Cryogenic Autogenous Pressurization Testing for Robotic Refueling Mission 3


NASA Goddard Space Flight Center
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 Fluid Transfer Module

- Receiver Tank
- RFMG Antennas
- L/V Detectors
- Wick-Heater
- Source Dewar
- FMD Vanes
Wick Pressurization Concept

- Wick
- Level Sensors
- Ullage
- Cryogen
- Outlet

- Insulated Flow Tube
- Heater
- Wick
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 cm² 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

Nitrogen Pressurization Test

Pressurization

Vent

Source Dewar Pressure

- Mass (Tank + Liquid)
• **Mass balance**

\[ 0 = m_{evp} + dm_v \]

• **Energy balance**

- \( Q_p + Q_{heater} = m_{evp} h_{latent} + m_i dh_i + m_v dh_v \)
  - \( m_{evp} \) - 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
  - \( m_i dh_i \) - 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.
• 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