White Paper

Data Centers are Warming Up to A New Cooling Design

Operate at higher temperature for better efficiency and cost savings

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In a review of chilled water system design concepts targeting data center cooling loads, it is found that the loads are typically all sensible load that do not require low chilled water temperature to remove moisture (latent load). In this white paper, Johnson Controls will discuss the new ideal chilled water temperature and its impact on Power Usage Effectiveness (PUE) for data centers.

Sustainability and reduction of carbon emission are key concerns facing the data center industry today. Estimates1 suggest that data centers account for up to 5% of global greenhouse gas emissions. With a significant portion of the energy – nearly 40% – being utilized on cooling systems for data centers, it's imperative that these facility operators invest in solutions for more efficient cooling and better heat management, while maintaining reliability and uptime.

Data Center Cooling

Water-cooled chillers are used in many data centers. A typical chiller is designed to supply chilled water at a particular temperature, which is based on the facility requirements, to meet the cooling load of the facility.

In a typical building application, the set point of chilled water temperature is determined by the sensible and latent load of the building. A certain minimum chilled water temperature is required to remove the moisture (latent load). The typical temperature of chilled water supply is set at 6.7°C (or 44°F) based on the ratio of sensible and latent load of building.

The work done by the chiller compressor is inversely related to the temperature of the chilled water supply. In other words, the work done increases as the chilled water supply temperature is reduced; and conversely, the work done is reduced as the chilled water temperature is increased (see Chart 1).

Work Done by Compressor (in Chiller) Measured Against Temperature of Chilled Water Supply

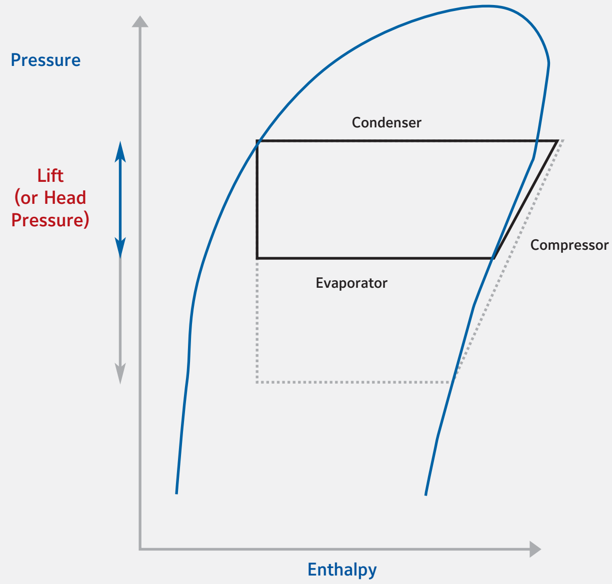

Chart 1

Source: Johnson Controls

At the same time, the power consumed by a chiller is directly proportional to the work done by compressor, or the "lift" of the compressor. This means that at a lower chilled water temperature, there is lower suction pressure and higher lift for compressor (that is, more work done).

[1] *https://www.mordorintelligence.com/industry-reports/global-data-center-cooling-market-industry*

To sum up, at a higher chilled water temperature scenario, the following happens:

- Higher evaporator pressure – which leads to
- Lower lift and lower work done for the compressor, and consequently
- Lower power consumption overall

It is estimated that for every 1°C increase in the temperature of chilled water, there is approximate 2-3% savings in power consumption for a typical chiller; and approximate 4-5% savings if the chiller is fitted with variable speed drive.

Comparison of Typical Performance of Chillers in Standard Comfort Cooling Buildings and Data Centers

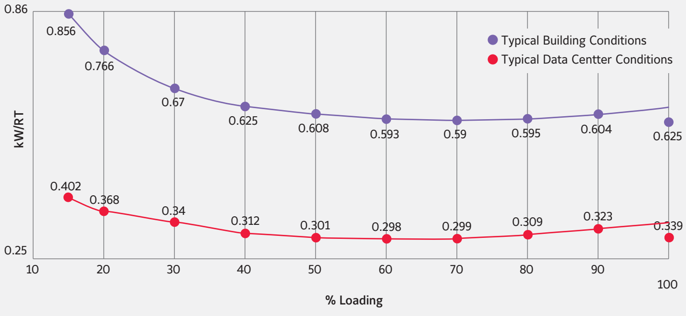

Chart 2

Source: YORKworks Selection Program

Warmer Data Center: A Sustainable Proposition

Traditionally, server rooms and data centers were designed to operate under very low room temperatures of between 18°C to 21°C due to the limitation of server racks. Over the course of the last decade, we have observed an increase in the design of data centers' room temperatures as server racks are designed to sustain much higher temperature. Today, it is not surprising to find the room temperature of data centers at a designed setting of 27°C or higher, depending on the server's grade.

To reach a pre-designed room temperature, the supply air to cool the space has to be lower than 26°C. The difference between the temperatures of supply air and the pre-set room reading determines the air quantity required to meet the room load. Hence, a higher supply air temperature that is closer to the pre-set room design would require a higher air quantity; while a lower supply air temperature needs lower air quantity.

The chilled water supply temperature in a chiller is determined by the supply air temperature required to meet the pre-set room temperature. Based on the warmer data center scenario, the typical temperature readings could now be:

- Pre-set room temperature at 26-27°C
- Pre-set supply air temperature at 20-22°C
- Pre-set chilled water temperature to air handler units (AHU) at 18-20°C

The biggest change is in the pre-set supply water temperature. It can now be raised from a typical low of 7°C to between 18°C and 20°C – which represents an increase of 11°C to 13°C in the temperature of water supplied to the chiller. This translates to a 40-45% reduction of chiller energy consumption.

