Extended Length Helium Pulsating Heat Pipes

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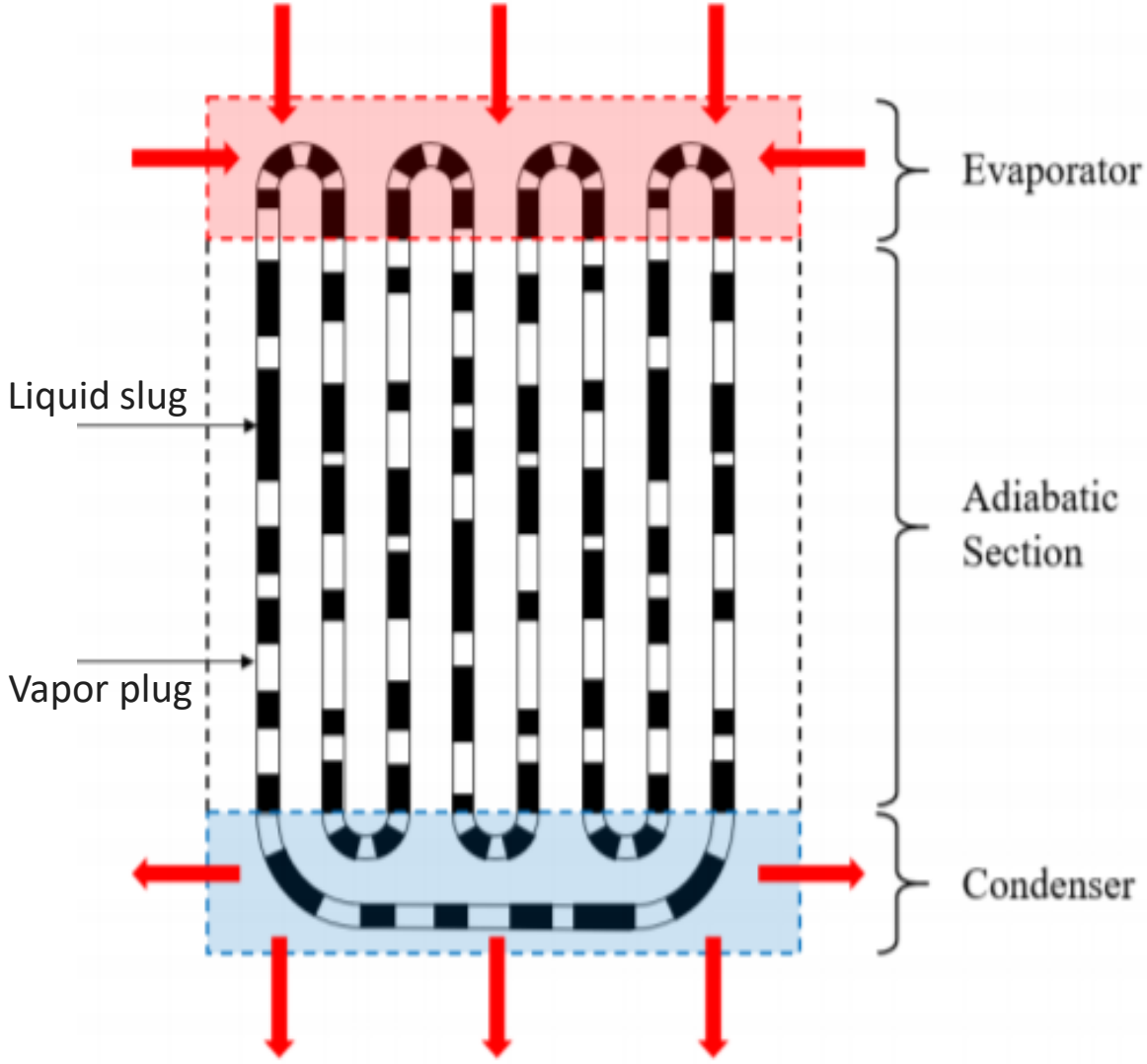
