Hotfire 4.1

Propulsion Subteam - McGill Rocket Team

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Abstract

Hotfire 4.1 aimed to test the MRT's first ever parabolic bell nozzle, as well as composite pre and post-combustion chamber spacers. The injector was the same as used in HF3.4 (Thorondor flight injector), the liner was the same as usual (paper phenolic), and the fuel was spincasted.

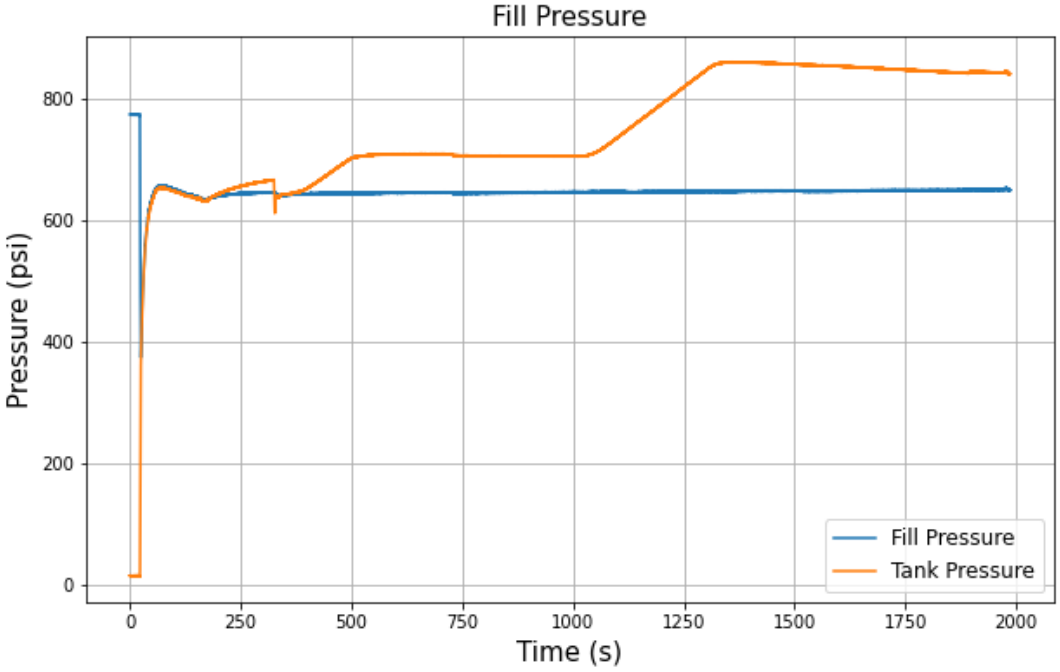
Table 1: Summary Results

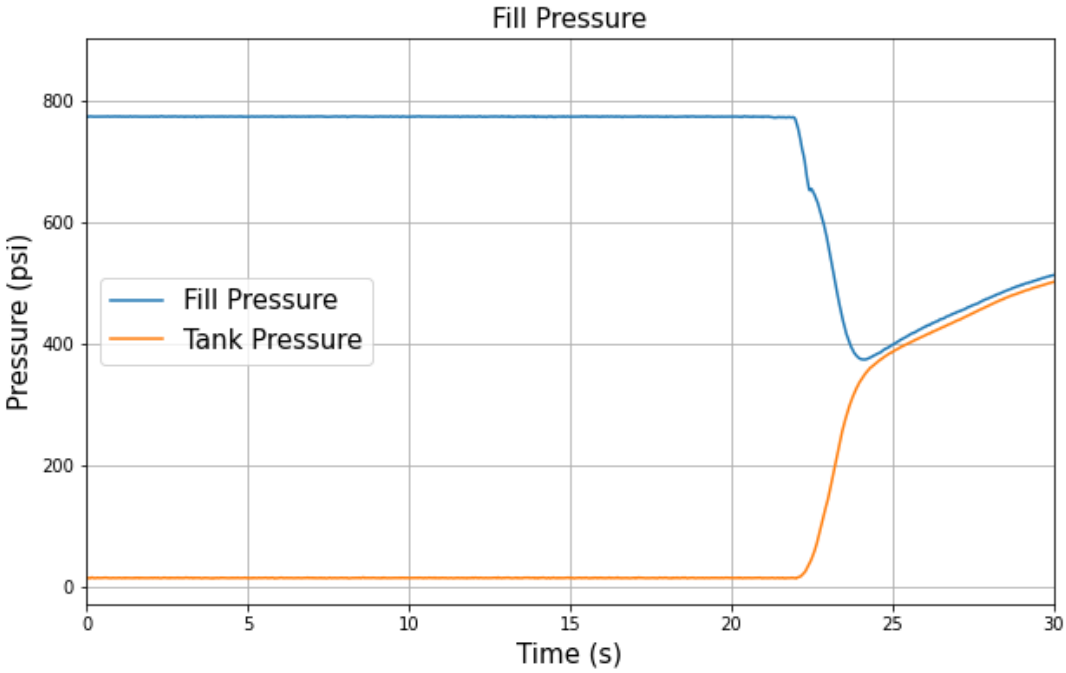
Variable	**Value**	**Unit**
Ambient Temperature	20	C
Run Tank Volume	15.33	L
Ullage Factor (estimate)	43.49	%
Fuel Mass	1.439	kg
Fill Time	1986	s
Peak Tank Pressure	840.3	psi
Peak Casing Temperature	224	C
Peak Run Pressure	596.9	psi
Peak CC Pressure	672.3	psi
Injector Holes	22	
Injector Hole Diameter	2	mm
Peak Mass Flow Rate (estimated)	1.459	kg/s
Average Mass Flow Rate (estimated)	0.951	kg/s
Burn Time	20	s
Peak Thrust	1,355.761	N
Total Impulse	12,414	Ns
Specific Impulse (nozzle estimate)	41.5	s

