DECISION POINTS ON CHILLERS FOR DATA CENTERS

Should you choose an air- or water-cooled system?

When determining a cooling strategy, data center designers and operators face many decision points regarding the cost of owning and operating their cooling equipment. In financial terms, these decisions usually involve tradeoffs between lowering the initial capital expenditure (CAPEX) or minimizing operating and maintenance costs (O&M), which include utility costs. CAPEX, O&M, and energy costs all combine into total cost of ownership (TCO).

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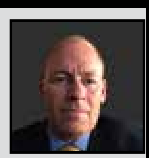

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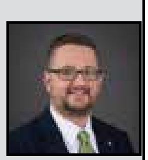

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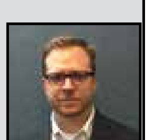

There are several technical issues involved in cooling equipment selection and sizing. Calculations about heat load, chilled water temperatures, ambient conditions, and other factors are all involved. What follows, however, is a broader view of the important economic decision points regarding two basic chiller categories: water-cooled centrifugal chillers and air-cooled scroll and screw chillers.

CHILLER SELECTIONS THAT LOWER ENERGY COSTS

Generally, the top-of-mind issue in choosing between chiller technologies is energy consumption. That's understandable because data center designers are typically focused on achieving a low power usage effectiveness (PUE) metric. Championed by the Green Grid Association, PUE is the ratio of total energy used by the facility divided by the energy used specifically by computing equipment. An ideal PUE of 1 would mean that all energy in the facility is being used for computing with no additional energy used for cooling, heating, or lighting — an impossible condition. Nevertheless, some data centers achieve PUEs of 1.2 and even lower.

Given the focus on saving energy, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has adopted new operating temperature guidelines to advance energy efficiency in data centers. ASHRAE Technical Committee 9.9 (TC9.9) was established to address all aspects of a data center's mission critical facilities, technology spaces, and electronic equipment/systems. The most recent TC 9.9 white paper titled, “Thermal Guidelines for Liquid Cooled Data Processing Environments” demonstrates the trend toward higher intake temperatures at IT devices.

This trend allows significant increases in computer room temperatures and, therefore, a reduction in energy used by cooling equipment. Recent findings show that relative humidity (rh) can be dropped as low as 15%, and even as low as 8% rh, with minor precautions, without danger to IT equipment from electrostatic discharge. Consequently, data center designers can take greater advantage of "free cooling" where available.

Given that energy efficiency is a critical decision point, what does that mean when selecting cooling equipment for a standalone data center? ASHRAE 90.1-2013 equipment efficiency tables show that water-cooled centrifugal chillers with capacities of 400 tons and higher are more efficient than other mechanical cooling technology, including air-cooled chillers, rooftop units, and self-contained systems.

To run at optimum efficiency, water-cooled centrifugal chillers must be specifically designed for conditions encountered in data center cooling. In general, data center cooling equipment addresses the temperature settings required by equipment — the "sensible cooling" load — rather than humidity levels for human comfort — the "latent cooling" load.

The most efficient chiller design for data centers, therefore, is a water-cooled centrifugal chiller designed for the "low-lift" conditions encountered with sensible cooling. It also helps if the chiller can utilize what is known as a "wide operating envelope." For example, a chiller with a wide operating envelope can supply warmer chilled water temperatures recommended by TC 9.9 for server inlet temperatures, an energy-saving capability.

OTHER DECISION POINTS AFFECTING CHILLER CHOICES

Of course, there are other factors besides energy efficiency that sway the decision toward one type of chiller technology or another.

If obtaining the lowest kW/ton of cooling is desired to drive down PUE, then the mechanical cooling selection is clear, as previously mentioned.

But important CAPEX decision points include: equipment costs, space requirements, wiring/plumbing costs, etc. Important O&M decision points can involve utility rates, water rates, sewage rates, maintenance costs, uptime reliability, noise, etc. These factors impact the TCO and make the decision matrix more complex.

Let's look at how these factors can affect decision making.

CAPEX COSTS

From the standpoint of first cost per ton of cooling, the difference between a water-cooled chiller and an air-cooled chiller of the same capacity does not necessarily show a significant difference. That's because the cost of an air-cooled chiller balances against the cost of a water-cooled chiller plus an accompanying water tower, which requires more piping and pumps.

Site costs must also be considered. The footprint of an air-cooled chiller is generally larger than a water-cooled chiller. For example, a 500-ton air-cooled chiller is 52 ft long. But space can be saved by installing water pumps underneath the chiller. And locating air-cooled chillers outdoors reduces the size and cost of the mechanical room. In comparison, a 500-ton water-cooled chiller is only 14 ft long. The size of a 500-ton cooling tower is 12- by 12-ft, plus additional space for maintenance access (pumps, water treatment equipment, piping, etc.). Again, taken altogether, applied costs tend to balance between the two types of systems.

More significant are the operating costs in the given application. Each chiller recommendation should be evaluated on the merits of the design load, load profile, local ambient conditions, and water/electric utility factors. For example, consider: What is the expense of water, water treatment, and sewage rates for makeup water? Is the water-cooled chiller optimized to handle lower water-tower temperatures? What control strategies are available to minimize system energy consumption under all weather and load conditions?