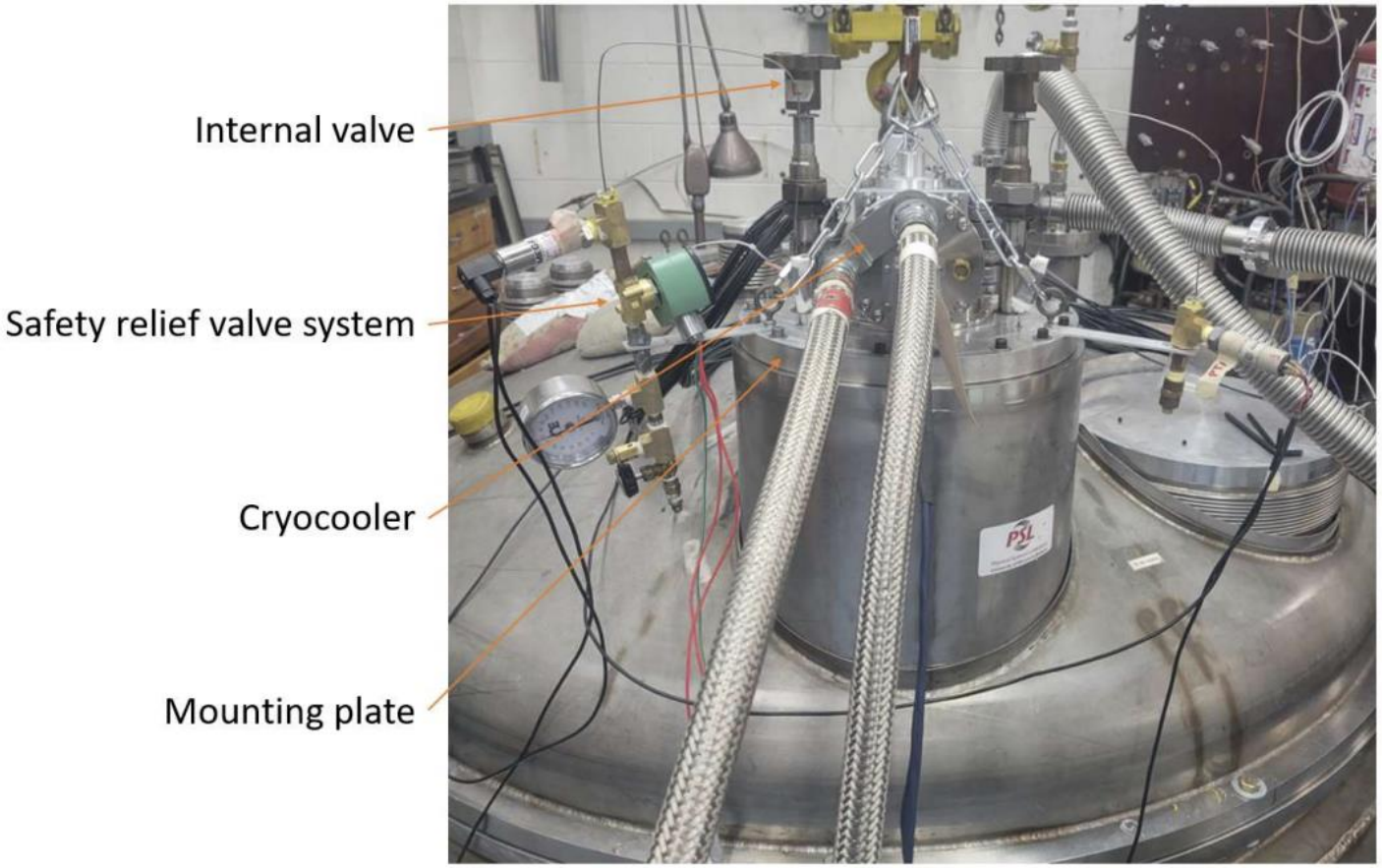
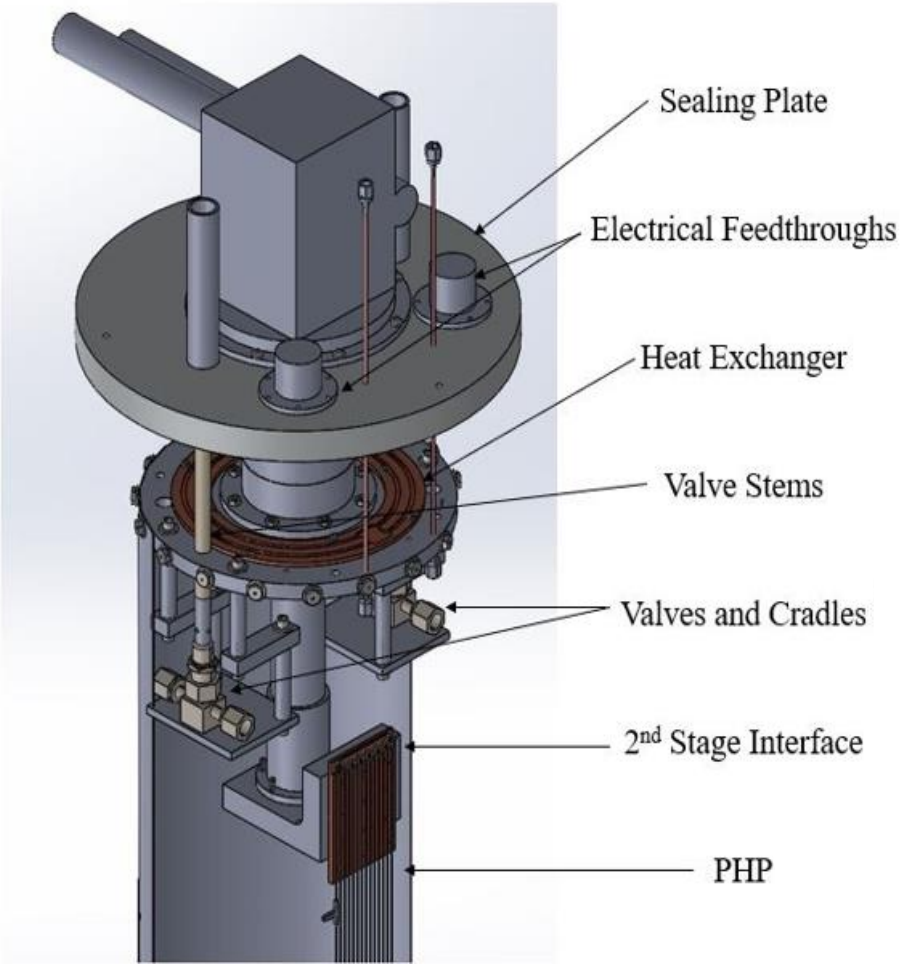
PHP Background

