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Achieving chip cooling at 1000W and beyond with single phase Precision Liquid Cooling

Authored by: Dr Jasper Kidger, Dr Kelley Mullick, Neil Edmunds
Iceotope Labs team: Alex Cushen, Brenon Carter

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Introduction

In 2023, the prominence of liquid cooling has surged within the data center industry, notably driven by the advancements in generative AI technology. Despite its presence in the market for over a decade, liquid cooling technology had primarily been confined to the high-performance computing sector without widespread adoption. Because of the compute densities required for AI, the overall rising thermal design power of IT equipment, and the overall need for sustainable solutions, the industry has latched onto liquid cooling as the solution for solving these challenges. This has been evident by nearly all technologists confirming now is the time for liquid cooling solutions to scale.

One of the challenges faced by liquid cooling solution providers is demonstrating the technology's capacity to facilitate chip-level cooling up to and beyond 1000W. The dense IT equipment needed to support AI – predominantly CPUs and GPUs – will require this type of cooling capability within the next three years. There has been a perception in the industry that single-phase liquid cooling is limited to approximately 400W. However, there are ongoing efforts to actively demonstrate how single-phase liquid cooling can achieve 1000W cooling.

Precision Liquid Cooling has achieved the 1000W industry cooling milestone

Iceotope's enclosed chassis Precision Liquid Cooling solution has achieved this industry milestone with our patented KUL SINK designs. This paper will share the results from a series of tests recently conducted to demonstrate the thermal performance of Precision Liquid Cooling. It will also highlight how the technology can go beyond the perceived 1000W limit to compete head-to-head with the cooling capable in two-phase immersion technologies without any of the risks tied to the fluids used in that technology.

Testing Procedure

A series of tests were conducted on four different Iceotope KUL SINK heat sinks using Intel's Airport Cove thermal test vehicle (TTV), a thermal emulator for the 4th Gen Intel® Xeon® Scalable processors. The TTV allows for comparison of different heatsinks and thermal interface material (TIM) types and can indicate thermal performance on real Xeon processors as the die area is identical. The results found in this paper are for the Iceotope designed copper KUL SINK in Figure 1.

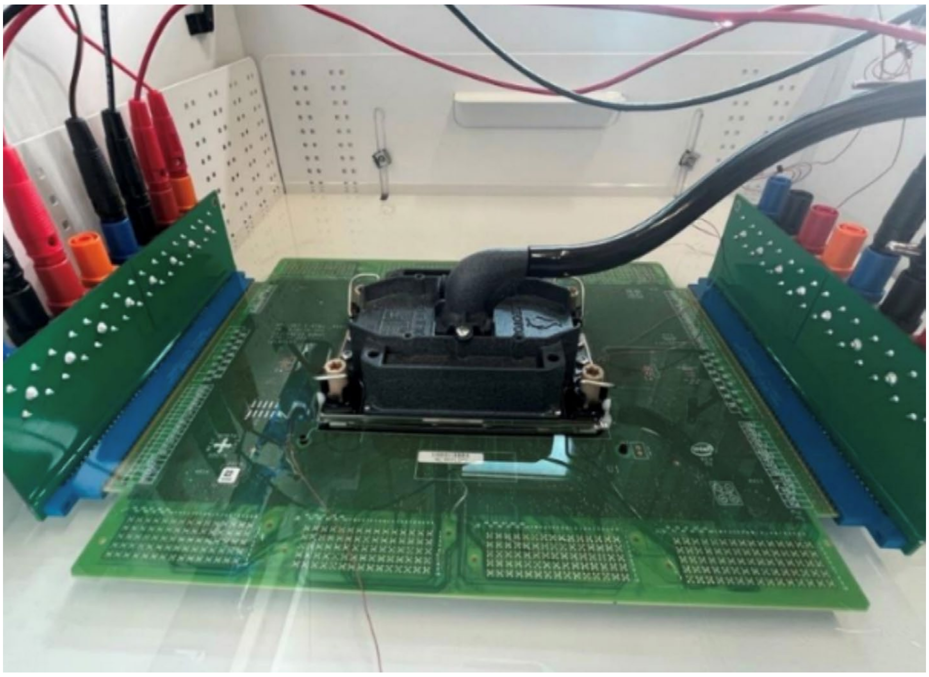

Figure 1. Photograph of TTV and Heatsink assembly

The Iceotope KUL SINK was fed with Shell S3X dielectric coolant at 40°C and at a range of flowrates up to 7.5 l/min. The Intel Airport Cove TTV was evenly heated at a range of input powers up to 1000W.

