Critical Systems: Thermal Trends

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BICSI CALA

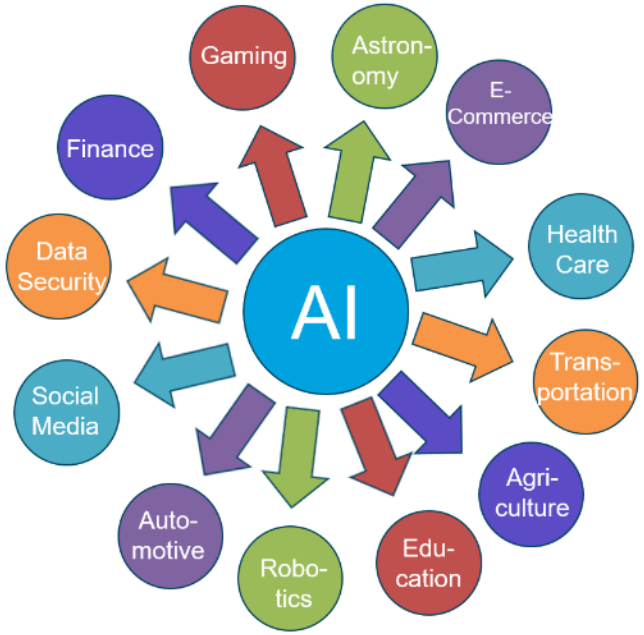


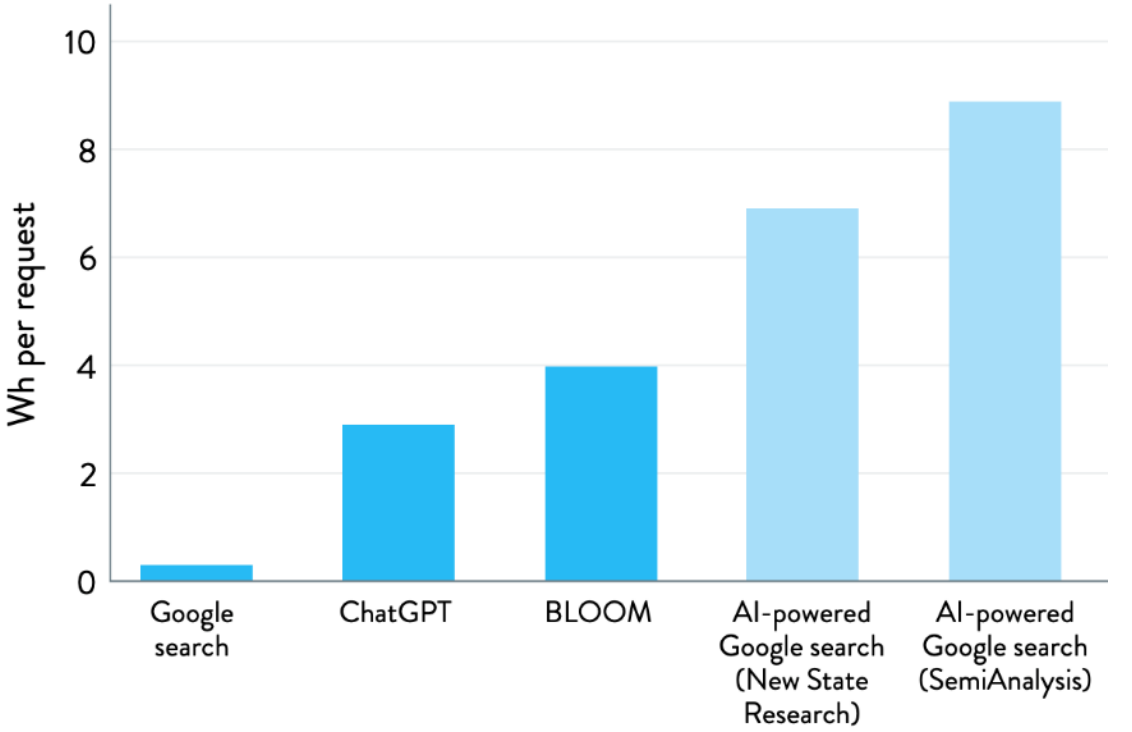
Critical Systems: Thermal Trends

Changing Trends in Power: Market Trends and Driving Forces

AI generated queries require 10x the power in comparison to a regular Google search

- Machine learning
- Natural language processing
- Graphics rendering
- Robotics
- Computer vision
- Algorithms





Electric Power Research Institute

CHATSWORTH PRODUCTS

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GPU Based Servers







Nvidia DGX H100	Dell XE9680	SuperMicro SYS-821GE-TNHR
• 8U • (4+2) 3.3kW power supplies • 56kW per cabinet	• 6U • (5+1) 2.8kW power supplies • 92kW per cabinet	• 8U • (4+2) 3kW power supplies • 56kW per cabinet

Cabinet Design

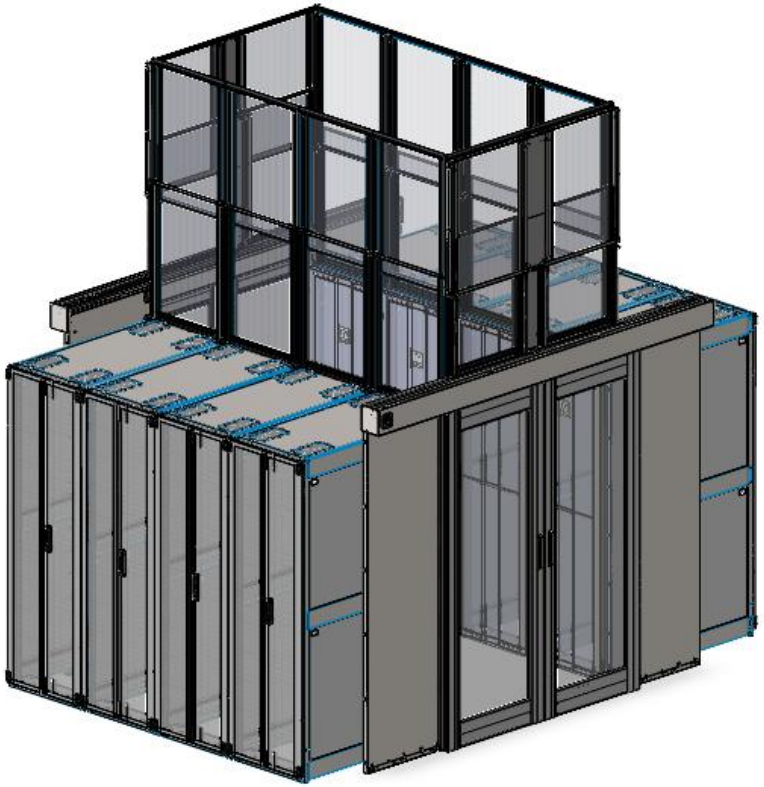
Improve Airflow Management

- Include airflow management designs / accessories to ensure effective conditioned and exhaust air separation for maximum equipment cooling
- Air Dam Kit
- Rail grommets or rail brushes provide air separation for high density cabling applications
- Snap-In Filler Panels
- Brush snaps into rail openings for ease of cabling
- Vertical Exhaust Duct options and configurations

