An Experimental Study on Low Pressure Frost Formation for Lunar Polar Water Capture

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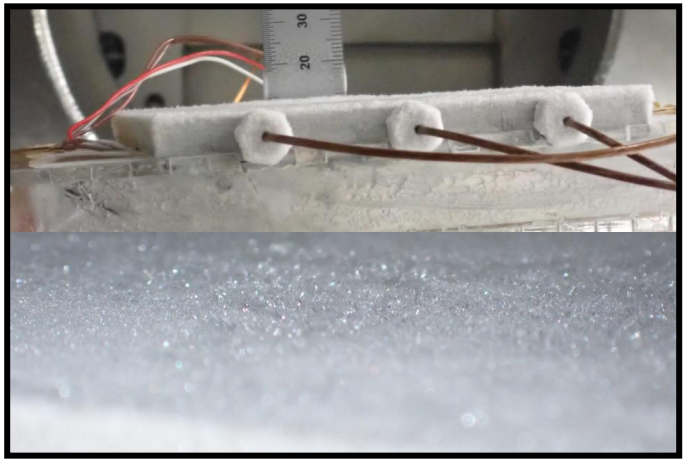
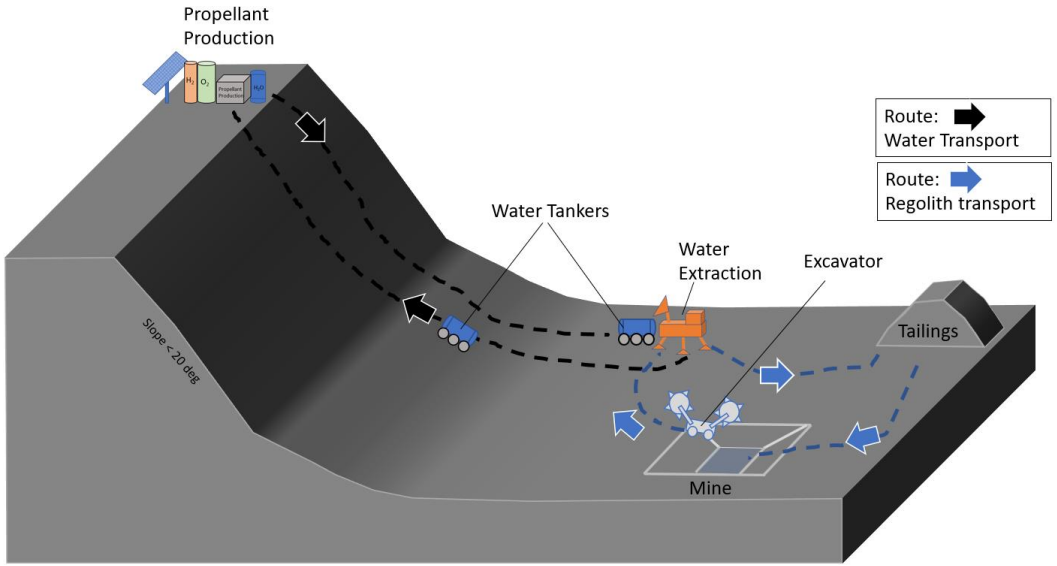
Presented by Beau Compton



Expectation

Reality

Background



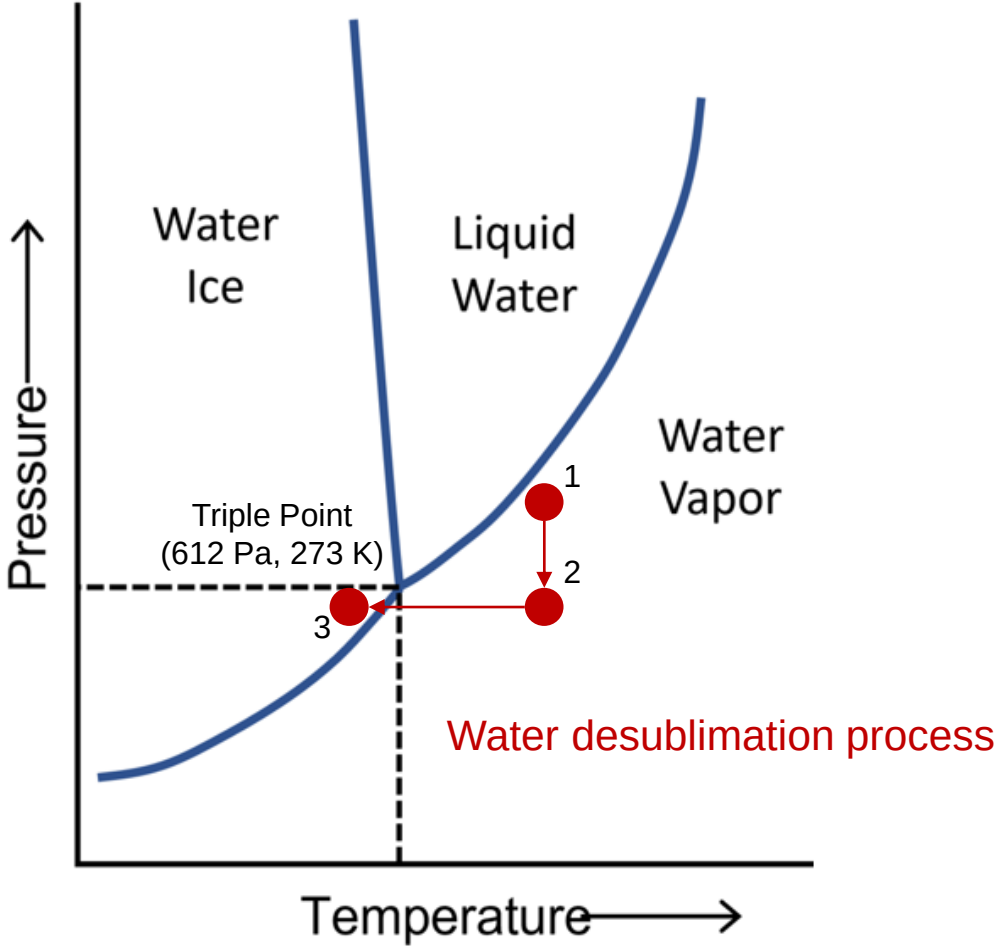
Potential Water Mine Concept of Operations

