



# Analytical Review of Exploration Extravehicular Mobility Unit Heat Rejection Performance

*"Trade names are used in this presentation for identification only. Their usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration."*



# Agenda

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- Introduction
    - Current Technology
    - Next Generation
  - Hardware and Test Setup
    - Hardware Overview
    - Test Setup
    - Testing
  - Performance
    - SWME Performance
    - Mini-ME Performance
  - Conclusions
  - Acknowledgments
  - References
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# Introduction – Current Technology

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- Active Cooling required for Extravehicular Activities (EVAs)
  - Current EMU (Extravehicular Mobility Unit) uses a sublimator
    - 2 functions:
      - Cools water that has been warmed by crewmember body heat
      - Remove humidity from the ventilation loop
  - Operation: Sublimates solid ice into gas to reject heat from the LCVG (Liquid Cooling and Ventilation Garment) loop to the vacuum of space
    - Exposes liquid water to vacuum through porous plate – freezes layer of water, sealing pores
    - Heat transferred from liquid water to the heat exchanger to the ice, allows gaseous water free movement through pores with latent heat
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# Introduction – Current technology

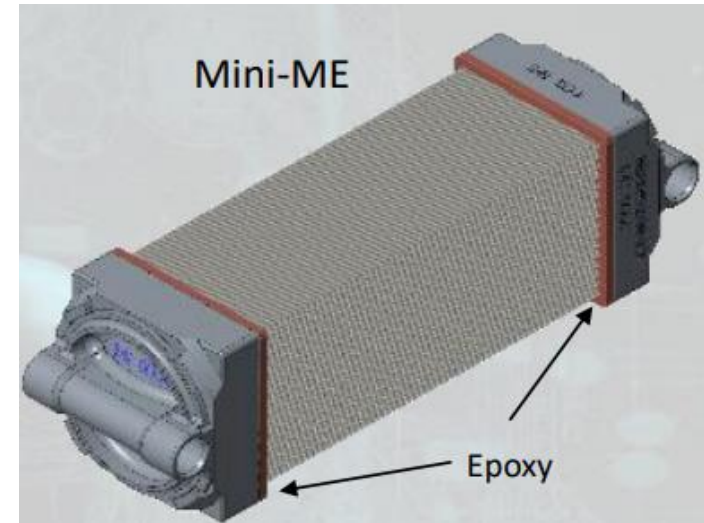
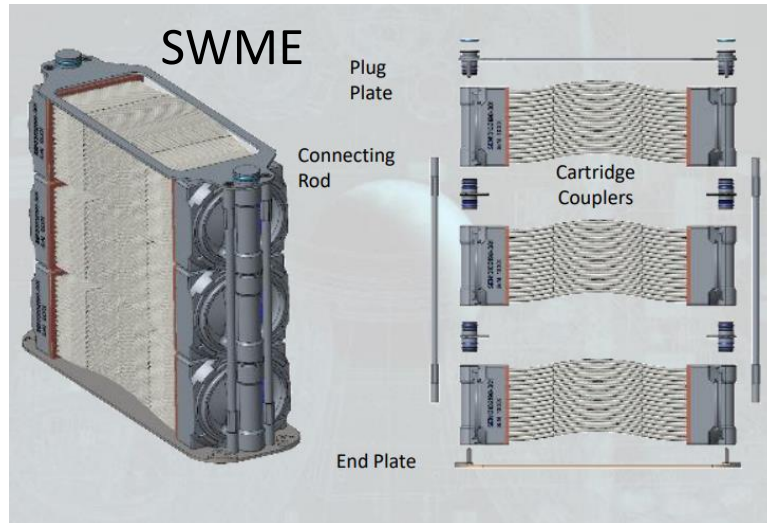
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- Next generation xEMU (Exploration Extravehicular Mobility Unit) uses a primary SWME (Spacesuit Water Membrane Evaporator) and an auxiliary Mini-ME (miniature Membrane Evaporator)
  - Operation: Liquid water in the suit is held in an FSA (Feedwater Supply Assembly) and circulated using water pumps
    - Water drawn out of the bags into the desired cooling loop (Primary or Auxiliary)
    - Water picks up heat from the crew member's body and goes through the SWME or Mini-ME where the water is evaporated rejecting the heat
  - Main differences: EMU has no FSA while the xEMU has an FSA
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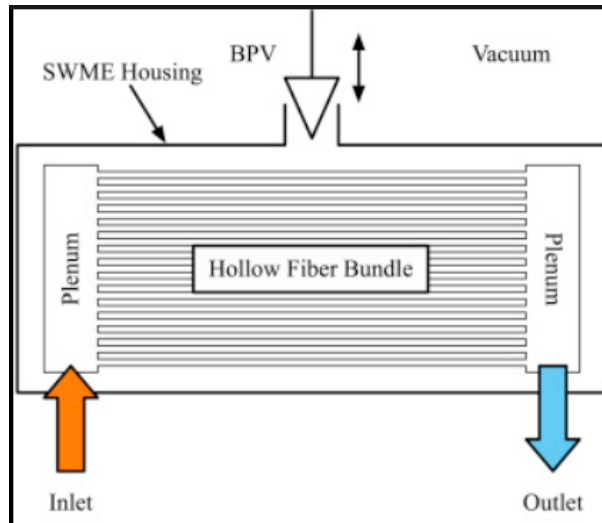
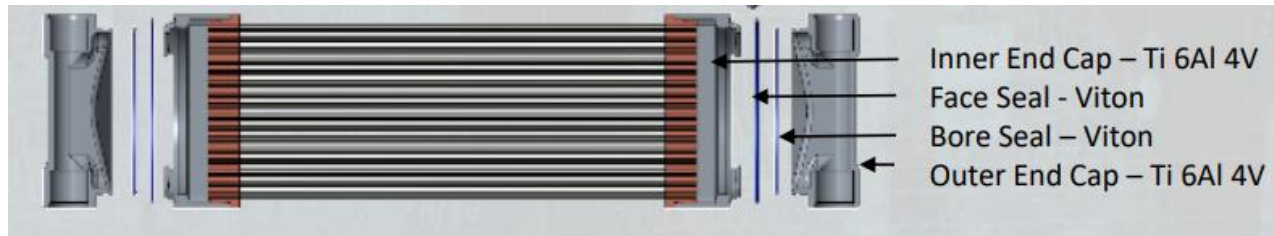
# Hardware Test Setup – Hardware Overview