Thermal performance testing was conducted in three phases. The schematic of the set up can be found in Figure 2 below. Phase 1 was the thermal testing of all Iceotope heatsinks. Phase 2 involved testing the solid copper KUL SINK at 1000W input power. Phase 3 included testing the solid copper KUL SINK with different TIM types. Flow rate was deduced by measuring the difference in pressure across the two dielectric pressure sensors.

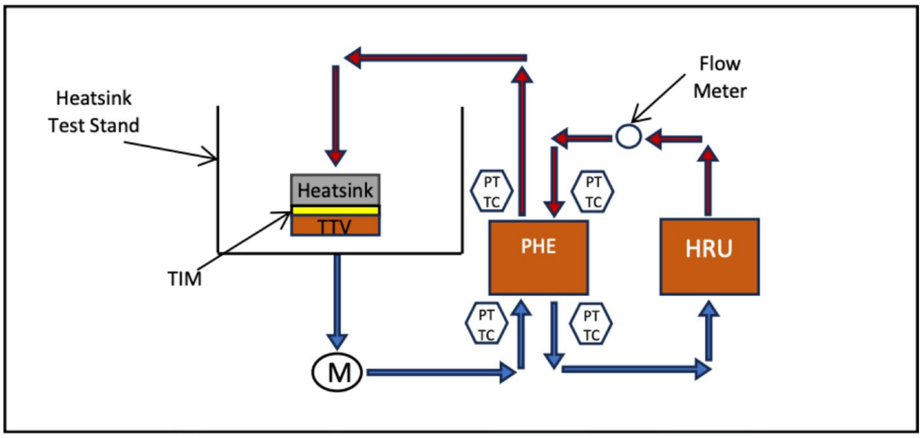

Figure 2. Schematic of test set up

It is critical for data center operators to know they are future proofing their infrastructure investment for 1000W and beyond

Test procedure:

1. The Heat Rejection Unit (HRU) was set to circulate a supply of cooling water to a plate heat exchanger (PHE) within the test stand.

2. On the test stand, a dielectric pump circulated the S3X dielectric coolant through the PHE before supplying the heatsink with dielectric at a known temperature and flowrate.

3. Once the dielectric has passed through the KUL SINK, it is allowed to overflow the KUL SINK and passes into the sump of the test stand before returning to the pump. This is analogous to a real Iceotope Precision Liquid Cooling system, where overflowing coolant exiting the KUL SINK would then be absorbing heat from all the other ITE components on the system motherboard, before returning to the pump.

4. The temperature of the dielectric was continuously monitored. A constant dielectric supply temperature was achieved by controlling the water-side flow rate and temperature of the HRU.

5. The flow rate of the dielectric was determined by measuring the pressure drop across the PHE. The characterization of flow rate vs pressure drop was determined when the test rig was first commissioned, across a wide range of flow rates and operating temperatures.

6. A pair of power supplies supplied the Intel Airport Cove TTV. This TTV comprises 4 separate dies, one of which is of a different electrical resistance to the other 3. The power supply configuration was set to give uniform heating across the 4 dies of the Intel TTV.

7. Thermocouples were embedded in the top-center of the Airport Cove TTV, and the bottom-center of the Icelake KUL SINK. This enabled both the overall thermal resistance from fluid to Tcase of the CPU to be calculated, as well as enabling Iceotope to monitor the thermal performance of the Thermal Interface Material (TIM).

8. For each test point, the system was allowed to stabilize, then the reported data obtained over a 15-minute averaging period.

Iceotope achieved an 11.4% improvement in thermal resistance compared to like-for-like test of a tank immersion

Performance Results

The testing validated our assumptions about the thermal performance of Precision Liquid Cooling. It is important to note that thermal resistance is expected to be agnostic to the power to the chip and consistent regardless of power input.

Key findings included:

- At a flow rate of 7.01 l/min, Iceotope's copper pinned KUL SINK achieved a thermal resistance of 0.039 K/W when a 1000W heat load was applied to the TTV. This translates to an 11.4% improvement in thermal resistance compared to like-for-like test of a tank immersion product containing a forced-flow heatsink.

- Thermal resistance remains constant at a given flow rate as the power was increased from 250W to 1000W.

- We have high confidence that testing at 1.5kW will yield the same consistency as 1000W test based on the testing of the thermal resistance from 250W to 1000W.

Further details can be found in Figure 3 and Figure 4 below.