As an illustration, a typical water-cooled chiller consumes 0.6KW/RT to supply 7°C chilled water. Following the change, the chiller would now be consuming 0.35 KW/RT to deliver 18°C chilled water supply – thereby achieving a savings of 45% (see Chart 2).

Increasing the Chilled Water Temperature: Some Considerations

It is evident from the chart above that the chiller functions more efficiently at a higher chilled water supply temperature. The intent, thus, should be to increase this water temperature to the maximum possible. However, there are some issues that are data center operators should be aware of. These include:

- Power consumed by air handler unit
- Safety margin for power failure mode
- Chiller design

AHU Power Consumption

The difference between room temperature and supply air temperature reduces as the chilled water supply temperature is increased to beyond 18°C. When this happens, a higher air quantity is required to meet the overall heat load, which leads to an increase in power consumption of the air handler unit. It is thus, important to strike a balance between achieving savings in chiller power and setting off an increase in air handler unit power.

Safety Buffer for Power Failure Mode

Since server load is highly concentrated, any disruptions to the power supply and room cooling may result in a rapid increase in the room temperature. To avoid such abnormal fluctuation in the server room temperature, it is a common practice, when designing a data center, to include a safety margin of 1°C to 2°C in room temperature in the event of a power failure. In other words, the room temperature is designed to operate at temperatures of 1 or 2 degrees lower than 26°C or 27°C. The above safety buffer, however, increases the chiller annual power consumption by 4-5%.

One alternative is to have a quick start feature in chiller design, that is, to enable a faster recovery to a cooling mode following a power failure (see Chart 3). Another solution is to design a storage tank that provides cooling in the event of a power failure and cooling is unavailable.

Time to Reach Setpoint for 500-ton (1,750 kW) Chiller at Low Load

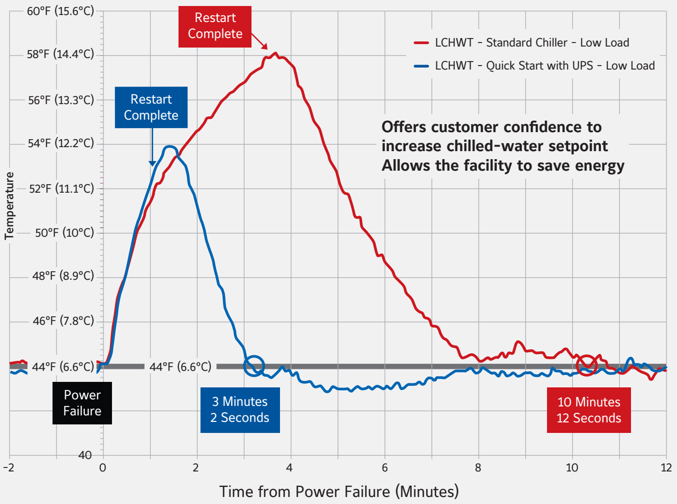

Chart 3

Source: Johnson Controls

YORK YMC² Magnetic Bearing Chiller Operating Envelope

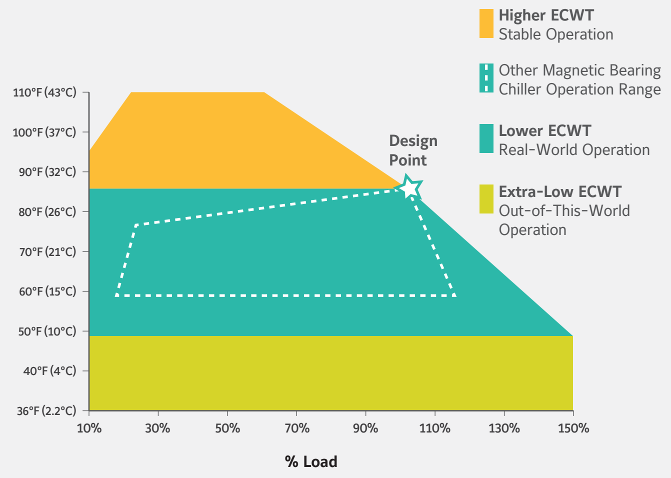

Chart 4

Source: YORKworks Selection Program

Chiller Design

Not all chillers are designed to operate at the higher chilled water temperature of 16°C due to issues such as oil return and motor cooling. Even for a chiller that is touted to operate at 20°C leaving chilled water temperature, it is done via the "artificial" increasing of the compressor head (lift) by limiting cooling tower temperature, thereby increasing the chiller power consumption. This approach will unfortunately increase power consumed by the chiller which defeats the original intent of raising the chilled water temperature.

The Johnson Controls YORK® chillers, on the other hand, are designed to operate at temperatures above 20°C , without any limits on the temperature of the cooling water. For instance, the YMC² magnetic bearing chillers can even operate in inverted scenario, that is, when the cooling tower temperature is lower than the chilled water supply temperature. Using magnetic levitation technology in its driveline to spin without friction, the YMC² chiller offers a quieter, more efficient operation, and is available in variable speed drive.

The Bottom Line

Sustainability concerns, coupled with advances in cooling and heat management technology, have seen shifts in the way data centers are being designed, managed and maintained. Today, with the right chillers, data centers can operate at a higher chilled water temperature of 20°C and above to maximize system efficiency and reduce Power Usage Effectiveness (PUE).

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