



# TestConX 한국

Korea

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# High Performance Liquid Cooling Solution

(for Next Generation Semiconductor Test)

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- Cooling & Evolution
- VC COOL : 3D-LCVC | PWS COMBO | TIM
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# Burn-In

- Burn-In
- Purpose
  - Reliability screening
  - Early failure detection
- Condition
  - Long duration
  - High power
  - High temperature stress

# Problem

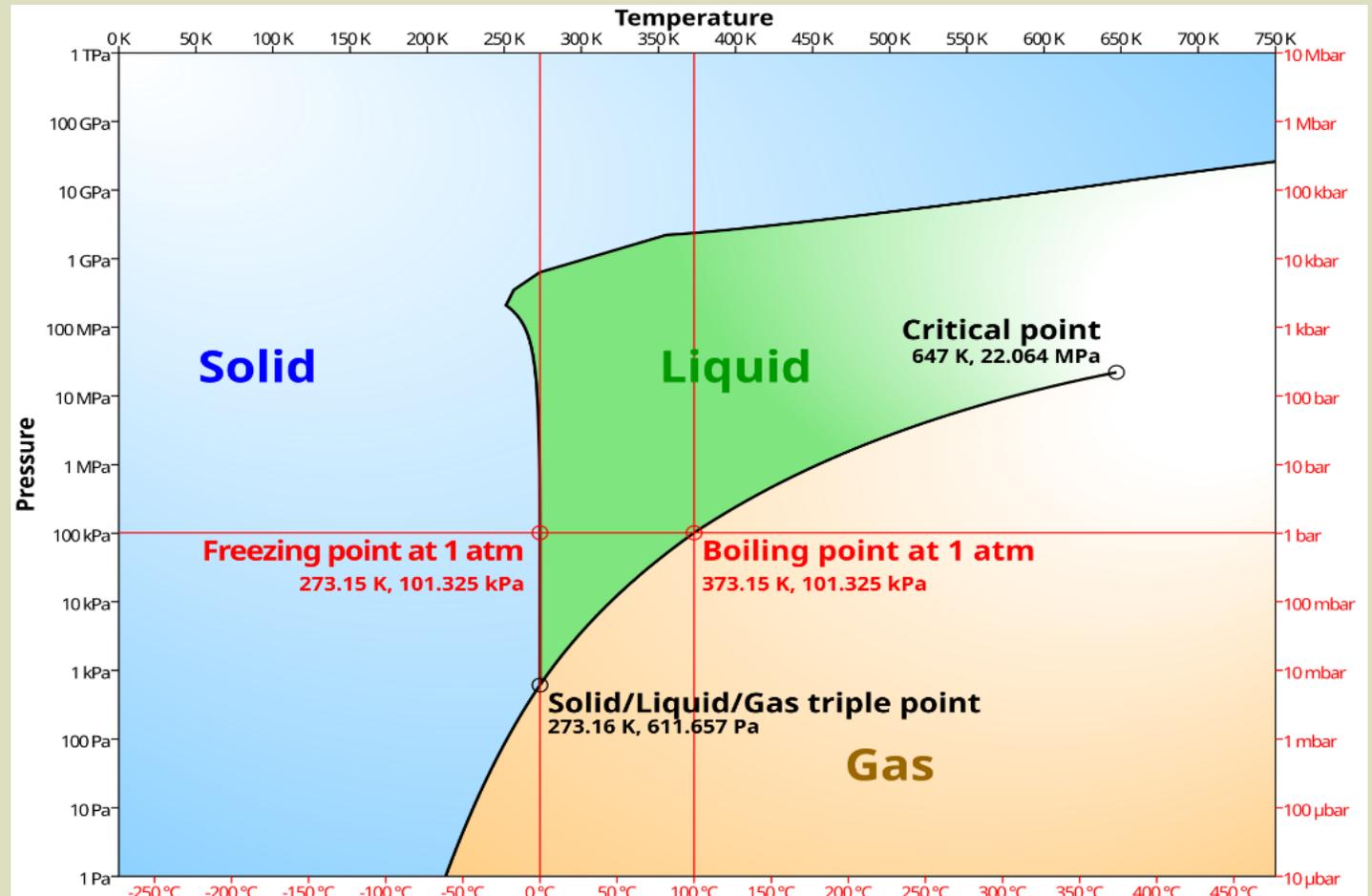
- Excessive heat → ‘Localized hot spots’ and ‘Uneven temperature’.
- Reliability degradation, yield loss
- Thermal stress and warpage can damage even good devices.
- Even under the same power and socket design, large  $T_{case}$  deviations are observed between DUTs → overkill and field returns.
- To ensure test accuracy, repeatability, and device reliability, an advanced thermal management solution is essential.

