

Effect of Pump Type on the Health of Various CMP Slurries

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Slide 1

Introduction

- A variety of types of delivery systems are used to pressurize and circulate CMP slurry to deliver it to the tools.
- Pressurization and circulation are accomplished by various means including pumping and pressure-vacuum technology.
- Typically, the slurry passes through the equipment providing the motive force approximately 100 times before it is used to polish wafers.
- Some CMP slurries are susceptible to agglomeration caused by mechanical handling.
 - limits the life of filters
 - reduces yield by causing wafer defects

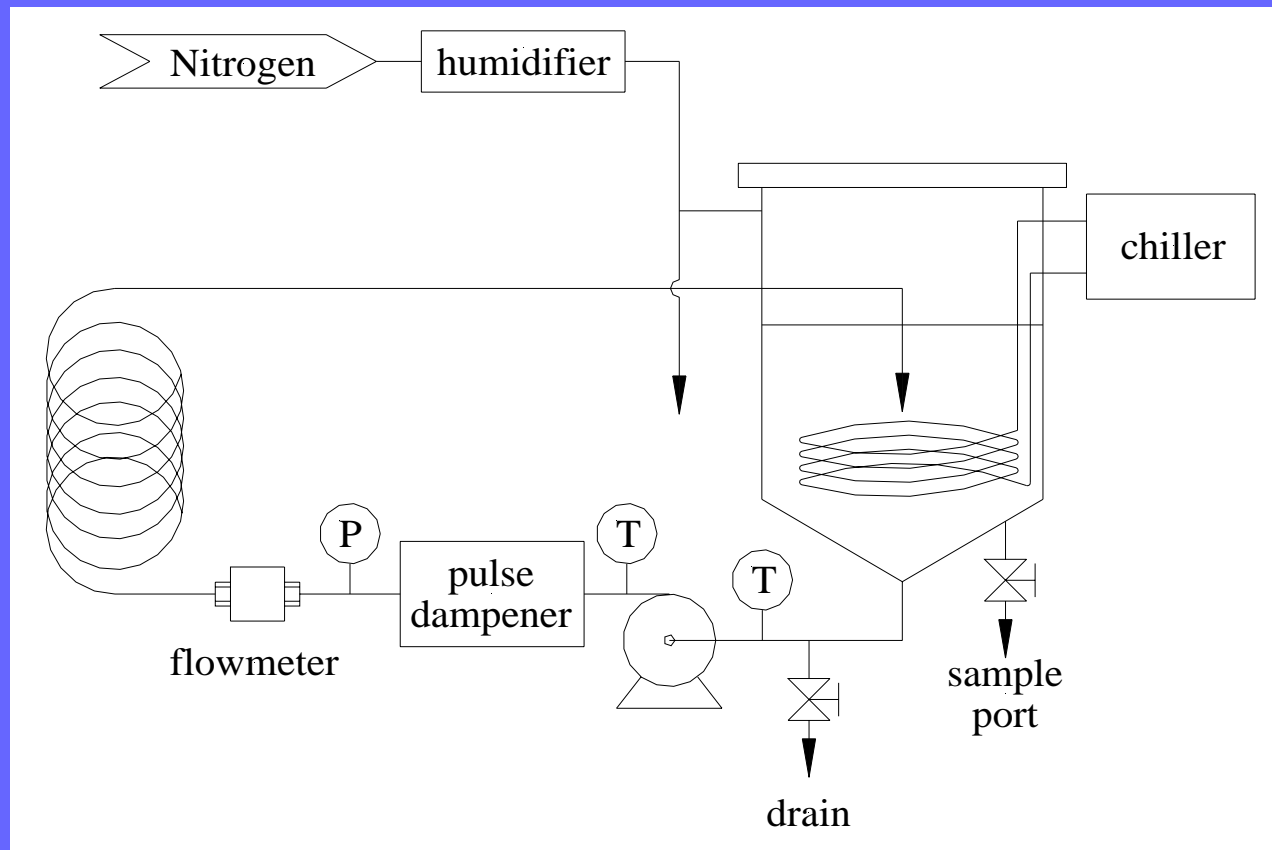


Experiment performed

- 4 CMP slurries were circulated in a simulated distribution loop using 4 different pumps to determine the effect of circulation on slurry health.
- A variety of slurry health parameters were monitored including:
 - Working particle size distribution (PSD)
 - Large particle tail of the slurry PSD ($\geq 0.5 \mu\text{m}$)
 - Zeta Potential
 - Total % solids
 - pH
 - Specific gravity



Test system schematic



Experiment details

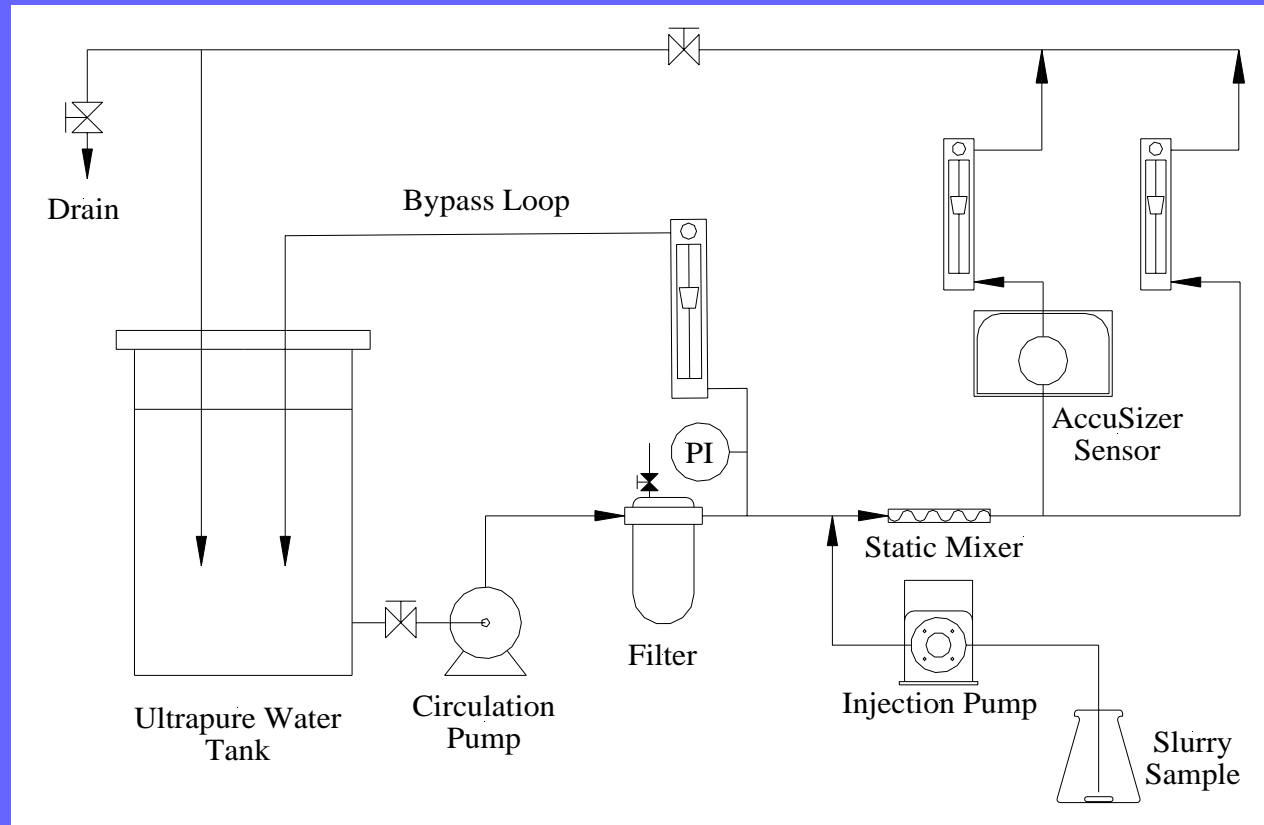
- Test system volume: 12 L of slurry
- Pump air supply or speed was adjusted to achieve the following test conditions:
 - Flow rate: 30 Lpm
 - Pump outlet pressure: 30 psig (gradual reduction to ambient pressure)
- Tank blanketed with humidified N₂: RH > 90%
- Slurry temperature: 22 ± 2°C

