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Pump Particle Shedding Evaluation

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Introduction

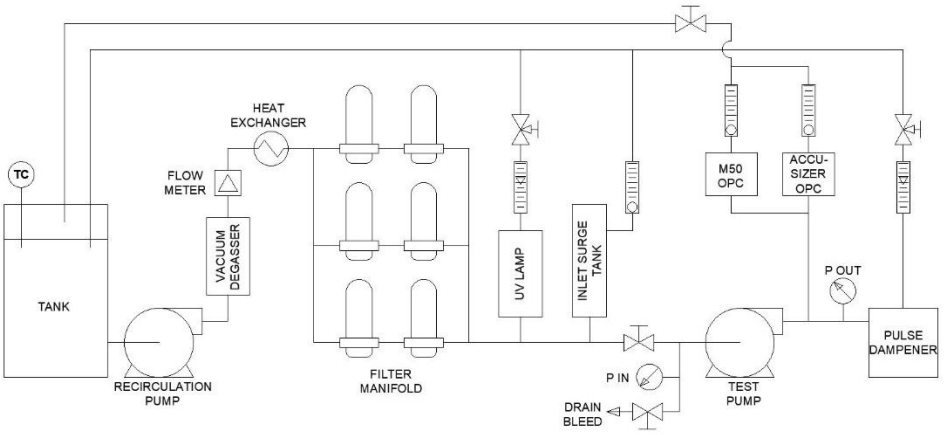
Three pumps were evaluated for particle shedding in ultrapure water (UPW) at two different operating conditions. The first pump tested was a PuraLev 600SU from Levitronix Technologies. The second pump tested was a MasterFlex B/T peristaltic pump with PharMed BPT Perfect Position B/T 87 tubing. The final pump tested was a Quattroflow 1200SU pump. The test was started on November 27th, 2018 and concluded on December 19th, 2018.

Experimental Procedure

A schematic of the pump particle shedding test system is shown in Figure 1. A centrifugal pump was used to deliver filtered water to the pump under test. This pump was operated continuously to circulate water through the main loop. The water was filtered using WL Gore 100 and 20 nm UPW 10" cartridge filters arranged in series/parallel. A flow meter and throttle valve were used to measure and control the flow rate and pump outlet pressure.

Two optical particle counters were used in this evaluation: a Particle Measuring Systems HSLIS M50 particle monitor and a Particle Sizing Systems Accusizer 780 liquid particle counter. The M50 has four size channels and measures the following particle sizes: ≥ 0.050, ≥ 0.100, ≥ 0.150, and ≥ 0.200 μm. The Accusizer was set for 32 different sized channels spaced linearly on a log-scale from ≥ 0.560 to ≥ 398 μm. Particle concentrations were recorded continuously downstream of the test pumps except for the initial start of the dynamic flush tests.

Figure 1. Schematic of test system



A spool piece was installed in place of the test pump to determine the background particle level of the test system. A valve located in the bypass loop was throttled to provide sufficient backpressure in the system to measure particle concentrations without a test pump in the system.

The test pumps were run under an initial operating condition, shown in Table I, for one day. The MasterFlex pump was run at a lower outlet pressure for its initial condition due to a 2.4 bar maximum outlet pressure rating. Following the initial break-in period, the quasi steady-state particle shedding from the pumps were monitored for one additional operating condition for a minimum of six hours. The desired operating conditions were achieved by setting the pump RPM speed and adjusting the pump outlet flow rate with a throttle valve located downstream of the test pump.

Table I. Test Operating Conditions

Pump	Operating Condition #	Outlet Pressure (bar)	Flow Rate (LPM)
Levitronix	1	2.5	16.0
	2	1.0	
MasterFlex	1	2.2	
	2	1.0	
Quattroflow	1	2.5	
	2	1.0	

Results

The average test system background particle level is presented in Table II. The data represents the two-hour averaged results at the end of a spool test conducted before each pump was connected to the system.

