Mixing Modeling Analysis for SRS Salt Waste Disposition

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INTRODUCTION

Nuclear waste at Savannah River Site (SRS) waste tanks consists of three different types of waste forms. They are the lighter salt solutions referred to as supernate, the precipitated salts as salt cake, and heavier fine solids as sludge. The sludge is settled on the tank floor. About half of the residual waste radioactivity is contained in the sludge, which is only about 8 percentage of the total waste volume. Mixing study to be evaluated here for the Salt Disposition Integration (SDI) project focuses on supernate preparations in waste tanks prior to transfer to the Salt Waste Processing Facility (SWPF) feed tank.

The methods to mix and blend the contents of the SRS blend tanks were evalutaed to ensure that the contents are properly blended before they are transferred from the blend tank such as Tank 50H to the SWPF feed tank. The work consists of two principal objectives to investigate two different pumps. One objective is to identify a suitable pumping arrangement that will adequately blend/mix two miscible liquids to obtain a uniform composition in the tank with a minimum level of sludge solid particulate in suspension. The other is to estimate the elevation in the tank at which the transfer pump inlet should be located where the solid concentration of the entrained fluid remains below the acceptance criterion (0.09 wt% or 1200 mg/liter) during transfer operation to the SWPF.

Tank 50H is a Waste Tank that will be used to prepare batches of salt feed for SWPF. The salt feed must be a homogeneous solution satisfying the acceptance criterion of the solids entrainment during transfer operation. The work described here consists of two modeling areas. They are the mixing modeling analysis during miscible liquid blending operation, and the flow pattern analysis during transfer operation of the blended liquid.

The modeling results will provide quantitative design and operation information during the mixing/blending process and the transfer operation of the blended liquid in the Salt Disposition Integration (SDI) facility. The results will also help validate the anticipated performance of the pump vendor's design.

DESCRIPTION OF THE ACTUAL WORK

The liquid mixing analysis for the Tank 50H waste tank shown in Fig. 1 includes three cases, all of which deal with a particular pump configuration using a combination of pump type, tank wall boundary, and the resulting flow pattern from that configuration. For the Savannah River National Laboratory (SRNL) pilot-scale blending testing [1], the 1.65 gpm acid solution of 1.14 specific gravity and 1.16 cp viscosity was added through the top of tank when the tank fluid is established by dual-jet pump as initial condition. The three primary cases considered for the mixing analysis are:

Case-A: A 1/10.85 scale model with no cooling coils to benchmark the model against the SRNL test results.

Case-B: A 1/10.85 scale model with cooling coils to benchmark the model against the SRNL test results.

Case-C: The prototypic tank model with and without cooling coils to estimate mixing time including the obstruction effect results of the cooling coils obtained by the Tank 50H models.

All the analysis took Computational Fluid Dynamics (CFD) approach with the three-dimensional prototypic configuration of SRS Tank 50H, as shown in Fig. 1. As shown in the figure, major solid obstructions including the tank wall, the pump housing, the transfer pump column, 560 2-in cooling coils, and the 82-in central support column will be included in the mixing performance model. In this work, two-equation turbulence model was used since typical Reynolds numbers for the operating conditions considered here are in the range of 10^5. Species transport equation was solved for the estimate of transient acid species concentration. At scale-down and full-scale models, flow obstructions due to the presence of the cooling coils were evaluated by the separate effect analysis via a partial modeling of the prototypic tank domain. Basic flow pattern behaviors used in the model was benchmarked against the SRNL test results [1] with and without cooling coils. The tests were conducted for a 1/10.85 scale tank containing three different fluids. The properties of the fluids used in the analysis are summarized in Table 1. The modeling results for the water will be mainly presented here.

Table 1: Supernate fluid properties used in the work

Tank fluid	Density, gm/ml	Kinematic Viscosity (Centipoise)
Supernate + Inhibited water (Deionized water + NaOH)	1.00	1.00
Supernate, NaOH + $NaNO_2$ + Deionized water	1.26	2.35
Supernate, NaOH + $NaNO_3$ + Deionized water	1.32	2.26

RESULTS

The transient governing equations of three momentum equations, one mass balance, two turbulence transport equations for kinetic energy and dissipation rate, and one species transport were solved by an iterative technique until the species concentrations of tank fluid were in equilibrium. The steady-state flow solutions for the entire tank fluid were used for the initial conditions. A series of the modeling calculations were performed to estimate the blending times for various jet flow conditions and to investigate the impact of the cooling coils on the blending time. The modeling results were also benchmarked against the pilot scale test results. All of the mixing models were performed with the nozzles installed slightly above the mid-elevation (about 16 inches) and parallel to the tank wall as shown Fig. 1.

