LIQUID COOLING:
WHY IT'S MAKING SUCH A SPLASH IN DATA CENTERS

Kevin Gray

Technical Business Development Manager, Thermal Solutions

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7x24 Exchange
The end-to-end reliability forum.
Northwest Chapter

Kevin Gray, Presenter Bio

- **BSME, The Ohio State University**
- **MBA, San Jose State University**
- **ASHRAE Member, San Jose Chapter**
- **Work Career:**
- Liebert, Application Engineer
- NSW, Sales Application Engineer / Product Manager
- Vertiv, Business Development Manager

Agenda

High Density – Liquid Cooling Drivers

Technologies To Address High Density Needs

- Rear Door Heat Exchangers
- Direct to Chip Cold Plates
- Immersion
  - 1 Phase
  - 2 Phase

Coolant Distribution Units

- Liquid to Liquid
  - In-Rack
  - In-Row / Perimeter
- Liquid to Air

Additional Liquid Cooling Technology

Additional Technical Resources

Liquid Cooling Progression

Trends Driving Liquid Cooling

Technology
- Storage Arrays
- Chips (CPU)
- Accelerator Chips (GPU)

Sustainability
- Energy Efficiency

Industry
- Internet of Things
- Artificial Intelligence
- Research Labs
- Financial Services
- Media
- Oil & Gas

According to Omdia's 2022 Data Center Thermal Management Market Analysis, the liquid cooling market will top $3B by 2026, with a 50% compound annual growth rate between now and then.

Let's See What AI Thinks

Liquid cooling is becoming increasingly important in data centers for several reasons:

- Increased processing power: As computing technology advances, data centers are processing more data than ever before. This requires more powerful processors, which generate a lot of heat. Liquid cooling is more efficient than air cooling at removing heat from high-performance processors.
- Density: With more powerful processors and the need to process more data, data centers are becoming denser. Liquid cooling allows for greater density by providing a more efficient and effective way to remove heat from the equipment.
- Energy efficiency: Traditional air-cooling systems consume a lot of energy, as they need to circulate cool air throughout the data center. Liquid cooling systems can be more energy-efficient, as they only need to move coolant directly to where it's needed, reducing energy consumption and costs.
- Reliability: Traditional air-cooling systems can be less reliable, as they can be affected by changes in temperature and humidity. Liquid cooling systems can be more reliable, as they are less susceptible to environmental factors and can maintain a more consistent temperature.

Overall, liquid cooling provides a more efficient, reliable, and scalable way to cool high-density data centers that are processing large amounts of data. As data centers continue to grow in size and complexity, liquid cooling will become increasingly important to maintain optimal performance and energy efficiency.

Content courtesy of ChatGPT

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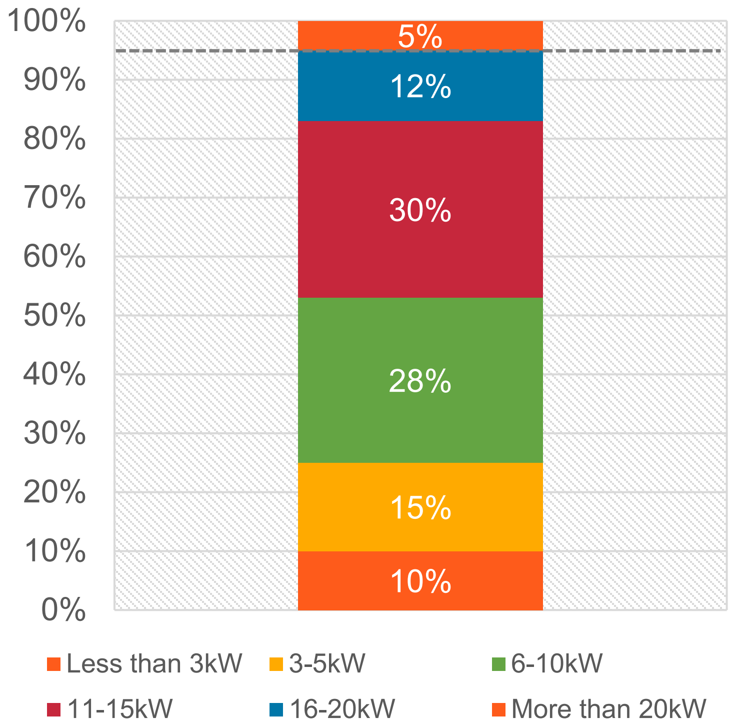
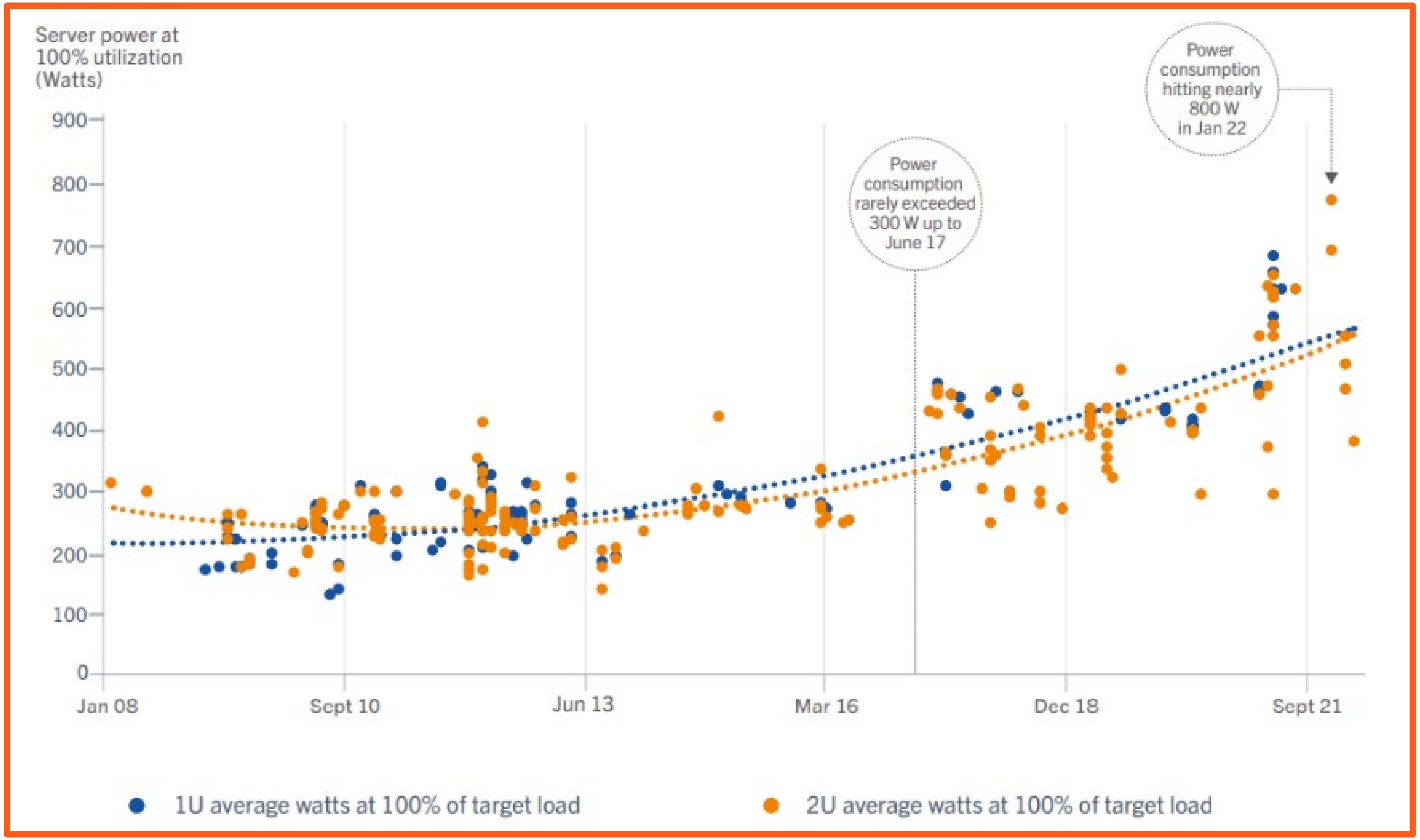
Increasing Rack Densities

