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Abstract

With increasing deployment of high-density racks of equipment, the greatest challenge for existing data centers becomes finding ways to extend the life and capacity of the data centers with limited cooling resources. The HP Modular Cooling System (HP MCS) makes it possible to achieve hardware densities and power consumption levels (up to 35 kW in a single rack) that have been difficult—if not impossible—to support with conventional HVAC systems. In particular, the HP MCS can be used in data centers to eliminate specific hot spots without revamping the overall infrastructure.

This paper explains why densification creates power and cooling challenges and how the technologies offered by the HP MCS overcome them.

Introduction

The deployment of high-density racks of equipment is creating power and cooling challenges for data centers worldwide. The server densification trend is intended to create efficiencies in floor space, cabling, and systems management. However, the growth in power density (watts per U) with each new server generation is causing data centers to limit rack utilization based on cooling capacity. Data centers are in dire need of new cooling solutions to reap the benefits of server densification.

HP is developing innovative cooling solutions that include highly efficient rack enclosures capable of supporting high power and heat loads. The HP MCS (Figure 1) is a closed-loop cooling system that is installed on HP 10000 Series G2 Racks.

The HP MCS uses modular fans and air-to-liquid heat exchangers to remove the high levels of heat generated by advanced server and mass storage systems. The HP MCS allows a data center to add computing power with minimal impact on the facility’s heat load, thus extending the life of the data center.

This paper explains the densification trend that is driving the need for direct cooling at the rack level, describes the technologies in the HP MCS that overcome densification issues, and identifies critical factors that affect whether the HP MCS is a viable solution in a specific data center environment.

Data center trends

Originally, data centers were designed to support large, water-cooled mainframes that consumed lots of power and generated intense heat in concentrated areas. As enterprise computers evolved, data center designs changed to support racks of multi-processor servers and storage systems that spread the power and cooling requirements over a larger area. Although this trend allowed data centers to scale easier, it created power distribution, cabling, and system management challenges. The emergence of 1U servers and blade servers allowed organizations to consolidate their data center infrastructures, decrease cable clutter, and streamline server management. However, most data
centers are having difficulty adjusting to the effect of high-density racks on power and cooling resources.

Increased power demands

A fully loaded 42U rack with dual processor (2P) 1U servers and storage drives requires over 12 kilowatts (kW) of power. A 42U rack containing 96 half-height BL p-Class blade servers requires 28 kW of power. As data centers try to accommodate more of these high-density racks, they are moving toward high amperage, three-phase infrastructures. Three-phase power is typically more efficient than single-phase power since it provides more than 150 percent of maximum available power provided by single-phase power.

Increased cooling demands

The consequence of more power is more heat. Virtually all power consumed by rack-mounted equipment is converted to sensible heat, which increases the temperature of the environment. The sensible heat load is typically expressed in BTU/hr, where 1 W equals 3.413 BTU/hr. Therefore, the heat load of each rack can be calculated as follows:

\[ \text{Heat Load} = \text{Power [W]} \times 3.413 \text{ BTU/hr per watt} \]

For example, the heat load for a 2P ProLiant DL360 G4 server is:

\[ 577 \text{ W} \times 3.413 \text{ BTU/hr/W} = 1,969 \text{ BTU/hr} \]

This means that the heat load of a fully-loaded 42U rack of DL360 G4 servers is 82,710 BTU/hr. In the U.S.A., cooling capacity is often expressed in "tons" of refrigeration, which is derived by dividing the sensible heat load by 12,000 BTU/hr per ton. The cooling capacity needed for a fully-loaded rack of DL360 G4 servers is

\[ 82,710 \text{ BTU/hr} \div 12,000 \text{ BTU/hr per ton} = 6.9 \text{ tons} \]

Limited data center capabilities

Few existing data centers were designed to provide this amount of cooling capacity for a single rack. Few data centers are capable of distributing adequate airflow directly to rows of such racks.

Many data centers limit power consumption and cooling requirements by limiting rack density (utilization). For example, Figure 2 shows the total power capacity and heat load of a fully-loaded rack of DL360 G4 servers. The figure also shows the number of servers that can be deployed per rack based on the average rack power density of a particular data center.

