U.S. DEPARTMENT OF
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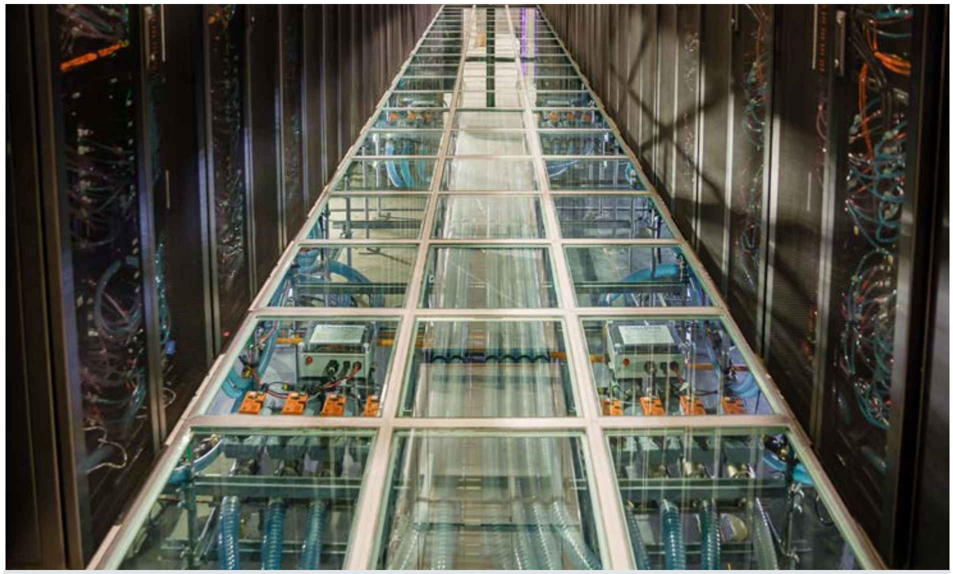
Sandia's Liquid-Cooled Data Center Boosts Efficiency and Resiliency

The Federal Energy Management Program (FEMP) encourages federal agencies and organizations to improve data center energy efficiency, which can offer tremendous opportunities for energy and cost savings. In this success story, a novel liquid cooling system provides reliable, resilient, and energy-efficient cooling for high-performance computing (HPC) systems at Sandia National Laboratories.



Water flows through flexible tubes and pipes visible through glass panels above two rows of Attaway's compute racks. At the end of the racks, cooling distribution units control water flow and rates. *Image Credit: Sandia.*

When Sandia installed the 650-kW Attaway supercomputer at their Albuquerque HPC data center in 2019, they sought innovative cooling concepts that would reduce the massive computer system's significant energy use. Technology partner Chilldyne offered a unique solution: a liquid system that operates under vacuum pressure for resilient, energy-efficient data center cooling.

Vacuum System Delivers Safe, Efficient Liquid Cooling

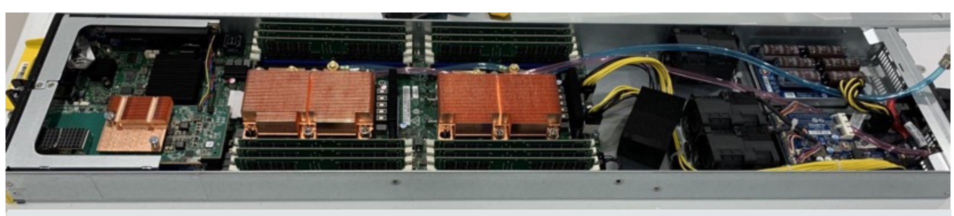
Within Attaway's cooling system, water swirls through flexible tubes and pipes flowing through the HPC compute racks. At the end of the racks sit a set of unique vacuum pumping systems, referred to as cooling distribution units (CDUs), which control the water flow and rates. The data center conserves energy by using warm water, rather than chilled water, to cool its HPC systems.

One of the Chilldyne system's most unique and valued features is that it operates within a vacuum to prevent leaks should a hose puncture—a major concern for a data center filled with valuable hardware and electronics. With vacuum pressure inside the hoses, a slight puncture will draw air into the system, rather than allowing water to leak out. The vacuum operation of the CDUs also allows for the use of flexible hoses rather than the rigid pipes that are required for positive-pressure cooling systems, enabling greater flexibility in data center design.

The water-based system accounts for 70% of Attaway's HPC data center cooling. Air accounts for the remainder—fans in each node provide primary cooling for low-power components. These fans also serve as a secondary source of cooling for Attaway in the case of a liquid-cooling failure. Without water cooling, the fans ramp up to cool Attaway with additional air. When water cooling is available, the motherboard fan controller runs the fans at a low rate to conserve power.

