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CST/WATER SLURRY MIXING AND RESUSPENSION (U)

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EXECUTIVE SUMMARY

A testing facility was configured to define agitator configurations and mixing parameters capable of maintaining a homogeneous CST/water slurry containing 10 wt% as-received CST (particle size range - 30 to 60 mesh) and 10 wt% size reduced CST (maximum particle size – 177 microns). A homogeneous slurry was defined as one where the CST concentration variance throughout the slurry is no more than 5%.

Using a baffled mixing vessel that dimensionally approximated a 1/240th scale DWPF Chemical Process Cell process vessel, homogeneity was readily attained with the size reduced CST using a 5-inch diameter flat bottom agitator blade in combination with a 5-inch diameter top marine impeller at agitator speeds of 500 rpm or greater. Homogeneity was also attainable at agitator speeds as low as 250 rpm when the 5-inch agitator blades were replaced with 8-inch diameter blades. Resuspension of the size-reduced CST solids into a homogeneous slurry after the size-reduced CST had been allowed to settle for 6 days was readily achievable.

Limited testing with a 10 wt% slurry comprised of ~ 1 wt% CST particles greater than 177 micron (the balance being less than 177 micron) indicated that it was not possible to achieve a homogeneous slurry with the 8-inch agitator blades at agitator speeds up to 700 rpm (the limiting speed because of amperage and temperature constraints of the agitator motor). A contract has been established with Philadelphia Mixers (a recognized expert in the mixing industry) to define agitator configurations and mixing parameters capable of maintaining a homogeneous water slurry containing 10 wt% as-received CST. Therefore, the content of this report primarily addresses test results with size reduced CST.

INTRODUCTION

Crystalline Silicotitanate (CST) was selected as one of the alternatives to the In-Tank Precipitation Process (ITP) for removal of cesium from the salt waste at Savannah River Site. The proposed salt waste treatment process using CST would involve passing a filtered salt waste through a fixed bed of CST. The CST would remove the cesium from the salt waste by ion exchange and the decontaminated salt would be incorporated into the Saltstone Process. The loaded resin would be removed from the column as an approximate 10 wt% slurry which would ultimately be blended with the sludge feed in the Defense Waste Processing Facility (DWPF) for incorporation into the waste glass product.

A melter feed containing as-received CST (particle size distribution of 30-60 mesh), has been shown to plug the DWPF Hydragard sampler [1]. Therefore, some form of CST size reduction will be required to allow use of the existing Hydragard sampler systems in the DWPF Chemical Process Cell. Hydragard sampling tests have demonstrated that the existing DWPF Hydragard sampler is capable of obtaining a sludge/frit/CST sample that is representative of the contents of the process vessels if the CST has been reduced in particle size to a maximum of 177 microns [1]. CST has been shown to have the same hydrodynamic characteristics as the DWPF frit when reduced to a particle size distribution comparable to the frit [2]. The capability of size reducing the as-received CST has been successfully demonstrated at off-site vendors [3].

The SRTC was requested to conduct small-scale mixing studies to define the agitator configurations and mixing parameters capable of producing homogeneous slurries of both as-received CST (30 to 60 mesh) and CST whose particle size has been reduced to a maximum particle size of 80 mesh [4,5]. A mixing criterion of 95% homogeneity has been selected.

Note: A top-to-bottom homogeneity of 95% is a generally accepted industrial standard for a "Well Mixed Tank".

This report documents the results of investigations into the mixing and re-suspension characteristics of two 10 wt% CST slurries. A size reduced CST slurry, (maximum particle size <177 micron) and this same slurry trimmed with CST particles greater than 177 micron whose particle size distribution is characteristic of as-received CST (30 – 60 mesh).

TEST EQUIPMENT CONFIGURATION

Figure 1 presents a drawing of the initial test equipment configuration. This represents a 1/240th scale model of a full-scale DWPF melter feed preparation process vessel. Design dimensions were chosen based upon published "Good Practices for Solids Mixing Tanks" and considerations of remote operation which will be required. Five differential pressure transmitters were initially installed in the mixing vessel to evaluate their potential to provide on-line measurement of the concentration of CST at various levels in the tank. Consistent specific gravity measurements at various levels of the tank would indicate uniform mixing of the CST slurry. The relationship between SpG and wt% CST had been previously developed.

Note: Initial testing revealed that the on-line specific gravity measurements were not reliable because of the turbulence caused by the agitator. Consequently, determination of the CST concentration in the mixing vessel was obtained through sampling and off-line total solids determinations.

The grab sampler design by Thermal Fluids Lab personnel was used to collect samples at various levels in the tank, (TOP, MID and BOT). The top sample collected material from the surface to about 4" below the surface (20-24" off the bottom of the vessel). The middle sample was taken 12-16" up from the bottom of the vessel and the bottom sample was taken 4-8" off the bottom of the vessel. The sampler collected a constant volume of material and therefore the mass of dried solids collected was used to quantify the degree of homogeneity. Table 1 presents the key design dimensions.

The baffle spacing from the wall for "Good Practices" applies more for larger tanks. For this tank it would predict a spacing of only 3-5 particle diameters. It is believed that this spacing would lead to dead spots and therefore the spacing from the wall was set larger at ¾ inch. Impeller diameter was chosen to be 5 inches compared to a "Good Practices" diameter of about 8 inches. This was done because plant design would likely require remote agitator removal and therefore a smaller ratio to tank diameter. However, an 8" impeller was also tested.

