Air Sampling Instrumentation Pump Performance Versus Altitude

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Background

Most portable air sampling systems contain small air pumps to draw in sample air. Our group, HARBOR, frequently flies instrumentation to high altitudes using 900 g – 1500 g weather balloons. One of instruments, currently under development, is aptly called the AtmoSniffer. This instrument is a multiple component system containing several chambers in which air flows across different sensors. It contains chambers for: a particulate sensor, a multi-gas sensor board, and lastly an end module containing the flowmeter and air pump. For this device to provide optimal performance it must have sufficient air flow through the system at any altitude.

Problem

Our problem to solve was to evaluate the performance of various pumps at different pressures correlating to different simulated altitudes. We would like to know how the pump flow rates and power draw across the pump changes with altitude.

Method

Four different pumps were tested in the lab: Furgut DC06/21FK-rotary vane pump, Furgut DC06/08/20F-rotary vane pump, Furgut 8891-diaphragm pump, and ozonesonde-piston pump. These pumps were tested at ambient pressure (~850 mb) and in a high-altitude environmental test chamber. The pumps were controlled with pulse width modulation (PWM) while monitoring the flow rate in standard liters per minute. Measurements were made with and without an air sample chamber attached inline to simulate a load. We also measured flow stability vs. pressure.
Target pressures for measurements were 856 mb (1.4 km, Ogden, UT), 700 mb (3 km, top of the Wasatch Front mountains), 150 mb (13.5 km, tropopause), 30 mb (24 km, inside the ozone layer), and 10 mb (31 km, typical max height of research balloons).

