Reaction Control System for High Altitude Balloons

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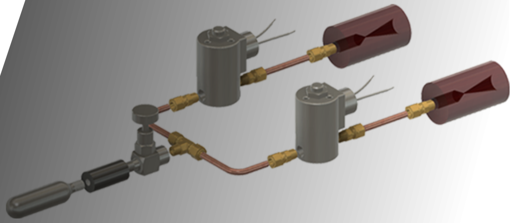


Nozzles

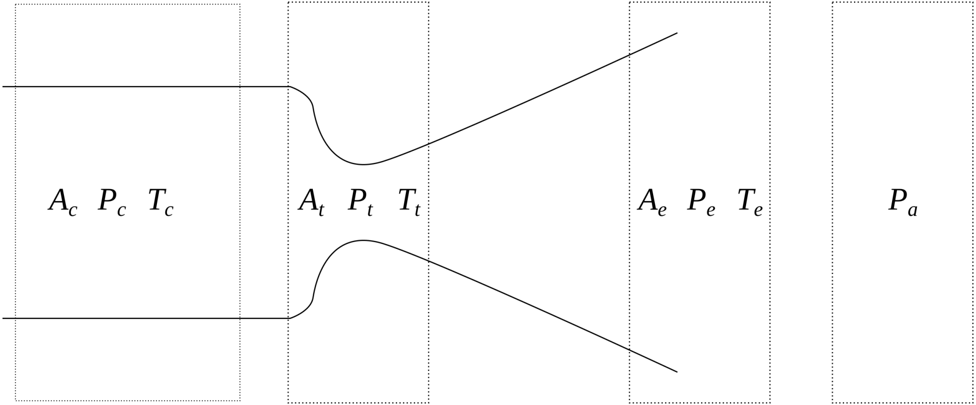


Figure: Basic nozzle design and some parameters.

Existing Nozzle Theory

$$\frac{A_e}{A_t} = \left(\frac{\gamma+1}{2}\right)^{\frac{1}{1-\gamma}} \left(\frac{P_a}{P_c}\right)^{\frac{1}{\gamma}} \left(\left(\frac{\gamma+1}{\gamma-1}\right)\left[1-\left(\frac{P_c}{P_a}\right)^{\frac{\gamma-1}{\gamma}}\right]\right)^{-\frac{1}{2}} \tag{1}$$

Optimum expansion ratio for nozzle

Nozzle Design

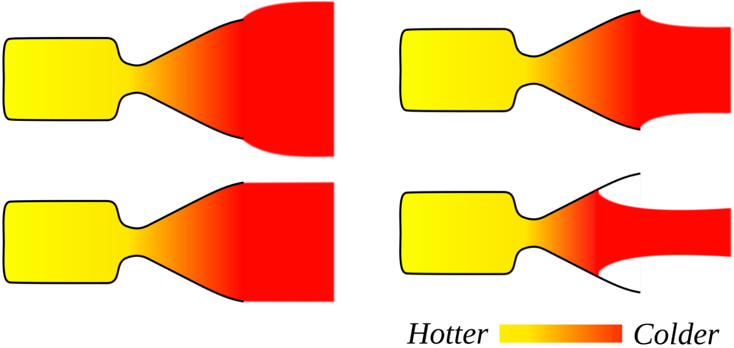


Figure: Nozzle expansion and temperature gradient visualized.

Specific Impulse

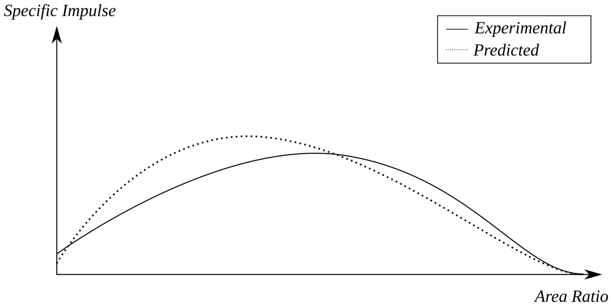
Definition of specific impulse:

