

Susceptibility of Different Slurry Types to Agglomeration

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Introduction

- A variety of types of delivery systems are used to pressurize and circulate CMP slurry to deliver it to the process tools.
- 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



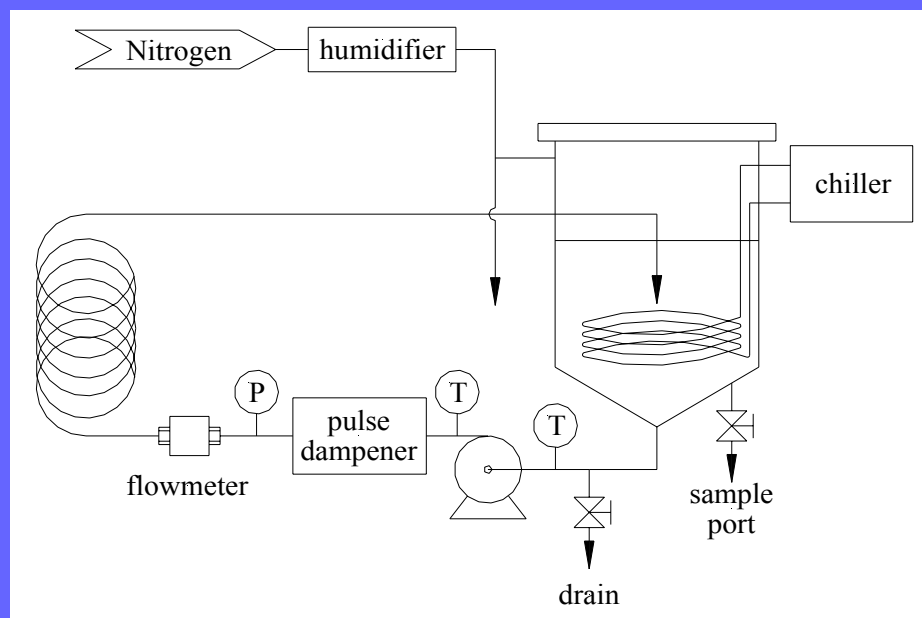
Experiment performed

- CMP slurry was circulated in a simulated distribution loop using 3 different types of pumps to determine the effect of circulation on slurry health.
- A variety of slurry health parameters were monitored including:
 - Working particle size distribution (PSD)
 - Dynamic light scattering (Particle Sizing Systems NICOMP 380ZLS)
 - UFA/SMPS (UltraFine Atomization/Scanning Mobility Particle Sizer)
 - Large particle tail of the slurry PSD ($\geq 0.56 \mu\text{m}$)
 - Particle Sizing Systems AccuSizer 780
 - Zeta Potential
 - Total % solids
 - pH
 - Specific gravity
 - Hydrogen peroxide concentration (when applicable)



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
- Tank blanketed with humidified N₂: RH > 90%
- Slurry temperature: 21 ± 2°C
- Pulse dampener included when applicable



9 CMP Slurries Evaluated

- Slurry Abrasive:
 - Silica (S1-S5)
 - Fumed silica slurry (1)
 - Colloidal silica oxide slurry (4)
 - Alumina oxide slurry (A1-A2)
 - Ceria slurry (C1-C2)
- Slurry Application:
 - ILD (S1)
 - Barrier (S2-S3)
 - W (S4-S5)
 - Copper (A1-A2)
 - STI (C1-C2)



Pumps Evaluated

- Diaphragm pump with pulse dampener
- Bellows pump with pulse dampener
- Levitronix magnetically levitated centrifugal pumps
 - BPS-1
 - BPS-3
 - **BPS-4**
 - BPS-200
 - BPS-600



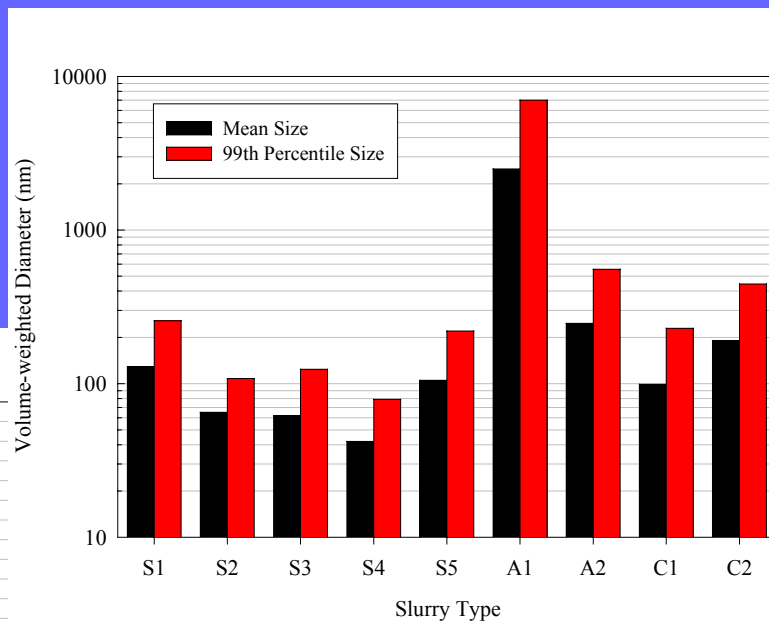
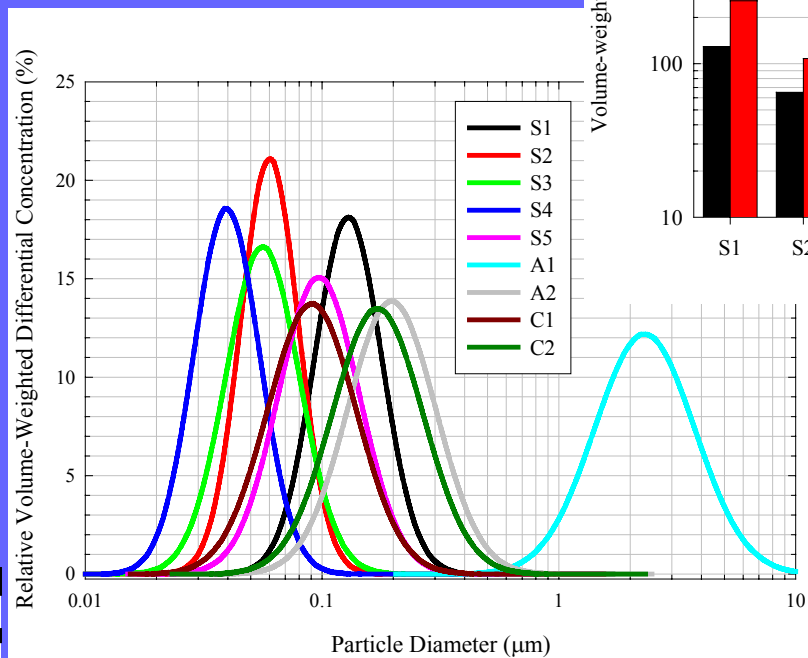
Pump Comparison

- Working PSD
- Large particle tail
- Other parameters
 - No significant change during any of the tests



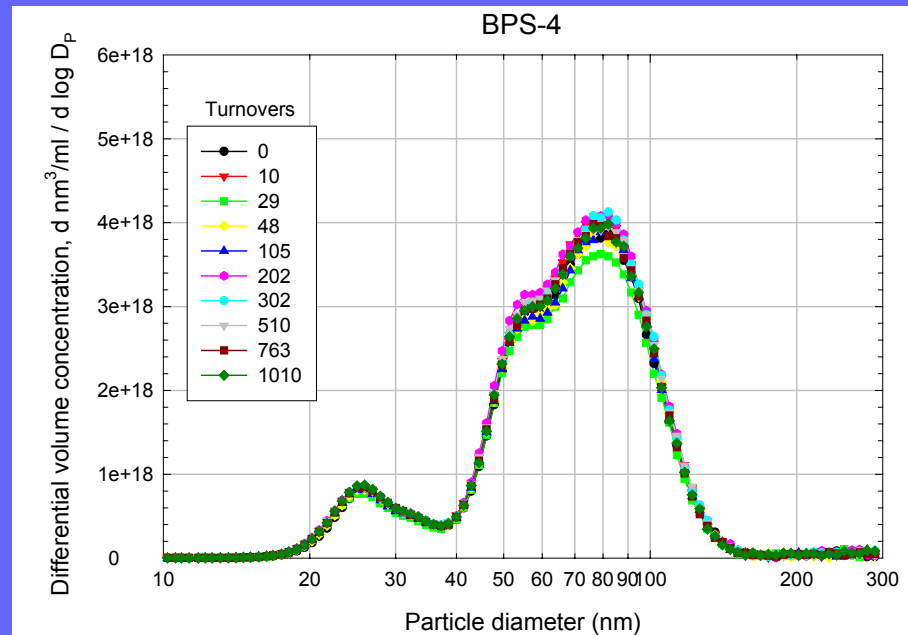
Working particle size distributions (PSDs)