Figure 1 CST Mixing Tank Configuration

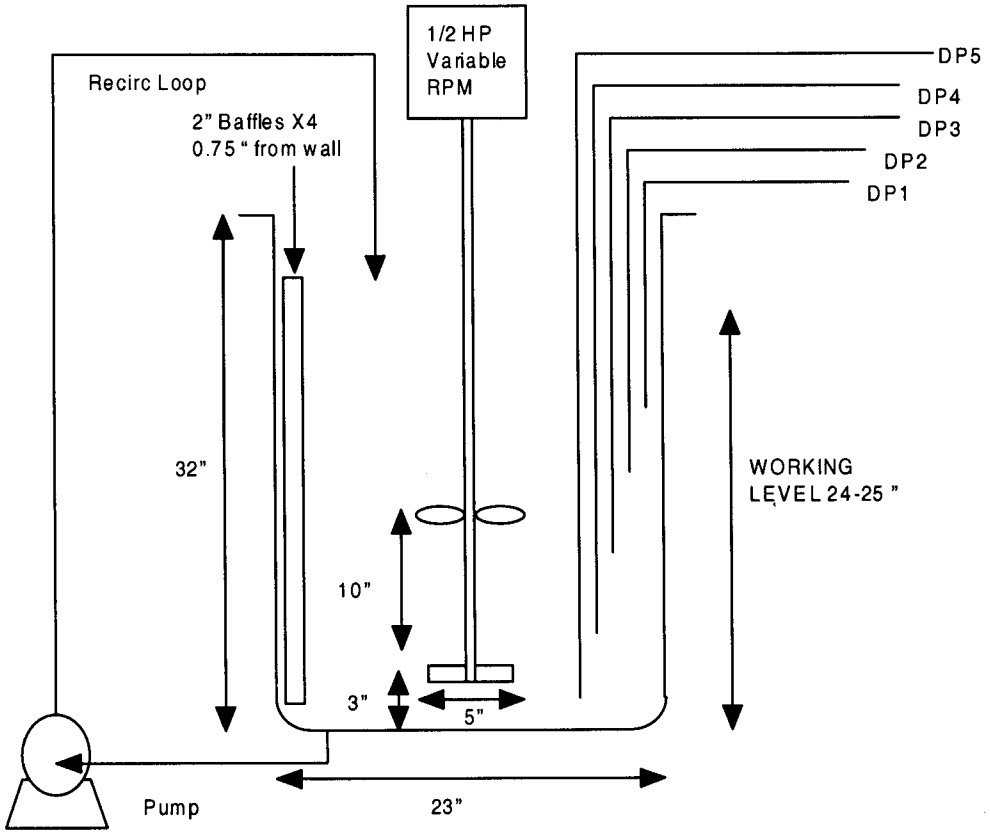
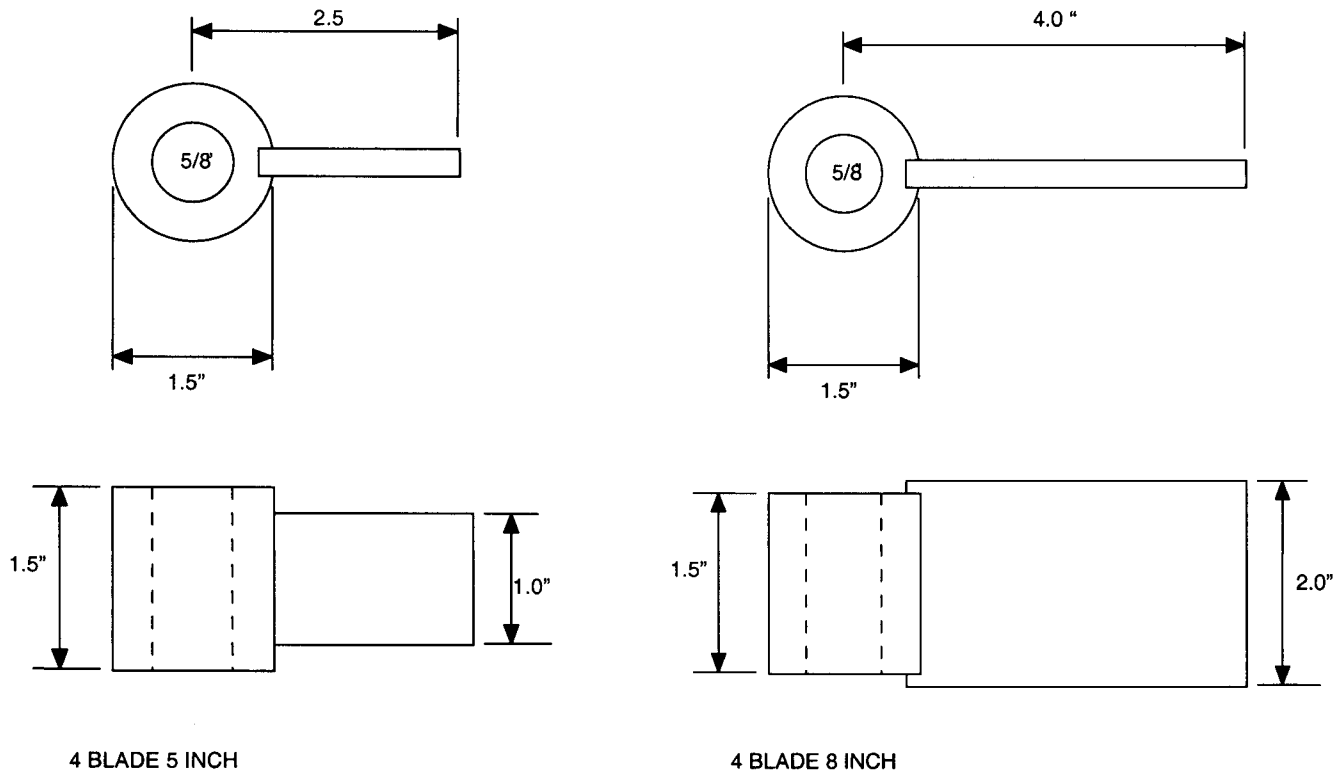


Table 1 Key CST Tank Design Dimensions

	Industry "Good Practice"	CST Tank
Tank Diameter		23 inches
Tank Height		32 inches
Baffles	1/12th Diameter of Tank	2 inches ~1/11 D
Baffle Spacing from Wall	1/72 Diameter of Tank	3/4 inch ~1/30 D
Working Level	Equal to Diameter of Tank	24 - 25 inches
Bottom Impeller	Flat 90 deg	Flat 90 deg
Top Impeller	45 deg or Marine propeller	Marine propeller
Spacing off Tank Bottom	1/3 working height	3 inches ~1/8 H
Impeller Spacing	1/3 working height	10 inches ~2/5 H
Impeller Diameter	1/3 Tank Diameter	5 inches ~1/5 H

Figure 2 depicts the dimensions of the 5" and 8" diameter 90 degree flat blade impellers.