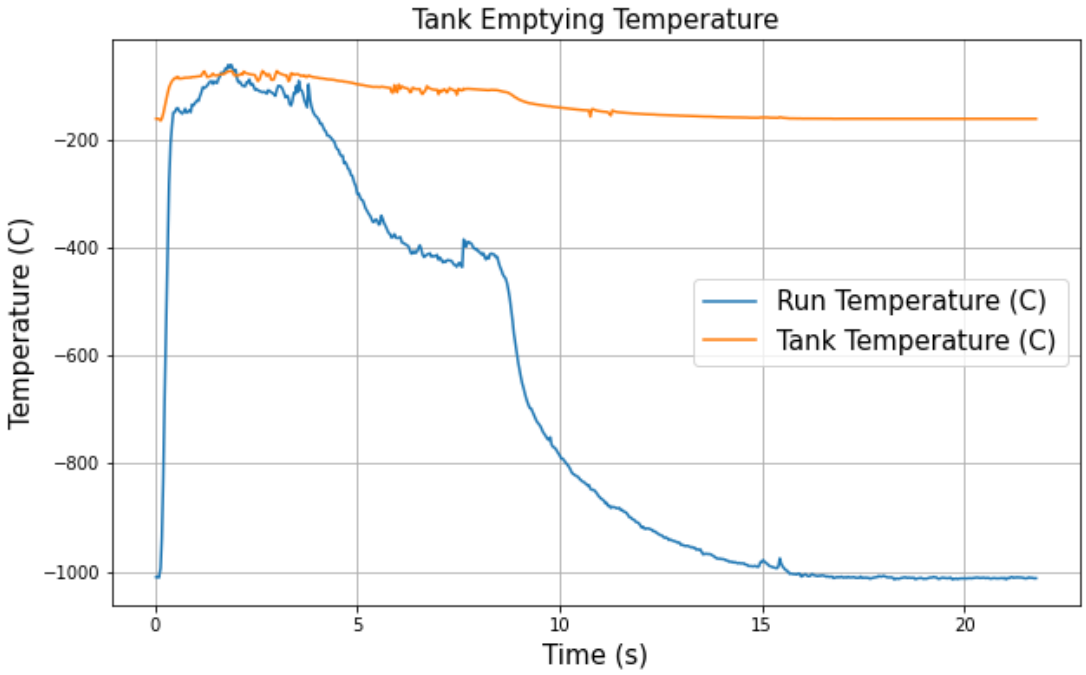
Table 2: Nitrous Mass Estimates

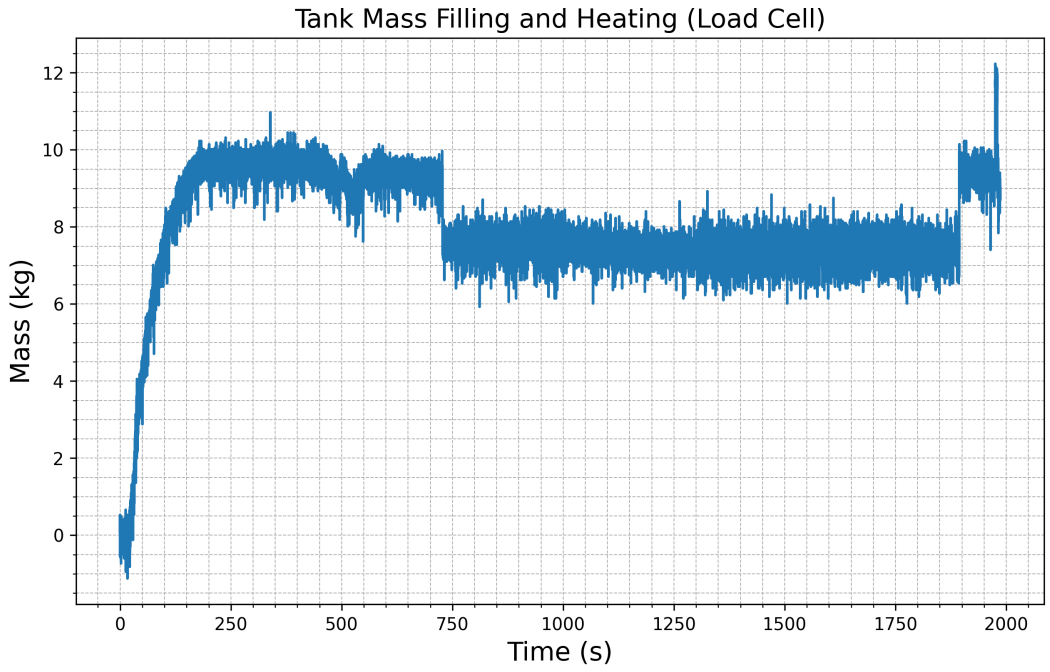
Variable	**Value**	**Unit**
Load Cell (end of fill)	9.5	kg
Integrated Mass Flow Rate Fit	9.395	kg
Liquid Mass (estimate)	9.35	kg
Gas Mass (estimate)	0.15	kg
Mean Mass	9.45	kg
Standard Deviation	0.0741	kg
Standard Error	0.0524	kg

