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Tank 27 Solids Disturbance Testing Using M-Star for the Impact of CSMP Usage on Blend Tank Mixing Effectiveness

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EXECUTIVE SUMMARY

Savannah River Mission Completion (SRMC) plans to operate Tank 27as a blend tank for future waste disposal operations. It is desirable to avoid additional worker exposure by using the planned commercial submersible mixing pump (CSMP) installations in Risers B2 and B4 to function as the blend pumps for prolonged blend tank operations. The purpose of this task is to evaluate the impacts to mixing across a range of pump installation heights from 1 to 201 inches above the tank floor. The CSMPs shall maintain adequate blending within a 24 hour maximum timeframe and an adequate nozzle discharge velocity as outlined in U-ESR-G-00030[1], using the specifications of the planned CSMPs listed in PO SRRA149971 and M-DS-G-00081. Specifications include: maximum pump diameter of D=22.5 in., dual nozzles placed tangentially opposed with nominal inside diameter of 2 in., total flow range (both nozzles combined) of 500 to 1950 GPM and maximum RPM of 1800. Tank 27 is expected to have a fill height maximum of 360".

This analysis began by using results from the 2010 testing and applying them to the Tank 27 design to calculate a mixing time as a function of pump flow rate.[2] These results were modified to account for the higher liquid level in Tank 27. Once the liquid level was increased to 360 inches, the results were modified to account for a higher viscosity in Tank 27 than in the testing. Once the viscosity was increased, the effect of changing pump elevation was applied to calculations of the mixing time in Tank 27. Finally, the uncertainty from the testing was included in the analysis to recommend a blend time as a function of pump flow rate and elevation.

The conclusion from this study is that the particles in tank 27 will be suspended at both the 600 and 900 gpm flow rates. Only particles above 90 micron will not be suspended in significant amounts when the flow rate is 600 gpm. At 900 gpm even 100 micron particles were thoroughly suspended in the tank. From the series of simulations it has been concluded that it will not be possible to mix tank 27 at the proposed fluid flow rates and not suspend the solid particles at the bottom of the tank.

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LIST OF ABBREVIATIONS

SRNL	Savannah River National Laboratory
SRMC	Savannah River Mission Completion
CSMP	commercial submersible mixing pump
CFD	Computational Fluid Dynamics

1.0 Introduction

Savannah River Mission Completion (SRMC) plans to operate Tank 27F as a blend tank for future waste disposal operations. It is desirable to avoid additional worker exposure by using the planned commercial submersible mixing pump (CSMP) installations in Risers B2 and B4 to function as the blend pumps for prolonged blend tank operations. The purpose of this task is to evaluate the impacts to mixing across a range of pump installation heights from 1 to 201 inches above the tank floor. The CSMPs shall maintain adequate blending within a 24 hour maximum timeframe and an adequate nozzle discharge velocity as outlined in U-ESR-G-00030[1], using the specifications of the planned CSMPs listed in PO SRRA149971 and M-DS-G-00081. Specifications include: maximum pump diameter of D=22.5 in., dual nozzles placed tangentially opposed with nominal inside diameter of 2 in., total flow range (both nozzles combined) of 500 to 1950 GPM, and maximum RPM of 1800. Tank 27 is expected to have a fill height maximum of 360".

SRNL performed an engineering analysis to calculate the miscible liquid blend time as a function of pump flow rate, pump elevation, liquid density, and liquid level.[3] This work was not able to determine the degree of solid particle suspension as a function of pump operating parameters.

SRNL was requested by SRMC to use M-Star CFD simulations to determine the extent of particle suspension in Tank 27 by the jet mixers pointing horizontally relative to the bottom of the tank so that the fluid jet will contact the walls of the tank at a 90° angle.

2.0 Experimental Procedure

2.1 Methods

A simulation was developed to test the effect of particle size and pumping speed on particle suspension in Tank 27. Tank 27 is 26 meters(88.6 feet) in diameter and 2.7 meters (9 feet) tall. The tank is filled with a Newtonian fluid that has a density of 1260 kg/m^3 and a kinematic viscosity of $2x10^{-6}$ m^2/s. The M-Star build contained a tank and fluid with these parameters, contained 2 jets set at a height of 201 inches above the bottom of the tank pointing directly at the walls of the vessel, was filled with numerous vertical cylinders to simulate the cooling coils, and 100,000 particles were added to the bottom of the vessel in a thin layer 0.12 m high (4.7 inches). The particle sizes were varied from 10-100 micron in diameter over the course of several tests. The flow rate of the pump was varied between 600 and 900 gpm. The acceptance criteria for the particle suspension were whether or not the equivalent concentration of solids stayed below 1.2 g/L.