Figure 2 Five and Eight Inch Diameter 90 Degree Flat Blade Impellers



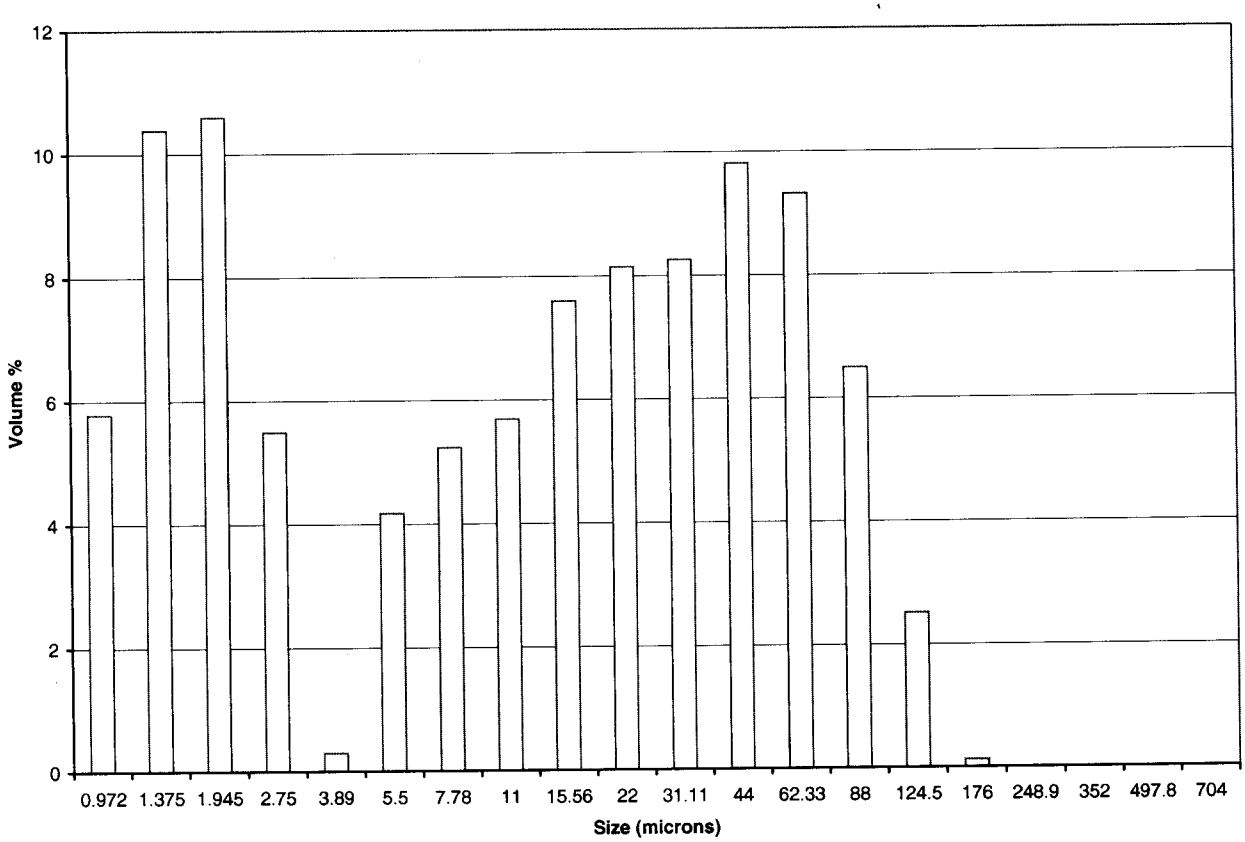
MIXING EXPERIMENTAL RESULTS

CST Particle Size <177 Microns

CST Slurry Preparation

The volume of size reduced CST slurry required for these tests made it necessary to combine size reduced material obtained from both the IKA and Microgrinding test runs [4]. IKA material contained particles significantly larger than 177 micron. These particles were removed from the slurry by wet screening through a 50 mesh sieve tray. Figure 3 presents the particle size distribution for the slurry used in this investigation. This particle distribution is very much like that expected from a particle size reduction process. The total weight percent solids of this slurry was 11.03 wt%.

Figure 3 Particle Size Distribution for < 177 microns CST Slurry

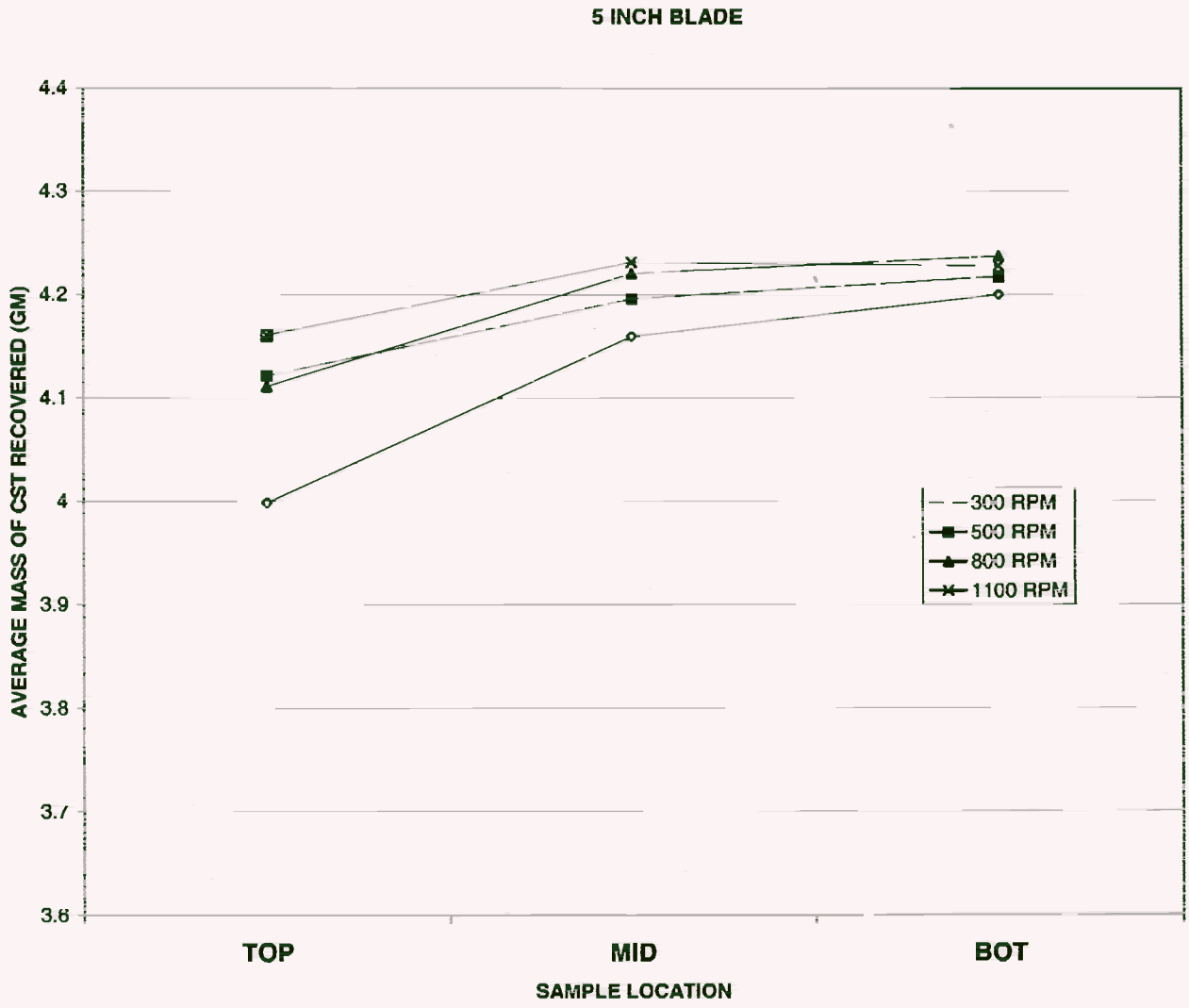


Mixing Results Using 5-Inch Diameter Agitator Impellers

Figure 4 below presents the average mass of dried CST collected in duplicate samples at various levels in the vessel for agitator speeds ranging from 300 to 1100 rpm with the 5"

