Estimating the Rate of Solids Accumulation in Double Shell Tanks – 17093

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ABSTRACT

This project describes a method of estimating the rate of solids accumulation in Low Activity Waste Pretreatment System (LAWPS) Double Shell Tanks (DSTs) from solids entrainment and precipitation in order to identify and recommend appropriate control measures to protect LAWPS feed schedules. By comparing various volume fraction solids in transfer volumes with the available tank storage needed to maintain LAWPS feed schedules the number of possible transfers before solids removal is necessary can be determined.

A family of curves spanning the range of values of volume fraction solids most frequently observed in grab samples was charted to show the transfer batch number at which point accumulated solids inhibit sufficient storage for waste feed schedules and thereby warrant solids removal. Results of this study indicate that in order to preclude solids removal activities during the LAWPS waste transfers, volume fraction settled solids levels in LAWPS transfers are required to stay below 0.0133 and 0.0183 for Feed Staging Tank 1 and 2, respectively. Results of this study show that the rate of solids accumulation will exceed the requirement, and therefore solids removal capability for LAWPS DSTs upgrades is required.

INTRODUCTION

The purpose of this evaluation is to assess the risk of solids accumulation in Low Activity Waste Pretreatment System (LAWPS) Feed Staging Tanks. The LAWPS campaign at Hanford is scheduled to treat 75.7 million liters (ML) (20 million gallons (Mgal)) of waste in order meet Waste Feed Delivery criteria for vitrification. Solids levels in LAWPS DSTs constrain available LAWPS feed batch sizes. LAWPS operations criteria thus require adequate control of solids entrainment and accumulation in the LAWPS DSTs to uphold the Waste Feed Delivery schedule.

Background

The LAWPS feed staging tanks represent a potential bottleneck for waste transfer scheduling should solids accumulate to the point that entrainment of settled solids will result in noncompliant feeds or the available volume of compliant waste feed is no longer sufficient.

During LAWPS, two feed staging tanks (referred throughout this paper as Feed Stage Tank 1 and 2) will alternate supplying waste feed to the LAWPS Feed Tank, with one tank providing waste to the LAWPS Feed Tank while the other tank receives feed and undergoes characterization. After a 6 month initial LAWPS Feed Tank waste qualification, no further waste qualifications will be performed in the LAWPS feed tank. All other LAWPS waste feed qualification will occur when the feed

is staged in Feed Stage Tank 1 or 2. Figure 1 below illustrates the configuration and example composition of the LAWPS feed and feed staging tanks for the upcoming LAWPS campaign.

