DATA CENTER Frontier SPECIAL REPORT

The Data Center Innovation Will Change the Way You Think About Liquid Cooling

Direct-on-chip, waterless, dielectric liquid cooling is a simple, safe, and sustainable alternative to traditional heat reduction alternatives.

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Introduction

The growing demand for high-density servers to support high-performance computing, artificial intelligence, and data analytics workloads at a massive scale is challenging conventional approaches to data center cooling.

Despite major gains in power efficiency, microprocessors are becoming steadily more power-hungry and giving off more heat as a result. The latest generation of microprocessors runs at more than 400 watts, up about 60% from five years ago. Roadmaps published by makers of server processors indicate that 600 watts could be the norm by the mid-2020s.

At the same time, rack density is also growing. The average server density per rack more than tripled between 2011 and 2020, according to Uptime Institute. Some racks now draw as much as 16 kilowatts and the high-performance computing infrastructure required to support artificial intelligence workloads may soon demand up to 50 kilowatts. And the trend is up and to the right. By some accounts, the AI hardware market will grow tenfold over the next five years.

The heat generated by all this computing power is too great for conventional cooling systems to tame. Data center operators have relied on room-scale air-conditioning for decades, but that approach has numerous disadvantages from an economic, environmental, and efficiency perspective.

Although the technology has improved and many data center operators have adopted efficient best practices such as the use of blanking panels, air dams, and airflow containment to raise room air temperatures to the limits specified by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers to maximize existing infrastructure, there are limits to how much air-cooling methods can achieve.

For one thing, air-conditioning is inherently wasteful because it cools the entire room rather than just the equipment inside. It requires managed airflows and mandates careful attention to space design to avoid airflow blockages that can cause disruptions that ultimately lead to overheating and equipment failure.

For the growing number of organizations that are focused on environmental, social, and governance issues, air-conditioning is also a liability because of its high energy cost and use of climate-threatening chemicals. At a time when water is increasingly becoming a precious commodity in many areas of the country, thermoelectric power plants are the largest source of water withdrawals in the U.S., consuming nearly 12,000 gallons per megawatt hour generated in 2020.

As Time magazine summed it up two years ago, AC Feels Great, But It's Terrible for the Planet.

LIQUID-COOLED SOLUTIONS

Many older facilities "are limited in their ability to supply the necessary airflow to cool high-density IT," noted Uptime Institute Research Analyst Jacqueline Davis. "A growing number of data center operators will consider support for direct liquid cooling."

Precision liquid cooling targets the heat at the source rather than at the room or row level creating, a more efficient, higher-capacity solution. The technology is on its way to becoming a standard for data centers running high-density server racks. The market for liquid-cooling IT equipment surpassed $2 billion in 2022 and is expected to grow 15% annually to $12 billion by 2032, according to Global Market Insights.

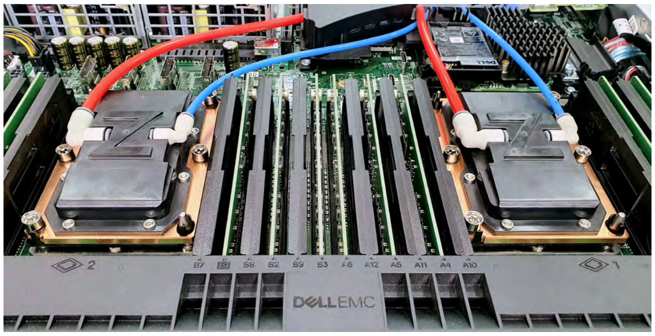
"To reduce power consumption and adhere to the ambitious emission standards and footprint goals set by different governments, data center operators worldwide are rapidly adopting energy-efficient and cost-effective liquid cooling technologies," the research firm wrote.

"Newer and more efficient cooling technologies such as liquid cooling can have a higher initial investment cost but may provide long-term cost savings in terms of energy consumption and maintenance," wrote research firm Astute Analytica in a recent report.

THE ADVANTAGES OF LIQUID COOLING

Liquid cooling has numerous benefits when compared to air-conditioning, starting with the fact that liquids conduct heat up to 1,000 times better than air. The raised floors and containment aisle that are common to most data centers aren't necessary and equipment can be packed together more densely because airflow isn't a concern. Liquid cooling also consumes far less power than air-conditioning, reducing energy consumption by up to 90%.

