Tank Sizing Analysis for the Reduced Gravity Cryogenic Transfer Receiver Tank

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Overview

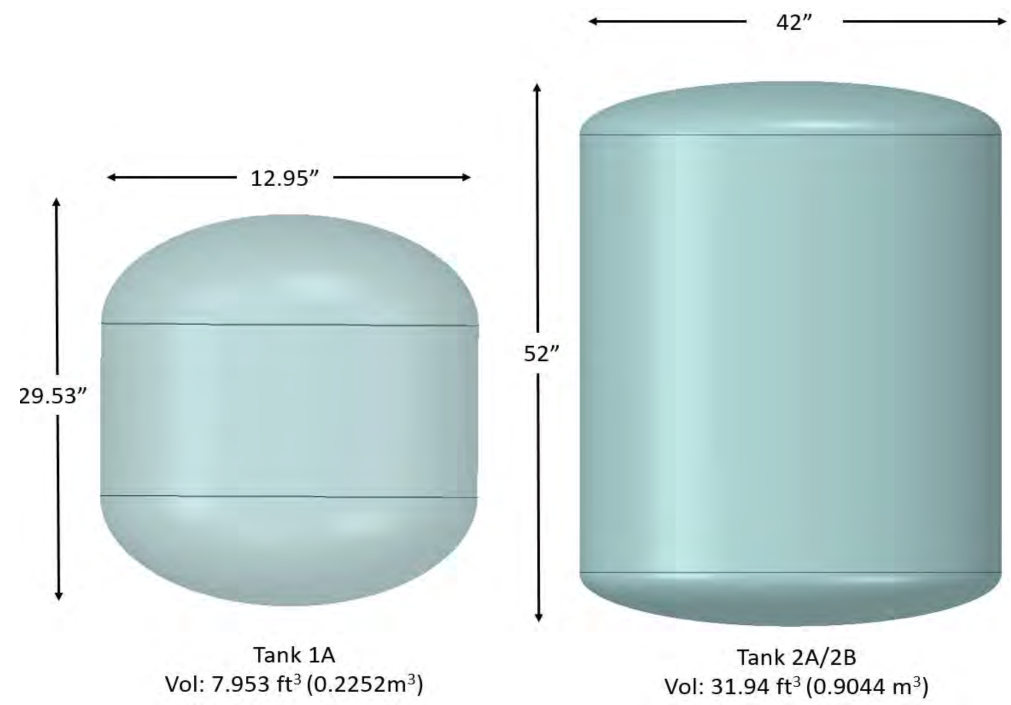
- Tank Chilldown Background
- Modeling Overview
  - Tank descriptions
  - Charge/Hold/Vent procedure
- Results
- Conclusions
- Future Work

Background

- Understanding fluid behavior in microgravity is essential to further development of in-space cryogenic systems
  - No current published data on tank chilldown in microgravity
- Reduced Gravity Cryogenic Transfer (RGCT) project is designed to investigate tank chilldown in a microgravity environment onboard a parabolic flight
  - 1 parabolic flight consists of 25 parabolas, 60s each
- Current study: what is appropriate tank size to complete chill down during 1 flight given 3 possible different chilldown scenarios?
  - Goal is to chill down the tank wall to some target temperature by the end of the flight

Tank Descriptions

- Tank Parameters to investigate:
  - Small vs. Large Tank Volume
  - Thin vs. Thick-walled