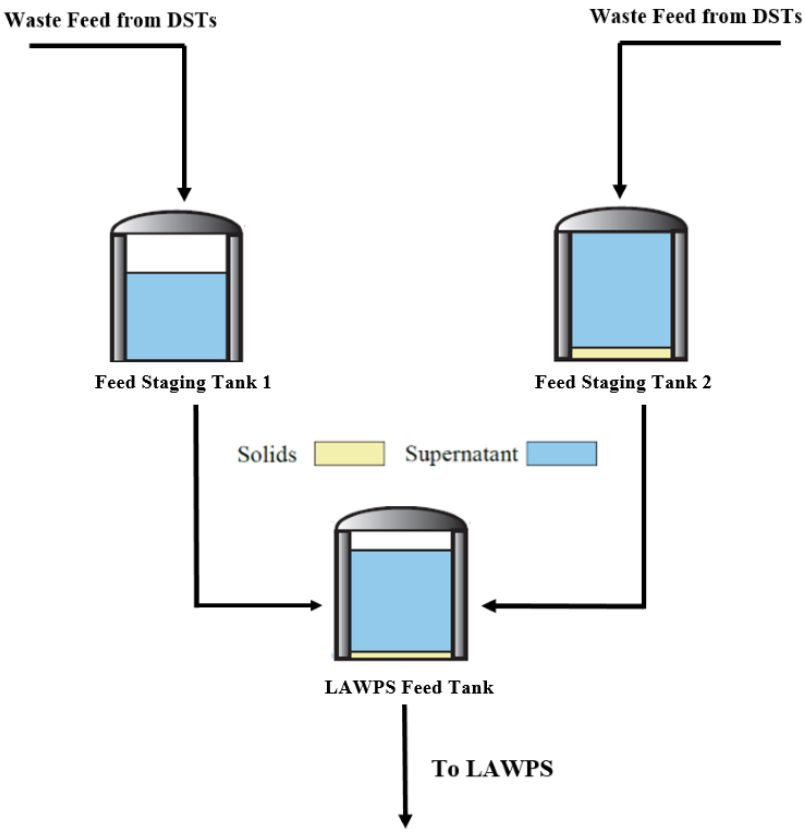

Fig. 1. LAWPS Feed and Feed Staging Tanks configuration. As the bottleneck for Waste Feed Delivery from Tank Farms to the Waste Treatment Plant, solids entrainment and accumulation in these tanks are of critical concern in maintenance of Waste Feed Delivery schedules.

Entrained solids include settled solids that are unintentionally drawn into the transfer pump as well as suspended solids that exist in a more distributed fashion throughout the liquid waste. If transfer pump inlets are placed in proximity to a settled solids layer, settled solids in this layer are thus the main concern for analysis purposes. Suspended solids will typically settle given sufficient time. Entrained solid types include:

- **High Level Waste (HLW) particles:** HLW particles are waste solids that, when settled, do not typically re-dissolve upon dilution. No significant threat of accumulation in LAWPS feed staging tanks of HLW particles was identified from grab sample reports [1].

- **Precipitated solids:** Precipitated solids result from the concentration of DST dilute supernatant during Evaporator campaigns. Dilute supernatant is

concentrated in the Evaporator at operating temperatures of 52 °C (125 °F). Prior to conducting an Evaporator campaign, evaporator feed boil down tests are performed to determine the target specific gravity (SpG) for the evaporator slurry. Even though the target SpG is selected to minimize the precipitation of solids, salt solids may still precipitate in the slurry receipt tank upon cooling, form a layer, and compact over time. An evaluation of waste feed boil-down data indicates that LAWPS feed staging tanks' solids layers would also compact with sufficient time.

METHODS

Three inputs were used to estimate solids accumulation: Evaporator boil-down data, Grab sample data, and Plan modeling data.

To estimate the rate of solids accumulation, DST supernatant and Evaporator slurry grab samples results were first examined. Volume fraction settled solids and SpGs from grab samples and modeling results were then compared with those of Evaporator campaign boil-down samples that showed solids precipitation. Results of this comparison were then used to identify at what volume fraction entrained solids and corresponding transfer volume the available feed staging tank storage was surpassed. The following section explains the validity of method inputs.

Evaporator Boil-Down Data

Evaporator campaigns increase salt concentration in supernatant by removing excess water in an attempt to balance increases in salt concentration with the need for tank space conservation. Operations are constrained against excessive evaporation which may increase the risk of excessive salt precipitation in tanks receiving transfers of Evaporator slurry.

During Evaporator boil-down studies, SpG and settled solids are measured over waste volume reduction intervals up to a target pot volume reduction. At this end step, boil-downs will often include an incremental dilution process to take measurements that finesse the SpG and settled solids correlation.

Expected solids in the diluted Evaporator slurry can be approximated by the boil down samples at the same SpG to attain a basis of understanding the sensitivity of salt precipitation over a narrow range of densities.

Grab Sample Data

Volume fraction settled solids in the Evaporator boil-down studies do not explicitly distinguish between HLW and precipitated solids. However, with near zero levels of HLW particles in DST supernatant feed to the evaporator, the slurry grab sample data supports the conclusion that precipitated salts in the Evaporator slurry are the primary contributor to solids accumulation [1].

