CT Associates, Inc.
7121 Shady Oak Road, Eden Prairie, MN 55344-3516
Telephone: (952) 470-0166 Fax: (952) 942-0293
Website: http://www.ctassociatesinc.com

The Effect of Two Pumps on Filter Retention

Submitted to:

David Simmons
White Knight Fluid Handling, Inc.

Submitted by:

Mark Litchy
CT Associates, Inc.

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Introduction

Diaphragm and bellows pumps produce large flow rate and pressure pulsations and hence typically use pulse dampeners to reduce the pulsations. Previous studies of the effect of pump pulsation on membrane filter retention have shown that filter retention decreased with increasing pump pulsation intensity and particle loading.[1,2] This evaluation was undertaken to determine the effectiveness of a new closed-loop pressure control system incorporating a White Knight bellows pump (Model #: PSA 060) and pulse dampener (Model #: DBA 060) at minimizing flow rate and pressure pulsations and thereby improve filter retention downstream of the pumps.

The objective of this evaluation was to quantify the magnitude of the pressure and flow pulsations from two pumps and compare the effect of the two types of pumps on the retention efficiency of a membrane filter.

Experimental Procedure

The pumps evaluated were a Levitronix BPS-4 centrifugal pump and a White Knight bellows pump (Model #: PSA 060) and pulse dampener (Model #: DBA 060).

Pulsation intensity:

Fast response pressure and flow rate transducers were installed downstream of the pump being evaluated to quantify the magnitude of the pressure and flow pulsations. An Entegris Model 4100 single-port pressure transducer (0-60 psig) was used to quantify the magnitude of the pressure pulsations. A Futurestar FM 3103-PS-XP/F (0-50 lpm) flow meter was used to quantify the magnitude of the flow pulsations. The pressure and flow rate measurements were collected at 1000 Hz. Data were collected and analyzed over one-minute time intervals at each test condition.

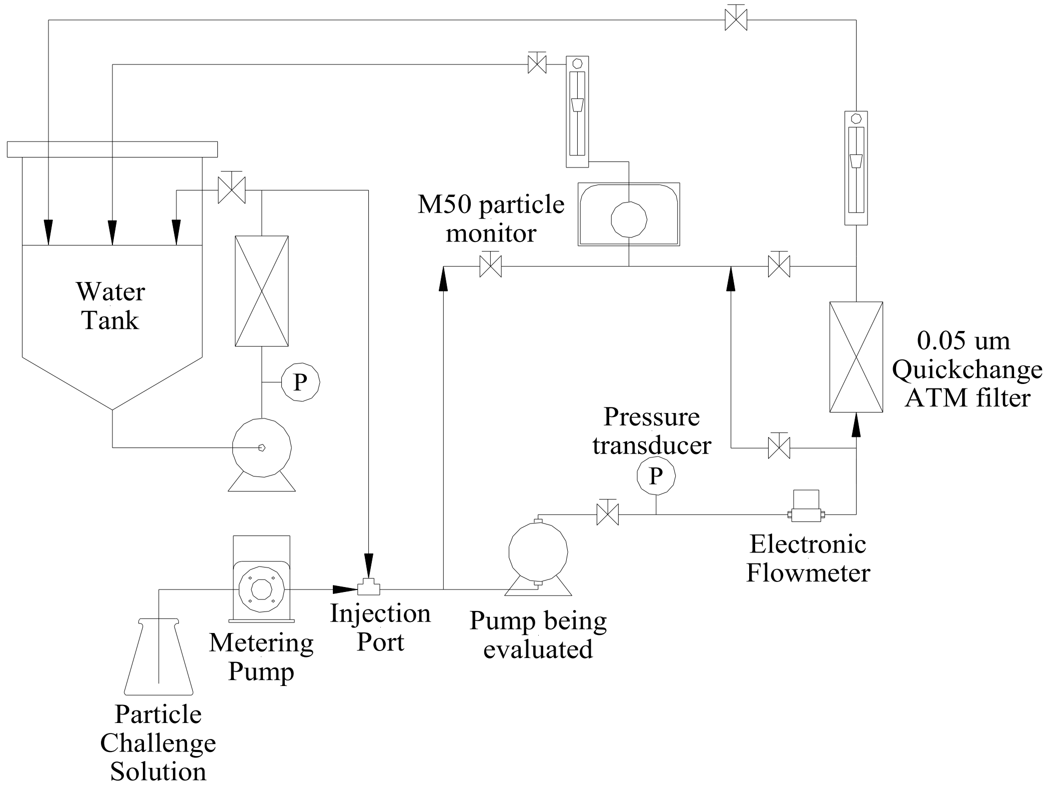
Filter retention measurements:

A schematic of the test system is presented in Figure 1. A circulation pump was used to provide a continuous feed of low particle (<1.0/ml ≥ 0.05 μm) deionized water to the pumps being evaluated.

Two optical particle counters were used in this evaluation: a Particle Measuring Systems HSLIS M50 particle monitor and a Particle Measuring Systems LiQuilaz S05 liquid particle counter. The M50 has four size channels and measures particles ranging from ≥ 0.05, ≥ 0.10, ≥ 0.15, and ≥ 0.20 μm. The LiQuilaz S05 has 15 size channels ranging from ≥ 0.5 to ≥ 20 μm.

Filter retention measurements were made by injecting monodisperse polystyrene latex spheres (PSL) into the flow stream upstream of the pump being evaluated. The PSL challenge solutions consisted of particle sizes ranging from 73 to 400 nm in diameter. Particle retention measurements were conducted at flow rates ranging from 5 to 10 gpm. Particle concentrations were monitored upstream and downstream of the test filter during each particle injection. In addition, upstream and downstream background measurements were made prior to and after each particle injection test to ensure the particle concentrations were adequately low to perform the particle challenge. Two 10" 0.05 μm Mykrolis Quickchange ATM filters were arranged in parallel during this retention evaluation. The filter face velocities ranged from 0.5-1.0 cm/min depending on the test flow rate. The retention efficiency was calculated for each pump at each particle challenge size.

Figure 1: Test system schematic



In this report, filter retention data are expressed as the filter log reduction value (LRV). The LRV is defined as:

$$LRV = \log_{10} ((C_I - C_{BI}) / (C_O - C_{BO}))$$

where:

C_I = particle concentration at the filter inlet during particle injection
C_{BI} = background particle concentration at the filter inlet after particle injection
C_O = particle concentration at the filter outlet during particle injection
C_{BO}= background particle concentration at the filter outlet prior to particle injection

The relationship between LRV and filter retention efficiency is shown in Table I.

Table I. Relationship between filter retention efficiency and LRV

LRV	Filter Retention Efficiency (%)
1	90
2	99
3	99.9
4	99.99

Results and Discussion

Pulsation intensity:

Figures 2-4 show the magnitude of the pressure and flow pulsations for each type of pump at approximately 5, 7.5, and 10 gpm, respectively. An analysis of the pressure and flow data is presented in Table II. The relative standard deviations (RSDs) were calculated over a one-minute test interval for each pump under each test condition.

The flow pulsations from the White Knight and Levitronix pumps were both relatively low and nearly identical, regardless of flow rate. The magnitude of the flow pulsations decreased with increasing flow rate.

The pressure pulsations measured were at least of factor of 10 higher than the flow pulsations measured, regardless of the pump or flow rate. This effect may have been influenced by the integration time of the flow meter which may not have had as fast of a response time as the pressure transducer. The magnitude of the pressure pulsations measured with each pump system were similar at 5 gpm. However, as the flow rate increased, pressure pulsations increased for the White Knight pump and decreased for the Levitronix pump as shown in Figure 5.