- Cartridges made of hollow fiber tube for water to flow through
- Mini-ME (auxiliary unit) one third size of SWME (Primary Unit)



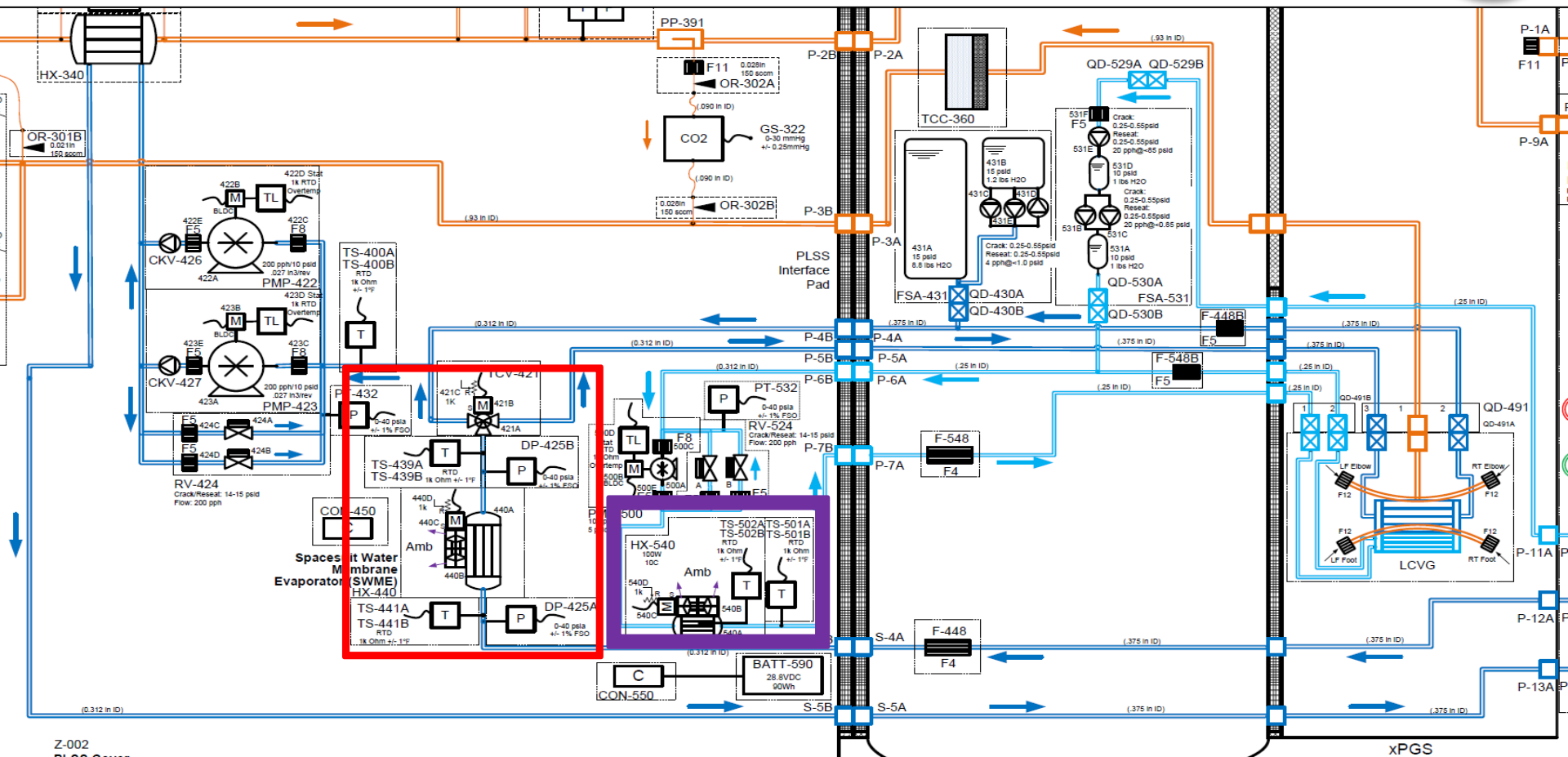
# Hardware Test Setup – Hardware Overview



- Cartridges made of five primary pieces
  - Fiber bundle, inner and outer end caps, face and bore seals
- Water flows through the inlet manifold, through fiber bundles, out the outlet manifold.
- Bundle is exposed to vacuum via the BPV (Back pressure valve) to induce evaporation and opens and closes based on required heating
  - Mini-ME BPV is either full closed or full open.

