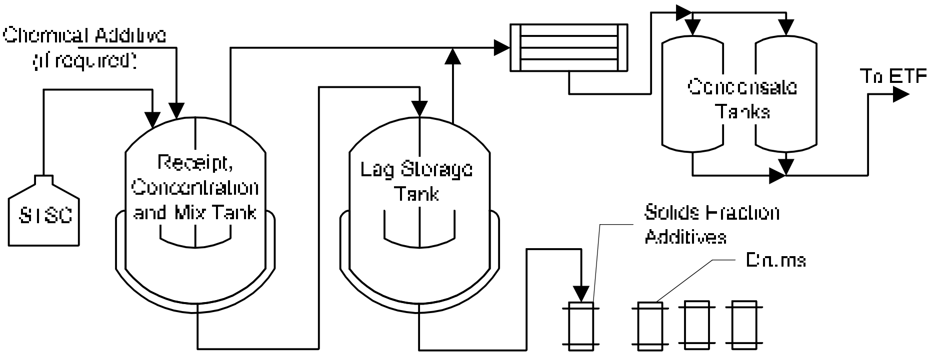

Figure 2. Simplified Flow Diagram for Water-Based Processes

TECHNOLOGY SELECTED

The identified technology approaches were screened using the criteria established in the Decision Plan [11], and focused bench top feasibility testing was conducted. Finally, engineering evaluation of the costs, schedules, technical maturity were developed and evaluated by the technical team. CHPRC empanelled a Decision Support Board (DSB) to review the collected information and formulate recommendations to the project. The CHPRC recommendations were developed based on input from the DSB and the CHPRC technical team. The criteria used in the evaluation process were as follows:

1. Safety
2. Regulatory/stakeholder acceptance
3. Technical maturity
4. Operability and maintainability
5. Life-cycle cost and schedule
6. Potential for beneficial integration with ongoing STP-Phase 1 activities
7. Integration with Site-wide RH-TRU processing/packaging, planning, schedule, and approach

Description of the Technology

CHPRC recommended that Warm Water Oxidation be identified as the technical baseline for the Phase 2 Treatment and Packaging project. In parallel, CHPRC recommended that DOE develop the Size Reduction and Fenton's Reagent Processes to a Technology Readiness Level of 4 (TRL-4) to further reduce risk, and potentially shorten the sludge treatment time by 2-3 years.

The updated and more detailed conceptual flowsheet on which further process development is based is given in Figure 3 below.

