Cryogenic Autogenous Pressurization Testing for Robotic Refueling Mission 3

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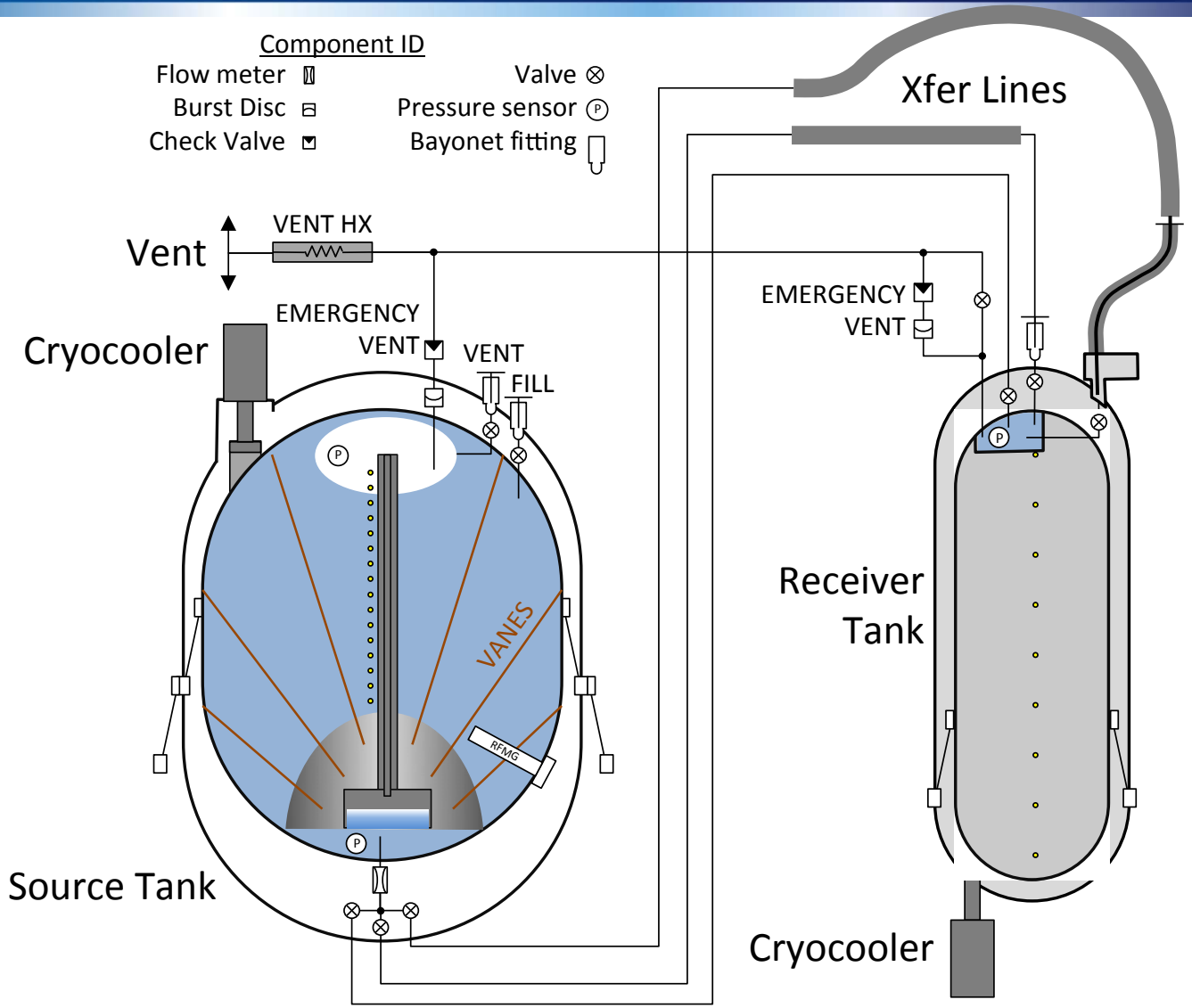
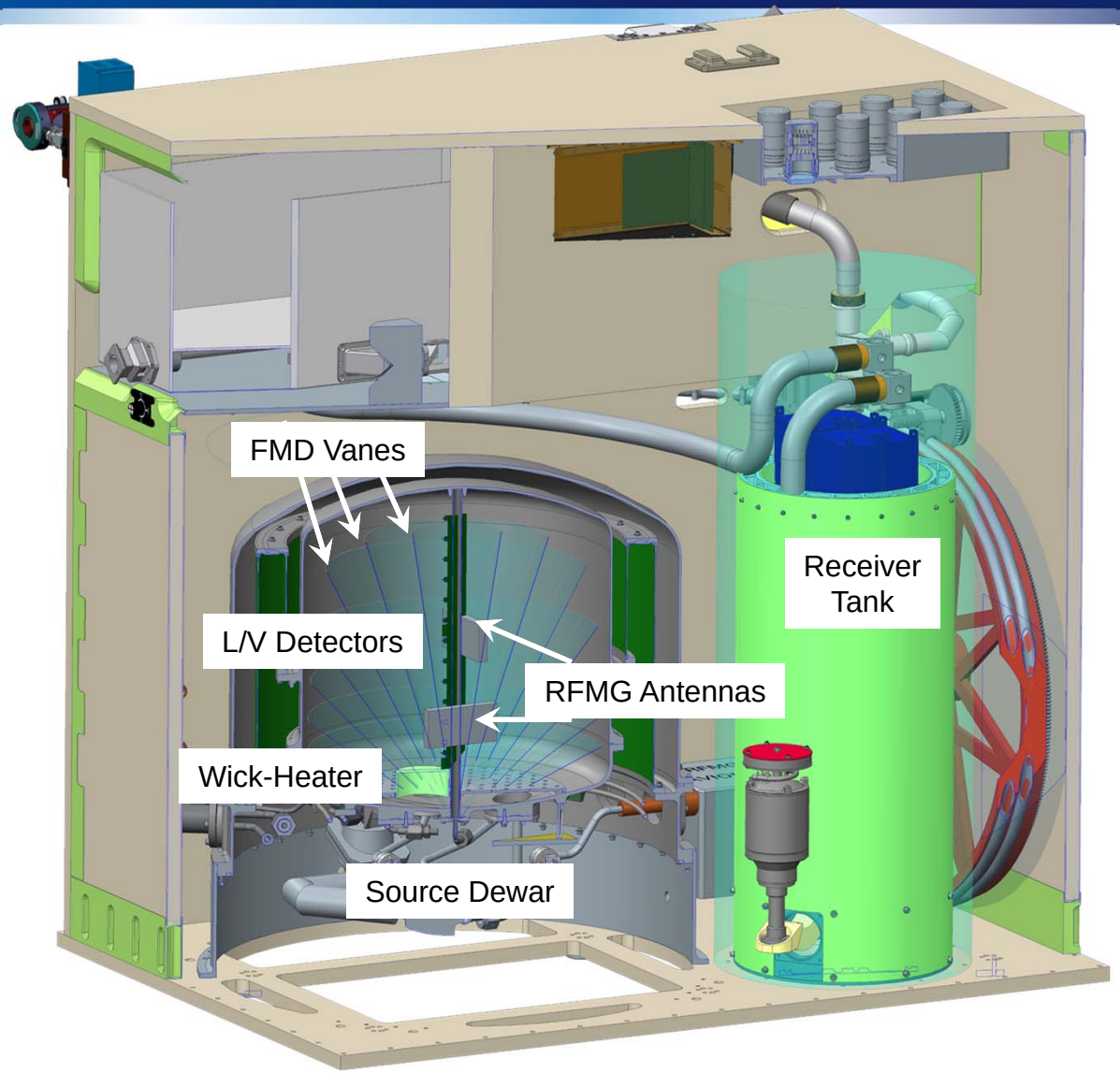
RRM3 Mission Objectives

