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The importance of world-class chemistry management for Direct-to-Chip (DTC) Liquid Cooling environments in AI factories

To mitigate the risk of prolonged, costly downtime in AI factories/data centers, organizations must take a proactive approach to monitoring and managing coolant chemistry and performance of the DTC Liquid Cooling tech loop

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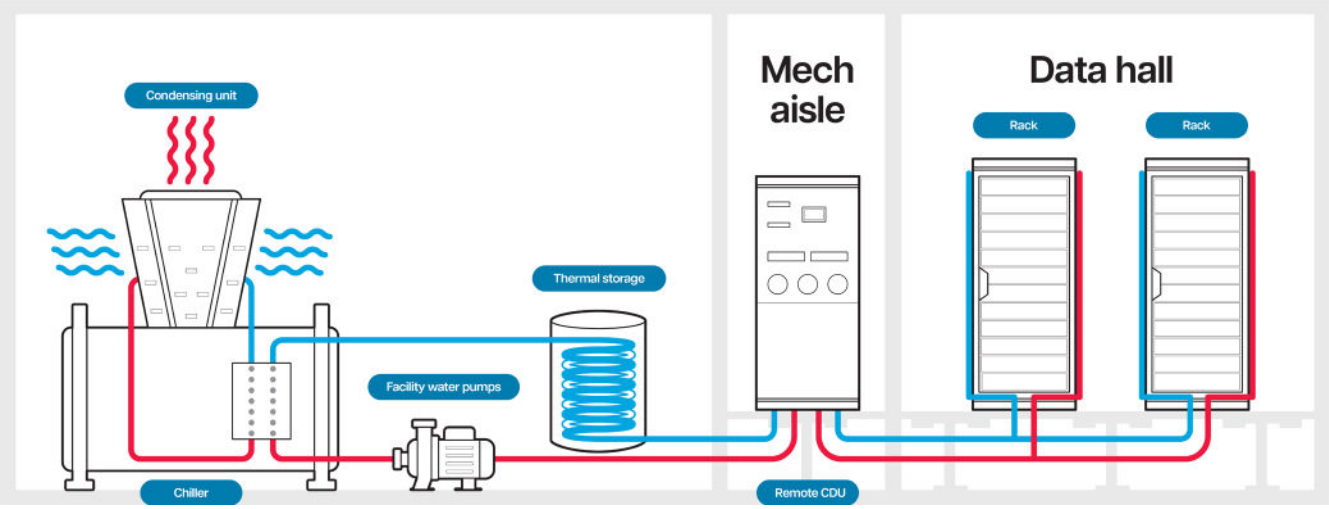


The AI industry has reached an inflection point that requires a shift to liquid cooling in data centers.

NVIDIA recently announced it has received $1 trillion in orders for its Grace Blackwell and Vera Rubin GPUs, both of which require Direct-to-Chip (DTC) Liquid Cooling. Grace Blackwell has a power density of 132-150kW+, depending on configuration, and the Vera Rubin will have power density of 208kW+. Both have thermal management needs that cannot be met by air cooling. They require DTC Liquid Cooling, and this introduces significant risk into data centers.

In a prior white paper titled "AI and HPC Direct-to-Chip Liquid Cooling Is redefining data center operations," Shultz discussed operational best practices that mitigate a number of significant risks of liquid cooling. The Ecolab R&D team detailed degradation mechanisms that can affect PG-25 (coolant) biostability in a separate white paper titled, "Biostability of Propylene Glycol in Technology Cooling Systems: Degradation Mechanisms and Mitigation." This new white paper discusses key steps that data center operators must take to mitigate significant risks related to chemistry and management of PG-25 used within the technology loop.

Tech loops are comprised of a complex system of pipes, pumps, filters, UQD (universal quick disconnects), rack manifolds, cold plates and heat exchangers that circulate coolant through the server racks to perform heat rejection and maintain optimal operating temperatures for high-density AI compute infrastructure. Technology cooling loops serve as the primary heat-transport system in the liquid-cooled data center environments.



Facility Loop - Treated water | **Tech Loop** - Remote CDU PG-25

The health of the overall AI environment is dependent on maintaining coolant chemistry within specified limits and ensuring the integrity of the technology cooling loops. Emerging coolant health issues can rapidly escalate, leading to reduced heat transfer efficiency, equipment damage, unplanned downtime, and increased operational risk. Key coolant health indicators include ΔP (differential pressure), pH, conductivity, turbidity and glycol concentration.

