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Test Report - Levitronix BPS-4 Bearingless Pump System Operated in Hydrogen Peroxide

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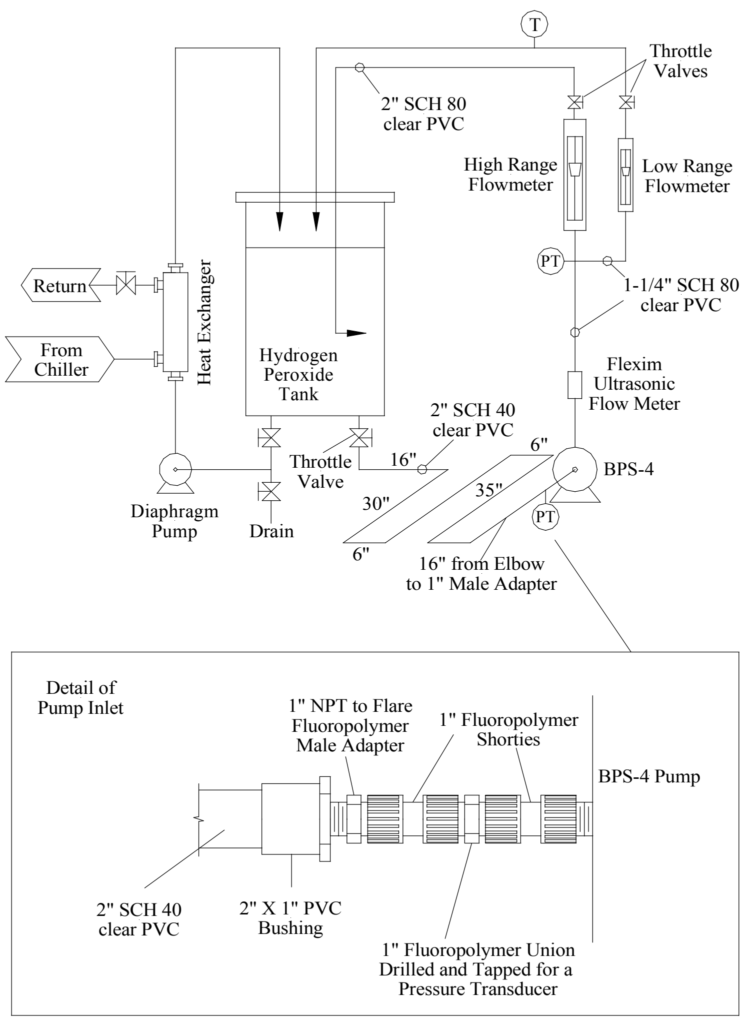
Objective:

The objective of this test was to generate pump capacity curves (pressure versus flow rate) for a Levtronix BPS-4 magnetically levitated centrifugal pump in concentrated hydrogen peroxide (H_2O_2) under simulated operating conditions. In addition, potential pump limitations resulting from outgassing of the H_2O_2 were investigated.

Test Apparatus:

A test system was designed and assembled to simulate the use of a Levitronix BPS-4 in a chemical delivery application of 30% H_2O_2 from a day tank (Figure 1 and Appendix A). The pump used in this test was a BPS 4.1 (Article # 100-10007, Serial number 160708-0727). The pump was fed by a 120-gallon flat bottom polyethylene tank containing 30% H_2O_2 . A 2-inch schedule 40 clear polyvinyl chloride (PVC) pipe was used as the supply line to the pump. The 2-inch PVC pipe transitioned to a 1-inch flare connection immediately prior to the pump inlet. A vacuum/pressure transducer was installed into a 1” flare union located at the pump inlet. This transducer was used to measure the pressure of the liquid at the pump inlet.

Figure 1. Test Apparatus



Exiting the pump, the 1-inch flare outlet transitioned to 1¼ inch schedule 80 clear PVC pipe. An externally mounted ultrasonic flow meter was installed on the 1¼ inch PVC pipe. The effluent was returned to the supply tank through high and low-flow flow meters. Throttle valves downstream of the flow meters and at the outlet of the supply tank were used to control the flow rate and inlet pressure to the pump. Table I provides details on the materials and instrumentation used in the test.