The reasonable limit of rack power and cooling capacity for a conventional forced-air (HVAC) cooled data center is 8 kW per rack, or 27,300 BTU/hr per rack. For power densities approaching 15 kW per rack, facility planners can use advanced thermal modeling technologies.
such as HP Static Smart Cooling\textsuperscript{1} to help determine the best layout of computing rooms and provisioning of cooling resources. For racks requiring more than 15 kW, the latest cooling techniques use a proven medium—water. Water can remove 3,500 times the amount of heat that an equivalent volume of air can remove. To take advantage of the cooling efficiency of water, HP has developed the HP MCS enclosure.

**HP MCS technology**

The HP MCS is designed for data centers that have reached the limit of their cooling capability or that need to reduce the effect of high-density racks on their facility. The HP MCS supports fully populated high-density racks while eliminating the need to add more facility air conditioning capacity.

**HP MCS subsystems**

The HP MCS enclosure includes an empty HP 10000 Series G2 rack. The enclosure contains three fan modules and three heat exchanger modules that slide into a cabinet mounted on the left side of the rack (Figure 3). Each fan module contains a variable-speed circulation fan. Each heat exchanger (HEX) module contains an air-to-water heat transfer device. Each HEX module discharges cold air to the front of the rack via a side portal. Chilled water for the heat exchangers can be provided by the facility’s chilled water system or by a dedicated chilled water unit (see “Installation considerations”).

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\textsuperscript{1} For more information, please read “Thermal Considerations in Cooling Large Scale High Compute Density Data Centers” at http://www.hpl.hp.com/research/papers/2002/thermal_may02.pdf
**Airflow distribution**

The HP MCS supports the front-to-back cooling principle used in most server designs. The HP MCS evenly distributes cold supply air at the front of the rack of equipment (Figure 4). Each server receives adequate supply air, regardless of its position within the rack or the density of the rack. The servers expel warm exhaust air out the rear of the rack. The fan modules re-direct the warm air from the rear of the rack into the heat exchanger modules. The air is re-cooled and then re-circulated to the front of the rack. Any condensation that forms is collected in each heat exchanger module and flows through a discharge tube to a condensation tray integrated in the base assembly.

**Figure 4. HP Modular Cooling System**

For controlled airflow, the HP MCS enclosure must be closed during normal operation. The enclosure has solid front and rear doors, sidewalls, and top and bottom covers. The front and back doors must be kept closed to ensure that the maximum amount of the cool air is retained within the system. All rack space must be either filled by equipment or enclosed by blanking panels so that the cool air is routed exclusively through the equipment and cannot bypass through or around the rack.

An Automatic (emergency) Door Release Kit is included with every HP MCS. The kit ships in the accessories box and is to be field-installed. The Automatic Door Release Kit is designed to swing the HP MCS front and rear doors open in the case of a sudden increase in the temperature inside the HP MCS. The open doors will allow the IT equipment to cool using the air from the datacenter.
Water circulation
Chilled water for the heat exchanger is regulated by the water group controller. This module contains a magnetic solenoid valve, check valve, flow meter, and condensate pump. The water group is connected to the facility’s chilled water system (or to a dedicated chiller unit) via flexible 33.8-inch (860-mm) inlet and outlet hoses. The condensate drain hose, overflow hose, and main inlet and outlet hoses can be routed through the back of the cabinet (Figure 5) or downward into a raised tile floor. The inlet and outlet hoses are terminated with 1.25-inch (31.8-mm) quick-connect couplings. Customers can request one additional matching coupling for each chilled water and return line.

Figure 5. Inlet and outlet hose connections in rear of the HP MCS

Power Redundancy
The HP MCS can operate from a single AC power source. It also provides for power redundancy through a transfer switch module (Figure 6) that accepts AC power from two sources.