Why poor chemistry management and operational processes in DTC environments will cost you

To successfully cool high-density GPUs, PG-25 in the tech loop must meet stringent quality metrics and operational standards. Data center operators must keep coolant chemistry within narrow defined bands for metrics such as glycol percentage, pH level, conductivity and turbidity. If not properly managed, issues can arise that impede the heat transfer for AI servers (GPUs, CPUs) and can damage equipment or lead to costly downtime:

- **PG-25 chemistry quality can endanger GPUs:**

  The concentration and quality of PG-25 coolant can decline if not properly managed. Shifts in chemistry can inhibit thermal transfer, create corrosion, or introduce particulates that significantly reduce heat transfer as coolant passes through the cold plates (and its 100 or 50-micron-wide fins) attached to GPUs, CPUs and memory chips. This can lead to rising operating temperatures that negatively impact performance or even cause damage to equipment. The cost of which for AI servers is magnitudes higher than traditional CPU-based HPC servers. A single rack of Grace Blackwell NVL 72 can cost $3.0 million-3.5 million, as well as the cost of downtime for repairs/replacement. Damage to GPUs connected to a larger 2500-gallon tech loop would represent more than 64 Grace Blackwell systems and potentially tens of millions of dollars.

- **Contaminated tech loops can cause prolonged downtime:**

  If an operations team does not properly manage and monitor PG-25, the entire tech loop can rapidly reach a level of contamination that requires a complete flush, clean and re-fill. When a tech loop reaches this level of contamination, a time-consuming 4-step cleaning process is required. The entire tech loop must be flushed, cleansed, re-flushed and re-filled. Then the new coolant must be tested (to ensure PG-25 glycol % are in the acceptable range) before the tech loop can go back into production. This process can take up to 8-12 hours for a loop of 2500 gallons, which means a typical loop with 64 cabinets of Grace Blackwell at a GPU hourly rental rate of ~$10.50 per GPU hour, could mean a loss of $400-600K in lost revenue for the end customer and Service-Level Agreement (SLA) penalties for the data center service provider.

- **Tech loop complexity can be a threat to system integrity**

  During installation and commissioning, flush and fill must be conducted with process rigor across all elements of the tech loop (e.g., CDU, SFN, load banks used for commissioning, SFN dead legs). With multiple parties – as many as five or more – linked to various components, improper handshake or scheduling mismatch between them can pose significant risk.

Real-time monitoring with detailed lab analysis is critical for DTC cooling

There are at least three ways that PG-25 (coolant) chemistry can be negatively impacted:

- Chemistry issues can emerge from certain contact points and metals in the loop. One example is the wetted surfaces of the tech loop itself, i.e., the piping system that brings PG-25 from the coolant distribution units, CDUs to the AI servers and inside to the cold plates. Another example is the metallurgy of the cold plates, and CDU components like pumps and piping. These contact points and metals, the wetted materials that touch the PG-25 must be of approved types to prevent leaching of contaminants into the PG-25, which can cause problems including contamination and degradation of fluid chemistry.

- Chemistry issues can also originate during certain steps in filling, flushing and operating the tech loop. For example, AI server cabinets typically contain 3–5 gallons of coolant (PG-25). Key risks during installation include the use of an incorrect PG-25 formulation or mixing incompatible brands of PG-25, or failure to properly purge nitrogen from cabinets shipped pre-charged by the OEMs (e.g., Dell, Supermicro). In addition, contamination of PG-25 during transport may introduce particulates into the tech loop, and the inadvertent introduction of air into the tech loop when the AI servers are connected. The presence of glycol, air, and heat can create conditions that support biological growth and subsequent system build up.

- Chemistry issues can also emerge during operations of the tech loop. For example, air that is accidentally allowed into the tech loop can create an environment that fosters microbio growth, which can alter the chemistry, degrade the PG-25 and lead to temperature spikes.

A proactive approach is needed to catch emerging issues early and mitigate them before they can escalate. For example, the end customer's operations team may accidentally introduce particles or other contaminants into the loop, or they may fill it with the wrong PG-25. When this happens, you want to know in real time to make sure it does not count against your SLAs.

Thus, real-time continuous monitoring of coolant quality and tech loop performance is required to ensure accountability for chemistry changes and SLA penalties. In addition, if these events happen you want to react quickly and remediate, to protect your end customers' investments in AI servers. Here are critical best practices for a successful proactive approach to coolant and tech loop management.

- **Properly assess the design and materials of the technology loop:**

  Data center designers must ensure the correct wetted materials are utilized in the technology loop piping and in the components of the CDUs. They must also ensure there are no areas where pockets of air can enter the loop. Failure to do so can damage equipment and negatively impact cooling. This step must be addressed during the design and construction phase of the data center to mitigate risk once the loop is operational.