- Dynamic Light Scattering (DLS) measurements



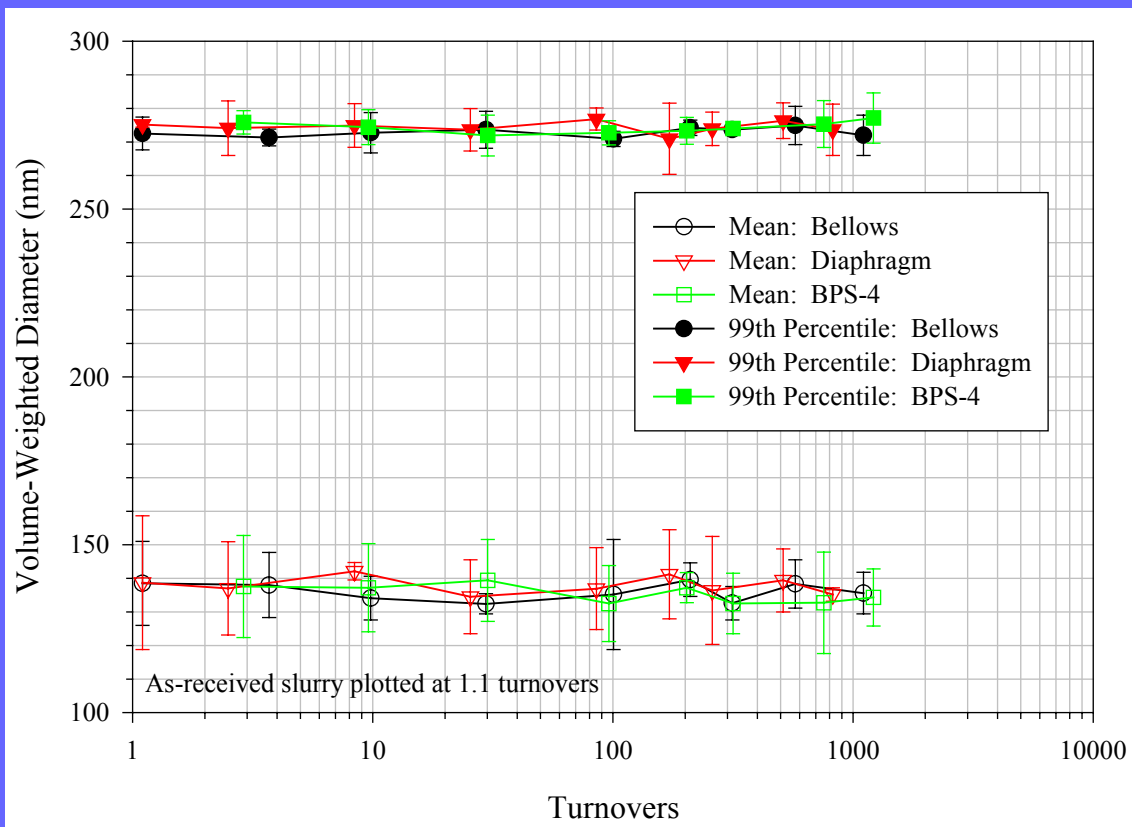
Silica slurry: Example of UFA/SMPS measurement

- UFA/SMPS technique
 - Aerosolize the particles and measure the size using a DMA
 - Measures both size and number concentrations
 - Does not assume a shape of the distribution

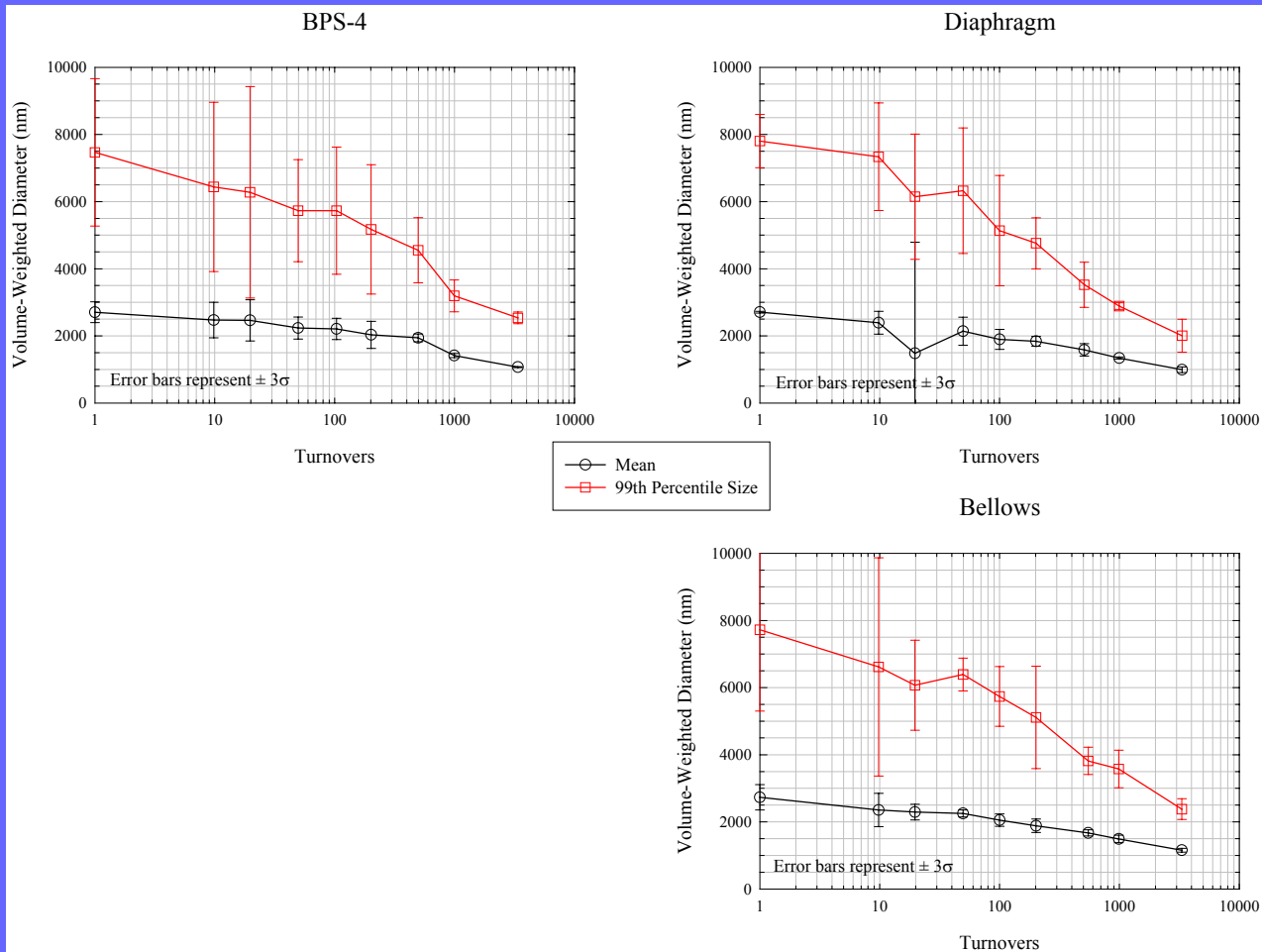


Grant DC (2008). "A New Method for Determining the Size Distribution of the Working Particles in CMP Slurries," 2008 Levitronix CMP Users Conference

S1 slurry: Working PSD measurements (DLS)



A1 slurry: Working PSD measurements (DLS)