Table II. Background Particle Concentrations

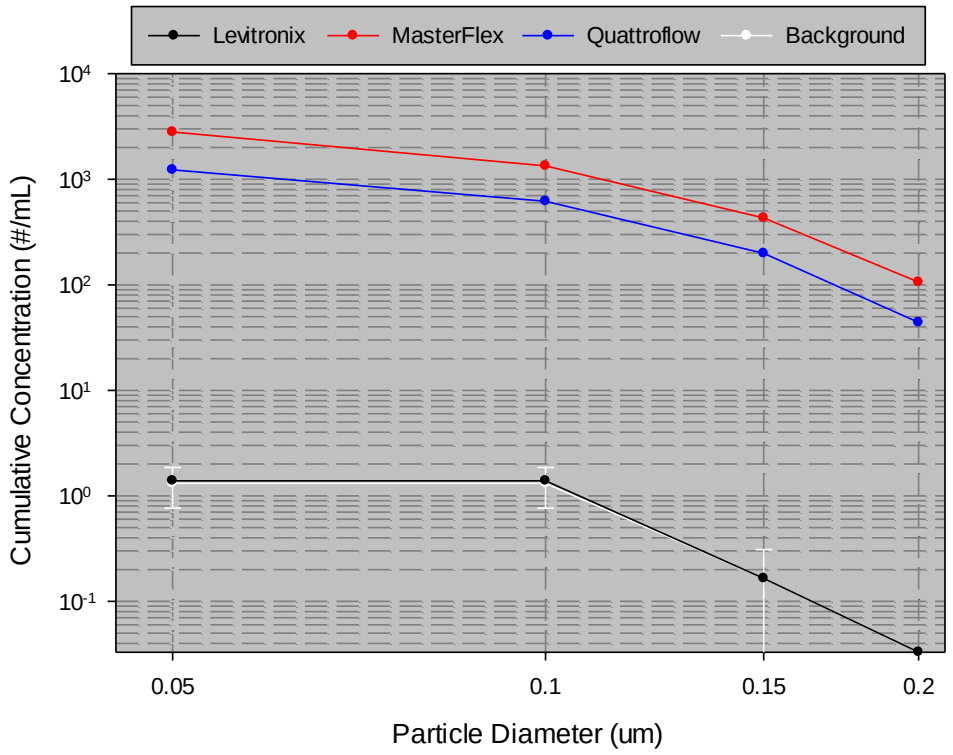
Cumulative Particle Concentrations (#/ml)							
All M50 Channels				First 3 Accusizer Channels			
≥ 0.05 μm	≥ 0.10 μm	≥ 0.15 μm	≥ 0.20 μm	≥ 0.56 μm	≥ 0.61 μm	≥ 0.77 μm	≥ 0.94 μm
1.31	1.31	0.17	< DL[1]	0.0091	0.0045	0.0004	< DL[2]

[1]M50 detection limit (DL) for a two-hour average is 0.033 #/mL
[2]Accusizer detection limit for a two-hour average is 0.00014 #/mL

The cumulative particle size distributions (PSD) generated by the M50 are shown in Figures 2a and 2b for operating conditions #1 and #2, respectively. The cumulative PSDs generated by the Accusizer are presented in Figures 3a and 3b for operating conditions #1 and #2, respectively. Each data point represents a two-hour average of the particle concentration downstream of the test pump. The average test system background is also shown in each of the plots in Figures 2 and 3. The background data is plotted with error bars, representing one standard deviation from the average background value, to display its variability of background levels at the different pump runs. The effect of changing the test pump's operating condition can be seen in Figures 4a and 4b for the first channel of the M50 and the Accusizer, respectively. Tabular data can be found in Appendix A.

