COOLING:
COLD PLATE



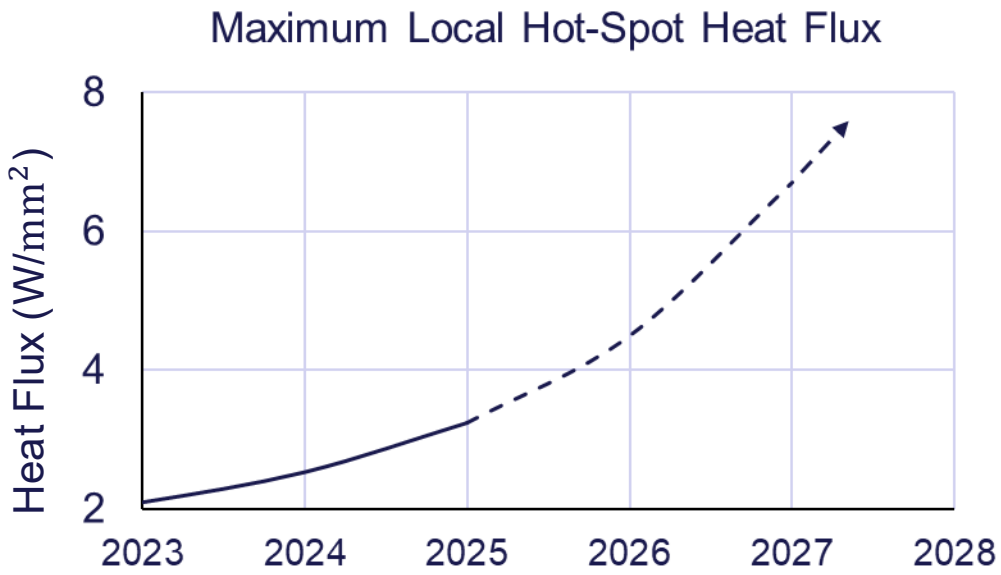
A Novel Liquid Cooling Solution:
A Negative-Pressure Two-Phase Water-Boiling Cold Plate with Enhanced Thermal Performance

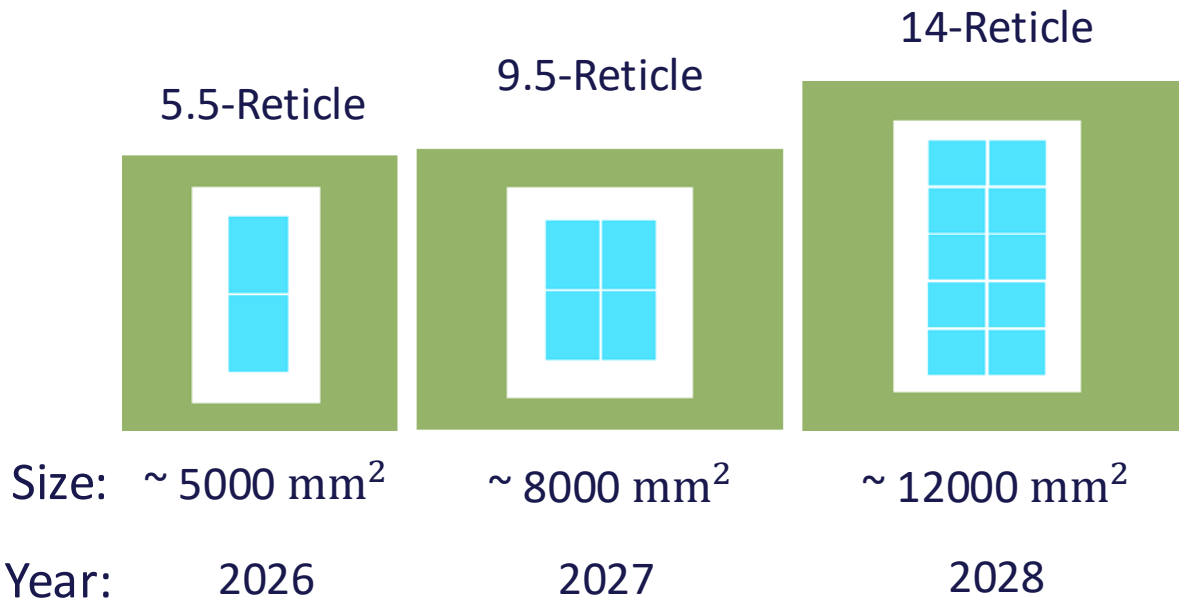
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Cooling Demands Continue to Increase

- GPU local heat flux increases exponentially
- Chip size increases concurrently, leading to a sharp rise in the amount of coolant required





Thermal Properties of Negative Pressure Water Boiling

- Water latent heat depends on operating pressure (saturation temperature), but remains an order of magnitude higher than typical refrigerants.