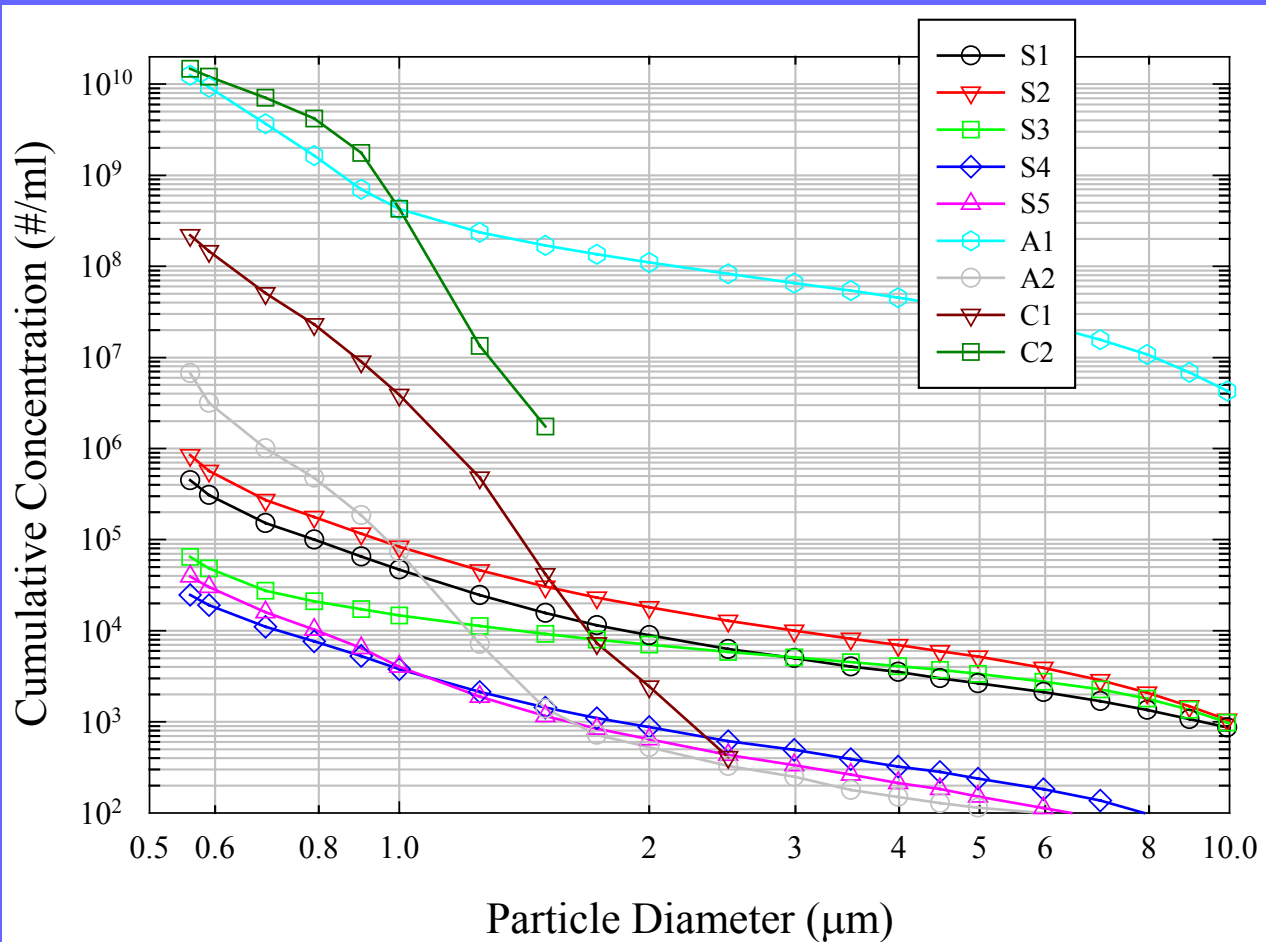


Summary of changes in working PSD

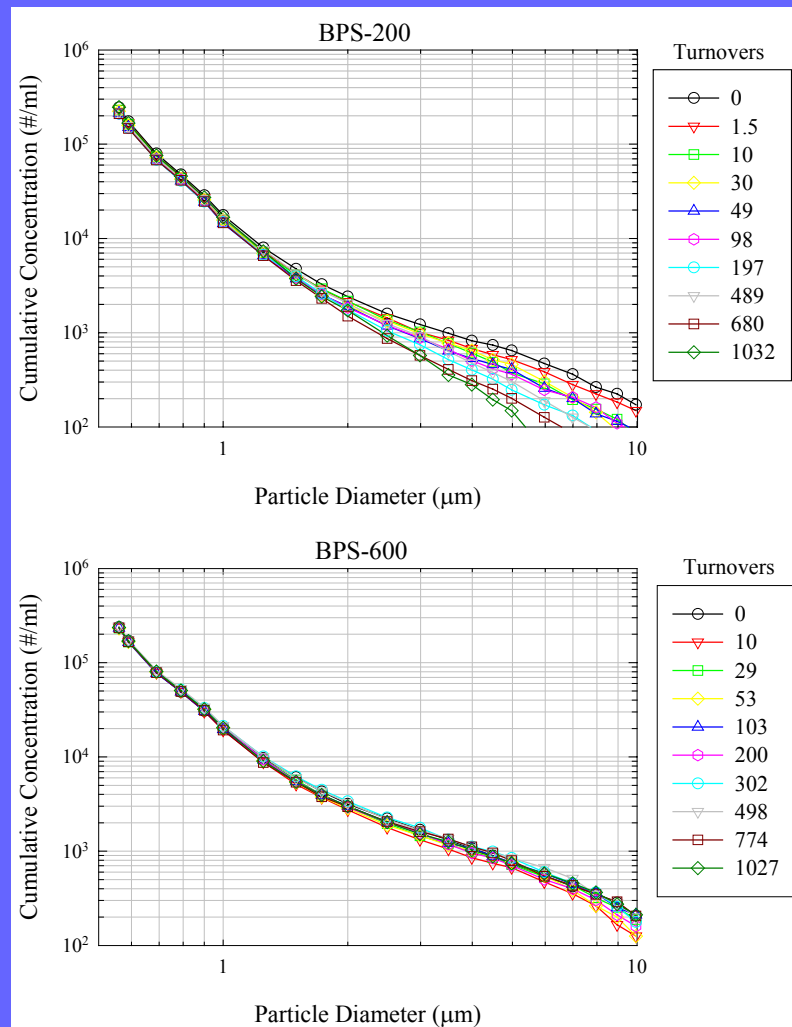
			Changes in Mean PSD after 1000 turnovers		
Application	Abrasive	Type	Centrifugal	Diaphragm	Bellows
ILD	fumed silica	S1	0	0	0
barrier	colloidal silica	S2	0	0	0
barrier	colloidal silica	S3	0	0	0
W	colloidal silica	S4	0	0	0
W	colloidal silica	S5	0	0	0
copper	alumina	A1	-	-	-
copper	alumina	A2	0	0	0
STI	ceria	C1	0	0	0
STI	ceria	C2	0	0	0

Symbol	Relative Change in Mean Size
-	> 10% decrease
0	< 10% change
+	> 10% increase

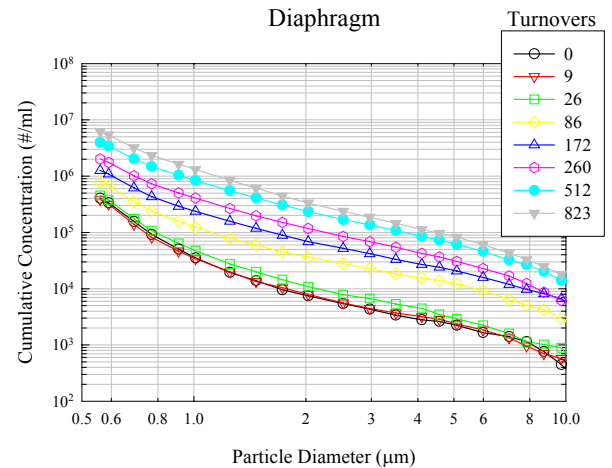
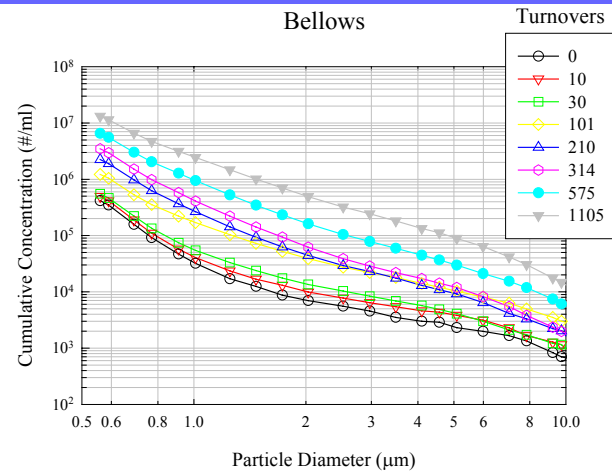
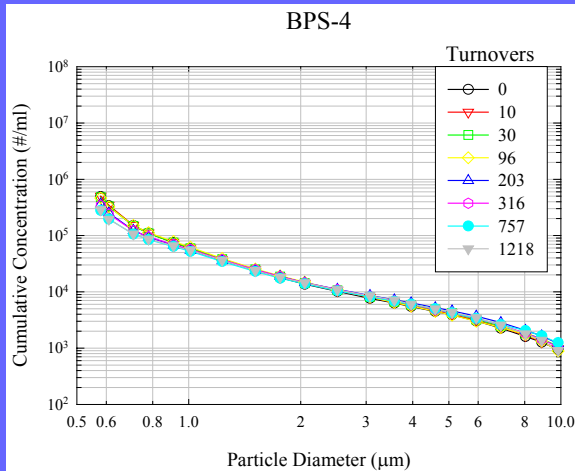
Large Particle Tail PSDs in As-Received Slurry