2.2 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.

3.0 Results and Discussion

Two series of simulations were done at flow rates of 600 and 900 gpm. Within each series the particle sizes were varied between 10-100 micron in diameter. The results from the 600 gpm tests are shown in **Error! Reference source not found.**. The results show that after 500 seconds the particles above 90 micron were the only particles that remained unsuspended in quantities that would keep the concentration of solids below 1.2 g/L. In Figure 3-2 the fluid flow and particle are shown as a function of time for 500 seconds of mixing time. These screenshots show that the jets flow horizontally until they reach the vessel walls and then flow downwards until contacting the particles at the bottom of the vessel between 100 and 200 seconds. The particles are then suspended by the expanding jet as time goes.

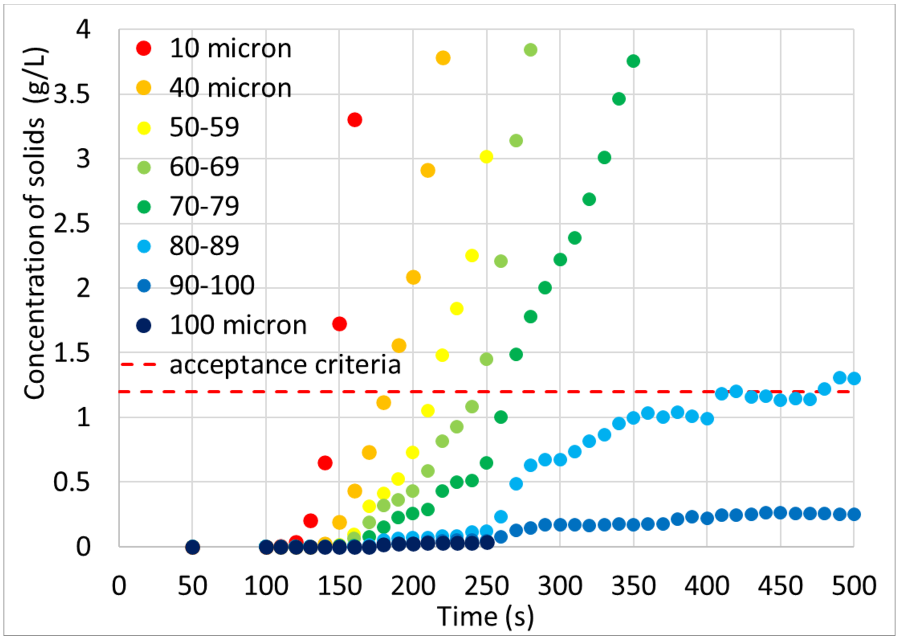

Figure 3-1 Concentration of solids suspended in fluid above 0.24 meters over time at 600 gpm

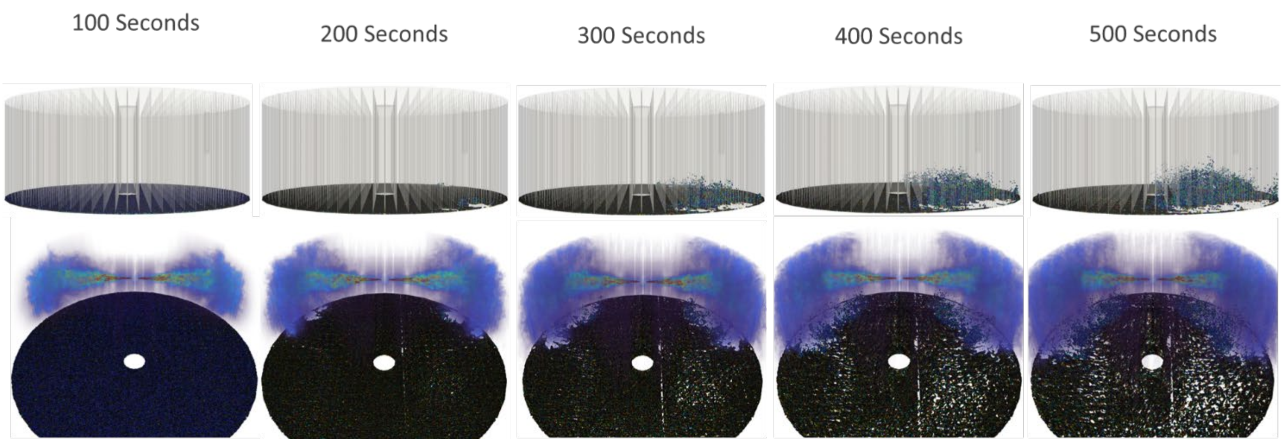

Figure 3-2 Screenshots of 600 gpm test with particle sizes ranging from 50-100 micron in diameter

