

Technical Concerns related to the WTP Plant

At the highest level, PNNL believes the vulnerabilities to the current Waste Treatment Plant design and operating plans are as follows:

Mixing Systems: The recent Newtonian vessel phase 2 testing has resulted in modified vessel mixing designs and operating conditions for mixing that “just meets” the minimum tank performance requirements. While solids uniformity is not necessary, the current designs allow solids to remain on the bottom during normal operations and allow solids stratification resulting in high concentrations near the bottom of the vessels and the pump suction lines. This will impact the ability to obtain representative samples and increase solids concentrations in the transfer lines. Given the considerable uncertainties in the properties of the waste feeds, mixing data, and scale-up, the lack of a significant design margin is a vulnerability that could lead to inadequate mixing and line plugging.

Solids Transport and Pumping: The pumps and transfer lines are likely to experience solids deposition and could potentially plug, especially given the stratified layers of solids that are expected in some of the vessels. Suction side priming failures due to inadequate net positive suction head (NPSH) and pipe plugging are also an increased risk at higher solids concentrations given the long suction line lengths.

Plant Processes: The many recent changes to the pretreatment process based on lessons learned from PEP testing, M3, and M6 have significantly impacted the flow sheet of the WTP and are likely to negatively impact the flow rates, plant operations and the resulting product out of the WTP. The complicated control scheme to avoid precipitation in the filtrates has not been demonstrated and was not part of the PEP testing. The caustic leaching temperature has been reduced to address vessel corrosion concerns but this, combined with efforts to limit caustic additions to control precipitation, may limit the amount of Boehmite that can be leached and will lead to a significant increase in the number of HLW canisters produced.

Gas Retention and Release: The information currently available to determine the gas retention of Hanford Tank Wastes in the PJM vessels may not be sufficient. The risk is that actual rheological conditions of materials being sent to the WTP from tank farms might not mix in the receipt vessels and would build to strengths and thicknesses that could not be handled in the design basis event.

Additional details of each of these vulnerabilities or concerns are provided in the following pages.

Mixing Vessel Concerns (M3)

- Phase 1 of the Newtonian vessel testing (WTP-RPT-182 *Pulse Jet Mixing Tests with Noncohesive Solids*) that examined the Newtonian vessels, provided examples showing that vessels FRP-02A/B/C/D, HLP-22, PWD-15/16, PWD-33, PWD-44, TCP-01 and UFP-01A/B were substantially under-powered and would not provide bottom clearing using the September 2007 designs. Vessels FEP-17 A/B and TLP-09 A/B were shown as marginal.
- Phase 2 testing conducted at Mid-Columbia Engineering's Facilities modified the vessel designs and operating conditions (solids concentrations, nozzle velocities, number of PJMs, bottom clearing sequence) for HLP-22, UFP-01, FEP-17 and FRP-02 with the goal of showing the minimum tank requirements for bottom material movement, post-design basis event (DBE) restart, and non-accumulation of solids during pump out could be achieved. The changes to the mixing systems in the vessels appear to "just meet" the minimum tank mixing requirements during the testing. This "Razor's Edge" approach means that any small change in a key testing element could result in a vessel that does not work at full scale in the plant. Engineering choices during the phase 2 testing that cause significant concern (due to designing on the "Razor's Edge") are:
 - The simulants used in the testing are not sufficiently bounding of the tank waste properties that are currently documented for the Hanford Waste Tanks (WTP-RPT-153 *Estimate of Hanford Waste Insoluble Solid Particle Size and Density Distribution*, WTP-RPT-154 *Estimate of Hanford Waste Rheology and Settling Behavior*, and WTP-RPT-177 *An Approach to Understanding Cohesive Slurry Settling, Mobilization, and Hydrogen Gas Retention in Pulsed Jet Mixed Vessels*).
 - The Plutonium oxide simulant particle use in phase 2 testing for HLP-22 and FEP-17 was sized to be 10 micron (using a 12 micron sieve cut) where in actual waste images, 4 of the 18 Pu particle photos (WTP-RPT-153) displayed particles that were over 10 microns (with one being a 23 micron sphere).
 - The design basis event (DEB) simulant formulation required a layer of solids at a concentration of $\approx 67\%$ solids concentration to achieve the "reasonable minimum upper bound" of 200 Pa shear strength within 24 hours. This simulant did not exhibit cohesive properties which is different from many of the actual waste sludge materials which do exhibit cohesive behavior. The non-cohesive simulant means the post-DBE simulant is expected to behave differently in mixing and mobilization tests than highly cohesive simulant (WTP/RPP-MOA-PNNL-00494 *Recipes for Simulant Strengths*).¹

¹ It was noted by the DNFSB (J Mansfield to I Triay, January 6, 2010, attachment 1) that simulants with bounding cohesive properties are likely to be more difficult to suspend than noncohesive simulants.