Particle size measurement

- “Working” particle size distribution
 - Measured using dynamic light scattering
 - Instrument used – NICOMP 380ZLS (Particle Sizing Systems)
 - All particles in a defined volume illuminated simultaneously
 - Particles are sized by measuring their diffusion coefficient
 - Measures relative concentrations
 - Sensitive to about 1% by volume
- “Large particle tail” size distribution
 - Instrument used:
 - AccuSizer 780 sensor (Particle Sizing Systems)
 - Measured using single optical particle counting.
 - Requires dilution
 - CMP Slurries contain $>10^{14}$ working particles/ml
 - The large particle tail contains about 10^5 - 10^9 particles/ml ($\geq 0.56\mu\text{m}$)



AccuSizer dilution system schematic

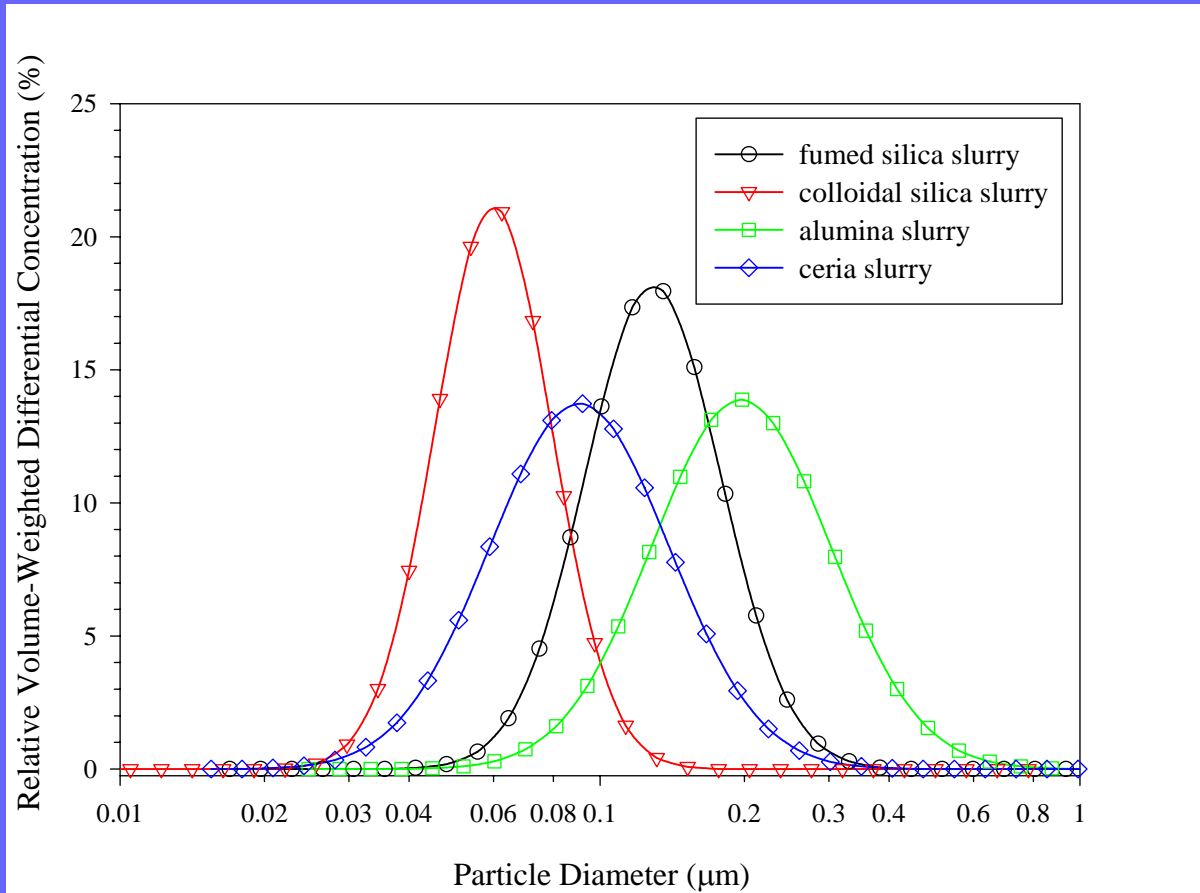


CMP Slurries Evaluated

- Fumed silica slurry
- Alumina oxide slurry
- Colloidal silica oxide slurry
- Ceria slurry



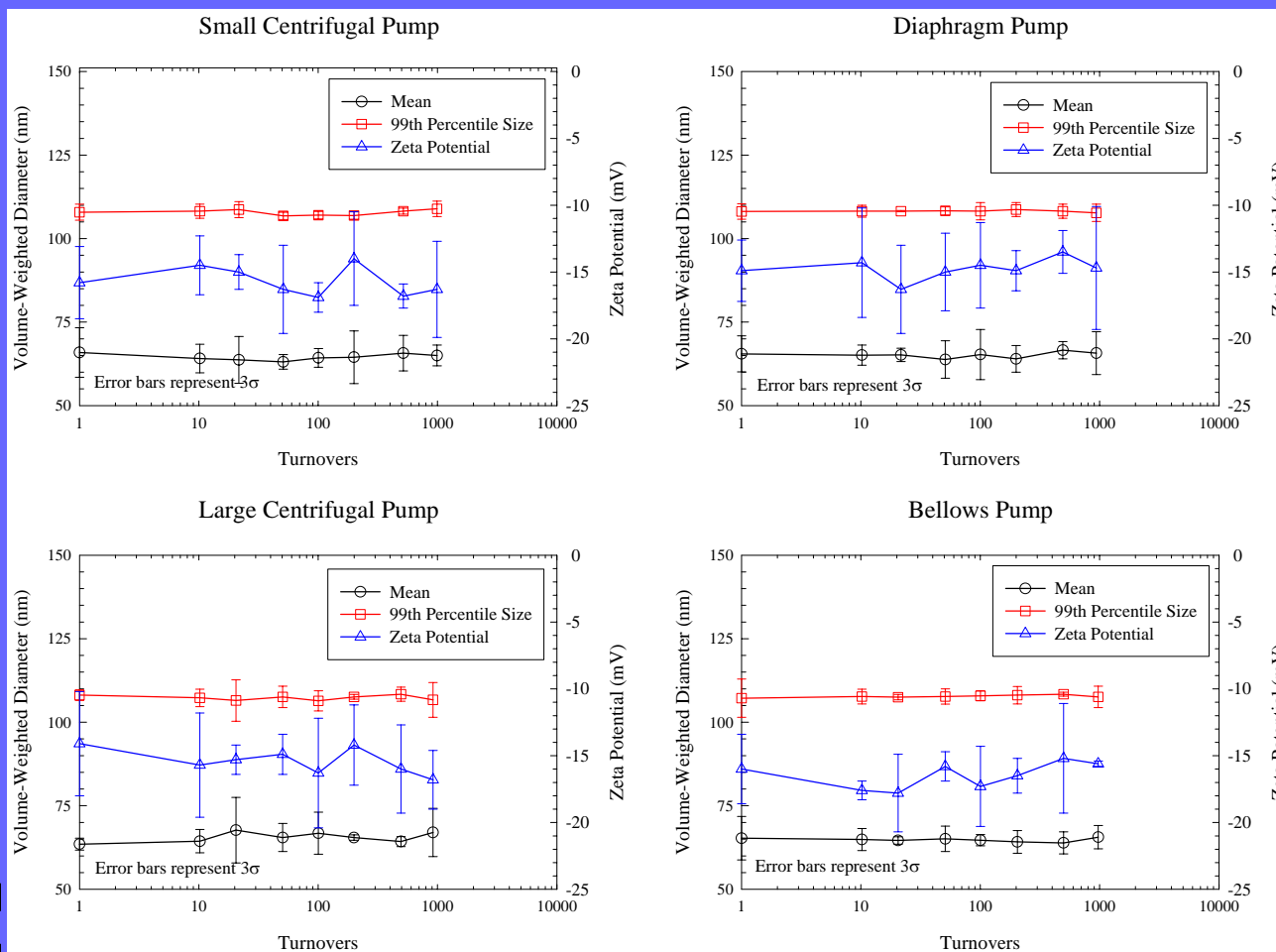
Working particle size distributions (PSDs)