Data

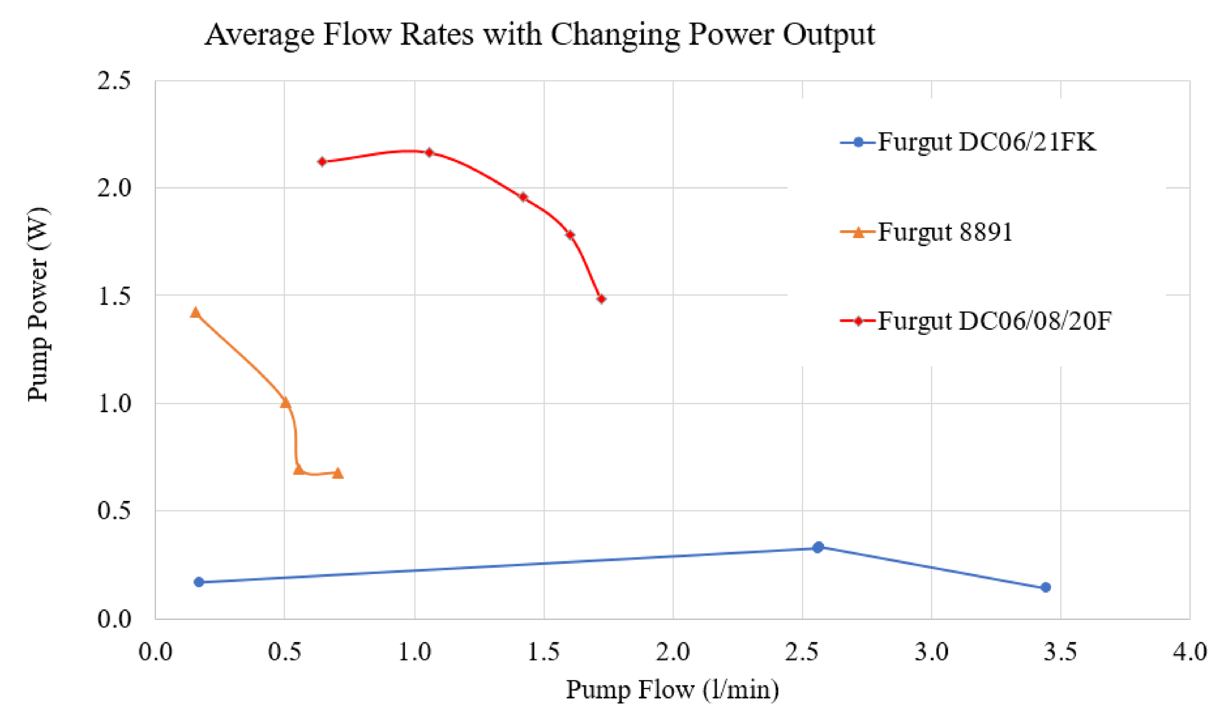


Figure 1. Flow output of each pump and corresponding power usages at 835mbar using an 8V power Supply. The Furgut DC06/21FK is significantly more efficient as it generates the most flow while using the least amount of power. The Furgut DC06/08/20F produces flow but also consumes five to ten times as much power. The Furgut 8891 pump produced little flow while using a relatively high amount of power.

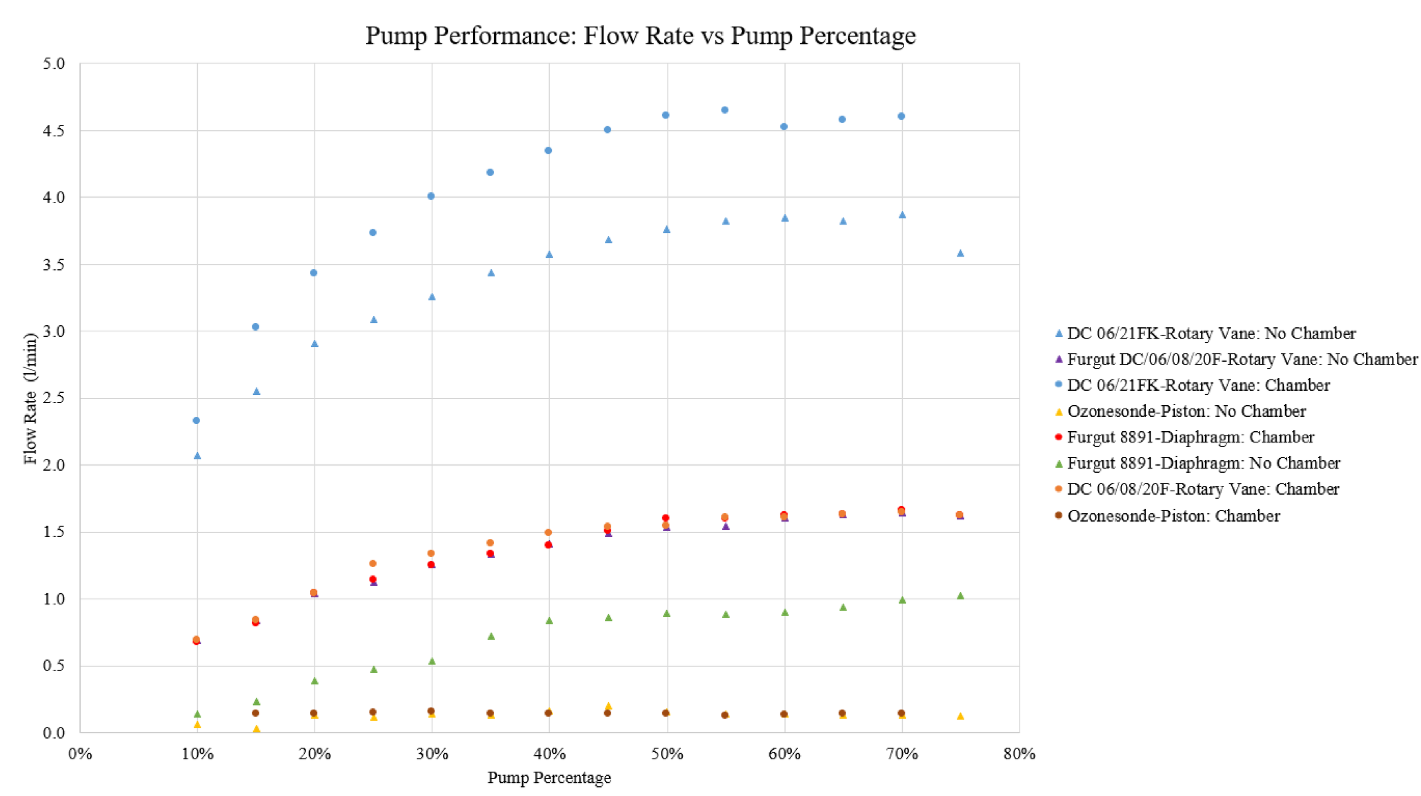


Figure 2. Preliminary measurements of four pumps at various pump speeds ranging from 10% to 80% of their total potential flow. The Furgut 8891 showed the greatest response to additional flow rate while the ozonesonde pump showed effectively no response to the changing percentage speeds. A comparison was also made using an empty air chamber connected to the flowmeter which yielded better responses from the pumps.