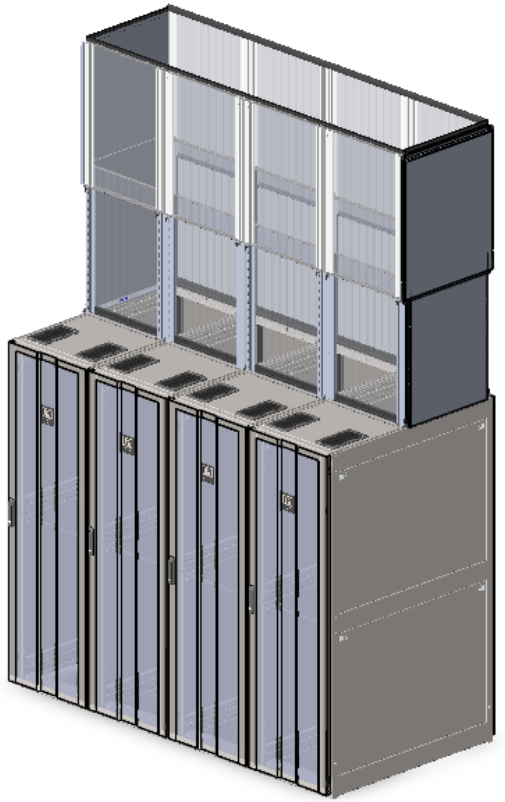


Adjustable Containment Applications

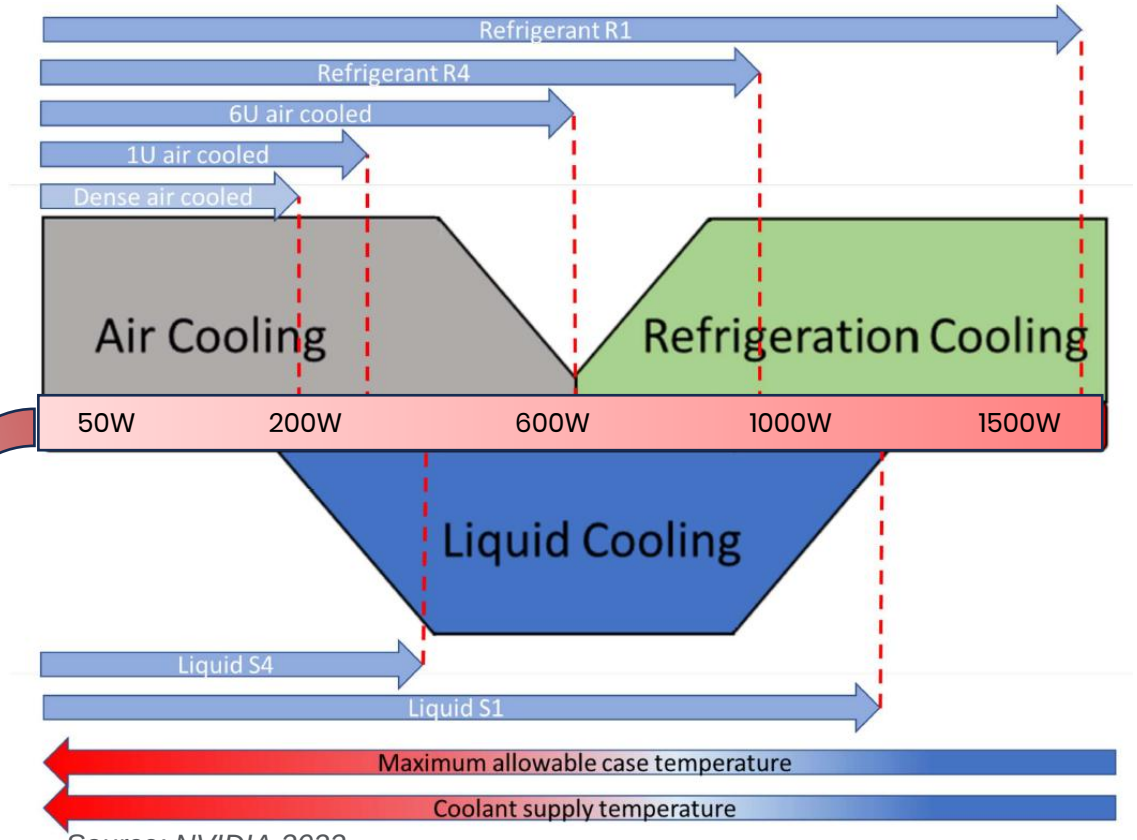
Hot Aisle Containment



Row Level Vertical Exhaust Duct



Drivers to Liquid Cooling – xPU TDP and Tcase



Source: NVIDIA 2022

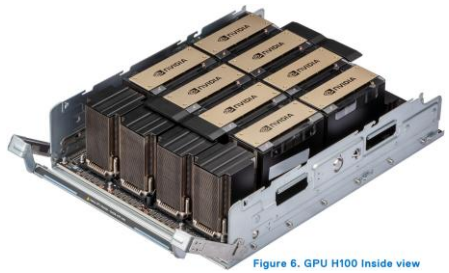
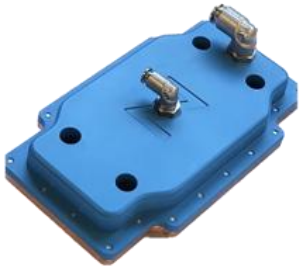
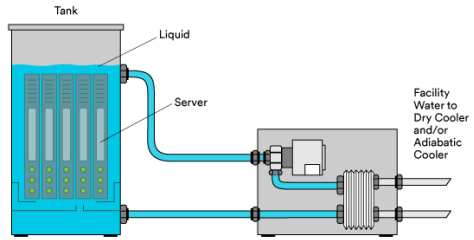
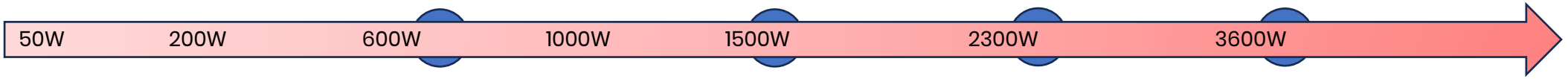


Figure 6. GPU H100 Inside view







2022: H100s & ChatGPT

2025 Q3: GB200

2026 1H: VR200

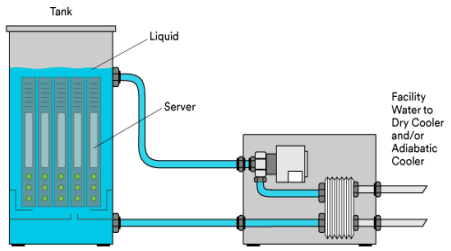
2027 2H: VR300

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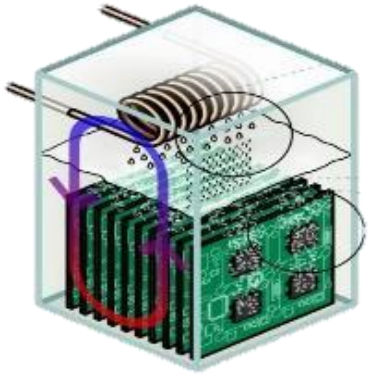
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Liquid and Liquid-Assisted Cooling