Figure 6. Transfer Switch Module
System management

The management module controls the water flow and fan speed to provide the needed cooling capacity and desired server inlet temperature as set by parameters in the web interface (Figure 7). The system maintains the temperature of the server intake air at the Server Intake Temperature Set Point by opening and closing the solenoid-actuated water valve. The valve opens when the server intake air temperature exceeds the set point. The valve closes when the air temperature falls below the set point, minus the Hysteresis Value. The system controls airflow by adjusting the speed of each fan module to maintain the server exhaust temperatures at the appropriate levels. The management module can be configured to send alert traps to HP Systems Insight Manager (SIM), HP OpenView, and other SNMP management applications if an alarm condition is detected. Administrators can use HP SIM to:

- Discover management modules
- Receive SNMP traps from the management module
- Conveniently launch the management module web interface

Figure 7. Management module interface

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2 The Hysteresis Value is added to and subtracted from the Server Intake Temperature Set Point to define the temperature range used to control the server intake temperature and optimize the water valve cycle frequency.

Administrators can monitor the operation of the HP MCS by using the Overview screen on the Home tab (Figure 8). The Overview screen displays graphic meters for server intake temperature and cooling system parameters.

**Figure 8. Overview screen**

Network monitoring, control, and feedback capabilities are provided through an operator display on the outside of the HP MCS front door (Figure 9). When the management module issues an alarm or warning, the message appears on the operator display on the Alarms menu.

**Figure 9. The operator display is conveniently located on the front door of the HP MCS.**
Cooling capacity versus system footprint

An HP 10000 Series G2 rack with an attached HP MCS requires approximately 1.5 times the width and 1.25 times the depth of a standard server rack (to allow for the fan and heat exchanger modules and front and rear airflow). However, one HP MCS enclosure has enough cooling capacity to support the heat load of equipment consuming 35 kW. This heat load is equivalent to that generated by three 10-kW racks and a 5-kW rack (Figure 10), yet the HP MCS occupies 50+ percent less floor space than four standard-footprint racks. Likewise, the HP MCS supports a heat load equivalent to 3.75 8-kW racks (30 kW/8 kW per rack = 3.75 racks) while occupying 65 percent less floor space and reducing the overall heat load on the facility.

**Figure 10.** Footprint comparison of 35 kW heat load

- Footprint of 4 racks = 4 x 6.83 sq. ft = 27.3 sq. ft
- Footprint of HP MCS = 12.25 sq. ft (50+ % less)
Facility limitations

The HP MCS designed for installation in a standard raised-floor data center environment. There are two basic ways to deploy the HP MCS:

- As a stand-alone unit
- Adjacent to an existing row of HP 10000 Series G2 cabinets

Important factors to consider before installing the HP MCS include:

- Floor loading capacity
- Chilled water requirements
- Cooling requirements
- Space requirements
- Power requirements

For more detailed information about installation considerations for the HP MCS, refer to the HP Modular Cooling System Site Preparation Guide, the HP Modular Cooling System Web Interface User Guide, or the HP Modular Cooling System User Guide at the links listed in the “For more information” section.

Floor loading in raised floor facilities

Weight is one of the most important factors to consider when installing the HP MCS in a raised floor facility. The raised floor must be able to support the static load of the fully assembled HP MCS and server cabinet as well as the weight of any additional cabinets as they are moved into position. Raised floor loading is not only a function of the weight, but also of the positioning of the equipment relative to the raised floor grid. The packaged weight of the HP MCS, which includes all packaging materials such as the skid and cartons, is 1310 lb (594 kg). The weight of a fully assembled HP MCS and an empty HP 10000 Series G2 Rack is 1130 lb (513 kg). The weight of a populated server rack depends on the equipment installed in the rack. Table 1 lists the ratings of a typical raised floor system that is satisfactory for the installation of the HP MCS.

