Air sampling pump performance versus altitude

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Introduction & Background

While not as exciting as sensor physics, it is important to get the air we want to study into the instrument. If the instrument is designed for flight as a sonde then the pump must be energy efficient, be lightweight, and actually pump air when the pressure is very low. The pump must move air faster than the response time of the sensors but not so fast as to cool those sensors that have internal heater elements.

Our application is a custom air sensor we call the AtmoSniffer. It has a gas chamber with a selection of gas sensors on a printed circuit board inside the chamber. The typical response time of electrochemical cell (EC) sensors is about a minute while metal oxide (MOx) sensors typically respond to 90% of the target in about 10 seconds.

The AtmoSniffer's gas chamber is 427 cc, which is a large volume compared to a standard ozonesonde with a chamber (the electrochemical cell) that is only 6 cc. With a target flow rate of 2.0 standard liters per minute, a 427-cc chamber will exchange its contents every 13 seconds. That's a good speed for the EC sensors, but a bit slow for the MOx.

The Test Chamber & Pumps

A vacuum chamber with multiple, independent pressure gauges and electrical feedthroughs was used to hold a stable "ambient" pressure. The pump under test was connected to a power supply while the current and motor voltage was measured to obtain power consumption. The pump was connected to a Honeywell AWM5101VN flow meter that had been tested previously at low pressures both inside this vacuum chamber and in flight to the mid stratosphere.

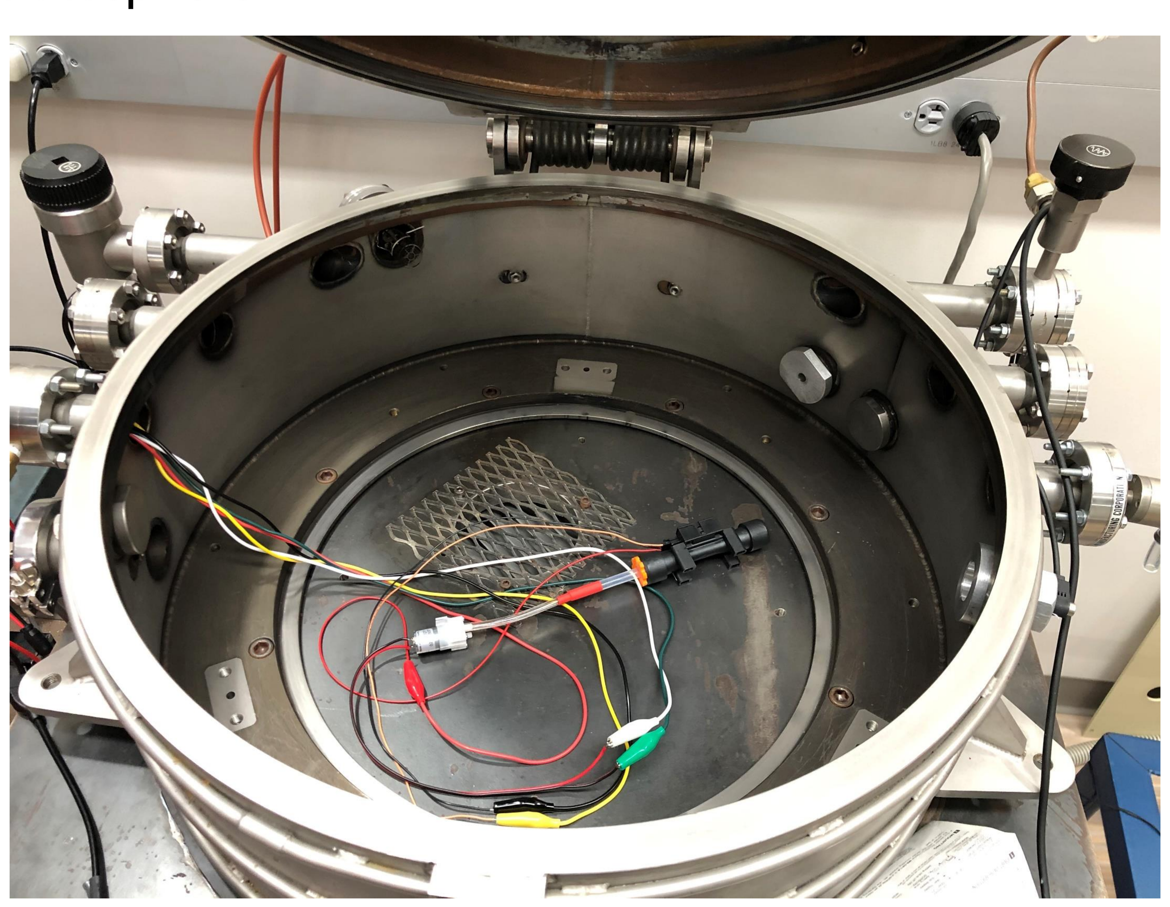


Figure 1. The test chamber with a Thomas pump and the flow meter inside. The flow meter has been independently tested against a tapered tube flow meter at multiple pressures above 500 mb. At lower ambient pressures to about 3 mb the calibration is harder but appears to be consistent with leak valve tests for comparison.