Immersion



Single-phase



Two-phase

Cold Plates



Single-phase Water



Two-phase Dielectric

Rear Door Heat Exchanger



RDHx is Close-Coupled Air Cooling



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Immersion Cooling

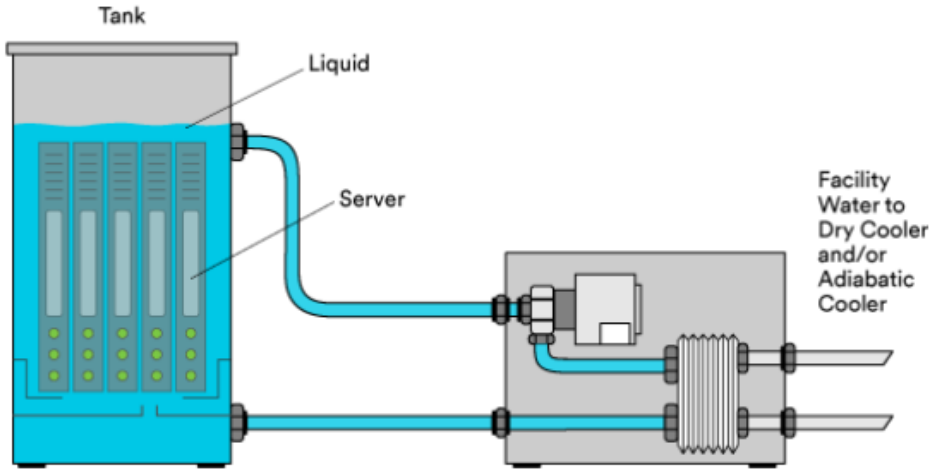
- Cooling method for IT hardware that is directly immersed in a dielectric (non-conductive) liquid
- Component heat directly and efficiently transferred to the fluid
- Liquid circulates through the system to a heat exchanger, the heat is removed, and the liquid recirculates
- Types of Immersion Cooling
  - Single-phase
  - Two-phase
- Two Immersion Coolant Types
  - Hydrocarbons (mineral, synthetic, bio-oils) for single phase
  - Fluorocarbons (fully engineered liquids) for two-phase



Photo courtesy of Gigabyte.com

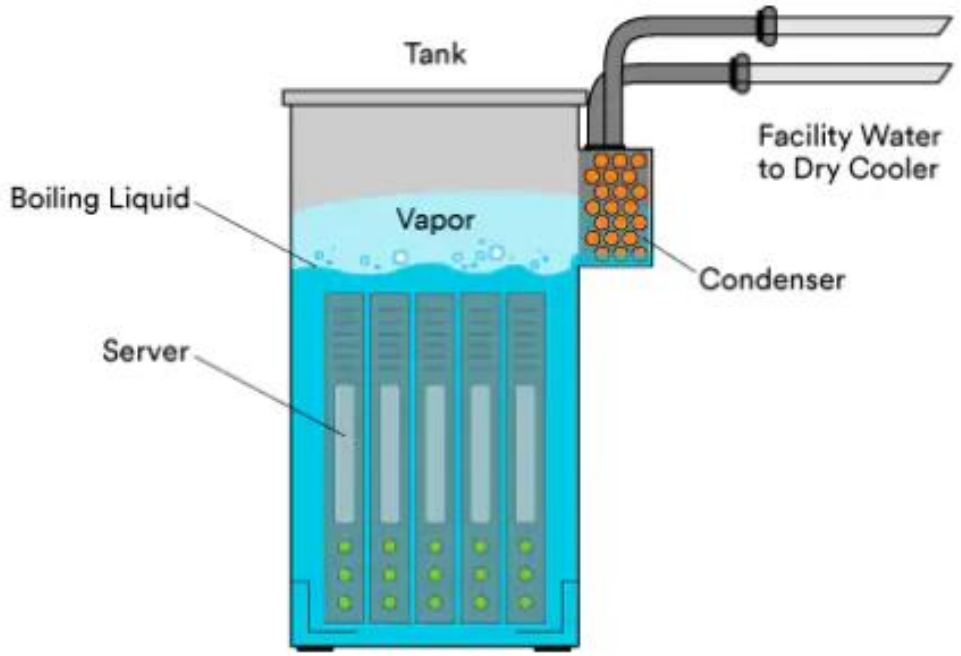
Single-Phase Immersion Cooling

- Application Process – heat transferred from completely immersed devices to the fluid. Fluid pumped out of the tank to a heat exchanger. Heat exchanger transfers heat to facility water. Facility cooling cools water and returns.
- Components
  - Large Liquid Filled Tank
    - IT equipment mounted vertically; housing removed
    - High volume of dielectric solution
  - Piping
    - Large high-volume, high-pressure circulation pumps
      - 2 loops minimum
    - Large diameter In / out piping – two loops minimum
  - Heat Exchanger
  - Facility water to dry cooler or adiabatic cooler
  - Dielectric coolant – always in liquid state
    - Very high boiling point so remains liquid