Plan Modeling Data

The number of transfers from the LAWPS feed staging to the feed tank is based on LAWPS modeling plans that are periodically updated. Both current tank conditions and LAWPS Planning Models will likely change. The average SpG for Evaporator slurry over the last six campaigns is 1.402. LAWPS modeling describes a range of SpGs approximately 1.25 to 1.29 for transfers between the feed staging tanks (post-dilution) and the LAWPS Feed Tank [2]. For LAWPS plan modeling purposes, it is conservative to account for a range of SpGs and observed values for settled solids in boil down studies.

Figure 2 compares Vol. % settled solids to measured SpGs at 18 °C from boil-down studies of Evaporator feed and Evaporator slurry and confirms the potential for solids deposition in feed staging tanks. Throughout this report, Vol. % is used in lieu of volume fraction in graphs to achieve a less cluttered y-axis. Data points labeled in Figure 2 represent measurements from sample boil-down studies at SpGs (both pre- and post-dilution) comparable to those in the range of relevant transfers in LAWPS transfer models.

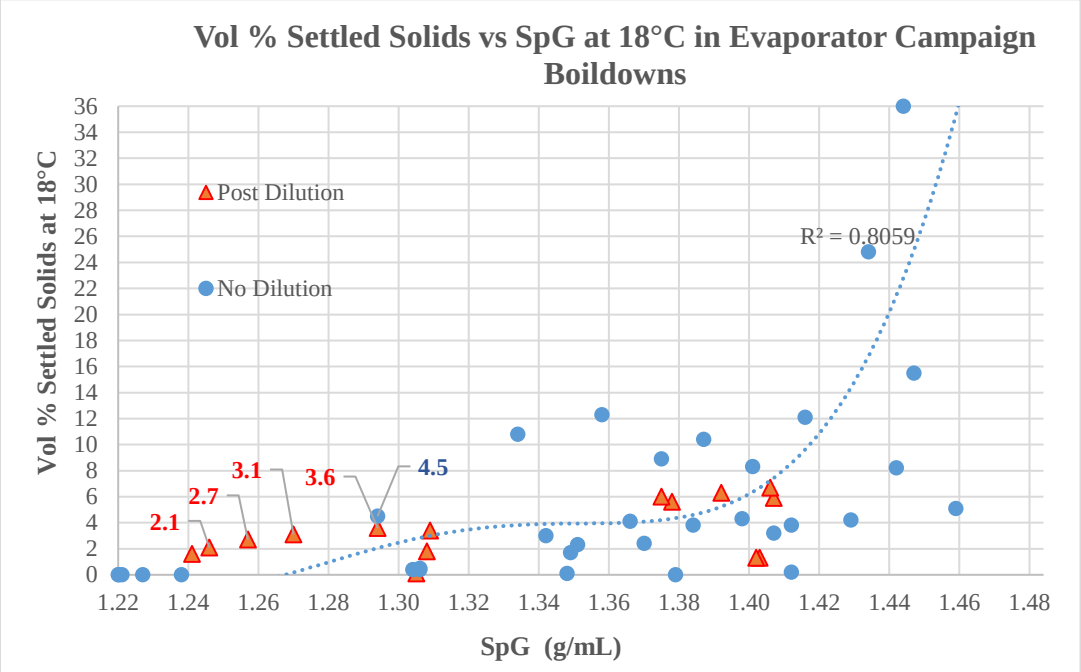

Fig. 2. The graph is used to show Vol. % solids levels values in Evaporator Boil-down studies fall within the range of LAWPS model predicted SpGs (1.25 to 1.29). This is an indication of potential Volume fraction levels of solid entrainment during LAWPS transfers to Feed Staging Tanks 1 and 2.

Solids detection post-dilution suggest early slurry concentrates are supersaturated, and that precipitation of sparingly soluble salts occurs with small increases in SpG.

Solids entrainment and accumulation in the Feed Staging tanks may also be affected by temperature, dilution, and residence time. The next sections address potential risks and significance associated with these parameters.

CONTRIBUTING FACTORS TO SALT PRECIPITATION

Temperature

Cooler temperatures drive more salts to precipitate out of solution. DSTs are well below the ground surface, thus cooling rates are subject to only mild seasonal effects via ventilation system inlets and the overall ventilation rates. Historically, LAWPS feed staging tanks Feed Stage Tank 1 and Feed Stage Tank 2 have averaged approximately 24 °C (75 °F) for supernatant temperatures.