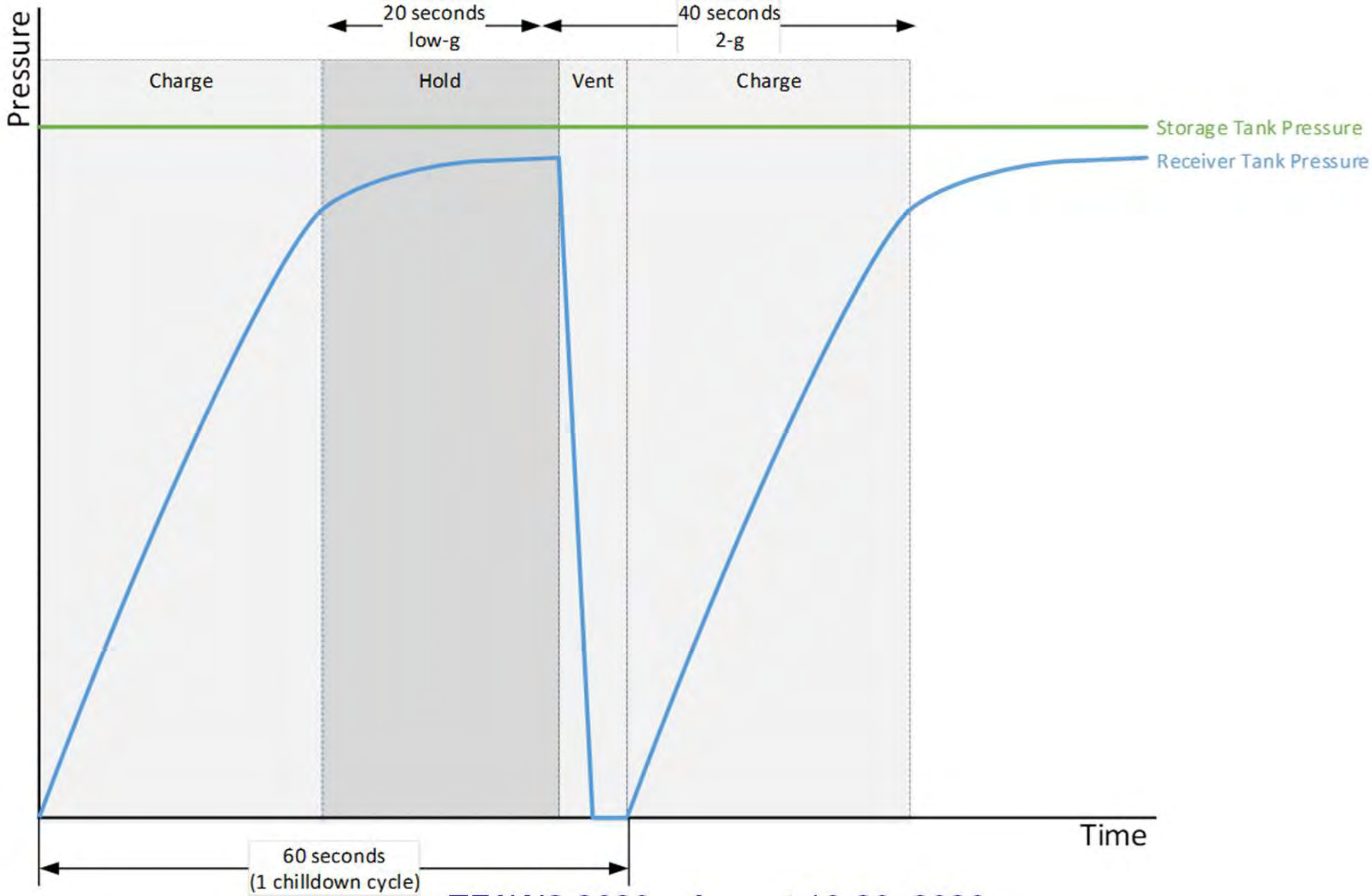
Tank	Description	Dry Mass (kg)	Internal Volume (m^3)	MEOP (psia)	Wall Thickness (in)
1A	Lower Limit	30.2	0.225	50	3/16"
2A	Upper Limit	79.0	0.904	64.3	3/16"
2B	Upper Limit, Thick-Walled	158.2	0.904	330	3/8"

Modeling Approach

- Thermal Desktop, multi-node model
- Working Fluid: nitrogen
- Tank wall material: Aluminum 2219
- Fluid in tank is modeled as twin lumps (liquid + vapor)
- Bottom fill dip tube injector with top vent
- Monitoring liquid temperature, pressure, and average tank wall temperature

