Technology Case-Study Bulletin

Data Center Rack Cooling with Rear-door Heat Exchanger

As data center energy densities in power-use per square foot increase, energy savings for cooling can be realized by incorporating liquid-cooling devices instead of increasing airflow volume. This is especially important in a data center with a typical under-floor cooling system. An airflow-capacity limit will eventually be reached that is constrained, in part, by under-floor dimensions and obstructions.

1 Introduction

Liquid-cooling devices were installed on server racks in a data center at Lawrence Berkeley National Laboratory (LBNL) in Figure 1. The passive-technology device removes heat generated by the servers from the airflow leaving the server rack. This heat is usually transferred to cooling water circulated from a

Figure 1: Passive Rear Door Heat Exchanger devices at LBNL

central chiller plant. However at LBNL, the devices are connected to a treated water system that rejects the heat directly to a cooling tower through a plate-and-frame heat exchanger, thus nearly eliminating chiller energy use to cool the associated servers. In addition to cooling with passive heat exchangers, similar results can be achieved with fan-assisted rear-door heat exchangers and refrigerant-cooled rear-door exchangers. Server racks can also be cooled with competing technologies such as modular, overhead coolers; in-row coolers; and close-coupled coolers with dedicated containment enclosures.

2 Technology Overview

The RDHx devices reviewed in this case study are referred to as passive devices because they have no moving parts; however, they do require cooling water flow. A passive-style rear door heat exchanger (RDHx) contributes to optimizing energy efficiency in a data center facility in several ways. First, once the device is installed, it does not directly require infrastructure electrical energy to operate. Second, RDHx devices can use less chiller energy since they perform well at warmer (higher) chilled water set-points.

Third, depending on climate and piping arrangements, RDHx devices can eliminate chiller energy because they can use treated water from a plate-and-frame heat exchanger connected to a cooling tower. These inherent features of a RDHx help reduce energy use while minimizing maintenance costs.

2.1 Basic operation

The RDHx device, which resembles an automobile radiator, is placed in the airflow outlet of a server rack. During operation, hot server-rack airflow is forced through the RDHx device by the server fans. Heat is exchanged from the hot air to circulating water from a chiller or cooling tower. Thus, server-rack outlet air temperature is reduced before it is discharged into the data center.

2.2 Technology Benefits

RDHx cooling devices can save energy and increase operational reliability in data centers because of straightforward installation, simple operation, and low maintenance. These features, combined with compressorless, indirect evaporative cooling, make RDHx a viable technology in both new and retrofit data center designs. It may also help eliminate the complexity and cost of under-floor air distribution.

Reduce Maintenance

Because passive RDHx devices have no moving parts, they require less maintenance compared to computer room air conditioning (CRAC) units. RDHx devices will require occasional cleaning of dust and lint from the air-side of the coils. RDHx performance also depends on proper waterside maintenance.

Reduce or Eliminate Chiller Operation

RDHx devices present an opportunity to save energy by either reducing or eliminating chiller operation. Because RDHx devices perform well at warmer chilled water set-points, they are typically more energy efficient than CRAC units. Potentially, a data center could eliminate chiller use completely by having the RDHx device reject heat using indirect evaporative cooling in a cooling tower.

2.3 Infrastructure requirements

At LBNL, the RDHx devices were connected to treated-water system connected to a cooling-tower by routing new pipes through the existing under-floor space. Overhead connections to an RDHx are also available from the manufacturer. The RDHx devices were plumbed with flexible hoses that included quick-disconnect fittings. These fittings allow the devices to swing open, or be removed, during server maintenance and upgrades, see Figures 2 and 3.

Figure2: RDHx hose connections

2.4 Capacity sizing

Cooling capacity is achieved by setting a flow rate with respect to the available coolant temperatures. Coolant flow rates can range from 4 GPM per door to over 15 GPM per door. Server outlet air temperatures can be reduced anywhere from 10°F (5.5°C) to 35°F (19.4°C), depending on coolant flow-rate and temperature and server outlet temperature. Discharge temperature from each RDHx to the data center also depends on the server's workload, which can vary continuously. Consequently, it is possible to have discharge air temperatures higher, or lower, than the desired server inlet air temperature for the data center. Therefore, the RDHx system should be commissioned to accommodate for this variability by modulating cooling water flow-rate, or temperature. In the case of higher RDHx discharge temperatures, a central cooling device, such as a CRAC unit, can compensate. Importantly, the case study demonstrated the necessity of having a comprehensive energy monitoring system to optimize performance and energy savings from the RDHx system. LBNL employed a wireless monitoring system to maximize energy savings.

3 Implementation

The installation of a RDHx is less complicated than installing a CRAC unit. However, prior to installing any additional cooling device, operators of data centers using under-floor air distribution should consider and implement appropriate energy-efficiency measures including:

- Scrutinizing floor tile arrangements & server blanking.
- Increasing data center setpoint temperature.
- Optimizing control coordination by installing an energy monitoring and control system (EMCS).
- Installing hot-aisle or cold-aisle isolation systems.