- **Implement a flush-and-fill room with detailed operational process to flush, clean and fill all new AI servers:**

  Data centers should be designed with a flush-and-fill room to mitigate major risks that occur when new coolant is added to new AI servers. This can prevent significant errors that can occur when teams work on this critical step, including poor filling practices, which can release or trap nitrogen or other gases in the rack. By having a room dedicated to this activity, operators can prevent errors and follow best practices like filling server racks from the bottom, controlling the temperature of the glycol, and maintaining positive pressure during hose changes.

- **Implement real-time monitoring before commissioning:**

  The best time to implement real-time monitoring is before an AI data center begins operations. Ideally, the implementation comes before the commissioning process so all sensors and probes can be fully tested and optimized in concert with the cooling system as a whole. This also allows you to establish benchmarks from Day 1 of operations and maximize the insights you derive from real-time data.

- **Ensure the tech loop piping is properly cleaned:**

  Protecting coolant chemistry starts with cleanliness. Data center operators must properly passivate, clean, flush and fill the tech loop to ensure no particulates or contamination from Day 1.

Utilize continuous glycol %, pH, conductivity and turbidity monitoring:

Changes in glycol % make coolant susceptible to buildups of microbio growth that can negatively impact cooling efficacy. By rapidly identifying shifts in glycol, operations teams and chemistry experts can make adjustments that maintain the quality of PG-25 (coolant) chemistry before they escalate into emergency situations like microbio growth building up and overheating GPUs, requiring the need to shut down and flush tech loops. To prevent localized corrosion in stainless steel and leaching of copper from cold plates, pH monitoring is critical. Acidic glycol doesn't dissolve stainless steel uniformly, it defeats the protective oxide layer and causes localized pitting or crevice corrosion that can fail components without obvious warning. Low-pH glycol directly dissolves copper from cold plates, thinning microchannels and reducing heat transfer long before obvious leaks appear. By utilizing continuous monitoring of the fluid health, you can see trends in all parameters and adjust accordingly before the damage is done.

- **Combine real-time monitoring with detailed lab analysis:**

  When real-time monitoring is combined with detailed laboratory analysis, organizations benefit from an early warning system as well as deeper insights that can only be obtained from a lab environment. Detailed lab testing by chemists with speciliazed expertise in coolant chemistry delivers insights that enable operations teams to remediate emerging issues in ways that customers can have confidence in.

- **Protect yourself from SLA penalties with accurate real time monitoring, quality operations from proven experienced Direct to Chip liquid operators:**

  Customer SLAs often have clauses that trigger penalties for downtime. Implementing real-time monitoring can be a powerful asset for assessing ownership of tech loop contamination and possible SLA penalties. Real-time data enables data center operators to deliver root cause analysis that tracks when incidents occur, what caused them, and how quickly they were addressed to resolve the PG-25 chemistry.

- **Extend real-time monitoring to the facility (primary) water loop:**

  In addition to monitoring coolant quality and performance of the tech loop, it is also a best practice to monitor the water loop that links to the rest of a facility's cooling infrastructure. For facilities using renewable water (e.g., gray water, reclaimed water, black water), monitoring of the water loop can reduce risk by alerting the operations team to the presence of pathogens or chemistry issues that could cause damage. And for facilities (regardless of whether they use municipal or renewable water), real-time monitoring gives the operations insight into issues that should be addressed before water is flushed from the system and exits the data centers. This can help your organization eliminate potential causes of downtime while also adhering to your sustainability objectives.

- **Drive continuous operational improvements that further reduce risk over time:**

  One of the most important benefits of real-time monitoring is how it drives adjustments to operational practices that deliver better outcomes. For example, analysis of this data, combined with the detailed lab testing, may reveal that certain processes are introducing contamination or turbidity into the cooling system, which can be reduced with chemistry remediation.

Salute has a strategic collaboration with Ecolab to deliver end-to-end chemistry and cooling management for AI environments that deliver all these best practices for managing coolant quality and tech loop performance. Ecolab's Cooling-as-a-Service program is integrated with Salute's DTC Liquid Cooling operations service to mitigate these risks of liquid operations, empowering companies to scale their AI operations with confidence.

Salute has secured contracts with key data center providers to support hundreds of billions of dollars of NVIDIA's recently announced $1 trillion GPU customer order pipeline. Amid rapidly growing AI infrastructure investments, this service provides the foundation needed to protect performance, reliability and capital.

To learn how Salute can protect your investments in AI computing, visit: Experience AI Ops with Salute.

Ecolab's Cooling-as-a-Service program mitigates key risks of DTC Liquid Cooling

Ecolab's innovative Cooling-as-a-Service (CaaS) program enables data center operators to successfully monitor and manage coolant chemistry and performance of the tech loop.