Basic ConOps for a lunar water plant:

- Excavate ice-bearing lunar regolith in the permanently shadowed region (PSR)
- Extract the ice in the form of water vapor
- Store the water vapor as desublimated ice*
- Bring the ice to the sunlit region for further processing

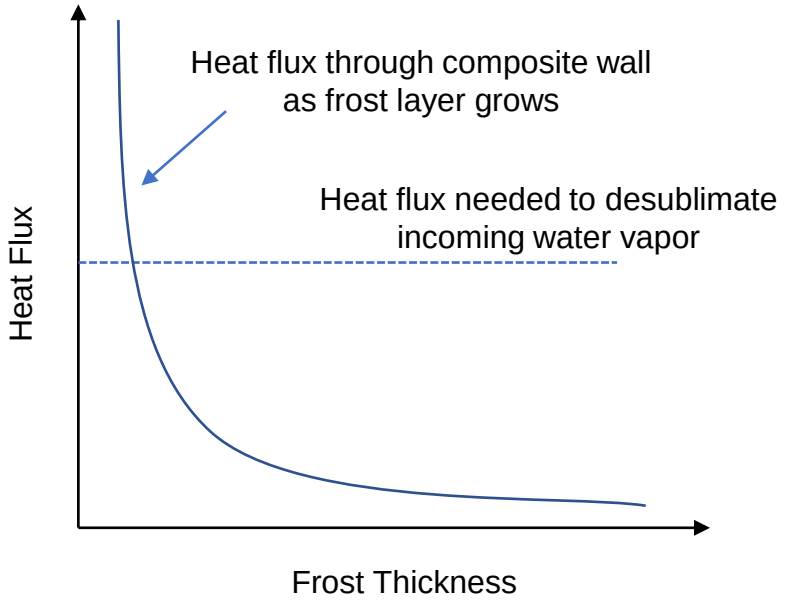
*Area of interest

Introduction

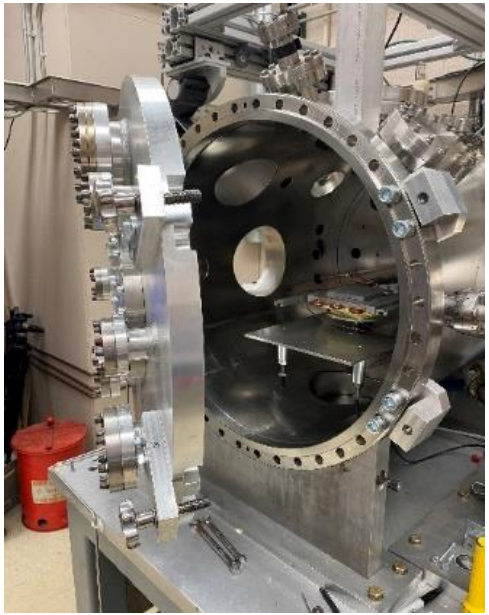


Introduction

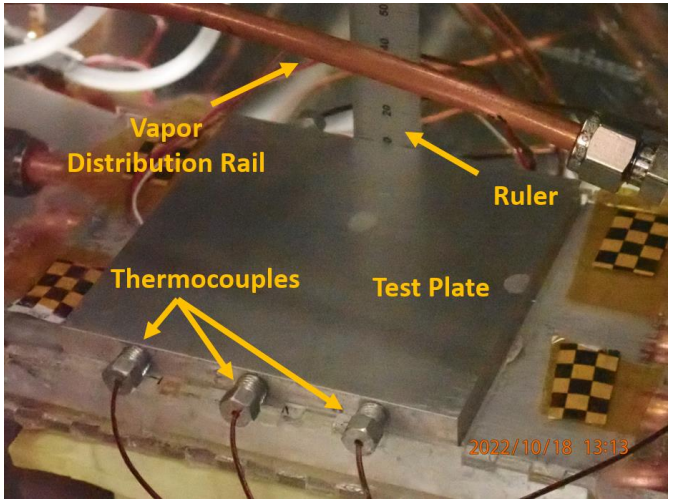
- Eventually, the evolving frost layer will have an insulating effect which will prevent desublimation at the required flow rate
- Little research has been published which evaluates heat transfer through a frost layer in near-vacuum conditions