Figure 2. M50 PSDs for Each Operating Condition Compared to Background

2a. Operating Condition #1



2b. Operating Condition #2

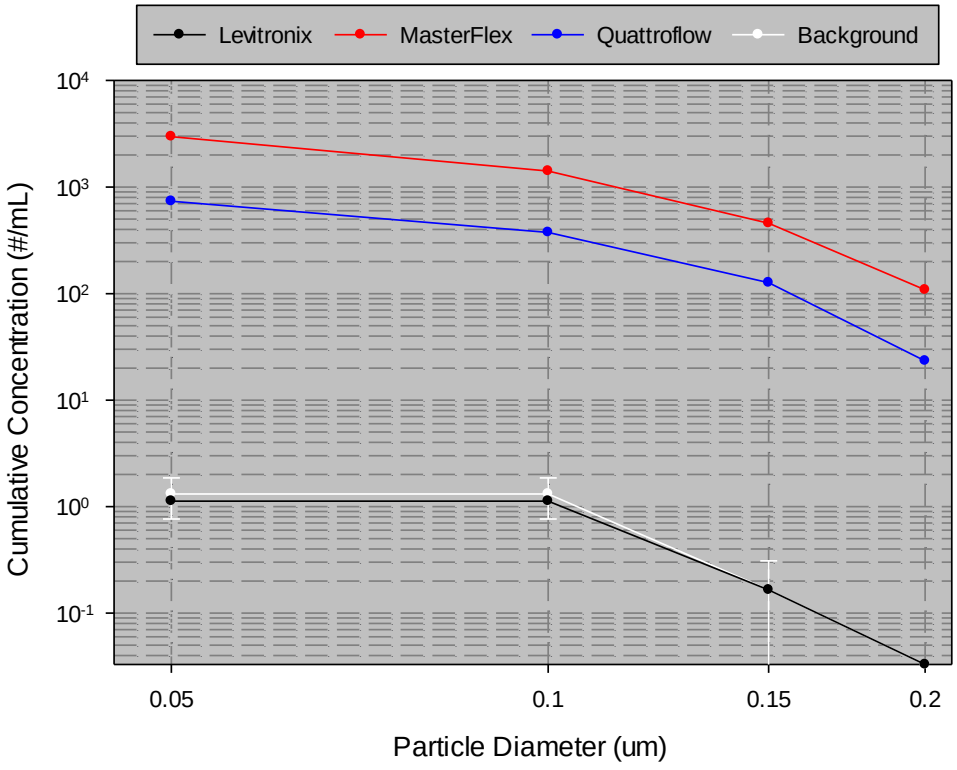
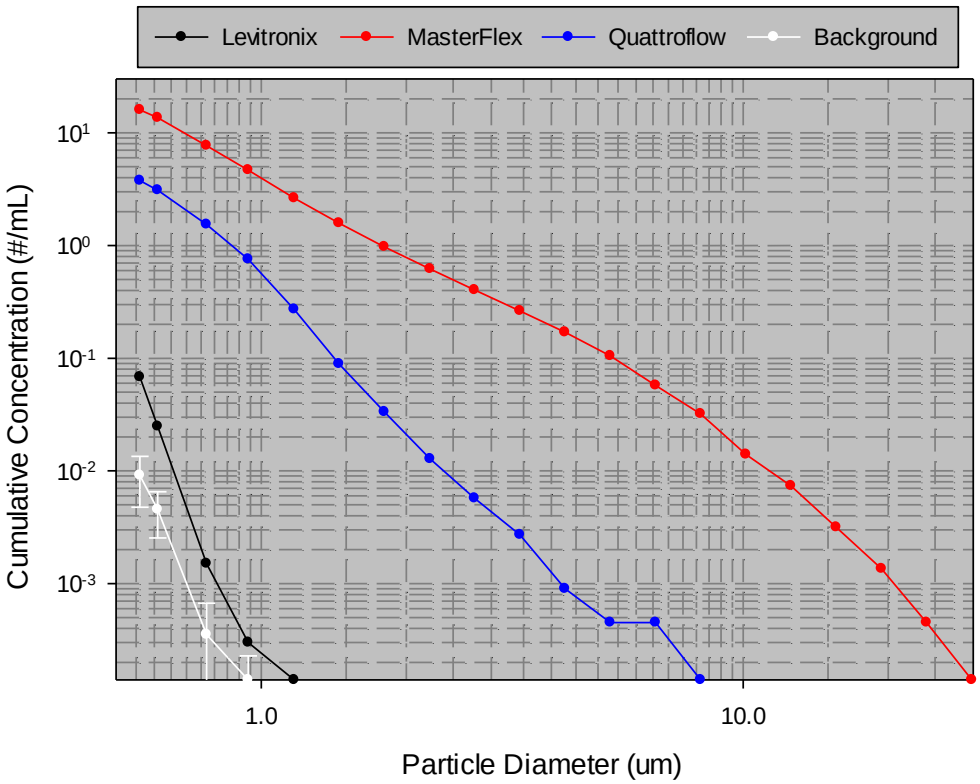