# Cooling

- Conventional : Air Cooling / Cold Plate
- Mainstream : Liquid Cooling / Microchannel / Vapor Chamber
- Emerging : Hybrid / Immersion Cooling
- Limitation of existing cooling  
Hotspot / Non-uniform cooling / Inlet-outlet  $\Delta T$  / High flow demand

# Cooling Evolution

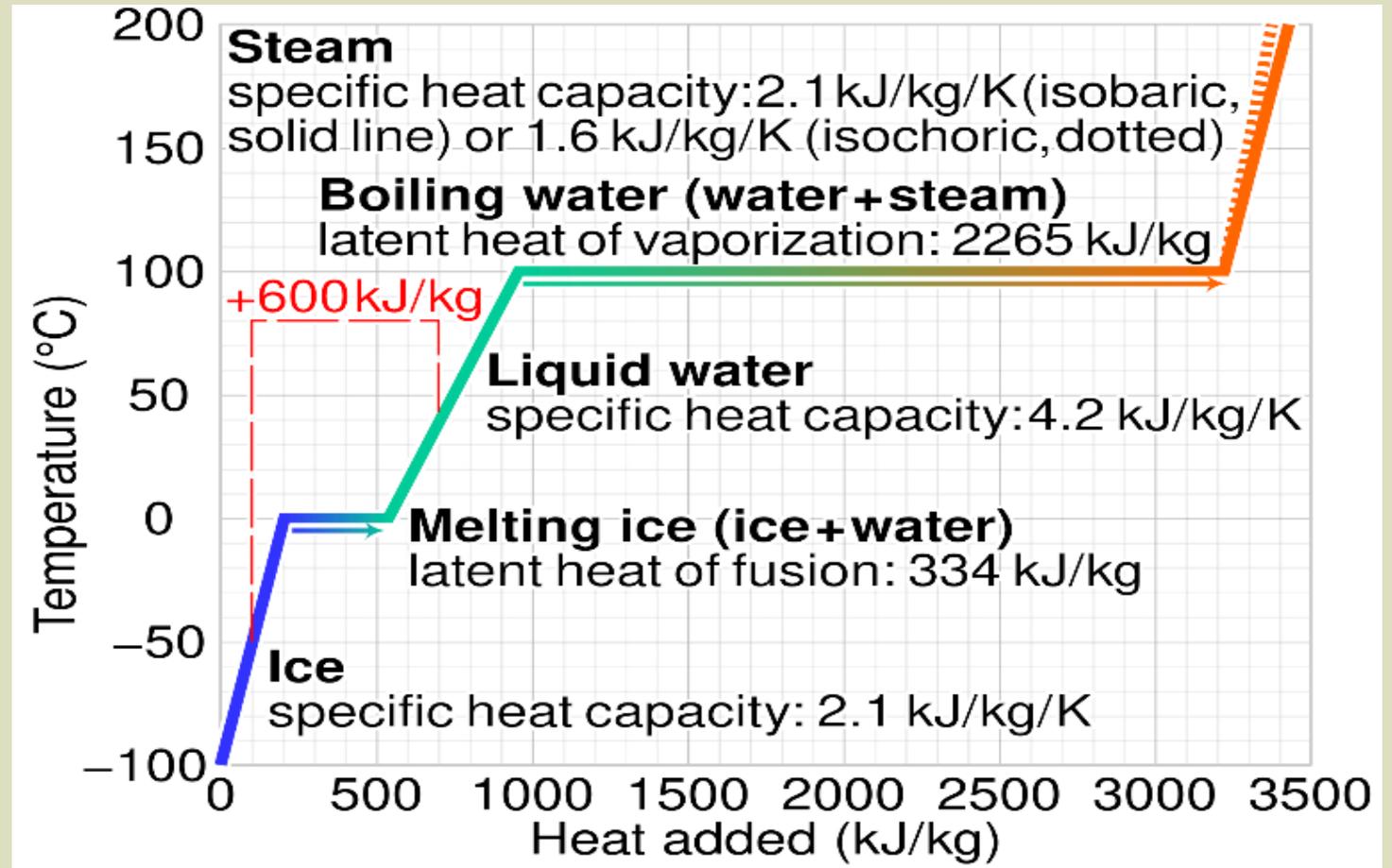
- Phase Change
  - Water Boiling
    - @1 bar : 100 °C
    - @ Vacuum : ? °C



