Full-Scale Vessel Testing of the Standard High-Solids Vessel for the Hanford Waste Treatment Plant Pretreatment Facility – 17282

Langdon Holton*, David Kosson**, Craig Myler***, Michaela Trenidad***, Russell Daniel***, Scott Monson***, Lincoln Griswold***, Nathan McAdams ***, David Dickey****, Richard Calabrese*****
* US DOE
** Vanderbilt University, CRESP
*** Bechtel National, Inc.
**** MixTech, Inc.
***** University of Maryland

ABSTRACT

Concerns over the mixing performance of the planned pulse-jet mixed (PJM) vessels for high solids applications in the Hanford Waste Treatment and Immobilization Plant (WTP) Pretreatment (PT) Facility, led to the development of a standard high-solids vessel (SHSV) design and full-scale vessel testing. The SHSV is intended as a potential replacement for several high-level waste feed receipt and lag storage vessels, ultrafiltration feed preparation vessels, and plant wash vessels. The SHSV design concept uses multiple smaller vessels (60 500 to 79 500 liters nominal batch size) to replace larger vessels, providing redundancy, improved mixing (PJM design and spargers), monitoring (multi-level bubblers), reduced material at risk, and improved structural features. The SHSV also requires qualification of a single vessel design for high solids Newtonian and non-Newtonian slurry processing, rather than earlier multiple vessel designs. Qualification of the SHSV design for mixing will be achieved through full-scale vessel testing (FSVT) with a prototypic SHSV under a set of most adverse design conditions in conjunction with additional engineering analyses. An Integrated Technical Team consisting of the U.S. Department of Energy (DOE), Bechtel National, Inc. (BNI), and independent experts was established to accelerate and provide oversight and direction to the test program and SHSV qualification. This paper will present an overview of the SHSV, full-scale vessel test and qualification program, and the management program to achieve closure of technical issues associated with PJM vessel mixing and control systems.

INTRODUCTION

One of the unresolved technical issues with WTP is associated with the ability of the PJM–mixed vessels located in the PT Facility to perform their required mixing functions, including the ability to control air to the PJMs. The WTP has 38 PJM vessels: 34 located in the PT Facility and 4 in the High-Level Waste (HLW) Facility.

DOE conducted an extensive PJM vessel testing program that was initiated in 1998. Based on the results of this program, adequate testing information exists to verify and confirm the mixing system design for 30 of the 38 vessels in the WTP. These 30 vessels contain liquid only, spent ion-exchange resin, or wastes and process

recycle streams that contain a low solids concentration—typically less than 5 percent by weight.

However, technical gaps exist in the ability to verify the PJM control system design and the mixing performance of the eight vessels in the PT Facility that would contain a higher solids concentration (greater than 5 percent by weight). The eight vessels with higher solids concentrations represent five vessel-designs in terms of total operating volume and number of PJMs. These eight vessels are also some of the largest in the PT Facility, having volumes of 113 500 to 605 500 liters and up to 18 PJMs. DOE determined the costs associated with testing these five large vessel designs would be very large, and the testing schedule could be lengthy. Thus, DOE is moving forward with a design solution that will replace, at a minimum, the five large vessel designs with a smaller SHSV design. This strategy has the potential to substantially reduce the vessel testing cost and schedule duration and has many operational benefits.

The approach to use a standardized, smaller high-solids vessel design is expected to:

- Add confidence that the vessel design will effectively resolve a hydrogen event by ensuring more complete mixing, thereby releasing any trapped hydrogen gas
- Add confidence that the vessel design will effectively resolve any criticality issue by ensuring solids are well mixed and do not accumulate in the vessel
- Provide operational contingency and plant reliability because the smaller vessel design will allow additional vessels to be placed in the design to provide redundancy
- Reduce the cost of and expedite PT Facility technical issue resolution.

The WTP Project is preparing for the third phase of a three-phase test campaign to demonstrate the required PJM control and mixing capability needed to resolve the PJM mixing technical issue. The mixing testing will be performed at the full-scale vessel test facility in Richland, Washington, using a full-scale prototype of the SHSV. The testing program is expected to be completed by the end of 2017.

DISCUSSION

Standard High-Solids Vessel Description

The SHSV (Figure 1) serve different functions in the PT Facility. The vessels will support receipt of tank waste from tank farms, blending of waste, storage of the waste, receipt of overflows/ultrafiltration flushes, and support of ultrafiltration/leaching/solids washing unit operations.