Average Density per Rack



17% have highest density rack over 16kW
Expect average rack density to increase over next two years

Rack Power Density Trends



Rising silicon power is a challenge facing all infrastructure operators

Uptime institute 2022

Air Cooling vs. Liquid Cooling and CPU Power

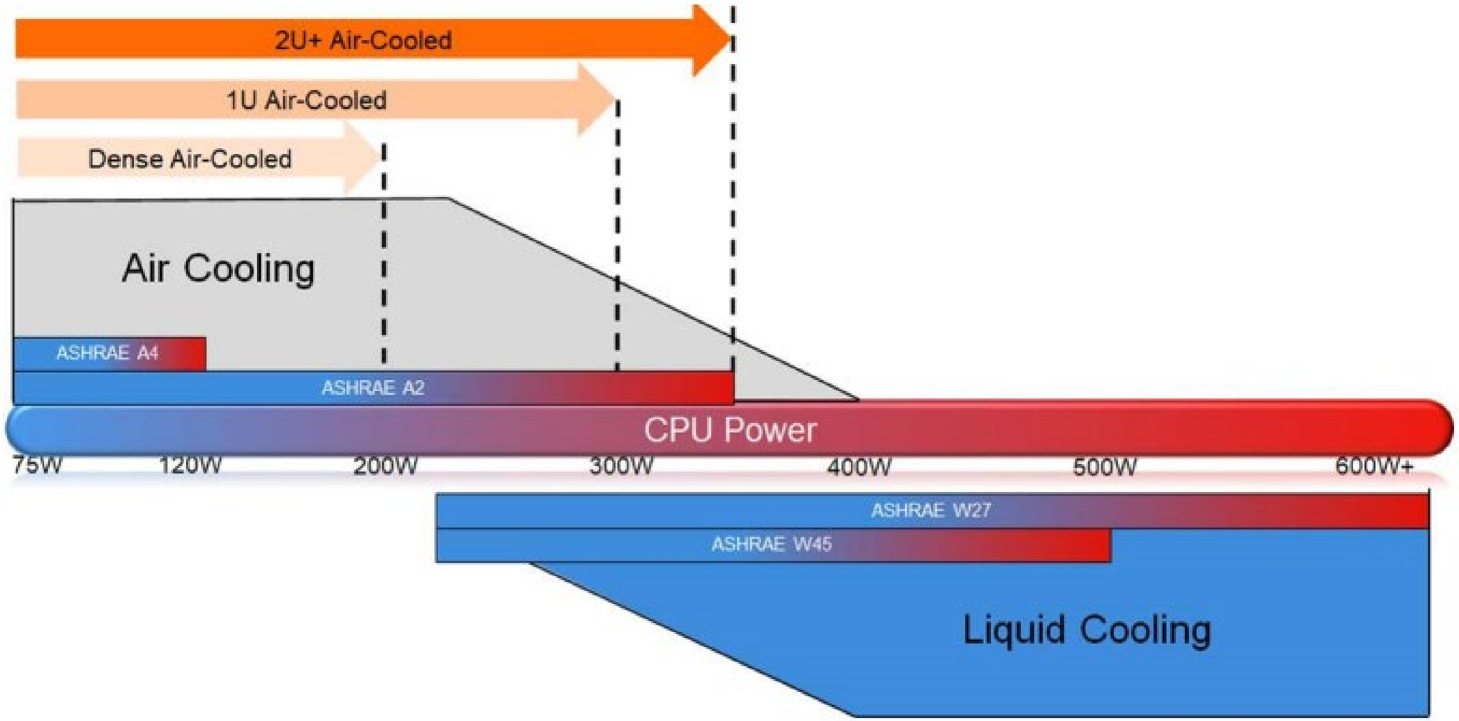


Figure 4 Air cooling versus liquid cooling, transitions, and temperatures.