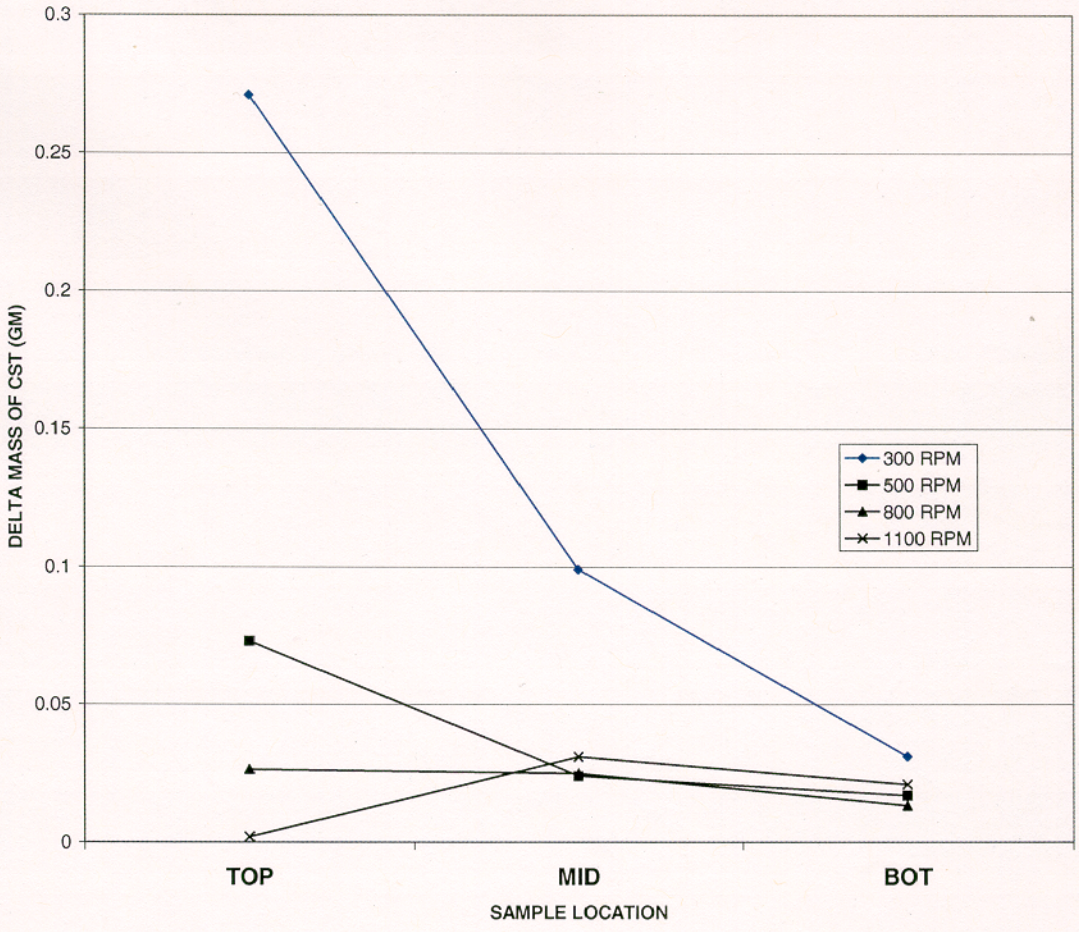
impellers. At 300 rpm, there is a discernable difference in CST concentration between the upper and lower regions of the mixing vessel. This difference becomes less as the agitation speed increases. However, none of these averages of duplicate samples is less than 95% of the bulk slurry concentration.

Figure 4. Average Mass of Dry CST Recovered Versus Agitator RPM and Sample Location



Only one individual sample that was taken at 300 rpm near the top of the slurry level was not within 95% of the bulk slurry. This may be due to sampling error or to variations inherent in sampling a dynamically changing concentration near the slurry surface at low agitation rates. Figure 5 below presents the variability of duplicate samples as a function of agitation. High agitation rates lead to more consistent samples with reduced variability.

Figure 5 Variability of Duplicate Samples Versus Agitator RPM and Sample Location



Results from four samples taken at each of the three locations at 300 rpm are presented in Figure 6. The average of the four samples demonstrates a higher concentration of solids at the bottom of the tank. Samples taken at the top of the tank are ~93% of the bulk concentration and therefore 300 rpm is not sufficient to meet the 95% uniformity criteria.

