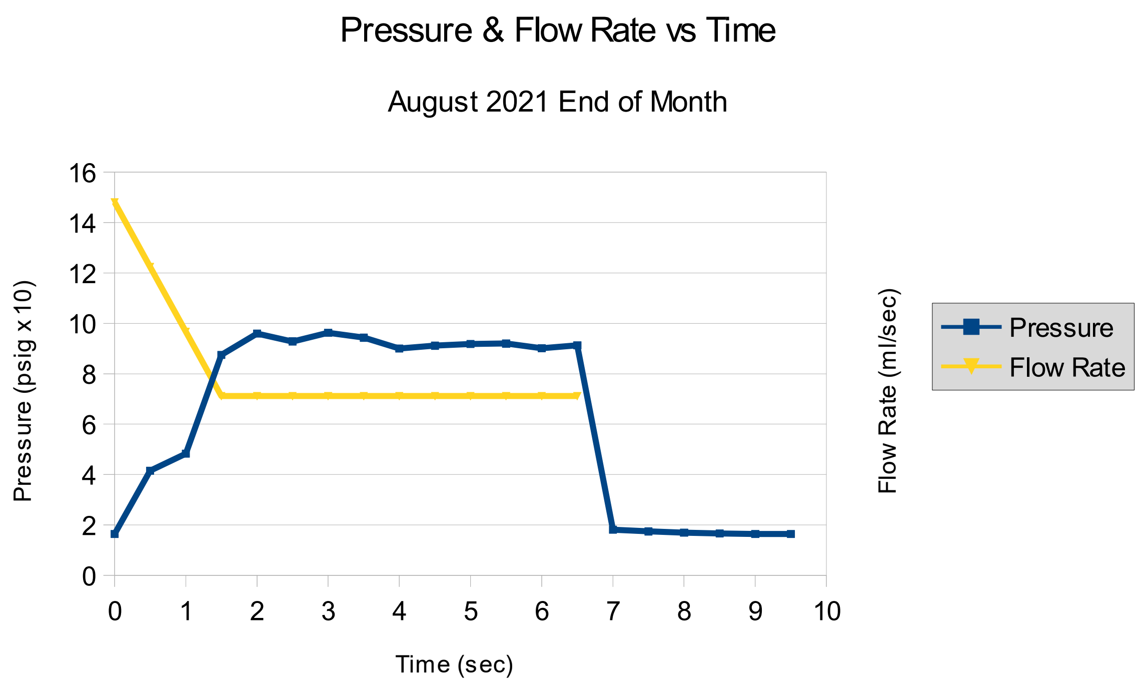
**Executive Summary**

Of the last five test in August 2021, the test on August 24 was the best. I increased the throat diameter to 5 mm, decreased the characteristic length to 33 in, increased the oxidizer tank pressure to 130 psig, increased the length of the fuel core to 16.5 cm, and added a pressure probe to the mixing chamber. Ignition occurred in 1.5 to 2.0 sec. The chamber pressure rose to ~93 psig in 2.0 sec and was steady throughout the ignition. Burn time was ~5 sec. The video shows a net positive thrust greater than 14 N (3.2 lb) at ignition and held throughout the burn time. Shut down was instantaneous. The oxidizer to fuel ratio was ~2.3 and total mass flow rate was ~13.4 gm/sec resulting in a characteristic velocity of 1,163 m/sec with a c* efficiency of ~77%. I still plan on launching a class I HTPE hybrid before the end of the year. Next month I'll lock down the thrust and begin building the flight system.




**Technical Stuff**

By experiment, I determined that the flow rate of water through the 1/4" stainless steel mist nozzle with a 1.0 mm orifice at 130 psig was 14.8 ml/sec. As such, I used 14.8 ml/sec as the flow rate of HTPE at t = 0. I surmised that the flow rate decreased linearly as the pressure increased. The total area under the flow rate curve is 52 ml, the volume of HTPE (50 ml of 85% HTP plus 2 ml of Ethanol) in the oxidizer tank. Therefore,

$$r_1 + r_2 = 14.8 \text{ ml/sec}$$

$$1/2\,(t_1)(r_1) + (t_2)(r_2) = 52 \text{ ml}$$

where $t_1$ = 1.5 sec and $t_2$ = 6.5 sec. Solving gives $r_2$ = 7.1 ml/sec. At an O/F ratio of 25, the ethanol flow rate was 0.28 ml/sec and the HTP flow rate was 6.83 ml/sec. At room temperature, the density of ethanol is 0.789 gm/ml and the density of 85% HTP is 1.37 gm/ml. As such, the mass flow rate of 85% HTP was 9.36 gm/sec and the mass flow rate of the ethanol was 0.22 gm/sec.

I measured the mass of the PLA/$KMnO_4$ before and after the test and the difference was 19.3 gm. From my previous experiments, I know that the PLA/$KMnO_4$ does not begin to erode until ignition. The total ignition time was ~5.0 sec. Assuming a uniform burn rate, the mass flow rate of the PLA/$KMnO_4$ was ~3.86 gm/sec. All together, the oxidizer mass flow rate was 9.36 gm/sec and the fuel flow rate was 4.08 gm/sec. This results in an O/F ratio of 2.3, close to theoretical of 2.5.

The total mass flow rate was 13.44 gm/sec. With a chamber pressure of ~108 psia (~93.3 psig) and a throat area of ~0.21 $cm^2$, the characteristic velocity was 1,163 m/sec with a respectical c* efficiency of ~77%.

As shown in the video, there was a net positive thrust, a steady burn, and a rapid shutdown. The mass of the system (rocket engine, propellant tank, plumbing, test frame, and propellant) was 1.45 kg giving a thrust of greater than 14 N (3.2 lb). Next month, I'll be repeating the test using this configuration and pinning down the thrust by placing additional mass on the rocket. If the O/F ratio holds, I can increase the volume of HTPE used to 55 ml. With 5 more ml to burn, I can get another second of thrust and still stay under the FAA regulation of 100 gm of propellants. Also, in September, I'll begin to design the flight system for a class I HTPE Hybrid rocket. I plan to launch a class I hybrid before the end of the year.