Simplified temperature/pressure phase change diagram for water. [1]

# Cooling Evolution

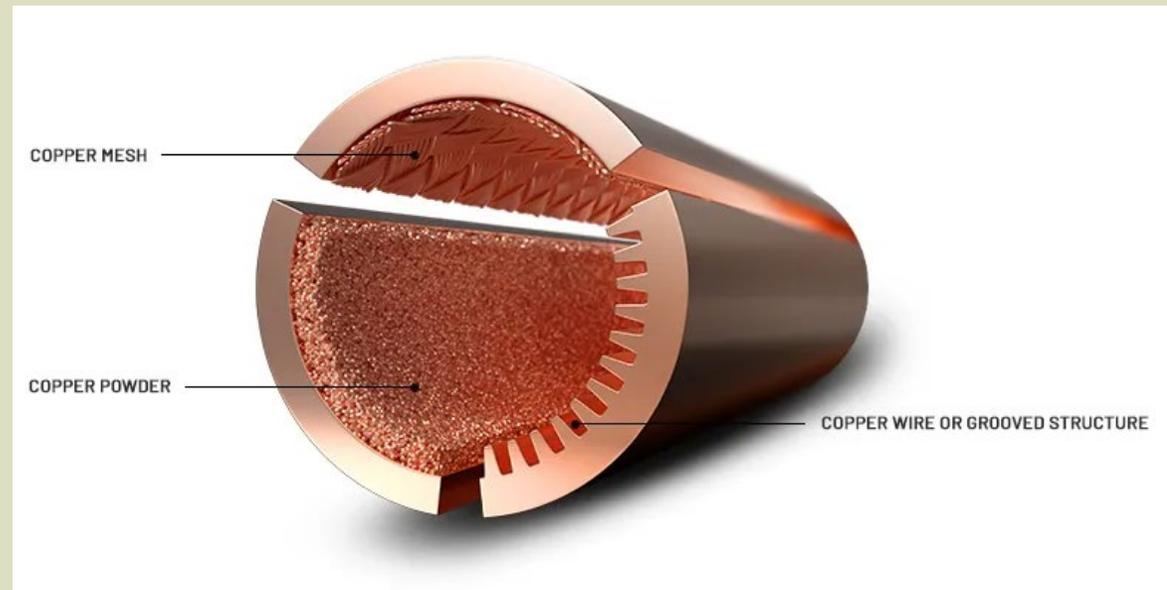
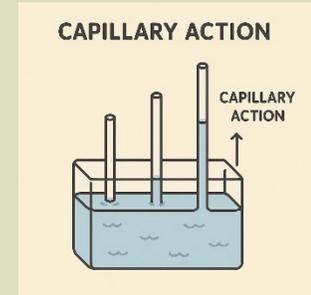
- Phase Change
- Latent Heat



Graph of temperature of phases of water heated from -100 °C to 200 °C [2]

# Cooling Evolution

- Wick  
Evaporation-Condensation cycle & Capillary action
- Heat Pipe(HP)
- Loop Heat Pipe(LHP)
- Vapor Chamber(VC)



