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Liquid Cooling: The Winning Solution for Data Centers

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Demand for artificial intelligence (AI), machine learning, and other power-hungry workloads — in tandem with rising concerns over data center sustainability — are ushering in a new era of liquid cooling in data centers.

While traditional air-cooled systems struggle to keep pace with CPU and GPU advancements required for high-performance computing (HPC) and the rising thermal output of IT equipment, liquid cooling is emerging as the favored solution for solving these challenges while also boasting major efficiency and sustainability benefits.

Once regarded as a niche solution, liquid cooling adoption is reaching an inflection point. A recent study by The Register of 800+ IT professionals indicates liquid cooling is primed for substantial growth in the coming years. More than 38 percent of survey respondents said they plan to employ liquid cooling by 2026, up from 20.1 percent in early 2024. As a result, the data center liquid cooling market is expected to triple to $10.61 billion by 2028, surpassing air cooling as a clear favorite among operators.

Technological and Ideological Shifts Driving the Need for Liquid Cooling

Advancements in technology — such as the rapid expansion of artificial intelligence (AI), the widespread implementation of 5G networks, and the proliferation of Internet of Things (IoT) devices — are collectively driving demand for liquid cooling solutions. These technologies generate substantial heat due to their intensive computational requirements and data processing loads. Furthermore, the trend towards higher rack densities in data centers exacerbates heat generation, necessitating more efficient cooling mechanisms.

Advanced workloads also require more processing to be completed at the edge where data is created. Open RAN and far-edge computing, as well as cloud computing environments, double down on the need for high-performance compute, high-density server deployment and efficient cooling to deal with the additional heat generation. Traditionally favored air-cooled systems simply cannot handle the increased heat output of advanced workloads and edge deployments, leading to issues with server performance and reliability.

Liquid cooling addresses these challenges by offering superior thermal management capabilities compared to traditional air-cooled methods. By directly contacting heat-generating components with a cooling liquid, liquid cooling efficiently dissipates heat, ensuring optimal performance and reliability in modern data center environments.

Also, operators are placing more emphasis on the importance of sustainability in their operations than ever. Sustainability isn't a singular problem we can engineer our way out of, but rather a broader tapestry encompassing energy efficiency, carbon, IT infrastructure, and renewable energy sources. Adopting sustainable practices like liquid cooling is a key first step for operators. By continuing to explore and invest in new technologies in the liquid cooling arena — like Precision Liquid Cooling — operators will see benefits beyond carbon reduction, such as fostering client attraction and retention, which will continue to drive further adoption of sustainable technologies in the long term.

Exploring Liquid Cooling Options

There are various types of liquid cooling being implemented in the data center industry, but not all solutions are the same.

Cold-plate cooling technology involves metal plates absorbing heat from electronic components, transferring it to a cooling fluid like water or dielectric liquid. This fluid circulates through a closed-loop system, releasing heat into the environment or another cooling system, maintaining optimal component temperatures. While effective, cold-plate setups can be complex and costly, especially for custom designs requiring rigid metal tubing. Implementing cold-plate cooling in large data centers with diverse setups can present challenges, including complex maintenance and training needs.Immersion cooling submerges servers or equipment entirely in a dielectric liquid or coolant, facilitating direct contact between components and the cooling fluid. Heat generated by the equipment transfers to the coolant, which rises to the surface for dispersal. However, this solution demands a complete redesign of data center structures, conflicting with long-term density, scalability, and serviceability goals. Moreover, both solutions eliminate brownfield data center space as an option and as they necessitate special training for equipment servicing.

Emergence of Precision Liquid Cooling

Precision Liquid Cooling (PLC) is gaining traction for its unique approach to cooling HPC systems while eliminating the need for specialized maintenance and complex equipment. PLC technology uses a dielectric liquid coolant delivered directly to the hottest components of the server. This approach allows for more precise temperature control and efficient heat removal, which results in higher performance and lower energy consumption, enabling more computing power in a smaller footprint.

Unlike traditional air cooling, where fans dissipate heat, PLC involves direct contact between the liquid coolant and CPUs and GPUs within the hardware. The ability to provide precise, targeted cooling exactly where it's needed most ensures no over cooling of less heat-intensive parts and offers significant sustainability benefits as energy consumption can be reduced by 40 percent and water consumption by 96 percent.

These solutions are also purpose-built to withstand harsh IT environments. With no server fans required, component failures are reduced by 30 percent. Dielectric fluid also reduces thermal stress, and the enclosed chassis makes the units impervious to gases, dust, and humidity. This extends the server lifecycle and lowers maintenance costs. Unlike air-cooled infrastructure, Precision Liquid Cooling does not require rack depopulation at higher densities, enabling the racks to run fully populated to facilitate more servers and storage devices, and/or denser IT loads.

A recent study by STL Partners further shined a light on the cost benefits of effective edge sustainability strategies, including PLC. The report finds that advanced edge sustainability strategies can reduce telco providers energy usage by 3-5 percent and the equivalent of one million tons of carbon dioxide (tCO2eq) emissions for a typical large group operator. These strategies, which include PLC, could save a typical large group telco operator up to $40 million a year in energy costs.

Future Outlook and Predictions

Due to its benefits, the future of liquid cooling is bright. A Dell'Oro Group Study predicts liquid cooling will jump from 5 percent of the data center thermal management market to 19 percent by 2026.

As the data center operations community seeks cooling innovations that push the limits of what's possible with alternative solutions, such as Precision Liquid Cooling, the industry will make notable strides toward the more sustainable and efficient future it desires, as long as operators are not afraid to embrace change.

Adopting sustainable practices and investing in new technologies offers benefits beyond carbon reduction; it fosters client attraction and retention strategies for data centers. This requires a broader conversation internally between all the stakeholders of the business to fully incorporate and maximize liquid cooling's benefits.

Altogether, as organizations continue their move to the edge, we'll continue to see efficient, high-performance solutions like liquid-cooled servers rise to meet the unique challenges at the edge. By leveraging innovative rack designs and emerging technologies such as Precision Liquid Cooling, which addresses several edge deployment pain points in one fell swoop, organizations can build scalable, efficient, and resilient edge computing infrastructure to drive digital transformation and unlock new opportunities for growth and innovation.