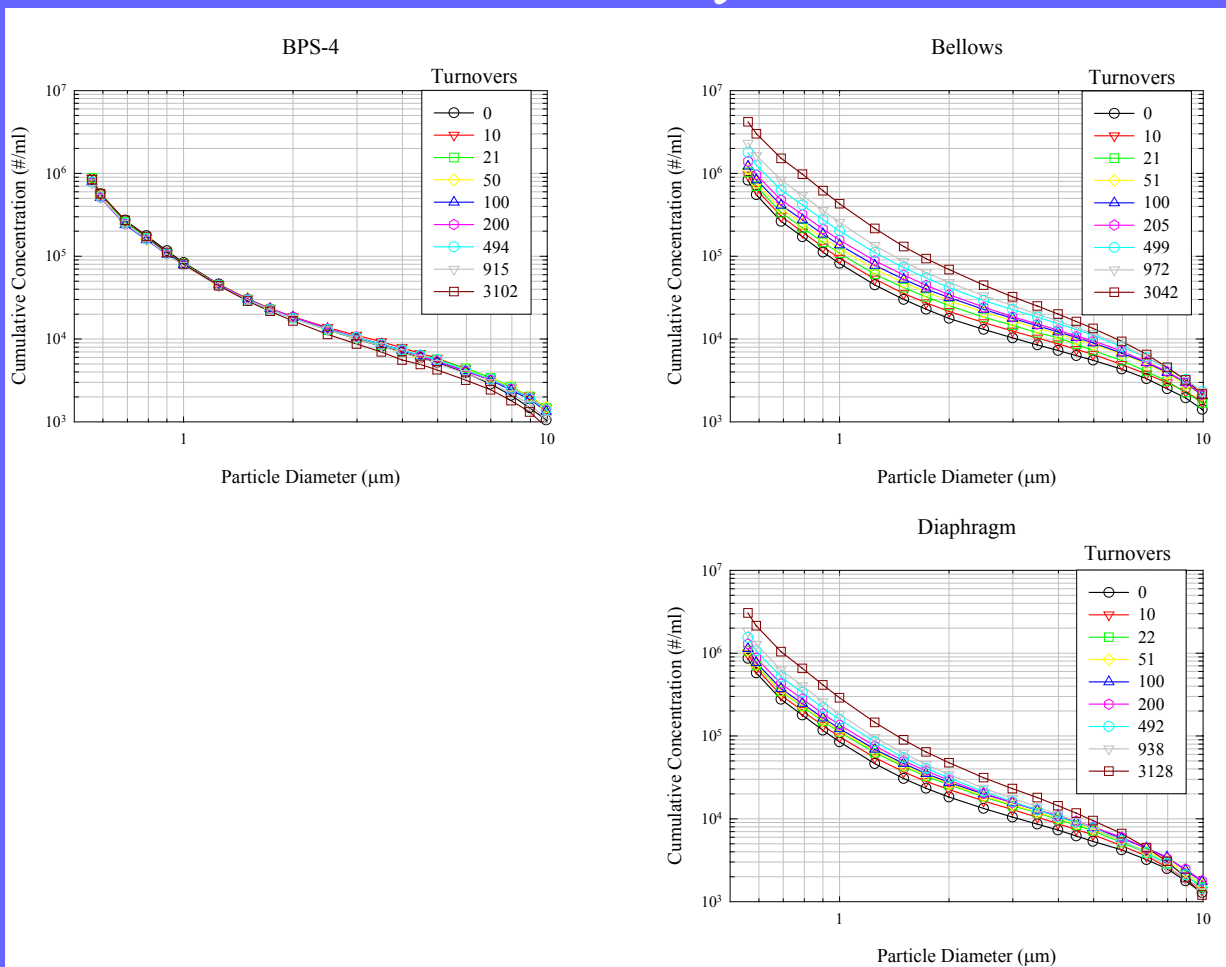
S1 slurry: BPS-200/BPS-600 Pumps



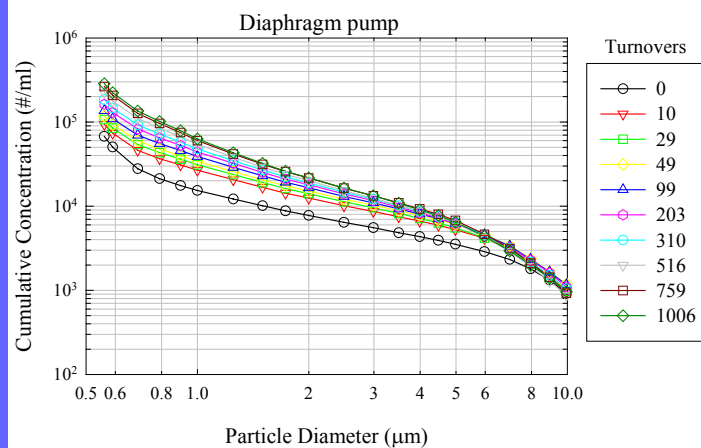
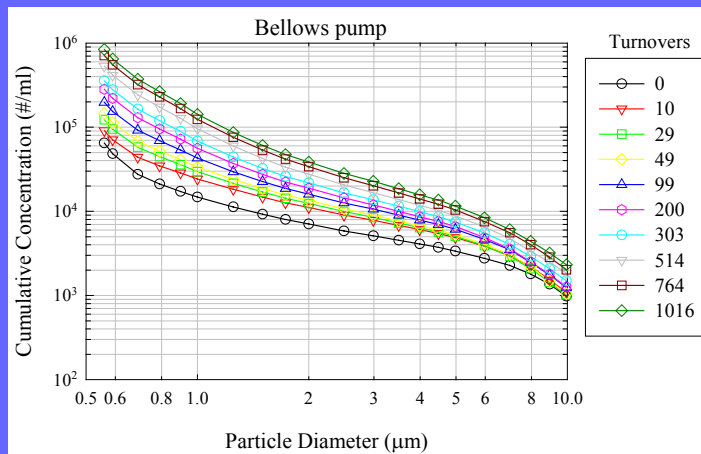
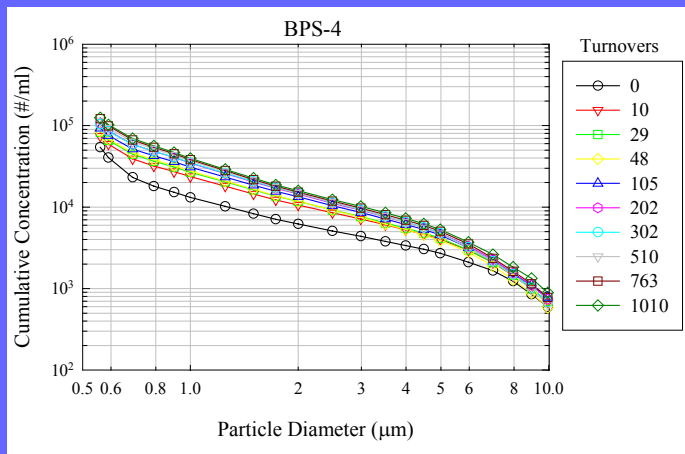
S1 slurry: BPS-4, bellows, and diaphragm pumps



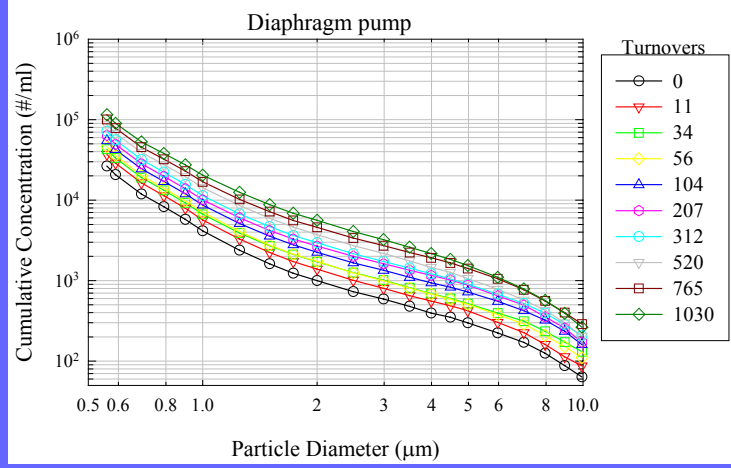
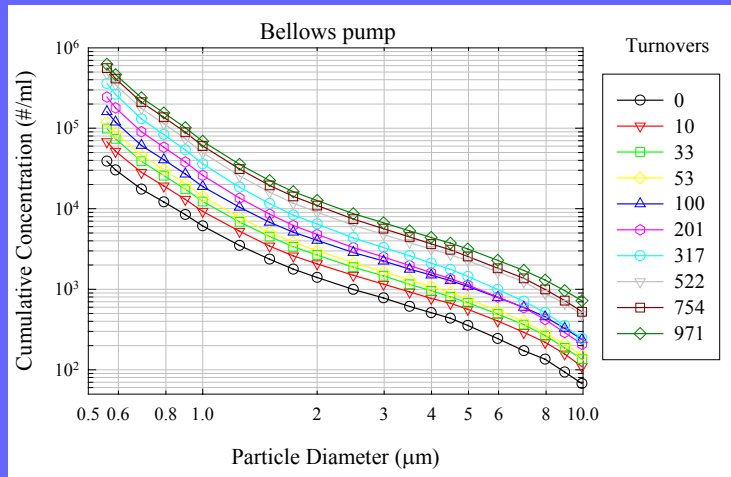
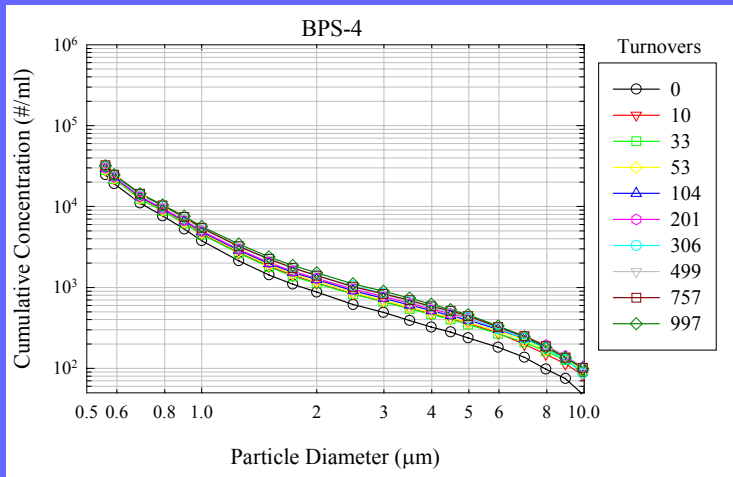
S2 slurry