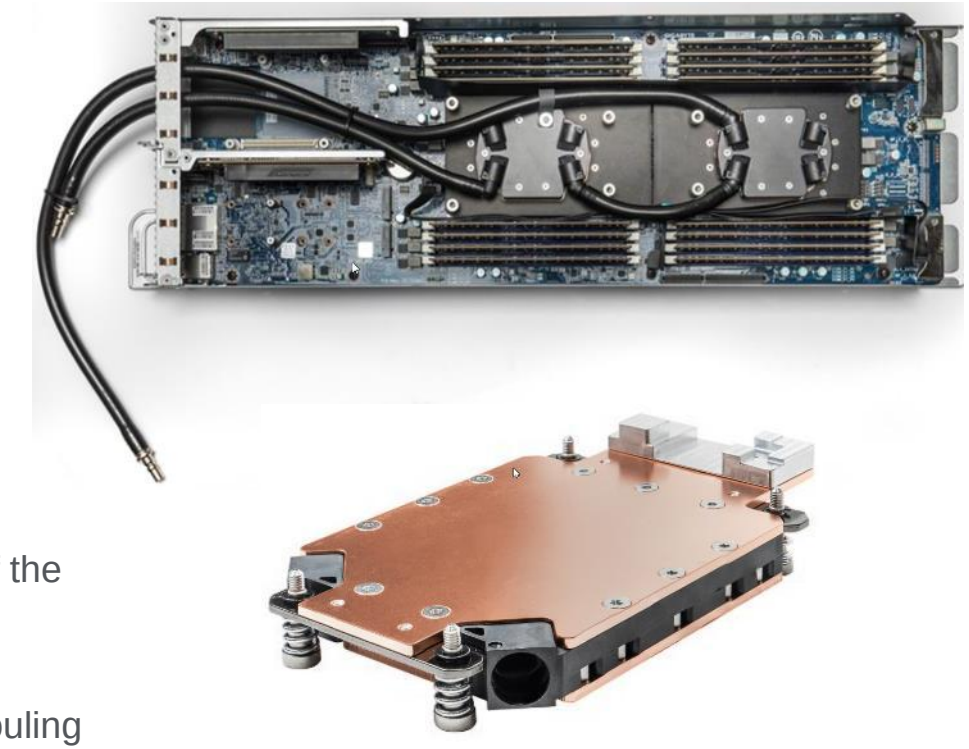
Two-Phase Immersion Cooling

- Application Process – fluid is boiled and condensed exponentially increasing heat transfer efficiency. High heat vaporizes heat transfer fluid, vapor rises from liquid (boils). Vapor condenses on heat exchanger (condenser) in the tank transferring heat to facility water and liquid drops into the tank.
- Components
  - Large Liquid Filled Tank
    - IT Equipment mounted vertically; housing removed
    - High volume of dielectric solution
  - Piping
    - Circulation pumps – single loop minimum
    - In / out piping – single loop
  - Heat Exchanger (condenser)
  - Facility water to dry cooler
  - Heat Transfer Fluid– changes from liquid to vapor
    - Low boiling point



Liquid Cooling Solutions: Direct-to-Chip Single-Phase Cold Plate

- Little to no data center infrastructure/ server change
- Support high Thermal Design Power (TDP) processors
- Water based solution pumped through server
  - Risk of leakage
  - Uneven heat distribution – coolant temp increases downstream
  - Higher pressure and higher flow as heat density rises
  - Solution maintenance chemical balancing and periodical replacement of the water-based liquid required
  - Cooling performance degradation over time due to corrosion, erosion, fouling and residue



Liquid Cooling Solutions: Direct-to-Chip Two-Phase Cold Plate

- Little to no data center infrastructure/ server change
- Support high Thermal Design Power (TDP) processors
- Heat Transfer Fluid pumped through server (not conductive)
- Two-phase pool boiling for even heat distribution
- Low pressure system reduces risk of leakage
- Closed-loop design – dielectric level, integrity, and viscosity of the liquid are preserved indefinitely



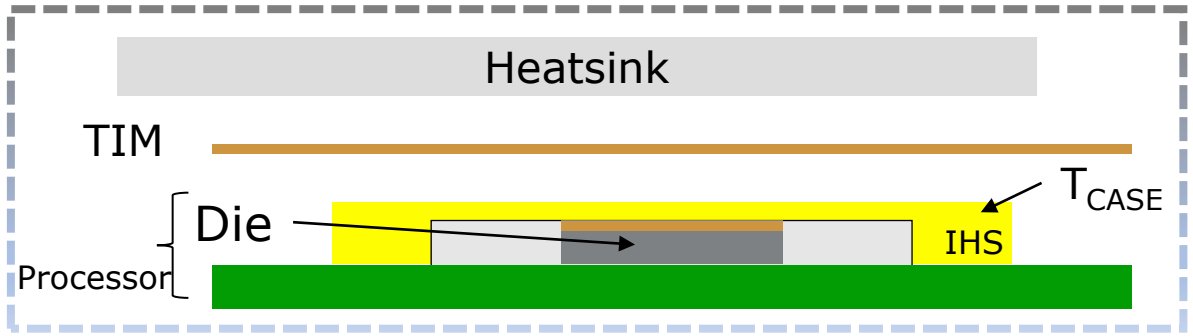


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Two-Phase Pool Boiling vs Single-Phase Cold Plate