Figure 3. Accusizer PSDs for Each Operating Condition Compared to Background

3a. Operating Condition #1



3b. Operating Condition #2

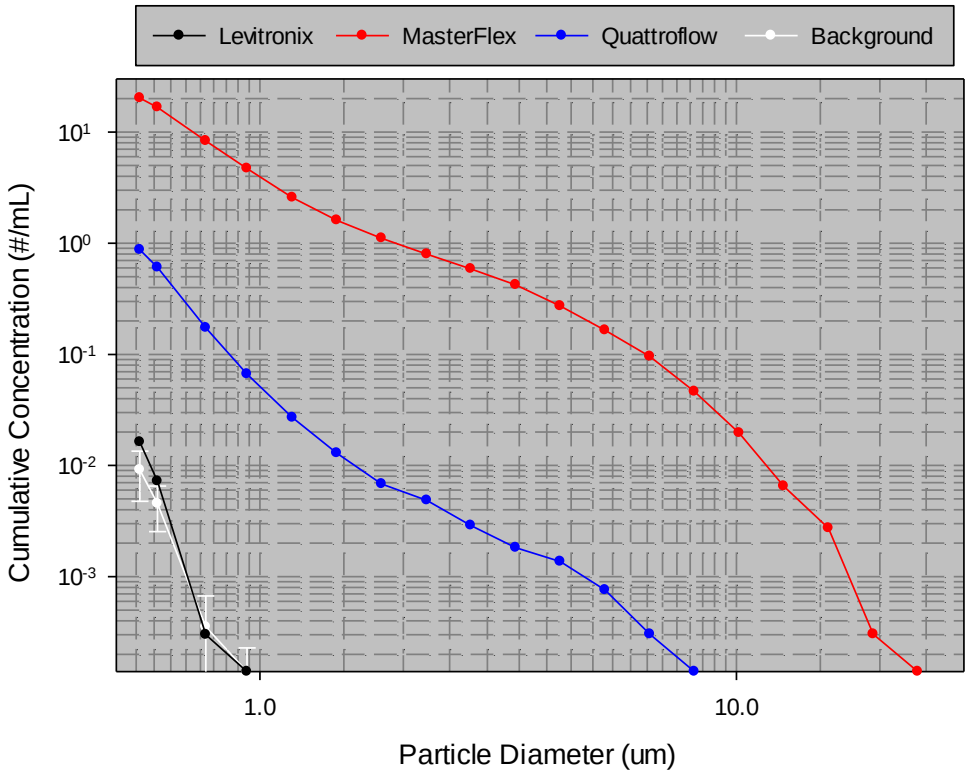
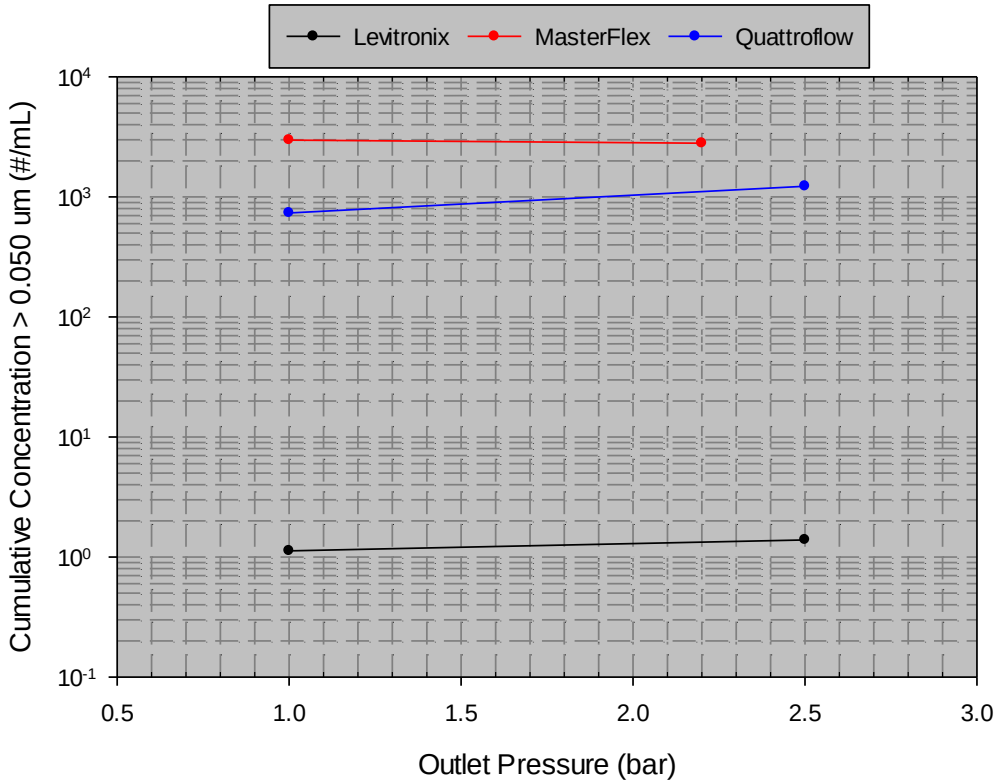
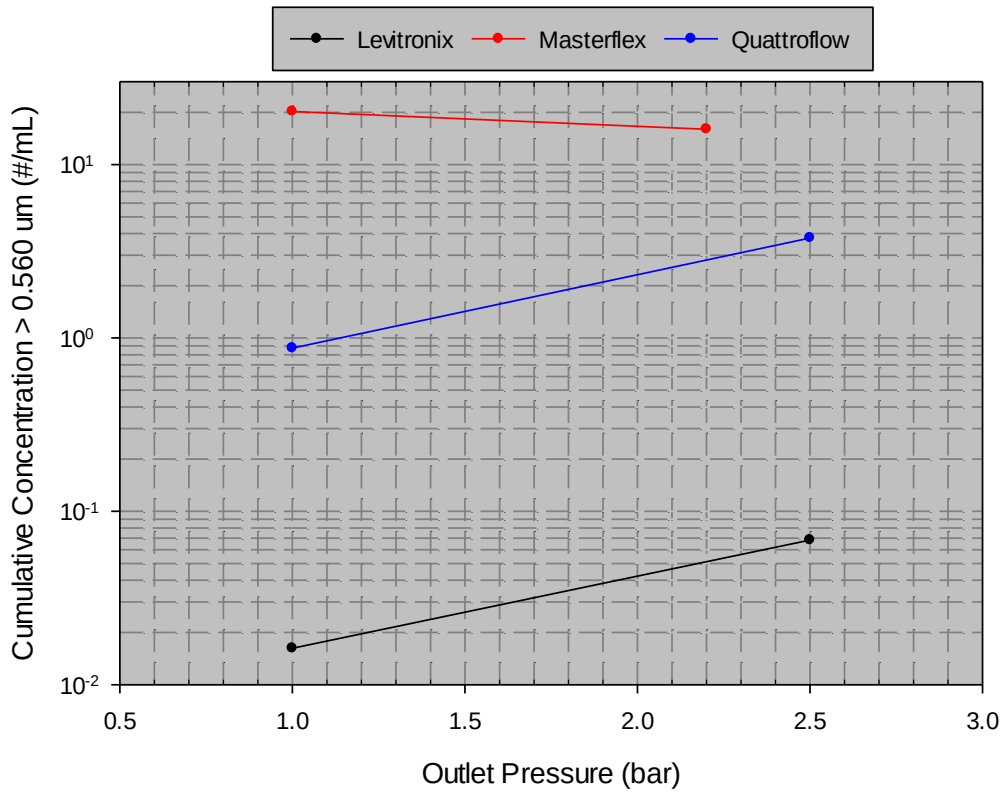