- Small capillary tubing loop that turns back and forth several times
- ID such that two-phase fluid is forced into a plug-slug regime
  - Bond number < 2
- Helium PHP applications:
  - Zero boil-off fuel storage
  - Large space telescopes
  - Extends the cooling distance of cryocoolers without compromising cooling capacity



Experimental Set-up





Experiment Specifications

PHP:

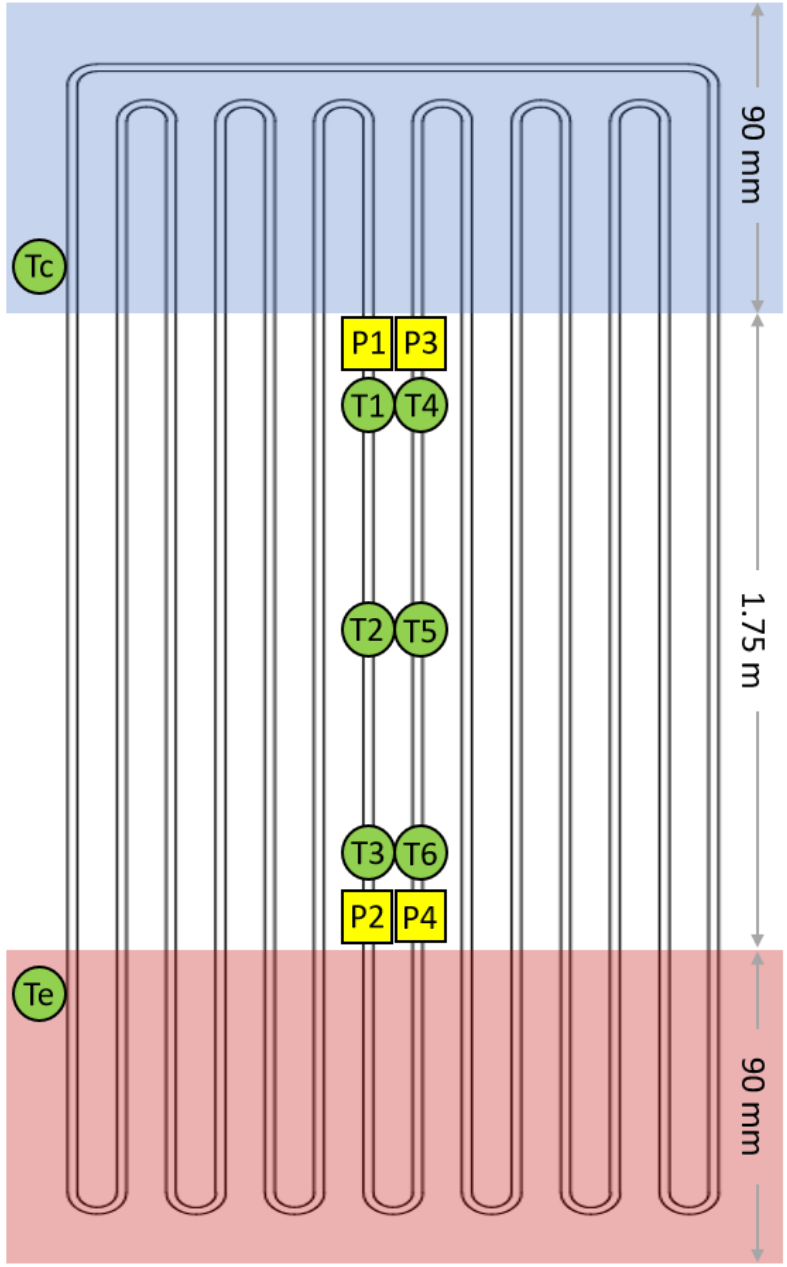
- 7 turns
- Adiabatic length: 1.75 m
- 90 mm evaporator and condenser lengths
- 0.5 mm tube ID
- Vertically oriented

Equipment:

- SHI RDK-415D2
- Cernox CX-1050-CU-HT-1.4L
- Omega PX419-050A5V

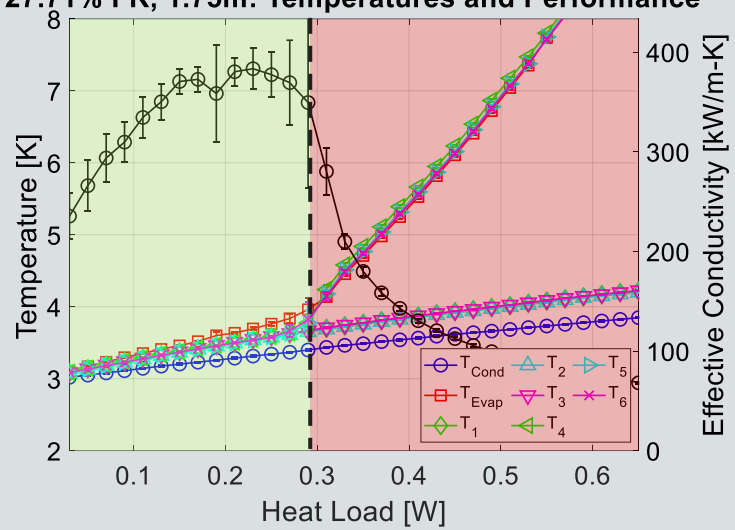
$$k_{eff} = \frac{\dot{Q}L}{NA_c(\bar{T}_{evap} - \bar{T}_{cond})}$$