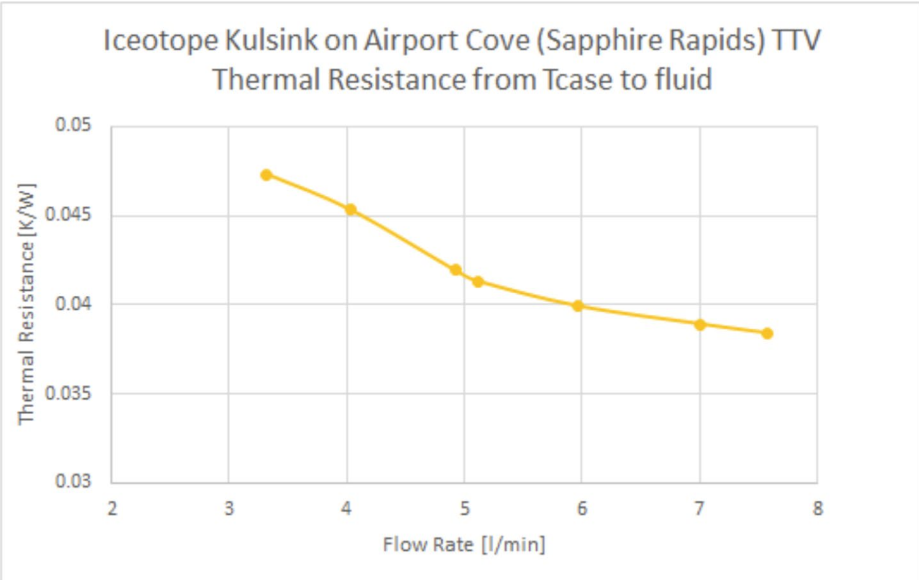

Figure 3. Iceotope KUL SINK TTV Thermal Resistance from Tcase to Fluid

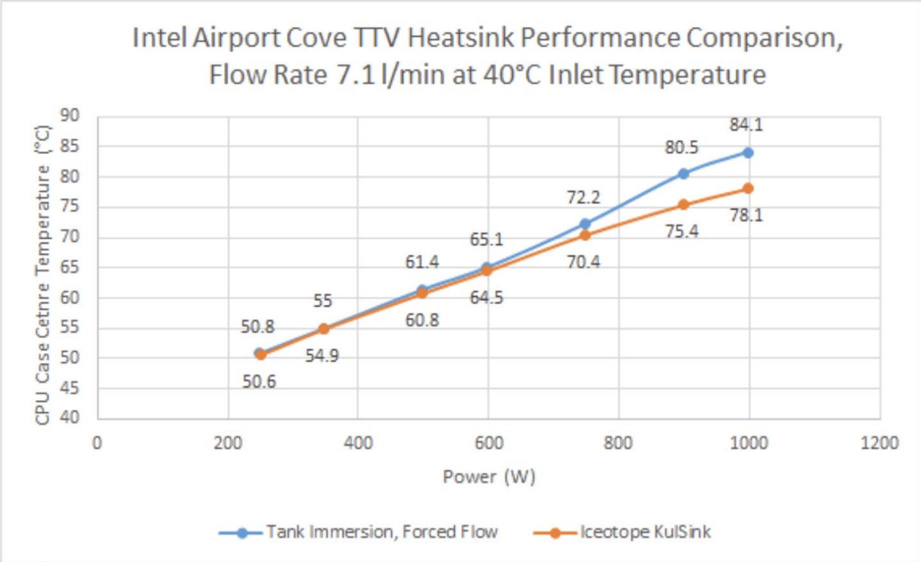

Figure 4. Intel Airport Cove TTV Heatsink Performance Comparison

Choosing technologies that can meet the demands of processor and chip roadmaps and future server generations will be key

Precision Liquid Cooling at 1000W and beyond

Looking ahead to the next decade, it is critical for data center operators to know they are future proofing their infrastructure investment for 1000W to 1500W to 2000W CPUs and GPUs. Choosing technologies that can meet the demands of processor and chip roadmaps and future server generations will be key.

Iceotope has proven the potential of its patented Precision Liquid Cooling technology to meet roadmap requirements in the cooling of high-power density chips. This has been achieved using minimal quantities of people and planet safe single phase dielectric fluids in combination with Iceotope's scalable, sustainable and serviceable precision delivery technology. Iceotope's technology relies exclusively on forced convection as the primary heat transfer mechanism. This will always offer greater thermal performance than natural convection.