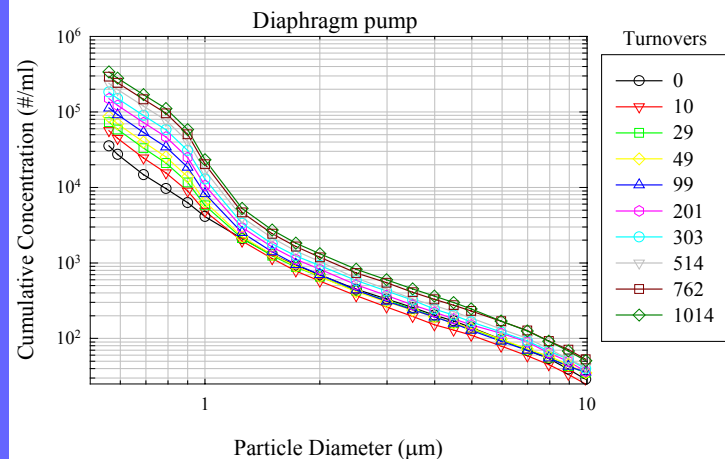
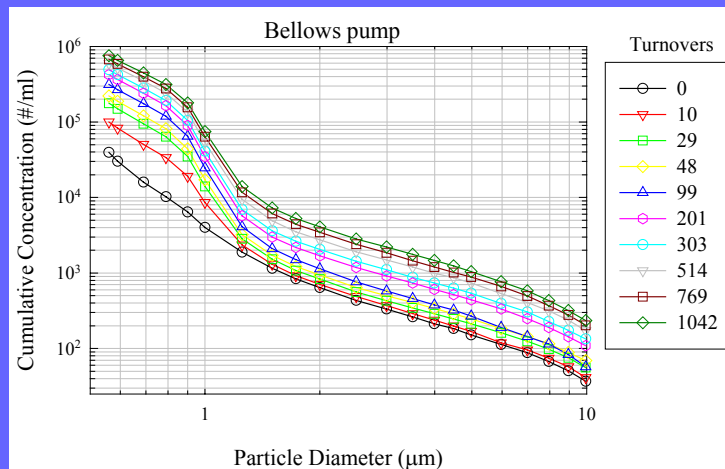
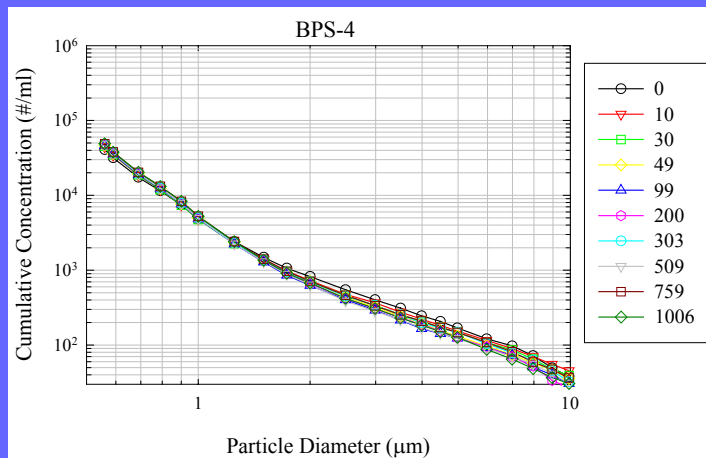
S3 slurry



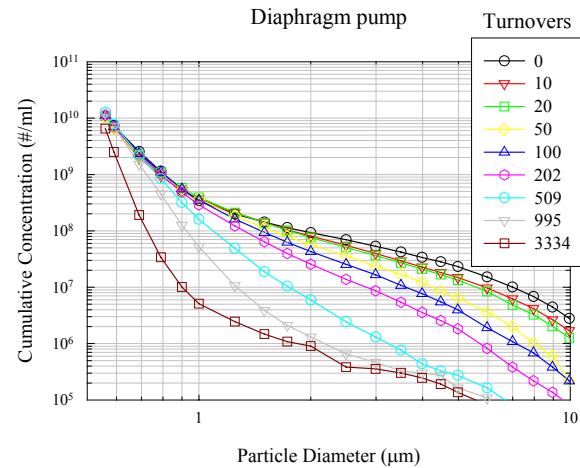
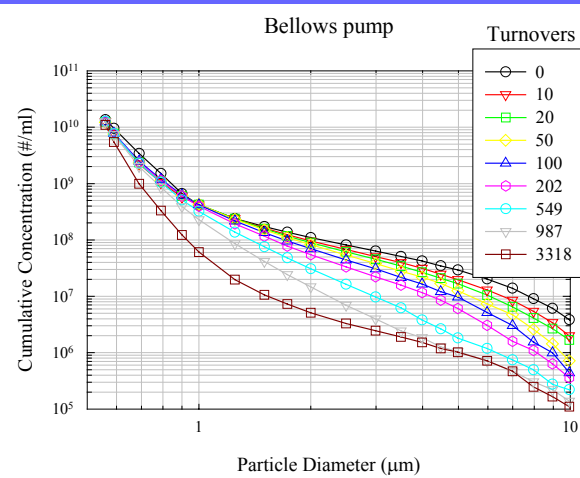
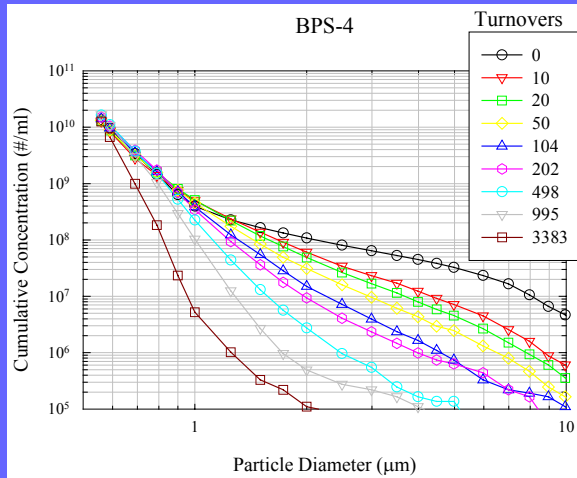
S4 slurry



