HLW Direct Vitrification

Submitted by PNNL, ORP, CUA-VSL, Energy*Solutions*

Proposed Concept

Current River Protection Project system models (Hanford Tank Waste Operations Simulator and Hanford Waste Treatment and Immobilization Plant [WTP] Dynamic Flowsheet Model [G2]) show the WTP High-Level Waste (HLW) Facility frequently idling while waiting for waste feed delivery and pretreatment (PT) processes. A key objective of the PT process is to remove a large fraction of the non-radioactive chemical components from the tank waste prior to HLW vitrification to reduce the amount of HLW glass produced and ultimately the project cost. Aluminum and chromium are the two primary insoluble chemical components to be removed from the sludge in the PT process, and their removal requires long cycles of leaching and washing.

Recent advances in glass formulation will, once sufficiently developed and demonstrated, increase the loading of both aluminum and chromium in HLW glass. In fact, recent estimates of the amount of HLW glass produced from all of the Hanford tank wastes without performing leaching with advanced glass formulations were as low as 40,860 metric tons (MT), or 13,530 canisters (Jenkins et al. 2013). At an average sustained rate of 5.25 MT of glass per day, this much glass could conceivably be produced in as little as 21 years. Coupled flowsheet models suggest that if sufficient low-activity waste (LAW) treatment capacity exists, the mission could be completed in 29 years (primarily limited by the time required for LAW treatment to reach full capacity). The direct feed HLW Facility (DFHLW) process fits logically as Phase 2 of the Hanford tank waste management framework (DOE 2013). Under Phase 2 of the framework, risk could be significantly reduced by immobilizing over 50% of the curie content of the tanks in under 1,000 canisters of HLW glass. We propose to extend the operation of DFHLW for the life of the mission, whereby sludge would be processed directly without pretreatment.

Key Aspects

The soluble components of the waste (sodium, sulfur, etc.) can be removed by using a settle-and-decant process followed by cesium ion exchange to return cesium to the HLW stream, according to the conceptual flowsheet in Figure 1. This proposed process has several advantages:

- The PT Facility could be designed to process a minimal amount of solids because the majority of the solids will be direct-fed to HLW. This will likely reduce the to-go cost for the PT Facility and speed its startup.
- The LAW, HLW, and PT facilities will be less closely coupled, allowing for more process flexibility.
- The HLW Facility may be able to start treatment of tank sludge sooner, reducing the risks posed by storage of sludge in Hanford tanks.
- The amount of sodium added to the process for aluminum leaching will be reduced by as much as 20,000 MT. This will reduce the required LAW treatment capacity.[1]
- The formulation for the high-aluminum HLW stream will be more consistent since the waste will be composed primarily of aluminum and therefore other waste components will have significantly less impact on glass formulation and properties.[1]

We propose that a DFHLW process be evaluated and potentially adopted as an improved flowsheet for managing Hanford tank waste (as shown in Figure 1). To enable such a flowsheet, a relatively large solids

[1] The reduced need for leaching is not unique to DFHLW; it can also be implemented in many potential flowsheets, including the baseline.

receipt and mixing vessel (or vessels) would be required near the HLW Facility to receive sludge transfers from the tank farms and transfer decant solution back.

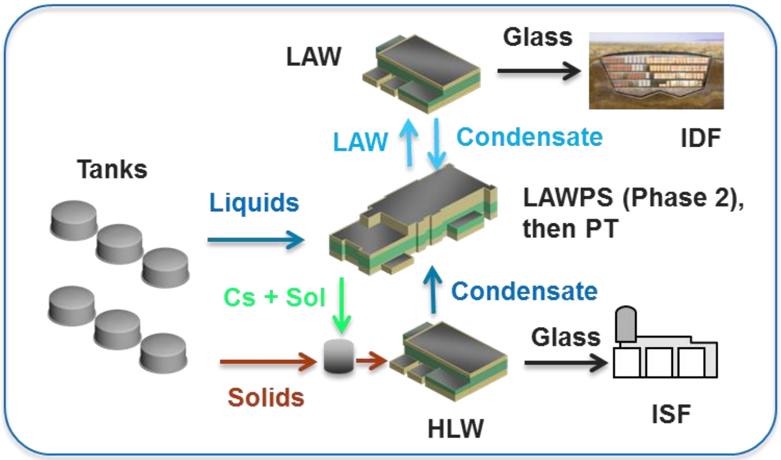

Figure 1. Schematic of Proposed DFHLW Process

A key difference that currently exists compared to previous analyses flowsheets that led to the decision to leach Al is the dramatic increase in Al_2O_3 concentrations in glass (up to nearly 30 wt% compared to 13 wt% in current WTP formulations).

