Test Facilities for the Demonstration of Pulse Jet Mixer Performance in the Hanford Waste Treatment Plant – 10275

Paul S. Townson*, and Peter E. Omel**
*Energy*Solutions*, Engineering and Technology Group, Richland, WA, 99354
** Bechtel National Inc., River Protection Project – Waste Treatment Plant, Richland, WA, 99352.

ABSTRACT

The Hanford Tank Waste Treatment and immobilization Plant (WTP) is a complex of radioactive waste treatment processing facilities designed and constructed by Bechtel National, Inc. (BNI) for the US Department of Energy (DOE). The facility will convert the Hanford Site tank waste into a stable glass form. The processed waste will be shipped to other sites for ultimate disposal.

Energy*Solutions* was awarded the contract to perform all work necessary to generate test data for the pulse jet mixing (PJM) systems in some of the WTP vessels. This contract included the detailed design, procurement, fabrication, installation, acceptance testing, data collection/testing, and decommissioning of a PJM Mixing Test Platform. The purpose of the PJM Mixing Test Platform is to demonstrate the Pretreatment Facility mixing behavior under normal and abnormal operating conditions. The test platform was fabricated early in 2009, in several modular skids, and started operation collecting NQA-1 data in July 2009.

As a second part of this contract, Energy*Solutions* also engaged Washington State University (WSU) for small and full scale flume testing to collect critical data such as boundary shear stress at the sludge surface, zone of influence of a full scale PJM, and demonstrating the effectiveness of the tank discharge pump suction line in picking up the larger, higher density solid particles.

This paper focuses mainly on the design, procurement, fabrication, and installation of the test facilities under an aggressive fast track schedule

INTRODUCTION

WTP Basis of Design

With a few exceptions, the tanks in WTP are mixed using PJM devices. These are long cylindrical vessels that draw fluid in by a vacuum and then pressurize to eject fluid to cause mixing; much like a baster draws in and expels fluid. These devices are very reliable and have no moving parts in the black cells that require maintenance over the life of the plant.

NuVision, formerly AEA Services, who own the proprietary PJM design data, have provided the design of the WTP PJM mixing systems. Based on waste characteristics, and tank size and geometry, the number and power of the PJMs is determined. Bechtel National is independently confirming the adequacy of these designs by scale testing in response to issues identified by the

External Flowsheet Review Team (EFRT) which was comprised of experts from the chemical processing industry, glass industry, the nuclear waste industry, national laboratories, and universities; whom were given the charter of challenging the design of WTP. The issues that were identified by the EFRT related to mixing system design include a design basis that discounted large particles, rapidly settling Newtonian slurries, and insufficient testing of the selected designs.

The PJMs can be operated either in a continuous pulsing mode, or turned off for a time and restarted in the pulsing mode, depending on process requirements. In vessels that contain particulates, the solids will settle between mixing periods. When the PJMs restart, settled solids should resuspend. The PJM Mixing Test Platform is a scaled model of specific WTP PJM mixed vessels that will provide data/demonstration testing to underpin the PJM design in these vessels.

Objective

Six objectives summarize the actions necessary to disposition issues documented by the EFRT. These six objectives are as follows:

1. Confirm the mixing system design of Newtonian vessels to resuspend solid waste following a mixing system shutdown.
2. Develop testing information that allows accurate prediction of required mixing time for various vessel mixing functions.
3. Determine if vessels UFP-02A/B (ultrafiltration feed vessels) have a hydraulic short circuit that would cause inefficient washing and leaching, i.e. dissolved solids removal.
4. Confirm that post-DBE mixing of vessels adequately releases hydrogen.
5. Demonstrate that normal process mixing successfully meets mixing requirements for each Newtonian processing vessel.
6. Demonstrate that melter feed preparation vessels blend glass formers to required homogeneity within mixing time requirements that match glass production rates.

The M3 Mixing Test Platform was designed and developed to support disposition of Objectives 1, 2, 4 and 5 and involved development of test plans and specifications that supported a series of three scale tests. These tests were to provide scale-up information and produce parametric data that characterizes the PJM nozzle velocity requirements to achieve “just suspended” settling solids, solids cloud height and solids distribution. These characteristics are provided as functions of solids density, particulate size, solids concentration, carrying liquid viscosity, vessel liquid level, and PJM drive parameters. The purpose of this series of tests is to confirm the AEA PJM design basis applied to the WTP Newtonian vessels. A second purpose is to characterize the effects of variables on performance, allowing insight on settling solids behavior that can be used to confirm that mixing function acceptance criteria are met. The initial proposal for these tests was at 4 and 8 foot diameter vessels, and also some full scale single and dual PJM testing at WSU. This report focuses on the PJM Mixing Test Platform which was designed to house to 4 and 8 foot test vessels, and the test facilities designed and built at WSU.