The 900 gpm tests show a much more drastic result compared to the 600 gpm tests. The 10 micron particle tests show that the particles are quickly suspended. Figure 3-3 a shows that over time there is a constant of loss of particles in the bottom 0.24 meters of the tank. After 73 seconds only about 12,000 of the initial 100,000 particles added are at the bottom of the tank. Figure 3-3 b shows that after 73 seconds the particles have been suspended as high as 5 meters. Figure 3-4 illustrates how thoroughly disturbed the particles are throughout the vessel. Unlike the 600 gpm tests the particles from every part of the tank have been disturbed.

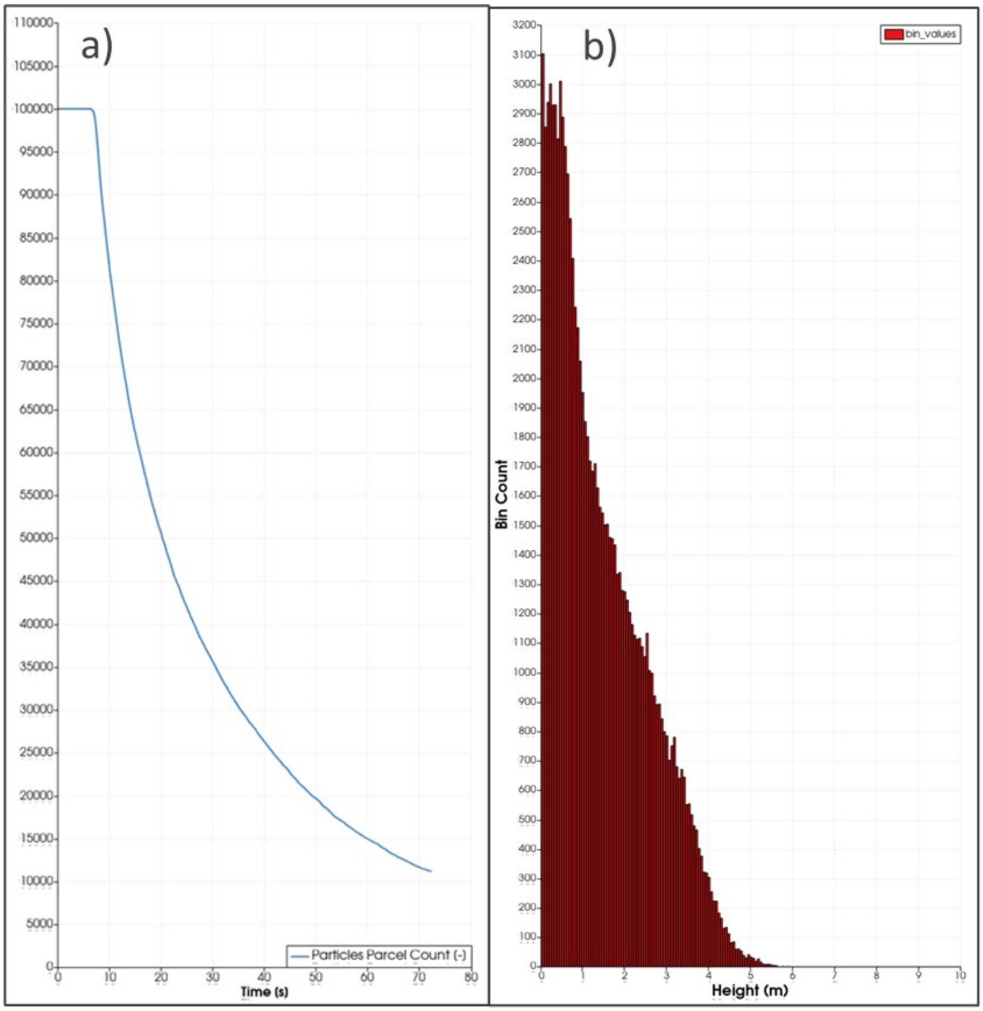

Figure 3-3 Results of the 10 micron particle simulation with a jet flow rate of 900 gpm a) Number of particles remaining below 0.24 m over time, b) Particle height distribution of after 73 seconds of mixing time