$$FR = \frac{V_l}{V_{PHP}}$$



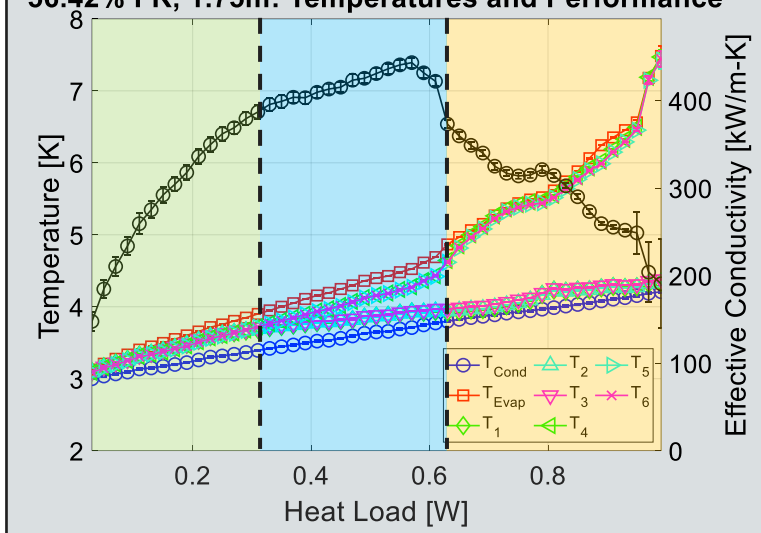
Progressively Increasing Heat Load

27.71% Fill Ratio



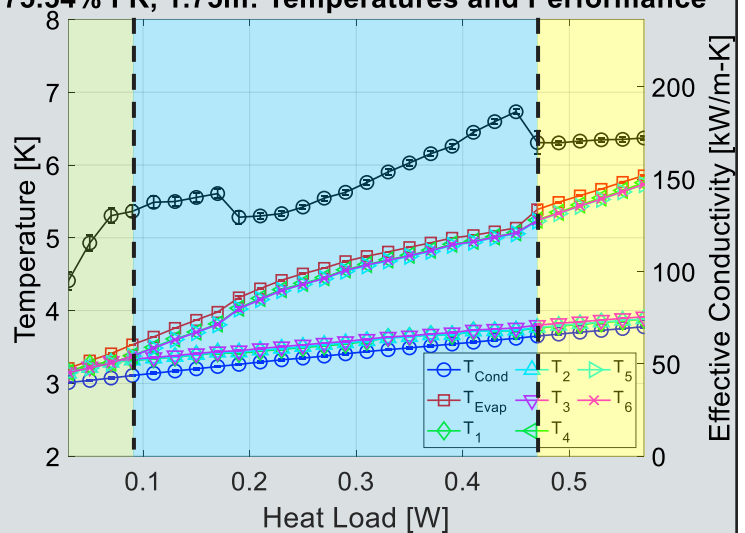
- Good performance at low heat load
- Hot tube dry-out at 290 mW
- Adjacent tube remains two-phase

56.42% Fill Ratio



- Optimal fill ratio
- Cold tube subcooled at 310 mW
- Hot tube superheated at 630 mW
- **443.4 kW/m-K at 610 mW**

75.54% Fill Ratio



- Poor performance
- Cold tube subcooled at 90 mW
- Hot tube supercritical at 470 mW

Both tubes two-phase

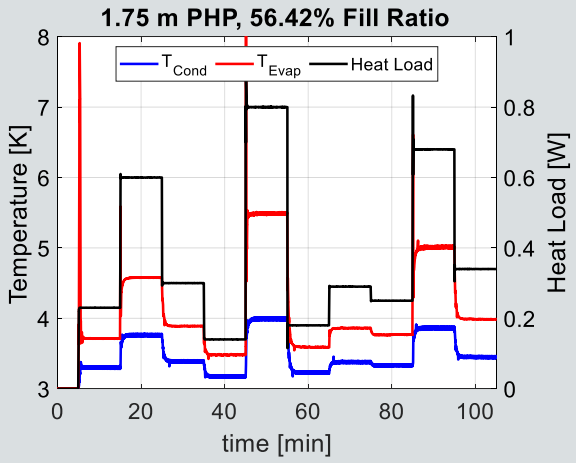
Cold tube two-phase, hot tube superheated