- Organized through GSFC Satellite Servicing Capabilities Office
- Robotic servicing via GSE closeouts
- Cryogen resupply is one aspect of overall fluid resupply
- Cryogen re-supply demonstration

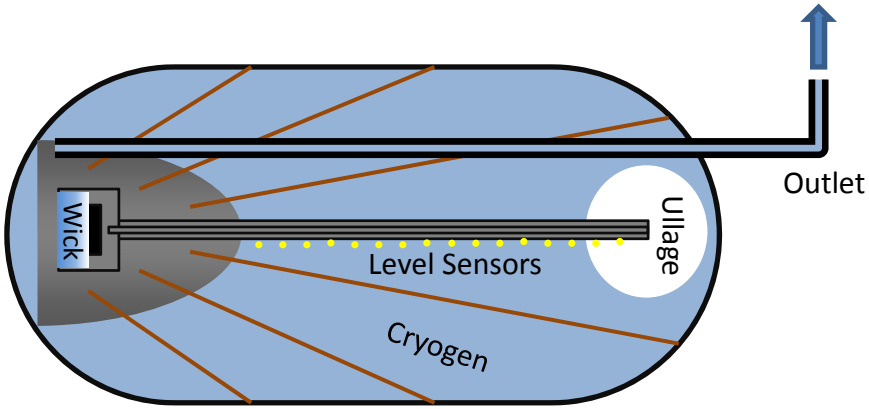
RRM3 Cryo Schematic

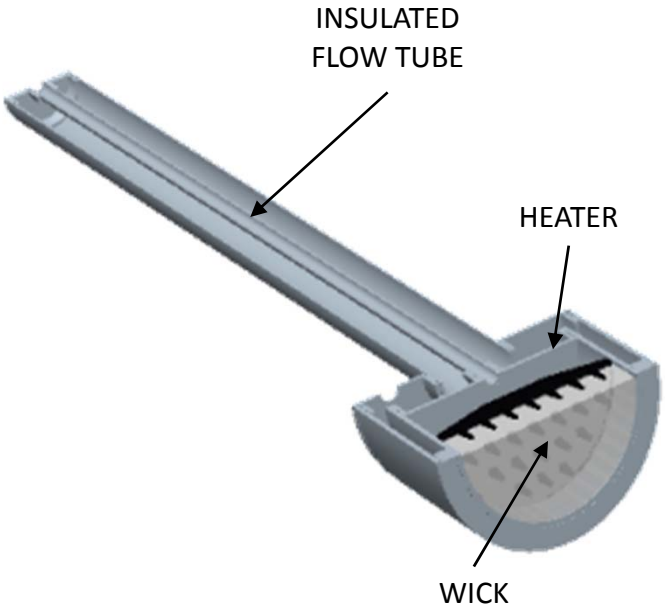


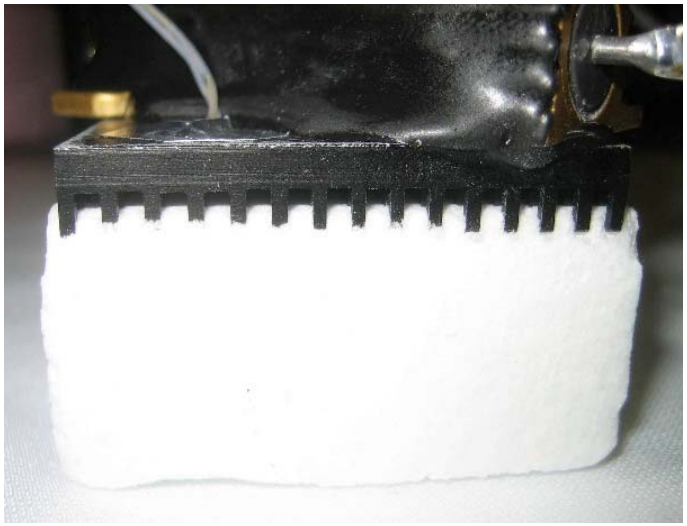
RRM3 Fluid Transfer Module

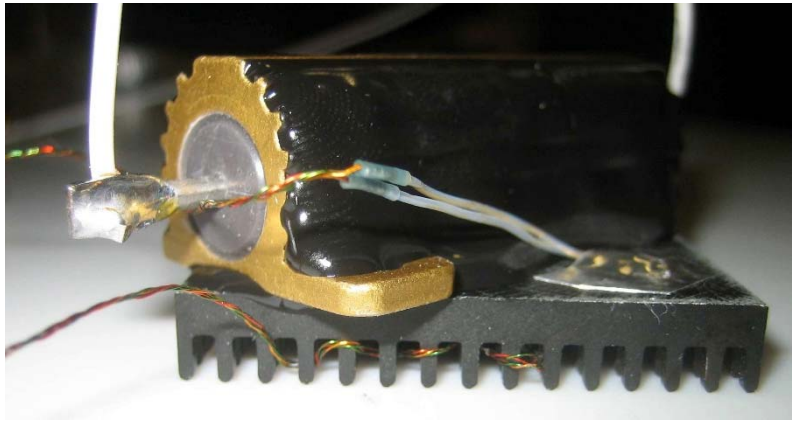


Wick Pressurization Concept





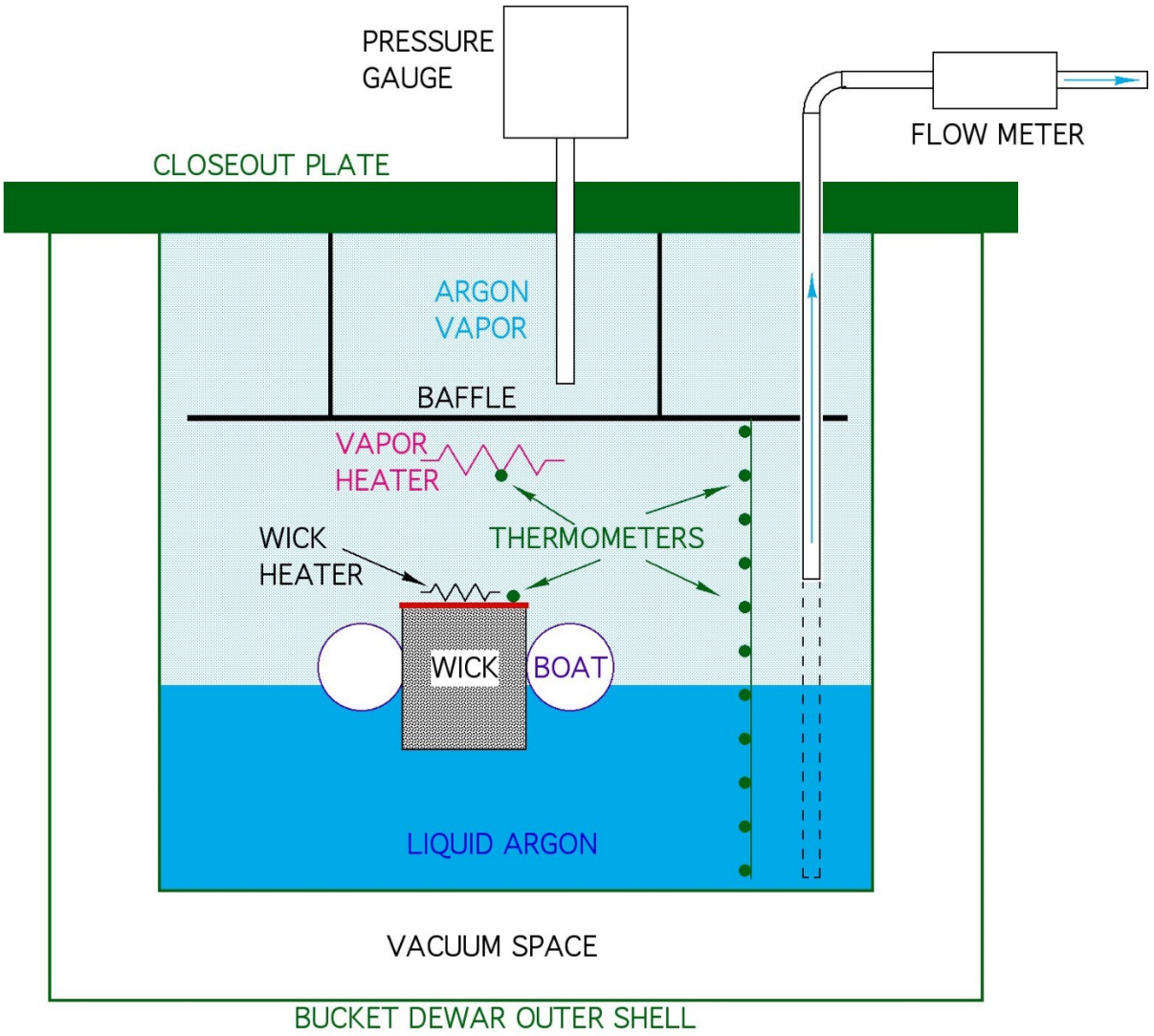




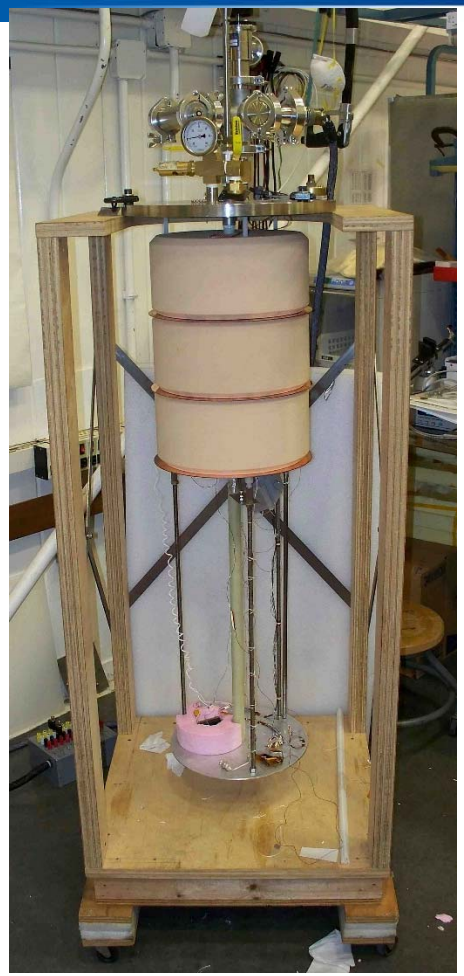