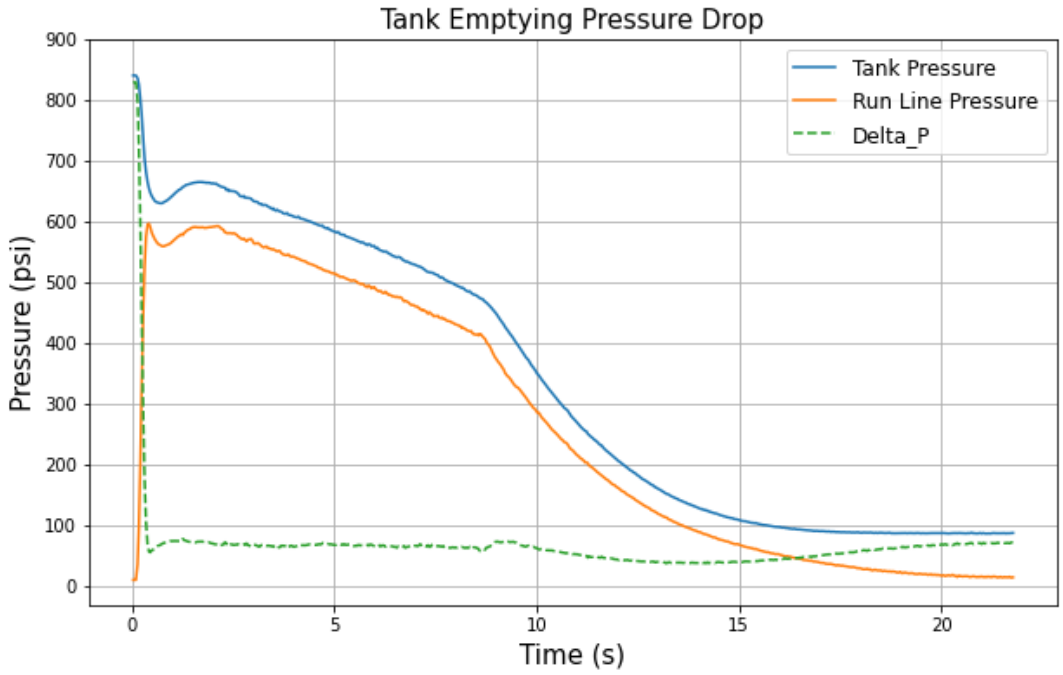
1 Plots

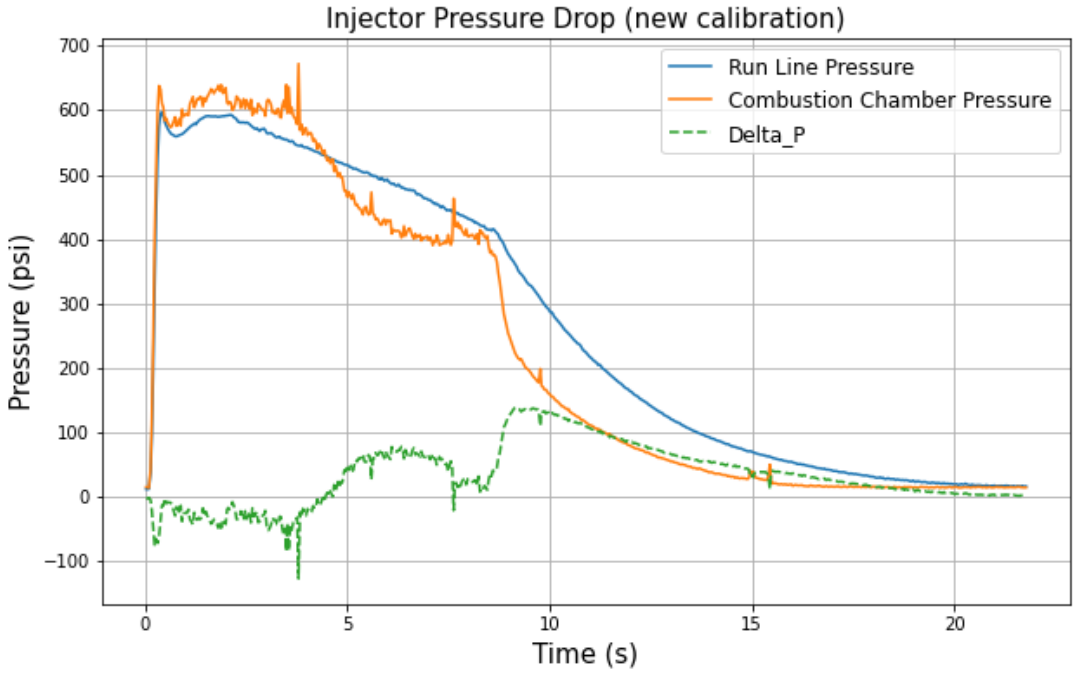

Fill Pressure
Pressure (psi)
Time (s)
Fill Pressure
Tank Pressure
0
200
400
600
800
0
250
500
750
1000
1250
1500
1750
2000