All of these basic measures will contribute to increasing the cooling capacity of your existing data center systems and may help avoid the complexity of installing new, additional cooling capacity.

Figure 3: Inside rack RDHx, open 90°

3.1 Site preparation and installation

- Determine chiller and cooling tower system capacity.
- Locate and determine access and connections to existing chilled-water, treated-water, and tower-water systems.
- Examine server racks for missing blanking and side plates.
- Remove or relocate obstructions to routing new piping under floor.
- Install new circulating pump(s), flow-balancing valves, and fittings, as necessary.
- Route piping and flexible hose.
- Install isolation and balancing valves.
- Prepare servers for possible down-time.
- Add new temperature sensors.
- Install heat exchanger door; check flexible pipe clearances.
- Purge and pressure test system for leaks.

3.2 Commissioning

LBNL encountered a variety of minor initial start-up issues related to the fit and finish of the RDHx devices such as air leaking around the RDHx devices and air short-circuiting within the racks. During startup, it is essential to monitor all liquid and air temperatures and coolant flow-rates to optimize RDHx performance. It is recommended that the following are commissioned as part any RDHx installation:

- Confirm point-to-point connections of temperature sensors.
- Ensure airflow leakage around the RDHx and recirculation within the rack is minimized.
- Verify server airflow temperature at inlet and outlet (before RDHx).
- Check air temperature at RDHx outlet.

Cooling Capacity at LBNL

- Inlet server air temperature = 70°F (21°C);
  Outlet server air temp = 100°F to 120°F (37.8°C to 48.9°C)
- Leaving air temperature from RDHx = ~80°F (26.7°C)
- Supply water temperature to RDHx = 72°F (22°C);
  Outlet RDHx water temperature = 76°F (24.4°C)
- RDHx water flow rate per door = 9 GPM (34 LPM);
  Total flow for six doors = 54 GPM (204 LPM)
- Heat removed: Q_{RDHX} = 500 x 54 GPM x (76°F – 72°F) = 108,000 BTUH or 9 Tons
- Server Load = 10 to 11 kW/Rack x 6 Racks = 66 kW
- Percent cooling load provided by RDHx:
  (9 Tons x 3.51 kW/Ton[conversion constant]) / 66 kW
  = 31.6 kW / 66 kW
  = ~48% of server waste heat removed by RDHx system

Cost at LBNL

The RDHx devices cost $6,000 per device plus installation and infrastructure additions.

- Measure RDHx coolant flow and inlet and outlet temperatures.
- Confirm inlet coolant temperature at each RDHx is above dew point temperature.
- Check for leaks at pump and in piping arrangements.
- Review and test new control sequences.

4 Lessons Learned

This demonstration project at LBNL provided lessons-learned that may be relevant to other RDHx projects. One unexpected result was the amount of excess cooling capacity created within the data center. The newly found capacity required coordinating RDHx cooling capacity with the existing CRAC units. Standard CRAC return-air control methods, which are beyond the scope of this bulletin, can present a challenging situation.

4.1 Airflow management

Airflow from under-floor outlets needed to be directed correctly. The location and adjustment of the supply outlets such as adjustable perforated tiles, was optimized prior to fitting RDHx devices. Air leaks around the rear-door heat exchangers required sealing since the doors did not always fit tightly. Additionally, LBNL found that RDHx devices were not well suited for all rack designs, especially racks older than 10 years. The potential for hot-air short-circuiting within the racks is widespread. To limit this situation, LBNL installed server rack blanking-plates and side-panels. In addition, LBNL used brush-type seals around RDHx hoses to mitigate this air-leak pathway.

4.2 Monitoring performance a necessity

An EMCS, BAS (Building Automation System), or other monitoring system, should be used to gather air temperatures and to develop trend information prior to installing a RDHx system. Generally in a data center, an EMCS with centralized, automated, direct digital control can coordinate energy use of cooling systems such as CRAC units, thus maximizing performance of the rack-mounted RDHx devices.

4.3 Metering for energy management

The LBNL demonstration project clearly validated the old energy-use axiom that generally states that you cannot manage energy without monitoring energy. Adequate metering and monitoring is essential to provide reliable energy-use data to sustain the performance of the RDHx installation.

4.4 Rethinking rack arrangements

RDHx technology may make creating what is usually referred to as "hot aisle isolation" less important. Using a RDHx can sufficiently reduce server outlet temperatures to point where hot and cold aisles are no longer relevant. In a new data center design, adjoining server racks may not need to have their outlet airflows facing each other. A series airflow arrangement, where air from a rack outlet supplies air to an adjoining rack's inlet, can be implemented. Depending on the rack arrangement in an existing data center, an RDHx system can simplify air management by eliminating the need for hot and cold aisle isolation.

5 References

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6 Acknowledgements

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