Table I. Test Apparatus Components

Component	**Manufacturer**	**Model Number**
Supply tank	Snyder Industries	5700000N-L
Pump inlet throttle valve	George Fischer	2” 546
High-flow throttle valve	George Fischer	1” 546
Low -low throttle valve	George Fischer	½” 546
High-flow flow meter	Blue-White Industries	F-451
Low-flow flow meter	Blue-White Indus	F-450N
Ultrasonic flow meter	Flexim	ADM 5107
Vacuum/Pressure transducer	Entegris	4150-100V-F03-D00-A-U1
Pressure transducer	E-Span	PP3-300
Heat Exchanger	Entegris	Phasor X
Temperature Sensor	George Fischer Signet	2350

Data from the ultrasonic flow meter, pressure transducers and thermocouple were collected using DasyLab Data Acquisition software. Data were collected every 0.5 seconds and averaged over 20 data points. The test was started on 2/22/2009 and concluded on 3/4/2009.

Test Procedure:

Two measurements were performed in this test. The first measurement, flow versus pressure, measured inlet and outlet pressures at 0, 10, 20, 40, 60, 80, 100, 120 liters per minute (LPM) and at maximum flow with the pump set at 4000, 5000, 6000, 7000 and 8000 RPM. This test was conducted at 18^{o}C and at 35^{o}C.

The second measurement, inlet restriction, measured the flow rate and outlet pressure while restricting the supply to the pump inlet. In this measurement, the flow rate was set at 40 LPM or 100 LPM with the pump inlet throttle valve fully open. The throttle valve was then closed to achieve an inlet pressure of approximately -1.5, -3 and -6 psig while measuring flow rate and outlet pressure. This test was also conducted at 18^{o}C and at 35^{o}C.

The test system was flushed four times with deionized (DI) water prior to beginning the test. The full test protocol was run at 18ºC in water prior to running in H_2O_2. Once the test was demonstrated in water, the system was drained and filled with 30% H_2O_2 supplied (MGC Pure Chemicals, Item Number 882446, Lot # M8M038MP, Expiration date – 12/31/2009). One drum of chemical was added to the system. The elevation of the tank and liquid level relative to the pump inlet provided a static head of 31.5 inches.

The first measurement was taken with the pump set at 4000 RPM. The flow out of the pump was stopped by closing the two throttle valves downstream of the flow meters. Data were collected for one minute. The flow was increased to 10 LPM by opening the low-flow throttle valve. After one minute, flow was increased to 20

LPM by opening the high-flow throttle valve. Data were collected for one minute. The procedure was repeated up to the maximum flow rate of the pump. The entire procedure was then repeated with a pump setting of 5000, 6000, 7000 and 8000 RPM. The heat exchanger was use as required to maintain the temperature of the test liquid at 18 ± 0.5ºC. The inlet restriction test was performed at the end of each flow test, prior to increasing the pump speed.

After completing the 18ºC test, the pump was set at 7500 RPM and a flow rate of 120 LPM. A space heater was installed in the cabinet to provide additional heating. Exhaust to the cabinet was restricted to minimize cooling from the outside room air. The combination of the heater and pump resulted in heating of the H_2O_2 to 35ºC in approximately 5 hours. Once this temperature was reached, the procedure described above was repeated.

Samples for determining the concentration of the H_2O_2 were taken at the beginning and end of the 18ºC test and at the end of the 35ºC test. Assay of each sample was determined by titration via end-point reduction analysis using potassium permanganate as the reducing agent and indicator.

Results:

The results of the flow versus pressure measurements tests are presented in Figure 2 through 4. The Y axis is the difference in pressure across the pump (outlet pressure minus inlet pressure). The X axis is the flow rate as measured by the ultrasonic flowmeter in the case of the water test or the rotometers in the case of the H_2O_2 test. The data from the ultrasonic flow meter was not used for the H_2O_2 as it had not been calibrated for use in H_2O_2. During the test, the actual pump speed, indicated on the pump controller, was monitored and compared to the pump set point. Flow data collected during times when the actual pump speed was lower than the set point are not presented. It can be seen that there was no significant change in the curves between all the test conditions (water, 18ºC H_2O_2 and 35ºC H_2O_2).