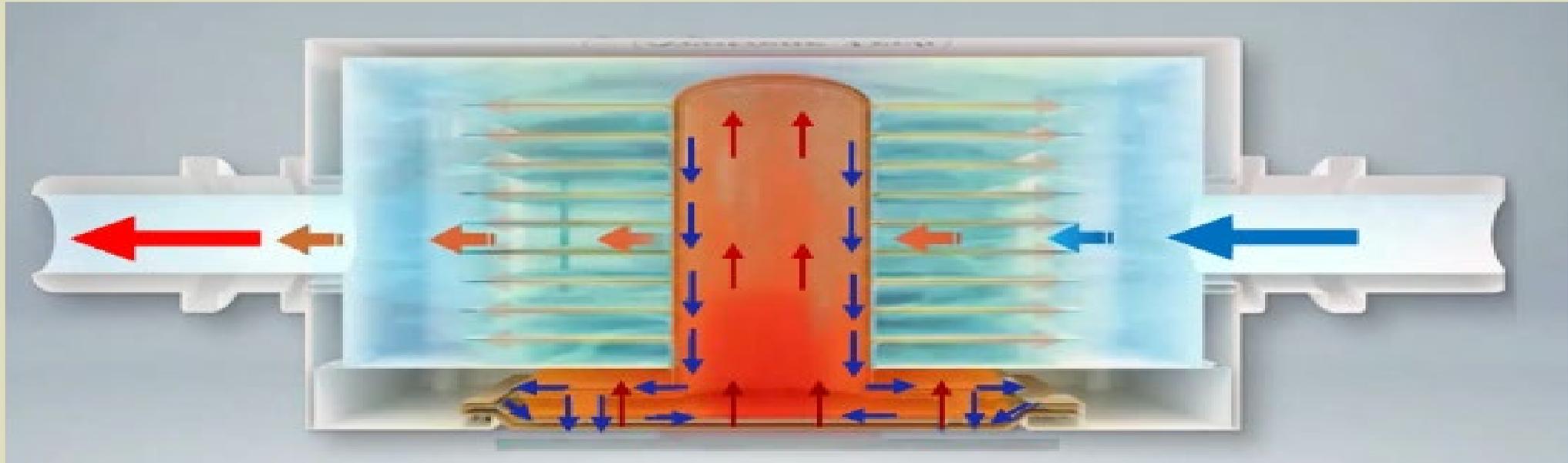
Heat Pipe [3]

# VC COOL : Concept

- Target Demand
  - Hotspot
  - Uniformity of temperature
  - High Density / High Power
  - Small Form Factor
- Solution
  - Hybrid : VC + Liquid Cooling + Micro Channel Architecture

# Key1 : 3D-LCVC

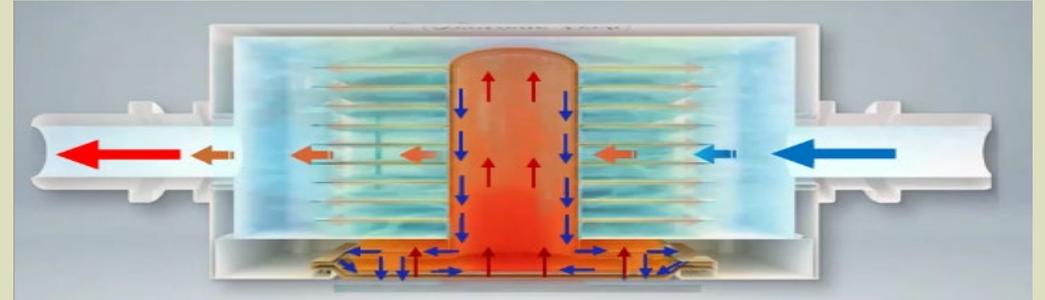
- Liquid Cooling + VC with Cooling Fins



# Key1 : 3D-LCVC

- Total Thermal Resistance

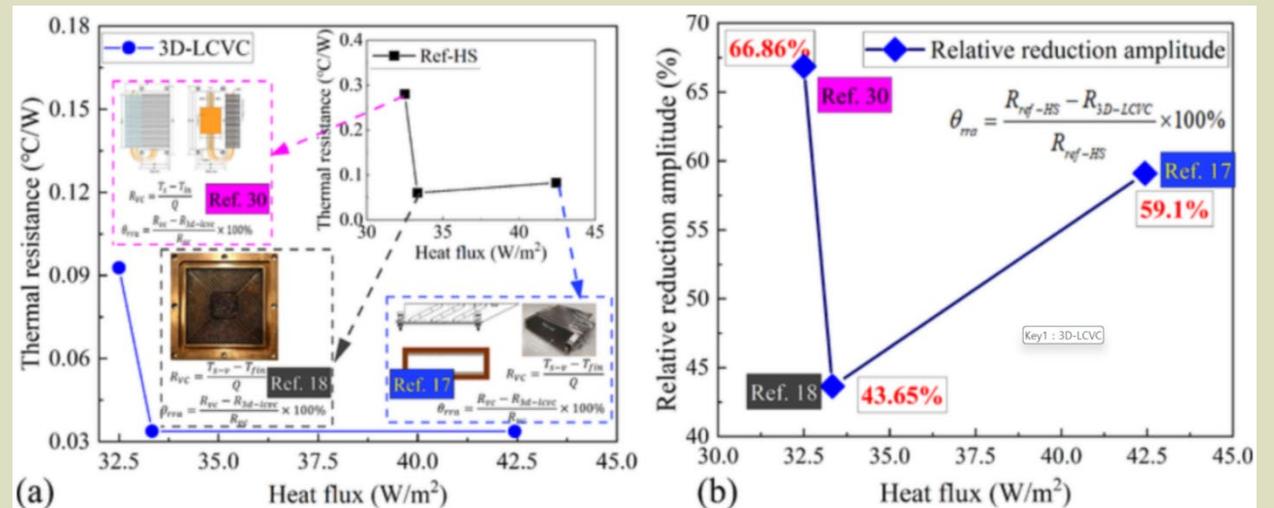
$$R_{\text{total}} = R_{\text{TIM}} + R_{\text{VC}} + R_{\text{interface}} + R_{\text{conv}}$$