FUNCTIONAL FEATURES OF PJM MIXING TEST PLATFORM

BNI approached Energy*Solutions* in August 2008 with a conceptual flowsheet for a test platform with the following functional features:

- Tank size, minimum tank diameter of 5 feet (which corresponds to >1/10 diameter of HLP-22) and height of about 12 feet.
- Mixing tank supported by feed tank and product tank of comparable volumes. Feed and product tanks can be mechanically agitated.
- Capable of supporting PJM arrays with prototypic drive systems with PJM arrays of 12 and 8 PJMs.
    1. 12 PJM array should emulate HLP-22 layout
    2. 8 PJM array should emulate FEP-17A/17B
    3. PJM drive configured to be prototypic of plant operation with prototypic function (drive, vent, and fill).
- Mixed simulant product from the test vessel is to be withdrawn from the bottom of the vessel at a scaled flow rate. Pump system is to include recycle loop to re-introduce waste simulant into the top of the PJM mixed tank at a range of scaled flow rates that may be varied for evaluation. The pump system shall also have the capability to withdraw supernate from the top of the test vessel and inject it into the suction of the transfer pump at scaled flow rates such that the suction dilution rate may be varied for evaluation.
- No temperature control is required.
- Measurement/instrument systems are to include:
    1. Concentration of solids vertically in a location that passes through the transfer pump suction and axially at the height of the transfer pump suction and the minimum and maximum operating levels in the vessel. This capability must be provided by sampling taps for sample `collection and measurement and should be provided by a redundant instrumentation technique.
    2. Quantification of solids volume remaining undisturbed on vessel bottom during operation.
    3. Sampling of solids remaining in the vessel heel to demonstrate whether large/dense solids are progressively segregated and enriched in the heel.
- Testing can be conducted out doors provided that freeze damage is prevented, foreign material exclusion precautions are effectively implemented and waste disposal requirements can be met.

The flowsheet for the resultant test platform designed to meet these functional criteria is shown in Figure 1.