The effect of restricting the inlet of the pump is presented in Figure 5 and 6. These graphs presents the results for all pump speeds tested in H_2O_2 at 18ºC. Additional data for 18ºC water and 35ºC H_2O_2 are located in Appendix B. As expected, the flow rate dropped as the inlet was restricted (Figure 5). The -6 psig inlet pressure was low enough to induce bubble formation out of the pump. Even with bubbles evident, no loss in pump prime or pump performance was observed (Figure 6).

In order to better understand the effect of a restricted suction on the pump output, an additional test was run with 18ºC H_2O_2. The test was similar to the previously described inlet restriction test except that inlet was restricted to -6 psig with a pump speed setting of 7000 RPM and a flow rate of either 40 or 100 LPM. The flow rate was then adjusted over the test range without changing the inlet throttle valve or the pump speed. The results of this test are seen in Figures 7A and 7B. The pump output remained relatively constant down to an inlet pressure of -6 psi for the suction restriction set a 40 LPM and down to -4 psi for the suction restriction set at 100 LPM.

The concentration of the H_2O_2 during the test was determined to be 30.5% by weight and did not vary over the duration of the test.

Figure 2. BPS-4 Differential Pressure versus flow curve, 18ºC Water

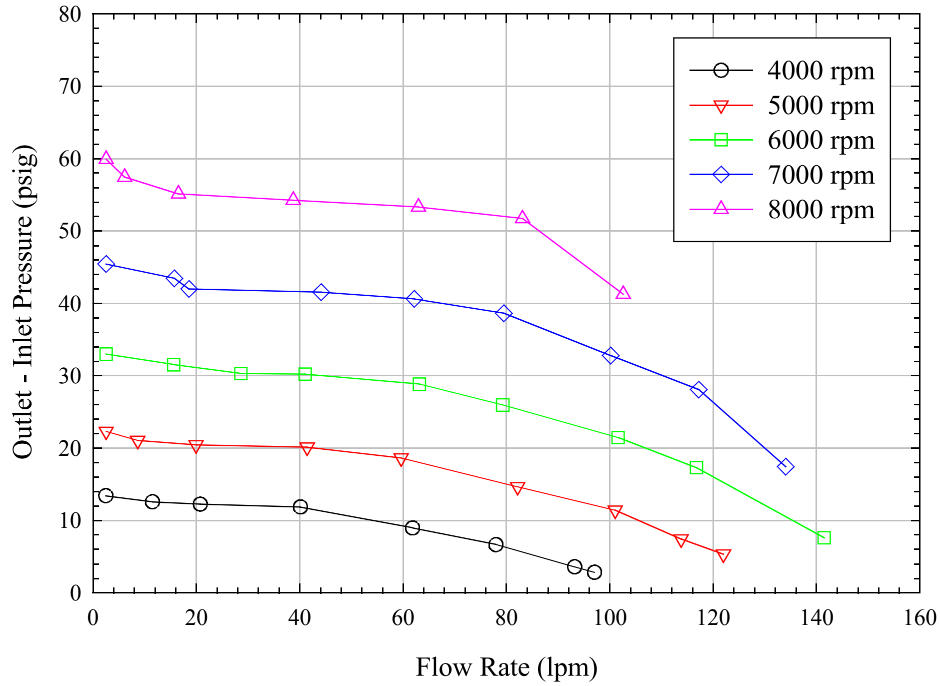


Figure 3. BPS-4 Differential Pressure versus flow curve, 18ºC 30% H_2O_2

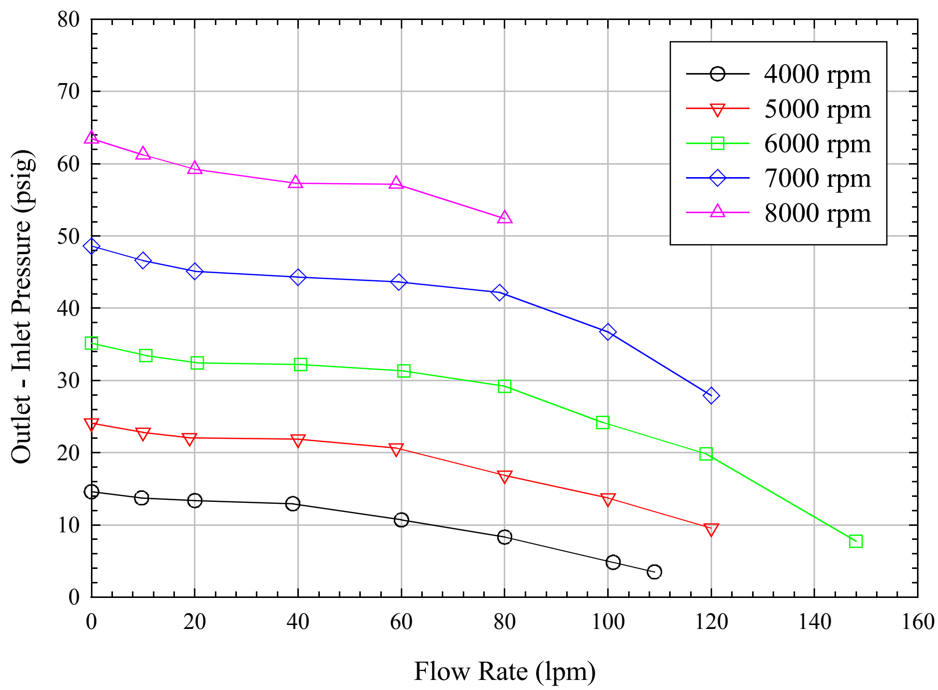


Figure 4. BPS-4 Differential Pressure versus flow curve, 35ºC 30% H_2O_2

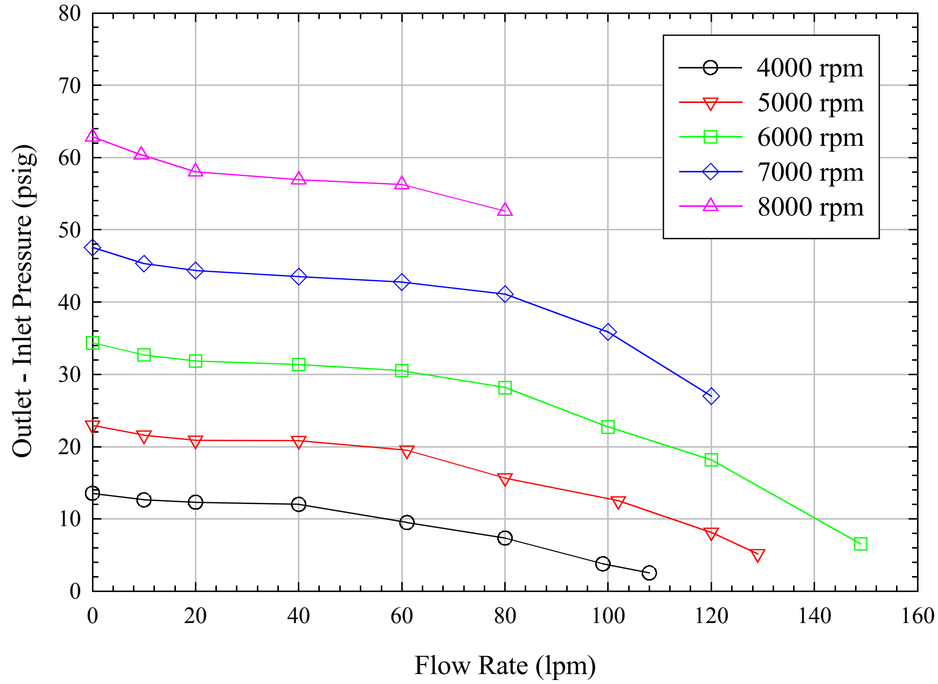


Figure 5. Effect of inlet restriction with initial flow of 100 LPM, 18ºC 30% H_2O_2 (Inlet pressure versus flow rate)