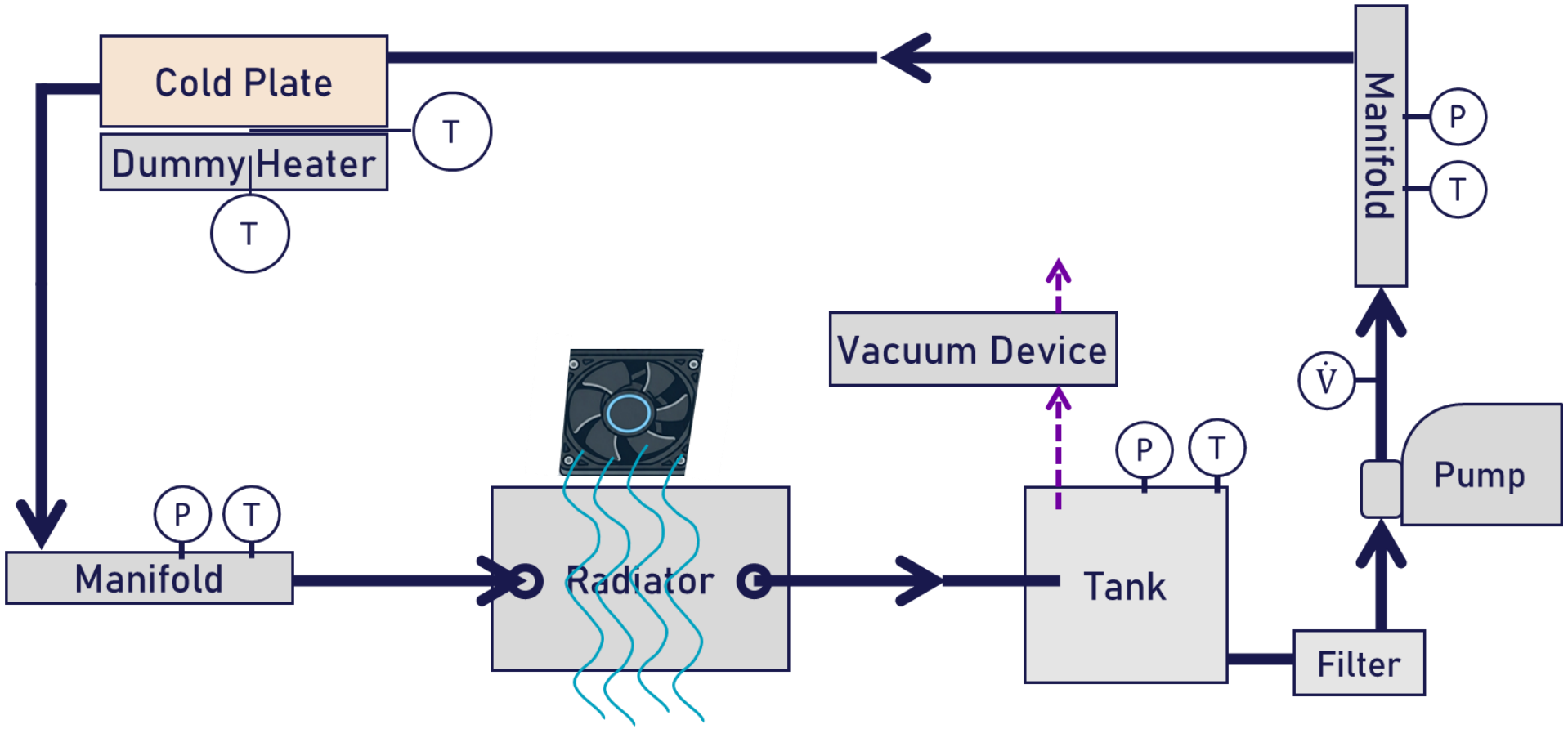
Thermal Properties @ 45°C	Air Cooling	DLC (PG25)	Pumped Two-Phase (R-515B)	Pumped Two-Phase (Water)
Density (kg/m^3)	1.1	1012	1109	**990**
Specific Heat (kJ/(kg·K))	1.0	4.01	1.45	**4.18**
Thermal Conductivity (W/(m·K))	0.027	0.49	0.07	**0.63**
Dynamic Viscosity (mPa·s)	0.019	1.32	0.15	**0.60**
Latent Heat (kJ/kg)	N/A	N/A	146	**2400**
Saturation Pressure (psi)	N/A	N/A	126.3	**1.4**

Characteristics of Negative Pressure Water Boiling

- Water-Based Two-Phase Cooling combines the high cooling performance of phase-change heat transfer with the low cost, high sustainability, and infrastructure compatibility of water.