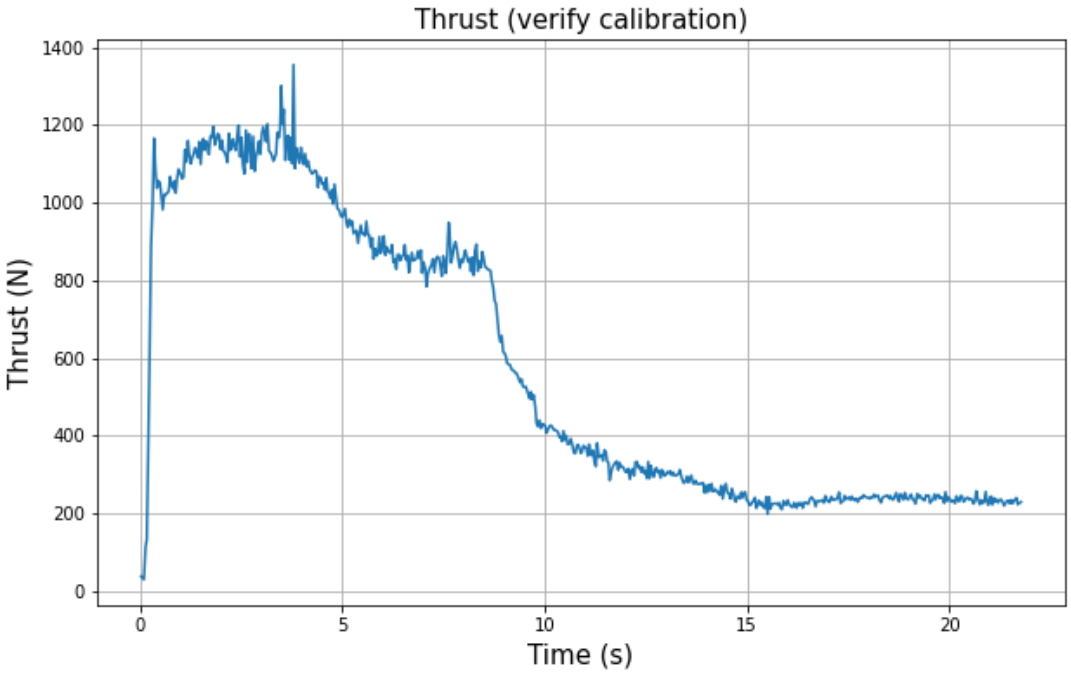

Fill Pressure
Pressure (psi)
Time (s)
Fill Pressure
Tank Pressure
0
200
400
600
800
0
5
10
15
20
25
30