Table II. Relative standard deviations of pressure and flow data

Flow Rate	RSD of Pressure Measurements (%)	
	White Knight	Levitronix
5 gpm	4.3	3.8
7.5 gpm	4.7	3.3
10 gpm	6.0	2.7
Flow Rate	RSD of Flow Measurements (%)	
	White Knight	Levitronix
5 gpm	0.5	0.4
7.5 gpm	0.3	0.3
10 gpm	0.2	0.2

Figure 2. Magnitude of pressure and flow pulsations for each pump at 5 gpm

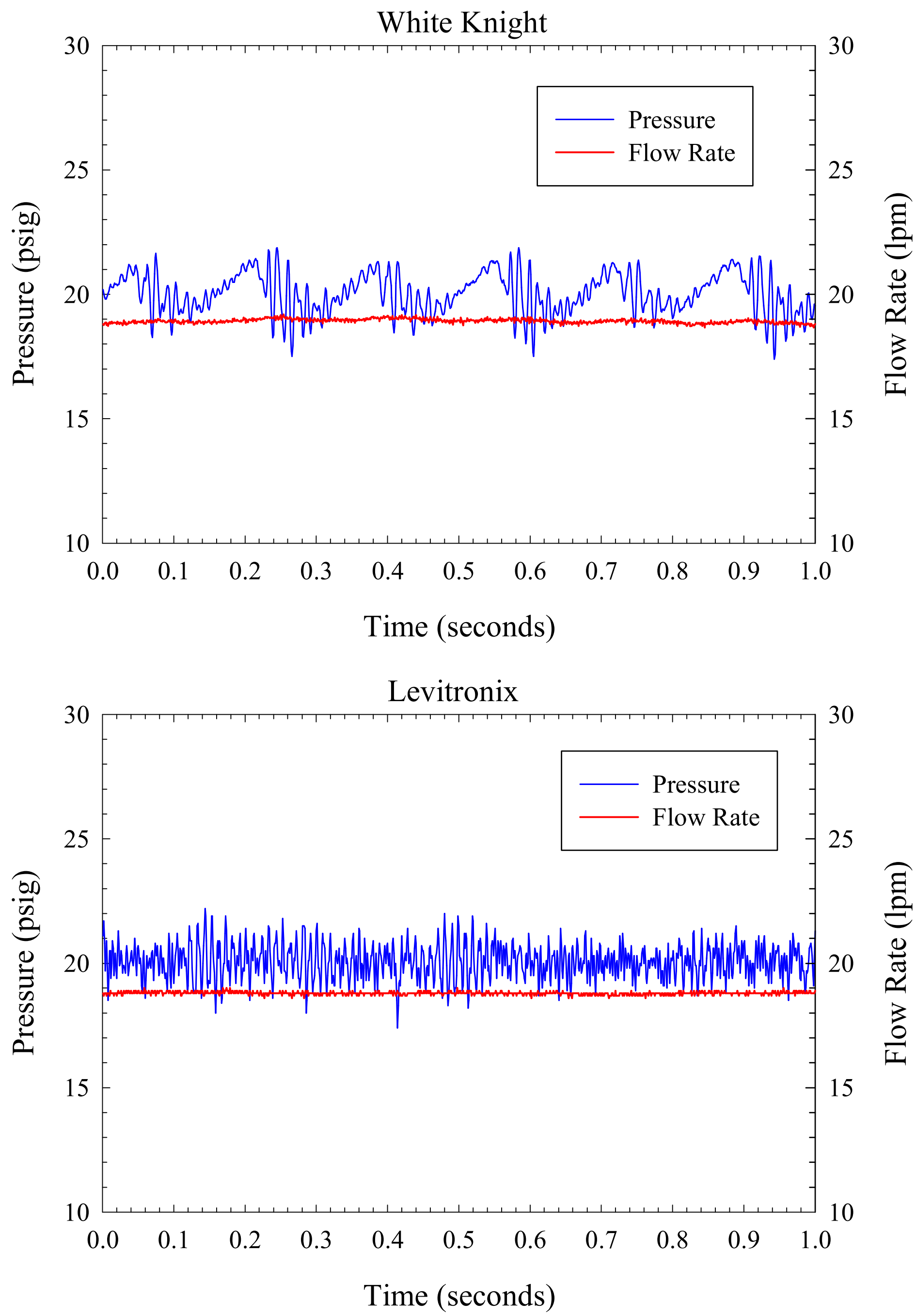
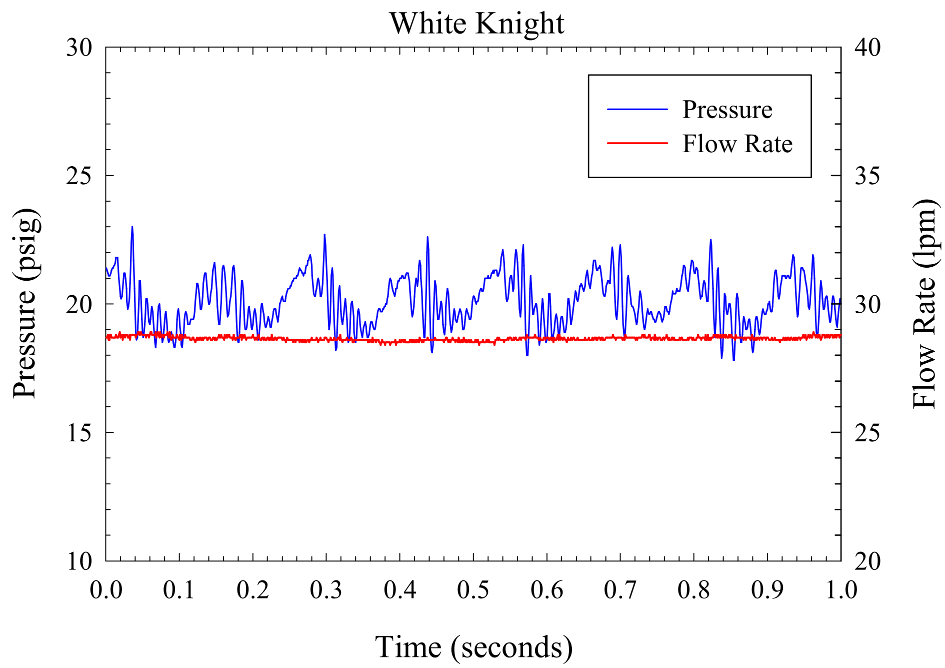