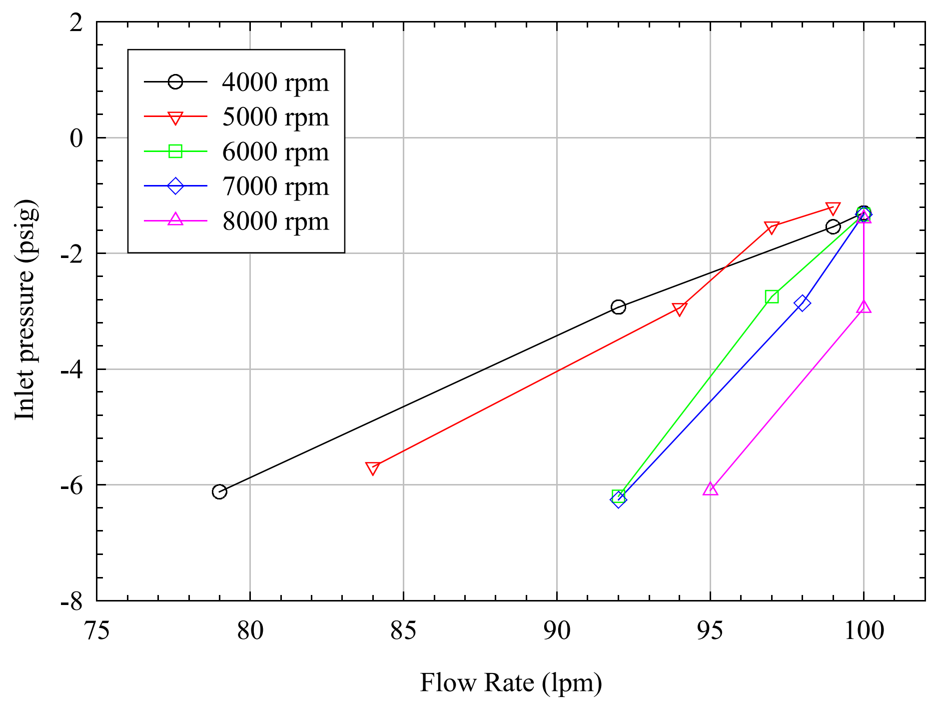


Figure 6 Effect of inlet restriction with initial flow of 100 LPM, 18ºC 30% H_2O_2 (Differential pressure versus inlet pressure)

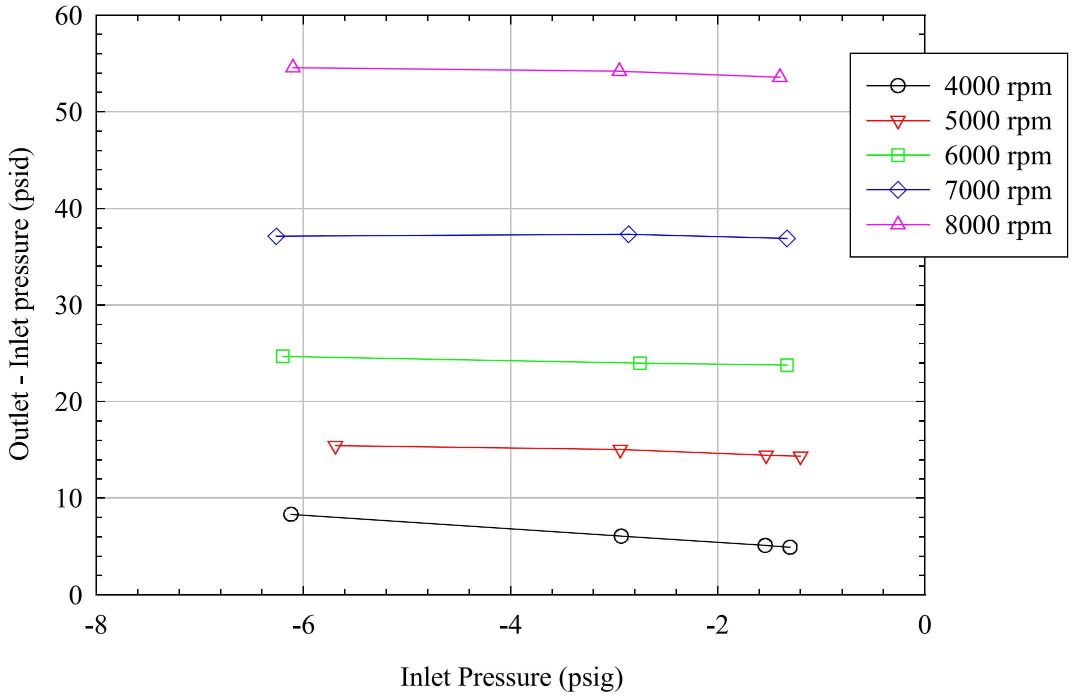


Figure 7A. Differential pressure versus flow rate with restricted suction, 18ºC 30% H_2O_2