	Air Cooling	DLC (PG25)	Pumped Two-Phase (Refrigerant)	Pumped Two-Phase (Water)
Heat Transfer Mechanism	Sensible Heat	Sensible Heat	Latent Heat	Latent Heat
Heat Transfer Coefficient	Low	High	High	Extremely High
Cooling Capability	Low	High	High	Extremely High
Required Flow Rate	N/A	High	Low	Low
Pumping Power	N/A	High	Low	Low
Temperature Uniformity	Fair	Good	Excellent	Excellent
Path to Multi-kW Chips	Limited	Practical Today	Under Active Development	Early Exploration
System Pressure	Atmospheric	Positive Pressure	Positive Pressure	Negative Pressure
Environmental Impact	Low	Low	PFAS、GWP	Minimal
Coolant Cost	N/A	Low	High	Very Low

Experimental Setup



- The large temperature difference available during water vapor condensation creates the possibility of rejecting heat directly to ambient air under certain operating conditions.

Thermal Performance Comparison

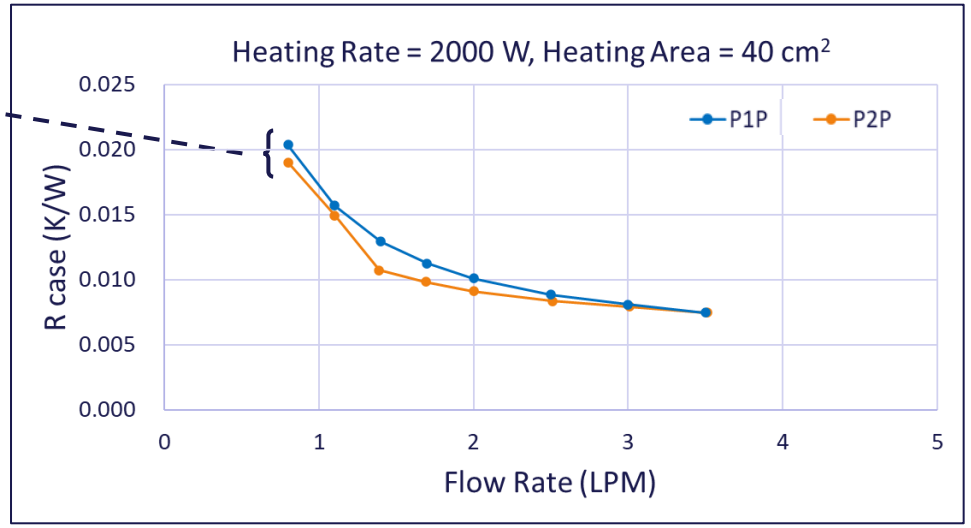
Boundary Conditions

* Single-phase water cooling (P1P)
  - T_inlet ≒ 30°C
  - P_outlet ≒ 15.3 psi

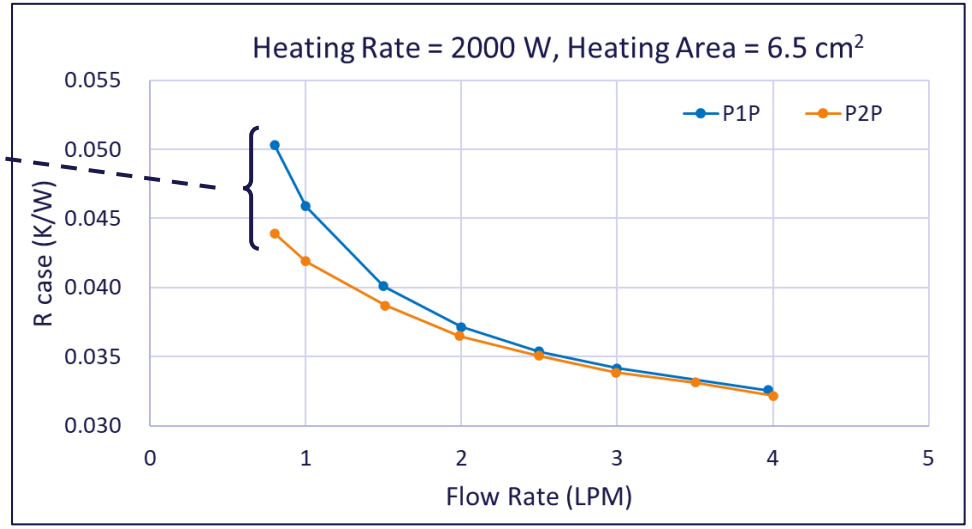
* Two-phase water cooling (P2P)
  - T_inlet ≒ 30°C
  - P_outlet ≒ 1.64 psi