Key features of the SHSV design:

- Inside diameter – 4.9 m
- Normal fill level – 5 m
- Vessel head shape – 2:1 elliptical
- Number of PJMs – 6
- PJM discharge location – 0.6 radius, vertical downward, 15 cm above floor
- PJM nozzle diameter – 10 cm
- Total PJM drive volume – 15 percent of vessel volume
- PJM nominal nozzle velocity – 12 m/sec
- Number of spargers – 13.

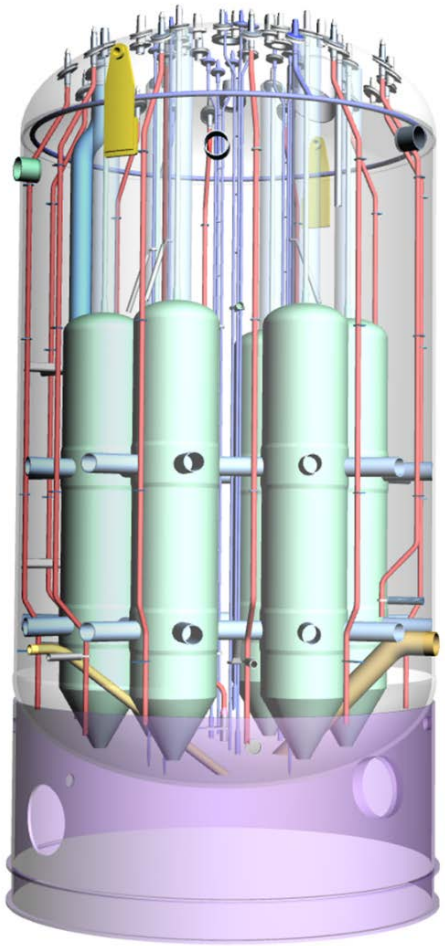

Fig. 1. Standard High-Solids Vessel Design.

Standard High-Solids Vessel Test Requirements

The functions of the SHSV include receipt, storage, processing, sampling, and transfer of radioactive waste under appropriate monitoring and control. A set of

requirements have been derived that support these functions. The requirements relevant to vessel mixing test program include:

- Mix to Support Transfer – The ability to resuspend settled solids and enable transfer from the vessel within a targeted flow rate range. Analyses indicate that waste can be resuspended by the mixing system, but the ability to maintain the targeted flow rate range in the presence of a pulsating solids concentration is to be verified by testing.
- Mix to Support De-Inventory – The ability to remove solids from the vessel outside of normal processing operations (e.g., to support cleanout).
- Mix to Support WTP Contract Throughput – The ability to support timely operation (i.e., vessel empty and fill times, blend times, and solids resuspension times and moving waste through the facility under appropriate process control). All aspects of this requirement are to be verified by analysis; however, test data is needed to support these analyses.
- Mix to Support Sampling – The ability to blend additions to the vessel such that samples are representative of the blend.
- PJM and Sparger Control – The ability to control the PJMs under all operational modes. The controls system parameters will be established during Phase 3 controls testing in the SHSV design test vessel and then qualified during mixing testing.

Requirements verification is expected to be achieved through a combination of analysis, review, and testing; in addition, some testing provides data that supports verification by future analyses.

Standard High-Solids Vessel Mixing Test Plan

An Integrated Technical Team consisting of the DOE, BNI, and independent experts was established to accelerate and provide oversight and direction to the test program and SHSV qualification. The Integrated Technical Team provided input and concurrence on the vessel mixing test plan.

This test plan:

- Identifies the mixing system requirements, associated test objectives, and acceptance criteria for successful completion of testing.
- Identifies tests and testing approaches needed to specify the simulants to be used as surrogates for radioactive waste slurries. A complementary simulant basis document identifies the required properties that the simulants to meet the goals of testing and bound the waste that will be processed in the WTP.

- Requires the parallel development of plans that describe how data and samples will be collected and analyzed and the uncertainties associated with that data.
- Will be executed through the development of detailed, step-by-step runsheets produced by the WTP Test Completion Team and implemented by the testing subcontractor. Runsheets are supported by test stand unit operating instructions produced by the test subcontractor.

The Test Completion Team and a vessel mixing Design Completion Team will review the data collected by test subcontractor prior to preparation of test reports. The results of testing will be documented in WTP test reports to be prepared by the Design Completion Team. These reports will be approved by the BNI Project Technical Director/Design Authority. The Mixing Integrated Technical Team will review test reports and will provide recommendations to DOE and BNI management for closure of the vessel mixing technical issue and that the SHSV design and PJM control system design is qualified for design implementation.