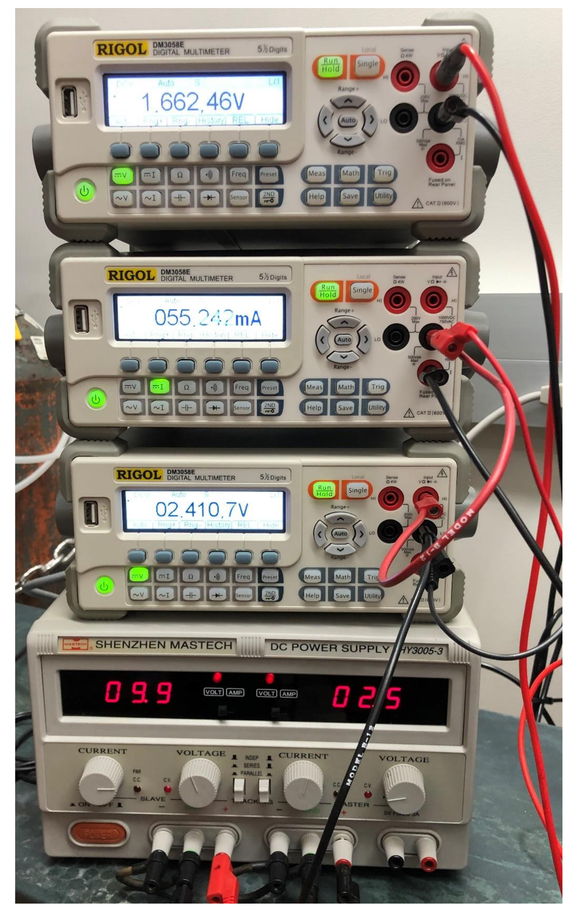
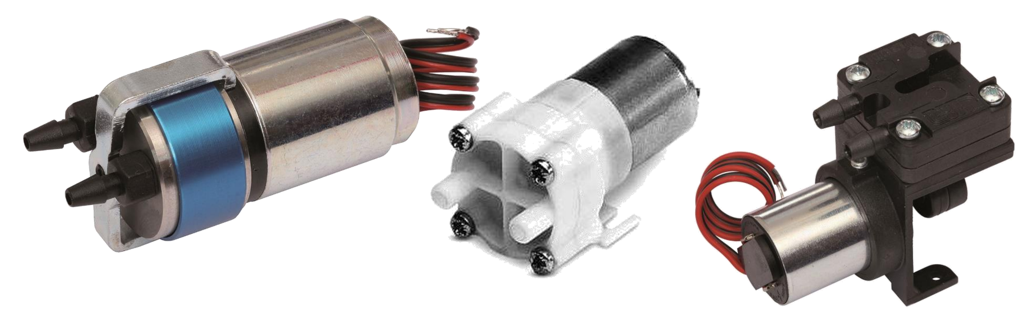


Figure 2. Recently calibrated six-digit bench meters were used to measure (top-to-bottom) flow meter signal voltage, pump current, and pump voltage across the motor. The power supply at the bottom provided a stable 9.9 V to the flow sensor supply input and the right side was used to power the pump motor.

Table I: The pumps under test. Our standard pump that we have flown multiple times is the DC06-F/31 Furgut rotary vane pump. The pumps are shown left to right in the order they appear top-to-bottom in the table.

Manufacturer, Design	Model	Price	Weight (g)
Furgut, Vane	DC06-F/31	$198	98
Thomas, Vane	G01-K	$60	30
Furgut, Diaphragm	FM1101-F6V	$125	37