The benefits of liquid cooling go beyond power efficiency. CPUs and GPUs operate faster and more efficiently at lower temperatures because individual cores can run longer without hitting thermal thresholds that automatically throttle performance to reduce the risk of overheating. Overall efficiency is improved because processors can do more work per unit of energy.



As Uptime Institute research director Daniel Bizo summarized, "Performance is best served cold."

Until recently, however, the use of liquid cooling has been principally confined to the largest scientific and academic computing environments. This is due to misconceptions about costs and reliability that are rooted in the comparatively primitive and expensive systems of years ago. Some data center managers may also believe liquid cooling is overkill, despite trends indicating that the size of the workloads they are processing will continue to grow.

It's true that water cooling, which has long been the most common approach, does have some potential downsides. One is that large infrastructure investments may be required to outfit the data center with the necessary plumbing and chillers. Cooling equipment also takes up space that could otherwise be used for servers, storage, and other IT gear. There are also legitimate concerns that an unintended release of coolant into the data center could cause liquid to come into contact with sensitive electronic components, leading to short circuits, corrosion, or other forms of damage.

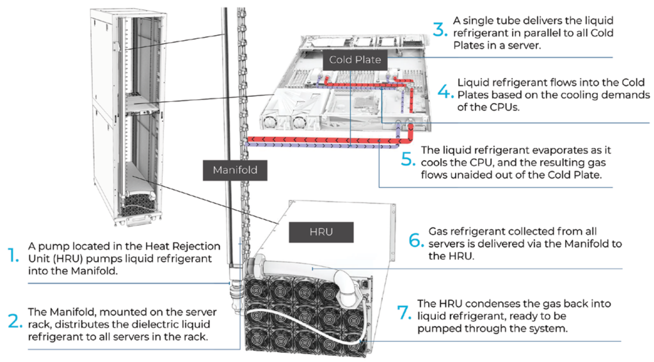
If a liquid cooling system isn't installed correctly, it may not effectively distribute the coolant or maintain proper pressure, which can lead to uneven cooling, localized hotspots, and damage to undercooled components. Failures in the pumps and power supplies required to chill and distribute the cooling liquid can also result in inadequate cooling, overheating, or other issues that can potentially damage infrastructure.

While these risks were common in the cooling systems of years ago, modern liquid cooling systems are designed with numerous safety measures, redundancy, and monitoring systems to mitigate the chance of damage. Recent innovations have made the technology both safer and more affordable.

BEYOND WATER

Given the risks and drawbacks of water-based cooling inside racks and servers, the industry has been moving toward more-efficient chemical alternatives. One of the most promising of these is dielectric fluid, a non-conductive liquid with very high resistance to electrical breakdown, even at high voltages.

Unlike water, dielectric fluid can come in direct contact with electronic components without damaging them. Components can even be immersed in dielectric fluid without the risk of harm. This enables cooling to be applied more uniformly across a server or rack, reducing the risk of hot spots. The thermal conductivity and specific heat capacity of dielectric liquids are higher than that of air. That makes them more efficient at removing waste heat.



Engineered refrigerant dielectric fluids are designed to evaporate at much lower temperatures than water, allowing liquids to transform into vapor and then condense back into liquid form at temperatures that are much lower than the boiling point of water. Heat can be rapidly transferred away from the equipment, allowing for improved cooling performance and maintaining lower operating temperatures.

Dielectric fluids have been engineered to be chemically stable and resist degradation over time. Unlike water-based solutions, they do not require filtration or replacement over the life of the system.

DIRECT ON-CHIP COOLING

The most efficient use of dielectric liquids is in direct-on-chip, waterless, two-phase liquid cooling. This technique pumps fluid into cold plates directly over electronic components such as CPUs and GPUs in a closed-loop system. Super-heated vapor is pumped back into a heat rejection unit where it can be reused to heat the air and water in the data center facility.

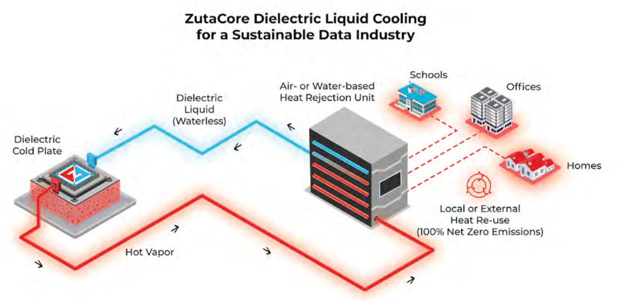
The elegantly simple design requires just three subsystems: direct-on-chip cold plates, liquid/vapor manifolds, and heat-rejection units. Direct-on-chip solutions fit easily within a 1U rack-mounted server chassis and can be retrofitted onto existing equipment. The result is that data centers can realize triple the processing capacity at less than half the energy usage and space of conventional cooling systems.