Charge/Hold/Vent Procedure

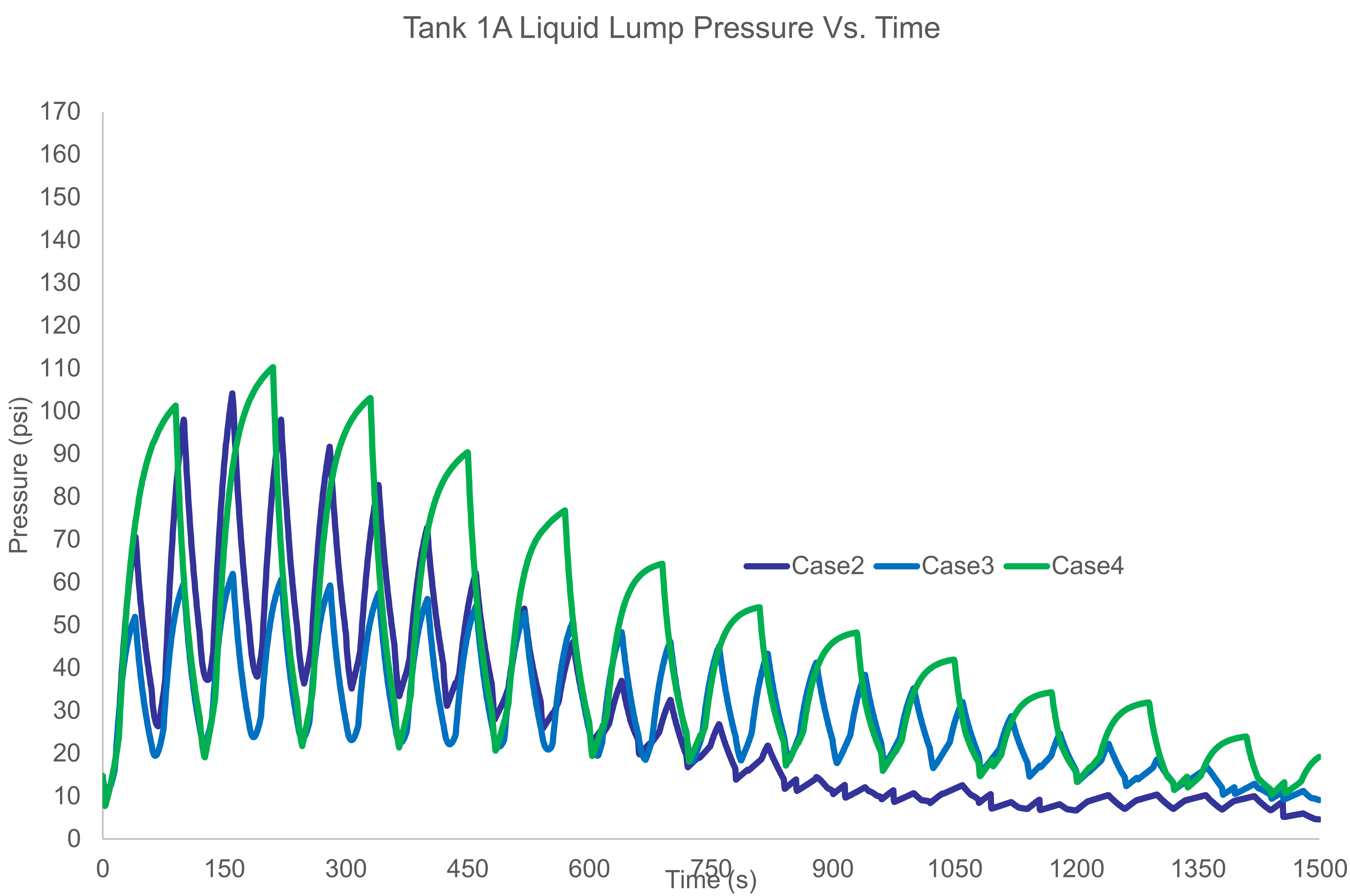
- Charge/Hold/Vent (C/H/V) Chilldown:
  - **Charge**: Supply Valve Open/Vent Valve Closed
  - **Hold**: Supply Valve Closed/Vent Valve Closed
  - **Vent**: Supply Valve Closed/ Vent Valve Open
    - Pattern is repeated once every 60s (or once per 1 parabola)