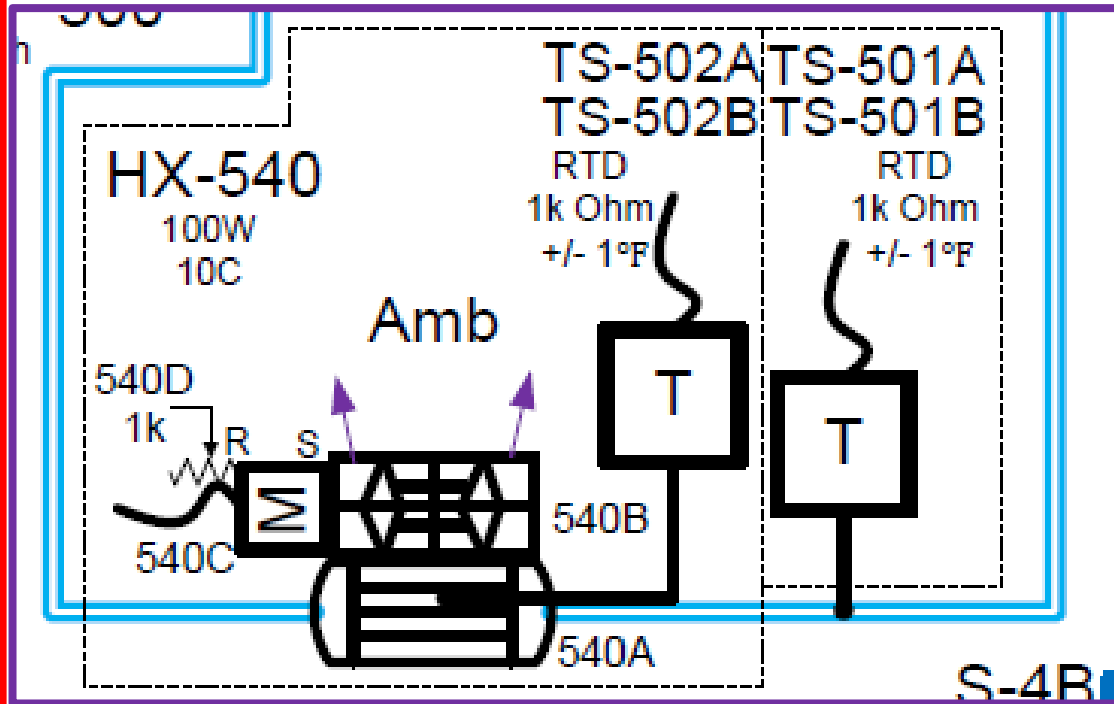
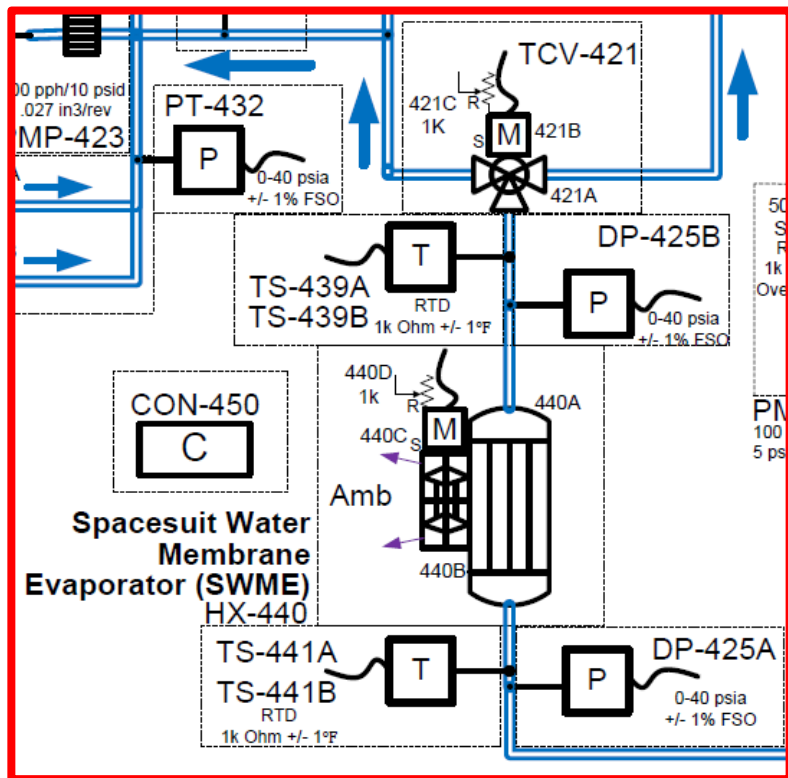