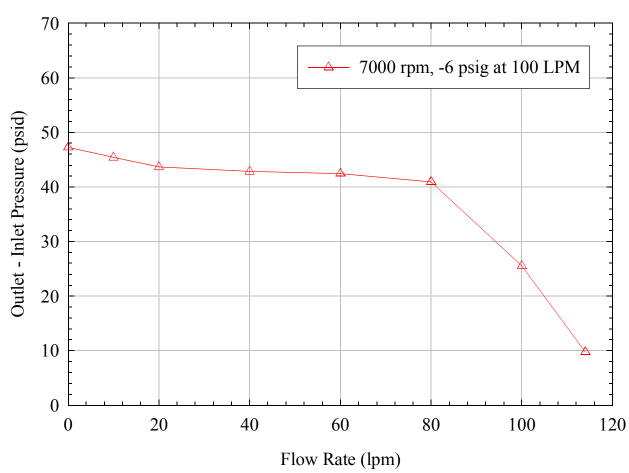
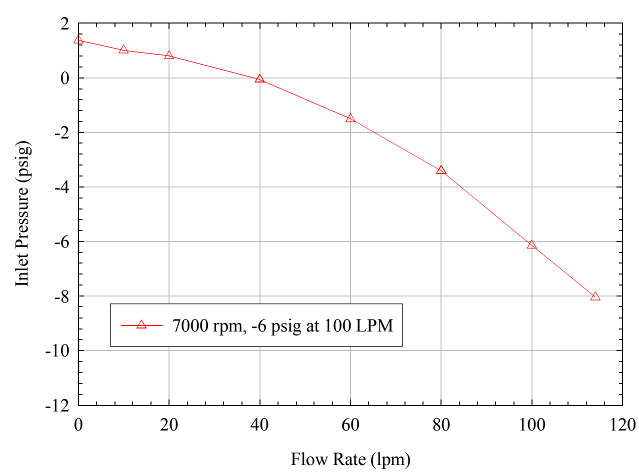


Figure 7B. Inlet pressure versus flow rate with restricted suction, 18ºC 30% H_2O_2



Additional observations:

Significant outgassing from the H_2O_2 was observed when the system was shutdown overnight and over a weekend. Gas collected in the supply line and could not fully clear while stagnant due to the transition from the 2-inch PCV to the 1-inch flare at the pump inlet (Figure 8). Starting the pump under these conditions was challenging. The pump speed during the startup needed to be high enough to draw a small portion of the trapped gas through the pump but not so high as to draw a large volume of gas in and create a vapor lock in the pump head. For this particular test configuration, it was determined that running at 2200 to 2500 rpm with no outlet restriction worked to clear the trapped inlet gas without vapor locking the pump. In a production application, a stand pipe coming up from a tee immediately prior to the 1-inch flare transition would allow gas to clear prior to entering the pump. This standpipe could be vented back to the supply tank or to exhaust. An alternative approach that would take less space would be to install a hydrophobic filter in the place of the standpipe. An appropriately selected hydrophobic membrane should allow gas to pass but not the chemical.

Small bubbles in the fluid were observed in both the 18ºC and 35ºC H_2O_2 test. The test conditions when bubbles were observed were pump speeds of 7000 and 8000 rpm and flow rates greater than 100 lpm. These conditions also result in a negative pressure at the inlet of the pump. The combination of the negative inlet pressure and high impeller speed may be causing outgassing of the H_2O_2 at this operating point. Bubbles were not observed during the DI water testing under any of the conditions.