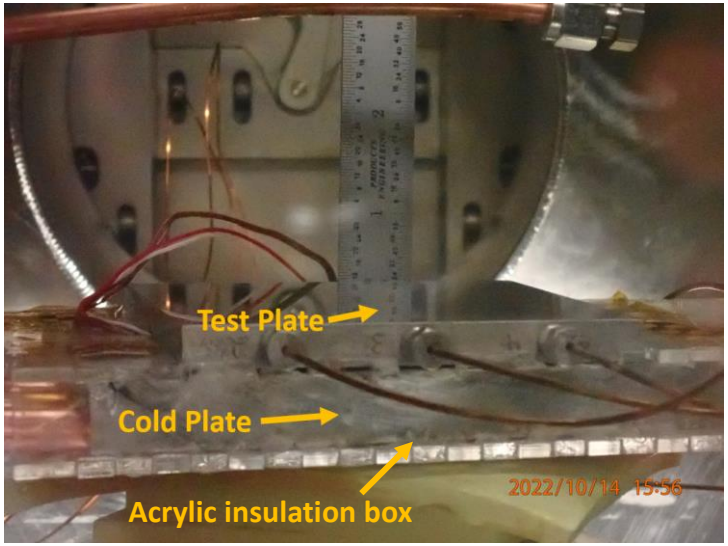
Experimental Setup



2 ft vacuum chamber at GRC



10 cm x 10 cm test plate with the vapor distribution rail above



Side view of test plate with the cold plate and ruler used to determine frost height

***Not pictured; heat flux sensor**

Experimental Setup

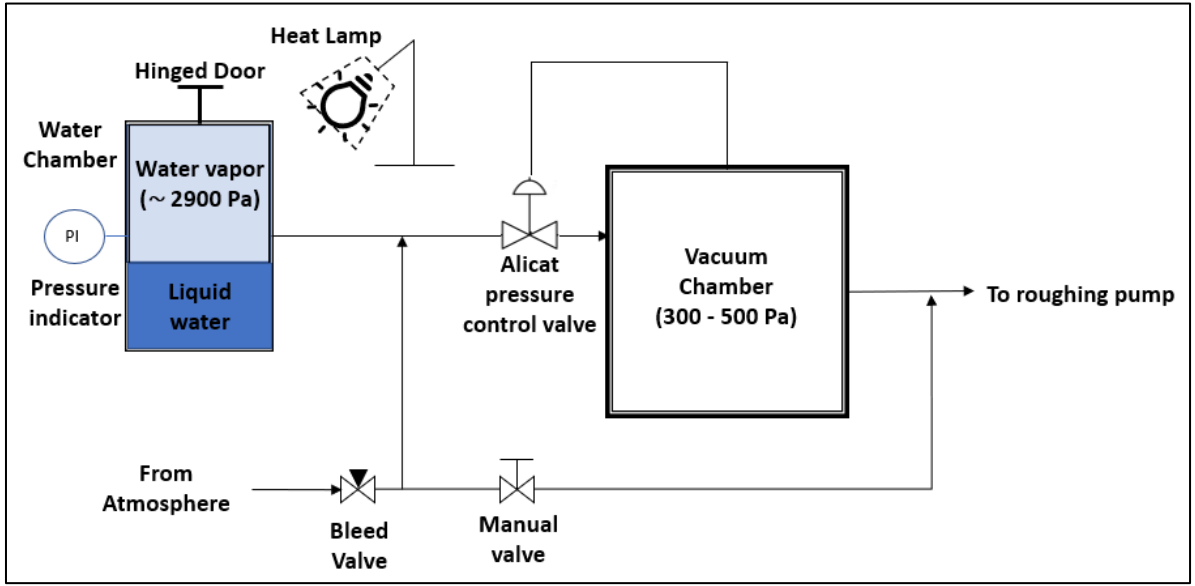
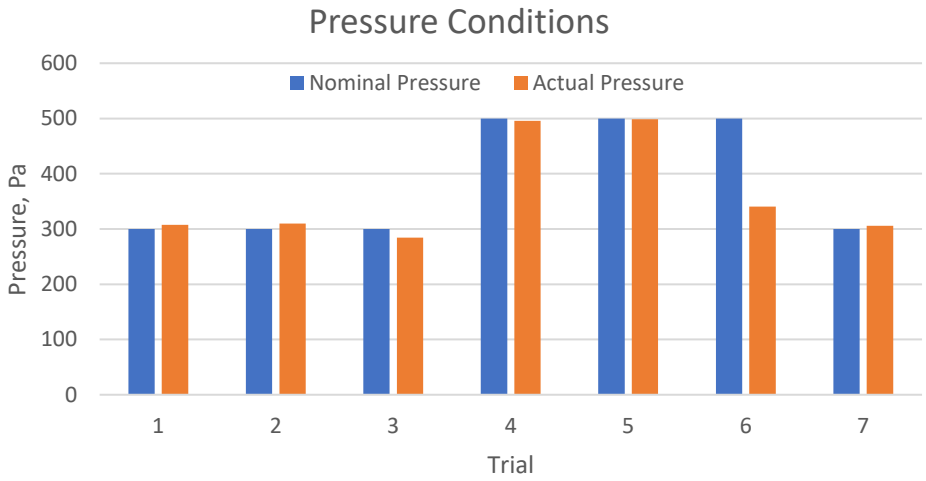
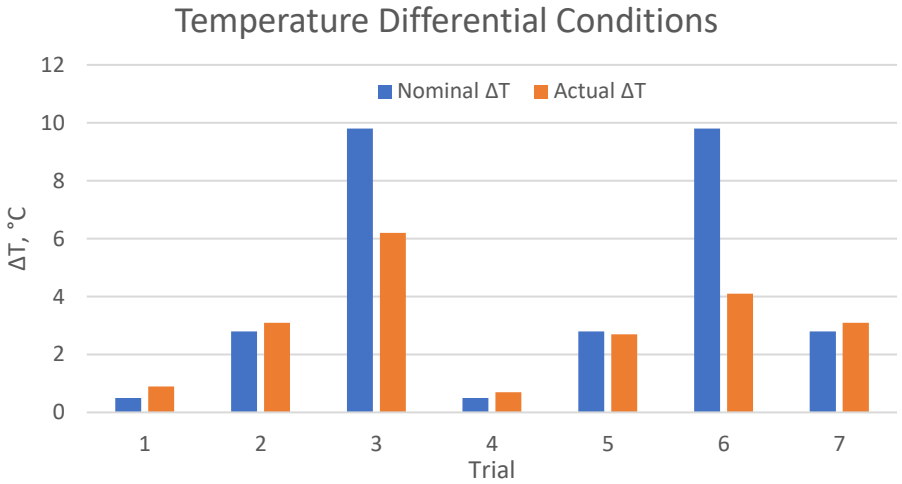