Designed for Resilience

The Chilldyne cooling system was built with redundancy/resilience in mind: If one element were to fail, others would continue keeping the system cool and the equipment safe. For instance, Attaway has a total of 24 compute racks and three CDUs. Under normal operating conditions, each CDU feeds eight compute racks; however, the cooling system also features six fail-over valves for redundancy. Each valve feeds four compute racks and is fed from two different CDUs, allowing the system to automatically switch to a different CDU if flow is lost from one. This way, if one CDU were to fail or be brought down for service, the two remaining CDUs would be able to cool all 24 compute racks. A detailed sequence of operation is provided in a new Sandia report titled *Cooling Performance Testing of Attaway's Negative-Pressure CDU*.[1]



Fans in each node provide primary cooling for low-power components and secondary cooling in the case of a liquid-cooling failure. Image Credit: Chilldyne

[1] Smith, David M., David J. Martinez, and Trevor Irwin. 2020. *Cooling Performance Testing of Attaway's Negative Pressure CDU*. Sandia National Laboratories, SAND2020-6888R. datacenters.lbl.gov/sites/default/files/206888r.pdf.

Positive Performance and Striking LEED Gold

As described in the report, Sandia researchers tested Attaway to determine the cooling system's ability to respond to sudden changes in states—such as an immediate change from an idle compute load to full load, and the system's robustness—for example, its ability to run at full load without any water cooling. The system performed reliably. Attaway responded to sudden compute load changes without throttling any nodes, and when a full load test was run without water cooling, the system was able to operate for a short time before throttling.

The results demonstrated that the Chilldyne system is able to keep the HPC central processing units at temperatures under 50°C (122°F) while maintaining a very low power draw within a highly redundant/resilient system design. Each CDU draws 3.4 kW under full load, representing only 1.6% of the system's total power. This is a large improvement as compared to earlier water-cooled system designs, which completely shut down with the loss of water flow.

Thanks to the innovative cooling system and other energy-efficient building features, Sandia's Albuquerque campus earned a U.S. Department of Energy Sustainability Award as well as the LEED v4 Gold BD+C: Data Center Certification in 2020.

Overcoming Fears About Liquid Cooling

Concerns about the reliability, redundancy, resilience, and risk of leakage related to direct liquid cooling for HPC components have been mitigated over the years, and the Chilldyne negative pressure system has made liquid cooling even safer. The system offers greater redundancy than other liquid-cooled systems, and 12 months of leak-free operation at Sandia speak to the efficacy of its vacuum-enhanced design.

Innovation in HPC

From deploying some of the early liquid-cooled systems, to helping develop and engineer the first HPC system to reach 1 teraflop (a measure of computer speed equal to one trillion floating-point operations per second), Sandia's rich history includes:

- Installing some of the first plug-fan cooling units, moving away from traditional centrifugal fans to create better air distribution under a raised floor
- Co-designing and installing the first instance of pumped liquid refrigerant cooling doors arranged in a laminar flow configuration.

Sandia approaches the deployment of HPC systems as a partnership with the vendor, where, in many instances, first-of-its-kind technology is installed.

Learn More

Learn more about cooling performance testing of Attaway's vacuum-based CDU at datacenters.lbl.gov/sites/default/files/206888r.pdf.

Read about how Sandia's data center earned LEED Gold certification at sandia.gov/news/publications/labnews/articles/2020/06-19/LEEDv4_Gold.html.

For questions about Sandia's Attaway HPC system, contact Dave Martinez at davmart@sandia.gov or David Smith at dsmith5@sandia.gov.

For information on NREL's energy-efficient data center work, contact Otto Van Geet at Otto.VanGeet@nrel.gov.

For questions about FEMP's data center technical assistance, contact Jefferey Murrell at Jefferey.Murrell@ee.doe.gov. ■

Building on the successful installation and performance of the Attaway system, Sandia is deploying a second 1,000-kW HPC system named Manzano, from Penguin, which utilizes Chilldyne's vacuum-integrated liquid cooling solution. The system entered production in early 2021 to help carry out Sandia's HPC mission.

Smart Energy Strategies for Federal Data Centers

FEMP collects and promulgates best practices and information for federal agency staff to understand, design, procure, and implement data center efficiency upgrades as a valuable component of their energy planning and management strategies. For more information, visit energy.gov/eere/femp/energy-efficiency-data-centers.

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