- Heat travels through TIM -> VC -> Interface -> Coolant
- Each segment contributes to total resistance
- Integrated structure eliminates multiple contact layers

# Key1 : 3D-LCVC

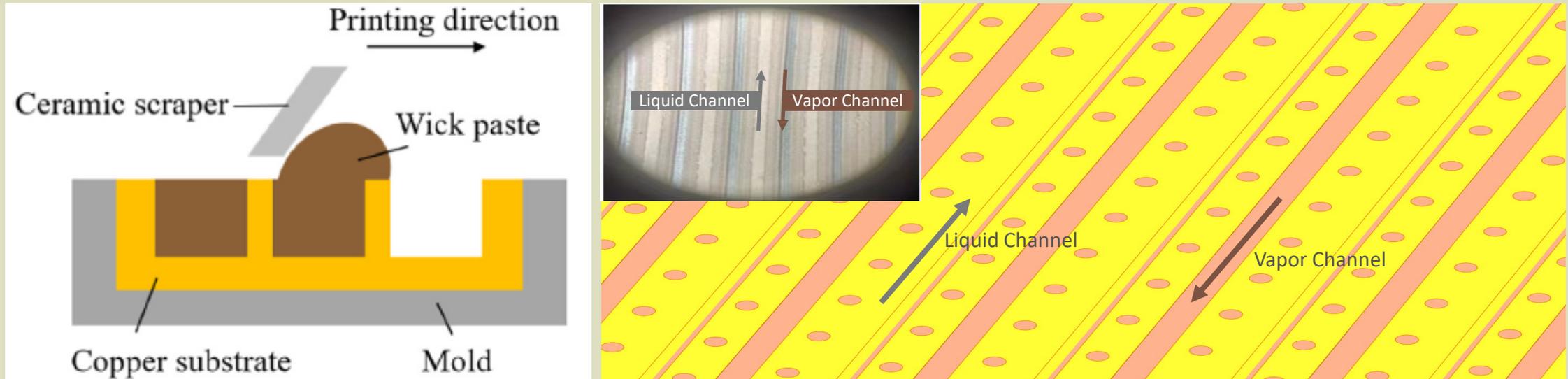
- All systems use phase-change heat transfer.
- 3D-LCVC integrates evaporation, condensation, and convection within one compact stack.
- Shorter vapor path + direct liquid contact → faster heat removal.
- 44–66 % lower  $R_{total}$ ,
- Improved  $\Delta T$  uniformity.



Thermal Resistance and relative reduction amplitude of the 3D-LCVC and conventional heat sink embedded with a phase-change heat spreader [4]

# Key2 : PWS

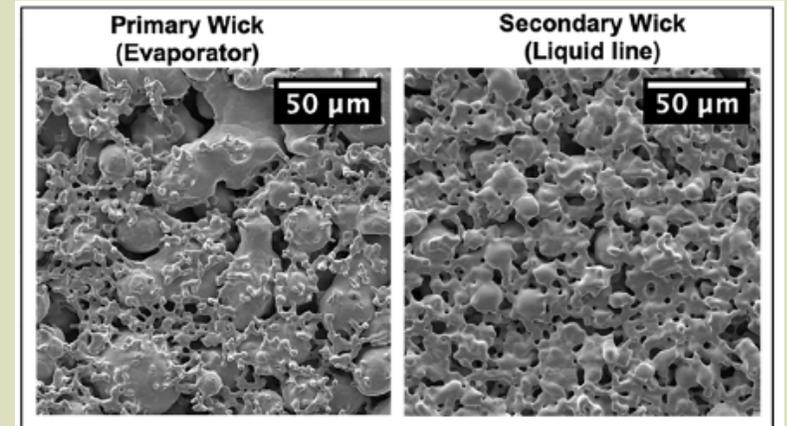
- Printed Wick Structure(PWS)