Figure 6. Variability of 300 RPM Samples Versus Sample Location

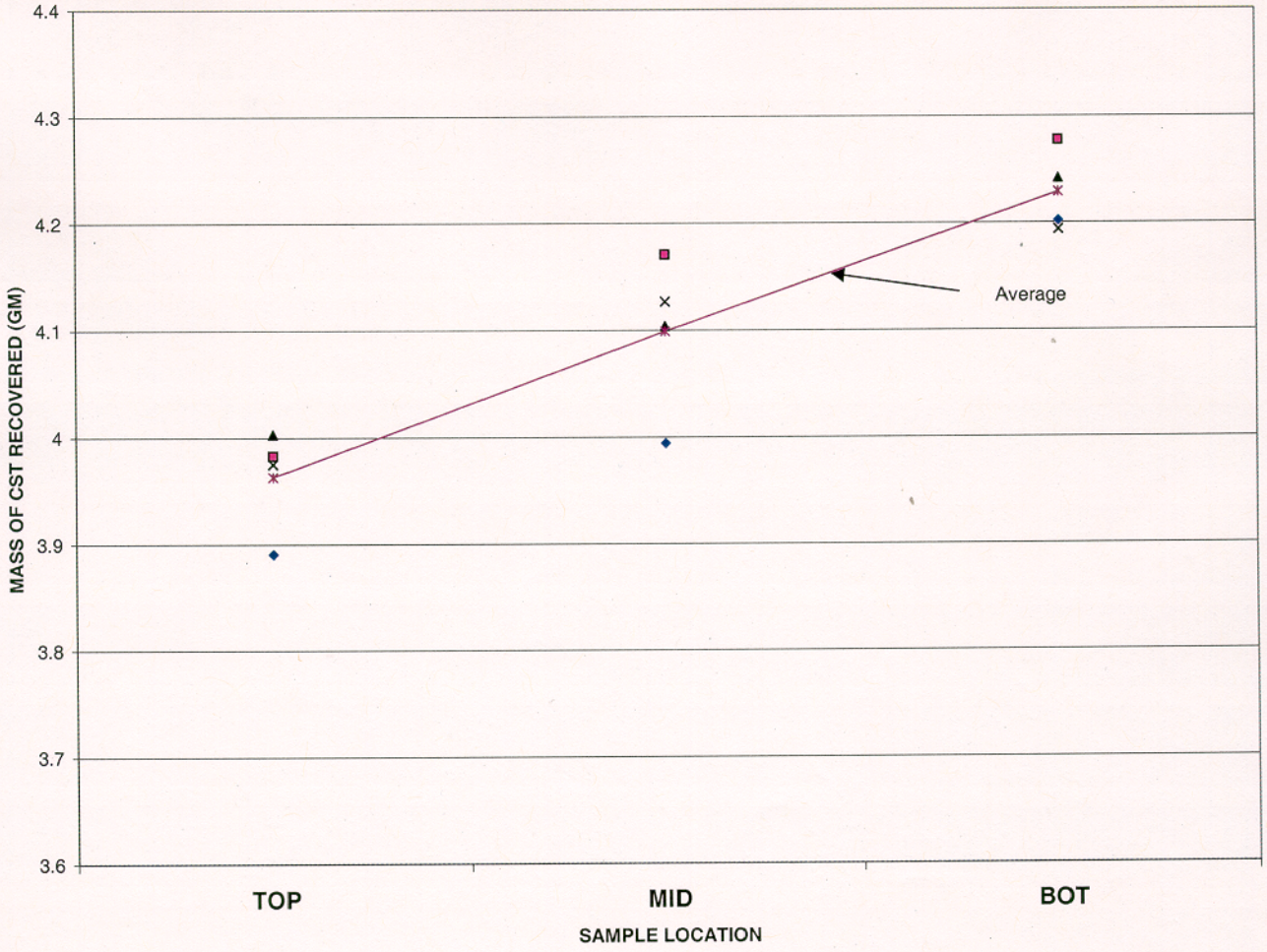


Figure 7 presents the power usage for the agitator using the 5-inch diameter blades. The nonzero intercept of power represents the power requirement of the variable speed drive and its display.

Mixing Results Using 8-Inch Diameter Agitator Impellers

The 5-inch agitator blades were replaced with 8-inch diameter blades. The spacing from the bottom of the tank and between blades was maintained. Figure 8 presents the mixing character for the 8-inch diameter blades. All individual samples were greater than 95% of the bulk concentration. The results indicate that 450 rpm gives better mixing than 250 rpm, but the difference is within experimental error.