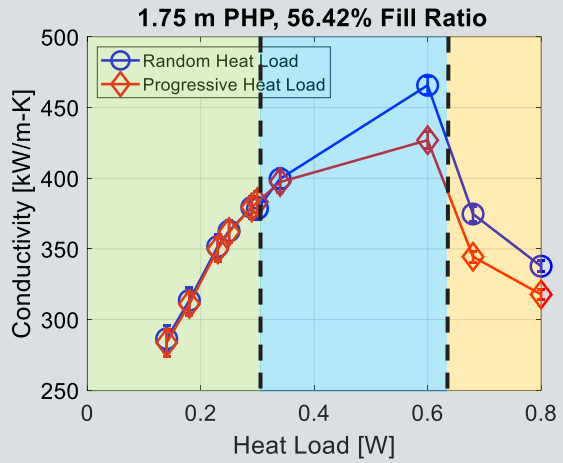
Cold tube subcooled, hot tube two-phase

Cold tube subcooled, hot tube superheated

Cold tube subcooled, hot tube supercritical

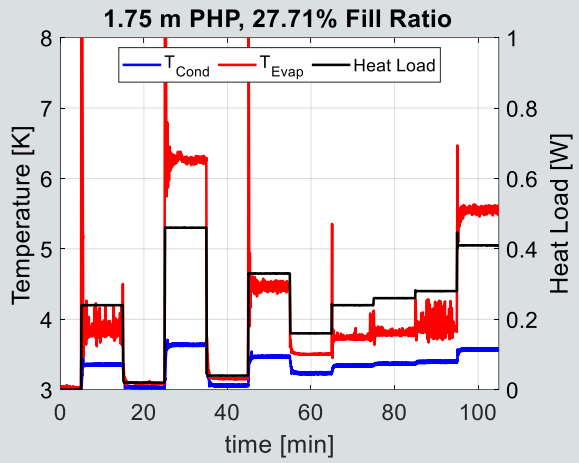
Randomized Heat Load

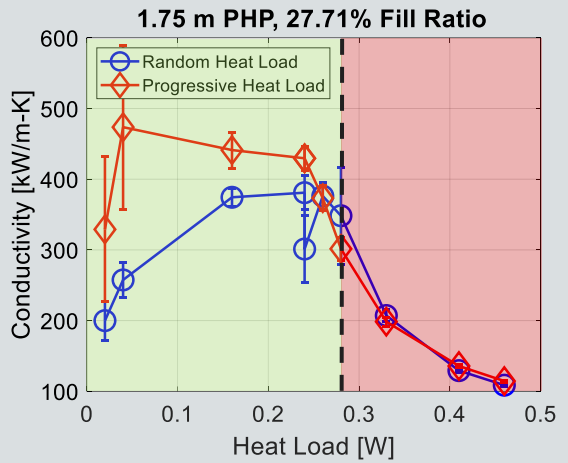




- Small evaporator oscillations
- **Performance matches in high-performance regions**
- Small difference at high heat loads
- No thermal runaway

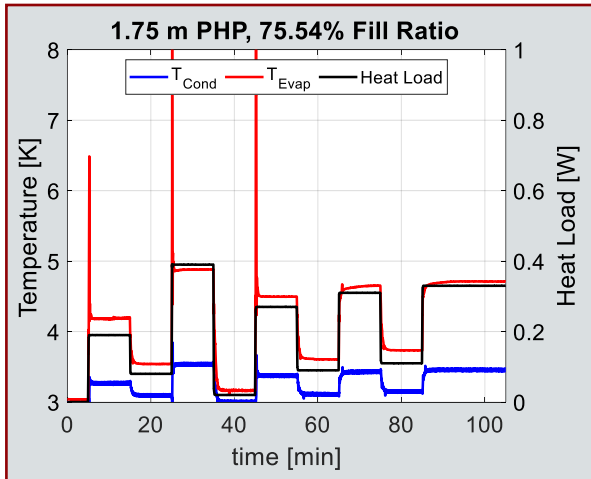
56.42% Fill Ratio

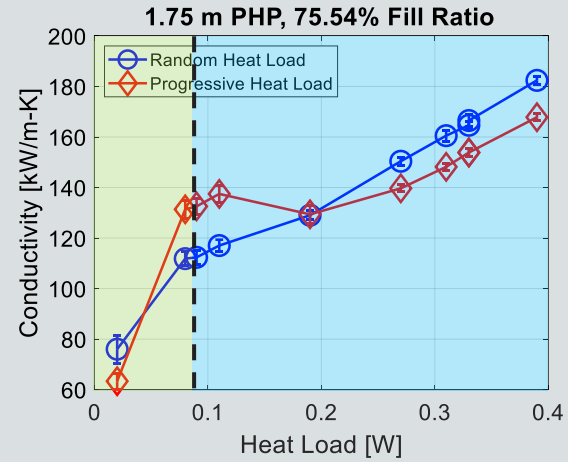




- Large evaporator oscillations
- Performance lower for randomized heat
- No thermal runaway