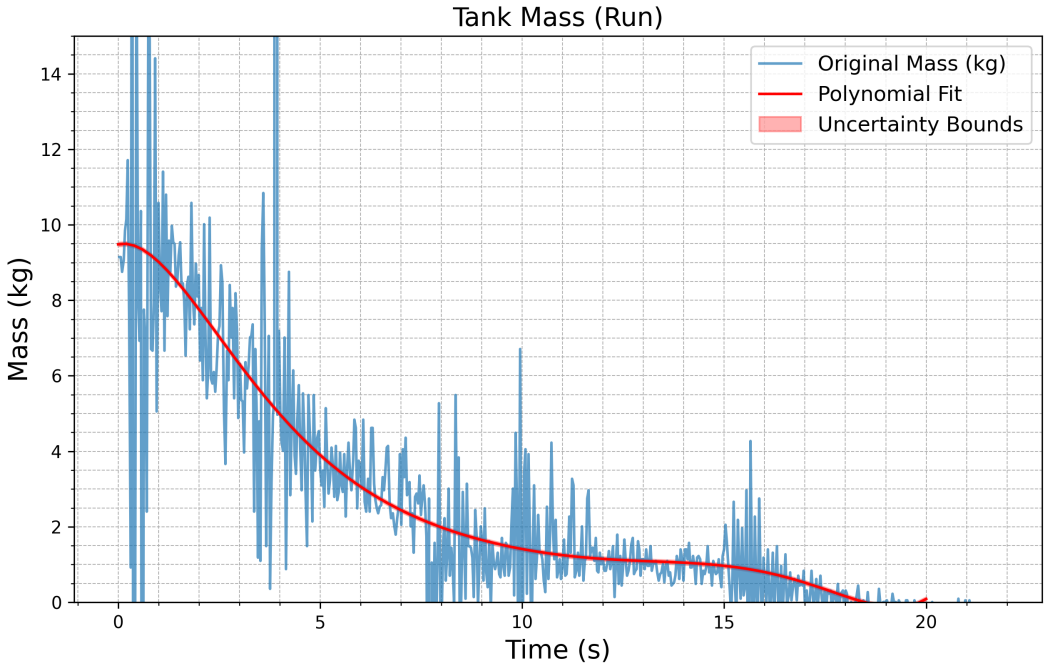

Tank Emptying Temperature
Temperature (C)
−200
−400
−600
−800
−1000
0
5
10
15
20
Time (s)
Run Temperature (C)
Tank Temperature (C)

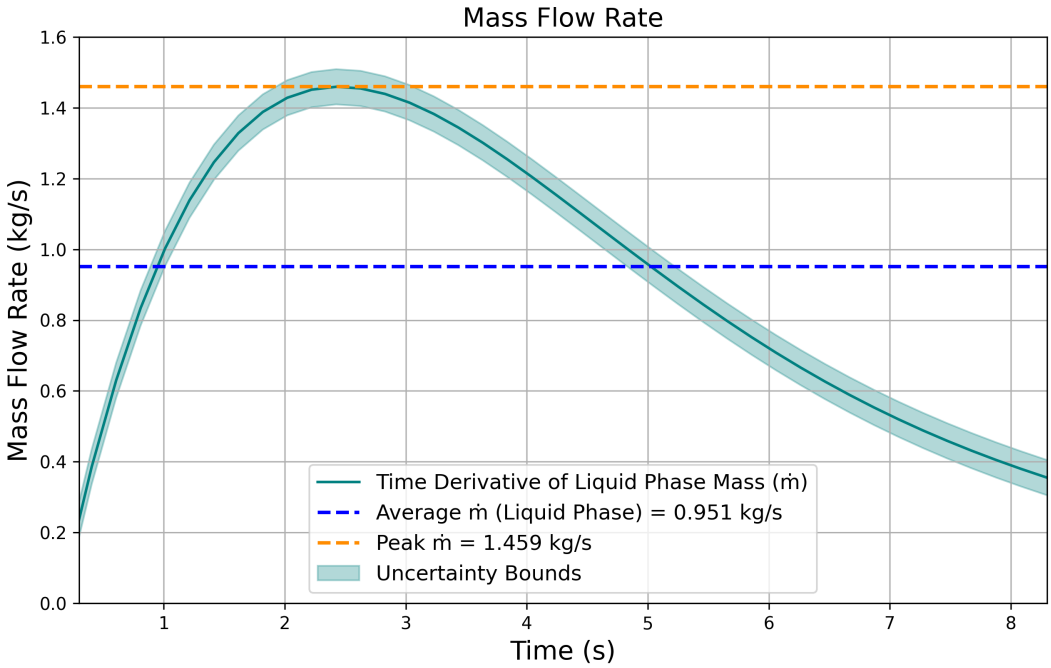

Tank Mass Filling and Heating (Load Cell)
Mass (kg)
12
10
8
6
4
2
0
0
250
500
750
1000
1250
1500
1750
2000
Time (s)