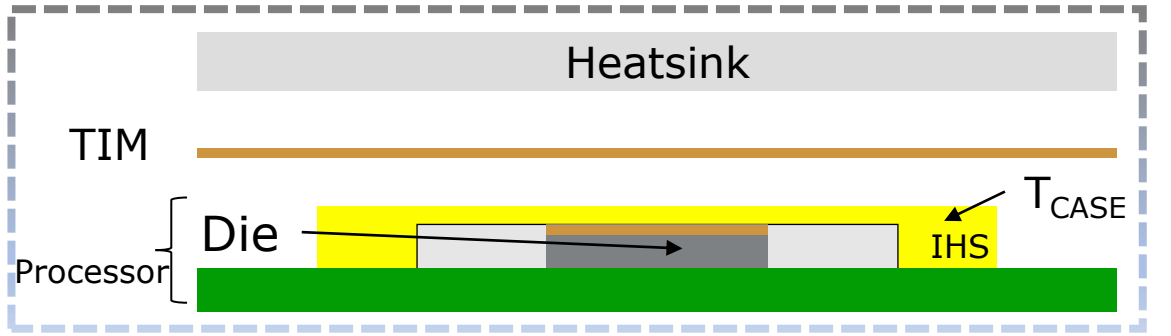
Two-Phase heat direction



Even cooling over the die



Single-Phase heat direction



Heat growing over the die

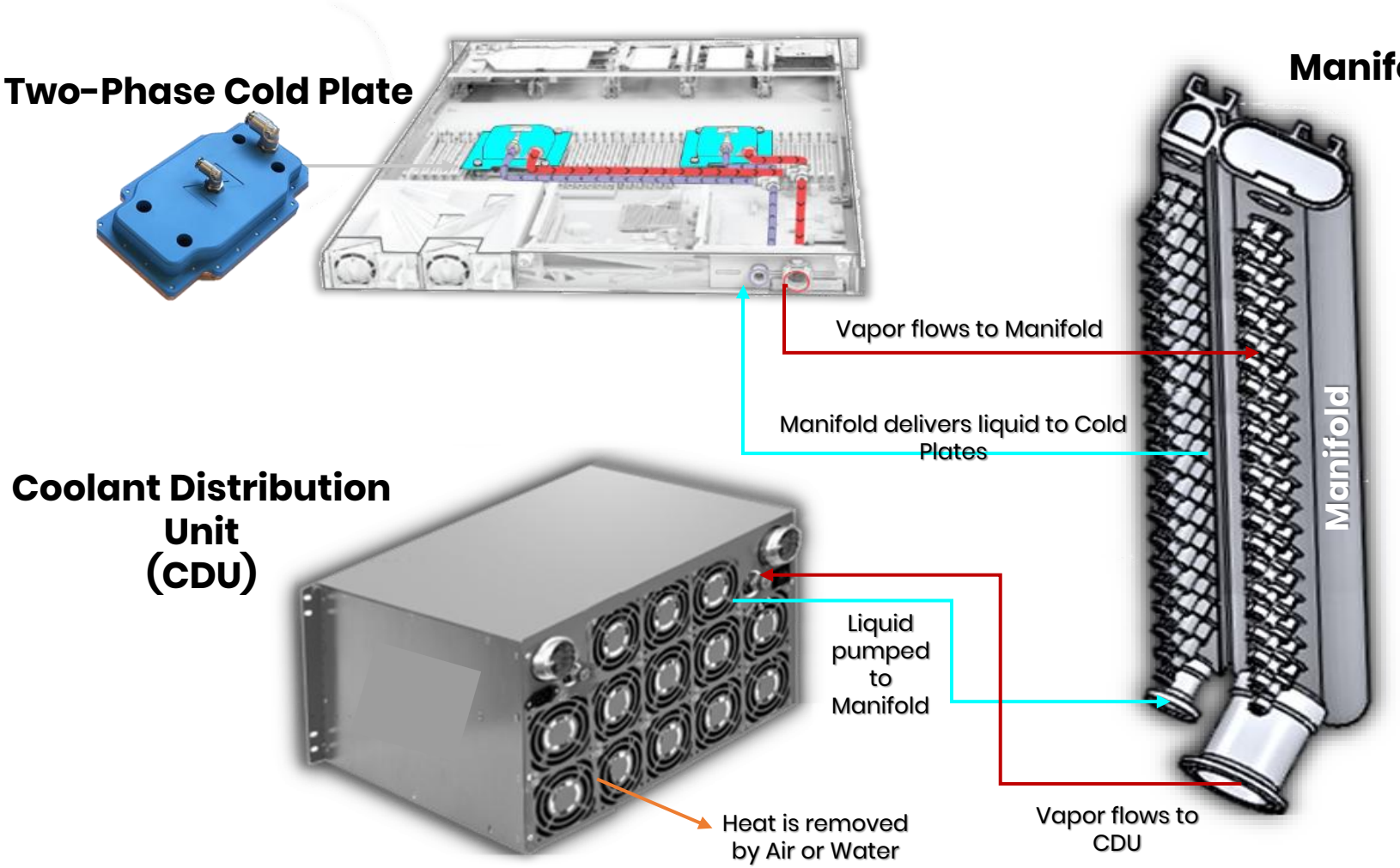


Single Phase Water requires at least 5° C lower inlet temperature to compensate for uneven temperature rise on the area of the CPU => more energy

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Direct-to-Chip Waterless Liquid Cooling for the Mainstream



Two-Phase Cold Plate

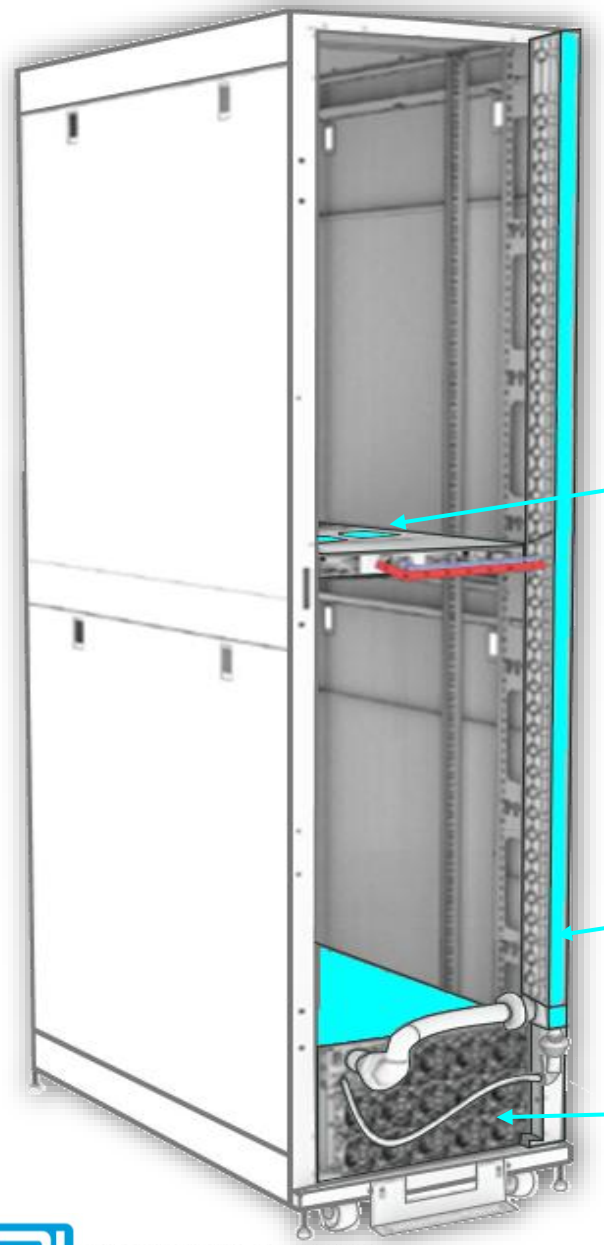
- Heat transfer fluid that is waterless, non-corrosive, and non-conductive.

CDU – Coolant Distribution Unit

- Delivers 70% heat capture

Manifold

- Liquid > Vapor









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Coolant Distribution Units (CDUs)

CDU Air / Water	Total Rack Capacity	CPU/GPU Capacity	RMU	Inlet Temp	Water Flow m^3/h
Air	20 kw	15 kW	6	25°C Air	N/A
Water	100 kw	70 kW	6	32°C Water	5
Water	85 kw	60 kW	3	32°C Water	3

- <4 Gallons of Dielectric Heat Transfer Fluid
- Fully reusable (20yrs) & recyclable
- Little to no disruption to the data center



3U CDU Water



6U CDU Water



6U CDU Air

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Distribution Manifolds

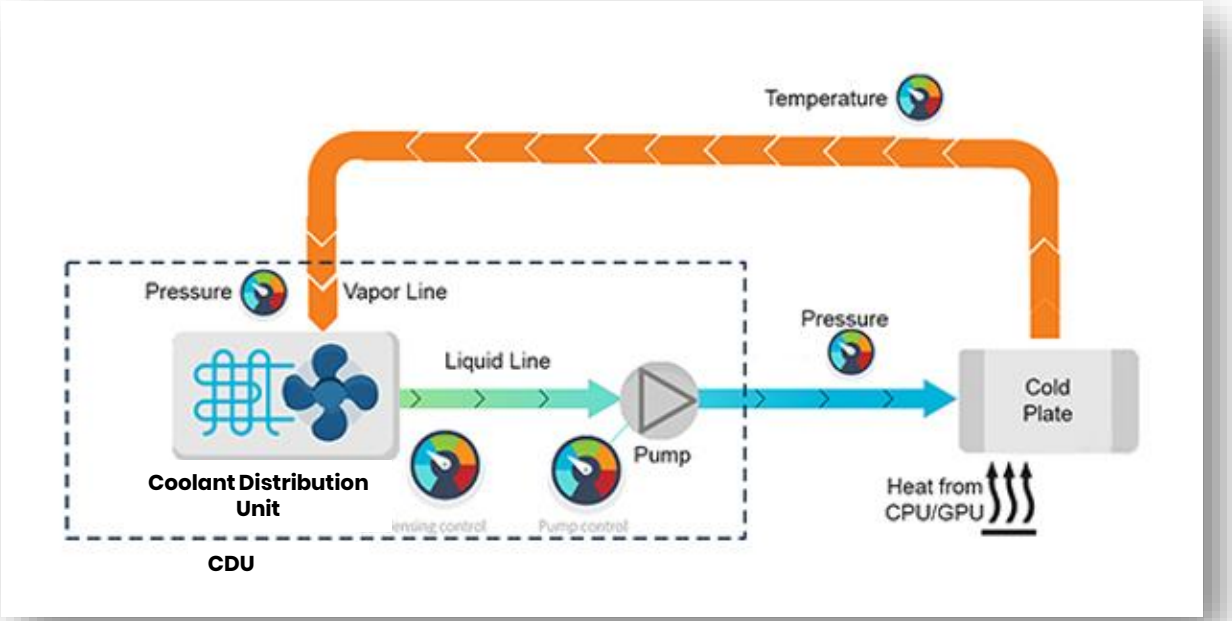
- **Manifold** distribute the dielectric fluid to the cold plates via outlet ports and returns vaporized fluid back to the CDU via inlet ports.
- A self-contained manifold that fits into standard and custom racks.