- The phase 2 of the Newtonian testing program established the nozzle velocities for Pulse Jet Mixers (PJM) by using scaling factors to adjust from the test vessel size to the full vessel diameter in the WTP. The scaling factor used for the zone of influence bottom movement tests was based on the Poreh (1967) work that conducted testing under significantly different conditions. The use of the Poreh scaling factor resulted in much higher PJM velocities in the test tank than had been recommended in the Phase 1 (WTP-RPT-182). Recent analysis by PNNL for potential non-Newtonian tank testing for WTP (WTP/RPP-MOA-PNNL-00507) have identified significant technical weaknesses in using Poreh (1967) based scaling factors for the testing conditions being used at the MCE test facility.
- The transfer/sampling system used at MCE's test facility is not geometrically scaled and functionally prototypic. The technical basis (or even the sampling bias) for using the system to collect data (that prove that solids do not accumulate during vessel pump-outs) has not been developed. The scaling of the transfer system and the related concerns are in WTP/RPP-MOA-PNNL-00507 (*Test Considerations for the Potential Engineering Scale HLP-27 Test*).
- The mixing systems in the non-Newtonian vessels were developed with some design margin but testing was directed at what was thought at the time to be the most challenging mixing requirement: that is the mixing of non-Newtonian slurries with rheological properties at the expected upper bound. Recently some concern has been raised by others that the vessels may at times contain slurries that exhibit Newtonian rheology. Limited data was obtained in the non-Newtonian test program with glass beads in water to assess the solids suspension capabilities of the mixing systems in the non-Newtonian vessels. It is unclear at this time if this data set is sufficient to form a design basis for the non-Newtonian vessels.
- PJM Technology: There has been a fundamental misperception about the maturity of PJM technology. This is new technology which is unproven for applications involving significant amounts of solids. This combination of new technology and solids was noted as particularly challenging at a work shop on Slurry Retrieval, Pipeline Transport & Plugging and Mixing.²

² Presentation by Dr. David A. Gottschlich, Independent Project Analysis, Inc, Titled *New Technology and Solids: A difficult Combination*, January 17, 2008 in Appendix A.4 of Smith et al, July 2009, Slurry Retrieval, Pipeline Transport & Plugging and Mixing Workshop, PNNL-18751.

Solids Transport and Pumping (M1)

- Technical Issues Related to Post Pump Lines
 - To the best of our knowledge, results of the M-1 Pipe line plugging studies (WTP-RPT-175 *Deposition Velocities of Newtonian and Non-Newtonian Slurries in Pipelines*, WTP-RPT-178 *A Qualitative Investigation of Deposition Velocities of a Non-Newtonian Slurry in Complex Pipeline Geometries*, and WTP-RPT-189 *Deposition Velocities of Non-Newtonian Slurries in Pipelines: Complex Simulant Testing*) have not been incorporated into the WTP plant design guide. Given the Hanford Tank Wastes and the WTP plant processes, the design guide must be robust enough to consider both the Newtonian and Non-Newtonian material transport challenges. Also the 30% factor in the design guide is not an engineering margin but a factor to cover the data scatter related to the correlation so the inclusion on additional margins would be needed to be conservative.
 - PNNL is unaware of a design guide (as of February 2010) for pumping of Non-Newtonian materials. Use of the Newtonian design guide will under predict critical suspension velocities for slurries carrying dense particles.
 - The stability map developed in WTP-RPT-175, identified the three boundary conditions (Laminar, Transitional and Turbulent Critical) that must be evaluated for each transport pipe to assure transport of the wastes do not result in partial or total (plugging) deposition. We do not believe the three part evaluation has been added to the design guide. Depending on the planned pumping mode, pipe lines from vessels FPR-02A, FEP-17A to B, Process drains for HLP-22 and FRP systems, HLP-22 transfer pump 21, and the transfer pump 17 for HLP-27 and HLP-28 all have actual velocities of below 4 feet per second as of the February 2010 design.³ The results documented in WTP-RPT-175 highlight the need to reevaluate these and other lines looking at all three boundary conditions. Given the nature of the materials being transported, the analyses are important to reduce the risk of pipe plugging.
 - The Bismuth Phosphate wastes have shown that they can gel (WTP-RPT-166 in the CUF Run), Crystallize (with significant temperature changes) and precipitate when exposed to high sodium levels. Wastes containing relatively high concentrations of phosphate have the potential to plug lines and disrupt the mixing process. Laboratory tests with actual waste samples show that these wastes settled rapidly (≈ 1 hr). Shear strength measurements indicate that the shear strength after 72 hours could range as high as 1500 Pa (WTP-RPT-167, Characterization and Leach Testing for PUREX Cladding Waste