From the modeling results, the main conclusions are made as follows:

- The modeling results are in good agreement with the SRNL test results as shown Fig. 2.
- An empirical equation for a tank with no coolibg coils agree reasonably with the current modeling results for the dual jet. That is, mixing time, t, for jet velocity U_o is

$$t = C \frac{D_t^2}{U_o D}$$

  where C = 3.7 (3.0 for the literature value of single jet), D_t and D is tank and nozzle diameters, respectively.
- From the sensitivity study of the cooling coils, it was found that the tank mixing time for the coiled tank was about two times longer than that of the tank fluid with no coils under the 1/10th scale, while the coiled tank required only 30% longer than the one without coils under the prototypic Tank 50H.
- The modeling results show that sludge will be disturbed when local velocity near the tank bottom is greater than 0.03 ft/sec. This velocity corresponds to U_oD is greater than 0.58 ft^2/sec, which is observed by the experimental observation.

REFERENCES

1. Leishear, R., Folwey, M., Poirier, M., Steeper,T., ,“Cooling Coil Effects On Blending in a Pilot Scale Tank”, AIChE Annual Conference, New York, New York (2010).
2. Lee, S., Leishear, R. A., Dimenna, R., Stefanko, D. B., “Analysis of Turbulent Mixing Jets in a Large Scale Tank”, ASME, Journal of Fluids Engineering, (2008)..

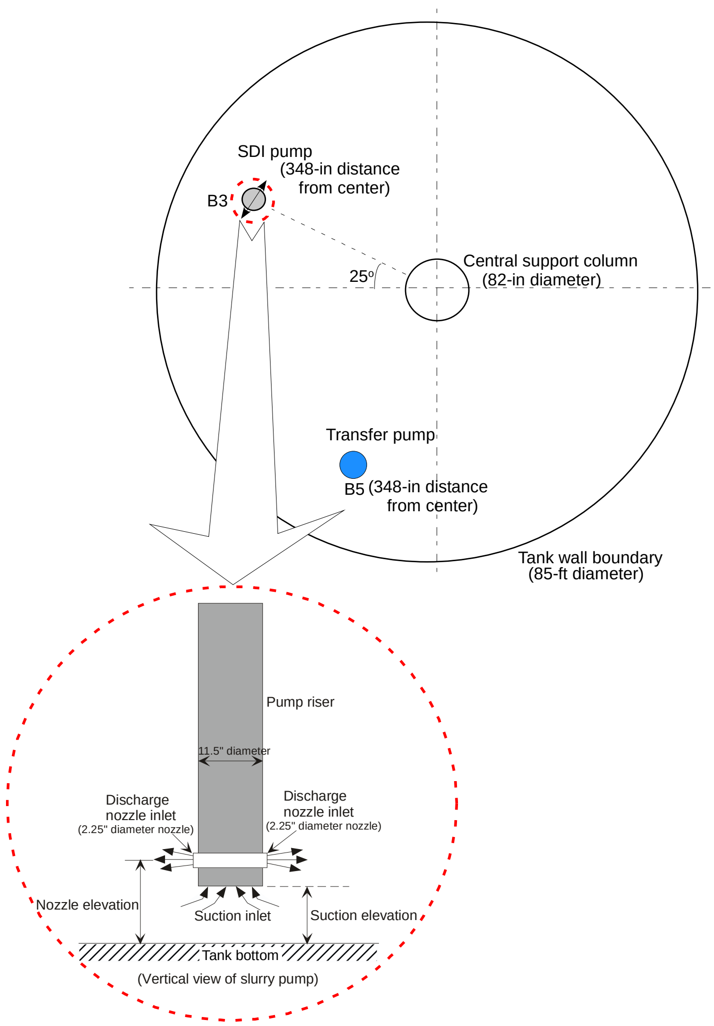

Figure 1. Geometrical configurations containing one blending pump and one transfer pump in the analysis of the Tank 50H mixing

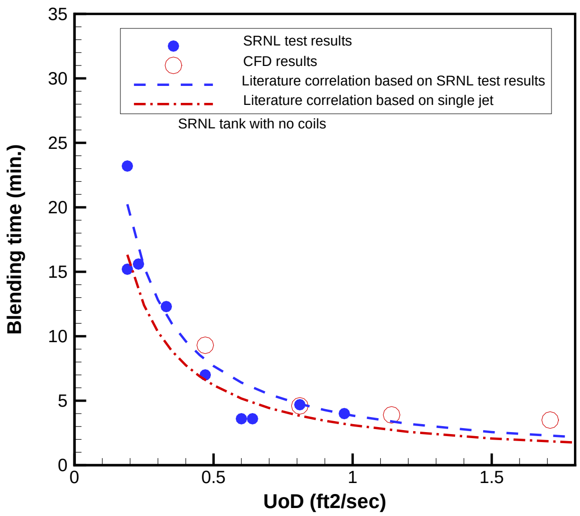

Figure 2. Benchmarking results of SRNL tank with no coils against the SRNL test results for the water-acid blending time