Table 1. Specifications for a typical raised floor

<table>
<thead>
<tr>
<th>Item</th>
<th>Rating</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead load</td>
<td>7 lb/ft² (34.2 kg/m²)</td>
<td>The weight of the raised panel floor system, including the understructure</td>
</tr>
<tr>
<td>Live load</td>
<td>313 lb/ft² (1528.3 kg/m²)</td>
<td>The load that the floor system can safely support</td>
</tr>
<tr>
<td>Concentrated load</td>
<td>1250 lb (567 kg) per panel</td>
<td>The load that a floor panel can support on a 1-in² (6.45-cm²) area at the panel’s weakest point</td>
</tr>
<tr>
<td>Ultimate load</td>
<td>4000 lb (1814 kg) per panel</td>
<td>The maximum load (per floor panel) that the floor system can support without failure (breaking or bending)</td>
</tr>
<tr>
<td>Rolling load</td>
<td>400 lb (181 kg) per panel</td>
<td>The load a floor panel can support (without failure) when a wheel of specified diameter and width is rolled across the panel</td>
</tr>
<tr>
<td>Average floor load</td>
<td>500 lb/ft² (227 kg/m²)</td>
<td>Computed by dividing total equipment weight by the area of its footprint. This value is expressed in lb/ft² (kg/m²).</td>
</tr>
</tbody>
</table>

For instructions on how to calculate the weight load of each HP Modular Cooling System, including installed equipment, refer to the HP Modular Cooling System Site Preparation Guide.
Chilled water requirements

There are three potential sources of chilled water for the HP Modular Cooling System:

- Direct connection to the building’s chilled water system
- A dedicated chilled water system
- A water-to-water heat exchanger unit connected to a chilled water or building water system

The HP MCS has been designed to connect directly to the facility’s chilled water supply. In a chilled-water system, an external air conditioner cools water typically between 40°F and 45°F (4.4°C and 7.2°C). This chilled water is pumped throughout the building for use by air-to-liquid heat exchangers.

To prepare the data center for the HP MCS, the HP Water Hook-up Option Kit must be installed before connecting the inlet and outlet water hoses to the water lines. The kit provides parallel and tapered thread couplings for different regional preferences. However, if the water quality, flow, pressure, or temperature does not meet the standards set forth in the HP MCS Site Preparation Guide, HP recommends that the water loop for the HP MCS be an isolated loop from the building’s water system or a dedicated chiller unit. A water loop provides for line isolation, better control of individual systems, and the ability to regulate water quality.

When it is necessary to isolate the HP MCS fluid supply/return loop from the main building water system, HP recommends a separate water-to-water heat exchanger. The heat exchanger provides easier control and monitoring of water quality. It also provides more flexibility to maintain the water at a higher temperature to reduce condensation.

Cooling requirements

The HP MCS is designed to add minimal heat-load in the room. Most of the heat generated inside the HP MCS cabinet is removed via the chilled water loop. The HP MCS exchanges a small amount of air with the room during normal operation. Depending on the room temperature, rack power consumption, and system configuration, up to 10 percent of the total internal heat load may be passed to the room.

In anticipation of future heat loads, isolated-loop chilled water piping should be designed and installed to support:

- Specific heat load increments (35kW or 150kW)
- The specific number of HP Modular Cooling Systems per row or loop
- Other site build-out planning parameters

As cooling, rack space, and equipment density requirements increase, the HP MCS can be quick-coupled into the isolated chilled water system.

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5 The HP Water-Hookup Option Kit is available separately.
Space requirements

The packaged size of the HP MCS (including shock pallet and cartons) is approximately 88.5 inches (2170 mm) high x 48 inches (1220 mm) wide x 70 inches (1778 mm) deep. The size of the enclosure from hinge to handle is 78.7 inches (1999 mm) high x 35.8 inches (909 mm) wide x 51 inches (1295 mm) deep (see Figure 11). Two high-density HP MCS systems occupy the equivalent floor space of three standard HP racks. The HP MCS can be aligned flush at the front or at the rear of an existing cabinet row to maintain an organized and uniform data center layout. The minimum recommended front and back clearances for performing maintenance on servers supported by an HP MCS are 48 inches (1,219 mm) and 36 inches (914 mm), respectively.

Figure 11. HP MCS dimensions (approximate)

NOTE:
The HP MCS is shipped with a metal stabilizing bracket bolted to the top of the MCS assembly. This bracket is for shipping purposes only and should be removed before system installation.
Power requirements

The HP MCS uses minimal electrical power (see Table 2) to create the cool air required by the equipment in the rack. Therefore, the HP MCS can be powered from existing 208/220V AC power in the enclosure/rack power strip. Electrical connections are made through a patch panel that provides connectors for the AC power. Two AC power connectors are provided for redundant power sources.