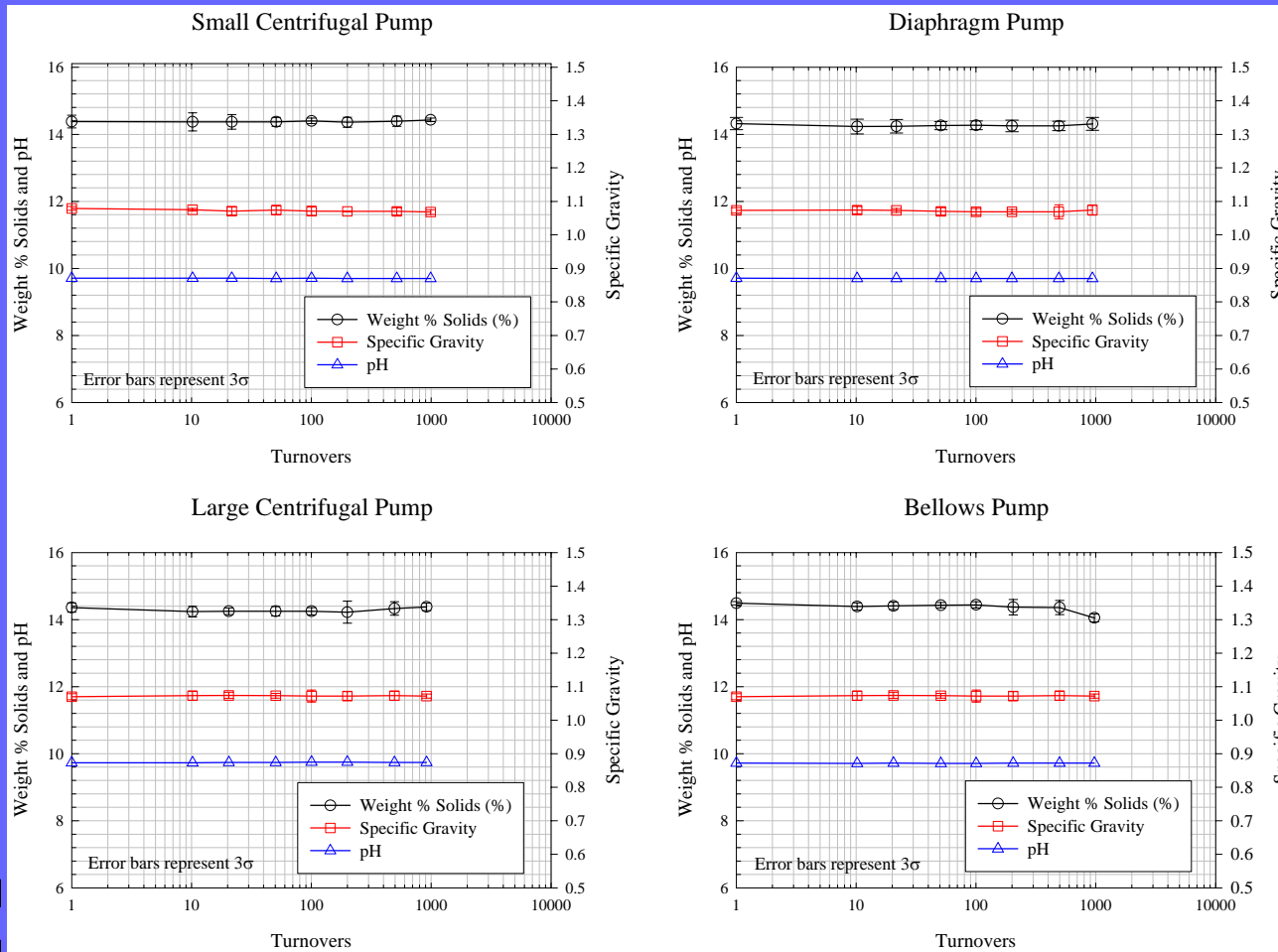
Pumps Evaluated

- Diaphragm pump with pulse dampener
- Bellows pump with pulse dampener
- Small and large magnetically levitated centrifugal pumps

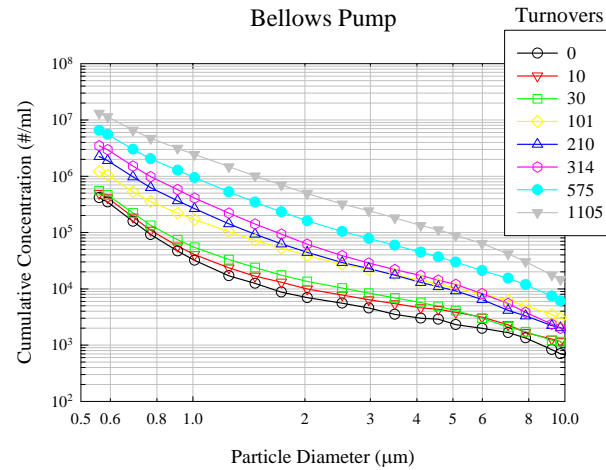
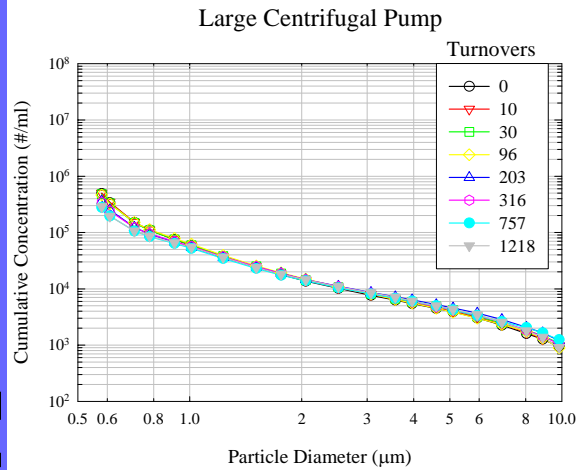
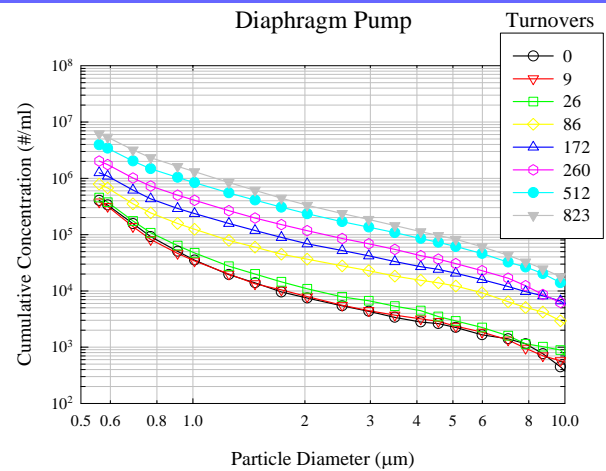
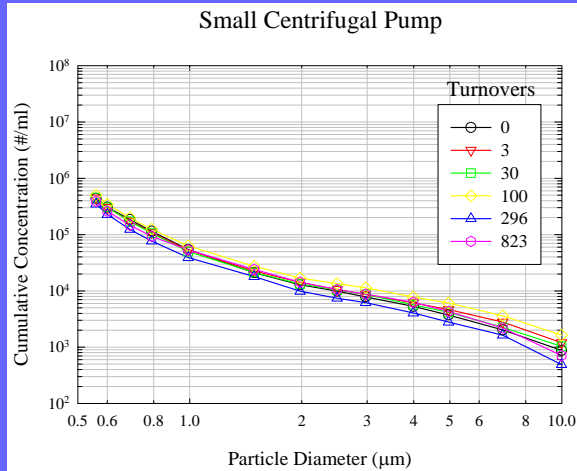
Examples of working PSD and zeta potential results (colloidal silica slurry)