  (saturation T = 48.3°C)

Performance improved by 7%

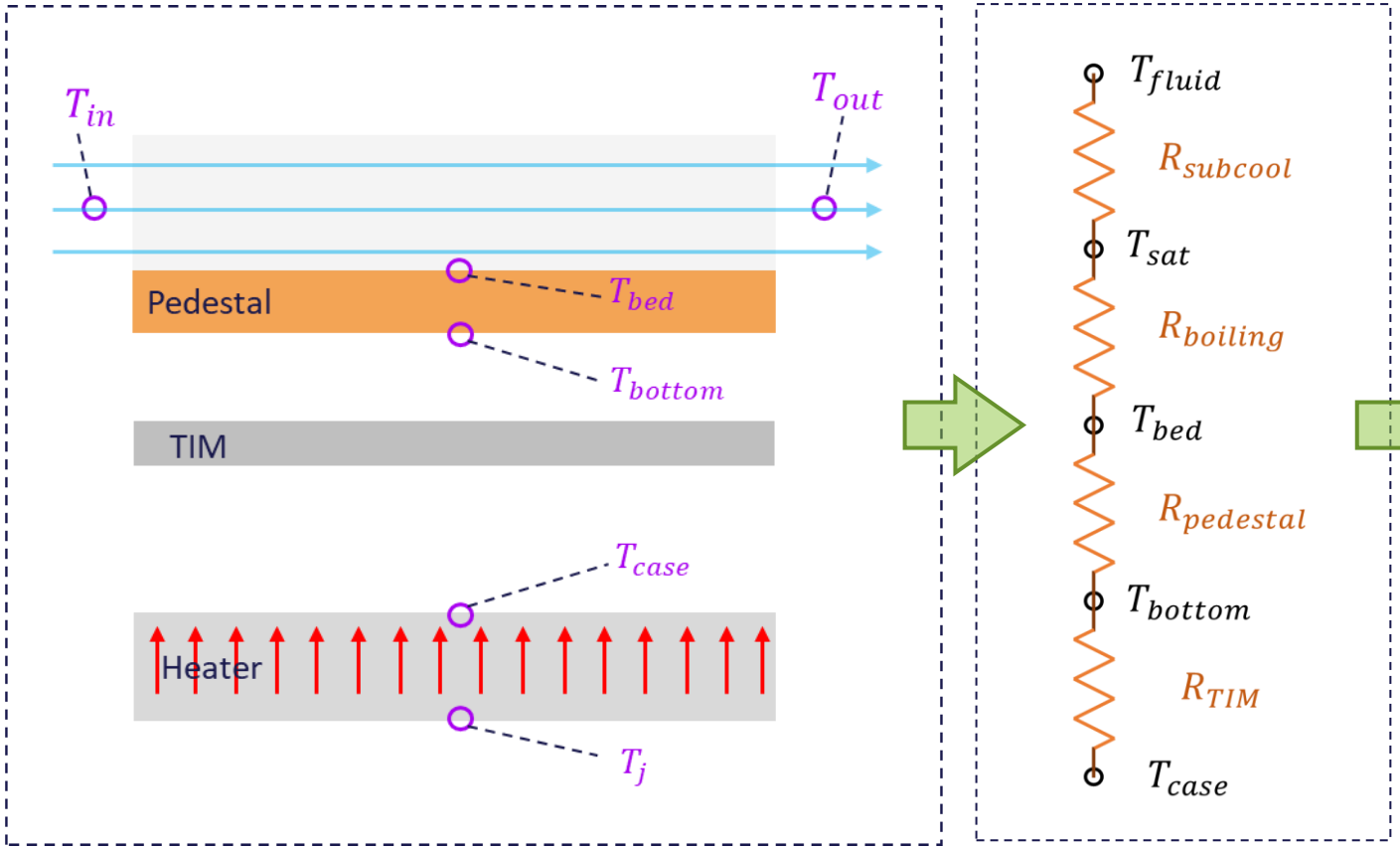


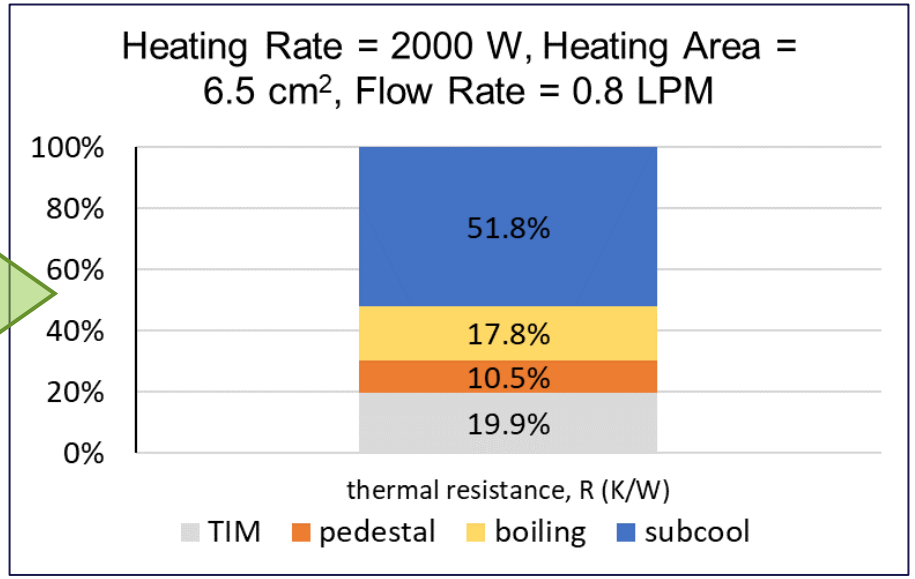
Performance improved by 15%



Cold Plate Thermal Resistance

- The thermal resistance is decomposed into several components





Key Advantages

Intrinsic Leak-Safe Operation

Because the system operates below atmospheric pressure, a breach tends to draw air into the loop rather than forcing coolant outward

Reduced Coolant Flow and Pumping Energy

By utilizing water's latent heat of vaporization, large amounts of heat can be transported with lower coolant flow rates and potentially reduced pumping requirements

Water-Based, Sustainable, and Infrastructure-Friendly

Water offers low cost, broad availability, environmental sustainability, and compatibility with existing liquid-cooling ecosystems

Potential Applications

- Distributed AI Infrastructure

Negative-pressure water-boiling cooling is particularly attractive for distributed AI infrastructure, where cooling efficiency, pumping power, leakage risk, and infrastructure simplicity are often more critical than in hyperscale data centers.

→→→ Smaller Cooling Loops / Higher Energy Efficiency / Simpler Infrastructure

Application	Benefit of Negative Pressure Water Boiling Cooling
Edge AI Servers	High compute density with reduced cooling power consumption
AI Inference Nodes	Enabling high compute density at distributed locations
Telecom / 5G Edge Sites	Efficient cooling for distributed AI infrastructure with limited utility support
Factory Edge Computing	Space-efficient thermal management for constrained installations