Source: Emergence and Expansion of Liquid Cooling in Mainstream Data Centers White Paper Developed by ASHRAE Technical Committee 9.9, Mission Critical Facilities, Data Centers, Technology Spaces, and Electronic Equipment, 2001 ASHRAE

Liquid Cooling Progression

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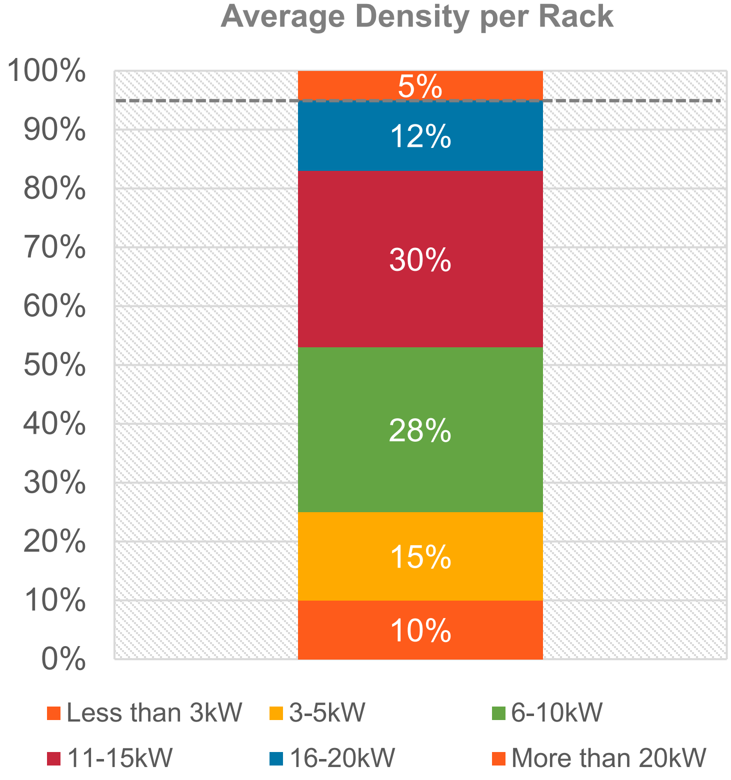
Increasing Rack Densities



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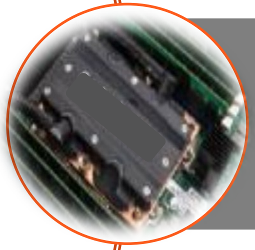
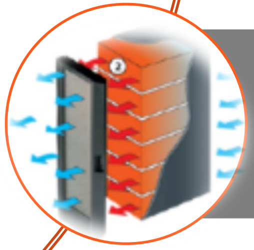
Liquid Cooling Technology Becoming Required

Immersion Cooling
Immerse entire server in fluid



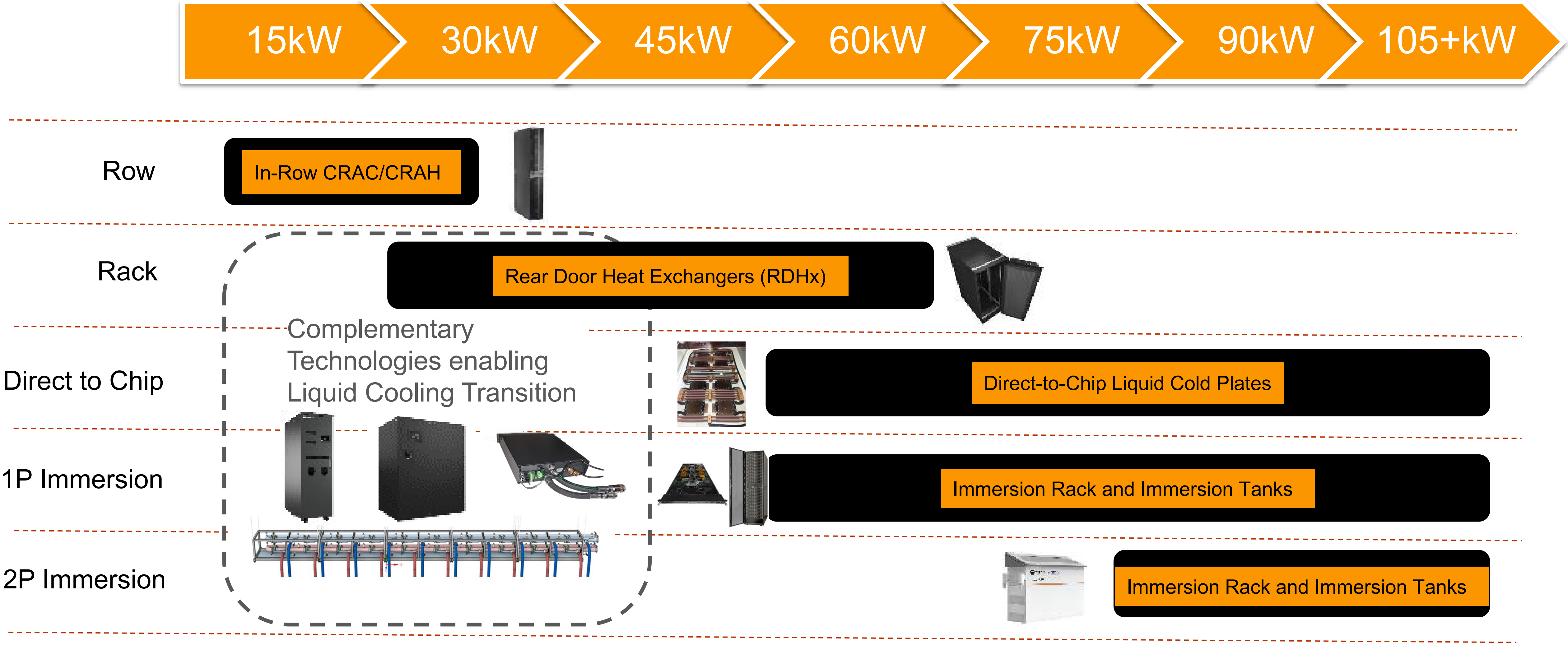
Direct-to-Chip
Cold plate on CPU with CDU to control liquid loop