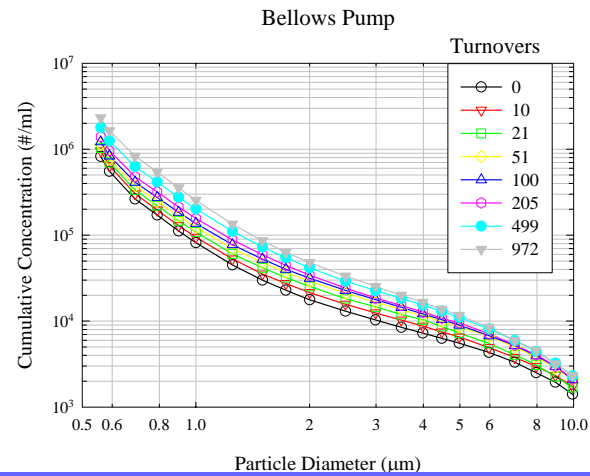
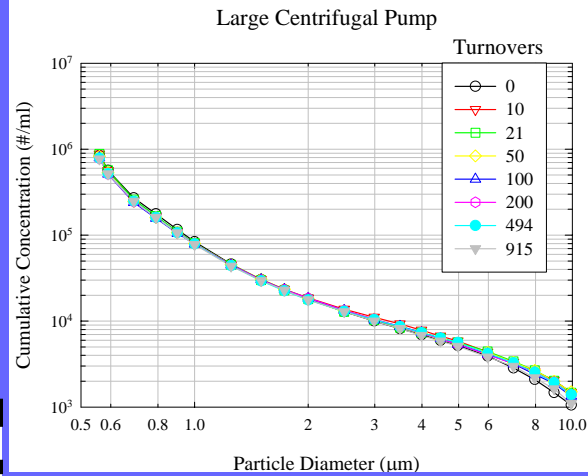
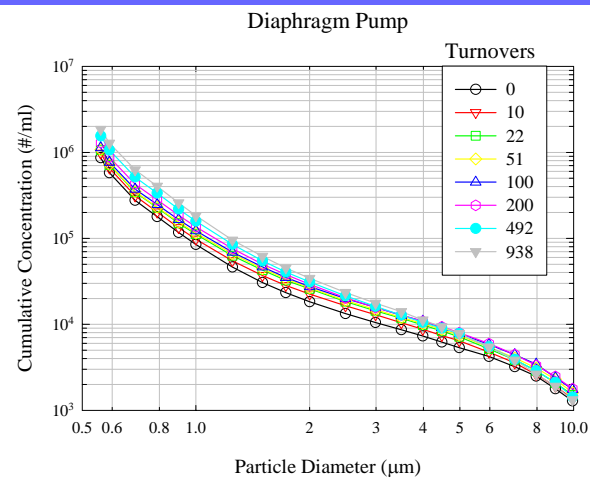
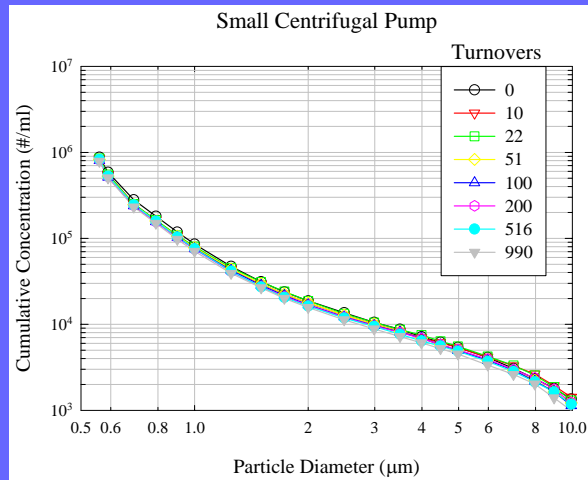
Examples of other slurry parameter results (colloidal silica slurry)



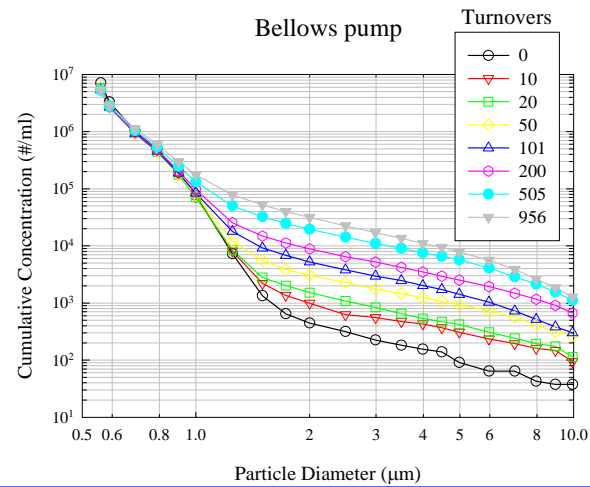
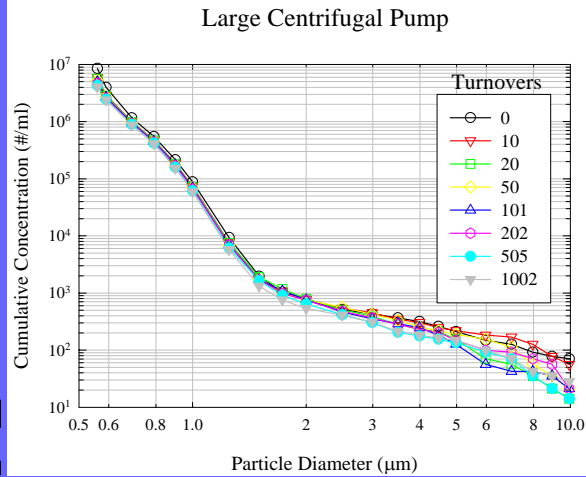
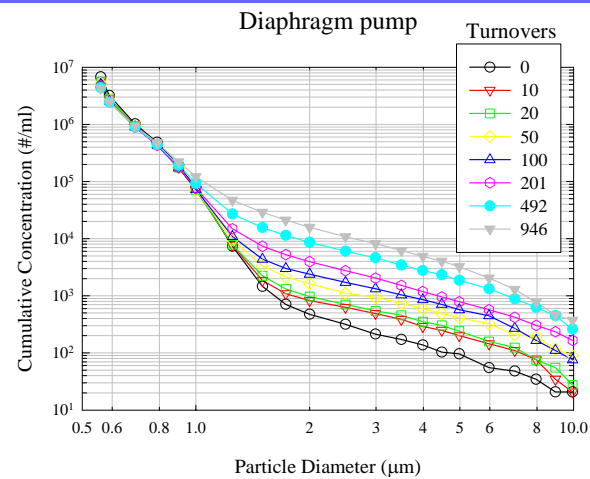
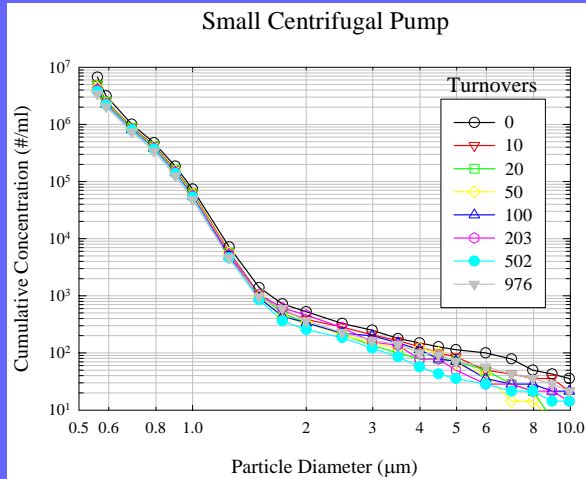
Cumulative PSDs measured in fumed silica slurry