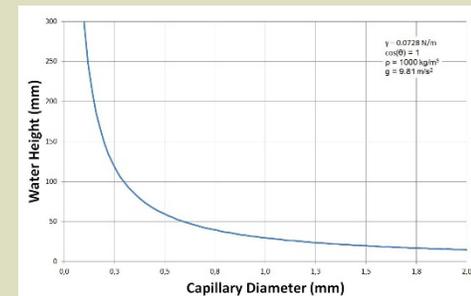
- PWS 3D capillary network with stable vapor–liquid separation
- Entrainment resistant
- Stable Capillary Return -> Stable Burn-in Temp. Control

# Key2-1 : PWS Combo

- Bi-porous(micro + macro)  
balances capillary suction and permeability
- Faster liquid return and  
enhanced dry-out resistance



The SEM images of the porous wick[5]



Water height in a capillary plotted against capillary diameter[6]

- PWS Combo ->Faster Rewetting ->Higher Heat Flux Stability

# VC COOL : Thermal Stabilization Path

- Low Thermal Impedance
- Integrated Cooling System
- TIM
  
- Forms an integrated thermal path
  - Die surface -> TIM -> Vapor Chamber ->Liquid Loop
  - Minimizing total thermal impedance.

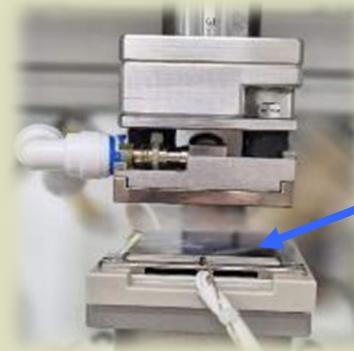
# Conventional Cold Plate vs Hybrid 3D-LCVC

Parameter	Conventional Cold Plate	Hybrid 3D-LCVC
Cooling Mechanism	Liquid convection only	Dual path (VC phase change + Liquid loop)
Heat transfer	1 direction	3D ( Horizontal + Vertical)
Temp Uniformity	$\pm 5\sim 8\text{ }^{\circ}\text{C}$	$\pm 2\text{ }^{\circ}\text{C}$
Inlet Temp Sensitivity	High	Low
Operating range	Limited at $> 100\text{ }^{\circ}\text{C}$	Stable up to $150\text{ }^{\circ}\text{C}$



# Performance Comparison

- Chiller : 15 °C, 6 L/min
- Cylinder : 60 KgF
- Power : 0.4~2.0 KW
- Data Track : 120 sec