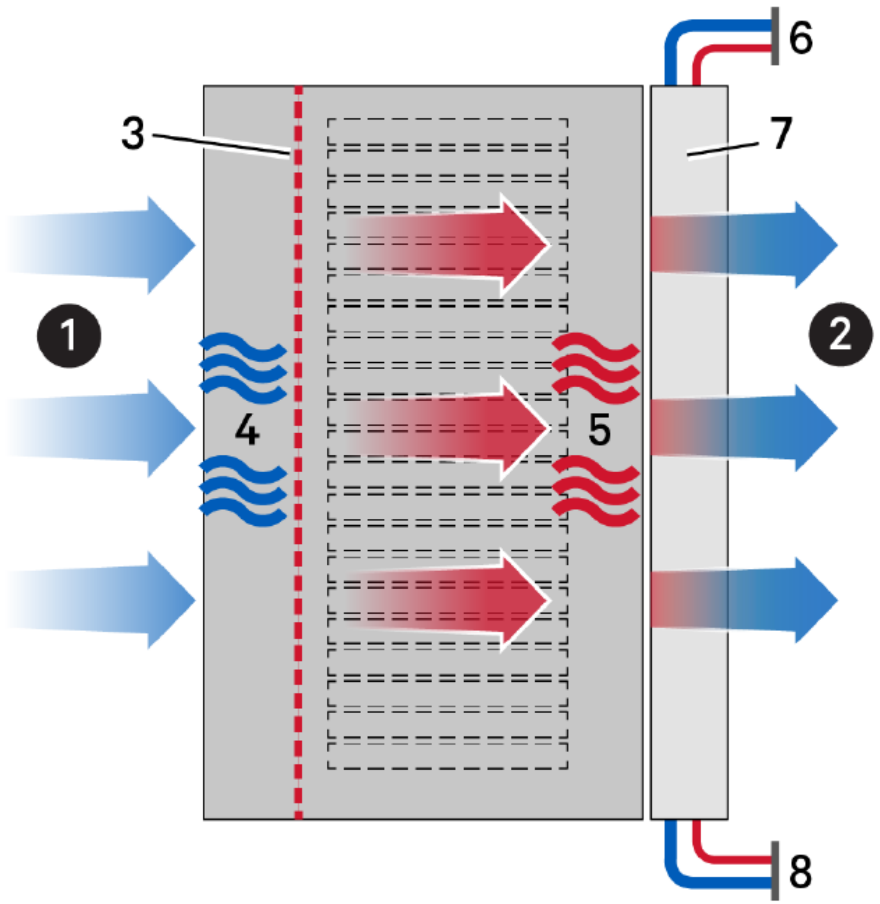
Rear-Door Heat Exchanger
Fans on door blow cold air through rack

VERTIV.

High Density and Liquid Cooling Technologies



Rear Door Heat Exchanger



Operation

- Ambient air (75°F) is drawn into the rack
- As it passes over the ITE (4→5), air temp rises
- Cool fluid is pumped into the RDHX (6)
- As the hot air passes over the HX (7), the heat is transferred to the fluid loop
- Warm fluid flows back to the heat rejection equipment (8)
- 75°F air is returned to the room (2)

RDHX Performance:

		DCD50			
IT Heat Load	40.0	kW	Sea level	0	ft
Server inlet air temperature	80.1	°F	Fluid	WATER	
Server inlet air relative humidity	55.0	%	Inlet fluid temperature	64.2	°F
Server DT on air	25.0	°F	Outlet fluid temperature	78.4	°F
			Unit fluid flow	19.50	gpm (US)
		Unit performances			
Unit	DCD50		Width	31.50	in
Server air flow	5086.7	cfm	Depth	4.72	in
Total cooling capacity	40.1	kW	Height	78.74	in
Sensible cooling capacity	40.1	kW	Weight	209	lbs
nSHR	1.00		Supply air temperature	79.9	°F
Unit air pressure drop	0.189	inH2O	Supply air relative humidity	55.1	%
		CW Coils			
Quantity	1	n°	Unit fluid side pressure drop	3.9	psi
Unit fluid flow	19.50	gpm (US)			

When to use a Rear Door Cooling Solution

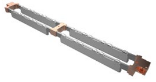
- **Increasing IT loads up to 50kW per rack**
- **Space savings for higher density racks (designs from 15kW to 50kW)**
  - Containers, Modular data center deployments, edge sites
- **Utilized chiller capacity and provide variable cooling loads per rack**
- **More easily retrofittable than other solutions**
- **As a move to lower PUE, sustainability**
- **For extreme loads, combine chip cooling with RDHX for 100% heat to liquid, 50kW+**
  - Loop rear doors and higher feed CW to chip cooling

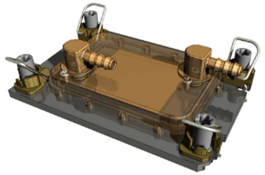
Potential Risks:

- **Rack must be seal tightly to prevent air leakage**
- **Rear door may not be able to swing all the way open**
- **Leaks could occur at the rack level**
- **Door must be closed for cooling to occur**

Liquid Cooling Technology

Direct to Chip: Heat is transferred from IT Equipment through conduction. ITE is NOT in direct contact with liquid coolant.





1-Phase ("Single Phase"): Liquid Coolant does NOT undergo a phase change as heat is transferred.

Liquid to Liquid CDU

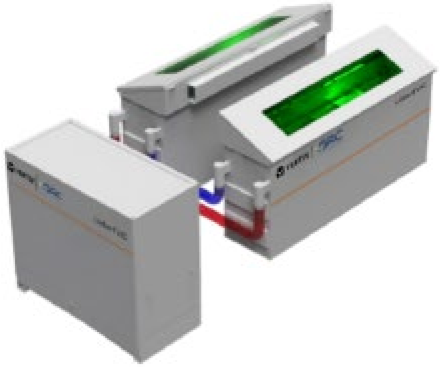
Liquid to Air CDU

In-rack CDU

2-Phase ("Two Phase"): Liquid Coolant DOES undergo a phase change as heat is transferred. Generally, boiling/evaporating (Liquid to Vapor).

Immersion: Heat is transferred from IT Equipment through convection. ITE is in direct contact with liquid coolant.