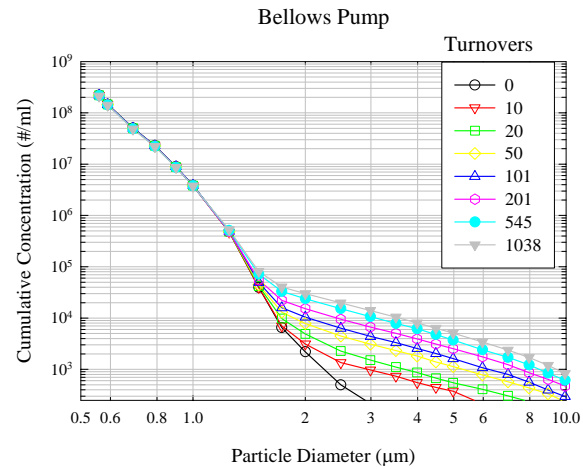
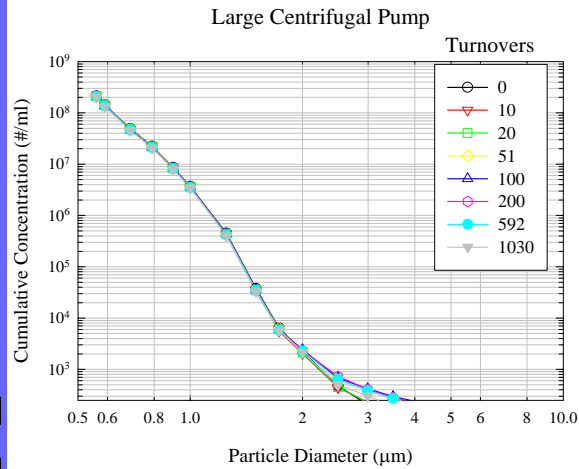
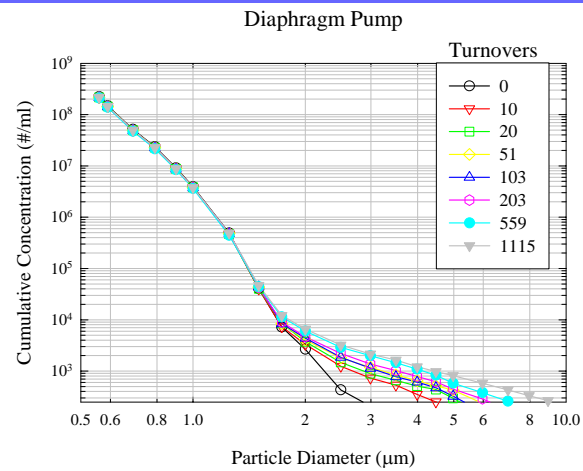
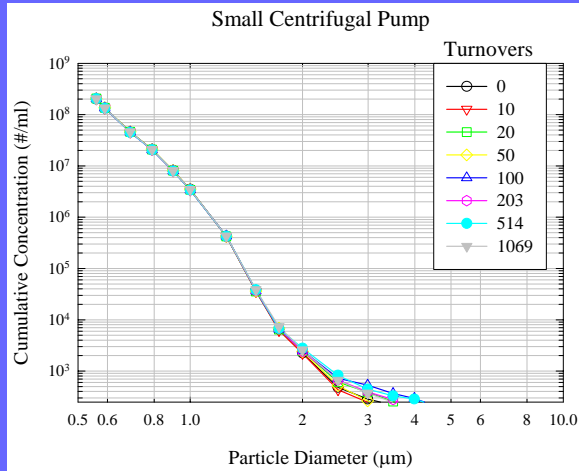
Cumulative PSDs measured in colloidal silica slurry



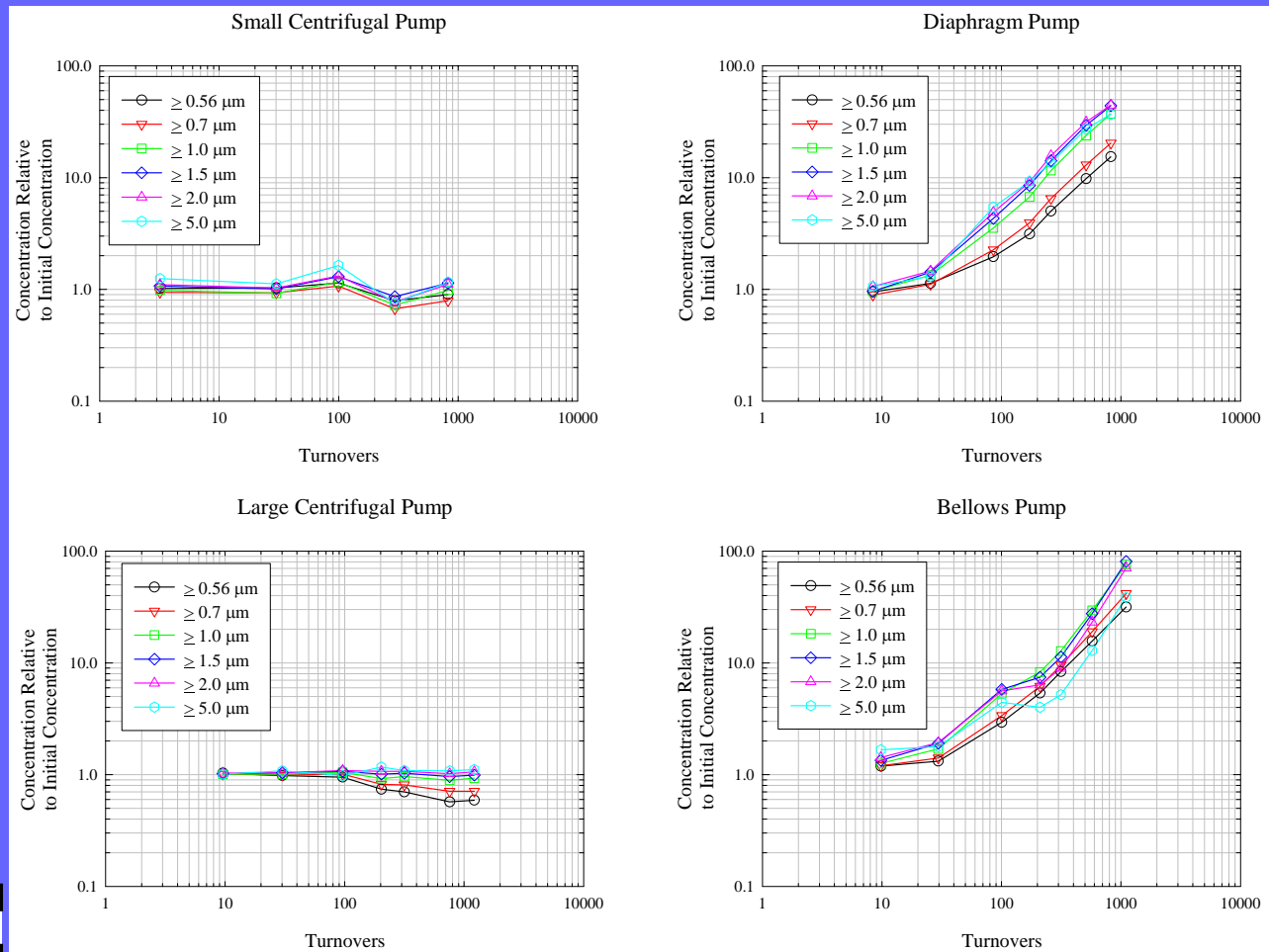
Cumulative PSDs measured in alumina slurry



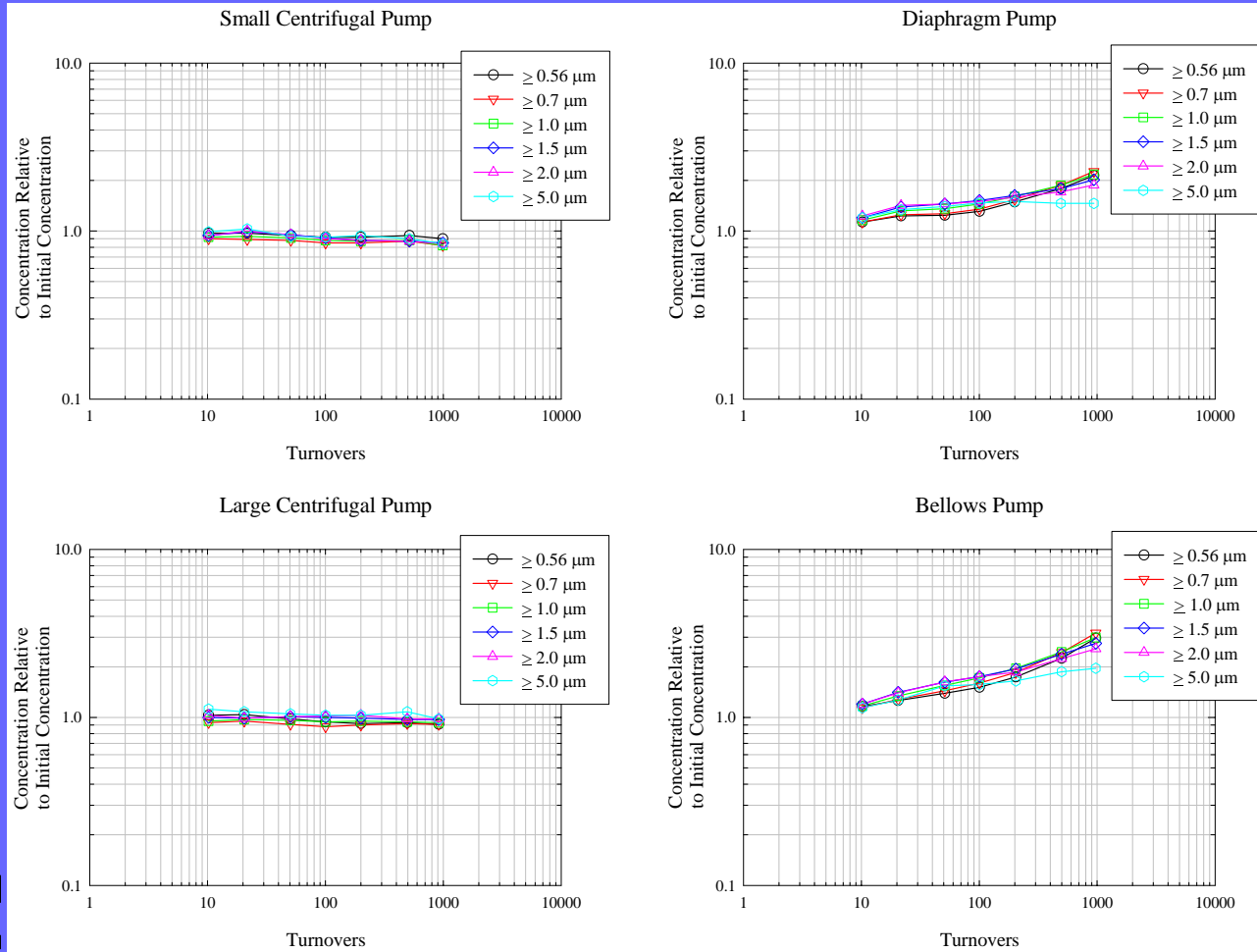
Cumulative PSDs measured in ceria slurry