³ A key message from a work shop sponsored by the US Department of Energy's Office of Engineering and Technology Office of Environmental Management was that laminar-flow regimes should be avoided in the design of slurry pipelines (Smith et al, Slurry Retrieval, Pipeline Transport & Plugging and Mixing Workshop, Vol 1, July 2009, PNNL-18751)

Sludge (group 3) and REDOX Cladding Waste Sludge (Group 4) Actual Waste Sample Composites) which is well above the 200 Pa shear strength targeted in recent Phase 2 mixing tests.

- Technical Issues Related to Suction Lines (M1)
 - High concentrations of solids in the suction lines cause much higher line losses (several times those provided in WTP-RPT-189) than are incorporated in the current design guide. This problem has increased as the need to fully mix the high concentration waste receipt vessels has been removed and much higher suction pipe input concentrations are now expected. The long suction pipe lengths make this problem critical.
 - The slow suction line velocities (resulting from the high line pressure loss) are expected to cause inline deposition of high concentration materials.
 - The design of positive displacement or Moyno® progressing cavity pumps on long suction lines with high line losses must evaluate the pressure at key points in the suction pipe. With the receipt vessels being at atmospheric pressure (~30 inches Hg), a pressure drop in the suction pipe to 2 inches Hg (or lower including vacuum) will allow the slurry to boil at plant temperatures (~80 degrees F). The creation of vapor in the suction lines has long been identified in slurry handbooks as the point where positive displacement pumps may not prime. If vacuum conditions are developed anywhere along the pipe, piping must be designed to handle the vacuum.⁴
 - Air entrainment at the pump inlet was observed at the PEP ultrafiltration loop at levels that limited pump performance (WTP-RPT-197 *Pretreatment Engineering Platform Phase 1 Final Test Report*). The entrained air degraded the ability of the pumps to meet the flow requirements.

Plant Processes Concerns (M6/M12)

- Post Filtration Precipitation – WTP has proposed a revised flow sheet to deal with the potential for post filtration precipitation. This new flow sheet relies upon a complicated control scheme to maintain the solutions below the solubility limit. In addition, temperature control at elevated temperatures (the objective is to increase the solubility) is a significant part of this control scheme. This control scheme has not been demonstrated and was not part of the pilot scale PEP demonstration. There is a significant risk that this control scheme won't work or will be too complicated to allow a reasonable production rate.
- Ion Exchange operating Temperature – As part of the above temperature control, the WTP has increased the cesium ion exchange temperature from 25 C to 45 C. Testing at ORNL has suggested that the resin may not have sufficient stability at 45 C. Testing is currently planned

⁴ A concern with the available net positive suction head (NPSH) was also noted by the DNFSB (J Mansfield to I Triay, January 6, 2010, attachment 4).

at PNNL to assess this impact, however there is a significant chance that these test results will challenge the design basis for the ion exchange system.