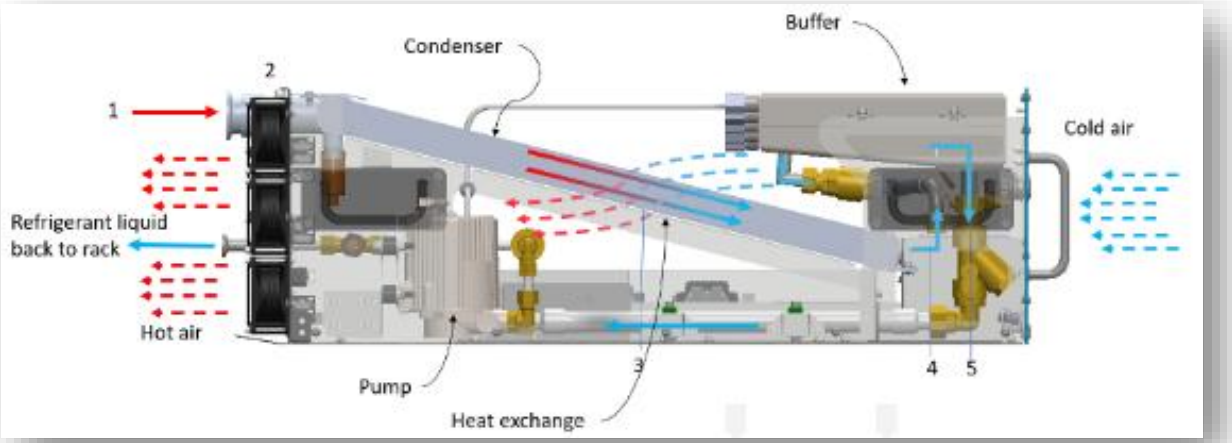




Two-Phase Cooling Loop

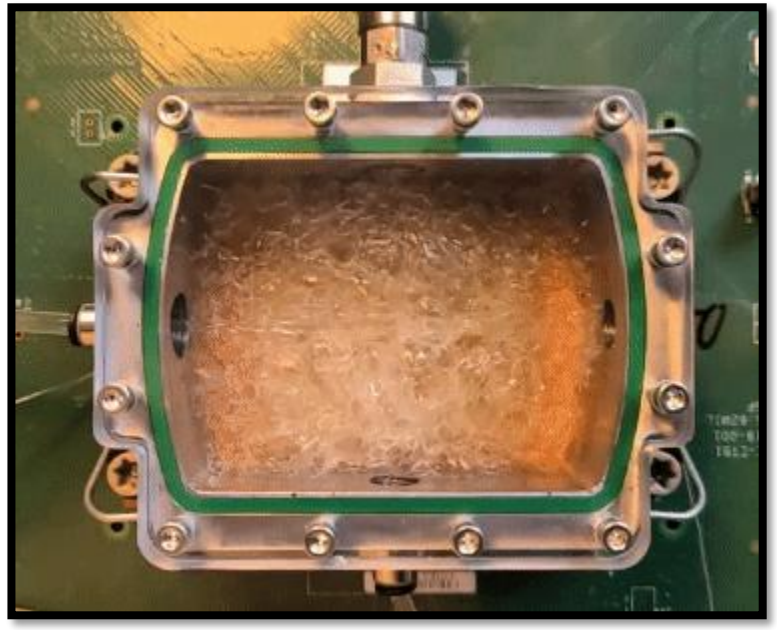
- Direct-to-chip, two-phase, on-demand cooling
- Heat transfer fluid coolant (non-conductive, non-corrosive, environmentally friendly)
- Liquid turns into vapor = up to 10X more efficient than single-phase LC
- Each cold plate is connected in parallel and self-regulated
- Closed-loop system
  - Controls pressure regardless of elevation
  - Significantly reduces maintenance relative to open-loop systems.



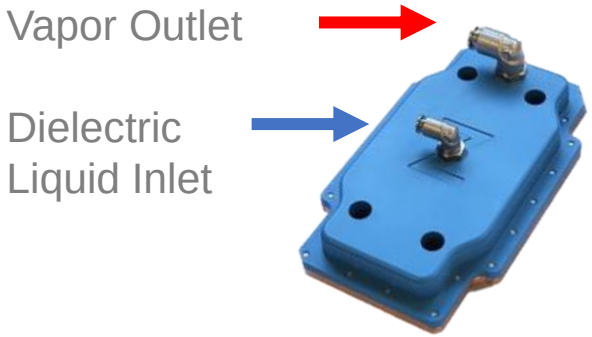


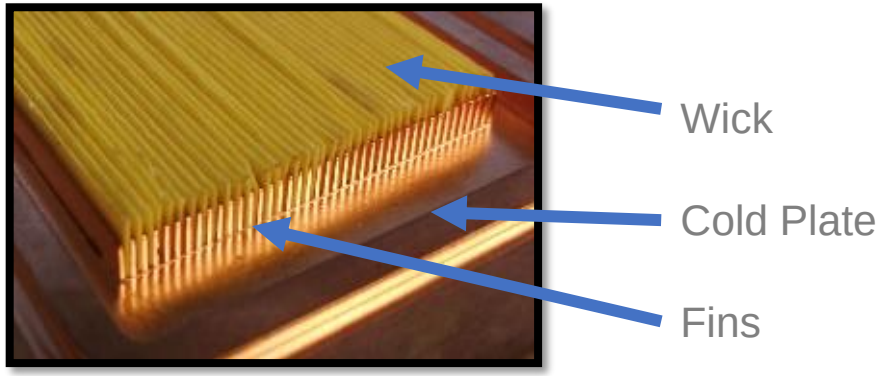
Dielectric Cold Plate

- Highest sustained performance with zero throttling
- Significantly reduces cooling costs
- Self-regulated pool boiling
- Qualified by leading processor manufactures
  - AMD, Intel, Nvidia
- Deployed into major server manufacturers
- AI-ready resilience — handles erratic power swings
- Longer silicon lifespan — uniform cooling reduces stress and extends hardware life