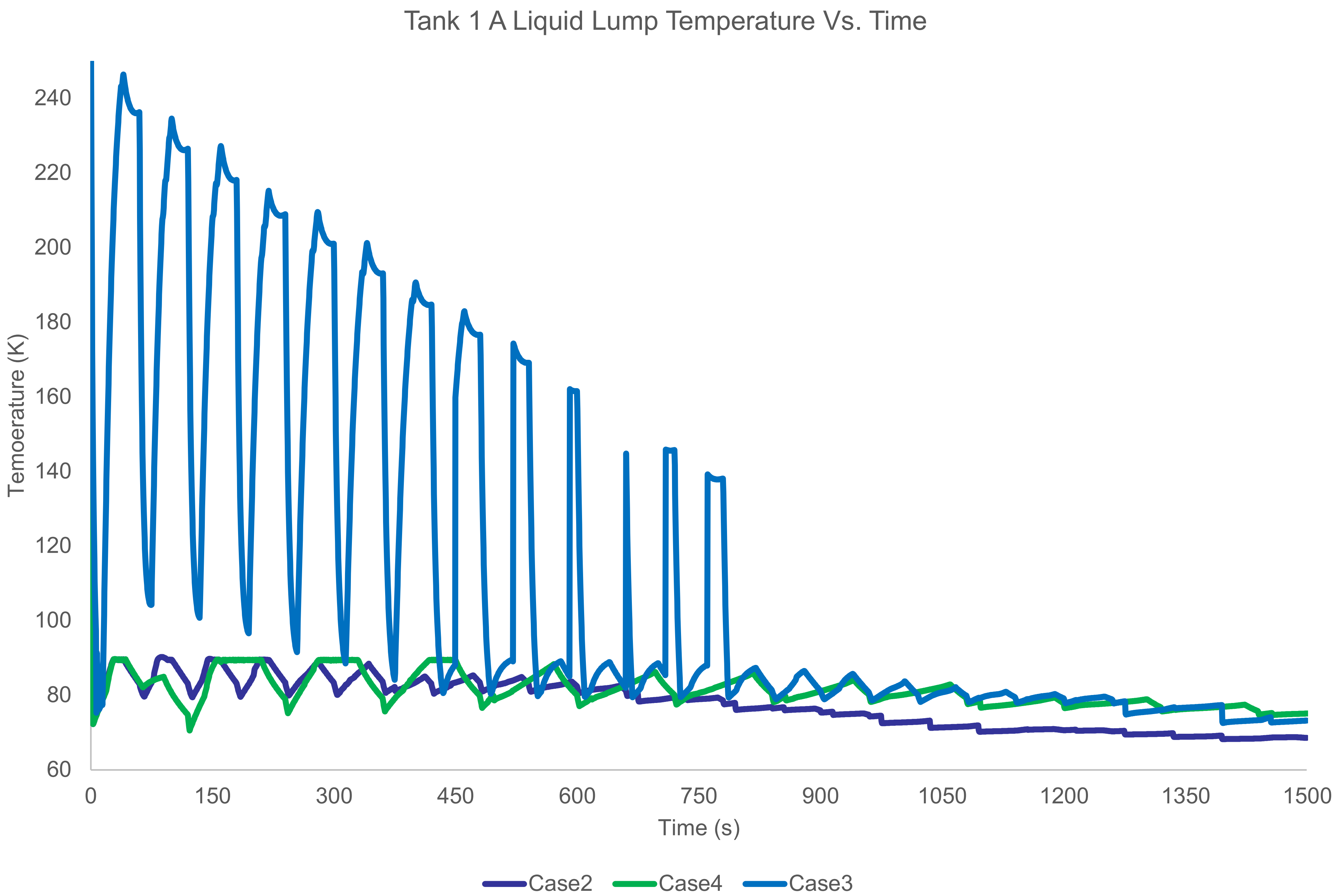
Different Chilldown Scenarios

Case No.	Parasitic Heat Load?	Flow Rate (gps)	Operation
1	No	100	Charge: 20s/ Hold: 25s / Vent: 20s
2	Yes	100	Charge: 20s/ Hold: 25s / Vent: 20s
3	Yes	50	Charge: 20s/ Hold: 25s / Vent: 20s
4	Yes	100	Charge: 17s/ Hold: 73s / Vent: 30s