- Leaching Performance – Due to vessel corrosion concerns, the leaching temperature is limited to 85 C for the caustic leaching process. At this temperature, the leaching of the Al in the mineral phase of boehmite will be significantly limited. Boehmite leaching has a relatively large activation energy (~ 120 kJ/mole) and as such is very temperature sensitive. Limiting the temperature to 85 C will significantly limit the quantity of boehmite that can be leached. This is compounded by the recent changes for post filtration control which aim to limit the quantity of caustic used. This limitation in caustic will also significantly impact the quantity of boehmite that can be leached. Taken together, these two changes may severely limit the leaching of boehmite – which represents up to 50% of the leachable aluminum in the tank farms. This will result in a significant increase in the number of HLW canisters produced with the resulting increase in plant operating time.
- Precipitation in Permeate (i.e. filtrate) Streams from Ultrafilters - Many permeates have been found to precipitate solids following the ultrafiltration process (WTP-RPT-197 and WTP-RPT-200 Rev 1, *PEP Support: Laboratory Scale Leaching and Permeate Stability Tests*). The solids are mainly (but not limited to) sodium oxalate and sodium phosphate. These precipitates cannot be sent forward in the process to ion exchange since the ion exchange columns will plug. The precipitates are either recycled back to the head end of the pretreatment process or dissolved with additional water. In either case the efficiency of the pretreatment process is impacted.
- Process Control – The WTP will also rely upon a process control scheme that includes very limited sampling after waste has left the feed tanks. This lack of process control input will lead to a very conservative approach to process operations. In particular, the control of process rheology will be a significant challenge. Small variation in process performance can produce significant swings in process stream rheology. The proposed rheology control strategy has not been demonstrated and was not part of the PEP demonstration.
- Process Stream Recycle - The WTP process involves a significant number of recycle streams that have the potential to recycle problem components. Known problem components include: Technetium (Tc), oxalate and glass forming chemicals. These components may buildup in the recycle streams causing various process difficulties.
 - Some of the Tc is volatilized in the melters (both LAW and HLW) into the melter off-gas systems. The off-gas streams are scrubbed to remove the Tc (and other components) which is recycled back to the pretreatment facility. Since both melters volatilize the Tc, the Tc will buildup in the process system. Glass forming chemicals that are recycled may form insoluble sodium alumino silicates in the evaporators in the pretreatment facility. This is an issue that has occurred at SRS as part of the DWPF processing. Sodium oxalate is sparingly soluble and precipitates in the filtrates from the ultrafiltration process. If the precipitates are not dissolved with excess water they are recycled back to the head end of the pretreatment process.

- Systems Engineering Update needed - Potential system impacts of changing processes and equipment indicate that a complete systems engineering review is needed to ensure integrated performance and to compare projected performance to processing requirements.
 - For example, in response to the identification of a caustic corrosion issue, the leaching temperature has been dropped from 100 °C to 85 °C. This impacts the rate at which Boehmite is leached. To offset the lower leach temperature, the processing time can be extended, more caustic can be added or a lower extent of leaching can be accepted (potentially increasing the amount of HLW produced). Another example is the proposed lower rheological operating limit of 6 Pa for yield stress (raised from 1 Pa) in the UFP-2 vessels. This increased limit is being considered to address an uncertainty associated with mixing of settling solids in the “Non Newtonian” vessels and may be achieved by operating at a higher solids concentration limit. This will impact the leaching, washing and filtration operations in the UFP-2 vessel.

Gas Retention Concerns (M3)

- There are significant uncertainties associated with a lack of quantitative results for PJM mobilization of settling cohesive slurries, and other uncertainties are associated with a lack of information for waste properties needed for quantifying PJM performance and gas retention. (See WTP-RPT-177 *An Approach to Understanding Cohesive Slurry Settling, Mobilization, and Hydrogen Gas Retention in Pulsed Jet Mixed Vessels.*) The vulnerability that results from these uncertainties is that the PJMs have not been shown to have adequate performance with cohesive solids which could lead to buildup of cohesive solids in the bottom of the vessels that could retain up to 20-30% flammable retained gas.
 - The first category is Technical Uncertainties for PJM Behavior with Settling Slurries
 - There is a scarcity of testing data for PJM performance on settled or stratified cohesive layers, and it is unclear if the existing correlations developed for vessels without layers can be used for settling waste. While the previous studies on PJM mixing of uniform non-Newtonian materials quantified many aspects of the PJM performance, data to quantify the roles of important operational parameters (jet velocity, pulse size, and duty cycle) and geometry (number of PJM tubes, nozzle size, bottom shape) are absent.
 - The second category is Technical Uncertainties for Waste Characterization.
 - The most significant uncertainty is that the existing models and data on settling dynamics and the strength of settled layers have not included experimental testing to confirm the scaling behavior or to determine the increasing strength with depth into a settled layer. It is expected that a sound understanding of settling dynamics will be needed to design, or to determine the operating limits of, a mixing system capable of managing the strength and thickness of settled layers.