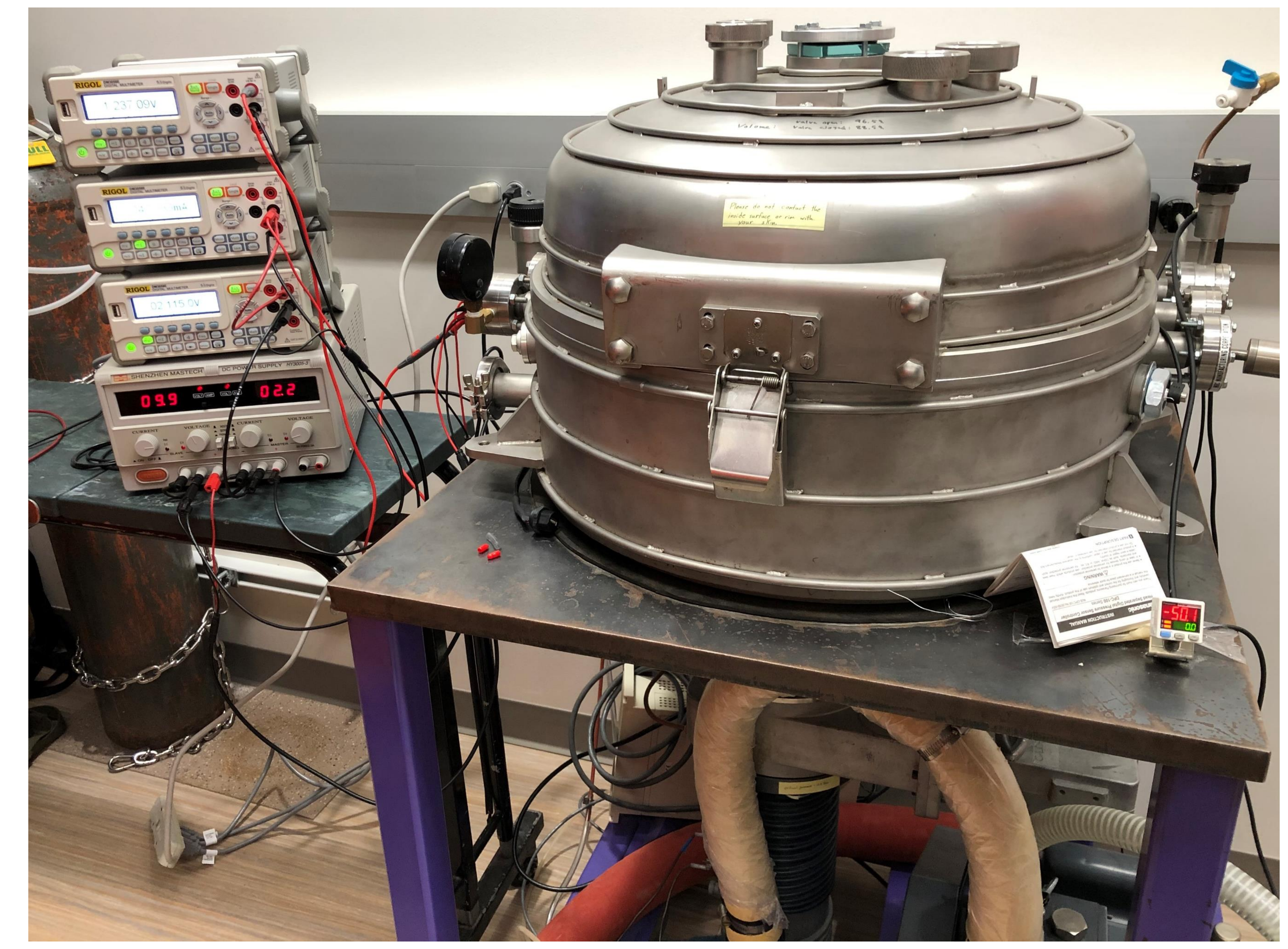


Figure 3. The entire test assembly with a pump inside under test. The vacuum pressure is measured with three independent gauges that are in agreement where their ranges overlap. (A dial gauge, solid state gauge, and thermocouple gauge.)