Diagram depicting water vapor introduction method

Test Conditions



- Two pressures:
  - 300 Pa
  - 500 Pa

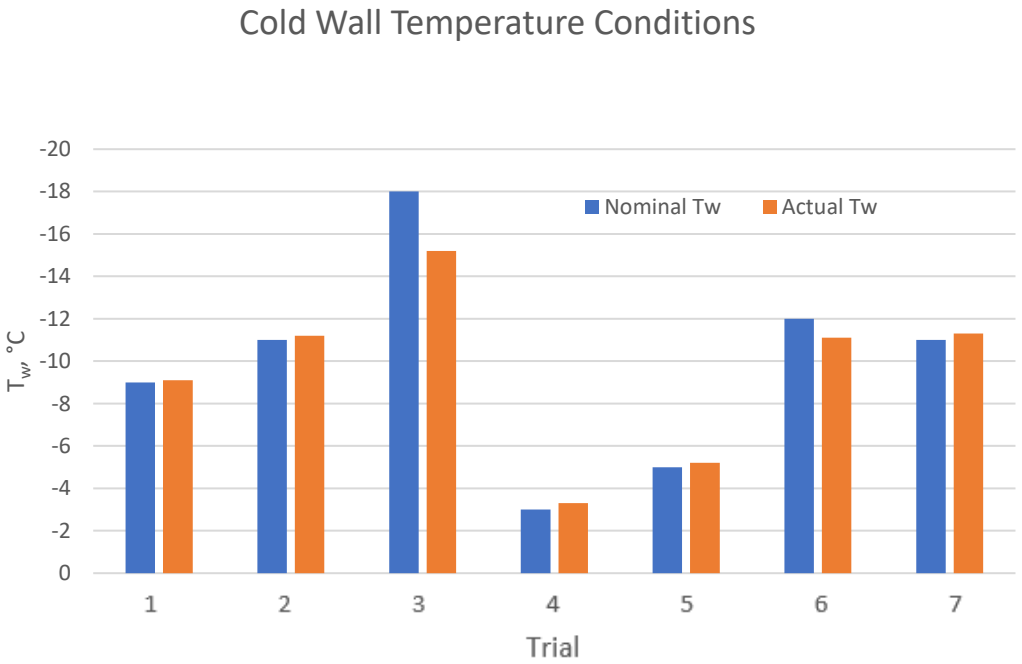


- Three temperature differentials
  - 0.5 °C
  - 2.8 °C
  - 9.8 °C

Test Conditions

$$\Delta T = T_{sublimation} - T_w$$

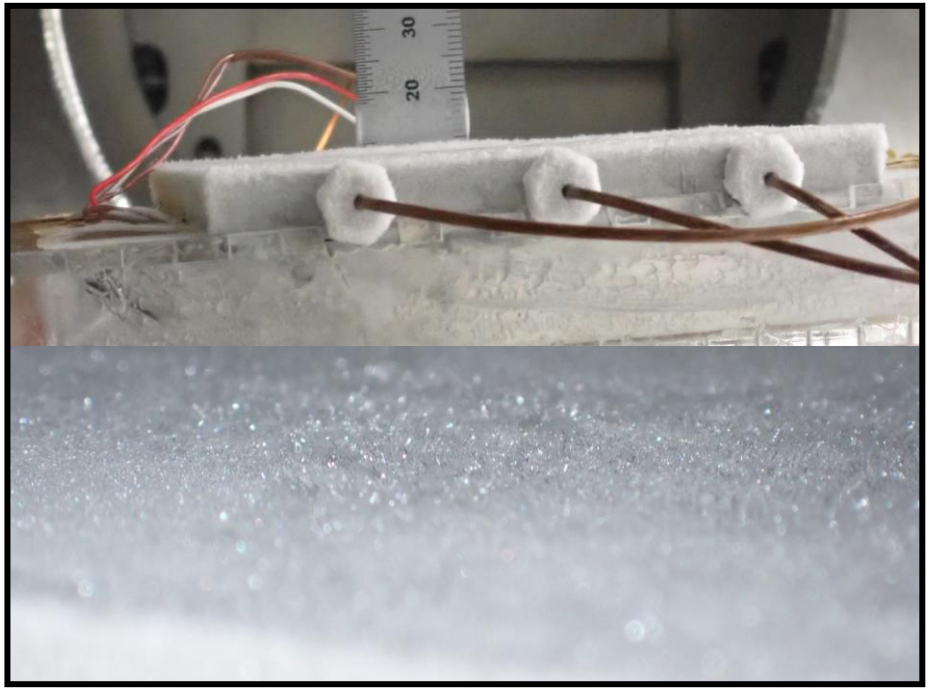
- **T_w range: -3 to -18 °C**



Expected Results

Expected frost characteristics:

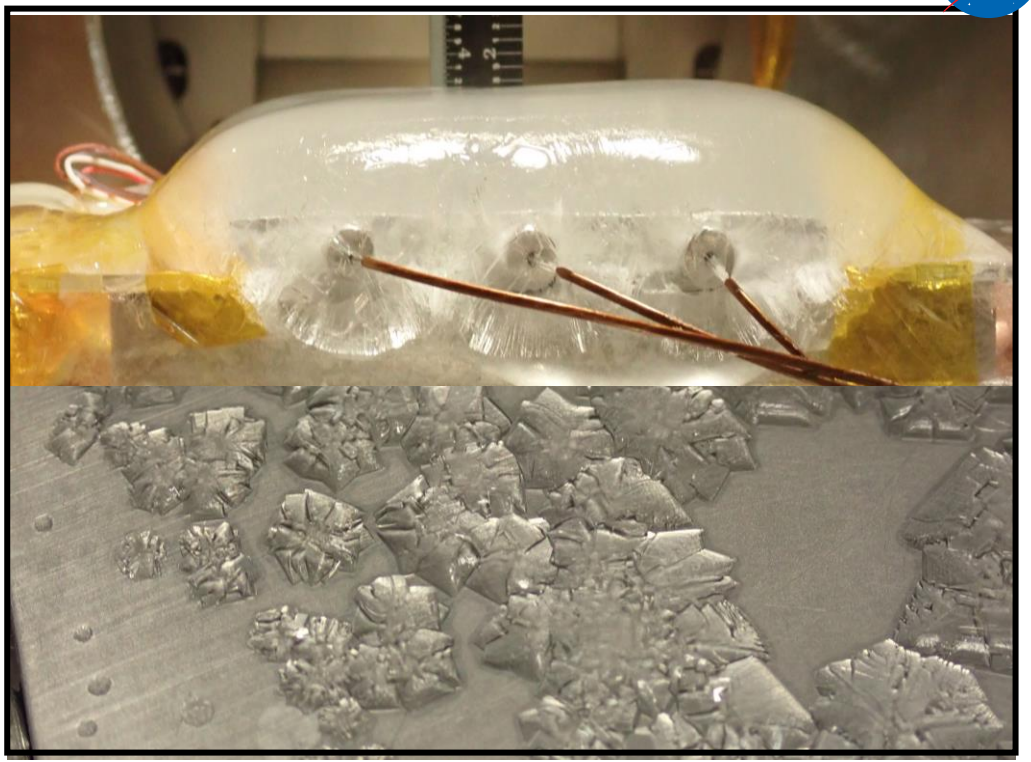
- Porous
- Short height
- Low bulk thermal conductivity