# Hardware Test Setup – Test Setup





# Hardware Test Setup – Test Setup





# Hardware Test Setup – Testing

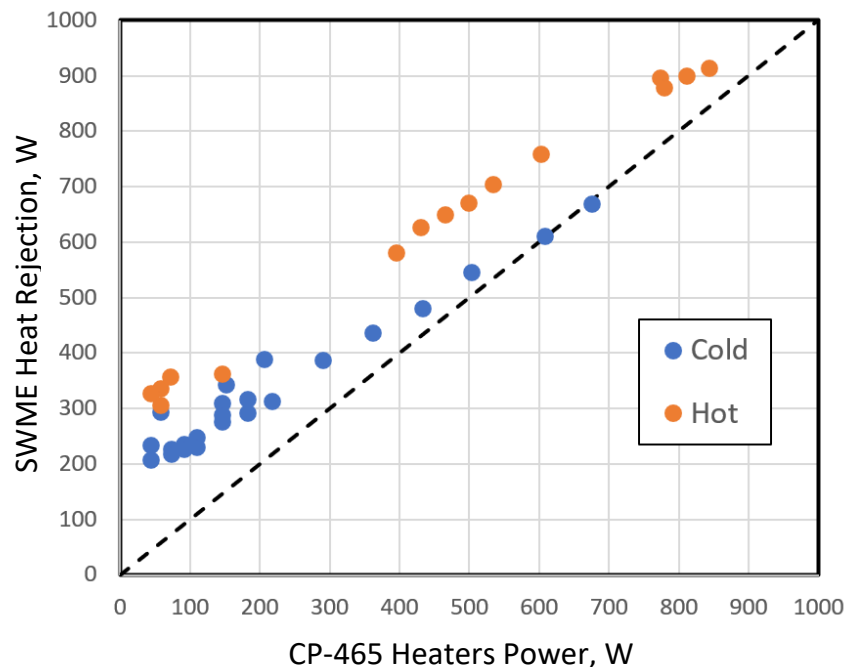
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- Thermal Vacuum testing allowed for maximum SWME and Mini-ME Maximum testing
    - SWME nominal heat rejection requirement is 700W minimum (current released spec)
    - Mini-ME nominal heat rejection requirement is 250W minimum (current released spec)
  - Thermal vacuum was an unmanned test series which required simulated heat input through test system heaters
  - Testing pushed SWME to 900W and the Mini-Me to 350W
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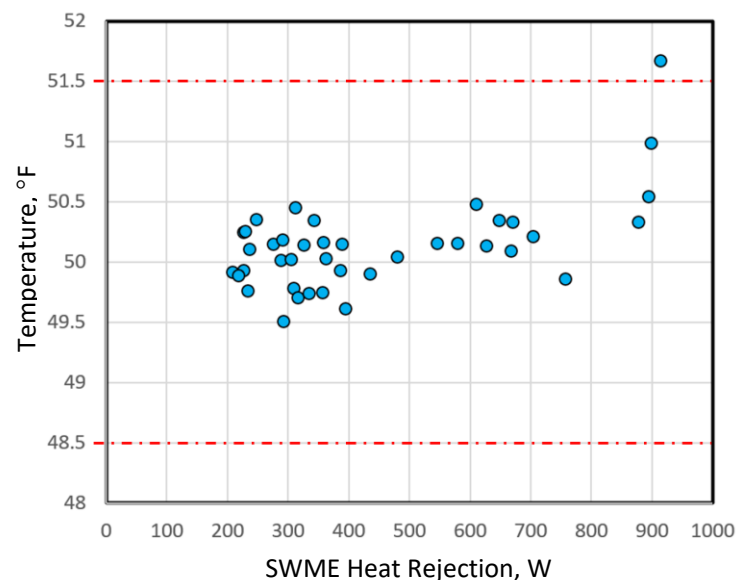
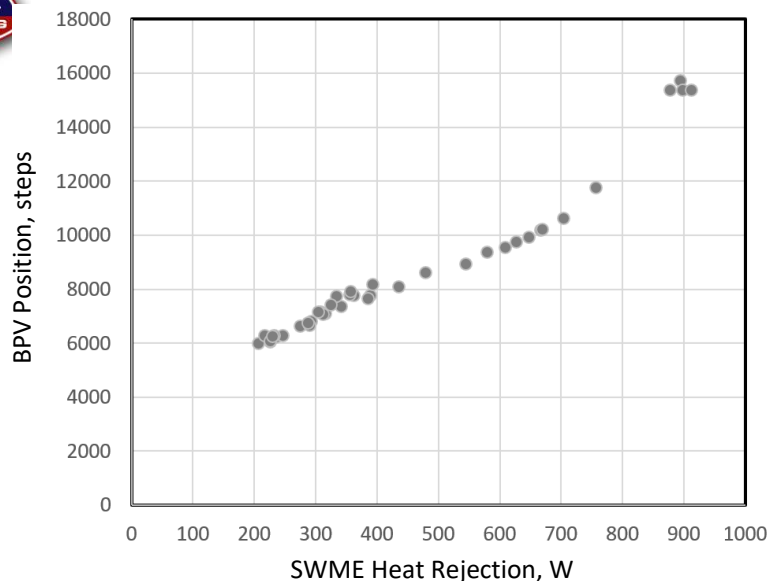
# Performance - SWME