Wick Pressurization Testing

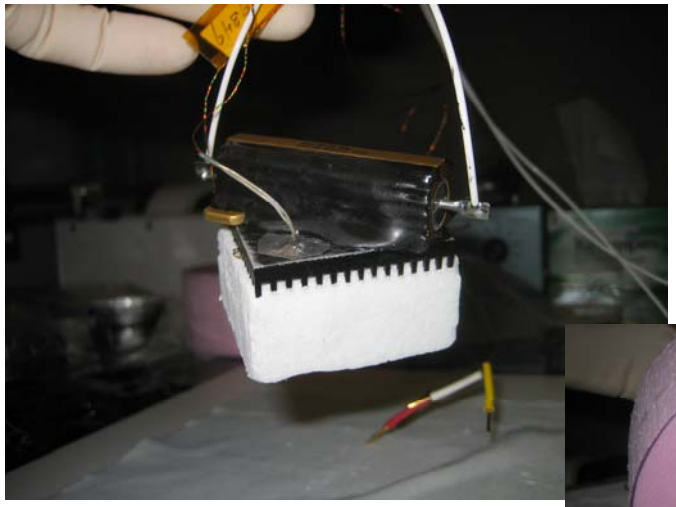
- Shuttle tile works well as a fluid wick for ground demo
  - LN2 wicks up ~2 cm into shuttle tile material in 1 G
  - Wick height ≥ 1 meter in accelerations up to 20 mG
- We demonstrated ability to wick LN2 1.25 cm above liquid surface with applied heat load
  - Up to 48 Watts applied on a wick of 16 cm^2 cross section area
  - Wick surface < 10K above saturated temperature
- We used the wick heater to transfer LN2
  - Scale under test dewar used to measure transfer rate