Technical Risk

Various components of DFHLW have been analyzed in detail, including:

- A general program plan (Ramsey 2012) and engineering analyses (Esparza 2012) for DFHLW as a transient to full flowsheet operations.
- Glass formulations to handle DFHLW feed streams (Vienna et al. 2013; Matlack et al. 2014) and glass volume estimates (Jenkins et al. 2013).
- Limited laboratory- and engineering-scale demonstrations, including feed processing of the DFHLW flowsheet with simulants in a scaled-prototypic joule heated ceramic melter (Matlack et al. 2014).
- Receipt of DFHLW into the HLW Facility to support staged startup (Meinert 2012, for example).

The settle-decant process to remove soluble chemical components from tank waste has been practiced in the past at Hanford and is currently practiced at the Savannah River Site. The proposed process is similar to that performed at the Savannah River Site. One risk is that the estimates of 13,530 canisters may be optimistic when implemented in a plant operation. Conservative glass formulation models estimate 19,100 HLW canisters for the no-leach case. At the nominal continuous rate of 5.25 MT of glass per day, this amount of glass could be produced in 30 years of steady operation. Our best current estimates suggest that the actual amount of glass will be somewhere between the two estimates and much closer to the lower canister count. If aluminum leaching is desired later for certain tank waste, in-tank leaching may be performed (Appel et al. 2005).

In short, the proposed option is known to be technically achievable, individual components have been demonstrated on the scale needed. The option would require only a modest amount of research and development or proof-of-concept.

Time to Deployment

The time required to complete the engineering studies and develop a preliminary project schedule will range between 1 and 2 fiscal years. This short schedule is due to the large amount of preliminary groundwork that has been performed in previous studies (e.g., Esparza 2012; Ramsey 2012). Development of engineering data to support final design and construction would likely require 5 years, but can be done in parallel with engineering studies and HLW Facility construction. Therefore, a reasonable engineering projection is a startup in 7 years. This time would allow for engineering studies, final design, construction of a feed receipt vessel (or vessels) near HLW vitrification, and completion of HLW Facility construction. Glass property data, models, and formulation algorithms are currently under development and will be available when needed to support reduced HLW canister counts (e.g., Kot 2014).

Pursuing this idea will only require a modest investment to mature/implement and then insert into the project or activity. It would support the planned work schedule and mission requirements in a cost-effective time frame.

Completeness of Option

The recommended next step is to perform a detailed engineering study to support the decision to implement this strategy and to plan the program. The high priority research activities to support this engineering study and facilitate the ultimate implementation of the strategy include the following:

- Develop waste acceptance criteria for the HLW Facility.
- Develop an appropriate set of simulants for testing of the DFHLW flowsheet.
- Perform laboratory- and engineering-scale demonstrations of the DFHLW flowsheet with simulants in scaled-prototypic test equipment.
- Develop glass property-composition data and models to support DFHLW composition envelopes of interest and high waste loadings.
- Update glass formulation and qualification algorithms for the revised waste feed.
- Perform laboratory-scale demonstration of the DFHLW flowsheet with actual waste samples.
- Collect data to support design based on design data needs documented in the detailed engineering study.

Work should begin on these efforts in parallel with the decision-making process to speed the ultimate implementation of the strategy.

Regulatory Considerations and Ability to Execute within DOE Orders/Regulations

The regulatory implications are not different from those in the proposed Phase 2 of the framework. The idea would not require DOE to solve regulatory issues, or acquire a waiver to existing DOE Orders. It is anticipated that stakeholders will view the proposed option as an acceptable and/or a good alternative to the approved baseline or existing commitments. NEPA/permits are likely achievable in the timeframes needed. Secondary waste streams and other factors are fully considered.