Figure 7. Agitator Power Usage Versus Agitator Speed

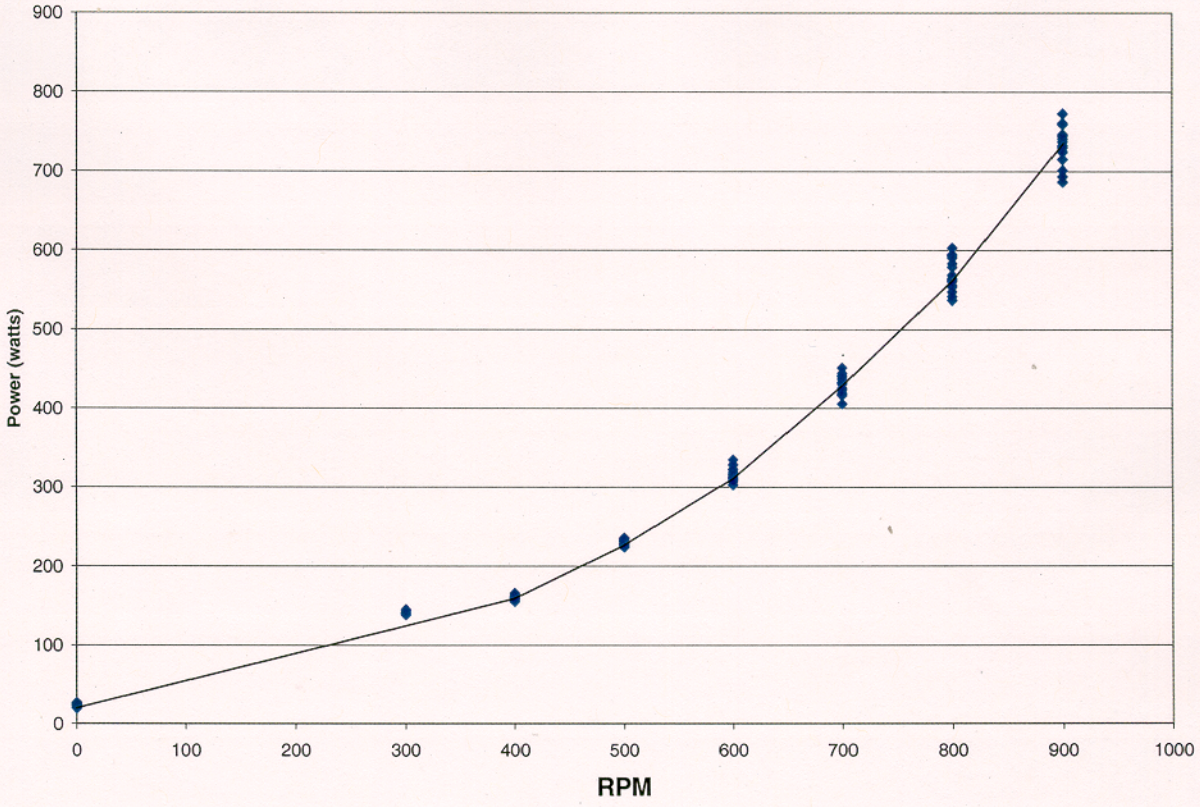
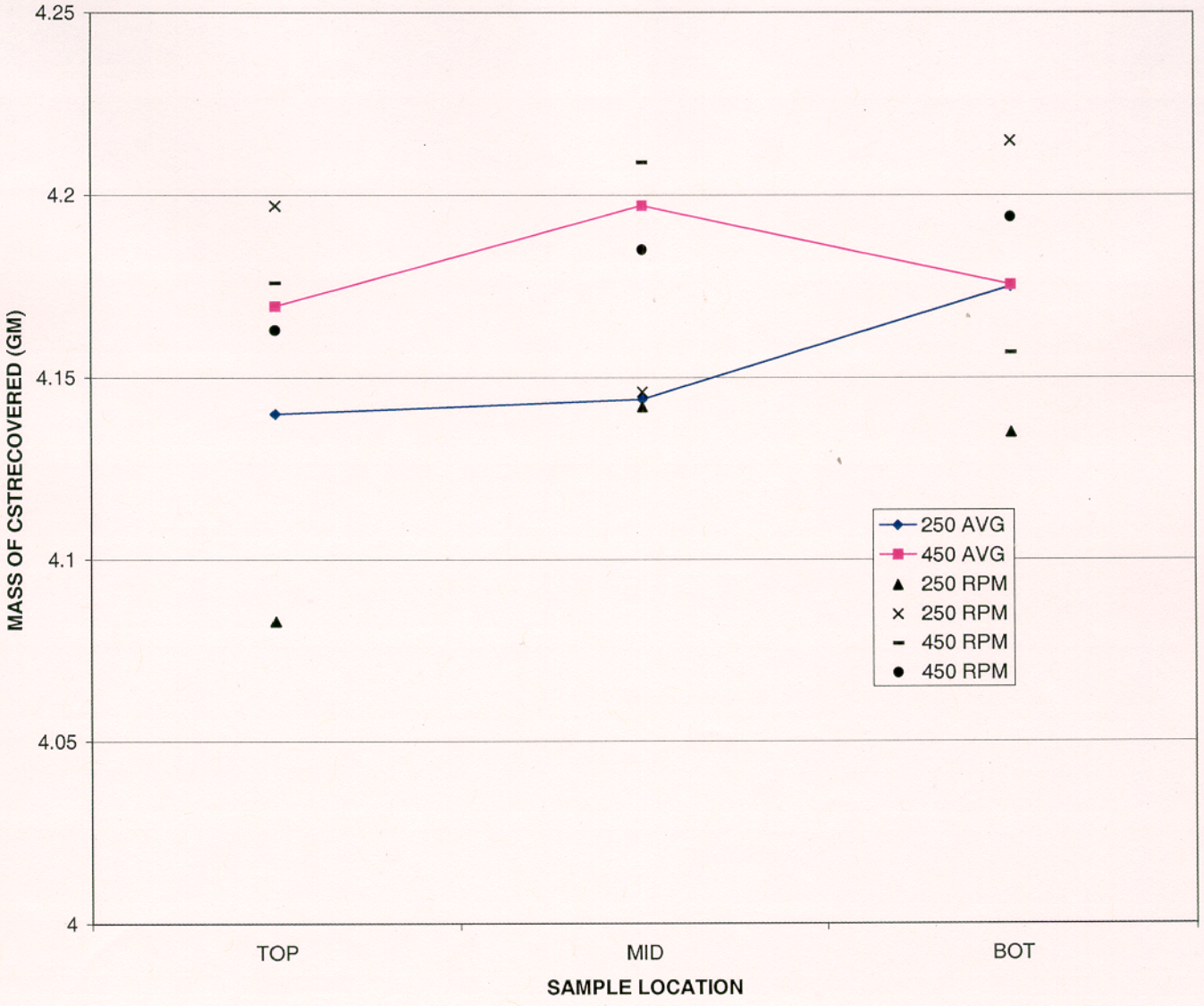


Figure 8. Sample Results and Averages versus Sample Location for 8-Inch Diameter Blades



CST Particle Size > 177 Microns

Slurry Preparation

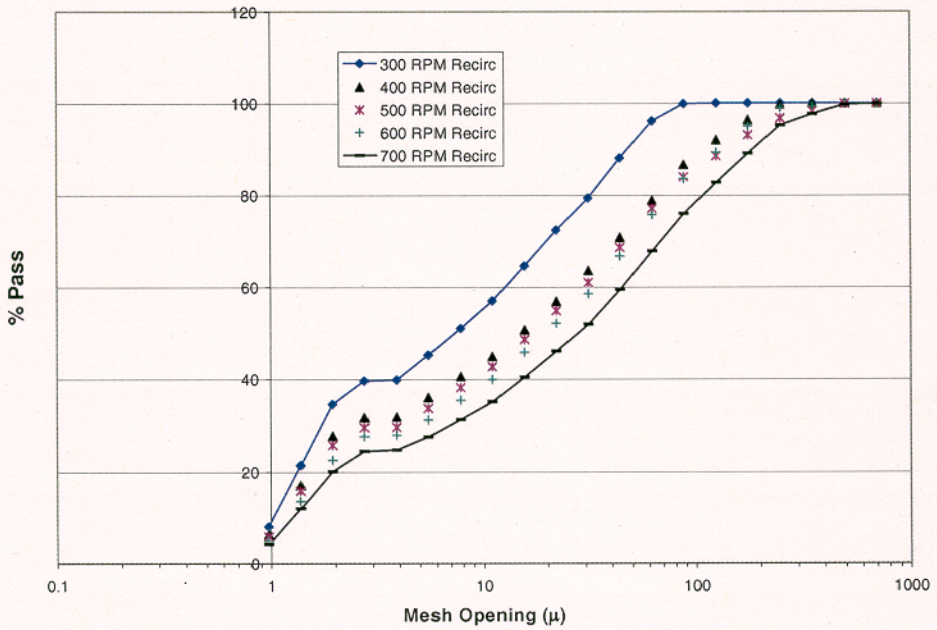
Although the decision was made to go to a mixing vendor to develop the mixing parameters for a 10 wt% as-received CST slurry, an attempt to study the mixing character of a CST slurry containing

particle sizes greater than 177 micron was made. A portion of the particles greater than 177 micron that were previously screened from the IKA size-reduced CST were reintroduced into CST mixing vessel containing the size reduced CST. The resulting slurry contained about 10 % particles in the range comparable to as-received CST while the remaining 90% of the solids were size reduced (<177 microns). Grab samples of this slurry were taken at various agitation rates from the slurry surface and from a recirculation loop pumping off the bottom of the vessel (see Figure 1).