Observed Results

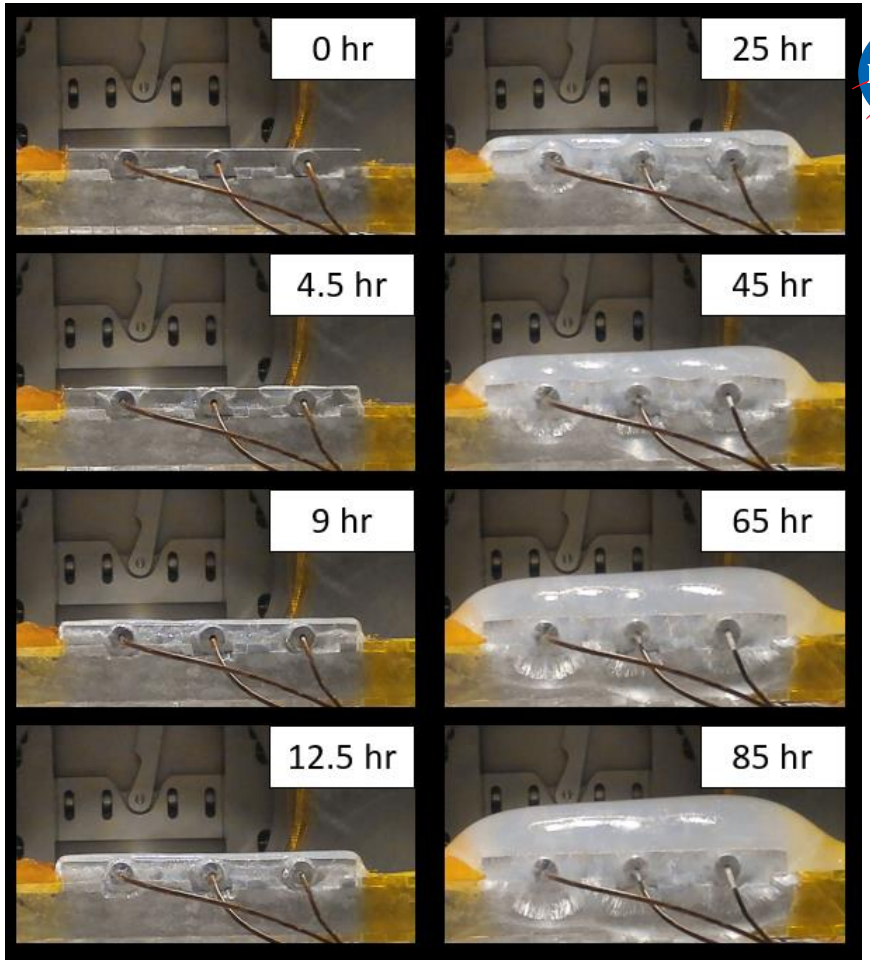
Observed frost characteristics:

- Highly dense (low porosity)
- Tall
- High bulk thermal conductivity



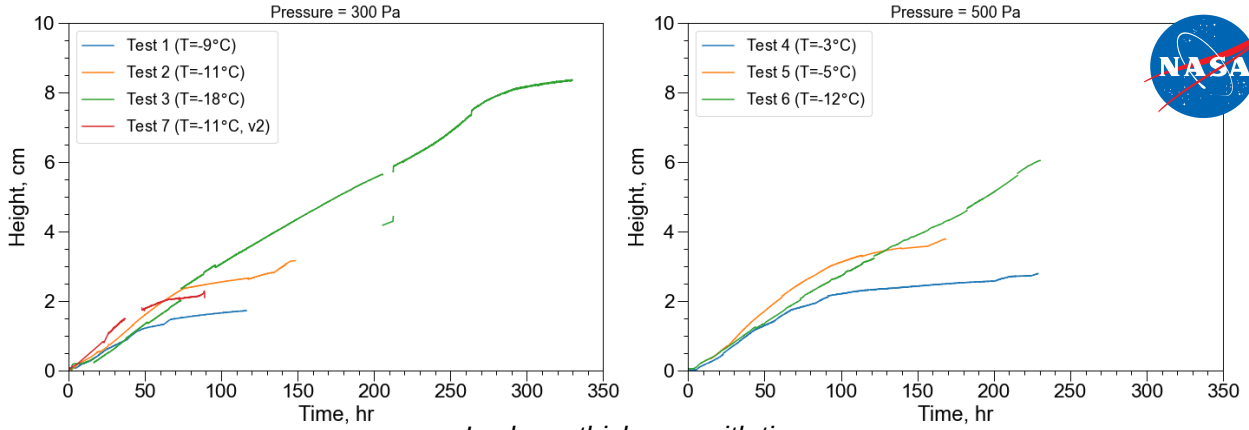
Observed Results

- High density led to high thermal conductivity, and therefore little insulation
- The layer kept growing until hardware failure in many instances

