Progress Update on the Waste Treatment and Immobilization Plant Pulse-Jet Mixed Vessel Testing Program – 16286

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ABSTRACT

The Waste Treatment and Immobilization Plant (WTP) is designed to use cylindrical-shaped pulse-jet mixers in the black cell vessels to mix the radioactive waste during process operations. Pulse-jet mixers operate like large turkey basters, using air pressure to suck radioactive waste up into the mixer and eject it back into the vessel at high velocity. Using pulse-jet mixers for keeping waste in process vessels adequately mixed is one of the design features that ensures that there are no mechanical parts inside the black cells that would require maintenance. The WTP Project is conducting a testing program to ensure the pulse-jet mixed vessels can address three design and nuclear safety concerns: 1) pulse jet mixer controls, 2) hydrogen gas generation, and 3) the potential for inadvertent criticality in the vessels.

The currently planned pulse-jet mixed vessel testing program is divided into three major test campaigns. The first campaign consists of testing to demonstrate pulse-jet mixed vessel control system design and operating concepts. The second test campaign consisted of informational testing of select prototypic PJM vessel features in a reduced scale facility. This testing informed decision making on selection of different mixing system configurations. This test campaign was completed in March 2015. The third test campaign is planned to test the complete functionality of a pulse-jet mixed vessel at full-scale using a prototype standardized high-solids vessel design.

INTRODUCTION

The U.S. Department of Energy (DOE) restricted engineering, procurement, and construction work on the Waste Treatment and Immobilization Plant (WTP) Project's Pretreatment (PT) and High-Level Waste (HLW) Facilities in 2012 because of unresolved technical issues. One of the major unresolved technical issues was associated with the ability of the pulse-jet mixer (PJM)–mixed vessels located in these facilities 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 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 concentrations (greater than 5 percent by weight). Accumulation of solids in the pulse-jet-mixed vessels resulting from inadequate mixing could lead to operational and safety concerns, primarily:

1. Pulse-jet mixer controls: Pulse-jet mixers must be controlled so that they pull waste in and push waste out in a carefully-calibrated stroke designed to avoid forcing pressurized air into the tank. Forcing pressurized air into the tank, known as an "overblow," could create excessive stresses on components in the vessel that can fatigue the vessel and cause structural damage.

2. Hydrogen Gas Generation: Radioactive wastes are constantly generating small amounts of hydrogen gas that the WTP is designed to remove through its ventilation system. However, if denser solid particles are allowed to settle at the bottom of a mixing vessel and form a sludge, hydrogen gas may get trapped in the sludge and accumulate. If an accumulation of gas were released all at once, it could create a flammable concentration of hydrogen gas at the top of the vessel.

3. Criticality: If the waste containing solid particles is not kept adequately mixed, heavy plutonium particles could accumulate at the bottom of a vessel in a formation that, under particular, but unlikely, conditions, could cause a nuclear reaction, or "criticality." A criticality event could generate heat and radiation, with a range of potential consequences depending on the size of the accumulation and other conditions in the vessel.

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 30,000 to 160,000 gallons 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 pursuing a design solution that will replace, at a minimum, the five large vessel designs with a smaller standard vessel design. This strategy has the potential to substantially reduce the testing cost and schedule duration.

DISCUSSION

The general plan for vessel selection and testing is provided in the report *U.S. Department of Energy Approach for Resolution of Pulse-Jet Mixed Vessel Technical Issues in the Waste Treatment and Immobilization Plant* [1]. As previously noted, DOE is pursuing a design approach that will replace up to 8 large vessels with varying designs in the PT Facility with a smaller standardized pulse-jet-mixed vessel design capable of mixing high solids. The smaller, standardized vessels (64 000

liters [17,000 gallons] and 5 m [16-ft] diameter) could replace up to eight larger vessels (up to 600 000 liters [160,000] gallons and 12 m [38-ft] diameter) representing five unique designs.

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 current pulse-jet mixed vessel testing program is divided into three major test campaigns:

The first campaign, being conducted at the Energy Solutions Engineering Laboratory in Richland, Washington (Fig. 1), consists of testing to demonstrate pulse-jet mixed vessel control system design and operating concepts. The first test campaign is divided into a phase 1 program using fluids with lightly loaded solids and a phase 2 program which will challenge the PJM control system to execute its design functions with simulant conditions that reflect the full range of fluids and slurries anticipated to be processed in the Pretreatment Facility. The first test phase was completed in December 2014. Testing results demonstrated successful control of the pulse-jet mixers. The Energy Solutions full scale test facility then underwent a maintenance/configuration stand-down to prepare for the second phase of testing. The second phase of testing started in late July 2015.

Figure 1. Energy Solutions Engineering Laboratory

The second test campaign consisted of informational testing of select prototypic PJM vessel (Fig. 2) features in a reduced scale facility at Mid-Columbia Engineering in Richland, WA. This testing informed decision making on selection of different mixing system configurations. This test campaign was completed in March 2015.

Figure 2. Prototypic (Scaled) PJM Test Vessel

The third test campaign is planned to test the complete functionality of a pulse-jet mixed vessel at full-scale using a prototype standardized high-solids vessel design. A contract for fabrication of the prototype standardized vessel was awarded in March 2015, with anticipated delivery to support start of full-scale testing as early as mid-2016.

CONCLUSION

DOE is executing a multi-phase full scale pulse jet mixed testing program to verify control and operation of pulse-jet mixed vessels used in the PT Facility. Tests to verify pulse jet mixer control for low solids fluid conditions comparable to those in the HLW facility and a majority of the vessels in the PT Facility was completed in

December 2014. Follow-on control system testing, expected to be completed in late 2015, extends the fluid conditions to high solids, high viscosity conditions representative of the most adverse conditions in PT Facility. Full scale testing of the standard vessel design, which is a proposed design for the PT Facility, is scheduled to commence in summer 2016 and extend for approximately one-year. This testing will complete the necessary test work to support a decision on utilization of the standard vessel design in the PT Facility.

REFERENCES

1. DOE/ORP-2014-03, 2014, U.S. Department of Energy Approach for Resolution of Pulse-Jet Mixed Vessel Technical Issues in the Waste Treatment and Immobilization Plant, U.S. Department of Energy, Office of River Protection, Richland, Washington.