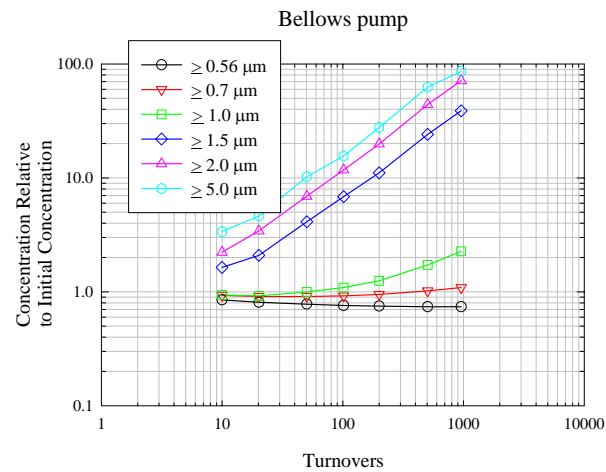
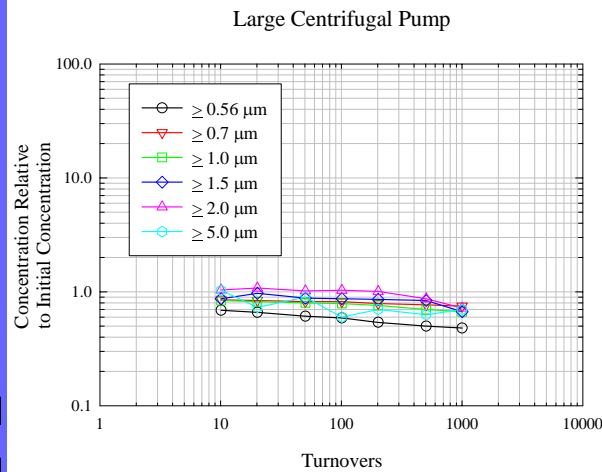
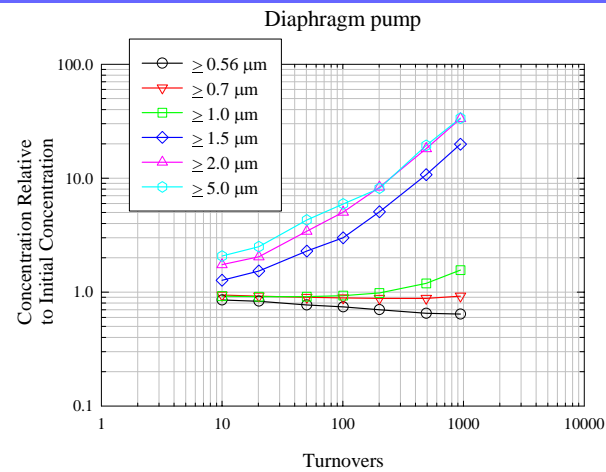
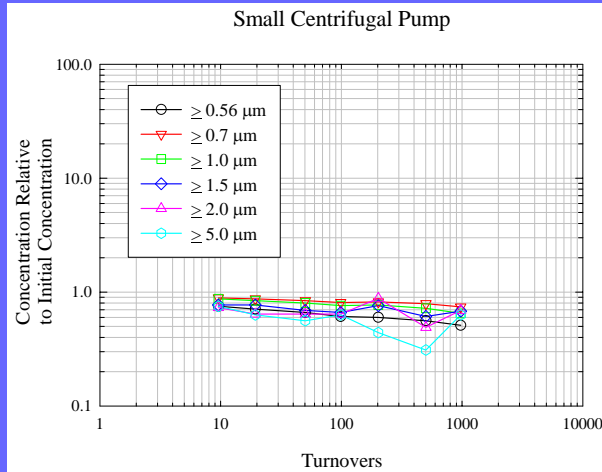
Concentrations relative to initial concentration during the fumed silica slurry tests



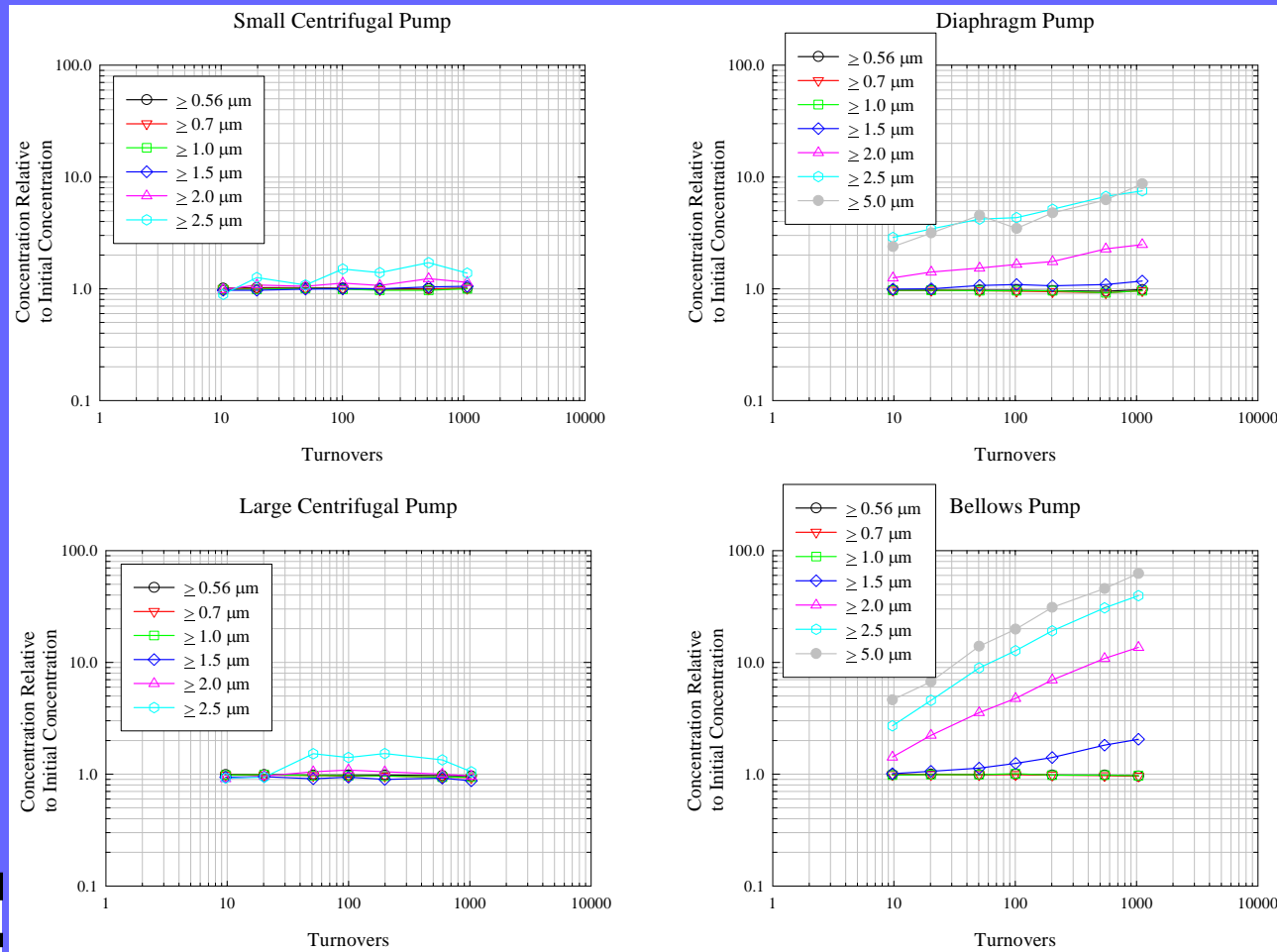
Concentrations relative to initial concentration during the colloidal silica slurry tests