Figure 8. Collection of gas in the supply line after prolonged shutdown

Summary:

A Levitronix BPS-4 magnetically levitated centrifugal pump was tested in water and 30% H_2O_2 under a simulated chemical delivery application. There was no significant effect on pump output running the pump with 30% H_2O_2 at room temperature or 35ºC as compared to water. Restricting the inlet does not effect the pump capacity when measured in terms of differential pressure (outlet minus inlet pressure). Operating the pump at less than 7000 rpm and a flow rate of less than 80 lpm with zero or slightly positive pressure at the inlet of pump appears to prevent the occurrence of bubbles in the H_2O_2 over the temperature range tested. Titration data generated during the test indicated that the H_2O_2 concentration remained unchanged, even with the observation of small bubbles at high operating points.

Outgassing from the H_2O_2 solution during a prolong shutdown can effect the startup of the pump if too much gas is drawn into the pump. Controlling the pump speed and flow rate during the startup or providing a vent at the inlet of the pump can mitigate this condition.

Appendix A. Photos of the Test Apparatus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Appendix B. Additional Graphs

Figure B-1. Pressure/flow curve, 18ºC water

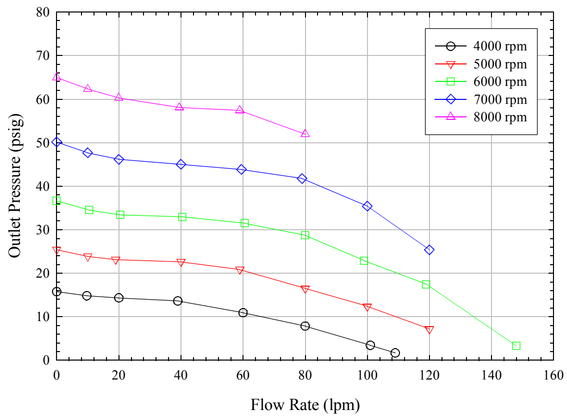

Figure B-2. Pressure/flow curve, 18ºC 30% H_2O_2

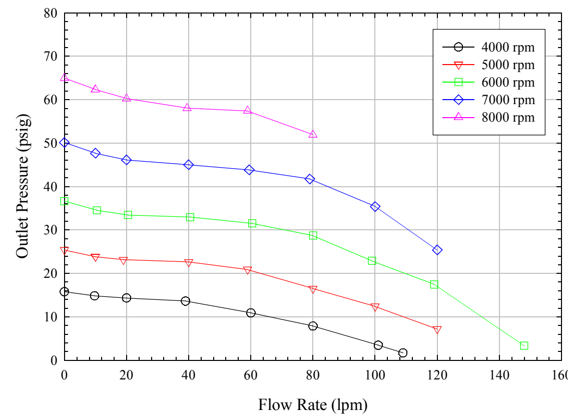

Figure B-3. Pressure/flow curve, 35ºC 30% H_2O_2

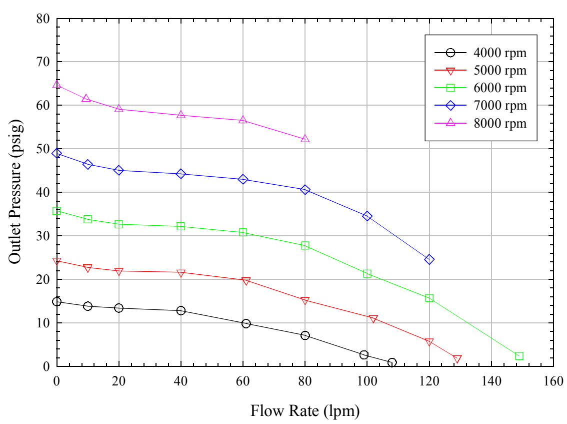

Figure B-4. Effect of inlet restriction with initial flow of 40 LPM, 18ºC 30% H_2O_2

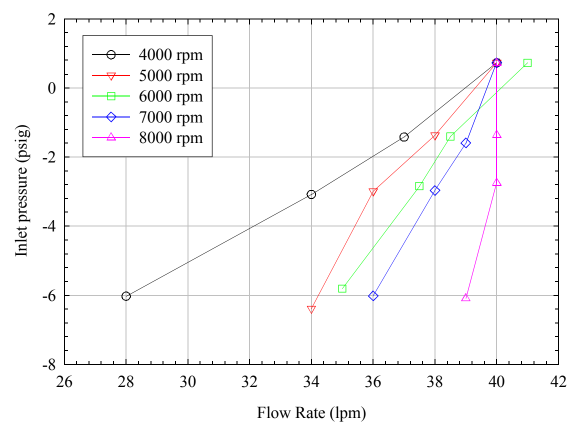

Figure B-5. Effect of inlet restriction with initial flow of 40 LPM, 35ºC 30% H_2O_2