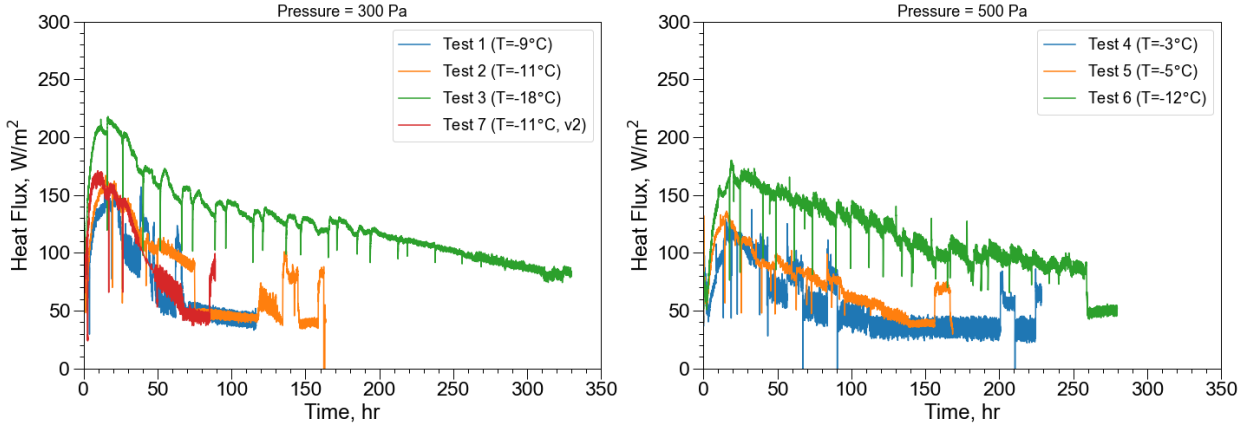


Observed Results

- The height increased linearly until approaching critical heat flux
- The heat flux decreased slower than expected