Mixing Results Using 8-Inch Diameter Agitator Impellers

Figure 9 presents the percent pass[(a)] versus mesh opening for the recirculation sample at agitation speeds of 300 – 700 rpm. At an agitator speed of 300 rpm, there were no CST particles in the recirculation loop greater than 80 mesh, or 177microns (i.e. all particles in the sample passed through an opening of 177 microns.). This indicated that 300 rpm could not resuspend any particles greater than 177 micron off the bottom of the tank sufficiently to be drawn into the recirculation loop. At 700 rpm, the presence of particles as large as ~500 microns were present in the sample from the recirculation loop. At this agitation rate, the agitator was pulling ~11.6 amperes which is close to the maximum rated motor current of 12 amperes. Higher agitation rates could therefore not be tested.

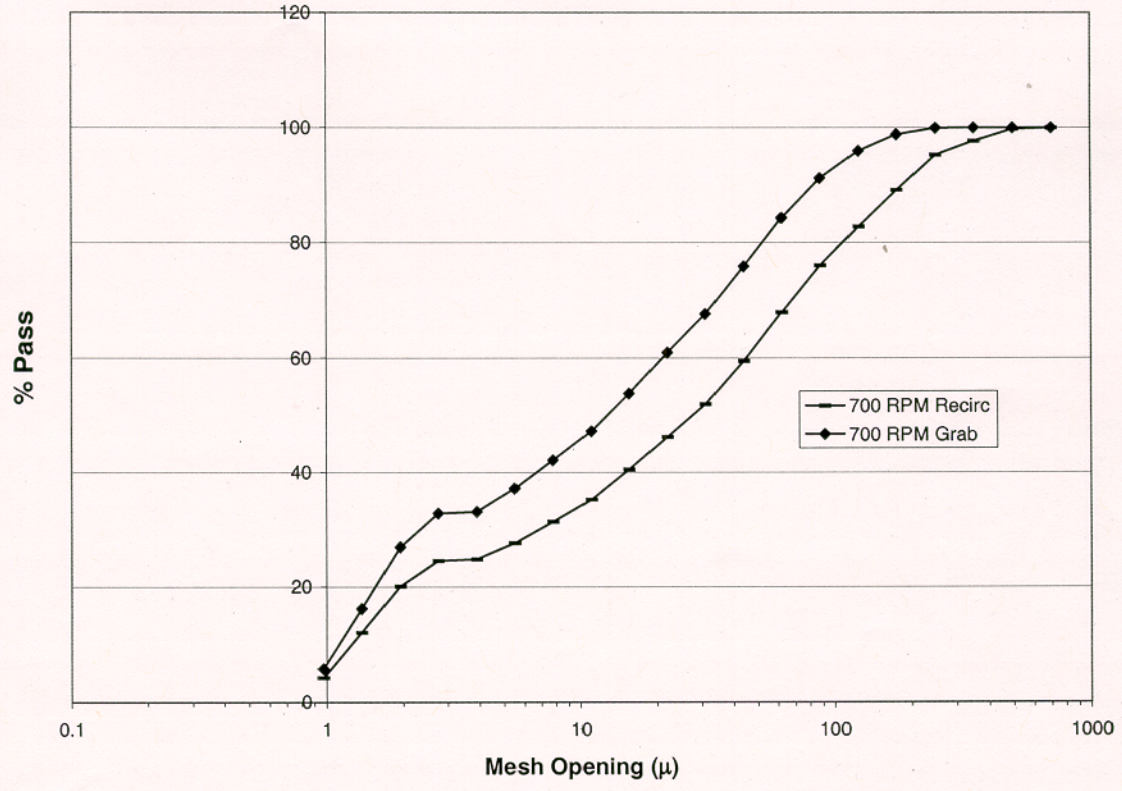
Figure 9. Recirculation Sample % Pass versus Mesh Opening (> 177 microns CST with 8 Inch Blades)



[(a)] wt % of particles in the slurry smaller than a given mesh size

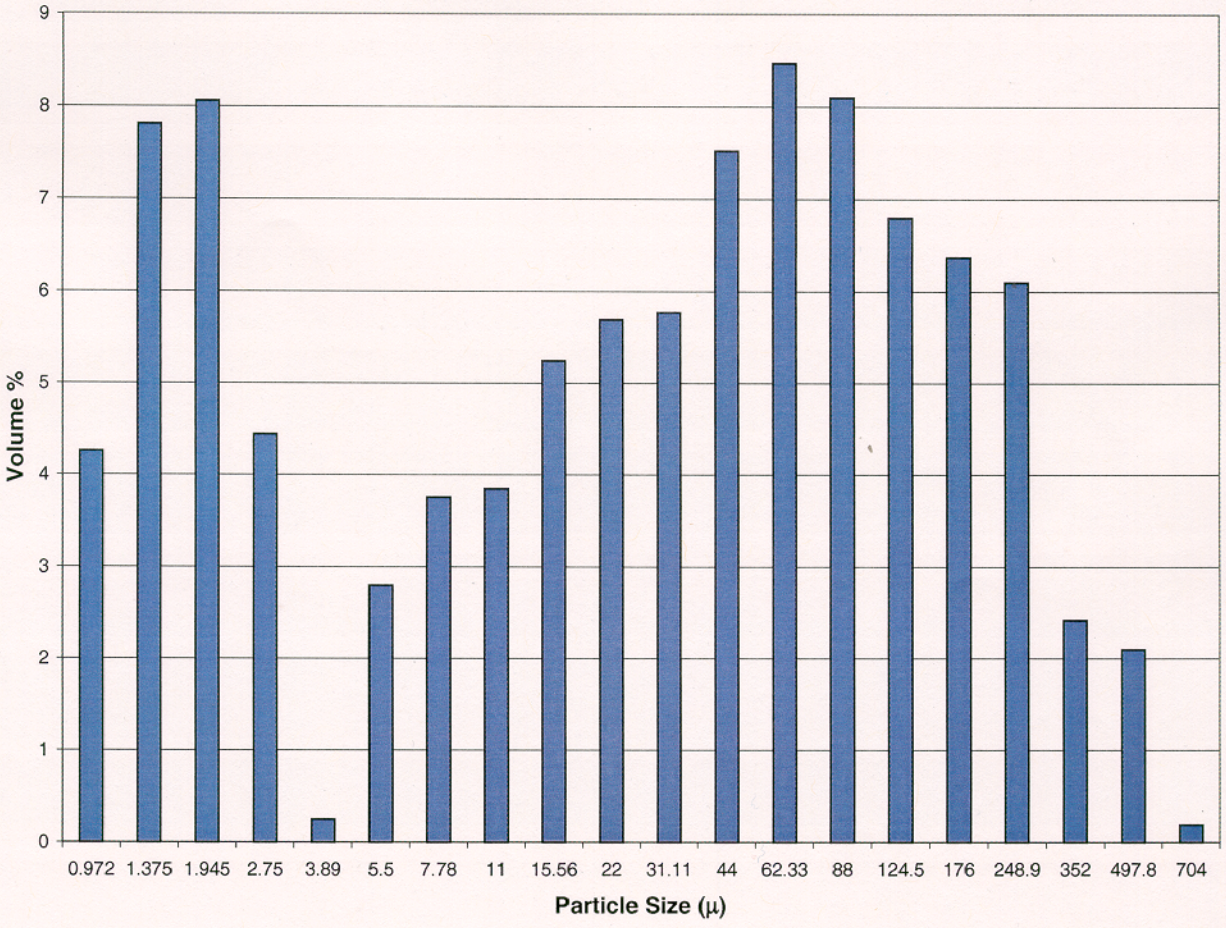
Figure 10 presents the percent pass versus mesh opening for samples taken from the recirculation loop and grab samples from the top of the tank at an agitator speed of 700 rpm. Grab samples from the top of the tank did not show any particles above 249 whereas particles as large as 700 micron were present in the sample from the recirculation loop. These data indicate that the vessel was not well mixed even at 700 rpm.