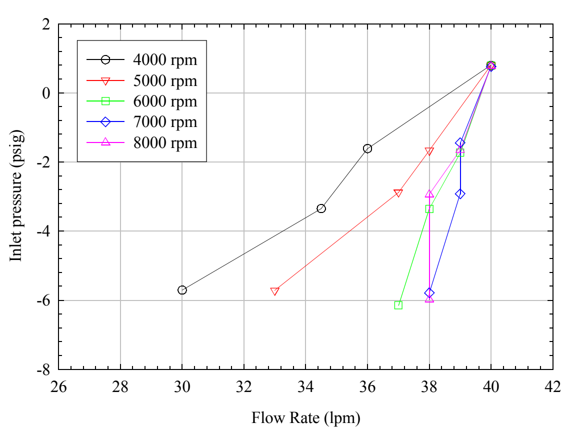

Figure B-6. Effect of inlet restriction with initial flow of 100 LPM, 35ºC 30% H_2O_2

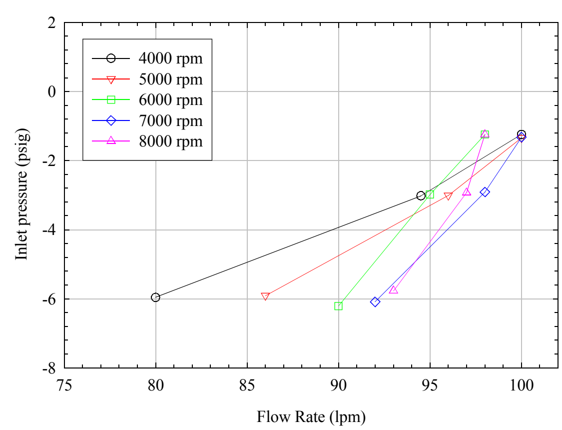

Figure B-7. Effect of inlet restriction with initial flow of 40 LPM, 18ºC 30% H_2O_2

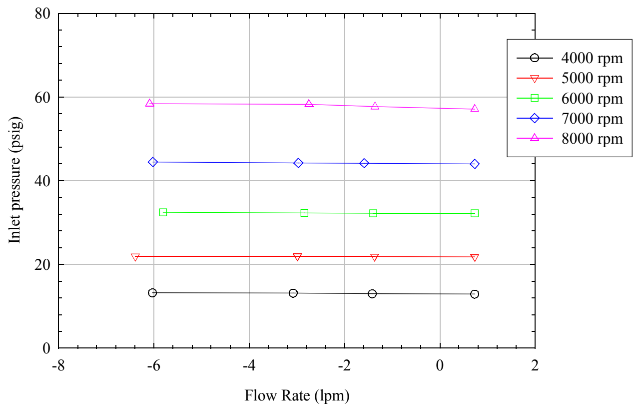

Figure B-8. Effect of inlet restriction with initial flow of 40 LPM, 35ºC 30% H_2O_2

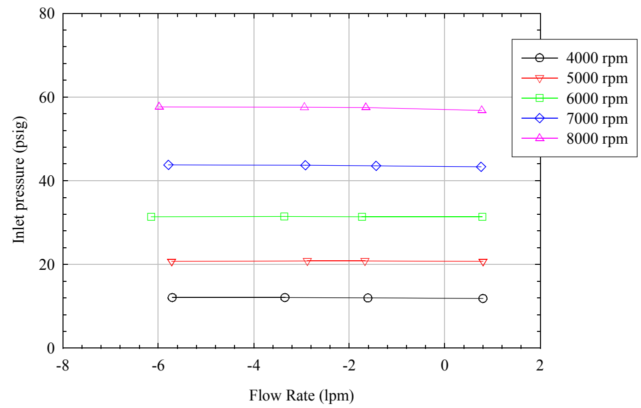

Figure B-8. Effect of inlet restriction with initial flow of 100 LPM, 35ºC 30% H_2O_2