Built on proven technology and processes, Ecolab's CaaS brings together a full suite of cooling management solutions that help unlock peak cooling performance all the way from the data center facility environment to the high-performance data computing servers. The program incorporates high-performance water management technology, smart coolant distribution units, connected coolants, and 3D TRASAR™ monitoring technology, all delivered through Ecolab's global service team.

Ecolab is a global leader in water, hygiene and infection prevention solutions and services, with more than 40 years of experience in thermal management across dozens of industries including power, life sciences, primary metals, microelectronics and more. The team's broad technical acumen enables Ecolab to identify and help mitigate the risks that come with critical closed loops. The company is a key member of Salute's ecosystem of companies that meet key needs of AI/HPC operations.

Salute's groundbreaking DTC Liquid Cooling operations service:

Ecolab's CaaS program is integrated into Salute's groundbreaking DTC Liquid Cooling operations service, representing state-of-the-art advancement for operational excellence in the AI industry.

This groundbreaking service is based on years of work by Salute's cooling and operations experts to prepare for the operational needs of AI environments. It is a blueprint borne out of thousands of hours of collaboration and interviews with NVIDIA, CDU manufacturers, chemistry manufacturers, chemistry distributors, leak management vendors, OEMs, hyperscalers and many other experts. That combined research and expertise made it possible to launch this comprehensive service that solves complex operational challenges for every company making major investments in AI/HPC. It delivers:

- A customized operational model based on the design and demarcation points of each facility
- Field-tested EOPs, MOPs, and SOPs covering every aspect of DTC operations – including chemistry management, leak detection, safety protocols, systems oversight, and risk mitigation
- Commissioning support that ensures all as-built systems are optimized
- A continuously updated knowledge base and world-class training program
- And rapid deployment of skilled personnel

Contact us today to discuss how we can help you establish world-class operations for your AI data centers.

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For more information about Salute's services for AI/HPC data center operations visit salute.com

About the Authors

John Shultz is the Chief AI Product and Learning Officer for Salute and a highly respected thought leader in the data center industry.

He brings nearly three decades of experience in digital infrastructure to this role leading Salute's AI-driven data center solutions, which enhance data design, build, and operations through AI innovation. Prior to joining Salute, Shultz was the founder and executive consultant at Advanced Data Center Consulting Group, which advised and trained data center service providers, investments managers on AI market trends, demand and direct to chip liquid operations In this role, he was also the industry's foremost educator and trainer of investment teams, data center service providers and other executives on the impact of AI on the data center market. Prior to founding that successful consultancy, Shultz held senior positions as the global head of product management at the two largest data center providers in the world: Digital Realty Trust, the world's largest wholesale data center company, and Equinix, the world's largest retail data center company. At both organizations, his responsibilities included P&L management, new product development, customer interviewing, competitive intelligence and acquisition. He is a graduate of Texas A&M University.



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He brings more than 20 years of experience driving global growth, product innovation and operational transformation across the industrial and technology sectors. Before joining Ecolab, Vishal served in senior leadership roles at Wabtec Corporation where he led global service transformation and technology-driven growth initiatives. Earlier in his career at GE Transportation, he held senior leadership roles where he oversaw billion-dollar product portfolios and drove innovation and operational excellence across global markets. Vishal holds a PhD in Industrial Engineering from Penn State University.



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Salute is leading the AI data center evolution

Salute is a world leader in comprehensive data center services. For over a decade, Salute's comprehensive data center services have been at the forefront of data center growth and transformation, offering a comprehensive suite of solutions designed to empower the world's digital economy. Salute is also a pioneer in meeting the needs of high-density AI/HPC computing, with a comprehensive solution to the operational needs of DTC Liquid Cooling data centers.

To learn more about how Salute protects your AI investments with industry best practices for high density, liquid based operations, visit our AI Hub here: **https://salute.com/ai-hub/**.

About Ecolab

A trusted partner for millions of customers, Ecolab (NYSE:ECL) is a global sustainability leader offering water, hygiene and infection prevention solutions and services that protect people and the resources vital to life. Building on more than a century of innovation, Ecolab has annual sales of $16 billion, employs approximately 48,000 associates and operates in more than 170 countries around the world. The company delivers comprehensive science-based solutions, data-driven insights and world-class service to advance food safety, maintain clean and safe environments, and optimize water and energy use. Ecolab's innovative solutions improve operational efficiencies and sustainability for customers in the food, healthcare, high tech, life sciences, hospitality and industrial markets.

For more information, visit **www.ecolab.com**.

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