- SWME performed as expected and achieved required output of 10°C consistently.
- During hot cases heat rejection was ~125W higher than cold cases
  - Expected SWME response. Environment heats up, more heat picked up by the PTCL (Primary Thermal Control Loop)



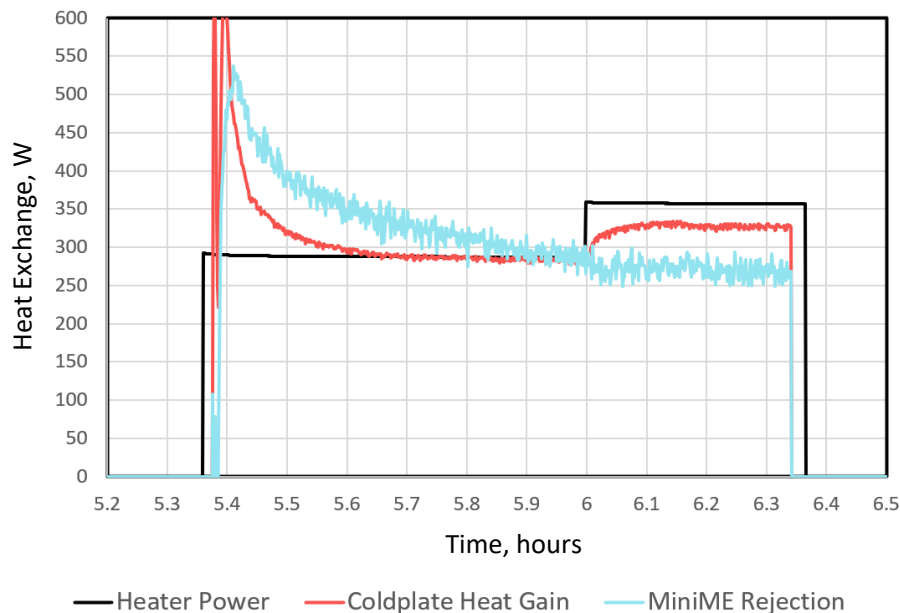
# Performance – SWME (HX\_440)



- BPV and Heat rejection are linearly related
  - Heat rejection increases BPV opens to compensate
- Outliers are at full BPV opening
  - Not on top of each other due to HX\_440 uncertainty
- Full open outliers are ignored for analysis due to the extreme conditions
- HX\_440 required to maintain outlet of  $\sim 10^{\circ}\text{C}$  ( $\sim 50^{\circ}\text{F}$ ) ( $\pm 0.83^{\circ}\text{C}$  ( $1.5^{\circ}\text{F}$ )) variation)
- Only one point saw above  $\sim 10^{\circ}\text{C}$  outlet temperature
  - Not fully steady state
- SWME performed exceptionally well