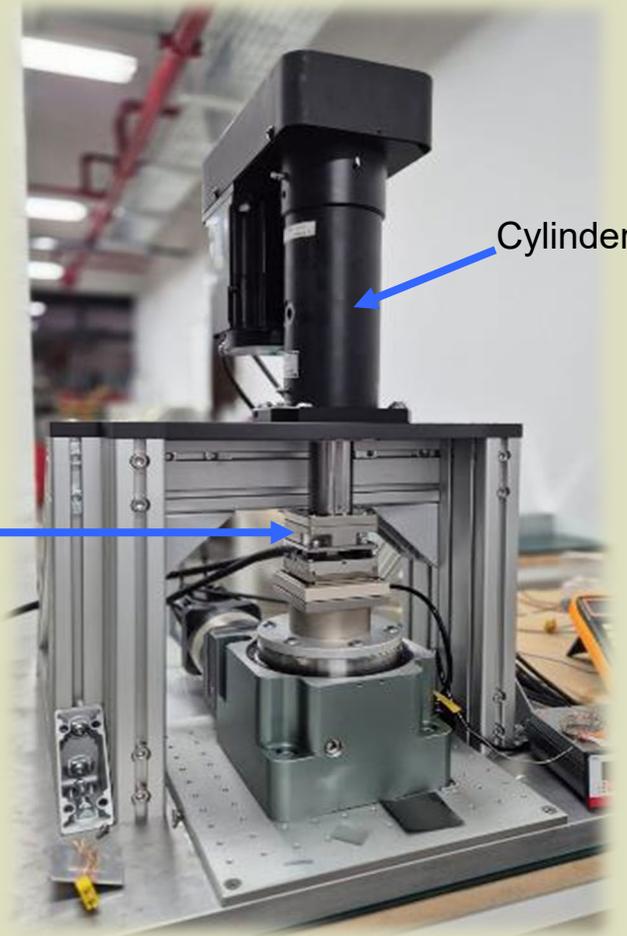


Heat Source



Chiller

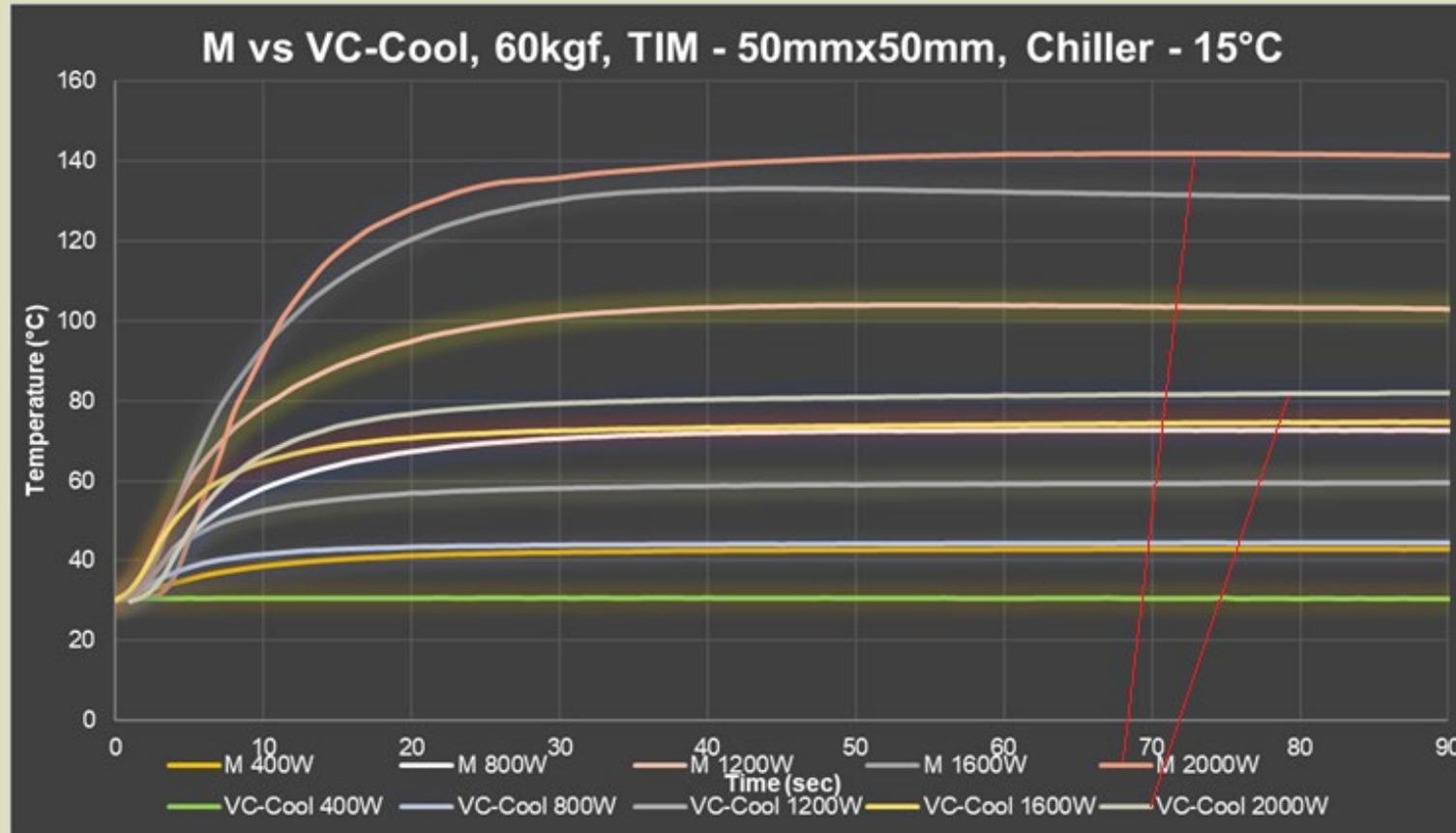
Liquid Cooler



Cylinder

# Performance Comparison

- 'Micro Channel' vs 'VC COOL'