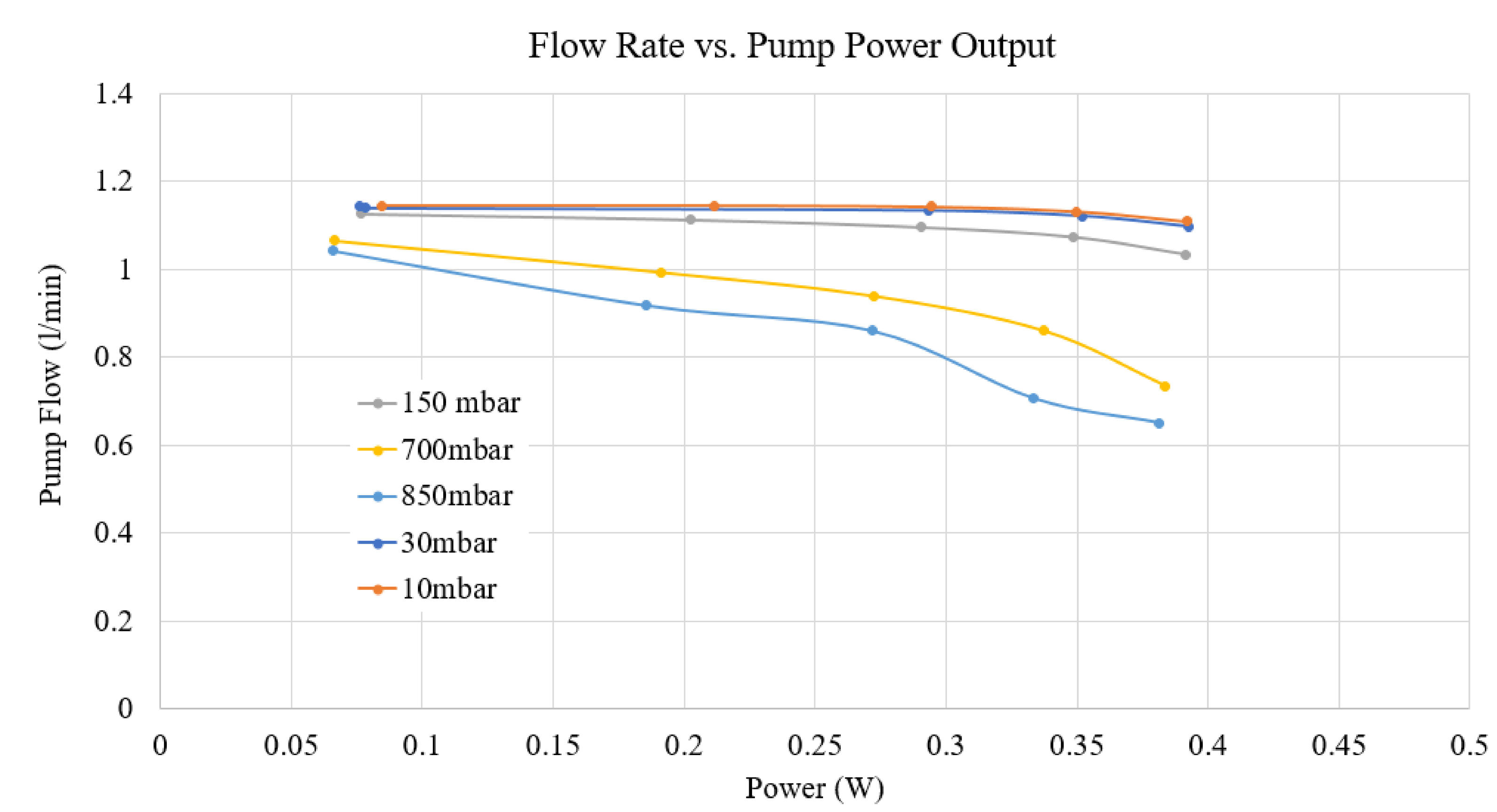


Figure 3. The flow rate and power usage of the Furgut DC06/21FK at various pressures using a 7.4V battery for power supply. The pump becomes more efficient as it approaches ambient pressure. At the highest simulated altitudes, 10 mbar and 30 mbar, the pump actually looses efficiency with increased power consumption. We'll be comparing this to other test pumps to see if this counter-intuitive result is repeatable.

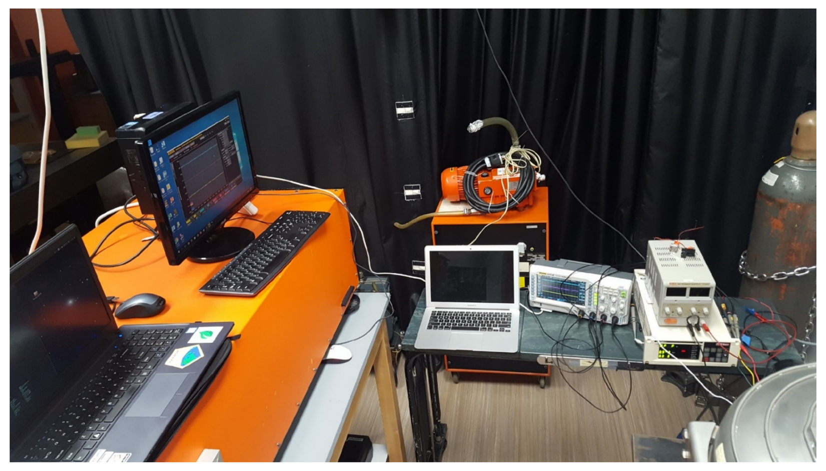
Vacuum Chamber Set Up

Our set up required the use of several components. We used an environmental vacuum chamber and a RIGOL DS1504Z oscilloscope. We communicated with our system through a Bluetooth connection. We set up our complete component assembly inside the environmental vacuum chamber. We connected voltage probes at four reference points on our circuit. The voltage signal was sent to an electrical feedthrough to the outside of the chamber. Oscilloscope probes were then attached to the corresponding pins giving us our reference signals on the oscilloscope display. We then used RIGOL oscilloscope software to capture and export our data into Excel.

Set up of environmental vacuum chamber system.

Oscilloscope readings of test voltages with pulse width modulation and the resulting surges in air flow. Surges happen anyway because of the pump vanes, but the PWM adds an additional small surge in flow.

Team Photo in the lab.



Set up for data collection.

Discussion

Upon initially testing four different pumps at various power outputs, the Furgut DC06/21FK was seen to have the most flow output and the Ozonesonde pump had no observable flow output. For this reason, the Ozonesonde pump was taken out of the subsequent tests.

After comparing flow output values compared to power draw from the pump, it can be seen that the Furgut DC06/21FK is by far the most efficient pump by using less than 0.5W while outputting >3.5 liters/ minute. The Furgut DC608 uses the most amount of power on average and outputs a maximum of 1.7 liters/minute. The Furgut 8891 at it's highest speed outputs no more than 0.7 liters/minute.

Conclusions

Our results showed us that the Furgut DC06/21FK produced the greatest flow with the least amount of power draw at atmospheric pressure. The Furgut 8891 showed the greatest response to varying pump speed but overall showed the least amount of flow to power efficiency ratio.

Next Steps

We will continue testing pumps in the high-altitude simulation chamber. We especially want to include more pumps in our testing processes. Due to time limitations we were not able to test all of our available pumps at other than ambient pressures except the pump reported here. With more data for a variety of pumps we will be able to select our optimal pump. Lastly, we will then have a sound method for evaluating any desired pump's performance for future systems.

Acknowledgements

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