Wick Lab Test Approach

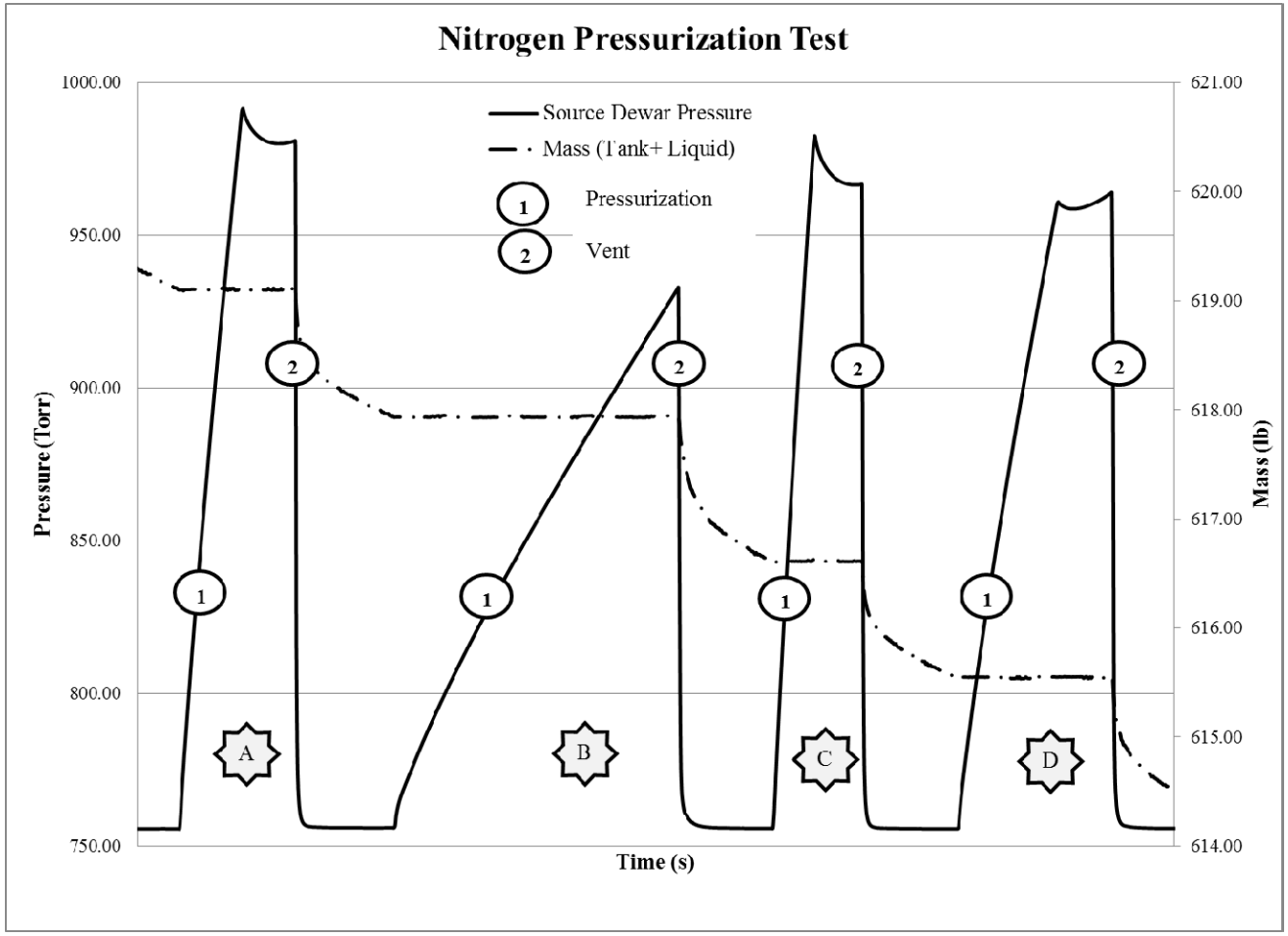


Wick Testing with LN2

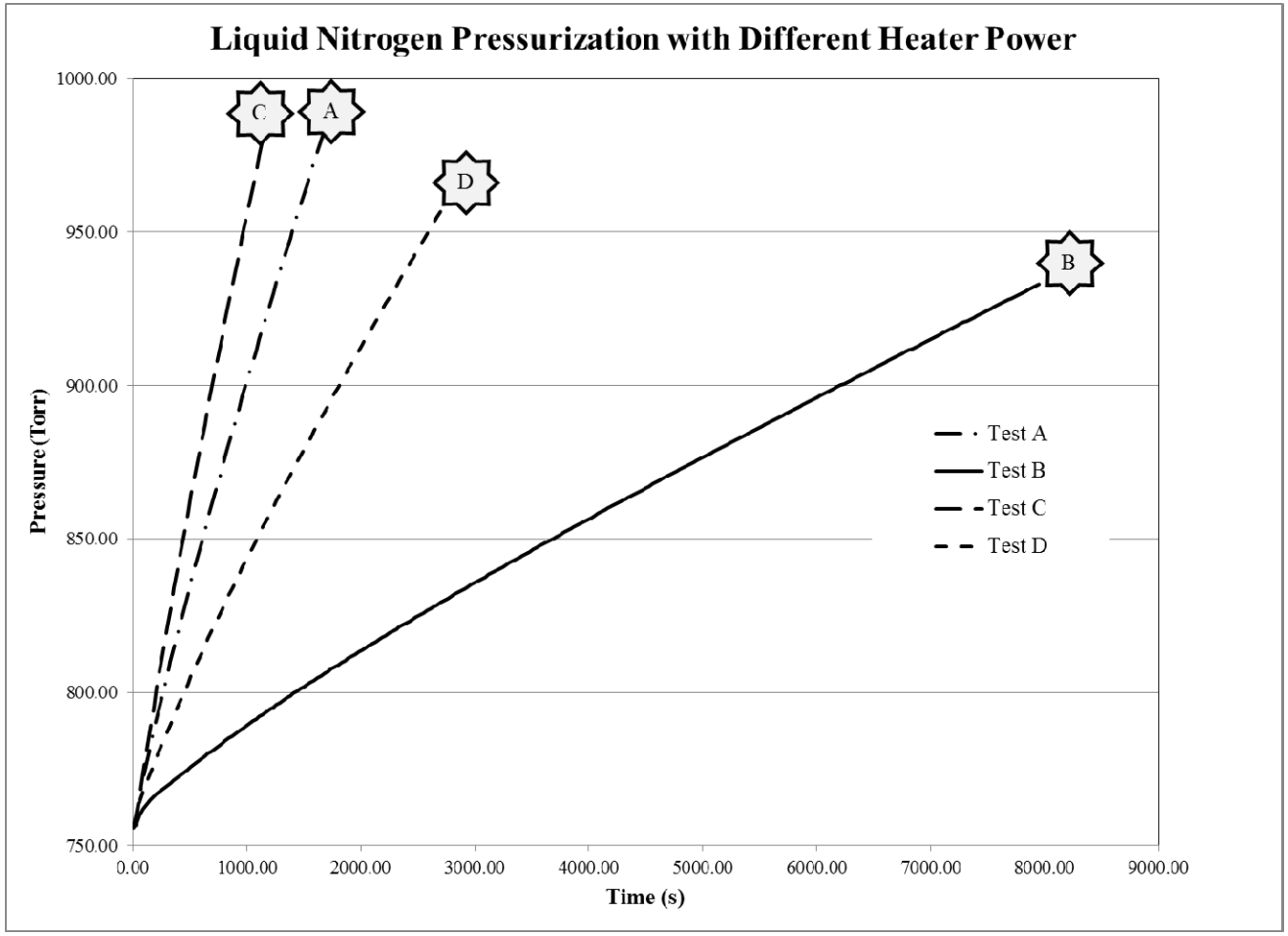




Pressurization Results



Pressurization Results

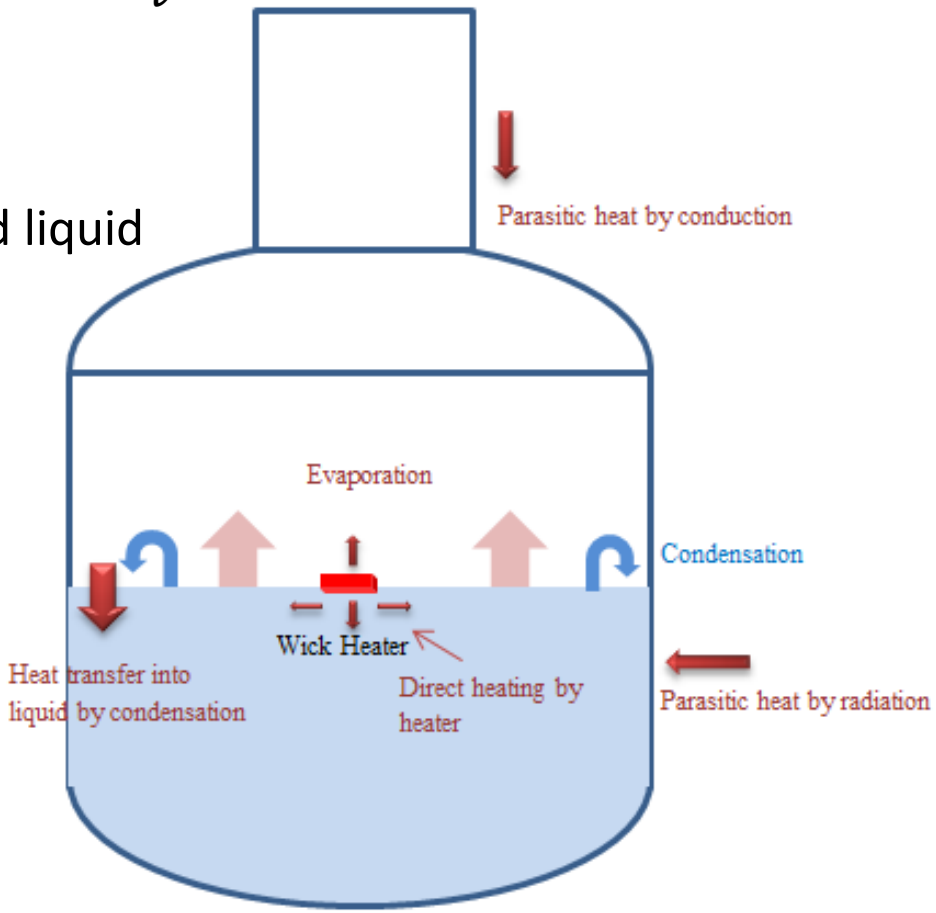


