ABSTRACT

The purpose of this dissertation is to provide a written record of the evaluation performed on the DWPF mixing process by the construction of numerical models that resemble the geometry of this process. There were seven numerical models constructed to evaluate the DWPF mixing process and four pilot plants. The models were developed with commercial software Fluent and the results from these models were used to evaluate the structure of the flow field and the power demand of the agitator. The results from the numerical models were compared with empirical data collected from these pilot plants that had been operated at an earlier date.

Mixing is commonly used in a variety ways throughout industry to blend miscible liquids, disperse gas through liquid, form emulsions, promote heat transfer and, suspend solid particles. The DOE Sites at Hanford in Richland Washington, West Valley in New York, and Savannah River Site in Aiken South Carolina have developed a process that immobilizes highly radioactive liquid waste. The radioactive liquid waste at DWPF is an opaque sludge that is mixed in a stirred tank with glass frit particles and water to form slurry of specified proportions.

The DWPF mixing process is composed of a flat bottom cylindrical mixing vessel with a centrally located helical coil, and agitator. The helical coil is used to heat and cool the contents of the tank and can improve flow circulation. The agitator shaft has two impellers; a radial blade and a hydrofoil blade. The hydrofoil is used to circulate the mixture between the top region and bottom region of the tank. The radial blade sweeps the bottom of the tank and pushes the fluid in the outward radial direction. The full scale vessel contains about 9500 gallons of slurry with flow behavior characterized as a Bingham Plastic. Particles in the mixture have an abrasive characteristic that cause excessive erosion to internal vessel components at higher impeller speeds. The desire for this mixing process is to ensure the agitation of the vessel is adequate to produce a homogenous mixture but not so high that it produces excessive erosion to internal components.

The main findings reported by this study were:

1. Careful consideration of the fluid yield stress characteristic is required to make predictions of fluid flow behavior. Laminar Models can predict flow patterns and stagnant regions in the tank until full movement of the flow field occurs. Power Curves and flow patterns were developed for the full scale mixing model to show the differences in expected performance of the mixing process for a broad range of fluids that exhibit Herschel–Bulkley and Bingham Plastic flow behavior.
2. The impeller power demand is independent of the flow model selection for turbulent flow fields in the region of the impeller. The laminar models slightly over predicted the agitator impeller power demand produced by turbulent models.
3. The CFD results show that the power number produced by the mixing system is independent of size. The 40 gallon model produced the same power number results as the 9300 gallon model for the same process conditions.
4. CFD Results show that the Scale-Up of fluid motion in a 40 gallon tank should compare with fluid motion at full scale, 9300 gallons by maintaining constant impeller Tip Speed.