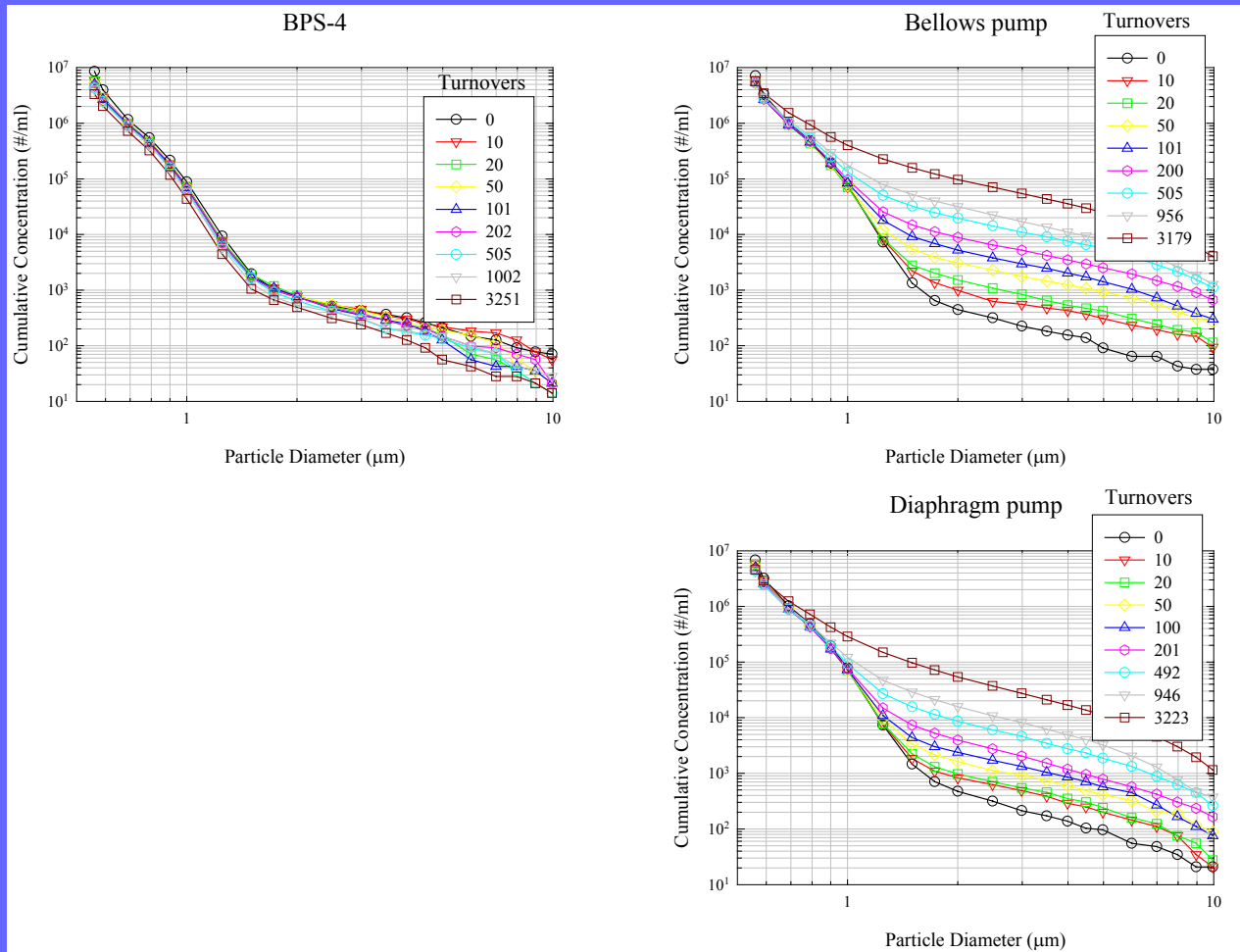
S5 slurry



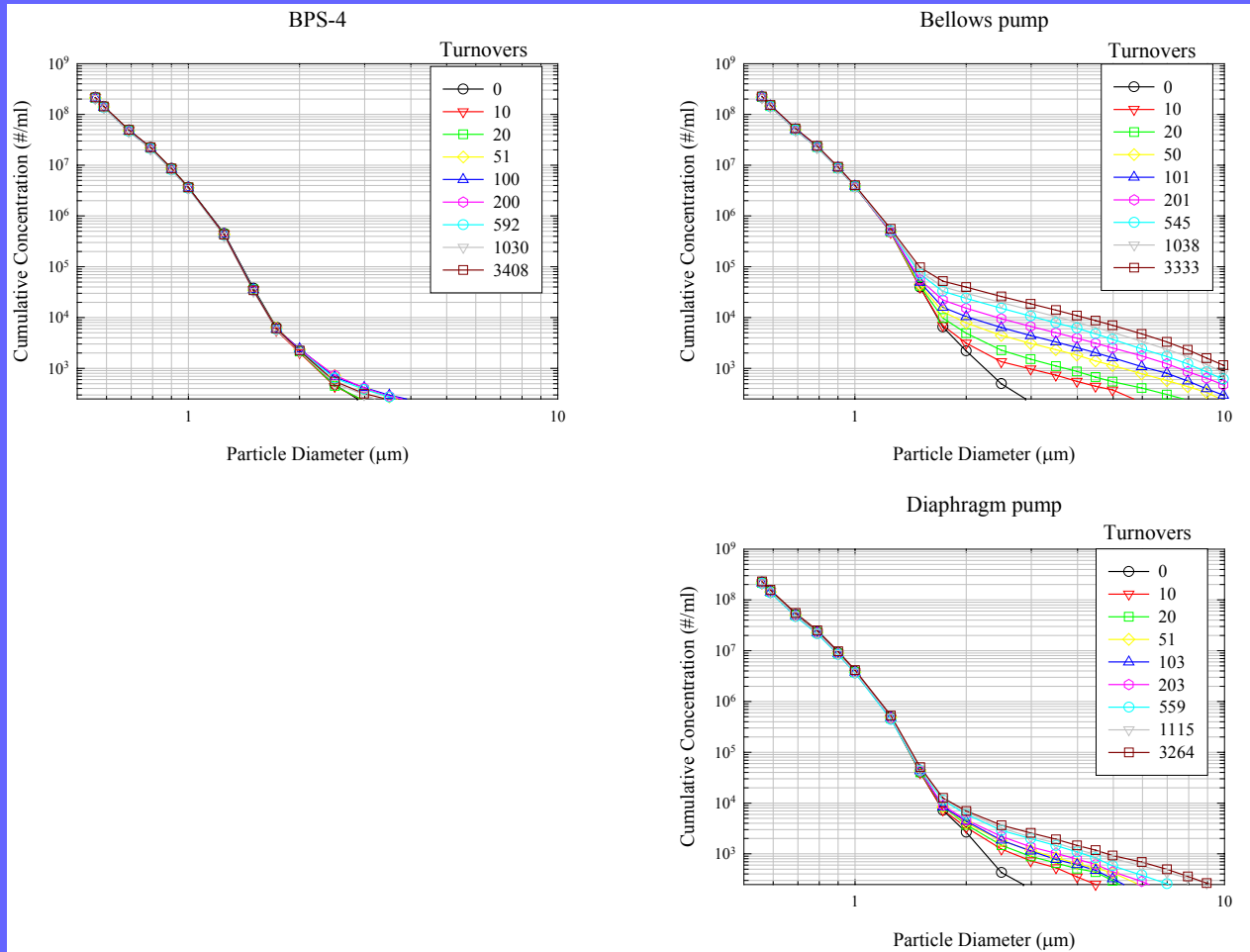
A1 slurry



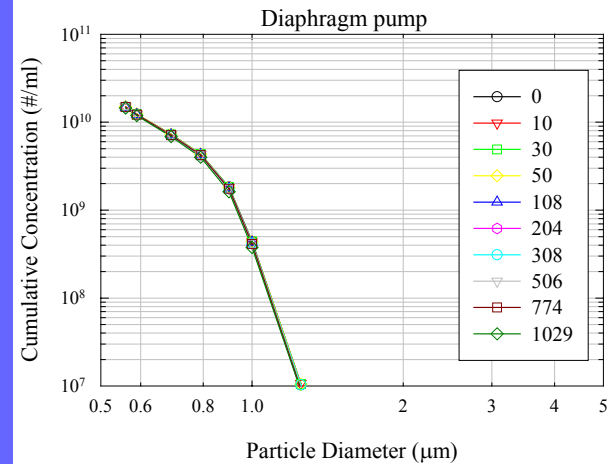
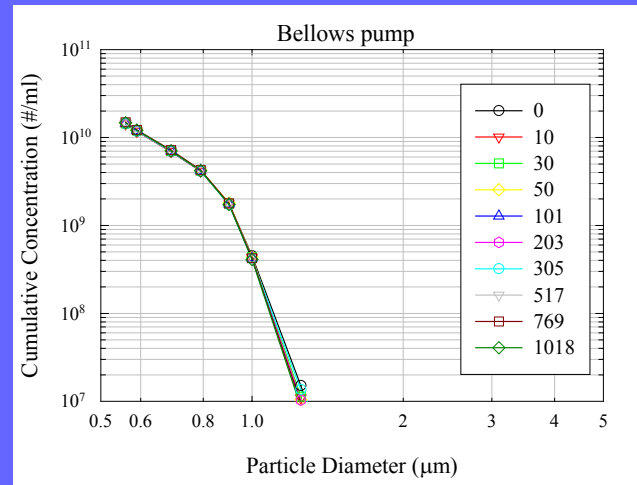
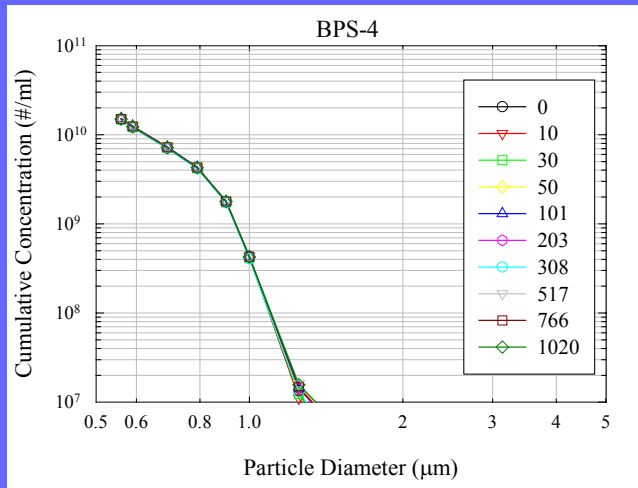
A2 slurry