Inside the dielectric cold plate





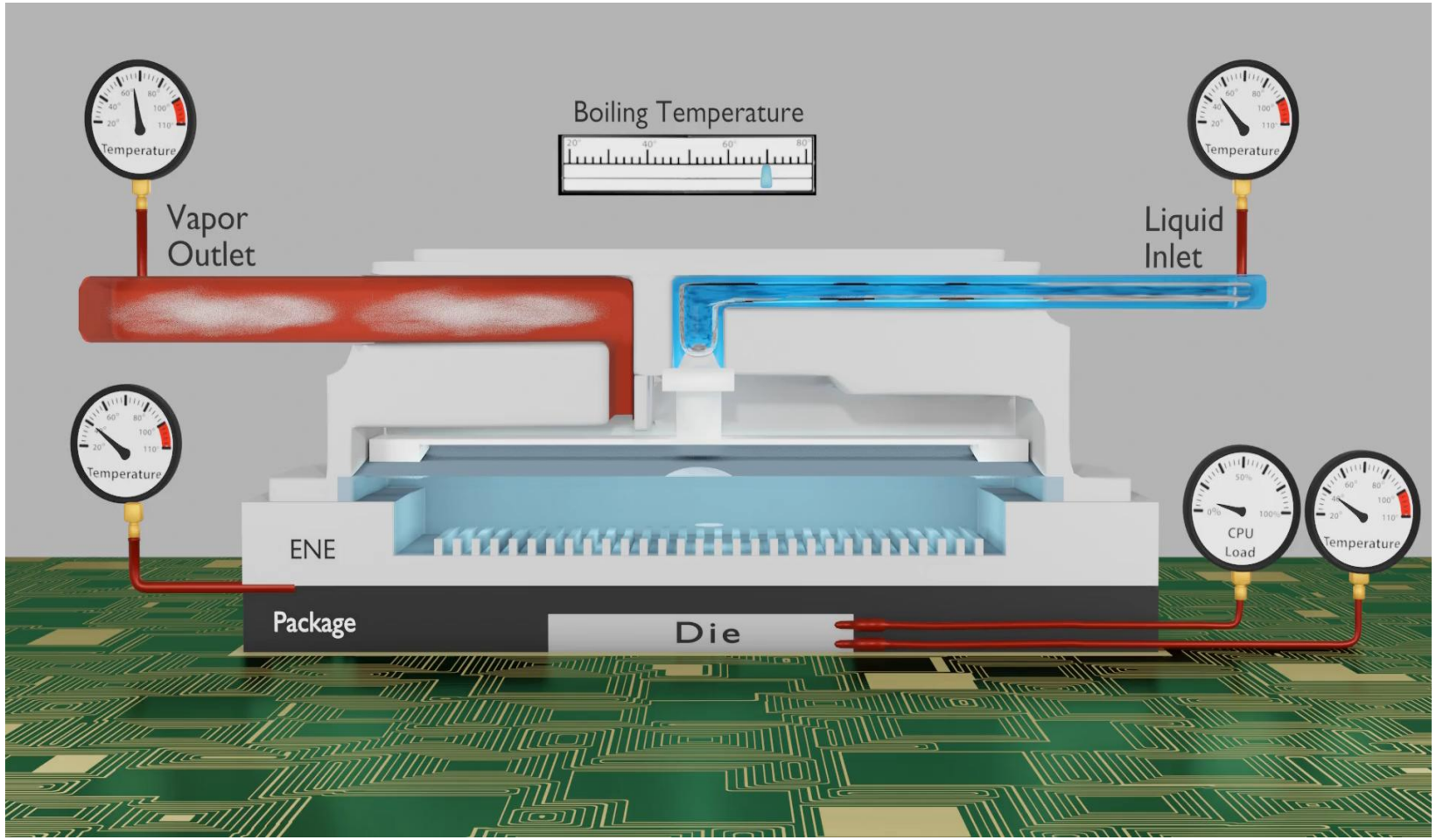
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Cold Plate On-Demand Pool Boiling

Stage 4: As vapor leaves the chamber, the fluid level reduces, the plunger opens, and more fluid enters the cold plate.

Stage 3: As the CPU temp increases, the fluid boils and vaporizes.



Stage 1: Fluid is pumped to the cold plate as needed for on-demand delivery.

Stage 2: As CPU performance increases, so does the temperature.

Direct-to-Chip Liquid Cooling Can Co-Exist

- Direct-to-chip liquid cooling can co-exist with current data center designs with the proper cabinet specification
- Direct-to-chip components are optimized in size and placement
  - Small diameter flexible tubing for liquid and vapor return
  - Slim profile distribution manifold
- Allows compliance to rack and cabinet sizing standards (TIA-569-C section 6.3.9 Racks and Cabinets)
- Provides sufficient space for cable management options to meet structured cabling standards for separation of telecommunications from power (TIA-569-C section 9.3.1; TIA-942 Section 7.3)







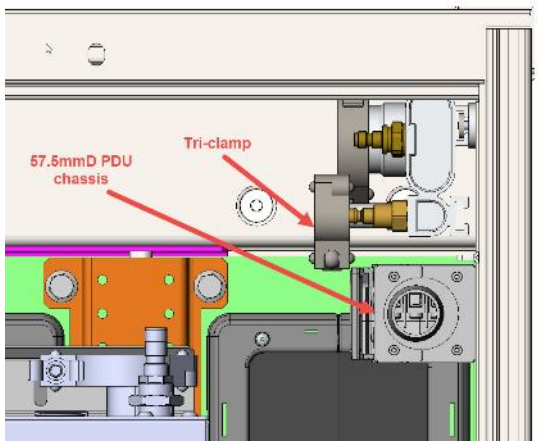
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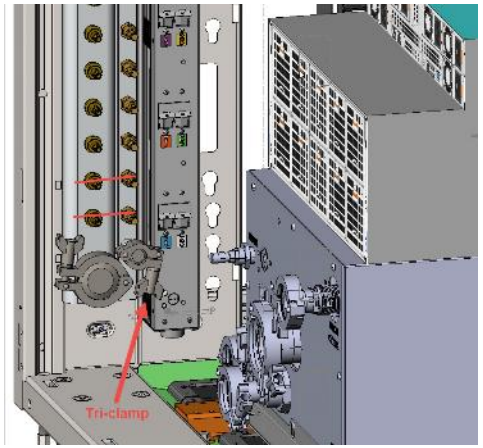
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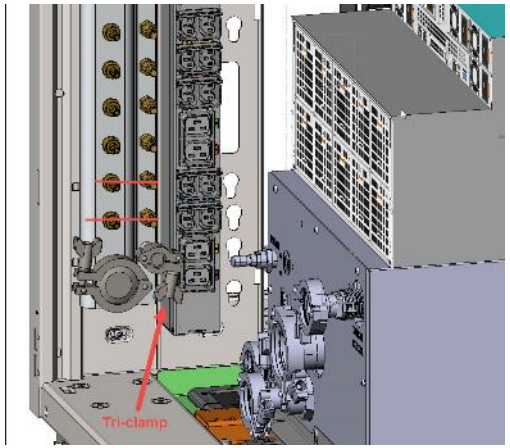
Space Considerations: Keeping Standards in Mind