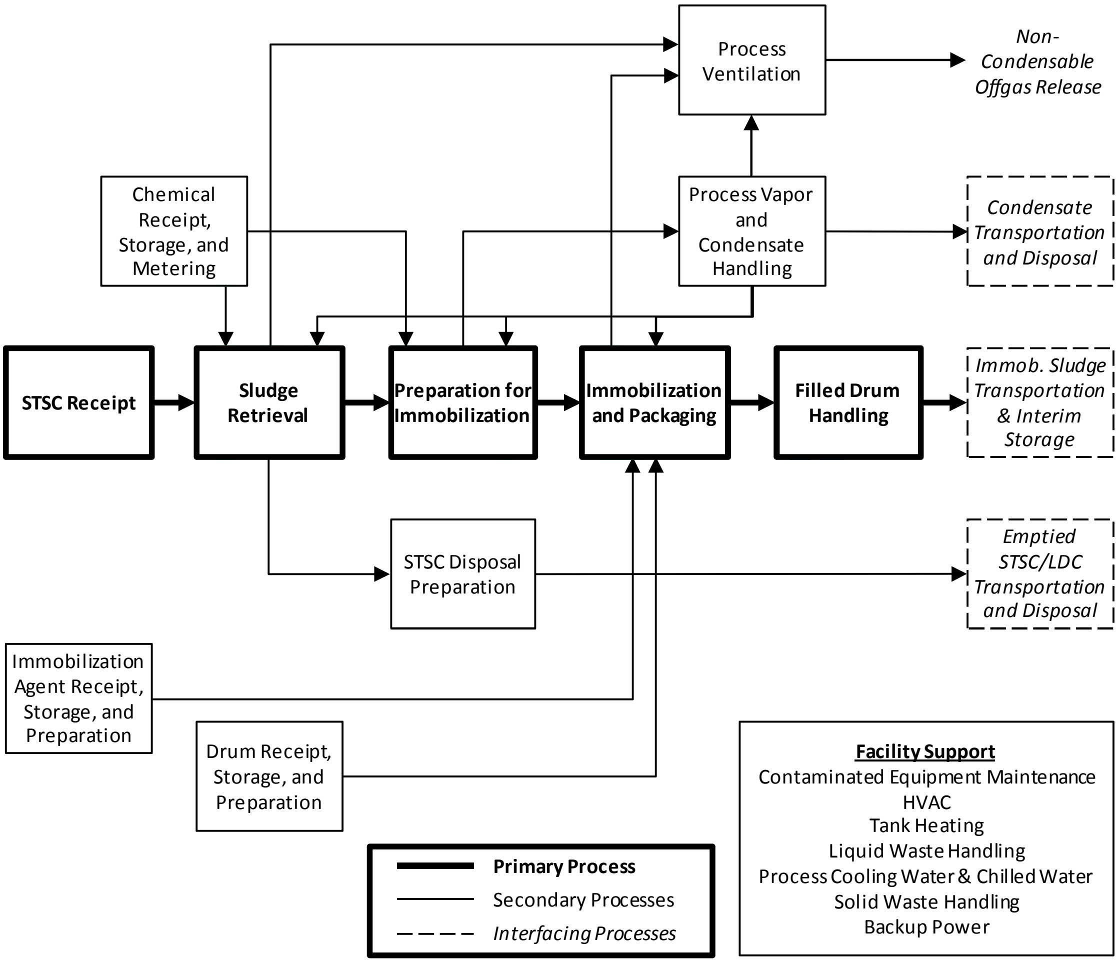

Figure 3. STP Phase 2 Process Flow Diagram.

The first order functional requirements for the Sludge Treatment and Packaging Facility, have been further defined in the *K Basins Sludge Treatment Project Phase 2 – Draft STPF Siting Study Decision Plan* [12]

- Receive the STSC into the STPF and position it for sludge retrieval.
- Retrieve the sludge from the STSC and transfer it to the RRT.
- Prepare the empty STSC for onsite disposal.
- Prepare the sludge for immobilization by oxidizing the uranium metal and reducing the volume of the sludge by evaporation.
- Immobilize and package the sludge to produce packages that: have no free liquids, have a determined content of WIPP reportable isotopes, have low external contamination suitable for onsite handling and storage, and are certifiable for eventual shipment to WIPP.

- Handle the immobilized sludge packages and prepare them for shipment to an onsite interim RH TRU storage facility.
- Handle the vapor and condensate from sludge preparation.
- Collect and dispose of excess wastewater (i.e., process condensate and any spills or leaks).
- Handle and prepare failed, contaminated equipment for disposal.
- Provide substantial shielding to protect operators.
- Provide remote handling capability to protect operators.
- At least demonstrate the performance attributes of a nuclear hazard category 2 facility.
- Provide safety-significant controls.
- Meet current seismic and other NPH requirements.
- Meet requirements of 10 CFR 835 and CHPRC-00073, CHPRC Radiological Control Manual.

During the development of the PTMP and subsequent siting studies, it became evident that the substitution of a second Receipt and Reaction Tank (RRT) for the originally configured Lag Storage Tank (LST) would enhance the process by giving it more flexibility in processing strategies and would reduce the processing time by chemically reacting two batches in parallel. A schematic diagram of the resulting improved process is given in Figure 4 below.