The Evaporator operates at approximately 52 °C (125 °F). Feed Stage Tank 1 recently reached 46 °C (115 °F) following receipt of Evaporator slurry from Evaporator Campaign-02. Over the subsequent six month period, waste levels in Feed Stage Tank 1 were constant at approximately 787 cm (310 inches). During this time, the bulk temperature dropped from 39 °C to 29 °C (102 °F to 85 °F) at a rate of -0.056 °C (-0.102 °F) per day, due substantially to evaporative heat loss from the primary confinement and annulus ventilation.

Understanding the rate of cooling alone does not suffice to assess evaporation rates if tank level measurements are unreliable. Unfortunately, current sludge level reports for Feed Stage Tank 1 are based on outdated core sample results. No current sludge level assessments have been made to determine whether salt deposition occurred following Evaporator Campaign-02. This information might be applied for future risk assessment for solids accumulation in various DSTs.

Dilution

Dilution of Evaporator slurry staged as waste feed in Feed Stage Tank 1 and 2 is required to achieve a 5.6 Molar sodium concentration to meet LAWPS waste feed qualifications. Dilution of waste feed is also effective for mitigating accumulation risks to the degree solubility of salts increase. Water volumes for dilution are subject to DST space availability, feed schedules, and salt molarity requirements. LAWPS transfer models describe a post-dilution average liquid SpG of 1.26 for transfers between the feed staging tanks and the LAWPS Feed Tank. Figures in the Results Section illustrate to what levels settled solids could potentially accumulate warranting a solids removal campaign. To remove solids from the tank, hot water sluicing can be used to re-dissolve salt solids for transfer to tanks designated for solids removal operations.

Residence Time & Time Constraints to Upcoming LAWPS Feed Schedules

LAWPS transfer modeling shows residence times following transfers of Evaporator slurry to slurry receipt tanks ahead of Feed Stage Tank 1 & 2 could extend to several months. Integrated Waste Feed Delivery Plans state the duration of 194

days is allotted for each tank sampling and characterization [3]. This period includes 14 days allocated to transfer, diluting, and mixing. The 194-day lag time it takes to fully qualify the feed to Feed Stage Tank 1 or 2 is the limiting step for feed transfer from the staging tanks into LAWPS Feed Tank. If the Evaporator slurry has an extended dwell time in an upstream receiver tank before it is transferred to Feed Stage Tank 1 or 2 it is likely that as the solution cools, many of the salt solids would precipitate in the receiver tank. Thus if care was taken with the subsequent transfer to Feed Stage Tank 1 or 2, many of these salt solids would remain in the upstream receiver tank.

Tank Space & Maximum Solids Volume Limitations

The tank capacity for the two Feed Staging Tanks is 1163 cm (458 inches) in height which equates to 4.77 ML (1.26 Mgal) in volume [4]. LAWPS modeling plans show average transfer volumes between the feed staging tanks and the feed tank to be 4.05 ML (1.07 Mgal). After a 4.05 ML transfer, the height of available tank space remaining is 175 cm (69 inches). A need to avoid excessive solids re-entrainment by locating the pump suction at least 30.5 cm (12 inches) above the settled solids layer has been identified. Subtracting the 30.5 cm pump inlet distance from the available tank space above the solids layer leaves 145 cm (57 inches) as the maximum height of solids accumulation before removal is obligatory, assuming the 4.05 ML batch size is maintained.

Equation 1 shows the maximum Volume fraction solids values required to avoid a solids removal campaign during LAWPS under the initial tank condition is found through the following direct computation:

$$Max\ Volume\ fraction\ solids\ = 100\% * \frac{(145cm - initial\ level)_{solids} * 4098 \frac{L}{cm\ of\ tank\ height} * \frac{ML}{1e6\ L}}{4.05 \frac{ML}{transfer} * Number\ of\ Transfers} \quad \text{(Eq. 1)}$$

RESULTS

The maximum Volume fraction settled solids limits required to avoid solid removal campaign based on the initial conditions of zero solids for Feed Staging Tank 1 and 2 is 1.33 and 1.83 Vol.% incoming Solids for 11 and 8 transfers respectively. It is assumed all incoming solids settle.