Figure 3. Magnitude of pressure and flow pulsations for each pump at 7.5 gpm



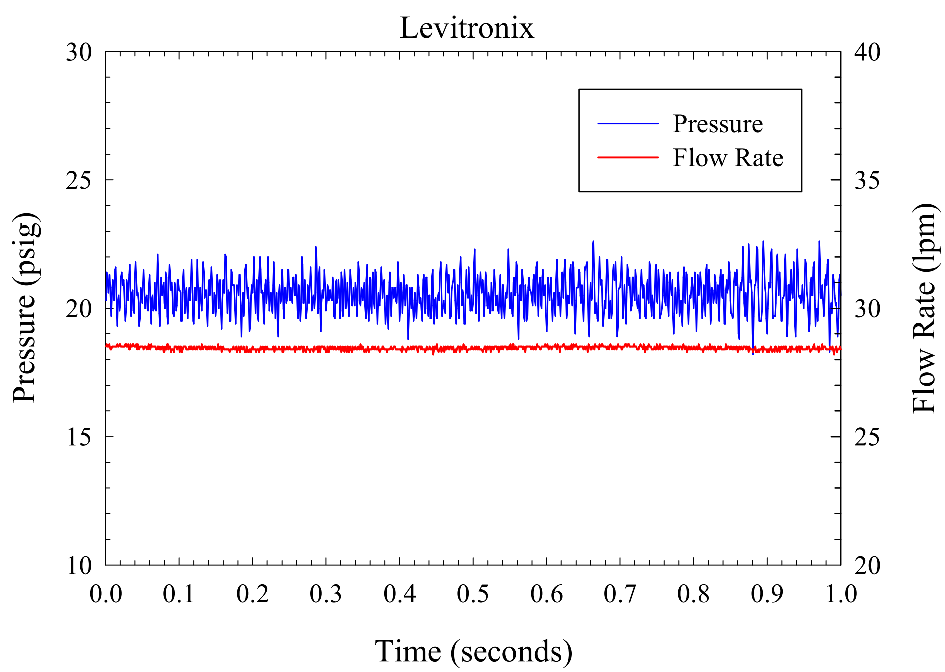


Figure 4. Magnitude of pressure and flow pulsations for each pump at 10 gpm

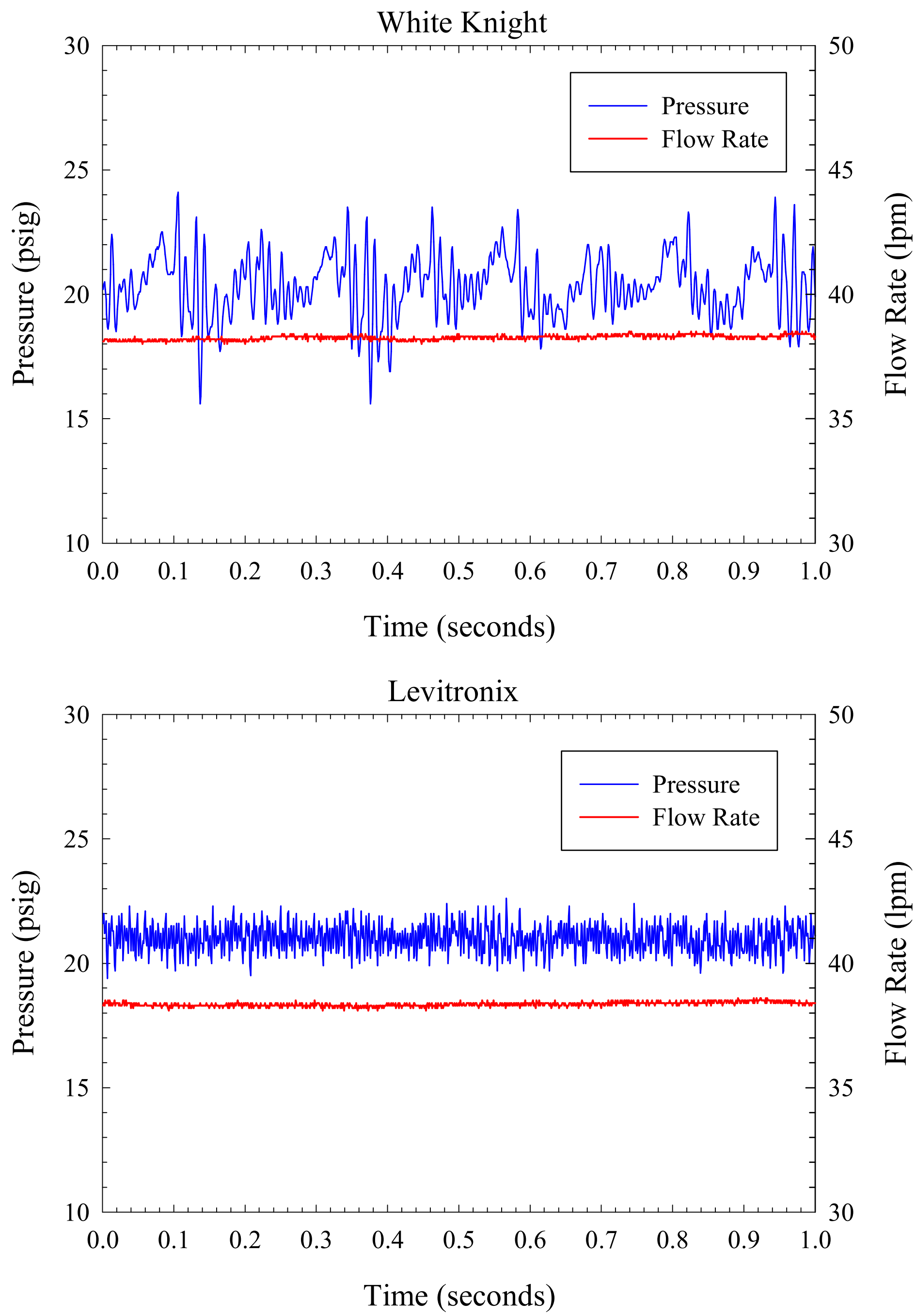
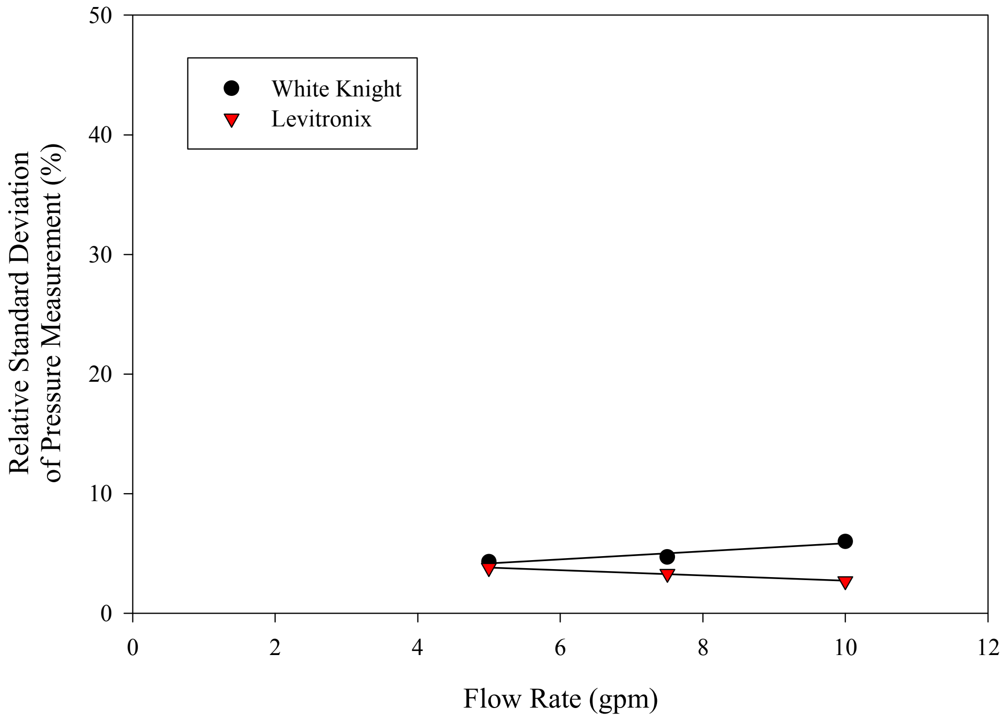


Figure 5. Relative standard deviations of pressure measurements as a function of flow rate



Filter retention measurements:

Table III and Figure 6 show the results of the filter retention measurements for each pump as a function of particle size and flow rate. Figure 7 presents the filter retention measurements for each pump as a function of the RSD of the pressure measurements quantified in this study. The maximum detectable LRV with this test method was 4, or a filter retention of 99.99%. The retention of 73 to 400 nm PSL particles by the 0.05 µm Quickchange ATM cartridges were found to be greater than 4 LRV with both pumps at flow rates ranging from 5 to 10 gpm. No measurable difference in filter retention was observed with these pumps. The 73 nm PSL size is the smallest detectable PSL size that the Measuring Systems HSLIS M50 particle monitor is capable of efficiently detecting.