27.71% Fill Ratio



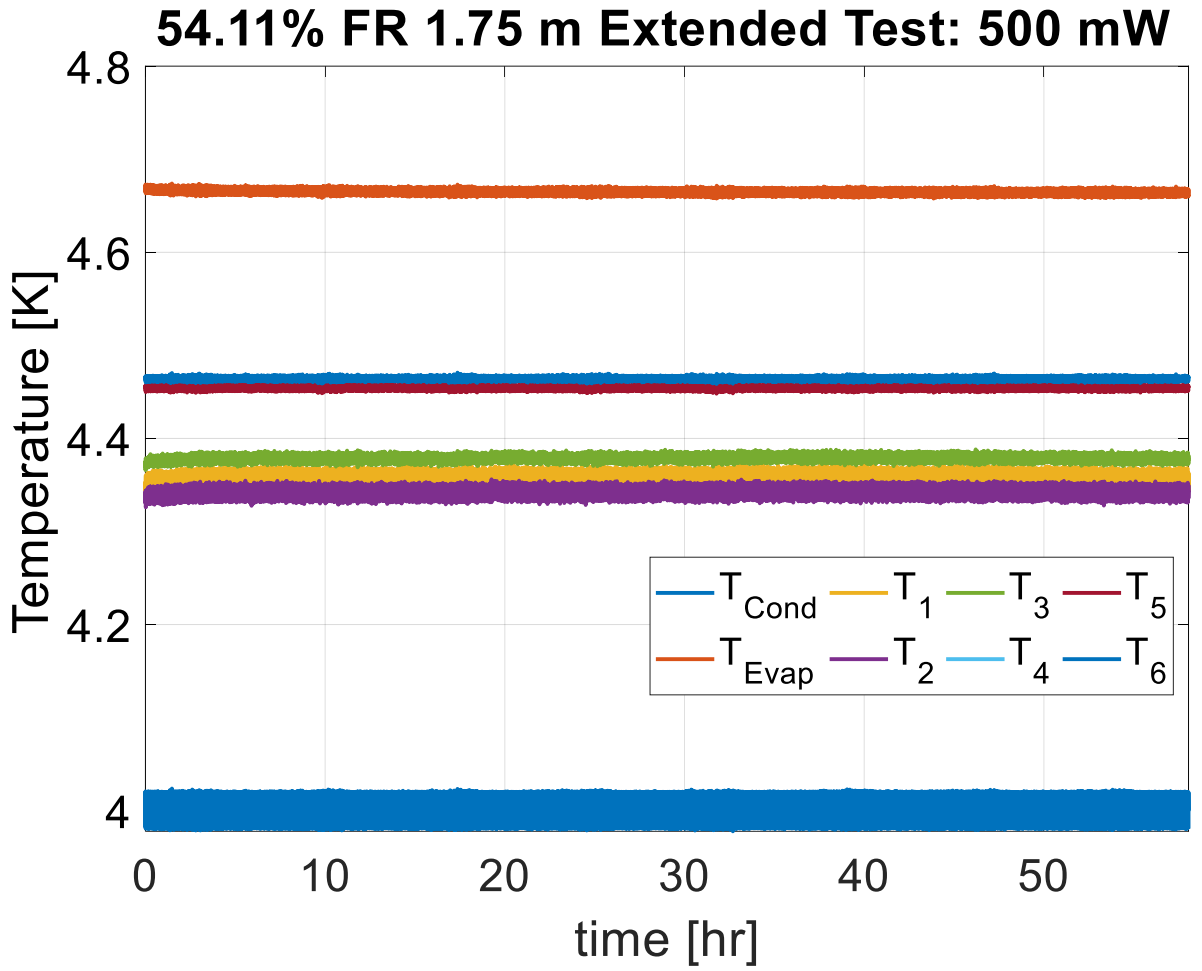


- Small evaporator oscillations
- Performances somewhat match
- No thermal runaway

75.54% Fill Ratio

Extended Period Test

- 58 hours with continuously applied heat load of 0.5 W
- Stable and steady performance and temperatures with no degradation
- Cold tub subcooled, hot tube two-phase
- Condenser temperature controlled at 4 K



Conclusions

- Helium PHPs can operate with excellent thermal performance for adiabatic lengths up to 1.75 meters
- Phase change is different for alternating tubes and depends on the fill ratio
- With the optimal fill ratio, the performance is not history dependent and large jumps in heat load do not induce thermal runaway
- Long-term operation of extended length helium PHPs is stable

Questions?

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