Mobile Data Centers	Potential for air-cooled condensation enabled by large temperature approach during phase-change heat rejection

Challenges and Future Opportunities

- **Current Challenges**

  Pressure-Sensitive System Behavior

  Sub-atmospheric water boiling systems are sensitive to pressure variations, which directly affect saturation temperature and boiling performance

  Scalability to Large Cooling Networks

  As the number of cooled devices increases, pressure drop, flow distribution, and system control become increasingly challenging, potentially requiring multiple cooling loops

  Technology Maturity

  Further validation is needed for long-term reliability, pressure control strategies, startup/shutdown operation, and large-scale deployment

- **Future Opportunities**

  High Cooling Performance at Low Flow Rate

  - Supporting future multi-kW AI processors
  - Enabling ultra-high heat flux cooling closer to silicon
  - Lowering coolant flow requirements and pumping energy
  - Providing an leak-safe path toward next-generation cooling architectures

Exploring the Future of AI Cooling Together

- Negative-pressure water-boiling cooling offers:
  - A potential path beyond conventional single-phase cooling
  - Improved Energy Efficiency
  - Intrinsic Leak-Safe Operation
- We welcome collaboration on:
  - AI/HPC server platforms
  - Cold plate development
  - Reliability validation
  - System integration

TAIWAN Regional Community

wistron

Let's Connect:
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Thank You!