Table III. Filter retention for each pump for each PSL particle size

Particle Size (nm)	RSD of Pressure Measurements (%)	
	White Knight	Levitronix
	5 gpm	
73	> 4	> 4
97	> 4	> 4
200	> 4	> 4
400	> 4	> 4
	10 gpm	
73	> 4	> 4
97	> 4	> 4
200	> 4	> 4
400	> 4	> 4

Figure 6. Retention efficiency (LRV) as a function of particle size

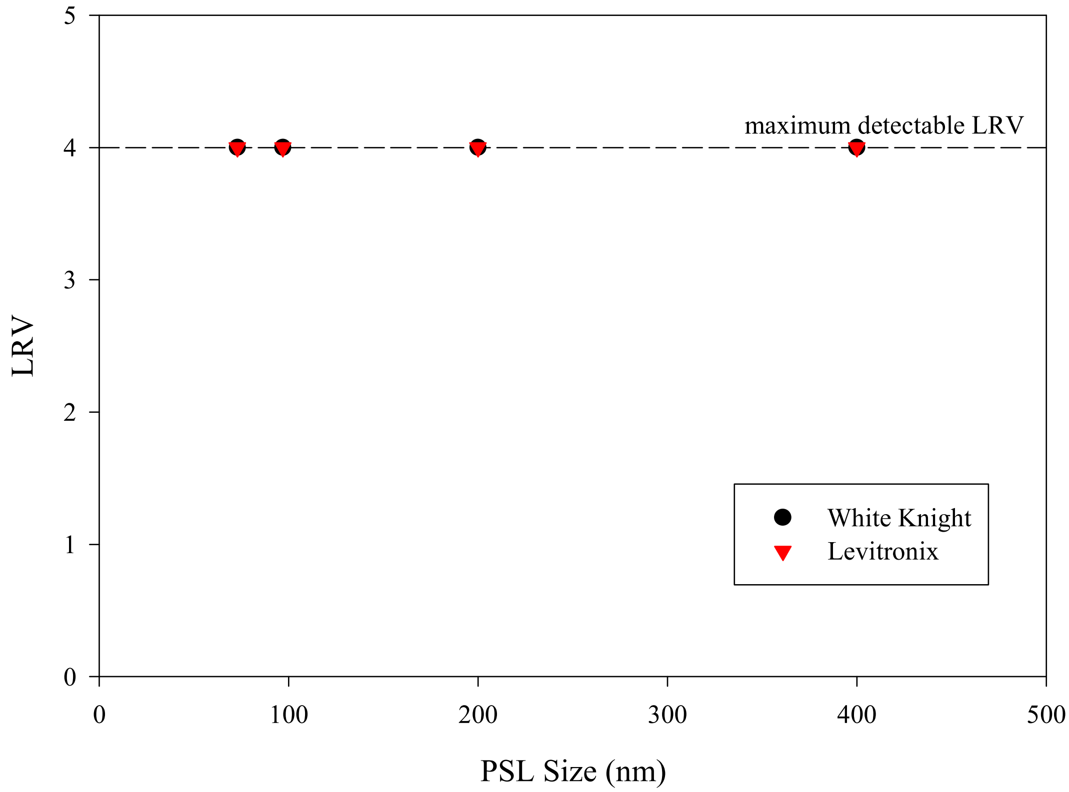
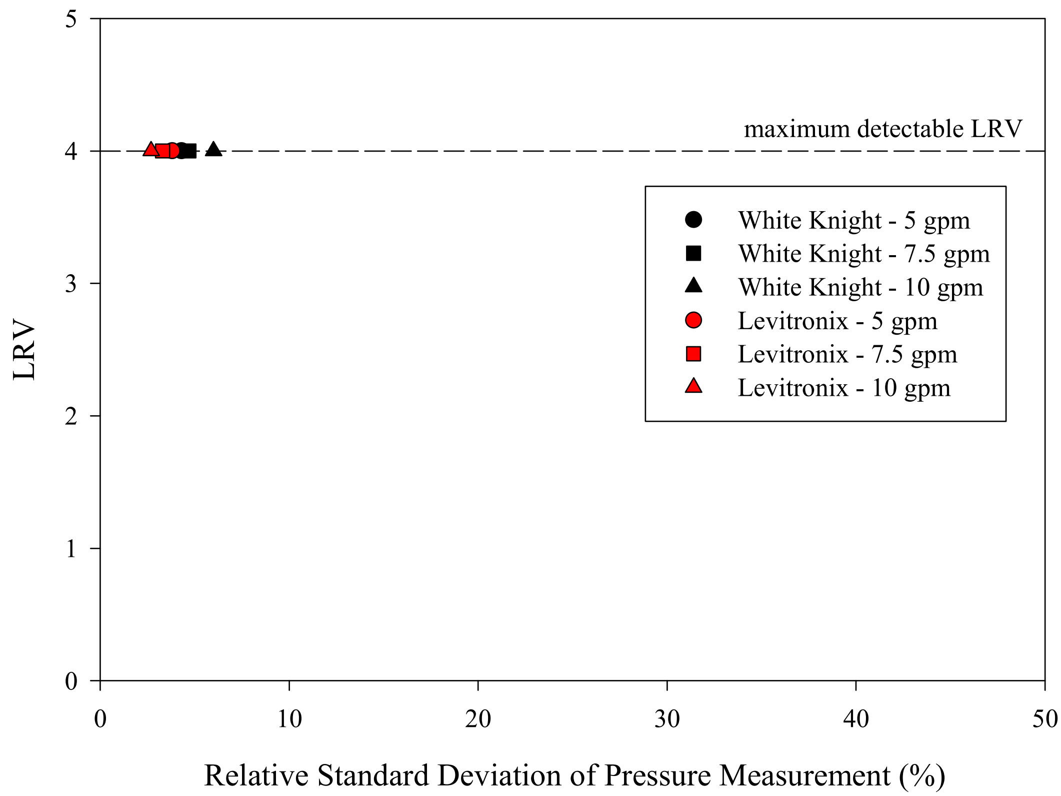