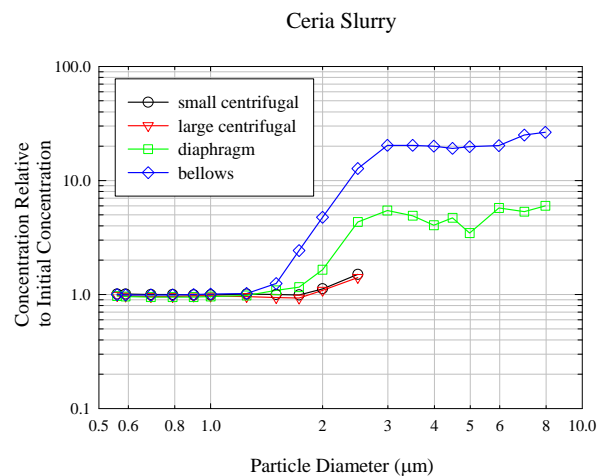
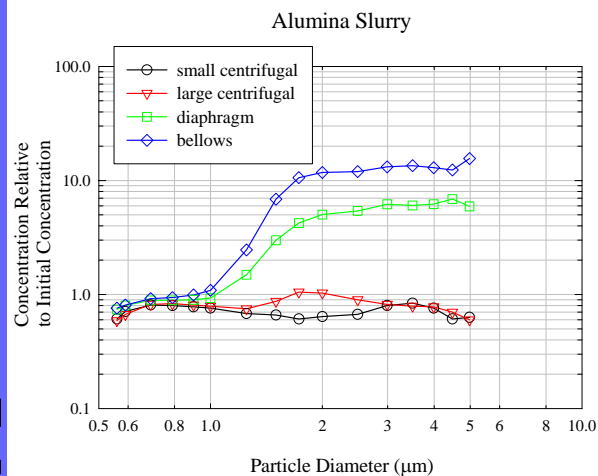
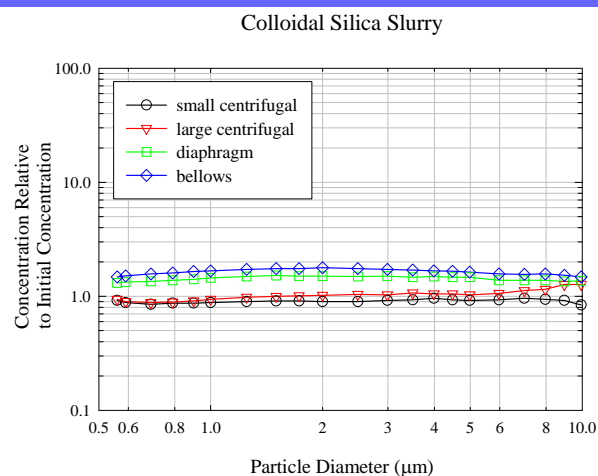
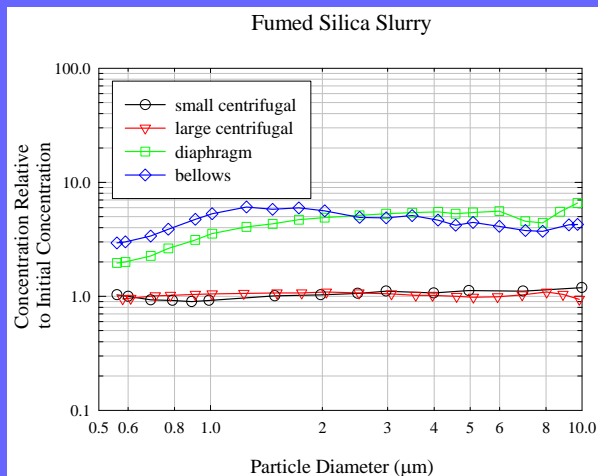
Concentrations relative to initial concentration during the alumina slurry tests



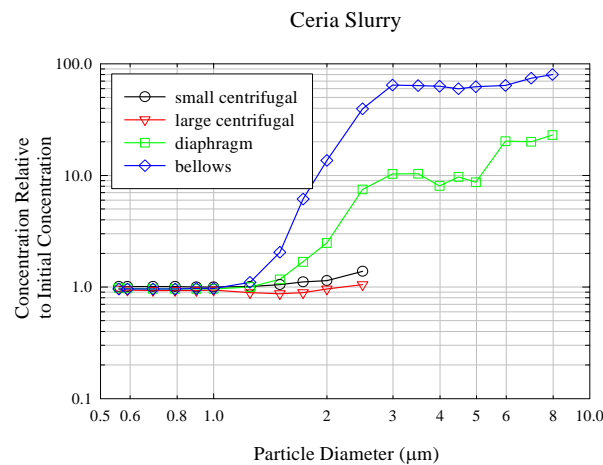
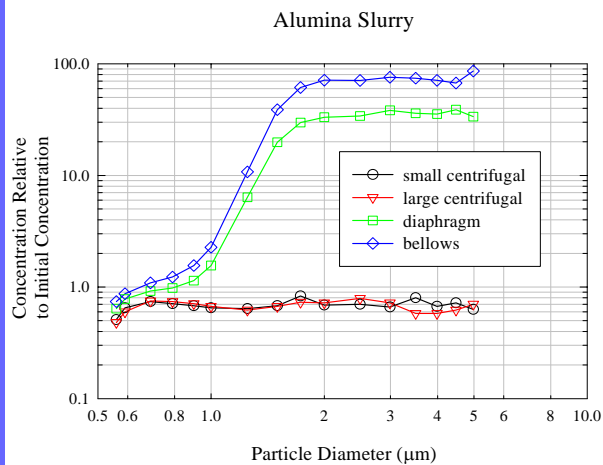
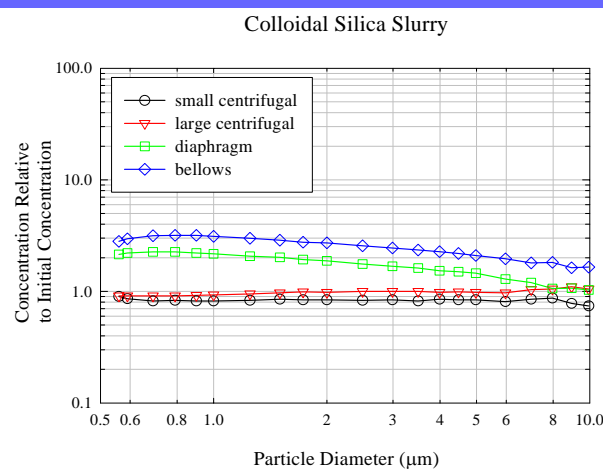
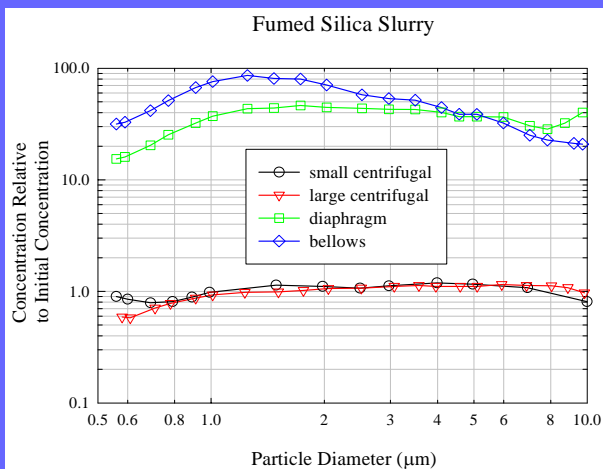
Concentrations relative to initial concentration during the ceria slurry tests



Concentration increases measured during all tests after 100 turnovers



Concentration increases measured during all tests after 1,000 turnovers



Effect of magnetically levitated centrifugal pumps on large particle concentrations

- No significant increases in large particle concentrations were observed with either centrifugal pump at any particle size in any of the slurries.
- A 30-50% decrease in the particle concentrations was observed in the alumina slurry for particles sizes from 0.56 μm to $\geq 5 \mu\text{m}$.