A single 3U or 6U in-rack heat rejection unit can support up to 100 kilowatts of computing power per rack and cool processors running at up to 1,000 watts, giving data center operators a solution that will support their needs many years into the future.

Because direct-on-chip cooling uses less power than air-conditioning, ambient room temperatures can be increased to reduce the need for air-conditioning. Cooling solutions can be applied incrementally as server racks are added, reducing or eliminating the need for major upgrades to air-conditioning and other data center infrastructure.

The self-contained solution eliminates the risk of electrical short circuits while also protecting electronic components from airborne dust, vibration, and other byproducts of air conditioning. Delicate components last longer because heat levels are managed more consistently and overheating is never an issue.

The bottom line is that direct-on-chip, dielectric two-phase liquid cooling supports higher levels of computing power at half the total cost of ownership with up to 100% heat reuse and reduced emissions.



DATA CENTER OPERATORS ARE CATCHING ON

Technology leaders like colocation provider Equinix are investing in this technology and see it as the future of data center cooling. Equinix tested a direct-on-chip system from ZutaCore at one of its New York facilities and reported energy efficiency improvements of up to 50% compared to compute power deployed in a traditional enterprise data center. It also saw a reduction in both the number of servers required and the amount of energy consumed by its customers' computing infrastructure.

"Data center liquid cooling will go from being almost exclusively in the HPC realm to becoming a standard requirement for systems," wrote Equinix Field Chief Technology Officer My Truong in a post on the company's blog.

Direct liquid cooling (DLC) has been a niche market until now, but "most data center operators predict a substantial increase in use within five years, particularly for cold plate systems," according to Uptime Institute. Its 2022 survey found that 18% of operators expect to use DLC in at least 50% of their racks within three to five years and nearly 80% are either using DLC or will consider using it in the future. Two-thirds cited cost-saving benefits from reduced energy consumption and more than half said they believe DLC provides them with better environmental sustainability.

The greatest concerns operators identified were increased cost and the risk of coolant leaks. Direct-on-chip, dielectric two-phase liquid cooling effectively addresses both concerns. Its total cost of ownership is superior to other techniques and the closed-loop design of the system minimizes the risk of coolant leaks. Furthermore, it is a low-pressure system that utilizes leak-proof fittings; in the unlikely event of a leak, the dielectric simply dissipates harmlessly into the air.

AN INTEGRATED SOLUTION

Although direct-on-chip systems can be retrofitted to existing racks, the simplest and most reliable solution is to use a rack that comes preconfigured with the cooling components included. Operators who aren't ready to make the full jump to dielectric two-phase liquid cooling should choose a cabinet that provides an upgrade path to maximize their current infrastructure through advanced airflow management solutions while offering a transition path to liquid cooling when needed.

For example, Chatsworth Products' ZetaFrame® Cabinet System comes with an industry-leading 4,000 lb. dynamic load rating and can easily support a loaded

rack with the integrated liquid cooling system when used in conjunction with a shock pallet. Equipped with in-rack eConnect® power distribution units (PDUs), Chatsworth's cabinets provide a complete solution to power and manage high-density loads, close to the device. The cabinet design and size allow liquid cooling to be added while preserving the ability to meet cable management standards.

Remote management capability provides continual automated monitoring with the ability to set thresholds and get notifications when they are exceeded. Power consumption is monitored at the output level of the rack power distribution unit and outlet-level monitoring allows under- or over-utilized servers to be identified. Electronic access controls and monitoring capabilities with Data Center Infrastructure Management (DCIM) software round out the features of this integrated solution.

PREPARE FOR THE FUTURE

The spiraling costs of building and expanding data center capacity show no signs of abating. Forward-thinking data center operators are looking for ways to wring the most value out of their current investments while preparing themselves for future server technologies that will be denser, hotter, and more power-hungry.

Direct-on-chip, dielectric, two-phase liquid cooling is one of the most promising technologies to reduce energy consumption, increase server density, and cut power requirements while improving a facility's sustainability profile.

An integrated solution that combines power-efficient server racks with cooling technology that handles growing workloads for years to come is one of the best ways for operators to prepare to take on tomorrow's energy challenges.