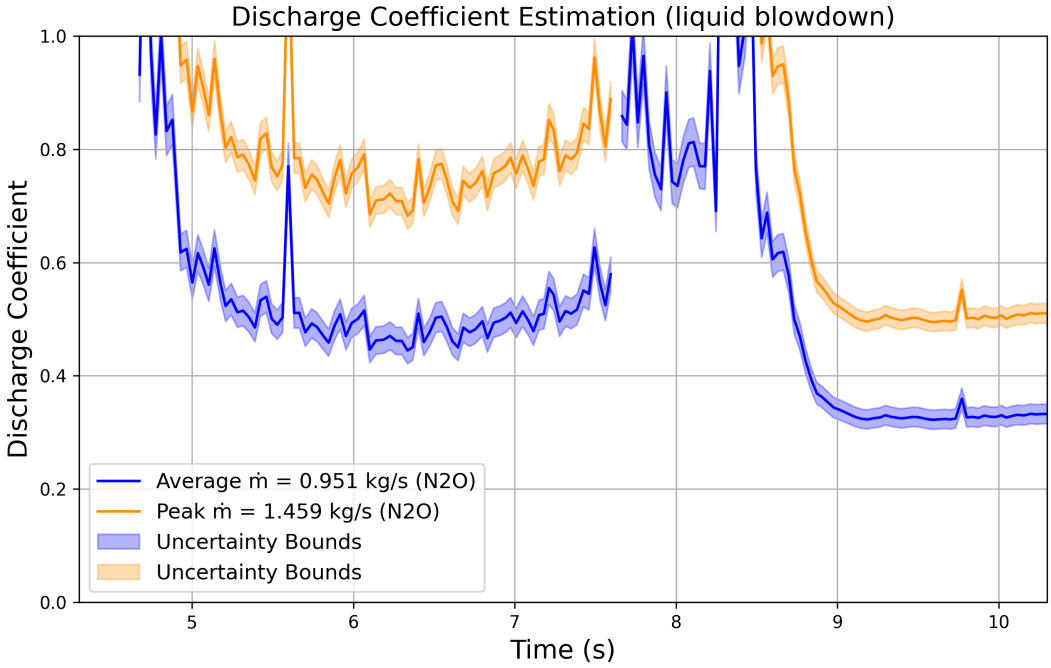

Tank Emptying Pressure Drop
Tank Pressure
Run Line Pressure
Delta_P
Pressure (psi)
Time (s)
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20

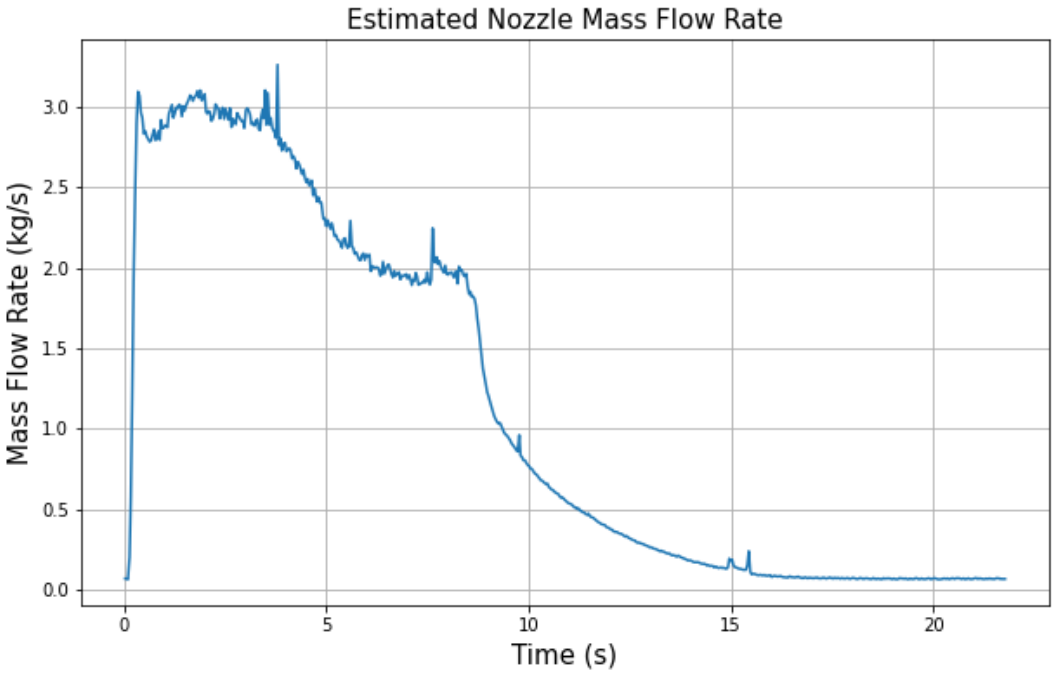

Injector Pressure Drop (new calibration)
Run Line Pressure
Combustion Chamber Pressure
Delta_P
Pressure (psi)
Time (s)
700
600
500
400
300
200
100
0
−100
0
5
10
15
20