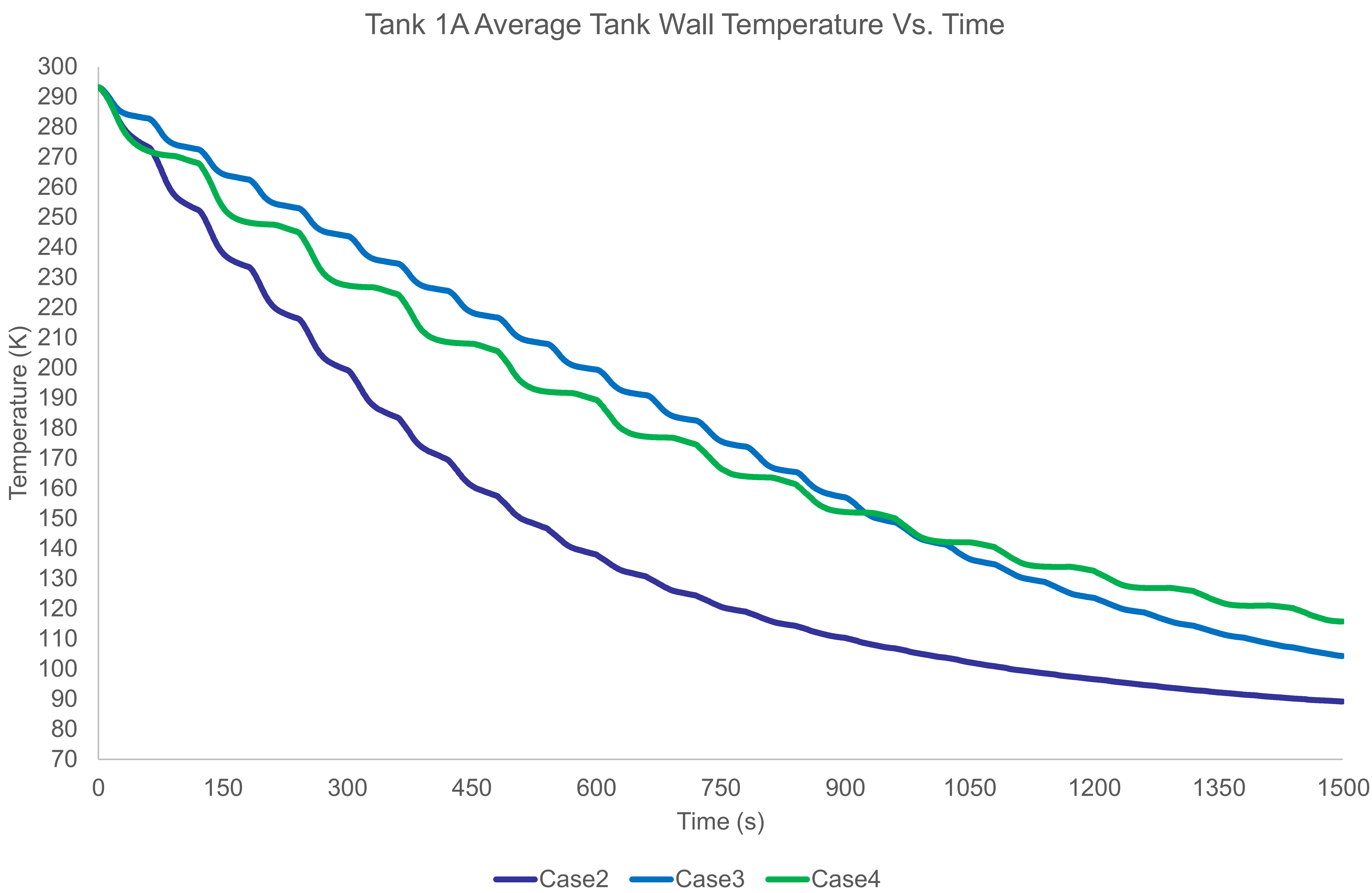
Tank 1A Results



Tank 1A Results (Cont'd)



Tank 1A Results (Cont'd)



Tank 1A Results Summary

	Propellant Used (kg)	Propellant Vented (kg)	Final Average Wall Temp (K)	Time (s)
Case 2	36.5	27.3	99.0	1500
Case 3	18.5	15.5	184.0	1500
Case 4	21.8	15.5	167.9	1500

Efficiency Parameters

$$\text{Propellant Efficiency} = \frac{Mass\ Transfered - Mas\ \ Vented}{Mass\ Transfered}$$

$$\text{Thermal Eff.} = 1 - \frac{Mass\ Vented\ \times\ hvap}{Tank\ Wall\ Mass \times Specific\ Heat \times Change\ in\ Temperature\ of\ Tank\ Wall}$$

$$\Delta T\ Factor = T_{Wall,final} - T_{sat,inlet}$$

Results: Large vs. Small Tank

Tank	Propellant Efficiency			Thermal Efficiency			Delta T Factor (K)		
	Case 2	Case 3	Case 4	Case 2	Case 3	Case 4	Case 2	Case 3	Case 4
1A	41.5%	20.6%	42.3%	43.8%	43.3%	48.0%	10	23.3	38.3
2A	25.2%	16.2%	28.9%	61.0%	60.6%	65.7%	21.8	106.8	80.7

- Case 3 has lowest propellant/thermal efficiency for both tanks
- Tank 1A has similar propellant thermal/efficiency whereas Tank 2A has significantly higher thermal efficiency
- Delta T factor is most important parameter in determining if tank can be successfully filled after childown
  - Tank 1A always has lower Delta T Factor than 2A
  - Case 2 always has lower Delta T Factor than Case 4