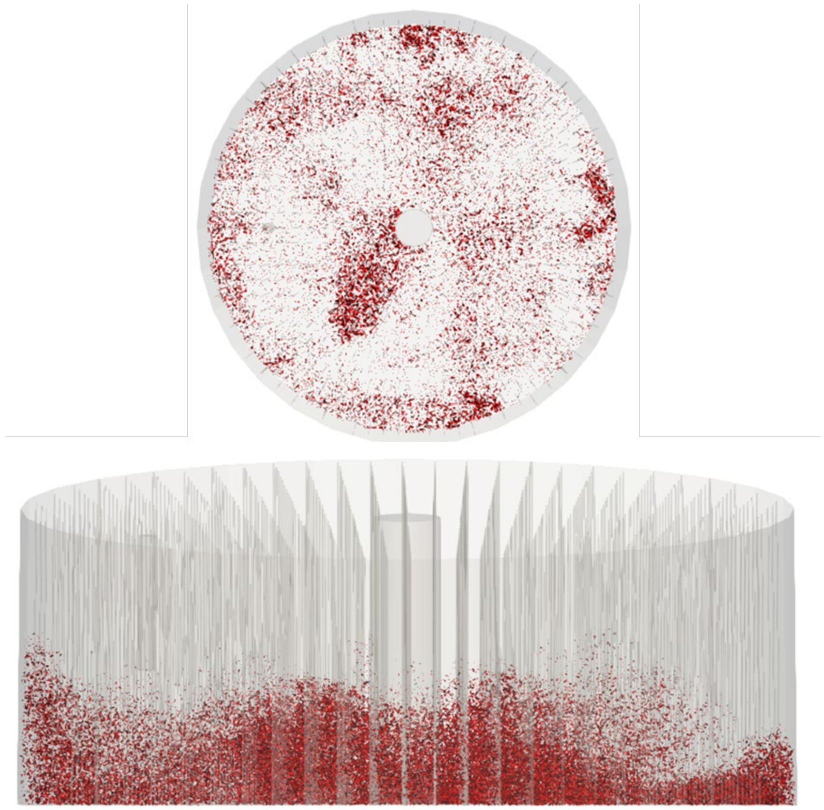

Figure 3-4 Screenshot of 900 gpm test with particle sizes ranging from 10 micron in diameter at 73 seconds of mixing

A 900 gpm flow rate test was run with 100 micron particles and the results show that the particles were easily disturbed even at this larger size. Figure 3-5 shows that after 174 seconds of mixing time less than 5000 of the original 100,000 particles remained at the bottom of the tank. Figure 3-6 shows that the particles are disturbed throughout the entire tank and even reach the top of the vessel.

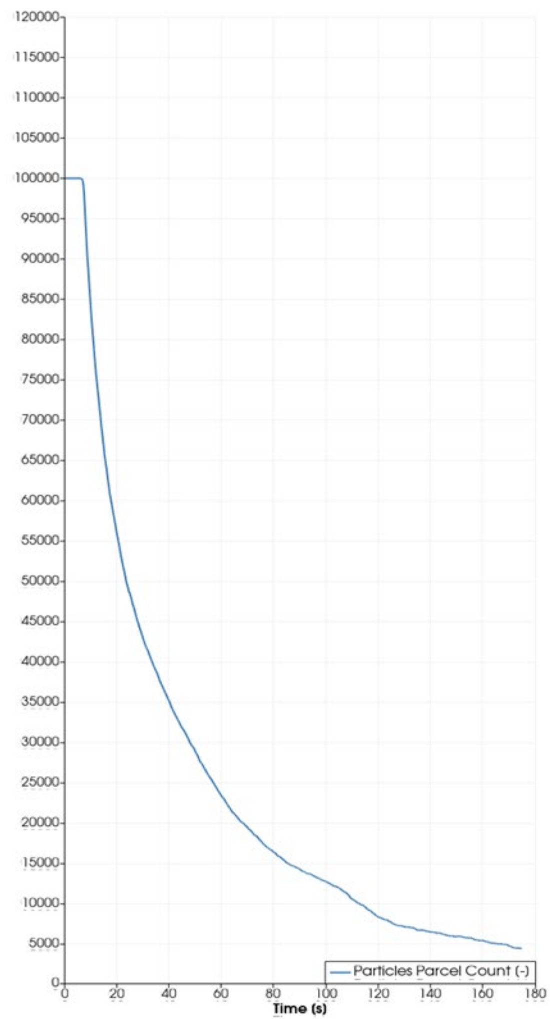

Figure 3-5 Number of 100 micron particles remaining below 0.24 m over time with a jet flow rate of 900 gpm

