STATUS AND DIRECTION OF THE BULK VITRIFICATION PROGRAM FOR THE SUPPLEMENTAL TREATMENT OF LOW ACTIVITY TANK WASTE AT HANFORD

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ABSTRACT

The DOE Office of River Protection (ORP) is managing a program at the Hanford site that will retrieve and treat more than 200 million liters (53 million gal.) of radioactive waste stored in underground storage tanks. The waste was generated over the past 50 years as part of the nation's defense programs.

The project baseline calls for the waste to be retrieved from the tanks and partitioned to separate the highly radioactive constituents from the large volumes of chemical waste. These highly radioactive components will be vitrified into glass logs in the Waste Treatment Plant (WTP), temporarily stored on the Hanford Site, and ultimately disposed of as high-level waste in the offsite national repository.

The less radioactive chemical waste, referred to as low-activity waste (LAW), is also planned to be vitrified by the WTP, and then disposed of in approved onsite trenches. However, additional treatment capacity is required in order to complete the pretreatment and immobilization of the tank waste by 2028, which represents a Tri-Party Agreement milestone between the US Department of Energy, the US Environmental Protection Agency and the State of Washington.

To help ensure that the treatment milestones will be met, the Supplemental Treatment Project managed by CH2M HILL Hanford Group, Inc. was undertaken in 2002. As an outcome of this project, the bulk vitrification process was recommended for further evaluation. The evaluation involves establishing a full-scale bulk vitrification pilot plant and treating actual LAW from Hanford tank 241-S-109 as part of a Research, Development and Demonstration project. The pilot-plant is scheduled to commence operations in late 2005. This paper will provide an overview of the bulk vitrification process and the progress in establishing the pilot-plant.

INTRODUCTION

The Hanford Site, located in southeastern Washington State, has been a U.S. government installation since 1943. The Site has served national needs first as part of the Manhattan Project and later in the Cold War era. Today, the U.S. Department of Energy (DOE) is responsible for the site, and its mission is environmental cleanup. Within DOE, the Office of River Protection is charged with retrieving radioactive waste from the Hanford tanks and treating it for its eventual disposal.

CH2M HILL Hanford Group, Inc., is the Office of River Protection's prime contractor and is responsible for storing and retrieving more than 200 million liters (53 million gal.) of highly radioactive and hazardous waste. This waste resulted from nuclear fuel reprocessing and is currently stored at 18 tank farm locations in 177 underground tanks: 149 single-shell (see Figure 1) and 28 double-shell tanks.

Fig. 1. One of Hanford’s single-shell tanks during construction.

Current plans call for the tank waste to be retrieved from the aging tanks and partitioned to separate the highly radioactive constituents from the large volumes of chemical waste. These highly radioactive components will be vitrified into glass logs in the Waste Treatment Plant (WTP), temporarily stored on the Hanford Site, and ultimately disposed of as high-level waste in the offsite national repository. The less radioactive chemical waste, referred to as low-activity waste (LAW), is also planned to be vitrified and then disposed of in approved onsite trenches.

In 1989, the Washington State Department of Ecology, the U.S. Environmental Protection Agency, and DOE entered into an agreement (known as the Tri-Party Agreement [TPA]) to ensure that federal regulations concerning Hanford Site cleanup were followed. The TPA milestones for completing the pretreatment and immobilization of Hanford tank waste are scheduled for completion by December 31, 2028.

To help ensure that these milestones will be met, the Supplemental Treatment Project was undertaken. The project, managed by CH2M HILL, involves the testing, evaluation, design, and deployment of supplemental LAW treatment and immobilization technologies. Applying one or more supplemental treatment technologies to the LAW has several advantages, including providing additional processing capacity, reducing the planned loading on the WTP, and reducing the need for double-shell tank space for interim storage of LAW. As an outcome of the Supplemental Treatment Project, the bulk vitrification process was recommended for further evaluation.

The bulk vitrification process is based on AMEC’s In-Container Vitrification™ (ICV)[a] process and involves batch melting in a disposable, refractory-lined steel container. Results from the FY-03 program were summarized by Thompson, et al. (1). A photograph of the full-scale container used in the FY-2003 Supplemental Treatment Project to demonstrate the bulk vitrification process with simulated LAW is provided as Figure 2. It is a robust, relatively simple treatment technology that results in a glass product with excellent durability, high waste loading, and significant waste volume reduction. This technology has been used commercially by AMEC in the US and internationally. The container size and configuration of the process varies depending on project requirements.