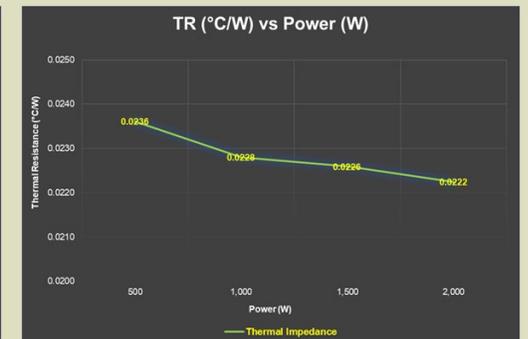
# Test : Inlet Temp

Thermal Measurement Condition					
Date of Testing	2/4/2025	Thermal Tester	Thermal Measure-01		
Ambient Temperature	25.3°C	Ambient Humidity	42.20%		
Test Power	0.5KW ~ 3.0KW	Heater Block Dimension	50mm X 50mm		
Fluid Temperature	20.0°C	Cold Plate Dimension	92mm X 92mm		
TIM (Thermal Cond.)	7.5 W/m-K	Pedestal Dimension	57mm X 57mm		
Pressure Drop	≤ 200 kPa	Fluid Rate	2.0 LPM		
Temp. Stable Duration	≥ 90 sec	TIM Thickness	0.05mm		
Power (W)	Actual P (W)	T <sub>case</sub> (°C)	T <sub>inlet</sub> (°C)	T <sub>outlet</sub> (°C)	T <sub>case-inlet</sub> (°C/W)
500	500.9	31.0	20.0	23.4	0.0220
1,000	1,000.7	42.1	20.0	26.5	0.0221
1,500	1,500.8	52.9	20.0	29.8	0.0219
2,000	1,964.3	62.2	20.0	33.0	0.0215
2,500	2,457.5	70.6	20.0	36.2	0.0206
3,000	2,943.1	80.1	20.0	38.9	0.0204

Thermal Measurement Condition					
Date of Testing	3/3/2025	Thermal Tester	Thermal Measure-01		
Ambient Temperature	24.6°C	Ambient Humidity	58.90%		
Test Power	500W ~ 2,000W	Heater Block Dimension	50mm X 50mm		
Fluid Temperature	40.0°C	Fluid Rate	2.0 LPM		
TIM (Thermal Cond.)	7.5 W/m-K	TIM Thickness	0.05mm		
Pressure Drop	≤ 200 kPa	Temperature Stable Duration	≥ 90 sec		
Power (W)	Actual P (W)	T <sub>case</sub> (°C)	T <sub>inlet</sub> (°C)	T <sub>outlet</sub> (°C)	T <sub>case-inlet</sub> (°C/W)
500	499.8	51.8	40.0	42.2	0.0236
1,000	1,000.0	62.8	40.0	45.6	0.0228
1,500	1,500.5	73.9	40.0	49.0	0.0226
2,000	2,000.2	84.5	40.0	52.3	0.0222



Inlet Temp 20 °C



Inlet Temp 40 °C

# Summary

- Burn-in test requires uniform temperature, stability, and reliability under extreme thermal stress.
- Conventional air or liquid cooling systems show hotspot issues and limited uniformity.
- Integrating a 3D vapor chamber and liquid cooling loop delivers consistent thermal spreading and efficient heat removal.
- Verified results show up to 67% lower thermal resistance and improved die-level temperature uniformity.
- Next-generation Burn-In test systems, where thermal uniformity directly impacts yield and reliability, require practical and scalable solutions such as VC COOL.

# Source

- [1] Wikipedia ([https://en.wikipedia.org/wiki/Phase\\_diagram](https://en.wikipedia.org/wiki/Phase_diagram))
- [2] Wikipedia ([https://en.wikipedia.org/wiki/Latent\\_heat](https://en.wikipedia.org/wiki/Latent_heat))
- [3] Namuwiki (<https://namu.wiki>), [Heat Pipe]
- [4] Li et al. (2024), Applied Thermal Engineering, Fig14
- [5] Chen et al. (2022), Applied Thermal Engineering, Fig. 2(b)
- [6] Wikipedia ([https://en.wikipedia.org/wiki/Capillary\\_action](https://en.wikipedia.org/wiki/Capillary_action))

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