$$I_{sp} = \frac{Thrust}{rate\ of\ mass\ ejection} \tag{2}$$

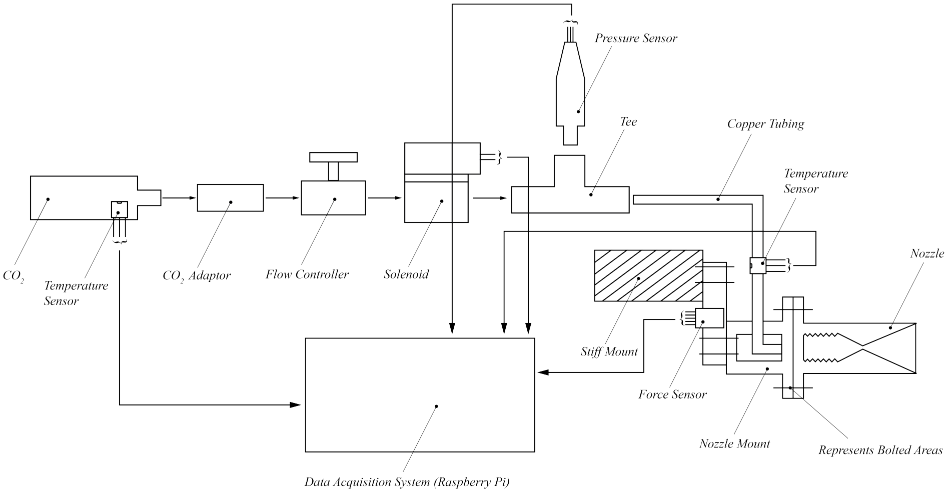
$$I_{sp} = \left(\frac{2\gamma G T_c}{(\gamma - 1)W} \left(1 - \left(\frac{T_e}{T_c}\right)\right)^{\frac{1}{2}} \right) + \frac{A_e}{A_t} \left(\left(\frac{T_e}{T_c}\right)^{\frac{\gamma}{\gamma-1}} \right) \sqrt{\frac{P_c}{\gamma \rho_c}} \left(\frac{\gamma + 1}{2}\right)^{\frac{\gamma+1}{2(\gamma-1)}} \tag{3}$$

Derived specific impulse

Develop an Experiment



Develop an Experiment



Manufacturing

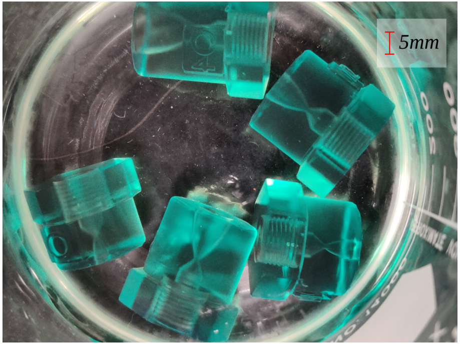
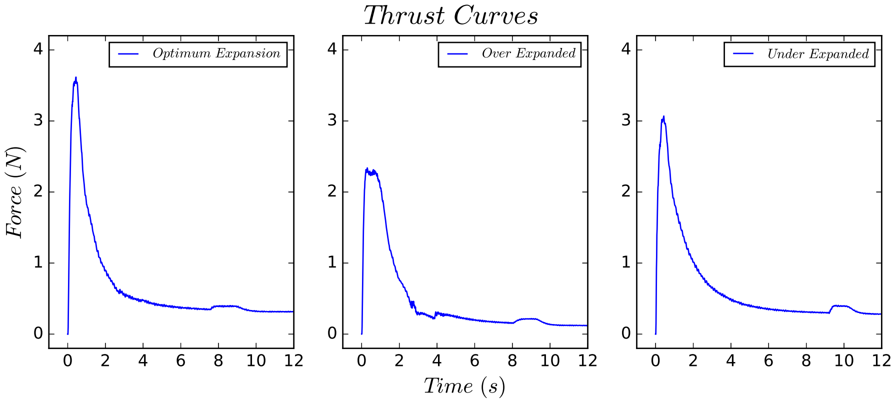


Figure: Nozzles bathing in isopropyl alcohol.