Figure 10. Percent Pass versus Mesh Opening (700 RPM Recirculation and Grab Samples)



Exact characterization of the vessel contents could not be determined because of the inability to adequately mix the vessel. However, the best estimate of the size distribution of particles in the vessel is presented in Figure 11 based on a recirculation sample taken at 700 rpm. (See Figure 11)

Figure 11. Particle Size Distribution For Greater Than 177 Micron CST Slurry



RESUSPENSION EXPERIMENTAL RESULTS

Test Parameters

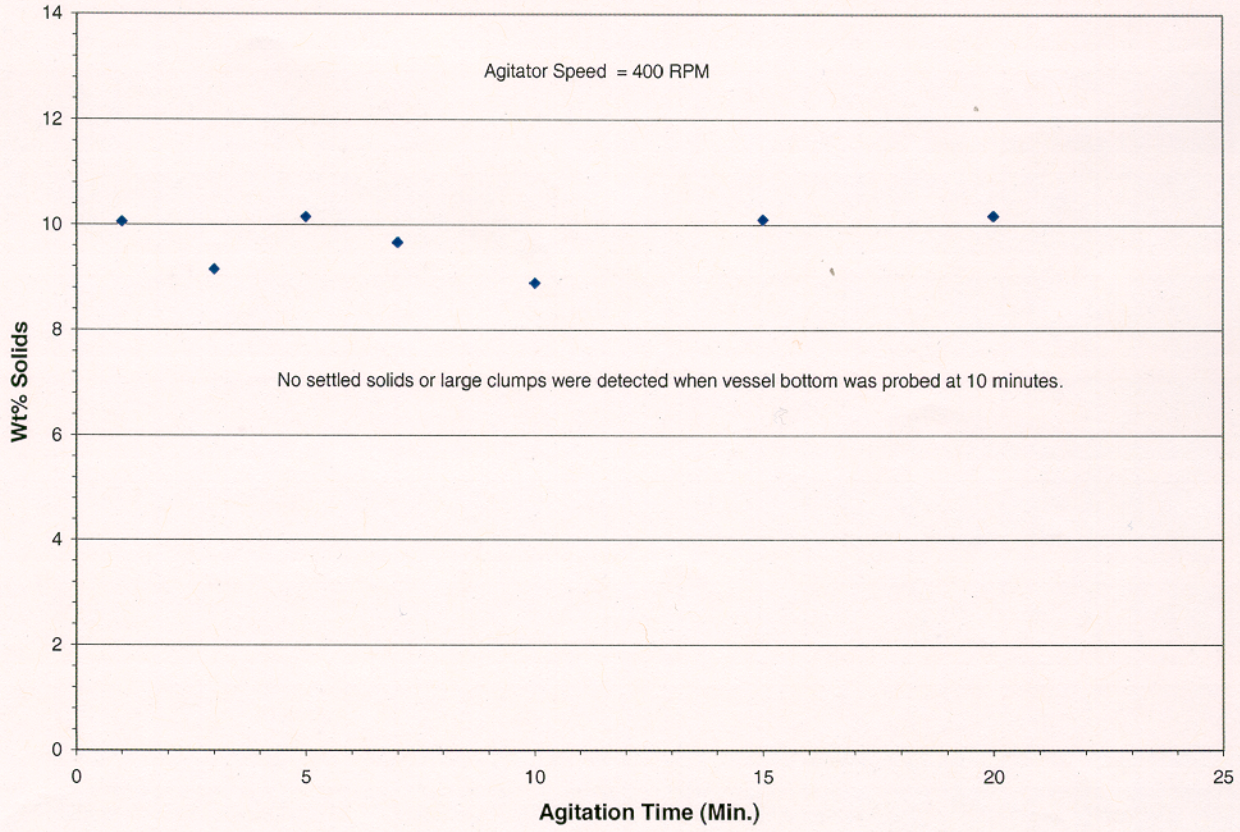
CST Particle Size - <177 microns
CST Concentration - 10 wt%
Agitator Impeller Diameter – 5-inch

Experimental Results

The CST slurry was allowed to settle for 6 days with no agitation. After 140 hours of settling, agitation was started at 400 rpm. Dip samples using a beaker were taken from the surface versus

time of agitation. The dip samples demonstrated significant variability compared to the grab samples, but dip sampling was the only method of sampling that could yield samples in the short time periods after agitation was started. Figure 12 presents the wt% solids of these samples versus time. The vessel appears to be well mixed within the first minute. Probing the vessel bottom after the 10-minute sample was taken demonstrated that no solids remained on the bottom and no large chunks of CST could be felt.

Figure 12. Re-Suspension Of 6 Day Settled < 177 Micron CST Slurry



CONCLUSIONS

- These tests demonstrated that attaining a homogeneous slurry of 10 wt% size reduced CST (<177 microns) is readily attainable using 5-inch diameter agitator impellers at agitator speeds of 500 rpm or greater. Homogeneity is also attainable at agitator speeds as low as 250 rpm using 8-inch diameter agitator impellers.
- Resuspension of the size reduced CST into a homogeneous slurry after being allowed to settle for 6 days was achievable using 5-inch diameter agitator impellers.

- At the maximum agitator speed attainable in the test facility (700 rpm – limited by motor current) using 8-inch diameter agitator impellers, it was not possible to attain a homogeneous slurry that contained CST whose particles sizes were in the range expected to be present in as-received CST (up to 700 microns).

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