- Tank
  - 1-Phase
  - 2-Phase



- IT Chassis
  - 1-Phase
  - 2-Phase

CDU Deployment Example – Direct to Chip

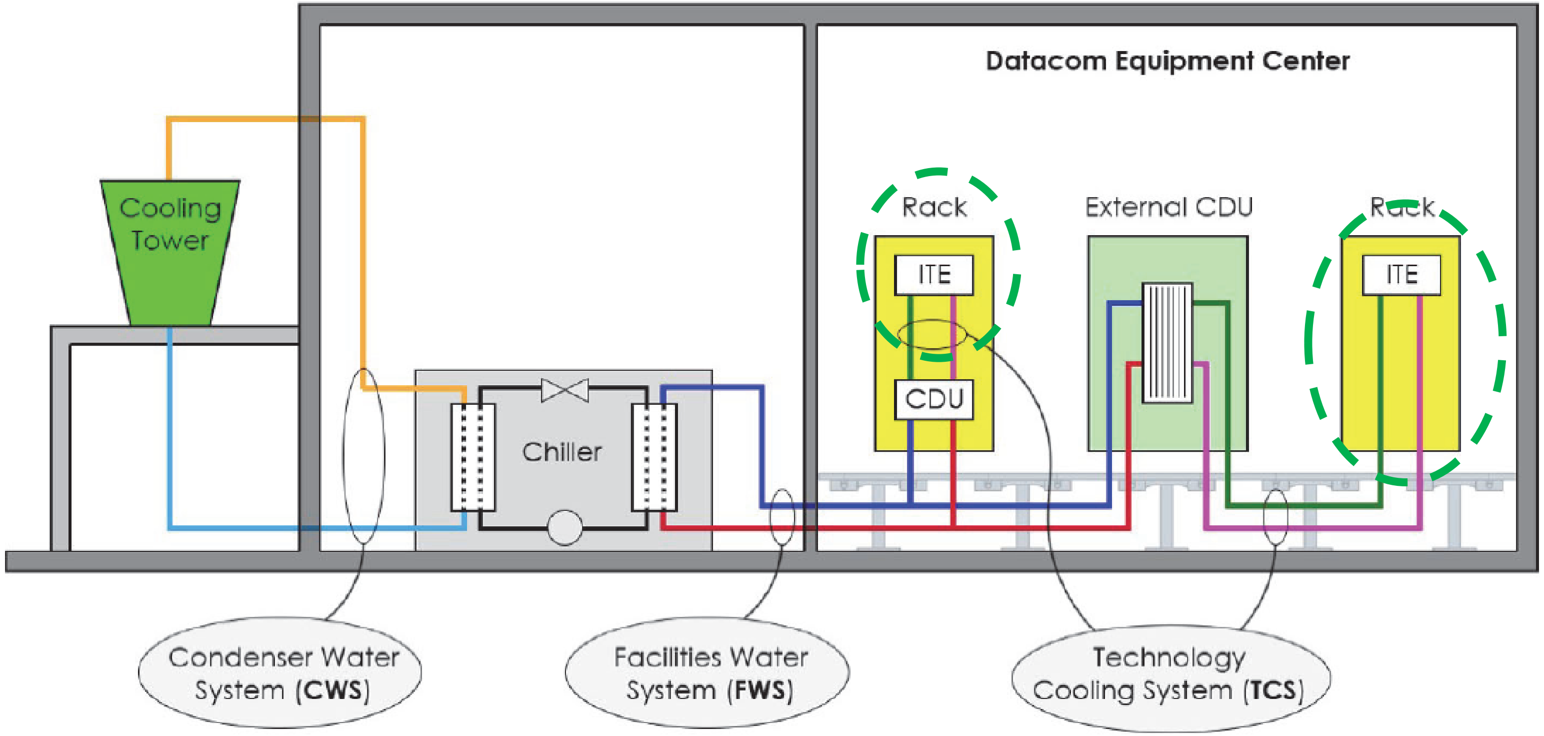
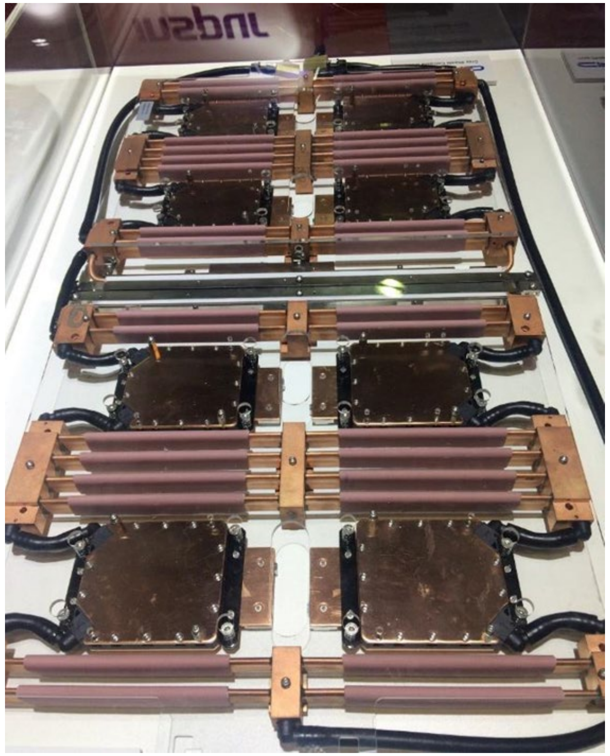


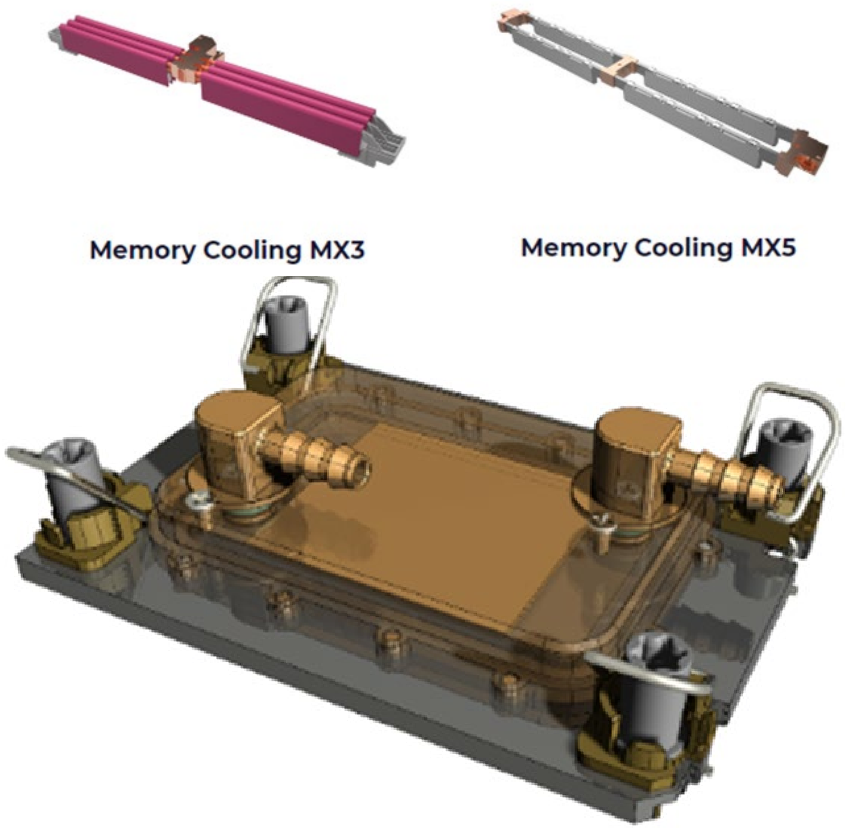
Figure 6 CDU liquid cooling system within a data center.