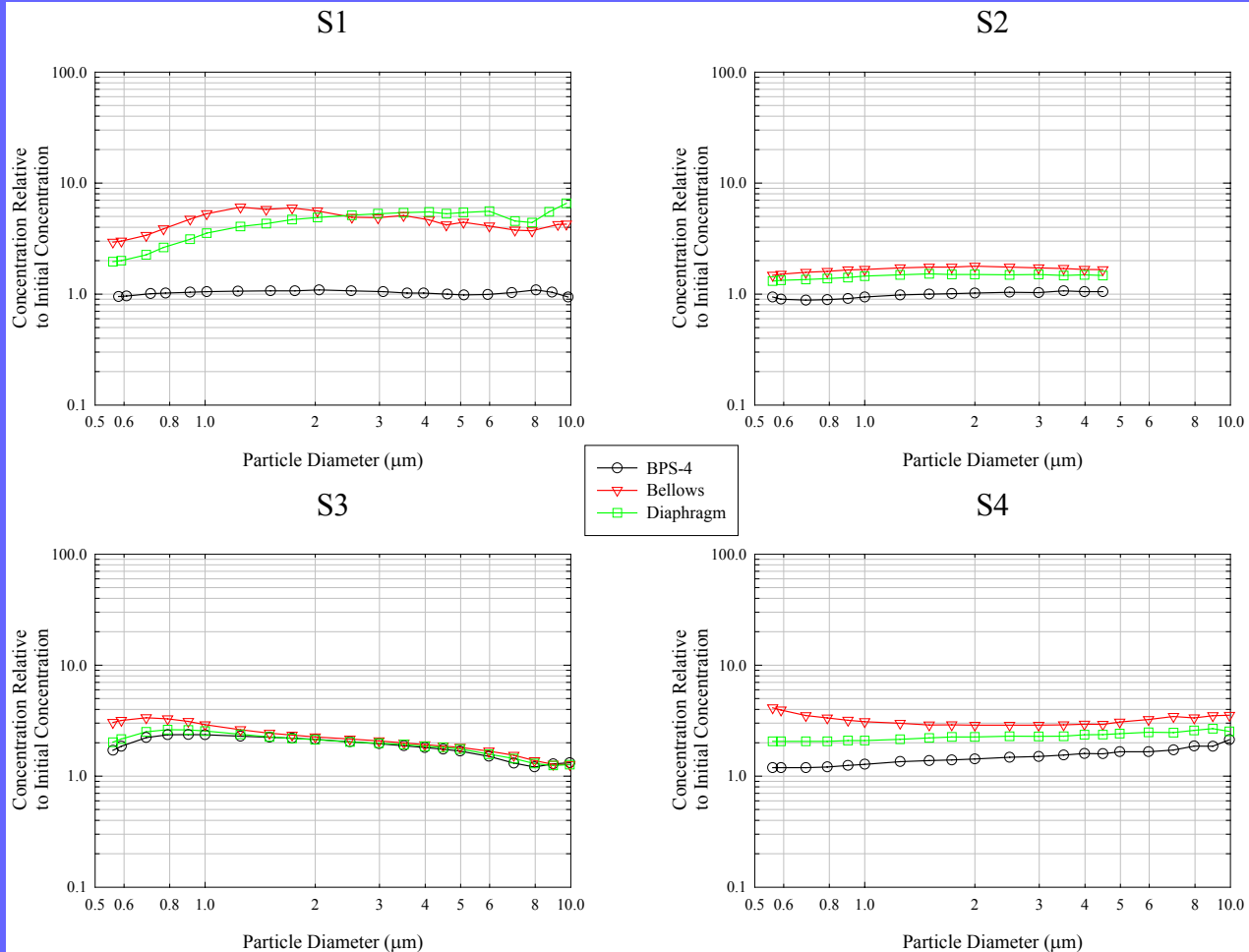
C1 slurry



C2 slurry

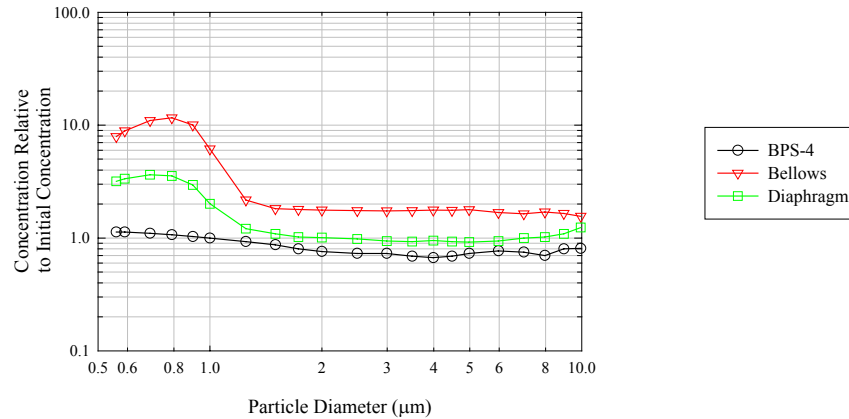


Concentration increases measured after 100 turnovers

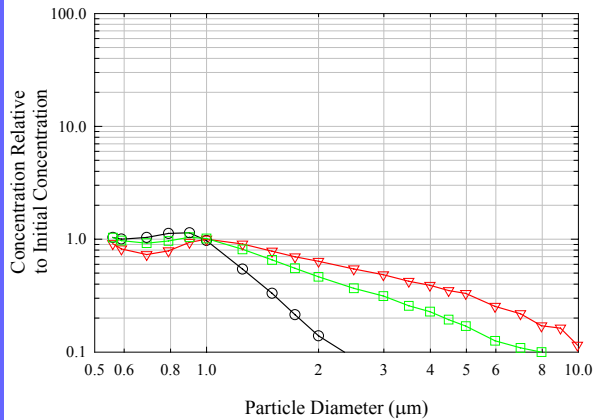


Concentration increases measured after 100 turnovers (cont'd)