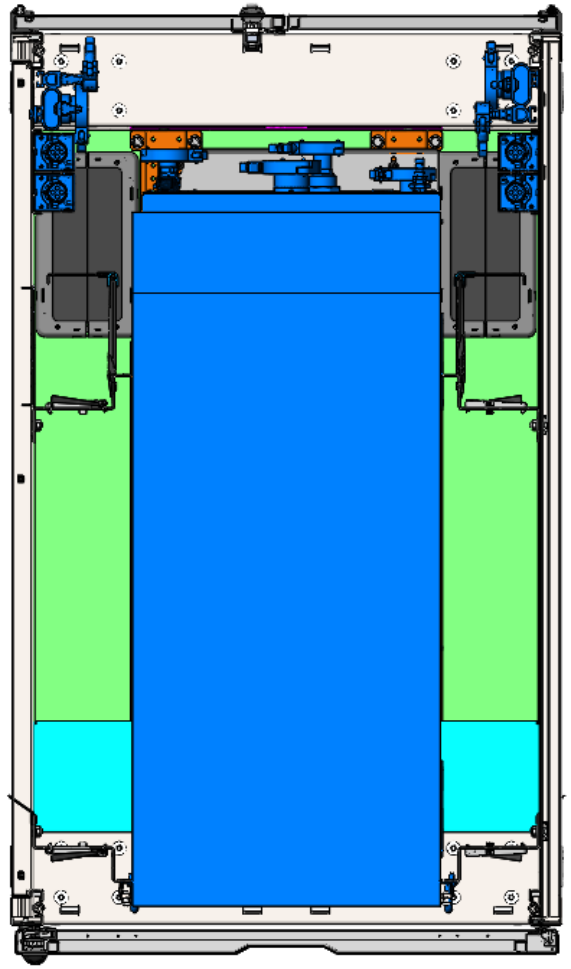
S in ALPS is not only for Solutions…it's a reminder to consider the additional Space

- Cabinet Level – Manifolds, PDUs, Cable Management, Air Flow (VED)
- Row Level – Water pipes/hoses, Power, Cable Pathways
- Room Level – FWS Manifolds, CDUs etc.

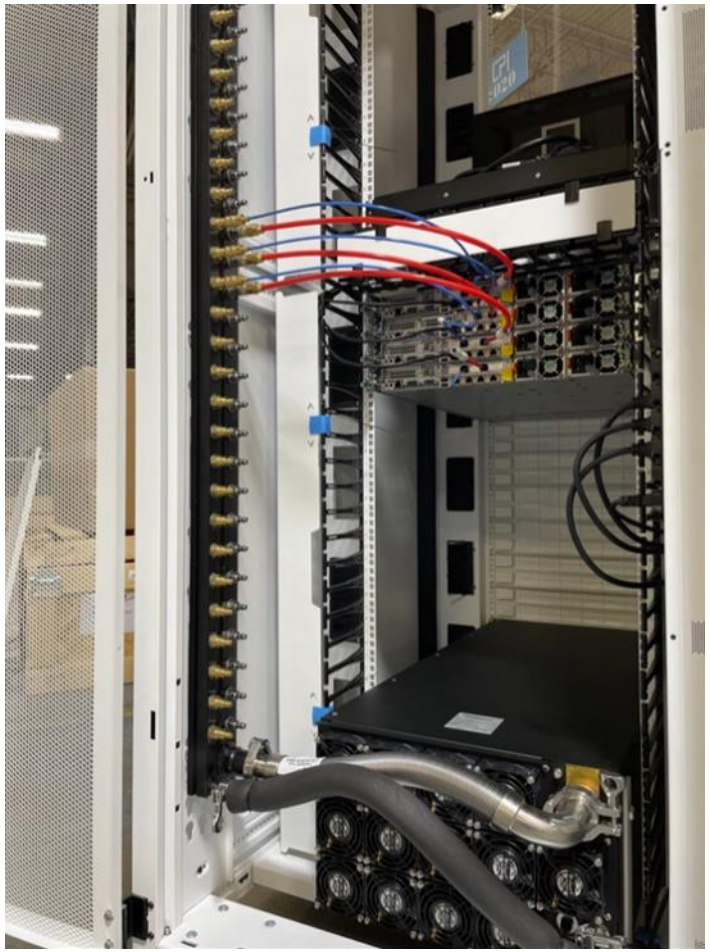








Liquid Cooling in a Cabinet System



- Cabinet optimized for integration with direct-to-chip liquid cooling
  - 800 wide X 1200 deep X 45U
  - 4,000 lbs. dynamic load rating
  - Manifold spatial and mounting requirements mirror PDU requirements
  - Enhanced cable management to meet cabling standards
  - Integrated airflow management
  - Heavy-duty shelf supports fully charged CDU (170 lbs, 77 kg)
  - Integration ready with heavy-duty shock pallet (ISTA 2B)
- Intelligent power management and monitoring with intelligent PDUs
- Physical security and access control

Rear Door Heat Exchanger

- High performance typically provides 50 kW – 75 kW of cooling capacity
- Provides close-coupled cooling for air-cooled IT
  - Equipment is air-cooled by intake air stream
  - RDHx removes the heat from the air - like an air-handler except in close proximity to IT
  - Heat is expelled to facility water loop
  - Room neutral air returns to the room
- Simple solution
  - Supports Green Field and Brown Field applications
  - Compatible with any air-cooled device
- Increases overall cabinet footprint as dimensions
  - Reduced hot aisle spacing
  - Increases system weight





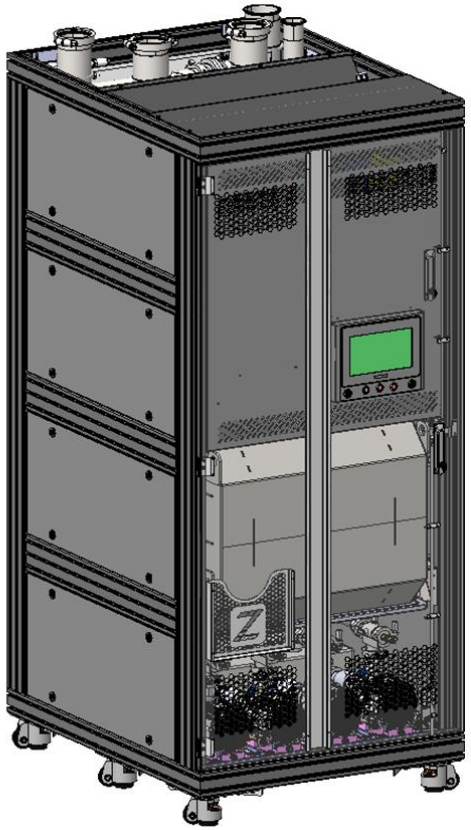


At Scale…

- DTC cold plates remove heat from xPU's
- Row based CDU is mounted in the row
- CDU removes heat from the fluid and expels it into the air stream of the hot aisle
- Typically, services 1-2 cabinets



Liquid to Air CDU
~240kW



Liquid to Liquid CDU
~1.2+ MW

- DTC cold plates remove heat from the xPU's
- Row based CDU is mounted at the end of the row
- CDU removes heat from the fluid and expels it into the facility water loop
- Typically services a row of cabinets (10 X 120kW)

...And Beyond

- Heat rejection capacity: 2+MW
- 2N design supported with 2 CDUs
- Power - 480Vac/3PH/60Hz, 400Vac/3PH/50Hz
- Double wide footprint
- Weight
  - Empty ~2200kg/~4850lb
  - Full ~3000kg /~6614lb.
- Power consumption: ~7 kW





Questions?

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