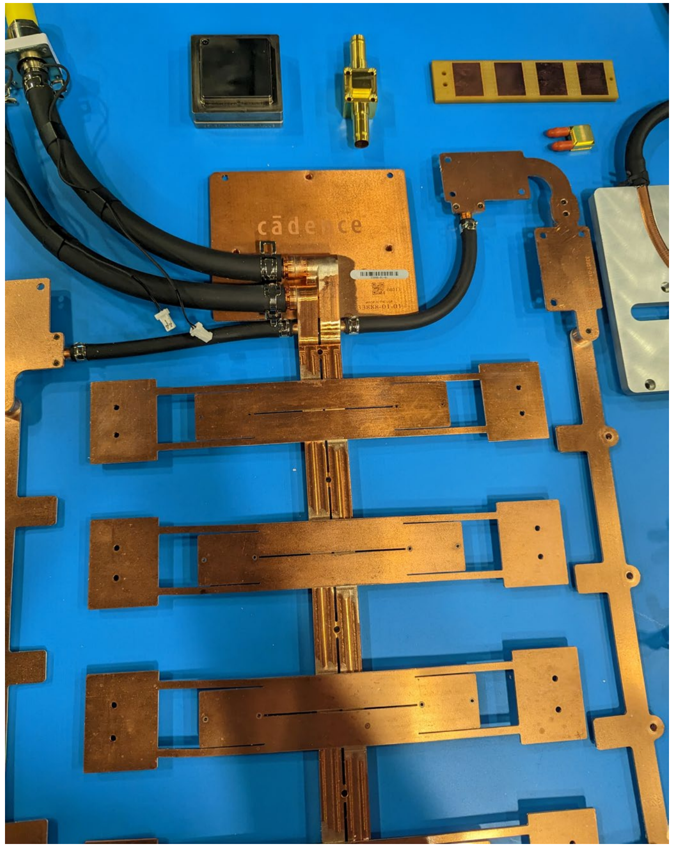
Source: ASHRAE Water Cooled Servers Common Design, Components And Processes TC9.9 Whitepaper

Direct-to-Chip Cold Plates

- Conduction of heat occurs through cold plates, attached to the surface of electronics
- Only captures "big ticket" heat generators – CPU's & GPU's
- Requires supplemental cooling to account for remaining ~20% of heat generated by other components
  - On a 100kW liquid-cooled rack, that means 20kW ***per rack*** is still rejected to the room air
- Micro channels -100 micron spacing requires strict fluid control to eliminate contaminants/debris







When to use Direct-To-Chip

- **Increasing IT loads above 30kW per rack and up to 100kW**
- **Space savings for higher density racks**
  - Containers, Modular data center deployments, edge sites
- **Utilized chiller capacity and provide variable cooling loads per rack**
- **As an even greater move to lower PUE, sustainability**
- **Liquid cooling via treated water or glycol mixture**
  - Dielectric fluids not required

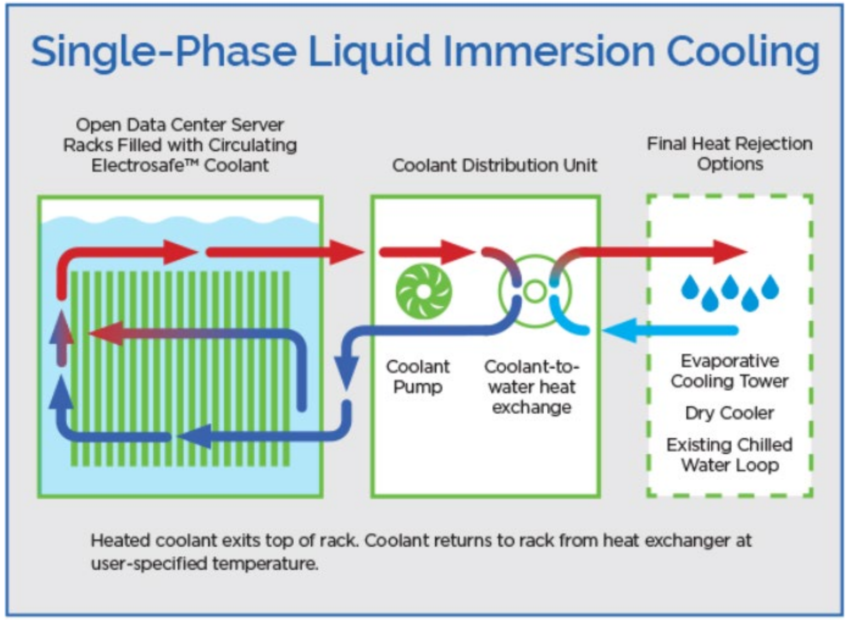
Potential Risks:

- **Likely still need some air cooling**
- **Maintenance requirements increase**
  - Secondary filtration required
- **Racks must be designed for liquid cooling (manifolds)**
- **Likely more expensive solution than traditional air cooling**
- **Leaks are harder to detect**

Liquid Cooling Coolants/Refrigerants

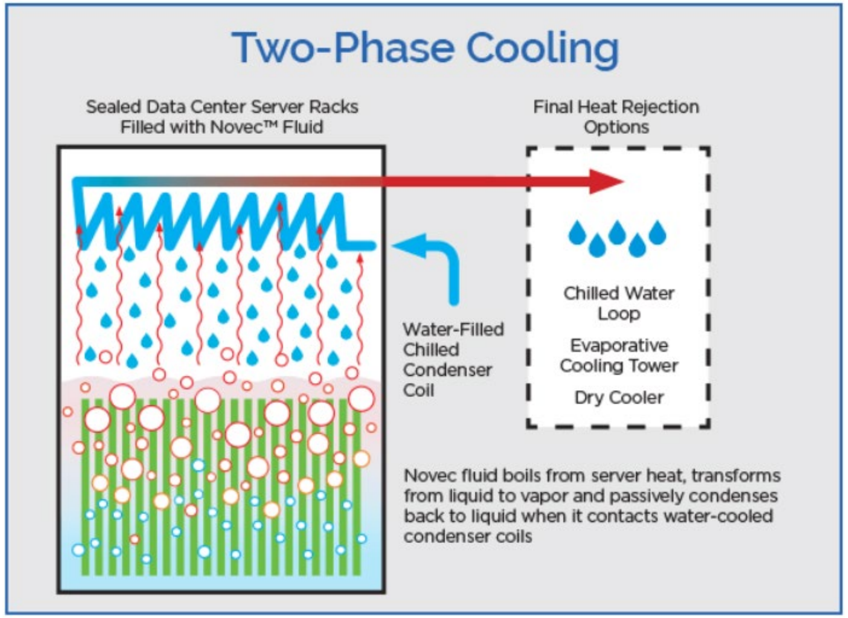
1-Phase

- Coolant always remains in a liquid state
- Single-phase immersion fluids are dielectric liquids. Several options are available
- The working liquid passes rejects it to the facility water loop via a CDU



