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WHITEPAPER

LIQUID-TO-CHIP COOLING

ENABLING THE NEXT GENERATION
OF HIGH-DENSITY DATA CENTRES



Executive Summary

The exponential growth of computing-intensive workloads, driven by artificial intelligence (AI), machine learning, advanced analytics and high-performance computing (HPC) has fundamentally reshaped the thermal demands of modern data centres. Traditional air-cooling architectures are reaching their physical and economic limits, particularly as rack densities exceed 30 kW and rapidly move towards 100 kW and beyond. Liquid-to-Chip and advanced immersion cooling technologies have emerged as critical enablers for the next generation of data centres, allowing heat to be removed directly at source. When designed and commissioned correctly, these solutions unlock higher densities, improved energy efficiency, reduced operational risk and long-term sustainability.

CAI Mission Critical is a global leader in the delivery and commissioning of liquid-cooled data centres, bringing deep technical expertise, proven methodologies and real-world project experience across multiple continents.

Why Liquid-to-Chip Cooling Is Now Essential

Air cooling has served the industry well for decades, but its limitations are now clear. As processor power densities increase, air's low thermal capacity requires excessive airflow, higher fan energy and increased infrastructure footprint. Liquid cooling fundamentally changes this paradigm by removing thermal energy directly from the highest heat-generating components, enabling higher densities with greater efficiency and reliability.

Liquid Cooling Technologies in the Modern Data Centre

DIRECT-TO-CHIP LIQUID COOLING

Direct-to-Chip cooling systems utilise cold plates mounted directly onto CPUs and GPUs. Liquid coolant circulates through these cold plates while residual heat is managed by a reduced air-cooling system, making this approach ideal for AI and GPU-dense environments.

IMMERSION COOLING (SINGLE AND TWO-PHASE)

Immersion cooling submerges IT equipment in a dielectric fluid. Single-phase immersion: Fluid remains liquid throughout operation and transfers heat via a heat exchanger. Two-phase immersion: Fluid boils at component hot spots, absorbing large heat loads during phase change before re-condensing. While immersion offers extreme thermal performance, it requires sealed systems, specialist fluids and heightened attention to materials compatibility and operational processes.



Key Benefits and Risks

Key Benefits includes rack density guidance (>30kW recommended; >100kW required), reduced need for air conditioning/humidity control, suitability for AI/GPU workloads. Risks and mitigation themes are (CDU redundancy, fluid verification, TAB/pressure setpoints, materials compatibility, couplings/quick connects, leak detection/mitigations, flushing).

>30kW
RECOMMENDED

>100kW
REQUIRED

CAI Mission Critical: Global Leaders in Liquid Cooling

CAI Mission Critical brings proven, hands-on experience delivering liquid cooling solutions at scale, including:

- ✓ A 3 × 25 MW colocation data centre in Johor, Malaysia, utilising Liquid-to-Chip technology, fully commissioned in 2023–2024
- ✓ A 100+ MW hyperscale colocation facility in the Middle East, deploying two-phase immersion cooling, currently in delivery
- ✓ A large-scale colocation data centre in Texas, USA, implementing advanced two-phase immersion cooling

This experience spans multiple climates, regulatory environments and operating models giving CAI a unique global perspective.



A Proven Commissioning Methodology

CAI applies a multi-level commissioning framework specifically adapted for liquid cooling systems.

DESIGN & INSTALLATION VALIDATION (CX LEVELS 1–2)

- ✓ Safety and documentation reviews
- ✓ Mechanical and electrical installation verification
- ✓ CDU installation inspections
- ✓ Primary and secondary loop pressure testing
- ✓ Rigorous flushing and cleanliness validation
- ✓ Leak detection strategy verification

Flushing is critical: both primary and secondary loops, to prevent long-term performance degradation and component failure.

FUNCTIONAL & LOAD TESTING (CX LEVELS 3–4)

- ✓ Component and alarm testing
- ✓ Communication and control verification
- ✓ Redundancy and failure scenario testing
- ✓ Load testing using specialist liquid-cooled test equipment
- ✓ Advanced functional and group failure scenarios

INTEGRATED SYSTEMS TESTING (CX LEVEL 5 – IST)

- ✓ Heat load testing at 33%, 50%, 66%, 75% and 100%
- ✓ End-to-end primary and secondary loop redundancy validation
- ✓ CDU power availability and busway load considerations
- ✓ Terminal unit and white-space integration testing

This structured approach ensures operational resilience before go-live, not after failure.

Conclusion

Liquid-to-Chip cooling is foundational to the future of high-density data centres. CAI Mission Critical provides the expertise and confidence required to deliver these complex systems successfully.

Prepared By:

Tom O'Farrell – Director of Client Engagement

May 2026



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+1 317-271-6082
CAIREADY.COM

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