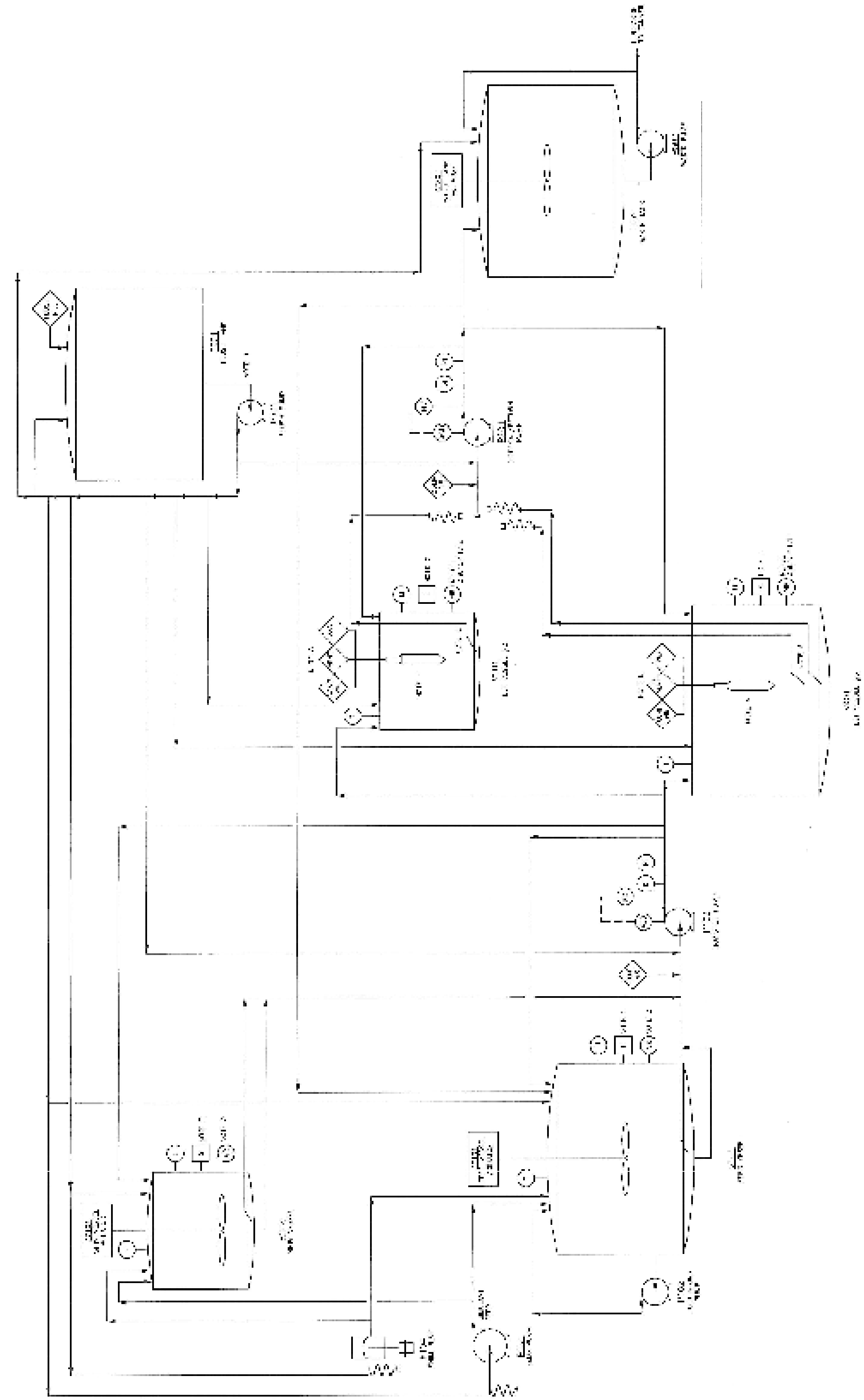

Fig.1: PJM Test Platform Process Flow Diagram

The platform design consists of two feed vessels, one 3000 gallon capacity, and a second smaller one at 500 gallon capacity. These have several interconnections to provide complete flexibility of feed make up, forward routing and recycle. The vessels then feed to either of two mixing test vessels. The two test vessels are fabricated from acrylic to provide for visual observation, one is 1.2 m (4 ft), see figure 2, and the second is 2.5 m (8 ft) in diameter. These vessels both contain a dished head which is close in geometry to the three vessels in WTP which are the focus of initial test work. The remainder of the platform comprises a flush water vessel and an effluent collection vessel. The test vessels are mixed by PJMs so there is a significant amount of equipment (compressor, vacuum pump, valve manifolds) to support these.

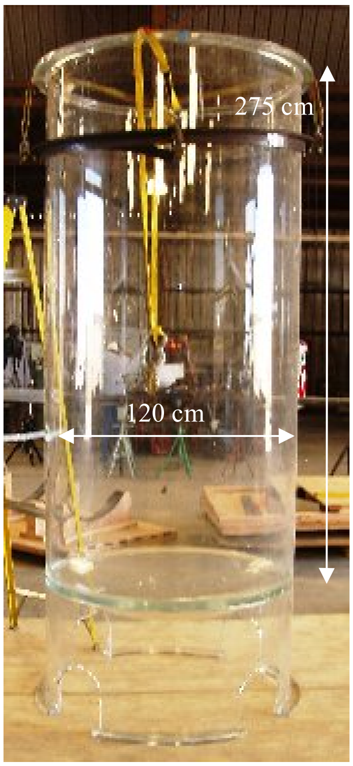

Fig. 2: 1.2m diameter acrylic test vessel

PJM MIXING TEST PLATORM CONSTRUCTION

The nature of the acrylic test vessels significantly impacted design choices for the platform. Being fabricated from acrylic they are extremely fragile, hugely expensive, and fabrication lead time is significant (upwards of 150 days). The vessels were available prior to platform construction, but if one of them were to be damaged in any way the aggressive test schedule would have been impacted. All pipe entries to the vessels have to be made through the open top, with no drilling through the walls. No equipment is allowed to be attached to the vessels imparting any loads or forces whatsoever. The vessels are anchored at the base and nothing physically touches or attaches to them anywhere else. All in vessel equipment (PJMs, sampling systems, and level instruments) are supported from a steel framework spanning the top of the vessel.