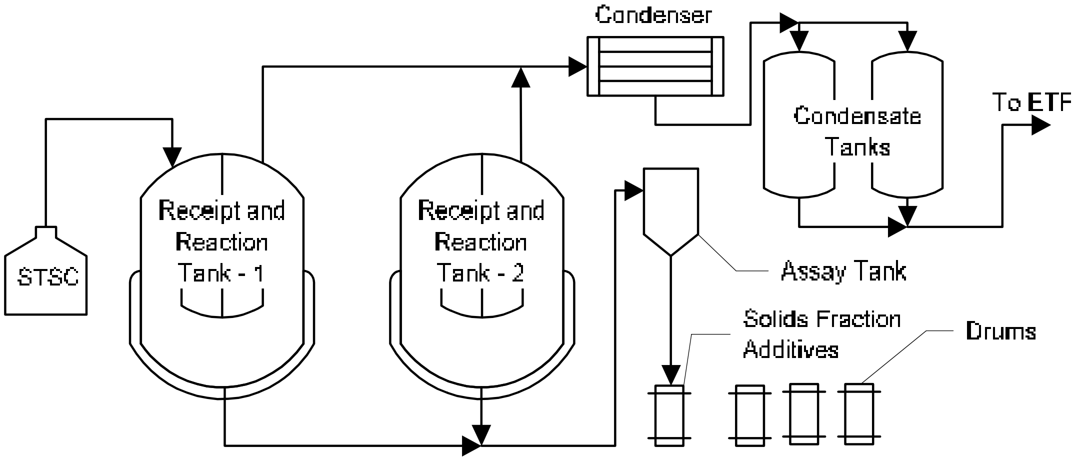

Figure 3. Warm Water Oxidation, Parallel Process

The baseline process can be broken down into the following main process steps:

- STSC transfer from T Plant to the Sludge Treatment and Packaging Facility (STPF).
- Retrieval of sludge from the STSCs and transfer to the Receipt and Reaction Tank (RRT).
- Preparation for immobilization by oxidation using heated water (i.e., WWO) for those batches that require it and concentration by evaporating water at about atmospheric pressure in the RRT.
- Immobilization by using additives to eliminate free liquids and packaging of the treated sludge into drums.

- Inspection and handling of the filled drums prior to transfer to a separate storage and shipping facility.
- Handling of vapor, condensate, and other waste streams generated by the process.

Enhancement Options

In addition, the following enhancement options, which reduce overall processing times, were evaluated to define the technology maturity activities required prior to incorporation into the baseline process. Significant proof of concept work has already been completed for these options under the TEAA.

- Size Reduction
- Chemical Oxidation (Fenton's Reagent)

The systematic approach taken to identify needed development testing and engineering evaluations included identification of the risks and issues related to each portion of the process. Development activities were then identified to:

- Resolve identified risks and issues;
- Support selection of technologies and design concepts to be implemented;
- Provide data needed to support design and associated safety and regulatory analyses;
- Verify enabling assumptions; and,
- Demonstrate selected technologies through at least TRL 4. General consideration was also given to development and testing needed to achieve TRL 6.

TECHNOLOGY DEVELOPMENT PLANNING

Tri-Party Agreement (TPA) milestone M-016-171 (due March 31, 2012) required DOE to "submit a schedule including proposed new interim milestones for bench scale or identified testing in order to meet M-016-173" [13]. The requirements for milestone M-016-173 (due March 31, 2015) stipulated that DOE should "Select K Basin sludge treatment and packaging technology and propose new interim sludge treatment and packaging milestones." The PTMP provided input to support development of the DOE submittal to satisfy TPA Milestone M-016-171, in addition to providing input for project planning purposes.

The development of the PTMP followed a structured evaluation approach adapted from DOE's TRA guide [13]; however, it should be noted that this was not a formal Technology Maturation Plan (TMP), and that much of the technology definition and verification testing described in the document would need to be completed prior to conduct of a formal Technology Readiness Assessment (TRA) and subsequent development of a TMP.