Results: Thin vs. Thick-Walled Tank

Tank	Propellant Efficiency			Thermal Efficiency			Delta T Factor (K)		
	Case 2	Case 3	Case 4	Case 2	Case 3	Case 4	Case 2	Case 3	Case 4
2A	25.2%	16.2%	28.9%	61.0%	60.6%	65.7%	21.8	106.8	80.7
2B	19.4%	14.0%	26.2%	62.3%	61.7%	67.0%	107.2	157.7	148.2

- Case 3 has again lowest propellant/thermal efficiency for both tanks
- Both tanks have similar propellant/thermal efficiencies
- Delta T factor is most important parameter in determining if tank can be successfully filled after childown
  - Tank 2A has lower Delta T factor than Tank 2B for all cases

Conclusions

- For parabolic flight pattern, the recommended tank size for an elliptical dome tank is closer to the size of Tank 1A (0.225 m^3) rather than Tank 2A (0.904 m^3)
- Thin-walled tank (3/16") has higher propellant and thermal efficiency than thick-walled tank (3/8")
- Thin-walled tank similar in size to Tank 1A is recommended for parabolic flight chilldown
  - Case 2 chilldown procedure (Charge: 20s/ Hold: 25s / Vent: 20s with a 100gps flow rate) recommended for this tank size

Future Work

- Further narrow down tank size and wall thickness
  - Test rig size
  - Maximize efficiency parameters
- Use of other injectors besides dip tube for chilldown