The schedule for the test platform demanded that the design proceeded in parallel with construction over a period of just six months from conceptual process flow diagram to rig handover to operations for commissioning. In order to achieve this, the platform was divided up into several skids and modularized such that individual skids could be built and shipped to sire individually as they were completed. The skids were all fabricated by Tessenderlo Kerley Services in Carlsbad, NM. The skids were identified as follows:

- P1 skid – feed and shim vessels
- P2 skid – test vessel #2
- P3 skid – PJM control valve rack
- P4 skid – test vessel #3
- P5 skid – flush and effluent vessels
- U7/8 skid - compressed air
- U3/9 skid - vent and vacuum

The skids were being installed into an existing facility in Richland, and the access and space restrictions required a specific delivery sequence to achieve the shortest installation time. The required order was: U7/8, U3/9, P5, P4, P3, P2, and finally P1. Figures 3, 4, and 5 show some of the skids under construction at TKS.

Fig. 3: Feed and shim vessel skid (P1) under construction

Fig. 4: Test vessel #2 skid (P2) showing the lower mounting ring for the acrylic vessel

Fig. 5: PJM control valve rack skid (P3) ready for shipping

On arrival at their final destination at Mid Columbia Engineering (MCE), Richland, WA, the skids were moved into position using air pallets. These enabled the skids to be easily moved by hand through a roll-up access door and literally slid into place. Once positioned, interconnection of the skids commenced and out of the many connections required between skids only six spool pieces required any rework, which is a very impressive achievement since these skids had never been connected together before. The aggressive fabrication schedule and shipping-as-soon-as-ready philosophy did not allow for this.

The PJM Mixing Test Platform was installed and commissioned on schedule due to tightly managed and well integrated teamwork between Energy*Solutions*, Bechtel National, Tessenderlo Kerley and MCE (see Figure 6). The platform went into operation very soon after installation and has been generating valuable test data since.

Fig. 6: PJM Mixing Test Platform design, installation and operations teams

RADIAL FLUME TEST PLATFORM DESIGN AND CONSTRUCTION

The second test platform which Energy*Solutions* was asked to manage construction of was a mock up of two full scale PJMs in a test vessel at Washington State University (WSU), Pullman. This test platform consisted of an approximately 6 m (20') square tank some 2 m (6') deep with two PJM nozzles, 100 mm (4") diameter mounted 3.9 m (152") apart. The water flow through each of these nozzles to achieve the design velocity of 12 m/s (39 ft/s) is 340 m^3/hr (1500 gpm). The objective of this platform was to lay down a bed of sand of known particle size across the floor of the flume, fill the flume with water and then pump water through the nozzles to identify the zone of influence (ZOI) of the PJMs, due to the sand being cleared radially. The flow needed to be started for 55 seconds and then stopped for 3 minutes repeatedly, which gave rise to design considerations to avoid potential water hammer.

The process flow diagram for the system is shown in Figure 7. The WSU facility possesses a 28,000 gallon under floor sump which was used as the source for the water. This was fed to two

40Hp pumps (P101, P201, one for each PJM) and then through an air actuated control valve (V105, V205), a flow setting valve (V106, V206), flowmeter (F101, F201) and into the flume. The pipe size used was 200 mm (8') throughout. It would have been impractical to stop and restart the pumps, so a return line to the sump just after the pump discharge and prior to the air actuated valve was installed. This had a pressure relief valve (PCV104, PCV204) which was set to open as soon as the pressure increased in the system above 37 psi when the air actuated valve closed. The air actuated valves were set to open and close over a time period of 2-3 seconds to avoid pressure spikes in the system, and this was demonstrated by dynamic flow modeling prior to commissioning. Operation confirmed this design with no water hammer or vibration whatsoever.