Chiller modeling programs are available from manufacturers to help answer these and other questions. The goal is to identify a chiller selection that justifies CAPEX costs based on energy savings from the expected kW/ton performance.

PEAK-DEMAND COSTS

Related to kW/ton performance is how the chiller selection helps minimizes peak-demand charges.

There are several key decision-points to consider: First, can the cooling load be shifted from peak hours using thermal storage? A typical strategy is to build ice at night in a thermal storage system, then use it to reduce the operation of mechanical equipment during the day. This strategy really comes into play where the utility has a time-of-day rate structure and surcharges must be avoided.

Otherwise, making ice actually consumes more energy than sensible cooling alone. For thermal storage applications, both air-cooled and water-cooled chillers have advantages. Air-cooled screw or scroll chiller selections may reduce the initial investment and involve fewer components by eliminating the need for a water-tower. But water-cooled centrifugal chillers can handle larger capacities well above 500 tons.

Another related consideration: Can the amperage draw of cooling equipment be minimalized during peak demand periods to avoid utility surcharges? A variable-speed chiller with a soft-start capability can. A soft-start reduces instantaneous power draw from the electric utility, which helps reduce demand charges. A control strategy is often used to sequence equipment startup to minimize demand spikes that otherwise occur with on-and-off cycling. This limits the amount of cooling available in a short time period, which could impact the functionality of the data center. The use of variable-speed drives (VSDs) allows all chillers to be started at the same time, which can provide cooling to the load quicker. VSDs also eliminate heat generated by inrush current, prolonging equipment life.

WATER COSTS

One obvious advantage of air-cooled chillers is the elimination of water tower CAPEX and maintenance costs. Water towers require chemical water treatment and the cost of water itself. Although water used by a water tower evaporates and doesn't enter the sewage treatment system, a municipality may assume all the water entering a facility leaves by the sanitary sewer.

In this case, both the amount of water and the corresponding sewage amount will be on the same bill. A local water authority may allow an approved water meter to be installed on the cooling tower makeup and bleed lines. The meter can validate the amount of evaporation that occurs, enabling an evaporation credit (or cooling tower credit) that can result in substantial savings.

Manufacturers of water-cooled chillers continue to develop technologies to shrink water tower size and water requirements. One innovation is an air-cooled radiator that removes heat from water before it reaches the tower, which helps reduce water tower size. Air-cooled fluid coolers also reduce the amount of water lost by evaporation, which can yield huge water savings. But to work, fluid coolers require a high tower water temperature, which raises the compressor lift (head pressure) and, thereby, prevents the VSD compressor motor from slowing down and saving energy.

MAINTENANCE COSTS

Different maintenance procedures are required for each type of chiller. As previously mentioned, the cooling tower of a water-cooled chiller does require water treatment to prevent microbial growth, as well as periodic blowdown and descaling. Tower fan and pump maintenance is also required. In addition to regular scheduled maintenance requirements, tube cleaning will eventually be required.

Air-cooled chillers require coil cleaning with water. Because of multiple compressors and fans, more air-cooled components may require more frequent maintenance — or replacement at a relatively low cost per component.

Chiller manufacturers continue to innovate ways to minimize maintenance by reducing complexity — but at an added first cost. For example, variable-frequency drives add expense, but they incorporate on-board electronics that provide more insight and control to minimize problems, simplify troubleshooting and maintenance. The introduction of variable-speed compressors using frictionless magnetic-bearings eliminates the need for oil management systems, thereby removing another maintenance task.

NOISE/SITE IMPACT

Acoustically, air-cooled rotary screw chillers present the most prominent noise-control challenges because the low-frequency sound they produce is difficult to control. Nevertheless, sound barrier walls and compressor blankets can be applied to reduce both the sound volume and tone to acceptable levels. Visually, the plume produced by water towers may be objectionable. This may swing the decision toward an air-cooled chiller selection, but there is another option. In some situations, a geothermal subterranean loop can be dug to use the ground for condenser-water heat rejection.

While an exotic and rarely used solution, a central geothermal chiller/heater system improves sightlines, provides good system efficiencies, and can improve the peak-load profile. However, a ground loop may not always work for a heat-rejection-only application due to the limited thermal conductivity of the ground itself. In such cases, a much larger ground field may be required to dissipate heat.

CONCLUSION

The factors impacting chiller selection for standalone data centers are complex. As a result, it is important to estimate potential chiller performance by using modeling programs available from manufacturers. Knowing how a chiller selection will perform at full and part-load and under design and off-design conditions at varying ambient temperatures will answer questions about chiller energy performance.

As important as kW/ton chiller performance is in calculating PUE, however, it is only part of the larger financial picture. Electric, water, and sewage rates can vary considerably depending on the region and municipality. Maintenance costs can also vary depending on local labor rates and the complexity of the technology. Unless the primary decision point is to achieve a low PUE, data center designers and operators need to evaluate all the factors. Considering the tradeoffs and making the appropriate choices can dramatically lower TCO of the chiller plant and help determine the project return on investment. ■