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Using Thermosyphon Hybrid Cooling System to Optimize Data Center Water Efficiency

The National Renewable Energy Laboratory (NREL) data center is home to warm-water liquid-cooled high-performance computing (HPC) systems that—while ultra energy efficient—generate a tremendous amount of heat. Evaporative cooling is an effective technique for managing that heat, as it is more efficient and less expensive than compressor-based cooling, but it requires a large, steady supply of water—more than 2 million gallons per year for NREL's HPC data center.

Driven by a mission to push the leading edge for data center sustainability, NREL recognized the need to make its data center not just energy efficient, but water efficient, too. So, in 2016, NREL, with partners Johnson Controls and Sandia National Laboratories, deployed an innovative thermosyphon cooler (TSC) as a test bed on the roof of the NREL's Energy Systems Integration Facility (ESIF). In combination with existing evaporative towers, the TSC forms an extremely water- and cost-efficient hybrid cooling system.

Water is relatively inexpensive, but it is a limited resource. As a result, improving water efficiency in data centers is important to their sustainability. NREL's groundbreaking work in this area is paving the way for others to follow suit.

Rounding Out NREL's Data Center Sustainability Story

The 10,000-square-foot HPC data center is located on NREL's Golden, Colorado, campus as part of its LEED Platinum rated ESIF. NREL's HPC data center has been called the most energy-efficient data center in the world, demonstrating a world-leading annualized average power usage effectiveness (PUE) of 1.036, pioneering work in component-level warm water liquid cooling, and waste heat capture and reuse.

The addition of the Johnson Controls BlueStream Hybrid Cooling System—an advanced dry cooler that uses refrigerant in a passive cycle to dissipate heat—has made NREL's HPC data center a leader in water efficiency, too. The TSC saved 1.16 million gallons of water in its first year of operation, and 2.10 million gallons during a two-year period, cutting water usage in the data center in half while continuing to operate at optimal energy efficiency. In the two years since installation, the TSC saved the equivalent of more than three Olympic-size pools of water. This accomplishment earned NREL and partners a 2018 U.S. Department of Energy Federal Energy and Water Management Award, and the Data Center Dynamics 2018 Eco-Sustainability award.

The thermosyphon cooling system sits on top of NREL's Energy Systems Integration Facility, which houses the HPC data center. The installation required only a 1-day outage to the data center. *Photo by Dennis Schroeder, NREL 41999.*

How TSC Compares to Traditional Cooling Options

Air-cooled heat exchangers use the ambient air dry bulb temperature as the heat sink. Air by itself is a relatively poor conveyor of heat, so it can take significant fan energy to reject a given amount of heat to the atmosphere. However when the dry bulb temperature is significantly lower than the process fluid temperature, only limited fan energy is required. The good news, though, is that they never require water.

Although evaporative cooling systems have many performance advantages during peak summer conditions, these advantages diminish with cooler ambient temperatures. Evaporatively cooled systems, such as those employing cooling towers, depend on a continuous source of low-cost water to reliably and economically address the cooling requirements.

Hybrid cooling systems combine the best of these traditional cooling options.

How It Works: An Efficient Hybrid Cooling System

In the ESIF HPC Data Center, IT equipment produce heat as a byproduct. This heat energy is captured in the data center's energy recovery water (ERW) closed-loop system. The three heat-rejection options for this IT load operate according to the following hierarchy:

1. When possible, heat energy from the energy recovery loop is transferred to the building process hot water loop to help heat the building or campus.

2. After reuse potential is exhausted, warm ERW flows to the fourth-floor mechanical space. When temperatures permit, heat is dissipated through the TSC.

3. The remaining heat is transferred from the ERW loop to a tower water open loop via the cooling tower heat exchanger.

The TSC system coordinates the operation for optimum water and operating cost efficiency—using wet cooling when it is hot and dry cooling when it is not. The unique design and controls of the TSC allow it to safely cool the primary cooling loop water and prevent freeze-ups even during subfreezing ambient temperature conditions.

The TSC is an additive piece of technology. For most operational cases, the user needs to have sufficient cooling tower capacity to handle the entire IT load on the hottest hours of the year (when the TSC can't contribute). The upside to this is added system resiliency. Among best practices revealed by the system: NREL is now performing cooling tower preventative maintenance work on cooler days when energy reuse and the TSC can handle the entire heat rejection of the IT load. ■

Beyond NREL

The advanced capabilities of TSC systems–and resulting water and cost savings are applicable to sites that have year-round heat rejection load and higher loop temperatures relative to average ambient temperatures. In the near term, the TSC system deployed at the ESIF has the potential for data centers around the world and is currently being implemented by collaborators from Sandia National Laboratories.

References

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Photo by Dennis Schroeder, NREL 24645.

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