Figure 3 and Figure 4 demonstrate solids accumulation from zero initial solids (only the number of batches are different) in order to illustrate operational limits if the tanks were emptied of solids before the LAWPS feed mission. Any initial solids levels in the Feed Staging Tanks would advance the need for solids removal. The y-axis in Figure 3 and Figure 4 is set at the maximum height of 145 cm (57 inches) to clearly show whether and at what Vol. % settled solids value and batch number (4.05 ML basis) the available storage space of the feed staging tanks is surpassed. Note that these curves are not intended to reflect any specific, planned feed scenario. They are intended to illustrate the potential risk associated with solids

accumulation in the LAWPS feed staging tanks, given an assumed solids concentration in the in-coming supernatant.

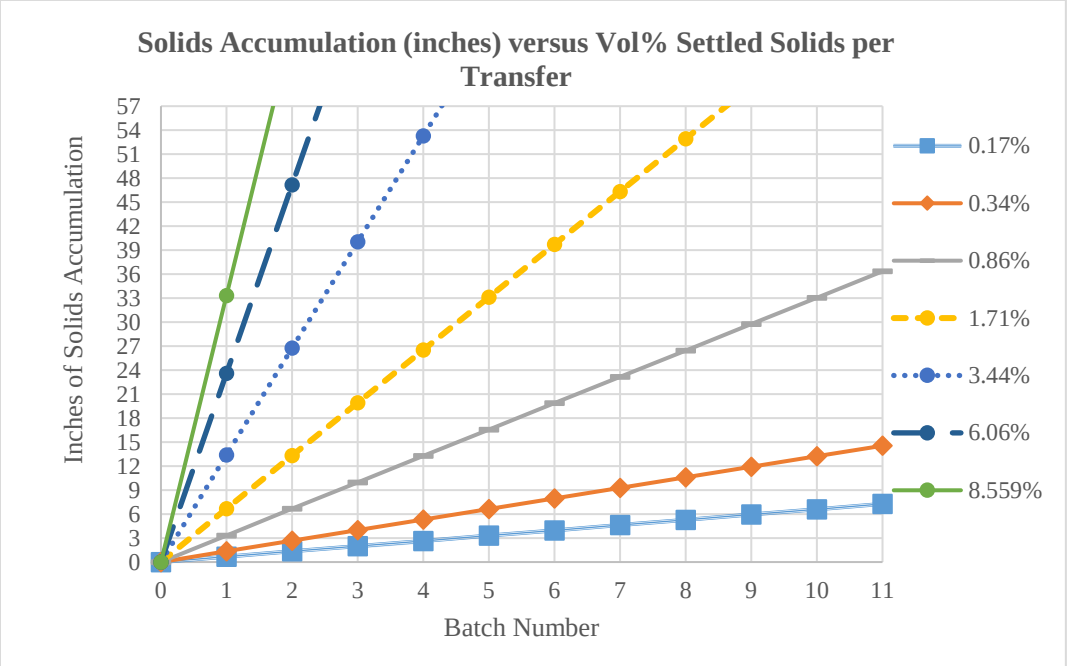

Fig. 3. For an average of 6.06 Vol. % solids level found in the Evaporator slurry, only two transfers are possible Feed Staging Tank 1 (scheduled for 11 transfers) before solids removal is required.