Wick Pressurization Theory

- Mass balance

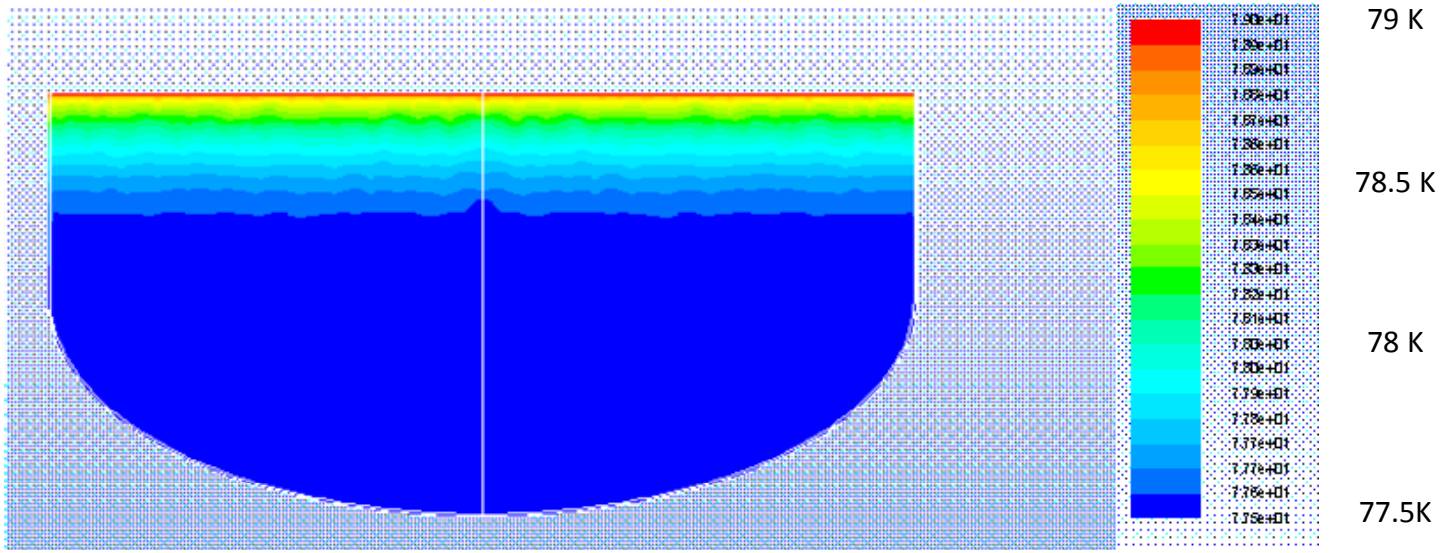
$$0 = m_{evp} + dm_v$$

- Energy balance
- $Q_p + Q_{heater} = m_{evp} h_{latent} + m_l dh_l + m_v dh_v$
  - m_{evp} - net mass of evaporated liquid
  - dm_v-change of mass of vapor
  - Q_p - parasitic heat
  - Q_{heater} - heater input
  - h_{latent} - latent heat of liquid
  - $m_l dh_l$ -heat into liquid
  - $m_v dh_v$ - heat in tow vapor