Fig. 2. Photograph of a 28-m^3 (37-yd^3) melt container and off-gas hood assembly during a full-scale bulk vitrification test with simulated LAW in FY-2003

As a next step, the Demonstration Bulk Vitrification System (DBVS) project was initiated in FY-2004 to design, procure, assemble and operate a full-scale bulk vitrification pilot-plant to treat up to 200,000 gallons of low activity tank waste from Hanford tank 241-S-109 under a Research, Development and Demonstration permit. The project will provide a full-scale bulk vitrification demonstration facility that can be used to assess the effectiveness of the bulk vitrification process under actual operating conditions. The pilot-plant is scheduled to commence operations in late 2005.

DBVS PROJECT STRUCTURE AND OBJECTIVES

The DBVS project consists of three main tasks including:

- Task 1 – Testing to support process improvements and waste form qualification.
- Task 2 – Design, procure, assemble and operate the DBVS facility using simulated LAW.
- Task 3 – Readiness review activities followed by gradual introduction of LAW into the plant.

The DBVS project will result in the production of up to 50 full-scale containers of immobilized tank waste to further research and develop systems, designs and operating philosophies envisioned for the production bulk vitrification System and to confirm the effectiveness of the bulk vitrification process in treating a wider range of tank wastes.

During operations of the DBVS facility, a number of operational and equipment parameters will be varied to evaluate the response of the bulk vitrification process for the treatment of actual LAW from tank 241-S-109. In addition, responses to variations in the feed composition will be evaluated to confirm the effectiveness of the bulk vitrification process for treating a wide range of low activity tank wastes at Hanford.

Glass waste form qualification work combined with a wide range of tests and analyses to help assess the effectiveness of the bulk vitrification process will be carried out over the life of the project.

Key objectives of the DBVS project include:

- Support the joint decision between the Department of Energy (DOE), Ecology and the Environmental Protection Agency (EPA) regarding Supplemental Technology
- Determine impacts of waste treatment operations on the equipment and support systems
- Gain valuable waste form qualification data to support full-scale production operations
- Validate equipment size, throughput and technical viability
- Evaluate the effectiveness of new process equipment
- Gain operational and maintenance experience with equipment
- Improve glass waste form performance including the reduction of additives and the evaluation of alternative soils as the source of glass formers
- Validate system technical viability and size
- Validate system throughput capabilities and refine life cycle cost estimates.

BULK VITRIFICATION PROCESS DESCRIPTION FOR THE DBVS PROJECT

A simplified process flow diagram for the DBVS plant is shown in Figure 3. An illustration of the DBVS plant highlighting some of the main components is provided in Figure 4.

For the DBVS project, the liquid waste from tank 241-S-109 will be retrieved by CH2M HILL and conditioned to remove solids to result in a 5 molar sodium solution. The liquid waste will be pumped to the DBVS pilot plant to a series of three waste receipt tanks.

To prepare a batch for treatment, liquid waste is pumped to a vacuum-type paddle dryer where it is mixed with soil and dried to an approximate moisture content of 1-3% by weight. The vapor that evolves from the dryer is filtered and condensed, then pumped to holding tanks for later transfer to a separate liquid waste effluent treatment system. After the soil and LAW is mixed and dried, zirconia (ZrO_2) at 7% by weight and boria (Br_2O_3) at 5% by weight will be added to the mixture to enhance the durability response of the resulting glass. A total of eight dryer batches are required for each container of glass. Each container of glass results in the treatment of approximately 13,000 gallons of liquid LAW.

The melt container is prepared in the box preparation building by lining the container with layers of insulation, sand and refractory panels. When the lining is in place, a mixture of graphite flake and soil is positioned in the bottom of the container. The mixture provides the initial pathway for the electrical current to flow between electrodes. Next, the hood (lid) and two electrodes are installed on the container such that the two electrodes are in contact with the mixture of graphite flake and soil at the bottom of the container. The hood includes a series of flanged openings along its top for the subsequent addition of soil / waste mixture through two ports and clean soil addition through three ports

