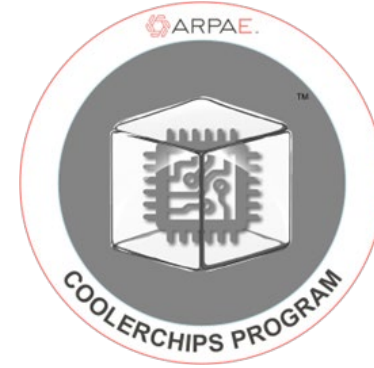




Dual-mode Hybrid Two-phase Loop for Data Center Cooling

Chanwoo Park (PI), University of Missouri

We developed a dual-mode hybrid two-phase loop technology that delivers outstanding cooling performance for data centers, combining high heat-flux capability, low thermal resistance, high energy efficiency, a compact and reliable design, orientation independent operation, and a fully-scalable architecture capable of supporting future 1 MW racks.

Problem/Set up

- AI servers consume high power (>1 kW per GPU), driving the need for advanced cooling solutions.
- Conventional cooling methods, including traditional liquid cooling, are no longer sufficient for rising AI thermal loads.
- Two-phase cooling offers major advantages, such as low thermal resistance and negligible power consumption.
- Thin-film evaporation stands out among two-phase cooling methods for its ability to meet these high cooling demands.
- Passive, capillary-driven thin-film evaporation in a microporous layer enables both low thermal resistance and high heat-flux cooling.

Solution/Product/Technology Description and Impact

- The dual-mode HTPL integrates a loop thermosiphon, loop heat pipe, and pumped two-phase loop, offering high heat flux, low pumping power, robust operation, orientation independent, and scalable architecture.
- In passive mode, the loop thermosiphon is ideal for standby or low-demand operation, requiring no power. Under higher loads, it switches to active mode (pumped two-phase loop) while keeping pumping power minimal.
- Capillary-driven thin-film evaporation in a microporous layer lowers thermal resistance and enables high heat flux, with an evaporator design that supports excellent scalability.

The Megawatt Rack

- Demonstration of 5-kW/1U server corresponds to a 210-kW rack system.
- The current design can be readily scaled to 500-kW rack system.
- With further design optimization, a 1-MW rack system is achievable.

System Integration Results and Midterm Milestone (1)

5-kW dual-mode HTPL for a mock 1U-server was demonstrated, meeting the COOLERCHIPS key performance targets.

- Total (chip surface to facility water) thermal resistance: $< 0.01 \text{ K/W}$
- Power density (for 126 kW rack): 115 kW/m^3
- Pumping power consumption: 0.82% (secondary loop: active, passive 0%) and 2.60% (total: combined secondary and primary loops) of IT power.
- Working fluid: water at an operating temperature of $> 60^\circ\text{C}$ mitigating microbial growth
- Full-scalable and orientation-insensitive evaporator design

What is Next: Detail of Upcoming Tasks

10 kW dual-mode HTPL system is planned for demonstration in 2026.

- Two-phase cooling of 10+ kW/1U for primary heat sources (GPU/HBM)
- Liquid cooling (700 W TDP) for auxiliary heat sources (CPU/HBM)
- 11-kW Coolant Distribution Unit (CDU) will be utilized.

What is Next: Timetable

**Components
(Q1-Q4)**

- **Component-level** design and performance measurements
- Thermal interface materials, condenser, evaporator
- Status: **Completed**

**3-kW
system
(Q5-Q8)**

- **3-kW rack-level** dual-model HTPL demonstration
- Multiple, large evaporators (1U form factor) using simulated heat sources
- Short-term reliability study (100 hrs)
- Status: **Completed**

**10-kW
System
(Q9-)**

- **10-kW rack-level** dual-model HTPL demonstration
- Multiple, large evaporators (1U form factor) using simulated heat sources
- Long-term reliability study (1000 hrs)
- Status: **In Progress**

Derisking Critical Components: TIM and Active Components

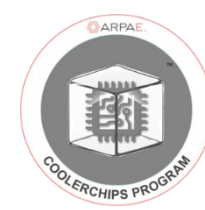
- The selected TIMs was simultaneously tested for over 2500 hr under steady-state and cycling conditions with different temperatures and pressures using a modified ASTM D-5470 test apparatus.
- Pump and evaporator have been evaluated for long-term reliability.

Needs/The Ask: Funding, Partnerships, Advisors

Needs on Partnerships

- Funding for full-scale rack system (>100 kW) demonstration
 - 10-kW system demonstration planned in 2026.
- OEM and suppliers
- Manufacturing
- Advisory board

Team



Project Name: Dual-mode hybrid-two-phase loop for data center cooling

Team Members and Roles



University of Missouri

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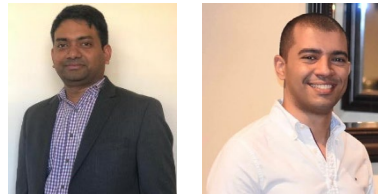


- Dual-mode HTPL development



Advanced Cooling Technologies, Inc.

Srujan Rokkam (Engineering Manager)
Ramy Abdelmaksoud (Project Engineer)



- 10 kW CDU development
- 10 kW system evaluation
- Tech-to-Market



National Renewable Energy Lab.

Douglas Devoto (Senior Research Engineer)
Paul Paret (Research Engineer)



- TIM thermal resistance measurement
- Reliability study
- 10 kW system long-term evaluation