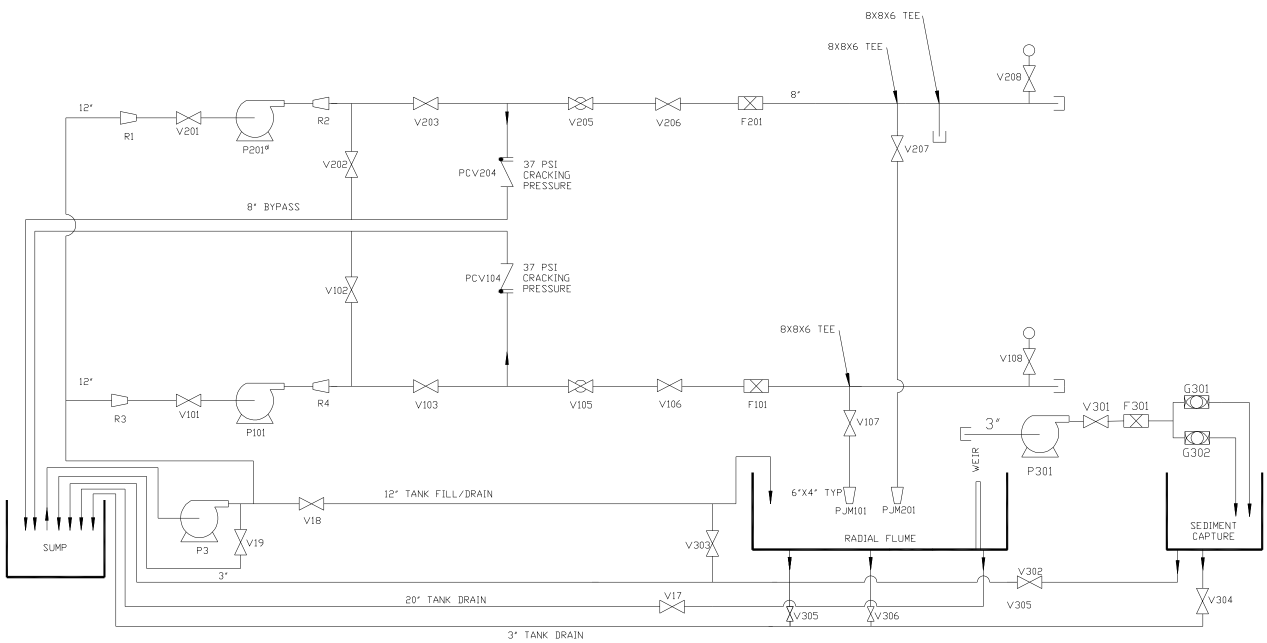

Fig. 7: PFD for Radial Flume at WSU

To facilitate observation of the action of the jets one side of the flume was completely replaced with a glass wall. Figure 8 shows the square vessel during construction with the glass wall to the right side. The vessel drain lines can be seen in the foreground, and the steelwork over the top of the vessel is to allow access for video and photography. Figure 9 shows a later shot of the water supply pipework to the PJMs. To the lower right is one of the 40Hp pumps, followed by the blue pressure relief valve on the flow return line to the sump, the red air actuated control valve and then the flowmeter in the vertical section of line on the side of the flume. As can be seen, all this equipment is very large in size due to the high volumetric flow required.

Fig. 8: Radial flume vessel during construction

Fig. 9: Water feed system to the PJMs

The radial flume was commissioned and testing commenced in September 2009. The total design and construction phase of the project was of the order of four months, which is very impressive considering the restricted labor available at a university. Figure 10 shows a photograph inside the flume showing the two PJM nozzles and the typical effect the jets has on sand placed on the flume floor. The platform is operated by a team of students and staff at WSU and is producing NQA-1 quality data for BNI. Installing and operating a large test platform in a university environment presented many challenges in itself and presented many educational opportunities for the students in the areas of industrial safety, quality data records, test procedure writing, and test execution. BNI and Energy*Solutions* staff are always on-site during testing to assist and advise, and this has enabled the test program to be executed with great success.

Fig. 10: Sand inside flume after testing clearly showing the ZOI of the jets

CONCLUSIONS

This paper has very briefly presented an overview of the design and engineering efforts required to get the PJM Mixing Test Platform and the Radial Flume Test Platform from paper to operating pieces of test equipment, against a very aggressive schedule. This required very close integration of several different teams from different companies (and a university), located in different geographic areas of the country. The authors would like to thanks all those involved from Energy*Solutions,* Bechtel National Inc., Tessenderlo Kerley Services, Mid Columbia Engineering, NuVision, WSU, and DOE-ORP for enabling these two projects to achieve success in delivering operating test platforms to allow the necessary data to be generated to characterize and underpin the design of the PJM systems in the Hanford WTP.