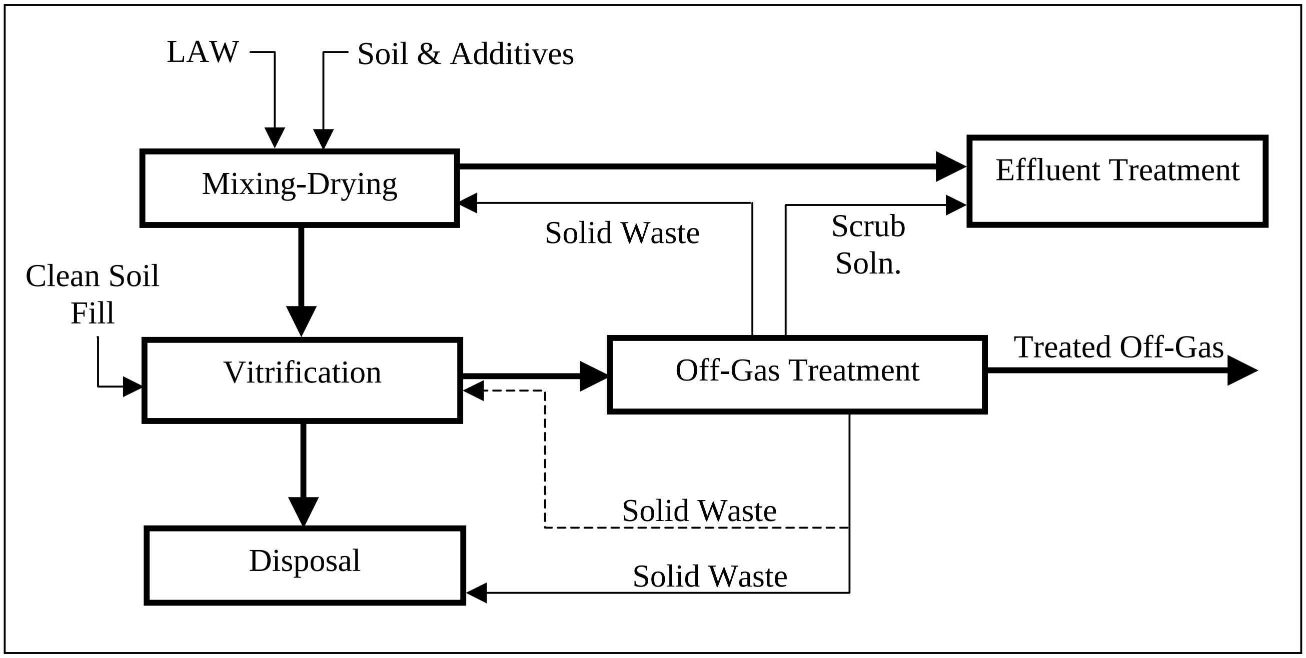

Fig. 3. Simplified process flow diagram for the DBVS plant

The prepared box is then moved with an air pallet system into position at the melt station. Connections are made for electrical power and instrumentation. An enclosure referred to as the auxiliary waste transfer enclosure (AWTE) is lowered in place and secured to the top of the hood. The AWTE provides confinement when connecting and disconnecting the off-gas piping and waste feed addition ports. Connections from feed hoppers for the soil / waste mix and clean soil are made to the flanged connections on the top of the hood within the AWTE.

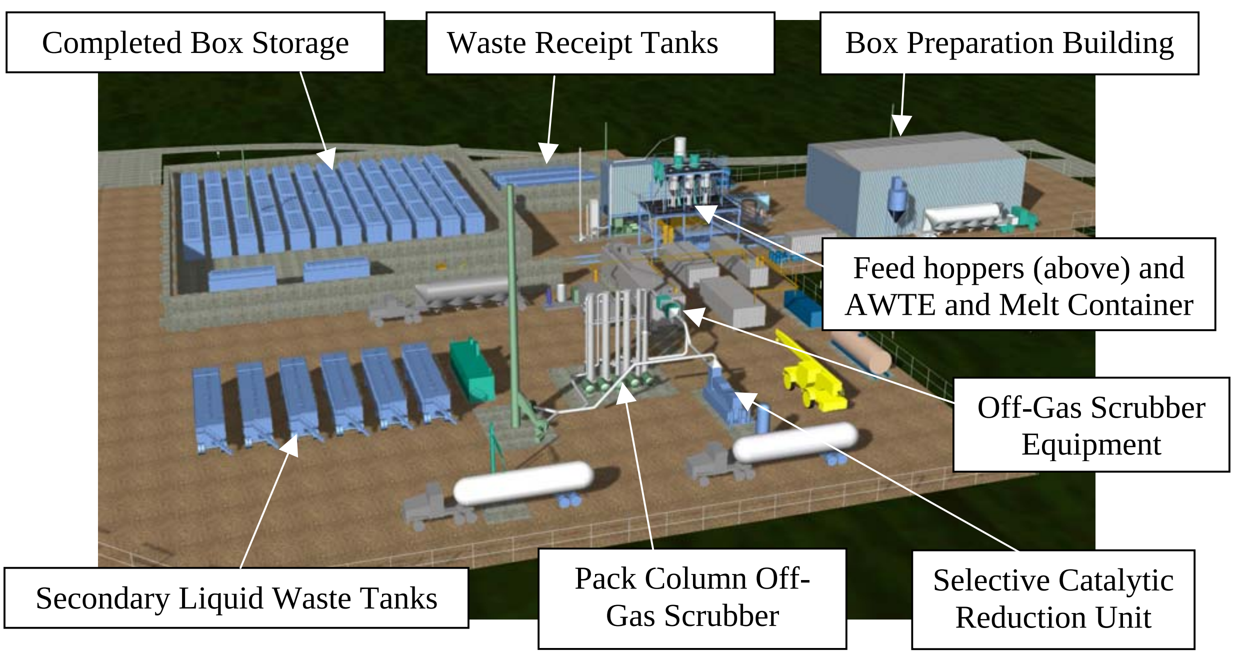

Fig. 4. Conceptual drawing of the DBVS plant showing the major features.