Data

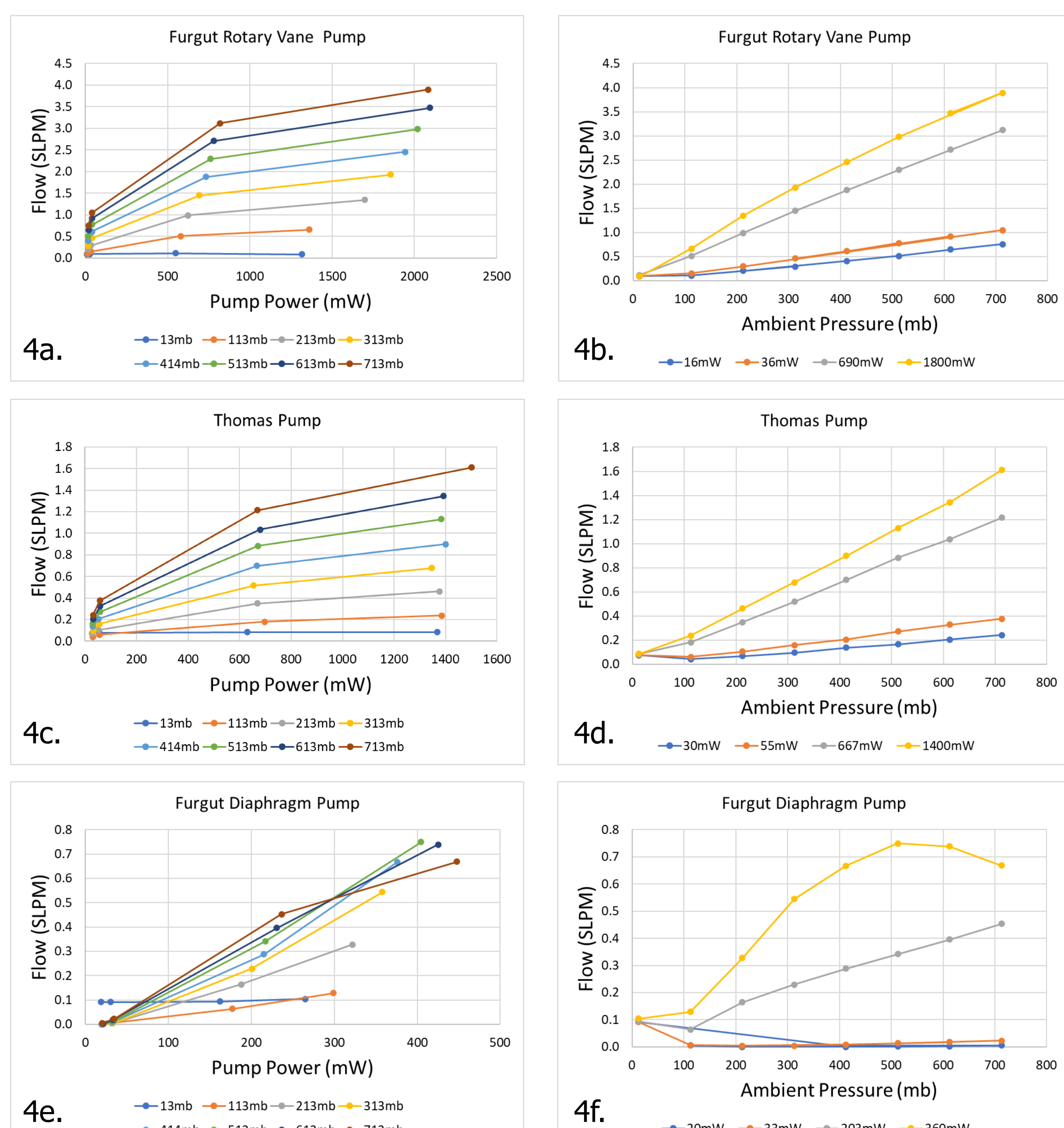


Figure 4. The three pumps we have tested so far in the same order as Table I. For the AtmoSniffer we need 2.0 SLPM, clearly only the expensive and heavy Furgut rotary vane pump is going to have a chance.

Results & Discussion

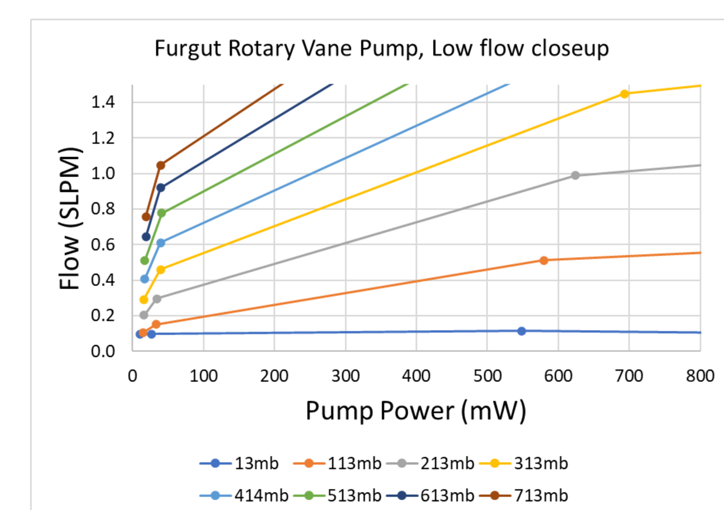


Figure 5. Close up of the low power region of Figure 4a.

1. Rotary vane pumps are more predicable than the diaphragm pump that we happened to test. This is consistent with earlier pump tests done in this chamber.
2. Increasing power does not increase pump flow in the same proportion. Using the lowest power to get the job done is the best option.
3. Looking at the right column of plots in Figure 4 shows a curious performance change below about 200 mb. This also shows up in other data not shown here.

Conclusions

For low flow demand applications there are multiple pumps available for air sensing equipment. Higher pump flow rates at higher altitudes will require testing to make sure it will work for your application. Most manufacturer datasheets do not specify flow rates at altitudes above typical ground elevations.

For ambient pressures below 200 mb pump behavior is unpredictable without testing.

Acknowledgements

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