In addition, Precision Liquid Cooling reduces energy use by up to 40% and water consumption by up to 100%. The highly configurable modular design enables rapid scalability from one server to many racks all within the same data center footprint or in any location from the cloud to the edge. The familiar vertical rack-based design is easy to maintain and offers a 6x density uplift compared to both tank immersion and traditional air-cooled technologies.

We have high confidence that testing at 1.5kW will yield the same consistency as 1000W

Conclusion

Iceotope Precision Liquid Cooling technology has achieved an important industry milestone as we were able to demonstrate cooling a 1000W silicon. Furthermore, it was done so at greater thermal performance than competing liquid cooling technologies. Future testing will demonstrate how even lower thermal resistance can be achieved for server generations to come. Precision Liquid Cooling technology is well poised to support future processor roadmaps from 1000W and beyond.

About Iceotope

Using industry standard form factors, Iceotope's Precision Liquid Cooling solutions offer extreme cooling performance, simplified maintenance, hot swapping, and significant cost reductions both inside and outside the data center.

About the authors

Dr Jasper Kidger

Jasper Kidger is the Head of ThermoFluids and a Computational Fluid Dynamics (CFD) specialist for liquid cooling IT equipment at Iceotope Technologies. In his role, Jasper oversees a team of engineers who perform thermal and fluid dynamic simulation work to support Iceotope's progress in the rapidly growing global market for liquid cooling. With over 25 years of experience in CFD, with a particular focus on the application of CFD for heat transfer and pollutant dispersion, Jasper is credited with pioneering Iceotope's use of simulation software to test its technology. He possesses immense knowledge of liquid cooling techniques in the data center industry, including the use of dielectrics for direct immersion, cold plates, and all related support systems of heat exchanges, pumps, manifolds and heat rejection units.

Before joining Iceotope in 2018, Jasper worked at engineering simulation company Ansys, Inc. for more than a decade, first as a Lead Engineer, and then as a Manager of Global Training Curriculum. In this capacity, he led a globally dispersed team of engineers responsible for creating training materials across multiple physics disciplines. He primed his skills in a previous role as Senior Scientist at the Health and Safety Laboratory, using CFD simulations in support of incident investigations.

Jasper holds a doctorate in turbulence monitoring for CFD, as well as a bachelor's of engineering, from the University of Manchester's Institute of Science and Technology.

Dr Kelly Mullick

Kelley Mullick is a Vice President at Iceotope responsible for business development with key OEM/ODM partners and technology alliances across the IT industry to highlight why Precision Liquid Cooling is critical in the edge/cloud markets for datacenter sustainability and delivers better TCO to the end customer.

Prior to joining Iceotope, Dr Mullick was a leader in product management in the Datacenter and AI group and helped develop Intel's liquid cooling strategy. Dr. Mullick's career spans ~20 years of systems engineering expertise, business acumen, and technical leadership in building platforms for the sustainable datacenter of the future, cloud workload optimization, software defined infrastructure, and new business models that deliver revenue. In addition to her technical achievements, Dr. Mullick is a champion for women and URM in tech. She developed programs and training delivered to ~3000 women to aid them in their career progression. She participates in the Open Compute Project (OCP) technical committees to help drive requirements and standards for immersive cooling in the datacenter. Furthermore, she is currently serving a 2 year board term for the IISEM&S (Modeling and Simulations) organization.

Dr. Mullick holds a Ph.D. in Chemical and Biomolecular Engineering from the Ohio State University.

Neil Edmunds

Neil Edmunds is the VP of Product management at Iceotope Technologies, where he's responsible for driving product features and performance to drive wider adoption of cutting-edge Precision Liquid Cooling technologies through collaboration, testing, market trend analysis and new solution development.

As one of the core team members supporting Iceotope's technological innovations through research and patents, Neil is an expert in liquid cooling solutions for data centers, and in particular their merits in achieving ESG standards and more efficient operations in the face of exploding data usage.

His strategic work with Iceotope's research teams and engineers is pivotal in driving company growth strategies, improving efficiency and developing wider communication around Iceotope's proprietary solutions. Neil regularly lends his thought leadership to industry publications on the need for improved cooling technologies and is a co-author of several Iceotope patents around heat sink arrangements, cooling apparatuses and uses of liquid coolants.

Neil has over 20 continuous years experience is product design and manufacturing of innovative solutions and manufacturing with a degree in Industrial Product Design.

To find out more visit
www.iceotope.com

To arrange a demo
Call: +44 (0)114 224 5500
Email: sales@iceotope.com