For the current technology development planning effort, Potential Critical Technology Elements (PCTEs) and associated technology maturation requirements were developed based on the TEAA and earlier STP studies, which have been updated based on more recent information. Overall process functions were systematically evaluated to identify PCTEs that may be classified as Critical Technology Elements (CTEs) in a future TRA. For the baseline process the following PCTEs were identified:

1. STSC Operations (STSC Transfer, Sludge Retrieval, and STSC Disposal Preparation)
2. Warm Water Oxidation Process
3. Integrated Waste Treatment and Packaging System
4. Agitation of Process Slurry Tanks
5. Slurry Transfer
6. Process Vapor and Condensate Handling
7. Sludge Assay and Control of Sludge Addition to Drums
8. Verification of Uranium Oxidation Completion
9. Remote Operating and Maintenance Features of Preparation for Immobilization
10. Immobilization and Packaging
11. Filled Drum Processing

During the initial concept definition phase a number of engineering studies would be needed to support selection of technologies and design concepts, develop optimized flowsheets, and to better define the scope of specific testing needed to support concept definition. Testing would be needed during this time frame to demonstrate functionality of candidate concepts or technologies and to provide performance data needed to compare alternatives. Once technology selection and concept definition have been completed, component and/or system validation testing would be performed for all PCTEs to achieve a minimum of TRL 4. Development work for a number of the technologies would involve substantial resources due to the required scale, support facilities, equipment, and/or complexity of testing. The bulk of the resources would be expected to be needed for the following:

- Engineering evaluations and proof of concept testing for Sludge Retrieval from STSCs
- Size Reduction engineering evaluation and development testing
- Warm Water Oxidation Process testing and flowsheet studies, including the chemical oxidation (Fenton’s Reagent) enhancement alternative
- Slurry Transfer system proof of concept testing
- Immobilization and Packaging engineering evaluations and development testing
- Development of data on behavior and properties of actual sludge during processing.

Additional testing and development work identified in the PTMP represent a smaller demand for resources as compared to the major items listed above. Testing needs for other technologies will be identified as the process design is developed.

CONCLUSIONS

Sludge Retrieval and Slurry Transfer equipment testing will need to be essentially full scale to achieve TRL 4 since the physical relationships of the major components are important and do not scale down easily. Since the testing will need to be at full scale, the investment in test systems and test support systems with better fidelity and capabilities at TRL 4 should be cost effective in view of the fact that they will have continued application for testing to demonstrate TRL 6.

The WWO and Chemical Oxidation process testing to achieve TRL 4 is expected to include tests with uranium metal and oxides at laboratory scale and bench scale, up to about a 4 liter batch size. This may be sufficient to resolve issues that must be addressed with uranium present. If not, larger scale process testing using uranium based simulants will be needed to achieve TRL 6. The required scale for TRL 6 testing with uranium based simulants will be determined after additional data becomes available. Equipment oriented testing for agitation of the process vessels will be performed at engineering scale (10% to 100% of full scale) with physical simulants (no uranium).

Proof of concept/screening tests for the Size Reduction Milling Tank will need to be at about 10% to 25% of full scale, while TRL 4 and TRL 6 testing will likely need to be on a larger scale (⅓ to ½ scale or larger). Since the testing to achieve TRL 4 needs to be at a similar scale to TRL 6, the investment in test systems and test support systems with better fidelity and capabilities at TRL 4 should be cost effective since they will have continued use to achieve TRL 6. Also, this approach will improve the quality of TRL 4 testing and lead directly to work required to achieve TRL 6.

Equipment for the Immobilization and Packaging System and its component sub-units will need to be tested at full scale or near full scale to address technology customization and integration issues. These issues include in-drum mixing and drum handling, controlling spread of radioactive materials, remote operations, and remote maintenance features.

Data on the behavior and properties of actual sludge will be developed using laboratory scale testing with existing samples of K Basins sludge. The results will be compared to data using physical simulants and uranium bearing simulants to verify that the behavior of the simulants is consistent with the actual sludge.

REFERENCES

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