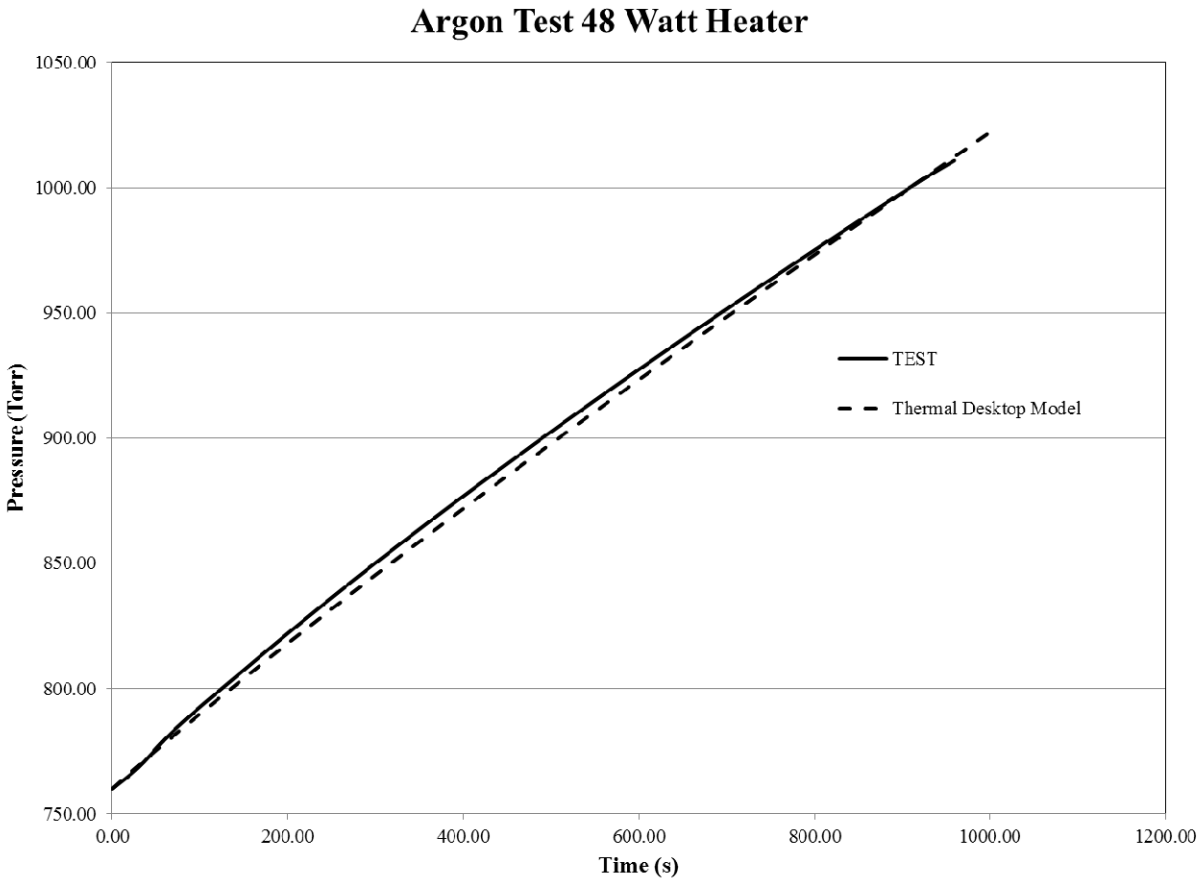
Analytical Comparison

- Heat into the liquid through
  - Conduction
  - Convection (ground operation)
  - Requires computational fluid dynamics analysis
  - We used Thermal Desktop to analyze conduction into liquid.
- Parasitic heat is estimated at 11 Watts.
- Thermal desktop model under predicts heat into liquid at lower heater power input.
- We are working on the User Defined Function using CFD modeling.



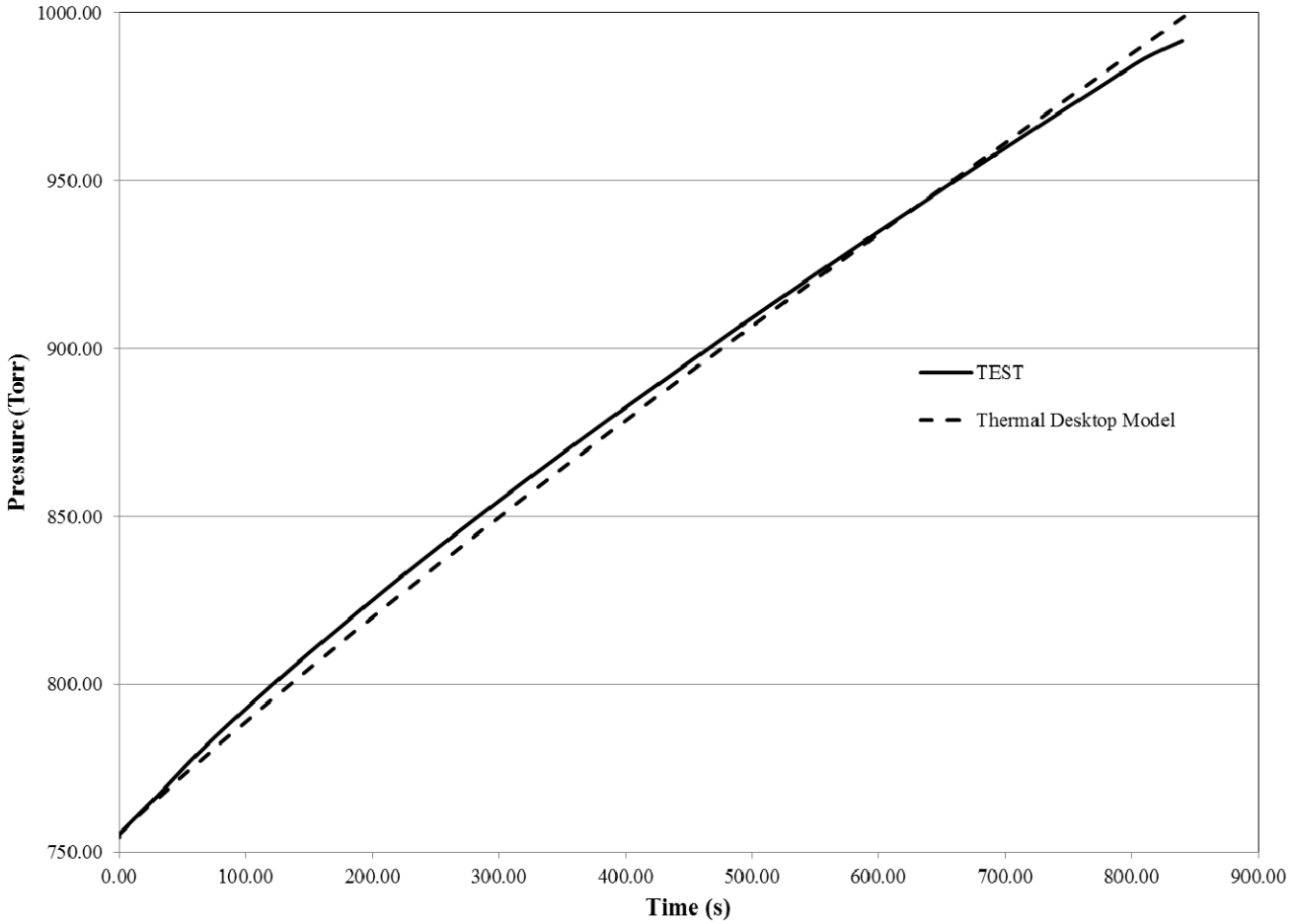
Results (Test A)