2-Phase

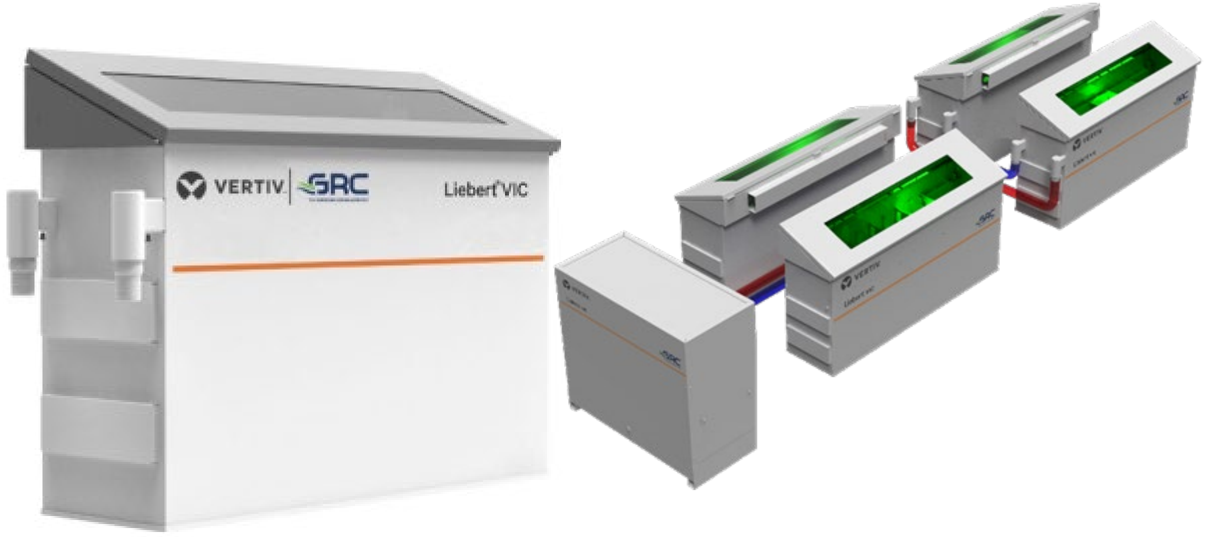
- Coolant evaporates (boils) at the ITE, re-condenses at the heat exchanger
- Takes advantage of Heat of Vaporization, which yields greater heat transfer capacity.
- Any escaping coolant evaporates, eliminating risk of shorting electrical equipment



Immersion Cooling

- Liquid Coolant transfers heat from IT equipment through direct convection (direct contact)
- Captures all of the heat from the IT equipment
    - Material compatibility becomes extremely important
- Dielectric Liquid (non-conductive)
    - Fluorocarbons, Vegetable Oils, Mineral Oils, or other synthetic fluids
- PUE levels down to 1.03

Tanks:



Chassis:

When to use Immersion

- **Increasing IT loads above 50 to 100kW per rack**
- **Lowest PUE requirements (less than 1.05)**
- **Potentially used without CDU**
- **Quiet operation**
- **Near 100% heat rejection through liquid cooling**

Potential Risks:

- **Larger physical footprint than other options**
- **Dielectric fluid complexities**
  - Some of these fluids will potentially not meet environmental standards
- **Warranty of ITE products**
- **2nd Touch requirements, specialized equipment**
- **Longer ROI timeframe, more expensive**
- **Messy**

