Demonstration of Copper-Water Heat Pipes and HiK™ Plates on the International Space Station (ISS)

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Presentation Outline

- Motivation
- Background
- ISS Flight APTx Experiment
- Results
- Conclusion
- Acknowledgment
Copper/water heat pipes and HiK™ plates are very commonly used for thermal management of electronics equipment on earth.

But have not been used in spacecraft thermal control applications due to the satellite industry’s requirement that any device or system be successfully tested in a microgravity environment prior to adoption.

ACT has achieved space flight heritage for its copper/water heat pipes and High Conductivity (HiK™) plates following the successful thermal testing on board the International Space Station (ISS).
Background: Copper-Water Heat Pipes

- **Benefits:**
  - Reliable, proven
  - High performance
  - Ground testable
  - Easy integration
  - Cost effective

- **ACT Capabilities**
  - Proven prototype & volume
  - Demonstrated capacity > 250,000 per year

- **Qualification / Space Readiness**
  - Freeze/Thaw tolerant
  - Shock/Vibe tolerant
  - Flight hardware tested on the ISS

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HiK™ plates have copper/water or copper/methanol heat pipes
- Flatten, solder in machined slots
- Can withstand thousands of freeze/thaw cycles
- Operate up to 12 inches against gravity (if water is used)

Effective thermal conductivity of 500 – 1200 W/m K for terrestrial applications, up to 2500 W/m K for spacecraft

Identical dimensions, 22°C reduction in peak temperature measured
NASA Marshall and NASA Johnson worked on an ISS flight experiment with components supplied by ACT.

Experimental configuration – 2 experiments
- Payload #1: VCHP with HiK™ plate – designed so that heat is delivered to the VCHP, whether or not the HiK™ plate works.
- Payload #2: Separate HiK™ plate

Envelope/Working Fluid Selection
- Monel-Copper/water for VCHP
- HiK™ plates with embedded copper/water heat pipes
The ISS test rack has a lower and an upper section.
- The lower section has a PCHX fluid loop from a previous PCM module test.
- PCHX loop currently on the ISS, with duplicate loop on ground
- The dimensions of the upper section, where our experiment would fit is 14” x 13.5” x 7.5” high
HiK™ Plate for the ISS Experiment in Payload 2: Ground Testing

- Two 53W (2” x 3”) silicon heaters will be used as a heat source on the top of the HiK™ plate.
- A chiller block was used to impose sink temperatures between -10 to 40° C
- Freeze/thaw testing was performed for the HiK™ plate on the ISS.
- Each HiK™ plate had 9 copper/water heat pipes. Each heat pipe can carry up to 65 W at 70 °C before dryout due to the capillary limit.
- Freeze thaw tests were conducted from temperature ranging from -30 to +70°C for two of the HiK™ plates.

- The plates were subjected to 15 freeze/thaw cycles.

- The embedded copper/water heat pipes can sustain these freeze/thaw cycles without damage.
Microgravity Testing of Payload 2 on the ISS

- Freeze/thaw testing was performed successfully for the HiK™ plate on orbit.

- The freeze/thaw tests were conducted for the HiK™ plate from temperature ranging from -10° C to approximately 40° C.

- Fourteen cycles of freeze-thaw and freeze-startup-thaw cycles were performed on orbit.
The following was demonstrated during 10 days of testing on the ISS:

- Successful operation of the copper-water heat pipes and HiK™ plate.
- Ability of the copper-water heat pipes and HiK™ plate to survive multiple freeze/thaw cycles.
- Copper-water heat pipes can carry the required power.
- Copper-water heat pipes and HiK™ plate can start up from a frozen state.
Conclusion

- ACT Inc., NASA Marshall Space Flight Center and NASA Johnson Space Center, worked together to test HiK™ plates in the ISS microgravity environment.

- Two HiK™ aluminum base plates were designed, fabricated, and tested successfully in ground and on the ISS.

- The flight test verified the operation of the HiK™ plates with the embedded copper/water heat pipes in micro-gravity environment.
Conclusion

- In the ISS test for payload 2, the copper-water heat pipes were embedded in a HiK™ plate, and subject to a variety of thermal tests over a temperature range of -10 to 40 °C for a ten-day period.

- Results showed excellent agreement with both predictions and ground testing results.

- The HiK™ plate underwent 15 freeze-thaw cycles between -30 and 70 °C during ground testing, and an additional 14 freeze-thaw cycles during the ISS test.

- This flight test on-board ISS is an important step toward qualifying copper/water heat pipes as a passive thermal management solution in support of future human and robotic space exploration missions by NASA.
### Acknowledgements

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- Mr. Angel Alvarez-Hernandez and Dr. Jeffery Farmer are the APTx NASA’s principal investigators.
Questions?

Thank you for your attention!