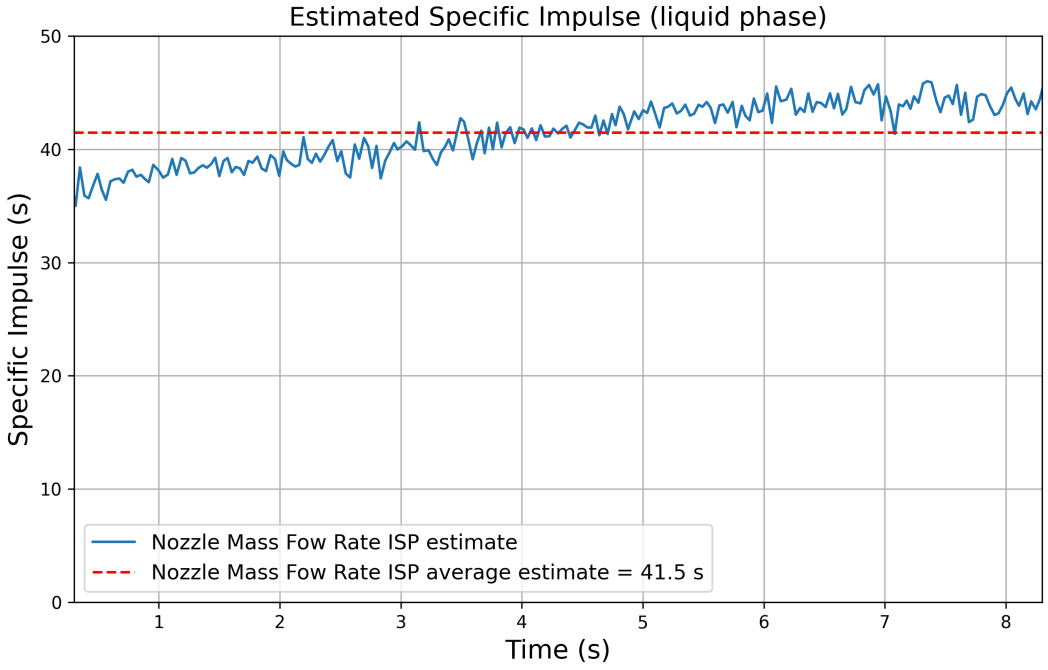

Thrust (verify calibration)
Thrust (N)
Time (s)
0
200
400
600
800
1000
1200
1400
0
5
10
15
20


Tank Mass (Run)
Original Mass (kg)
Polynomial Fit
Uncertainty Bounds
Mass (kg)
Time (s)
0
2
4
6
8
10
12
14
0
5
10
15
20


Mass Flow Rate
Mass Flow Rate (kg/s)
Time (s)
Time Derivative of Liquid Phase Mass (ṁ)
Average ṁ (Liquid Phase) = 0.951 kg/s
Peak ṁ = 1.459 kg/s
Uncertainty Bounds


Discharge Coefficient Estimation (liquid blowdown)
Discharge Coefficient
Time (s)
Average ṁ = 0.951 kg/s (N2O)
Peak ṁ = 1.459 kg/s (N2O)
Uncertainty Bounds
Uncertainty Bounds


Estimated Nozzle Mass Flow Rate
Mass Flow Rate (kg/s)
Time (s)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
5
10
15
20


Estimated Specific Impulse (liquid phase)
Specific Impulse (s)
Time (s)
Nozzle Mass Fow Rate ISP estimate
Nozzle Mass Fow Rate ISP average estimate = 41.5 s
0
10
20
30
40
50
1
2
3
4
5
6
7
8

2 Issues Encountered

The burn was not nominal, most likely due to a fuel (or post-combustion-chamber spacer) mechanical failure which clogged the nozzle, cause a high combustion-chamber pressure for the first 4 seconds, and overall very poor performance. The negative injector pressure drop value for the first few seconds, despite the visible absence of sustained backflow from the video footage and tank emptying mass graph, is to be investigated further.

3 Conclusions

As a result of the non-nominal burn, neither the nozzle nor the spacers got validated. Further testing should be performed before testing them again in a hotfire, to prevent such issues from happening again. Further details can be found in the complete test report document.