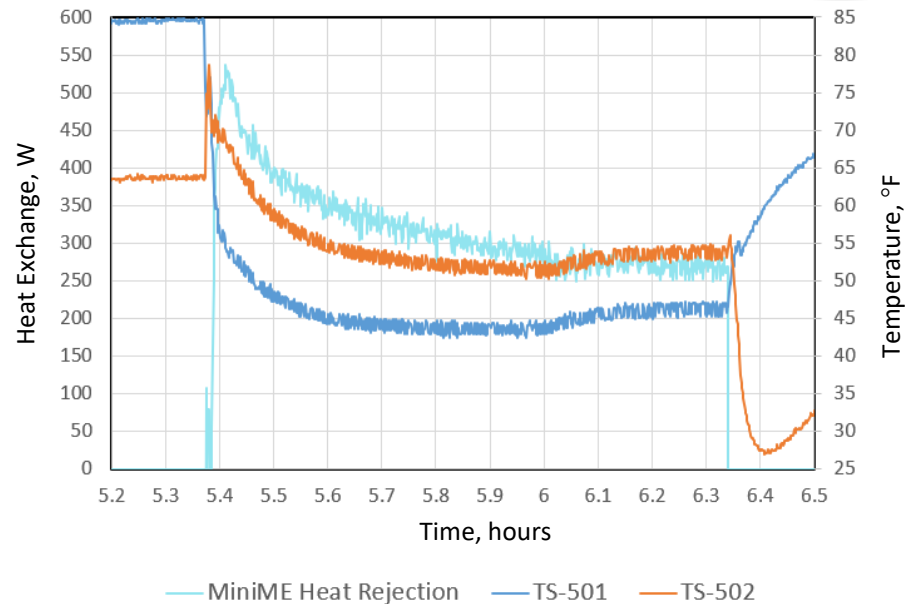
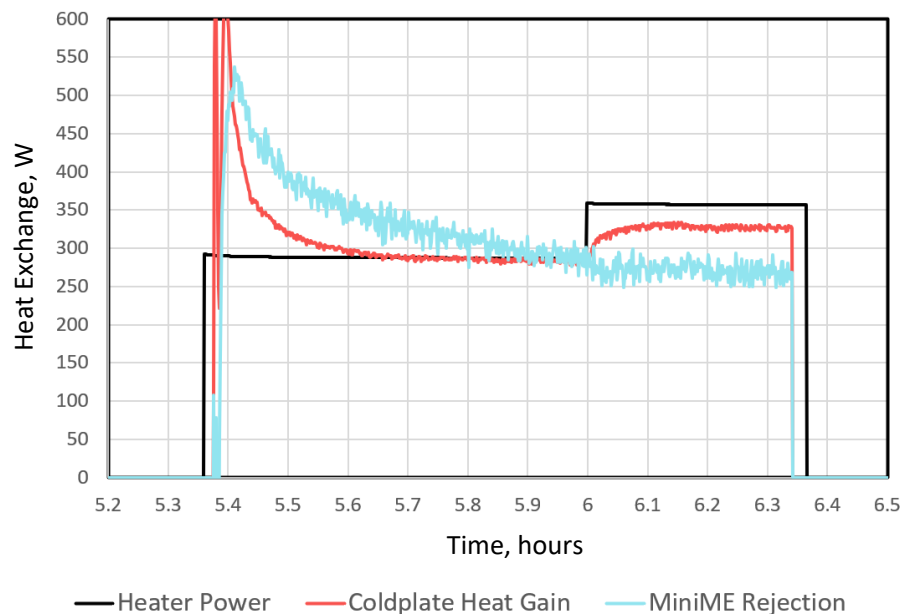
# Performance – Mini-ME (HX\_550)



- Mapping not as in depth due to consumables available in auxiliary loop
- Mini-ME, like SWME, also showed strong performance
- Unexpected trend attributed to steady state not being achieved at first injection point



# Performance – Mini-ME (HX\_550)



- Mapping not as in depth due to consumables available in auxiliary loop
- Mini-ME, like SWME, also showed strong performance
- Unexpected trend attributed to steady state not being achieved at first injection point
- Designed to operate at max of 250W with max water outlet of below 10.5°C
- Designed to operate at max of 250W with max water outlet of below 10.5°C (51°F)
- Exceeded expectations with 6.66°C (44°F) outlet at 300W and 7.77°C (46°F) at 350W
- BPV full open, cannot adjust heat rejection



# Conclusions

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- SWME and Mini-ME outperformed their heat rejection requirement
  - Due to the successful mapping, it has been solidified that both the SWME and Mini-ME do not require any further design work on heat rejection
  - Heat rejection success was a wonderful highlight to thermal vacuum testing
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# Acknowledgements by Authors

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    - Kathryn Robertson
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-