Table 2. Power requirements of HP MCS

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Value</th>
<th>Comments</th>
</tr>
</thead>
</table>
| Number of power cords         | 2 (for redundancy), cord length: 98 in. (2.5 m) | System ships with 4 cords, 2 with the L6-20P plug and 2 with the IEC 309 plug.  
  North America/Japan – Plug L6-20P  
  International – Plug IEC309 |
| Minimum operating voltage    | 180 VAC                                    |                                                                          |
| Maximum operating voltage    | 240 VAC                                    |                                                                          |
| Frequency range              | 50/60 Hz                                   |                                                                          |
| Number of phases             | 1                                          |                                                                          |
| Rated line current           | 15 A                                       | Per line cord                                                            |
| Maximum operating power      | 2500 VA                                    | Maximum power is the sum of the worst-case power consumption of every subsystem in the box and should be used to size worst-case power consumption for facility installation. |

For other power considerations, such as grounding, ESD, conductor/circuit breaker sizing, and power cord connectors, refer to the HP Modular Cooling System Site Preparation Guide available at the URL listed in the “For more information” section.
Environmental requirements

The HP MCS specifications are based on requirements for an HP Environmental Class C2 computer room environment where products are subject only to controlled temperature and humidity levels. The allowable and recommended temperatures and relative humidity (RH) values are shown in Table 3. High humidity can cause galvanic action to occur between some dissimilar metals. Galvanic action can result in high electrical resistance between connections.

Table 3. Allowable and recommended temperature and humidity values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended temperature*</td>
<td>68°F (20°C) to 77°F (25°C)</td>
</tr>
<tr>
<td>Allowable temperature*</td>
<td>59°F (15°C) to 90°F (32°C)</td>
</tr>
<tr>
<td>Recommended relative humidity</td>
<td>40% to 55% RH</td>
</tr>
<tr>
<td>Allowable relative humidity</td>
<td>20% to 80% RH</td>
</tr>
</tbody>
</table>

The temperature ranges identified in this table are for locations 0 to 5,000 feet above sea level. The maximum operating temperature must be derated by 1°C per 1,000 feet for locations 5,000 to 10,000 feet above sea level.

HP MCS installation and maintenance services

HP provides worldwide Site Datacenter Thermal Quick Assessment Services along with installation and maintenance Care Pack services to streamline deployment of the HP MCS. The HP MCS Care Pack services help increase uptime and productivity with rapid-response support on a 24x7 or 13x5 basis. The HP MCS Care Pack services are independent of Care Pack services for other HP rack and power products. For more information about these services access the services Web page at http://h20219.www2.hp.com/services/cache/111072-0-0-225-121.html.

Summary

The innovative design of the HP MCS can extend the life and capacity of data centers with limited cooling resources. The HP MCS also integrates with existing and future HP universal server cabinets and does not affect how servers are currently deployed, operated, and maintained. The HP MCS:

- Provides a path for customers to increase power density up to 35 kW per rack
- Supports fully populated high-density racks while reducing the overall heat load on the facility
- Saves valuable floor space and cooling resources that would be required for under-utilized racks

For detailed information about installation considerations for the HP MCS, refer to the HP Modular Cooling System Site Preparation Guide, the HP Modular Cooling System Web Interface User Guide, and the HP Modular Cooling System User Guide. The Web links for these documents are listed in the “For more information” section on the following page.
For more information

For additional information, refer to the resources listed below.

<table>
<thead>
<tr>
<th>Resource description</th>
<th>Web address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Considerations in Coolings Large Scale High Compute Density Data Centers (for information about HP Static Smart Cooling)</td>
<td><a href="http://www.hpl.hp.com/research/papers/2002/thermal_may02.pdf">http://www.hpl.hp.com/research/papers/2002/thermal_may02.pdf</a></td>
</tr>
</tbody>
</table>

Call to action

Send comments about this paper to [TechCom@HP.com](mailto:TechCom@HP.com).