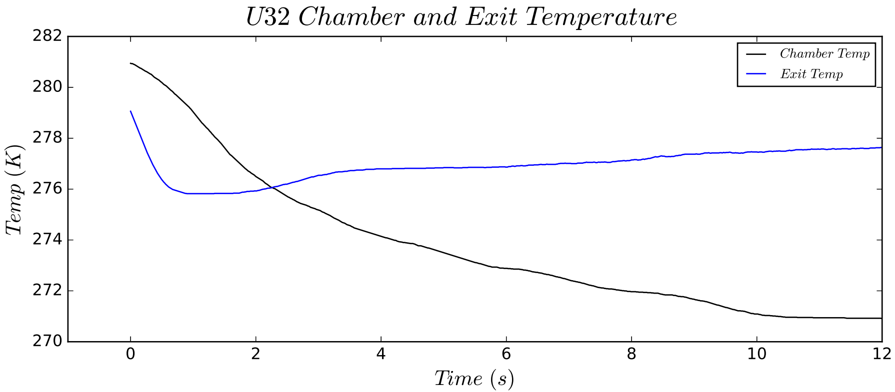
Data Collection



Analysis

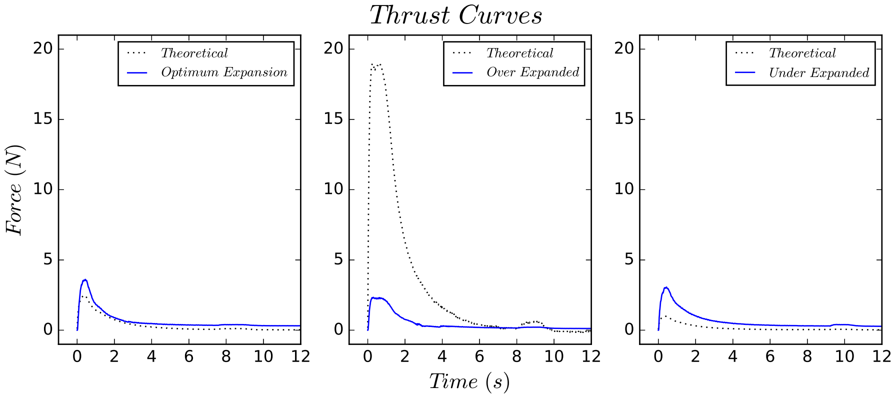
$$F = A_t P_c \left(\sqrt{\frac{2\gamma^2}{\gamma - 1} \left(\frac{2}{\gamma + 1} \right)^{\frac{\gamma+1}{\gamma-1}} \left(1 - \frac{T_e}{T_c} \right)} + \left(\left(\frac{T_e}{T_c} \right)^{\frac{\gamma}{\gamma-1}} - \frac{P_a}{P_c} \right) \frac{A_e}{A_t} \right) \tag{4}$$

Analysis



U32 Chamber and Exit Temperature
Chamber Temp
Exit Temp
Temp (K)
282
280
278
276
274
272
270
0
2
4
6
8
10
12
Time (s)

Analysis



Thrust Curves
Force (N)
Time (s)
Theoretical
Optimum Expansion
Theoretical
Over Expanded
Theoretical
Under Expanded
0
5
10
15
20
0
2
4
6
8
10
12

Solutions

- Placing thermocouples in better locations
- Measure change in mass over time

Payload Integration

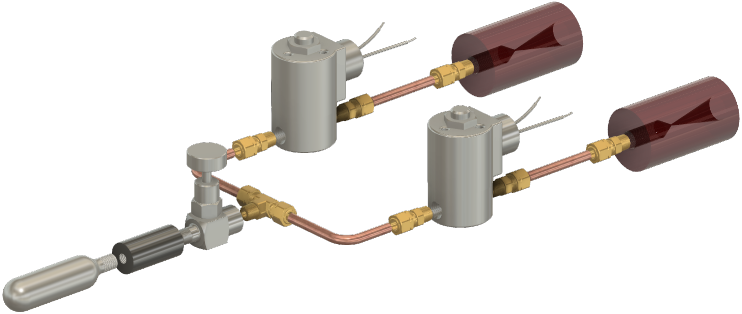


Figure: CAD Render of the plumbing system for my RCS.

Conclusion

1. Missing some information to complete characterization of the CGT
2. Solid foundation for future work
3. Integration into HABP
4. Flight on board a HAB

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