When preparations are complete, three batches from the mixer-dryer are transferred with a vacuum transfer system to feed hoppers located above the AWTE and conveyed into the melt container through piping within the AWTE. When the three batches are in the container, melting is initiated by applying an electrical potential to the two electrodes. A current flow is established through the graphite / soil pathway in the bottom of the container causing the path to heat and melt. Continued application of power causes the adjacent mixture of soil and waste to melt. When the waste mixture is molten, it becomes the primary conductor of the current. During operations, a total of five additional dryer loads are conveyed into the container.

Off-gases are collected and treated during the melting operations. The primary off-gas treatment steps include the following:

- An initial step of particulate filtration through two self-cleaning sintered metal high efficiency air filters that are installed in series. Blow down from the filters is collected and recycled back to the dryer where it is mixed with the next batch of feed.
- A wet scrubber system that includes a quencher followed by a two-stage high efficiency scrubber. The scrubbing solution is a dilute caustic solution to neutralize acid gases, remove particulates that may have passed through the initial filters and remove condensables.
- Two stages of high efficiency particulate air (HEPA) filters to remove any residual particulates or aerosols from the gas stream.
- Activated carbon followed by a polishing filter. The carbon removes residual radioactive iodine from the off-gas stream. The polishing filter protects against the carbon filter media being carried forward.
- Selective catalytic reduction (SCR), which reacts ammonia with NOx in the presence of catalysts to produce water vapor and nitrogen gas. The SCR uses an air-to-air heat exchanger and an electric heater to pre-heat the off-gas stream before it enters the SCR reactor.
- As a back-up to the SCR, a packed column scrubber is used for NOx removal from the off-gas stream. It is used in case the SCR fails. The off-gas is treated within the scrubber through a series of six treatment towers to convert nitric oxide (NO) and nitrogen dioxide (NO_2) to nitrogen (N_2) and into nitrate and nitrite salts. The resulting liquid waste is transferred to secondary waste storage tanks before the solution is transferred by tanker truck to a separate effluent treatment facility.
- Two redundant fans provide the force to draw the off-gases from the container through the off-gas treatment system and discharge it through a stack.

Stack monitoring equipment is provided to detect releases of radioactivity at the stack as well as the concentration of gases such as NO_x, SO_x, CO, CO_2, and total hydrocarbons.

When all of the waste material in the container has been melted, electrical power to the melt is shutoff and the melt begins to cool and solidify within the container. Clean soil is then conveyed into the container through clean soil feed ports within the AWTE to fill the void in the container and to provide radiological shielding at the top of the container. Feed ports are then disconnected within the AWTE, the flanged connections on the top of the hood are closed, and the AWTE is retracted.

The container is then moved with the air pallet from the melt station to the box storage area for cooling, eventual sampling and storage. Following sampling and analyses, a test report will be prepared for each separate batch or group of batches.

DBVS PROJECT STATUS

The DBVS plant design is currently nearing the 90% completion level. Several long-lead equipment components are on order and preparations for construction on site has commenced. The design is scheduled to be completed in the Spring of 2005 with construction scheduled to start shortly thereafter. Construction and commissioning of the plant will occur through the Fall of 2005.

A series of tests with simulants will then follow to confirm that operator training is complete, operating procedures are validated and the equipment is operating properly before conducting tests with actual LAW. The first radioactive test will involve approximately 1,000 gallons of actual LAW solution combined with approximately 12,000 gallons of simulated waste solution.

TEST PROGRAM

The project includes a test program to support process improvements and to collect data to support waste form qualification. The testing includes laboratory, 1/6th scale and full-scale bulk vitrification tests. As part of the overall program a 1/6th scale test using a mixture of 94.2% waste simulant and 5.8% actual LAW was successfully conducted in 2004. A photograph of the 1/6th scale test equipment is shown below during initial tests with simulated LAW. The main objectives for this test were to investigate improvements to reduce the amount of soluble technetium salts found within the waste package but outside of the glass that were identified in earlier tests, and demonstrate that actual Hanford tank waste could be processed at larger scale. Previously, Hanford LAW had been vitrified only at crucible scale. The 60-hour test proceeded smoothly without any operational difficulties resulting in the processing of 123.6 kg of simulant, LAW and soil mixture. The initial results indicate that process improvements reduced the amount of soluble Technetium within the waste package by 75 to 90%.

Fig 5. Photograph of 1/6th scale bulk vitrification equipment.

ACKNOWLEDGEMENTS

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FOOTNOTE

[a] In-Container Vitrification™ (ICV) is a trademark of AMEC Inc.