CDU Deployment Example

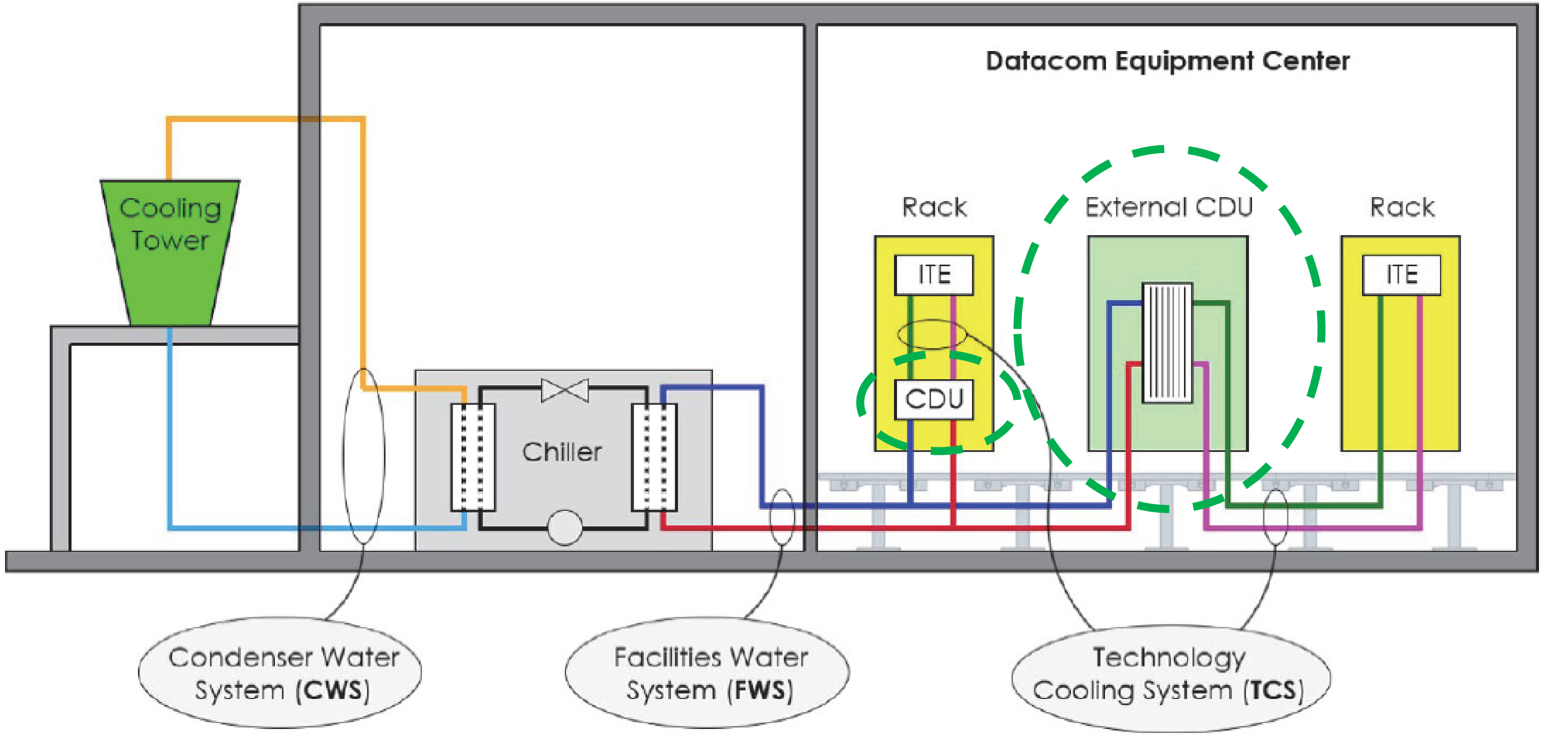
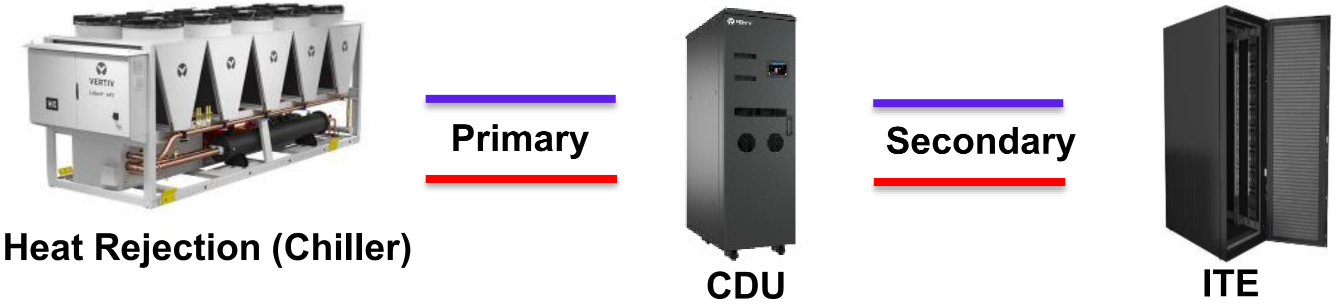


Figure 6 CDU liquid cooling system within a data center.

Source: ASHRAE Water Cooled Servers Common Design, Components And Processes TC9.9 Whitepaper

Coolant Distribution Units (CDU) Feature and Benefits

- Essential separation of the primary (facility) water from the IT equipment, providing low pressure, clean water to liquid cooled IT equipment
- Low water volume in secondary loop, reducing leak risk.
- N+1 pumps, inverters, expansion vessels, pressure & temperature sensors for built-in redundancy.
- Tightly controlled secondary water temperature (±1°C) and maintained above room dew point to prevent condensation
- Large surface area heat exchangers to provide high cooling capacity with low approach temperatures, with optional two stage cooling to cater for low heat loads without loss of control.
- Perimeter/In-Row and In-Rack options available. Liquid-to-Liquid and Liquid-to-Air options available.



In-Row/Perimeter CDU (Liquid to Liquid)

- Heat Exchangers potentially designed to transfer up to a MW or more of load
  - Unit likely limited based of pump power rather than heat exchanger capability
- Can support several liquid cooled racks, immersion tanks, or RDHx at a time
- Multiple CDUs often tied together in a single loop
- Generally designed with a redundant pump (all pumps running = more flow)
  - Level of redundancy must be defined (pump level, unit level)
- Secondary filtration included
- Could be installed in-row, perimeter, or external to the data center
- Retrofittable to existing chilled water data centers
- Most common form of CDU

Additional Resources

ASHRAE

- ASHRAE Technical Committee 9.9, Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment
  - White Paper *"Emergence and Expansion of Liquid Cooling in Mainstream Data Centers":* https://www.ashrae.org/file%20library/technical%20resources/bookstore/emergence-and-expansion-of-liquid-cooling-in-mainstream-data-centers_wp.pdf
  - White Paper *"Water-Cooled Servers Common Designs, Components, and Processes":* https://www.ashrae.org/File%20Library/Technical%20Resources/Bookstore/WhitePaper_TC099-WaterCooledServers.pdf
  - Datacom Series Book "*Liquid Cooling Guidelines for Datacom Equipment Centers, Second Edition*": https://www.techstreet.com/ashrae/standards/liquid-cooling-guidelines-for-datacom-equipment-centers-2nd-ed?ashrae_auth_token=&gateway_code=ashrae&product_id=1873288

The Green Grid

- Liquid Cooling Total Cost of Ownership Tool: https://www.thegreengrid.org/en/resources/library-and-tools/468-Liquid-Cooling-Total-Cost-of-Ownership-Calculation-Tool
- White Paper *"Liquid Cooling Technology Update":* https://www.thegreengrid.org/en/resources/library-and-tools/442-WP

ASME

- White Paper *"Power Usage Effectiveness Analysis of a High-Density Air-Liquid Hybrid Cooled Data Center":* https://asmedigitalcollection.asme.org/InterPACK/proceedings-abstract/InterPACK2022/86557/V001T01A014/1153400

Open Compute Project (OCP)

- White Paper *"DATA CENTER LIQUID DISTRIBUTION GUIDANCE & REFERENCE DESIGNS":* **https://www.opencompute.org/documents/ocp-acf-reference-design-guidance-white-paper-pdf-1**

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Contact Info:
Kevin Gray
Technical Business Development Manager,
Thermal Solutions
Email: kevin.gray@vertiv.com
Phone: 925-519-7717

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