Effect of diaphragm and bellows pumps on large particle concentrations

- Large increases in particle concentrations were observed during tests with both pumps in 3 of the slurries (all except colloidal silica slurry).
- In the silica slurries, concentration increases occurred over a wide range of particle sizes.
- Very large increases occurred in the fumed silica slurry; small increases occurred in the colloidal silica slurry.
- Little concentration increase was observed for particles $< 1.0 \mu\text{m}$ in size in the alumina and ceria slurries, but very large concentration increases were observed with both pumps for particles $\geq 2.0 \mu\text{m}$ in size.

Effect of diaphragm and bellows pumps on large particle concentrations (cont'd)

- The particle sizes above which concentration increases occurred during the diaphragm and bellows pump tests were similar in all slurries.
- The concentration increases observed with the bellows pump were typically about twice the increases with the diaphragm pump, except during the ceria slurry tests in which the increases appeared to be even higher.

Summary of the concentrations changes in large particles ($\geq 0.56 \mu\text{m}$) during all tests

Slurry	Submicron particles (0.5-1.0 μm)				Supramicron particles ($> 2.0 \mu\text{m}$)			
	Small Centrifugal	Large Centrifugal	Diaphragm	Bellows	Small Centrifugal	Large Centrifugal	Diaphragm	Bellows
Fumed Silica Slurry	0	0	++	++	0	0	++	++
Alumina Slurry	0	0	0	0	0	0	++	++
Colloidal Silica Slurry	0	0	+	+	0	0	0	+
Ceria Slurry	0	0	0	0	0	0	++	++

Symbol	Concentration change	Concentration ratio after 1,000 turnovers
0	None	0.5 - 2.0
+	Increase	2-10
++	Large Increase	> 10

Summary of effect of pumps on slurry properties

Pump Type	Large Particle Tail ($\geq 0.56 \mu\text{m}$)		Other Slurry Properties
	Submicron Particles	Supermicron Particles	
Centrifugal pumps	<ul style="list-style-type: none"> • Minimal effect 	<ul style="list-style-type: none"> • Minimal effect 	<ul style="list-style-type: none"> • Minimal effect
Diaphragm and bellows pumps	<ul style="list-style-type: none"> • Large increase in fumed silica slurry • Small increase in colloidal silica slurry • Minimal effect in alumina and ceria slurries 	<ul style="list-style-type: none"> • Large increase in alumina, fumed silica, and ceria slurries • Small effect in colloidal silica slurry 	<ul style="list-style-type: none"> • Minimal effect

Conclusions

- Previous work has shown that silica based CMP slurries are susceptible to agglomeration induced by extensive slurry handling.
- This study has shown that non-silica based slurries such as alumina and ceria are also sensitive to agglomeration.
- Both slurry type and pump type are key factors influencing agglomeration.
 - Minimal changes in slurry properties were observed during tests with the magnetically levitated centrifugal pumps in all 4 slurries tested.
 - Large increases in the large particle tail were observed in 3 of the 4 slurries during the bellows and diaphragm pump tests.
 - The bellows pump caused more agglomeration than the diaphragm pump during most of the tests.
 - Fumed silica slurry was most susceptible to agglomeration; colloidal silica slurry was least susceptible; ceria and alumina slurries were similar.

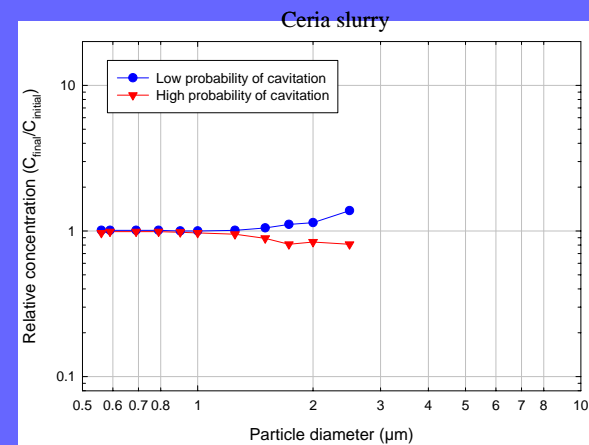
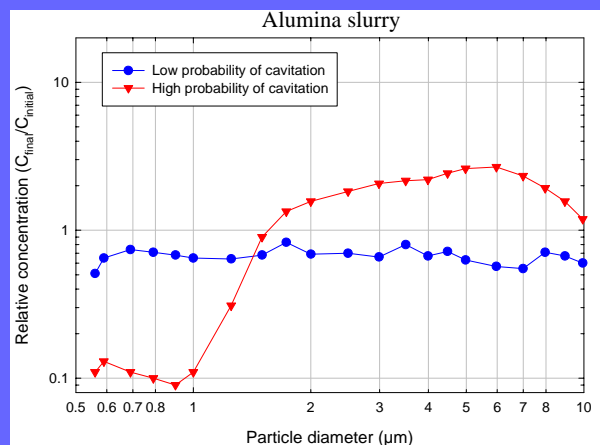
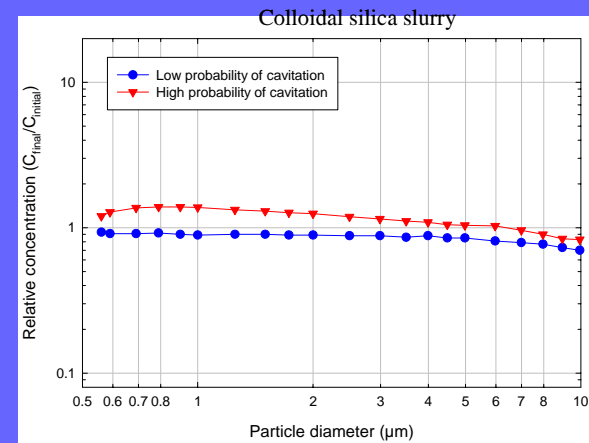
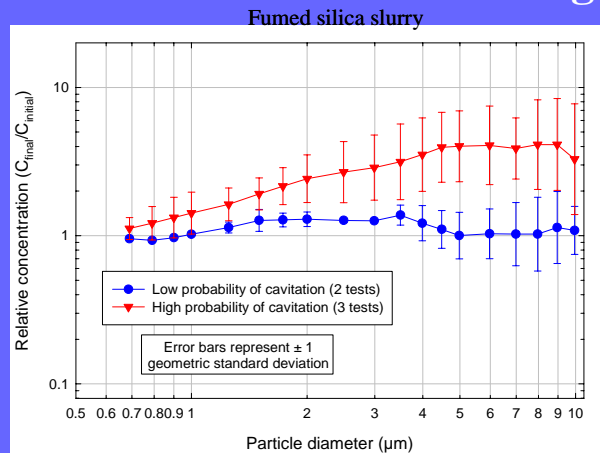




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Changes in particle concentrations in silica slurries after 1,000 turnovers at low and high probabilities of cavitation



The effect of handling on concentration of large particles

Slurry	Submicron sized particles (0.5 – 1.0 μm)				Supermicron sized particles ($\geq 2 \mu\text{m}$)			
	Centrifugal (2 types)	Diaphragm	Bellows	Cavitation	Centrifugal (2 types)	Diaphragm	Bellows	Cavitation
Fumed silica	0	++	++	0	0	++	++	+
Alumina	0	0	0	-	0	++	++	+
Colloidal silica	0	+	+	0	0	0	+	0
Ceria	0	0	0	0	0	++	++	0

Key:

Symbol	Concentration change	Concentration ratio after 1000 turnovers
-	Decrease	< 0.5
0	None	0.5 – 2.0
+	Increase	2 - 10
++	Large increase	> 10