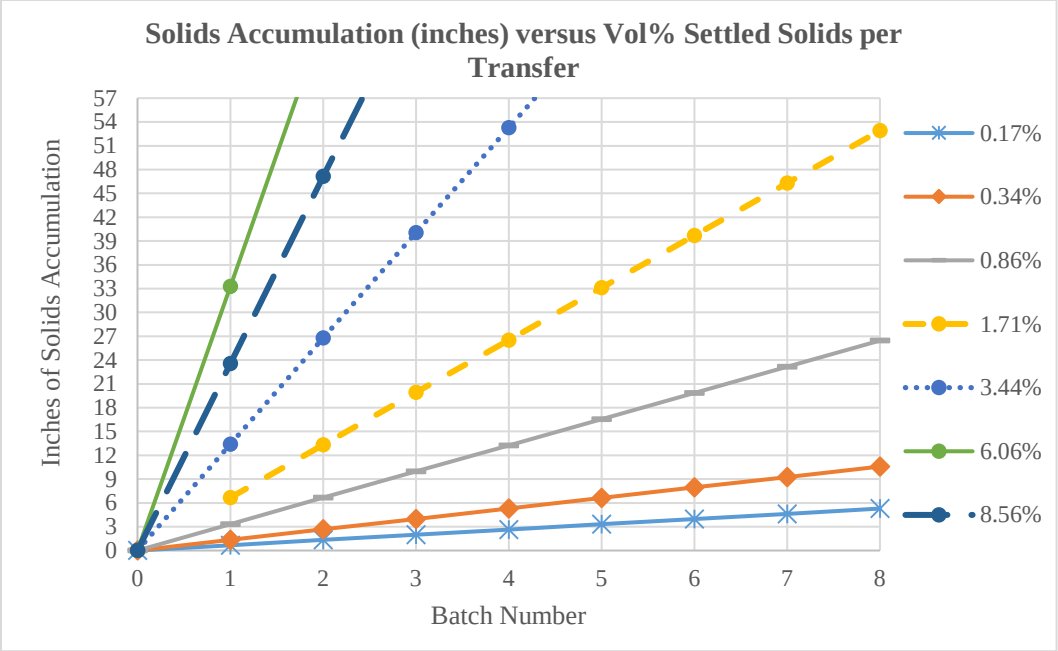

Fig. 4. For an average of 6.06 Vol. % solids level found in the Evaporator slurry, only one transfer is possible to Feed Staging Tank 2 (scheduled for 8 transfers) before solids removal is required.

CONCLUSIONS

Results of this evaluation determine there is a need for the Direct Feed Low Activity Waste Double Shell Tank upgrades to provide for solids removal capabilities. To mitigate interruptions to LAWPS Waste Feed Delivery, a number of options should also be considered in four axes of approach:

- Equipment Operational Controls
  - Reassess whether the 30.5 cm (12 inch) separation assumption between the transfer pump inlet and solids layer during retrievals could be relaxed. Pump inlet position should be based on test data that examines solids entrainment as a function of operating conditions of the transfer pump. Reduction of suction separation from deposited solids would increase working volume in the feed staging tanks but could not exceed a 3% improvement in working volume.

- Waste Analysis
  - Conduct particle settling analysis, and centrifugation of solids, upon waste qualification samples in order to ascertain projected solids in decant transfers to LAWPS Feed Tank and to project solids accumulation in the feed staging tanks.

- Solids Retrieval and Waste Storage

- Remove any existing solids ahead of the LAWPS campaign in feed staging tank
- Optimize solids removal operations for fast turnarounds and relocation of the tank solids.
- Allow sufficient waste residence time in Evaporator slurry receipt tanks for solids to settle prior to transferring to Feed Stage Tank 1 and 2.

Modifying waste transfer volumes into the feed staging tanks in an attempt to mitigate solids entrainment is one strategy that would change the timing of solids accumulation. Reducing batch sizes from 4.05 ML would leave additional room in the feed staging tanks for solids to accumulate without impinging on the 30.5 cm (12 inch) separation distance. However, the smaller batches would still require 194 days to qualify and would require additional transfers. It would also not change the total amount of solids accumulating in the tanks.

While further research is required to finesse both understanding of solids precipitation parameters, using this estimation method can help operations assess appropriate control measures for LAWPS solids accumulation in an effort to minimize interruption of Waste Feed Delivery schedules.

REFERENCES

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