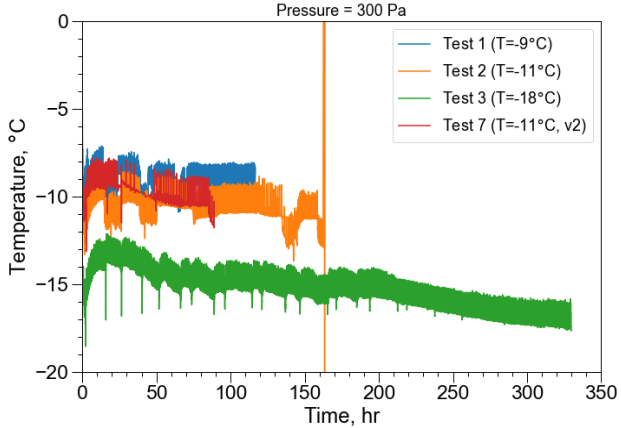


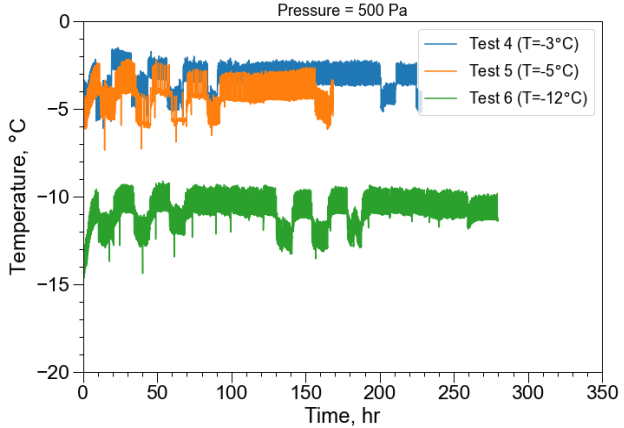
Ice layer thickness with time

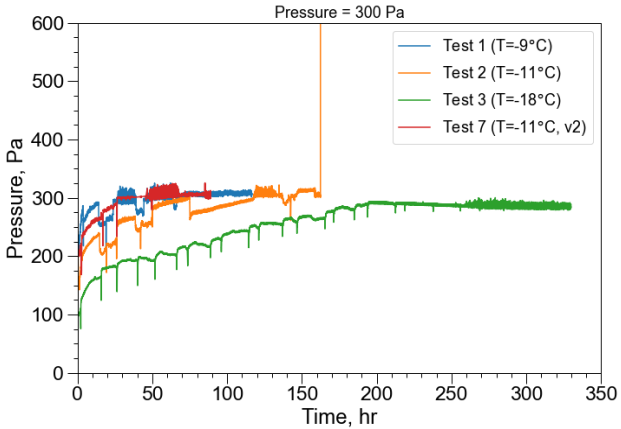


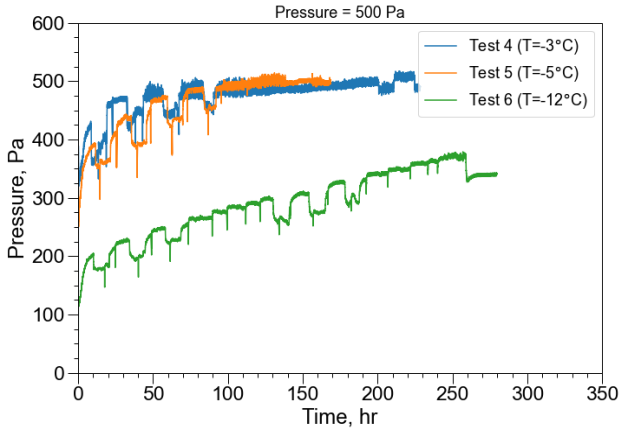
Heat flux with time

Observed Results









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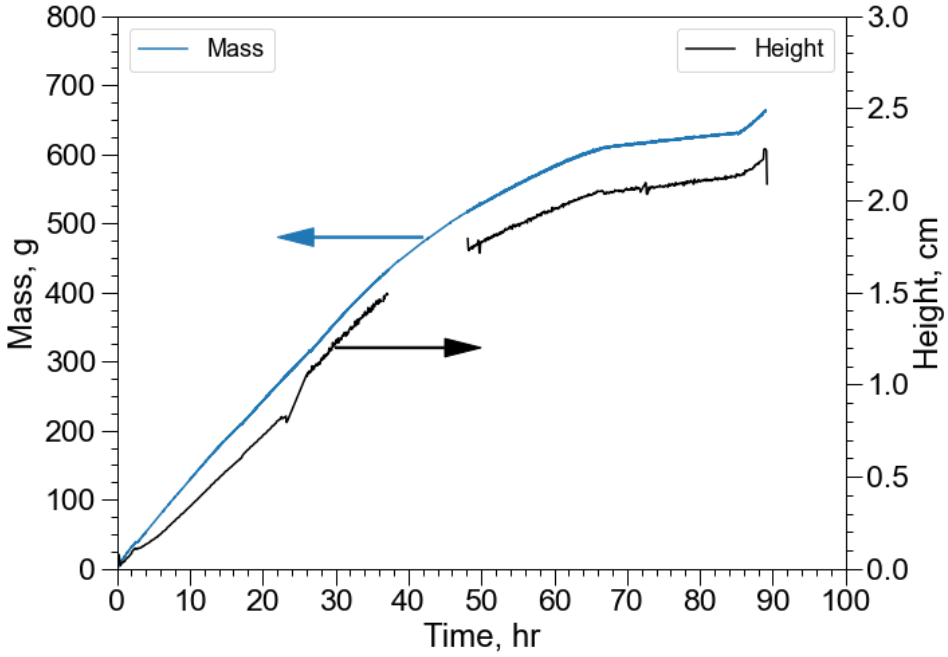
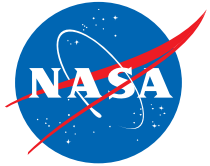


Conclusions

- Water vapor forms denser and clearer ice than expected under low-pressure (300 – 500 Pa) and low-temperature (-18 to -3°C) conditions over long periods (50 – 300 hr)