Figure 7. Retention efficiency (LRV) as a function of pressure pulsation at multiple flow rates



Summary

The magnitude of the pressure and flow pulsations from a White Knight bellows pump incorporating a closed-loop pressure control system and a Levitronix BPS-4 pump system were characterized.

The flow pulsations from the White Knight and Levitronix pumps were both relatively low and nearly identical, regardless operating conditions tested. The pressure pulsations measured were at least of factor of 10 higher than the flow pulsations measured, regardless of the pump being tested. The magnitude of the pressure pulsations measured with each pump system were similar at 5 gpm. As the flow rate increased, pressure pulsations increased for the White Knight pump and decreased for the Levitronix pump.

The retention of 73 to 400 nm PSL particles by the 0.05 µm Quickchange ATM cartridges were found to be greater than 4 LRV with both pumps at flow rates ranging from 5 to 10 gpm. No measurable difference in filter retention was observed with these pumps.

References

1. Litchy MR, DC Grant and R Schoeb (2005), "Effect of pump pulsation on membrane filter retention," *SCP Global Technologies' 9th International Symposium on Wafer Cleaning and Surface Preparation*.
2. Litchy MR, DC Grant, and R Schoeb (2006). "Effect of Pump Pulsation and Particle Loading on Membrane Filter Retention," Proceedings of the 25th Annual Semiconductor Pure Water and Chemicals Conference, Sunnyvale, CA., pp 105-125, Feb 15, 2006.