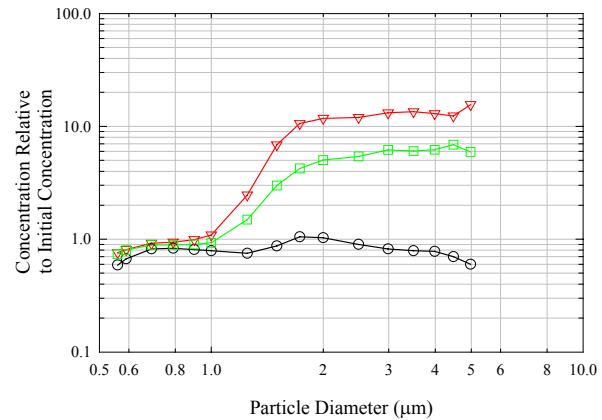
S5



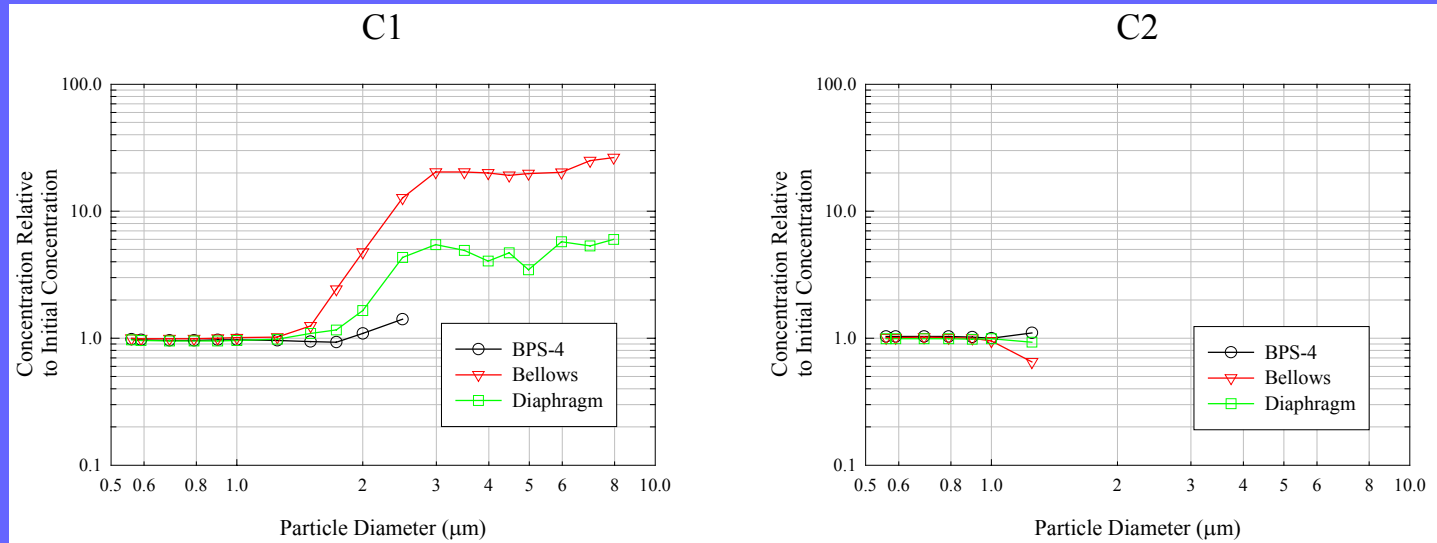
A1



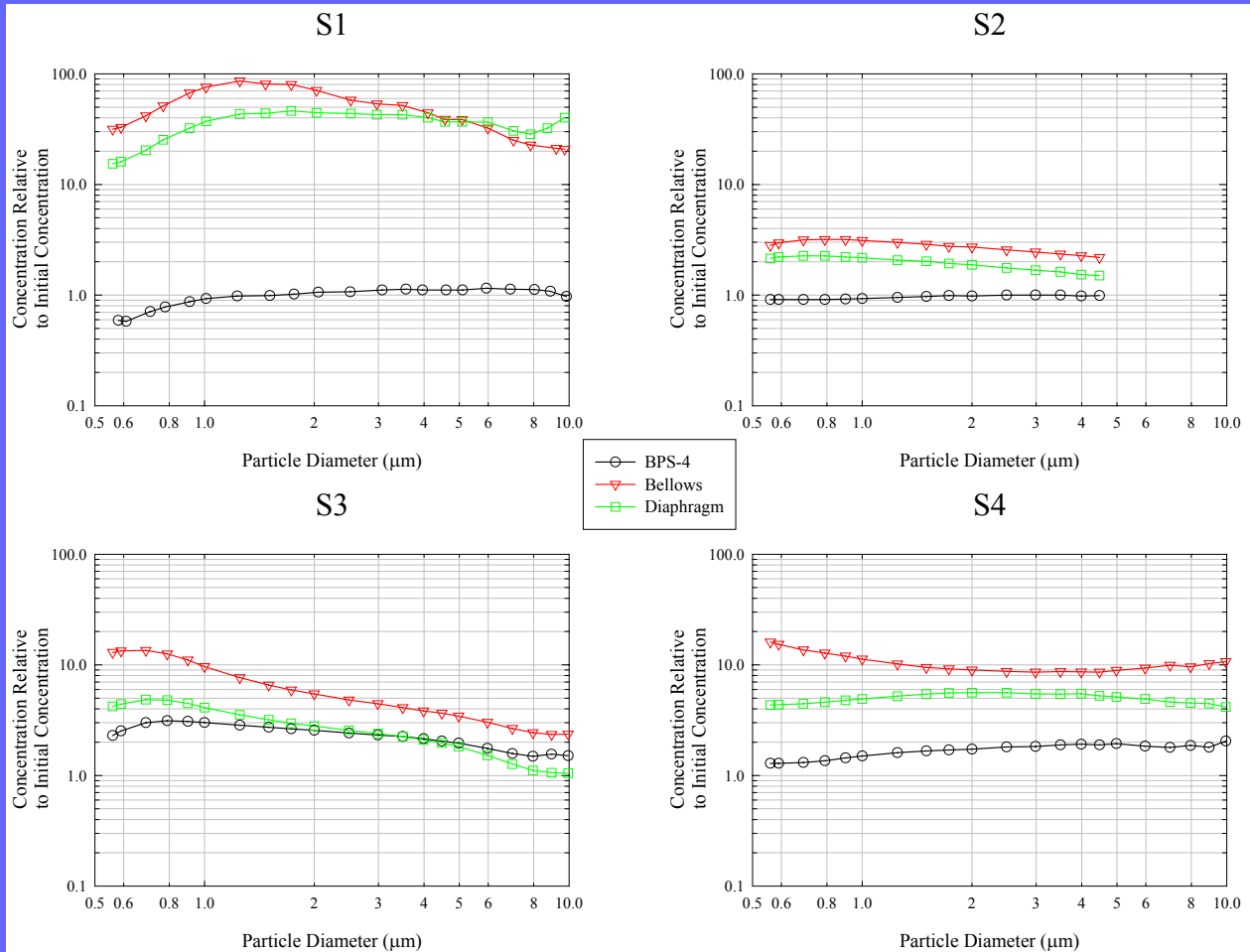
A2



Concentration increases measured after 100 turnovers (cont'd)

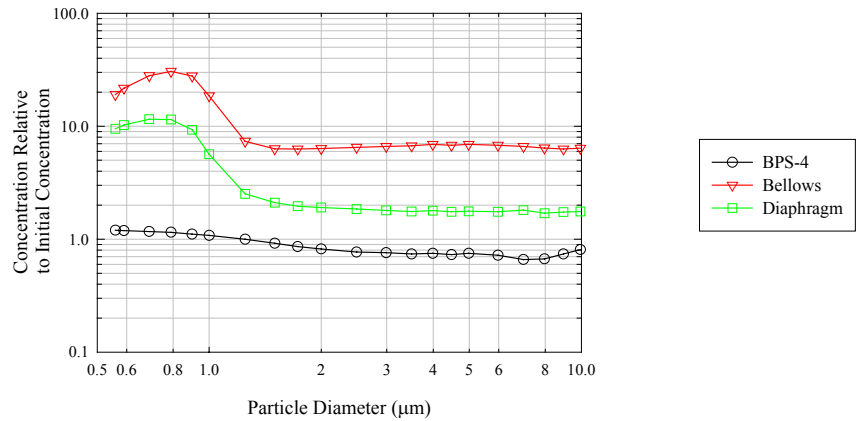


Concentration increases measured after 1,000 turnovers

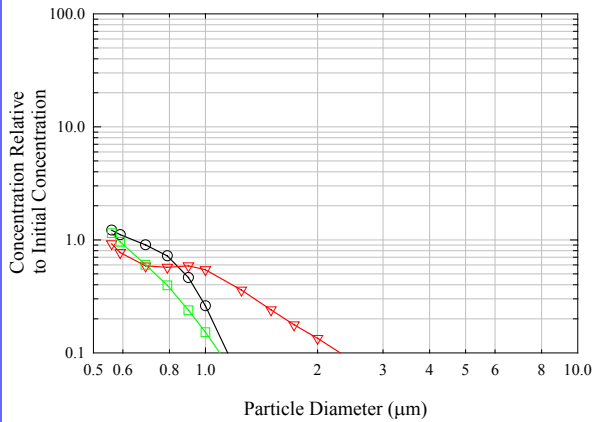


Concentration increases measured after 1,000 turnovers (cont'd)

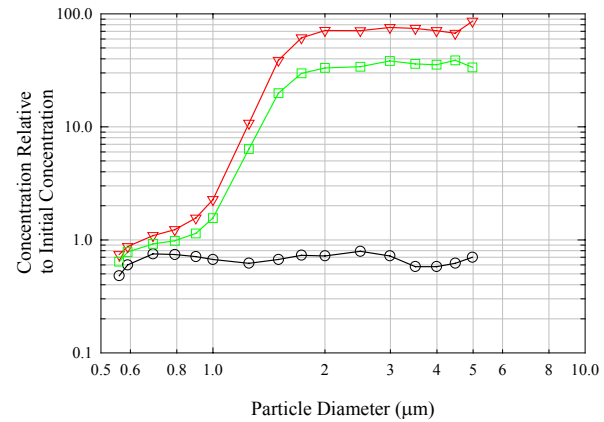
S5



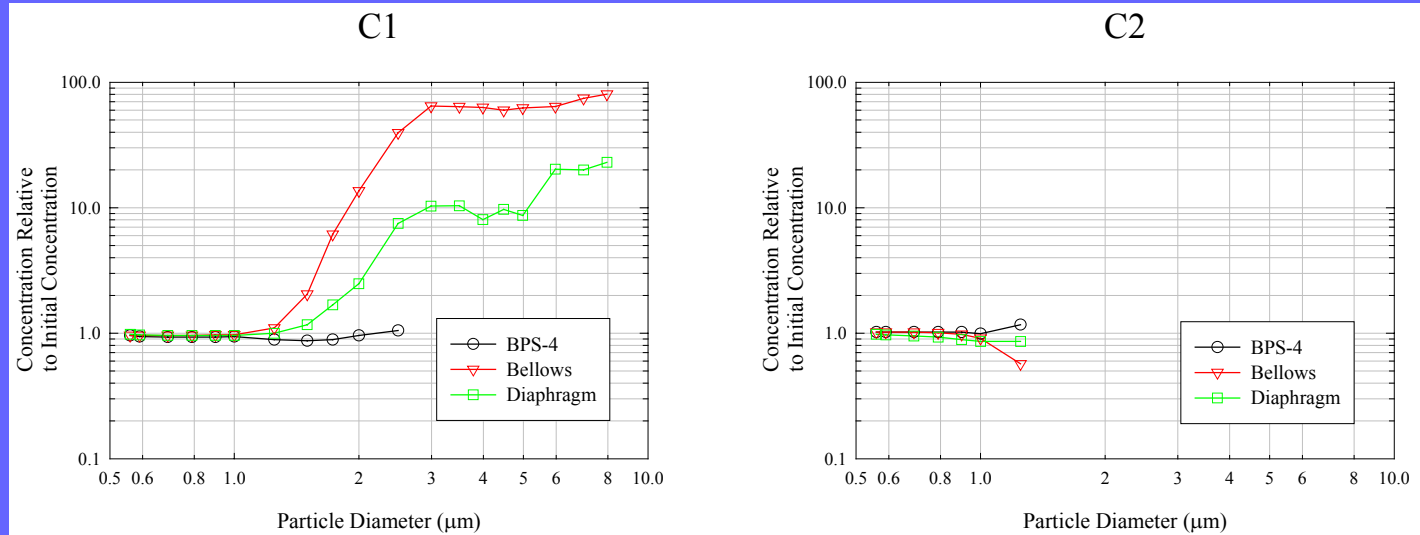
A1



A2



Concentration increases measured after 1,000 turnovers (cont'd)



Summary of changes in large particle concentrations

			Submicron particles (0.56-1.0 µm) after 1000 turnovers			Supermicron particles (> 2.0 µm) after 1000 turnovers		
Application	Abrasive	Type	Centrifugal	Diaphragm	Bellows	Centrifugal	Diaphragm	Bellows
ILD	fumed silica	S1	0	++	++	0	++	++
barrier	colloidal silica	S2	0	+	+	0	0	+
barrier	colloidal silica	S3	+	+	++	+	+	+
W	colloidal silica	S4	0	+	++	0	+	++
W	colloidal silica	S5	0	+	++	0	0	+
copper	alumina	A1	0	0	0	-	-	-
copper	alumina	A2	0	0	0	0	++	++
STI	ceria	C1	0	0	0	0	++	++
STI	ceria	C2	0	0	0	NA	NA	NA

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



Summary

- Most silica slurries are sensitive to handling-induced particle agglomeration, but to varying degrees.
- Some ceria and alumina slurries were also sensitive to handling, while others did not appear to be.
- No significant changes were observed in all slurry properties during all pump tests with only 1 slurry.

Summary of effect of pumps on slurry properties

Pump Type	PSD		Other Slurry Parameters
	Working PSD	Large Particle Tail	
BPS-4 pump	<ul style="list-style-type: none"> • Significant decrease in 1 slurry (A1) 	<ul style="list-style-type: none"> • Significant increase in 1 of 9 slurries 	<ul style="list-style-type: none"> • Minimal effect
Diaphragm and Bellows pumps	<ul style="list-style-type: none"> • Significant decrease in 1 slurry (A1) 	<ul style="list-style-type: none"> • Significant increase in 7 of 9 slurries • Large increase in 4 of 5 silica slurries • Large increase in at least 1 slurry of each type silica, alumina, and ceria slurry • Large increase with at least 1 slurry in each application area 	<ul style="list-style-type: none"> • Minimal effect