Figure 4. Operating Condition Comparison for Each Particle Counter

4a. M50



4b. Accusizer



Observations

The two hour averaged PSD data, shown in Figures 2 and 3, gives a clear comparison of the particle generation levels between each pump and each of its operating conditions. The MasterFlex pump produced the largest particle size and concentrations compared to the other two pumps. There were minimal differences between its two operating conditions, shown in Figure 4. The Quattroflow pump also generated large particle concentrations, but showed a decrease in concentration when switched to the lower outlet pressure condition. The M50 OPC data in Figure 4a shows the Levitronix pump operating near background levels for both operating conditions. The Accusizer data in Figure 4b shows a very small bump in particle counts above background during the initial operating condition; however, the particle counts then decrease to background levels during the lower outlet pressure condition.

Summary

Three pumps were tested for particle shedding in ultrapure water. The pumps were broken in under an initial operating condition for a maximum of 24 hours. A second operating condition was then set and run for a minimum of 6 hours. The MasterFlex and Quattroflow pumps generated particle levels 2-3 orders of magnitude greater than the Levitronix pump. Regardless of operating conditions, the concentration of particles downstream of the Levitronix pump was near the background concentration in the system.

Appendix A – Particle Data

Figure A1 – Quasi Steady-State Shedding

		Cumulative Concentration (#/mL)						
	Pump	Background	Levitronix		MasterFlex		Quattroflow	
OPC	Channel Size (um)		Initial Condition	Second Condition	Initial Conditi	Second Condition	Initial Condition	Second Condition
M50	0.05	1.311	1.388	1.124	2809.124	2972.860	1227.769	735.533
	0.10	1.311	1.388	1.124	1340.132	1412.628	618.281	375.100
	0.15	0.165	0.165	0.165	430.843	456.926	199.107	126.467
	0.20	< DL	< DL	< DL	106.182	108.364	44.066	23.333
Accusizer	0.56	0.0091	0.0682	0.0162	15.9817	20.2315	3.7685	0.8739
	0.61	0.0045	0.0248	0.0072	13.5812	16.6485	3.0934	0.6055
	0.77	0.0004	0.0015	0.0003	7.6841	8.3220	1.5359	0.1735
	0.94	< DL	0.0003	< DL	4.6727	4.6930	0.7574	0.0665
	1.17	< DL	< DL	< DL	2.6356	2.5724	0.2712	0.0270
	1.45	< DL	< DL	< DL	1.5770	1.6086	0.0889	0.0129
	1.80	< DL	< DL	< DL	0.9727	1.1086	0.0335	0.0068
	2.24	< DL	< DL	< DL	0.6201	0.7962	0.0128	0.0048
	2.77	< DL	< DL	< DL	0.4042	0.5880	0.0057	0.0029
	3.44	< DL	< DL	< DL	0.2628	0.4221	0.0027	0.0018
	4.27	< DL	< DL	< DL	0.1703	0.2729	0.0009	0.0014
	5.30	< DL	< DL	< DL	0.1051	0.1650	0.0005	0.0008
	6.58	< DL	< DL	< DL	0.0575	0.0958	0.0005	0.0003
	8.16	< DL	< DL	< DL	0.0321	0.0464	0.0002	0.0002
	10.1	< DL	< DL	< DL	0.0140	0.0195	< DL	< DL
	12.6	< DL	< DL	< DL	0.0074	0.0065	< DL	< DL
	15.6	< DL	< DL	< DL	0.0032	0.0027	< DL	< DL
	19.4	< DL	< DL	< DL	0.0014	0.0003	< DL	< DL
	24.0	< DL	< DL	< DL	0.0005	0.0002	< DL	< DL
	29.8	< DL	< DL	< DL	0.0002	0.0002	< DL	< DL
	37.0	< DL	< DL	< DL	< DL	0.0002	< DL	< DL
	45.9	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	57.0	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	70.7	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	87.7	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	109	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	135	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	168	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	208	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	258	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	320	< DL	< DL	< DL	< DL	< DL	< DL	< DL
	398	< DL	< DL	< DL	< DL	< DL	< DL	< DL