Test Methodology

Testing will be conducted at the Atkins Engineering Laboratory (Figure 2) located in Richland, Washington. The building includes a 17-m-high bay and an opening roof hatch. A tower to the south of the facility houses the jet-pulse pair (JPP) drive system for the prototypic PJM mixing equipment and simulates the operational elevation for the valve racks, which are prototypic of the WTP.

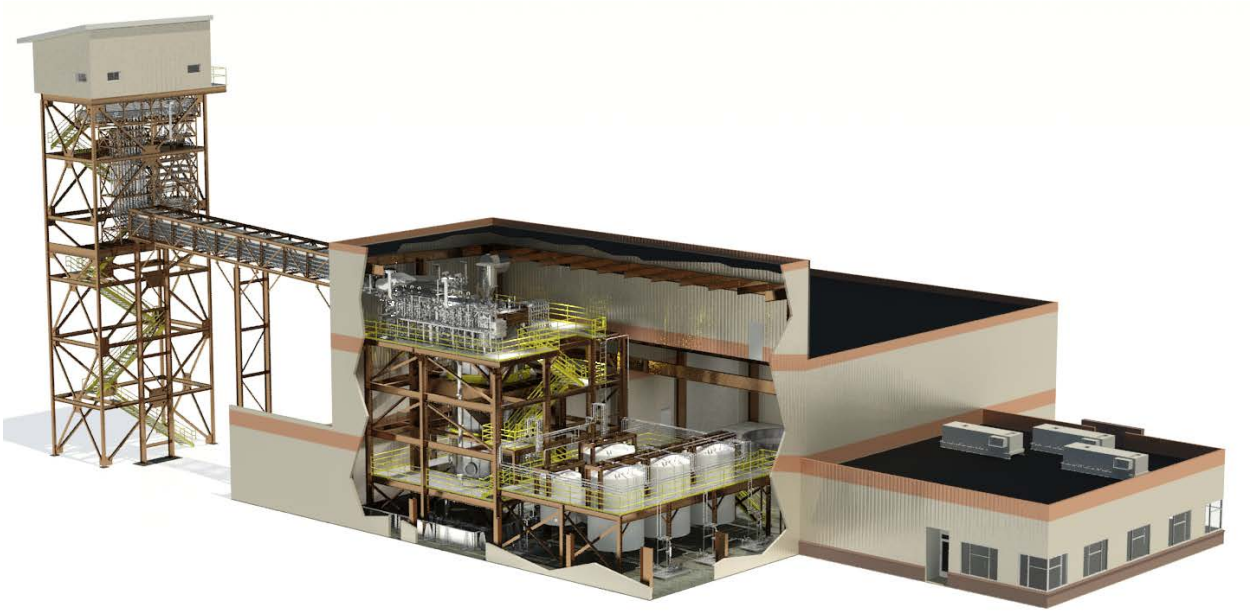

Fig. 2. Atkins Engineering Laboratory.

Testing will exercise three vessel operating modes: transfer, blend, and deinventory. Testing will be conducted with Newtonian and non-Newtonian simulants. Data will be collected as needed to verify the requirements associated

with these operations. Heels will be removed and characterized for large particles as part of vessel cleanout to prepare for subsequent tests. Opportunistically, secondary data will also be collected. Informational testing at additional test conditions will also be conducted.

During the execution of this test program, data will be collected both electronically via the data acquisition system and via hardcopy manual data records. Manual data records include all handwritten entries in test instructions, test logs, operator data sheets, operator check lists, and analytical results.

Tests will be considered successful if the testing evolutions are accurately executed and data is collected as described in the test plan. For each of the test sequences, testing success criteria would include ensuring that most adverse design conditions are achieved, that PJMs and spargers are operated as defined in engineering specifications, and there are no quality-affecting issues with NQA-1 calibrated instrumentation or test procedures (including runsheets and platform operation procedures) during testing. Also, testing success requires that identified samples are successfully collected at the prescribed times and specified analyses successfully completed. The qualified vessel design must also meet all waste treatment production and functional requirements specified in the WTP contract.

CONCLUSIONS

DOE and BNI will conduct full-scale vessel mixing testing in 2017 on an SHSV design planned to be used in the PT Facility. The SHSV design could replace up to eight larger vessels in the current design for processing the most challenging, high-solids waste slurries in the PT Facility. Use of the SHSV simplifies and PJM vessel mixing technical issue and provides many potential benefits once the PT Facility is operating. An Integrated Technical Team has provided oversight of the vessel test planning and will review test results to make recommendations for closure of the vessel mixing technical issue and for use of the SHSV in the PT Facility design.