- Thermal Desktop Model showed good prediction for high heater power. Repeated this test with a cooling loop in the baffles of the cryostat to reduce heat leak.



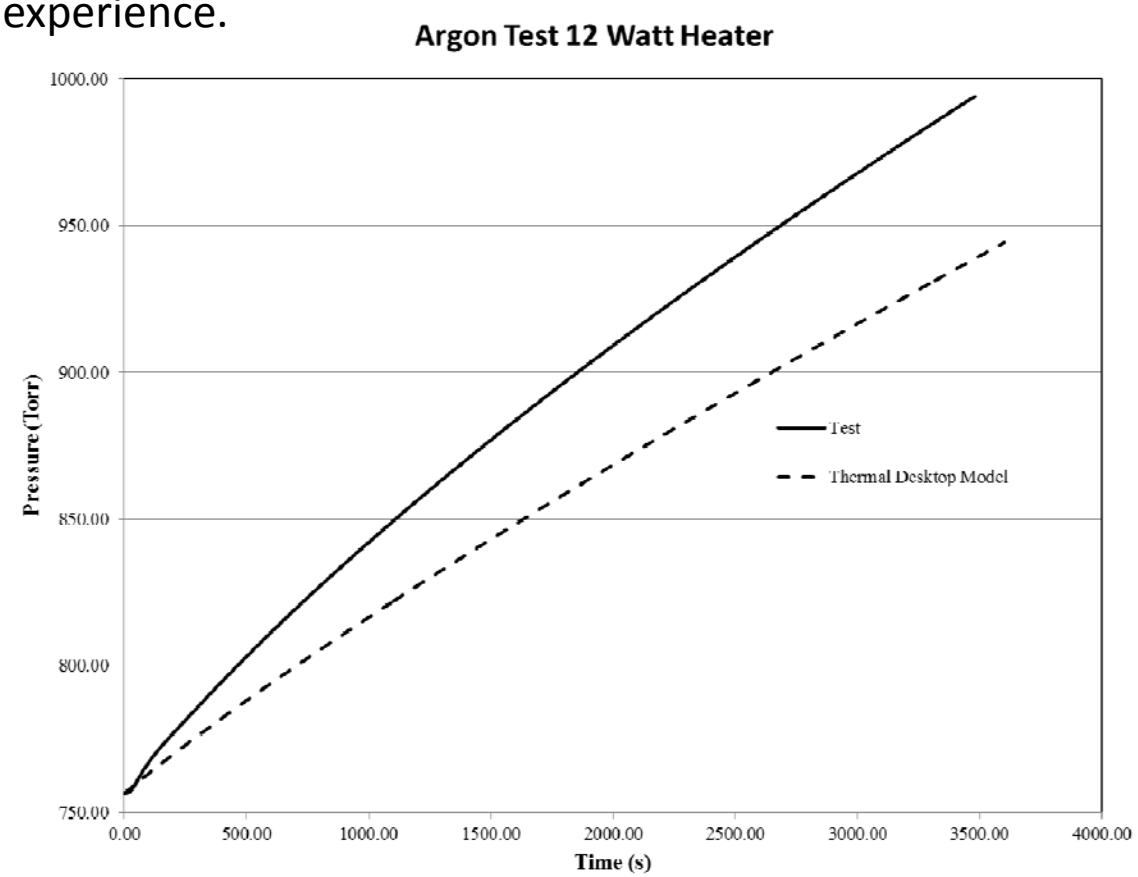
Results (Test C)

- Repeated the 48 W input power test with a cooling loop in the baffles of the cryostat to reduce heat leak.
- No significant effects on test and prediction



Results (Test D)

- Thermal Desktop model does not perform well with low heater input power, or self-pressurization (Test B not shown but similar to Test D Below)
- Future work will improve model for self-pressurization and low heater input power. Plan to collaborate with Glenn Research Center and their pressurization modelling experience.



Future Work

- CFD modeling of bath in 1 g
  - Account for convective mixing in lab test
- Flow-impedance measurement (LN2 in shuttle tile material)
  - Allow optimal sizing of flight wick configuration
- Flooded wick test
  - Demonstration of off-optimum performance in percolator mode
- Flight wick design
  - Target rate 200 liter/hour in zero g