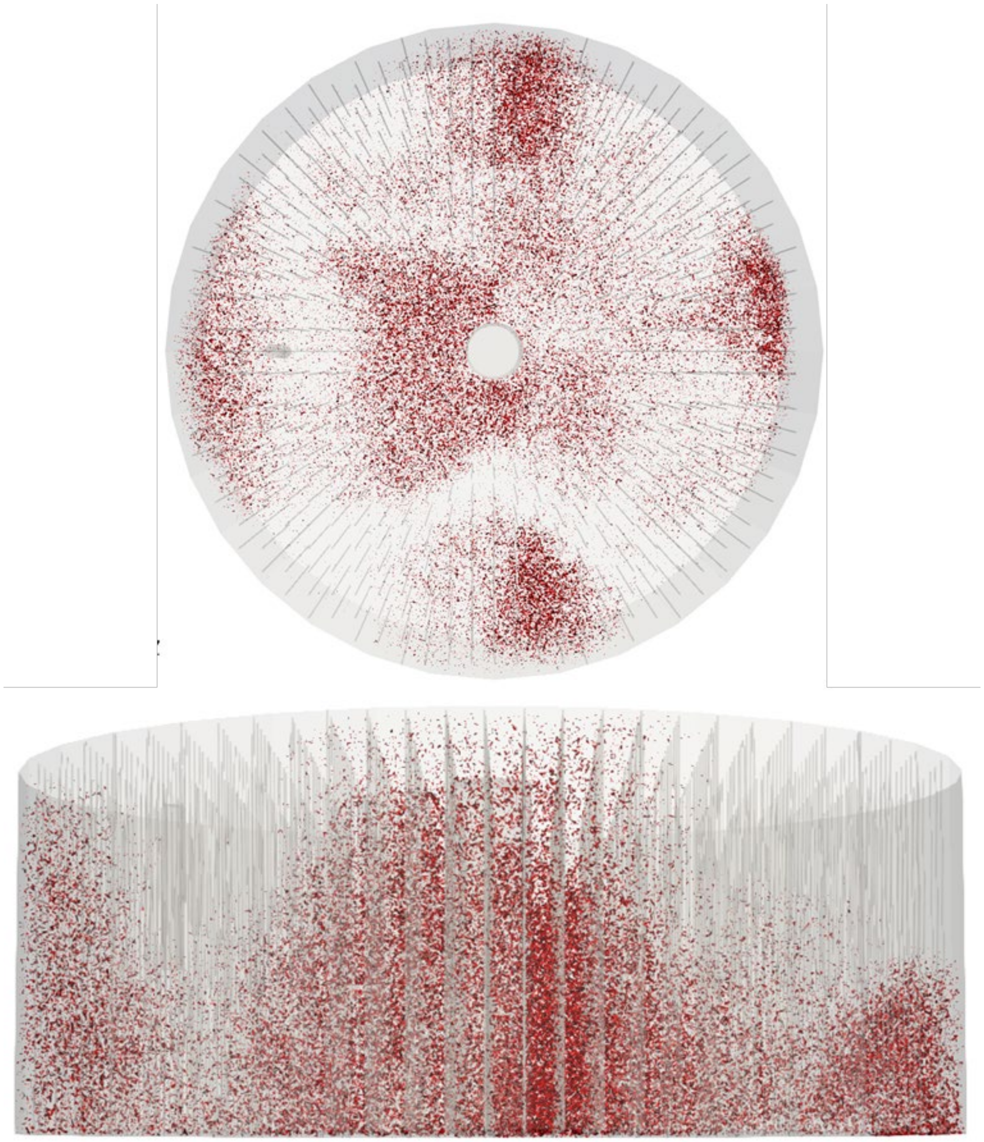

Figure 3-6 Screenshot of 900 gpm test with particle sizes ranging from 100 micron in diameter at 174 seconds of mixing.

4.0 Conclusions

In conclusion the particles in Tank 27 will be suspended at both the 600 and 900 gpm flow rates. Only particles above 90 micron will not be suspended in significant amounts when the flow rate is 600 gpm. At 900 gpm even 100 micron particles were thoroughly suspended in the tank. From the series of simulations, it has been concluded that it will not be possible to mix Tank 27 at the proposed fluid flow rates and not suspend the solid particles at the bottom of the tank.

These results are consistent with previous SRNL pilot-scale testing.[4]

5.0 Recommendations, Path Forward or Future Work

It is recommended that, since solids will be suspended due to operation of the CSPMs, the solids should be allowed to settle before the removal of any fluids after mixing.

6.0 References

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