- The resulting higher thermal conductivity and heat flux is beneficial to ISRU equipment where mass and power consumption are primary concerns
- More studies are needed to understand if these unique results extend to a wider array of conditions:
  - Temperatures
  - Pressures
  - Contaminants
  - Flow rates
  - Plate orientations/geometries


NASA

Experimental Tests

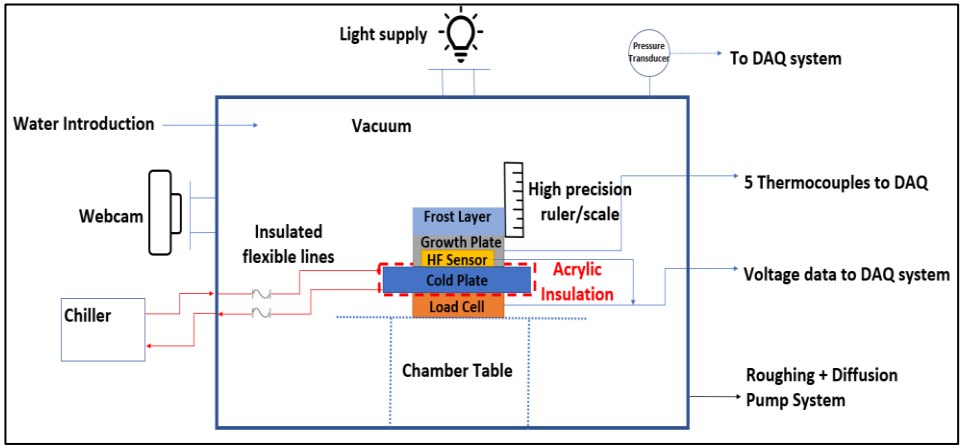
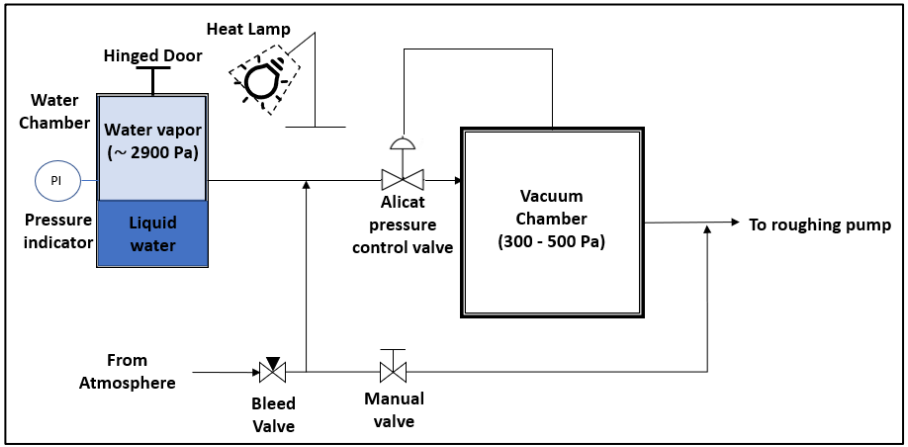


Diagram depicting hardware setup



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