Cost Avoidance/Direct Cost Savings

This concept will avoid or reduce several costs:

- Cost associated with delayed full flowsheet startup that result from the need to develop a PT Facility capable of safely and efficiently managing high-shear-strength slurries with fissile and potentially gas-generating materials. This cost could be conservatively estimated at $690 million per year of schedule delay.

- The cost of increased supplemental LAW treatment capacity required to treat the 20,000 MT of excess sodium used in leaching (both capital and operating expense). A detailed cost estimate was not possible for this change, but costs will likely range between $500 million and $2 billion.
- The cost of inefficient operations that is inevitable with closely coupled facilities that must all be online and at capacity at the same time.
- The cost of Tank Waste Characterization and Staging Facility (TWCSF) capacity to facilitate safe operation of the PT Facility. A relatively large, well-mixed receipt vessel (or vessels) will be required near the HLW Facility to support DFHLW operation. However, it can be assumed that this vessel (or vessels) will cost less than the TWCSF.

These cost avoidances should be balanced against the increased amount of HLW glass for storage, transportation, and disposal resulting from a flowsheet without leaching; although advanced glass formulations have reduced this effect. It should be noted that previous estimates for HLW glass disposal costs are significantly higher than those currently estimated; for example, the current estimates of HLW canister disposal cost are between $140K and $390K per canister (Chu 2013), compared to previous estimates of greater than $850K per canister. Beyond these obvious cost avoidance factors, the simplified process will reduce schedule risk. In addition, and perhaps most importantly, DFHLW could immobilize over 50% of the curie content of the tank farms in the first 1,000 canisters of HLW glass and thereby reduce the risk posed by tank waste within a couple of years of full operation. Thanks to the enhanced glass models currently being developed by the Office of River Protection, DFHLW is both viable and economically attractive.

References

Appel J, M Beary, R Orme, and G Boechler. 2005. *Assessment of Caustic Leaching in the Tank Farms*. RPP-24808, Rev. 0, CH2M Hill Hanford Group, Inc., Richland, WA.

Chu S. 2013. *U.S. Department of Energy Nuclear Waste Fund Fee Adequacy Assessment Report*. U.S. Department of Energy, Washington, D.C.

DOE. 2013. *Hanford Tank Waste Retrieval, Treatment, and Disposition Framework*. U.S. Department of Energy, Washington, D.C.

Esparza BP. 2012. *Preconceptual Engineering Study for Direct Feed High-Level Waste*. RPP-RPT-53225, Rev. 0: OUO, Washington River Protection Solutions, LLC, Richland, WA.

Jenkins KD, RF Gimpel, and Y Deng. 2013. *2013 Tank Utilization Assessment (TUA) Part 1: Potential Impact of Advanced Glass Models on the WTP*. 24590-WTP-RPT-PE-13-003, Bechtel National, Inc., Richland WA.

Kot WK, K Gilbo, H Gan, I Joseph, and IL Pegg. 2014. *Enhanced HLW Glass Property-Composition Models – Phase 1*. VSL-14R3080-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, D.C.

Matlack KS, WK Kot, IS Muller, IL Pegg, and I Joseph. 2014. *Support for HLW Direct Feed*. VSL-14R3090-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, D.C.

Meinert FL. 2012. *Phased Startup Scenario Evaluation using the Hanford Tank Waste Operations Simulator*. RPP-RPT-51936, Washington River Protection Solutions, LLC, Richland, WA.

Ramsey WG. 2012. *Direct Feed High-Level Waste Flowsheet Development Plan*. RPP-PLAN-53598, Rev. 0: OUO, Washington River Protection Solutions, LLC, Richland, WA.

Vienna JD, DS Kim, DC Skorski, and J Matyáš. 2013. *Glass Property Models and Constraints for Estimating the Glass to be Produced at Hanford by Implementing Current Advanced Glass Formulation Efforts*. PNNL-22631, Rev. 1, Pacific Northwest National Laboratory, Richland, WA.