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Improving Performance Of Large Chilled Water Plants

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Although large campus central chilled water plants can be designed to be energy efficient, the most impact on the overall system performance often is how the connected building systems are designed to interface with the control plant.

Improving Chilled Water ΔT

Many large central chilled water systems depend on high chilled water temperature differential, ΔT, to minimize pumping energy and optimize chilled water thermal storage capacity. Buildings directly connected to central chilled water distribution systems should be designed to minimize pumping energy and maximize return chilled water return temperature to the central plant. High ΔT is achieved with proper coil and control valve selection, piping and pumping design and supply water control.

Maximizing the ΔT between the chilled water supply and return will maximize the cooling load that can be met with a given chilled water flow rate. Chilled water ΔT is primarily determined by cooling coil effectiveness at the loads and is not something that can be achieved with controls or control sequences at the central chiller plant.

Cooling Coils

Maximizing cooling coil performance is crucial for the entire chilled water system operation. Chilled water ΔT will be determined by how well the terminal devices perform. Cooling coils should be selected to satisfy the load, considering the expected supply water temperature delivered to the coil.[1] Temperature gain in the distribution system as well as heat exchangers should be considered. Chilled water temperature at the cooling coil inlet can sometimes be several degrees higher than the supply temperature leaving the central plant. The return water temperature and leaving air condition at each coil depends on coil configuration, airflow across the coil, entering air enthalpy and entering water temperature.

When designing new buildings to connect to an existing central plant, it is many times best to use an 8 row/10 fins per inch coil.[2]

When evaluating the potential for connecting an existing building to a high ΔT central chilled water system, careful evaluation of the existing coils is prudent when considering a potential lower chilled water supply temperature and the coils ability to meet the system ΔT requirements. Generic AHRI-certified rating and selection programs (available from several coil manufacturers) can be used to model existing coil conditions/construction. The coil construction can be matched and the impacts of the different chilled water supply temperature can then be modeled for the existing coils. Many times the existing coils may not need to be changed out when the higher ΔT central plant has a lower supply water temperature than the original coils within the existing building being connected to the plant.

Coil performance is generally based on mean temperature differential of the supply and return water temperatures at the coil. For a given coil selection and load, the warmer the supply water, the more water the coil needs to meet the load, resulting in a lower return water temperature. *Figure 1* shows the effect on ΔT for a cooling coil at different entering water conditions with a constant load. ΔT will also degrade as the entering air temperature approaches the design return water temperature during part load conditions.

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Coil Control Valves

In maximizing ΔT two-way control valves are necessary for all cooling coils; do not use three-way valves at any coil. Pressure drop at the rated flow rate can vary, depending on where the cooling coil is located in the system hydraulic gradient curve. Several easy-to-use hydraulic modeling programs are available for modeling hydraulic performance and optimizing pipe and valve sizing within the building.

To accomplish high ΔT through a range of load conditions, the coil control valves and actuators must[3]:

- Be selected and sized in the hydraulic gradient so that the valve uses its full stroke;
- Have a high rangeability for controlled operation at very low flow;
- Be able to shut off against the highest anticipated differential pressure;
- Close when the air handler or terminal unit is off; and
- Be controlled to maintain leaving air design conditions.

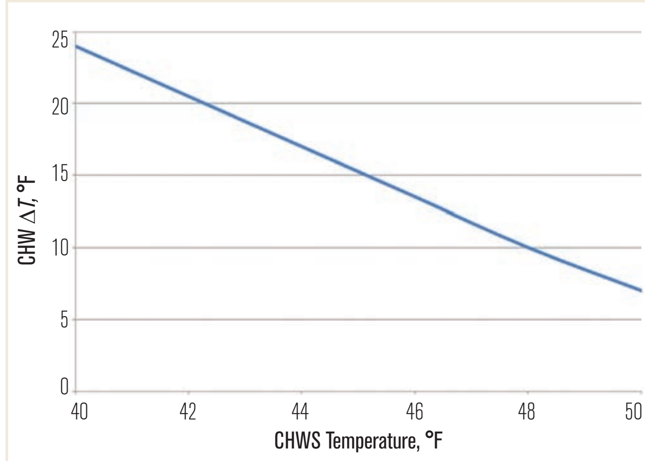
High ΔT can be accomplished with the proper design, construction and operation of coils, control valves and control sequences. There are other operational causes for low ΔT e.g., low entering air temperature during airside economizer, which can never be eliminated. Therefore, the chilled water plant design and chiller selections should account for the range of chilled water ΔT anticipated throughout the year.

Chilled Water Building Connections

It is critical to understand the central plant distribution system pumping control scheme prior to designing the building connection. This includes understanding the potential range of differential pressure the building connection would encounter throughout the year.

The most common building connection in campus-type chilled water systems is a direct connection since the same entity owns the central plant, distribution and buildings. Direct connections are suitable in a system with low-rise buildings where the static head in the distribution system can be kept low. District cooling systems tend to use an indirect connection with heat exchangers to isolate the customer's chilled water system from the district chilled water system. This column focuses on direct connection options.

FIGURE 1 Impact on LWT from varying EWT for an original 45°F EWT/55°F LWT chilled water coil while maintaining the same airside conditions. Assumes constant load.



Direct connections are either decoupled or non-decoupled. A decoupled building connection as shown in *Figure 2* is typically configured with a crossover bridge, building pump and building return water temperature control valve. The crossover bridge allows the building return water to blend with the supply water and is intended to hydraulically decouple the building from the chilled water distribution system. This was common practice prior to variable frequency drives and networked control systems.

Decoupled connections also have been used when connecting a building that was designed for a higher chilled water supply temperature than the central chilled water system. This technique was used to blend up the chilled water supply temperature to the building to provide the original higher cooling coil design temperature. To optimize ΔT and maintain good temperature and humidity control, it is best to use the colder supply temperature at the coils. Existing buildings should changeout the control valves for the lower flow required to meet the cooling requirements. Blending to raise supply temperature will always increase pump energy and (perhaps counter-intuitively) decreases return water temperature and thus decreases overall plant ΔT as shown in *Figure 1.*

In my experience these practices typically lead to problems relative to building pump and fan energy, control instability, capacity and comfort as well as possible loss in building latent cooling capacity. Therefore, decoupled connections are unnecessary and should be avoided.

Three-way control valves and bypasses should be eliminated in buildings connected to large chilled water

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systems if trying to maintain high Δ*T*. In rare circumstances when chilled water supply temperature degradation due to long residency in the chilled water system is a concern, a small bypass at the end of the distribution system may be provided and controlled to maintain cold supply water temperature.

Where sufficient distribution differential pressure is available, a non-decoupled direct connection may require no more than a supply and return pipe with appropriate energy metering. When the existing differential pressure at the building connection is excessive for the control valve requirements, a differential pressure control valve could be used at the building connection to reduce the differential pressure to that required for the building coil control valves to operate properly. This should be avoided when designing the complete distribution system by choosing a pumping strategy that minimizes the differential pressure gradient in the chilled water distribution system.

The non-decoupled approach can be modified where differential pressure at the building connection will not be adequate during all of the year by adding a building pump that is installed with a parallel bypass and check valve so the pump is only operated when it is required to increase differential pressure for the building as shown in *Figure 3*. Parallel pumps can also be used to provide redundancy. The bypass check valve pressure loss should be less than 1 psi (7 kPa) to prevent water flowing through the building pump when it is off. Many times, the building pump only will be required to operate a fraction of the year when higher cooling loads are experienced, resulting in higher required building loop pressure drop.

FIGURE 2 Decoupled direct building connection.

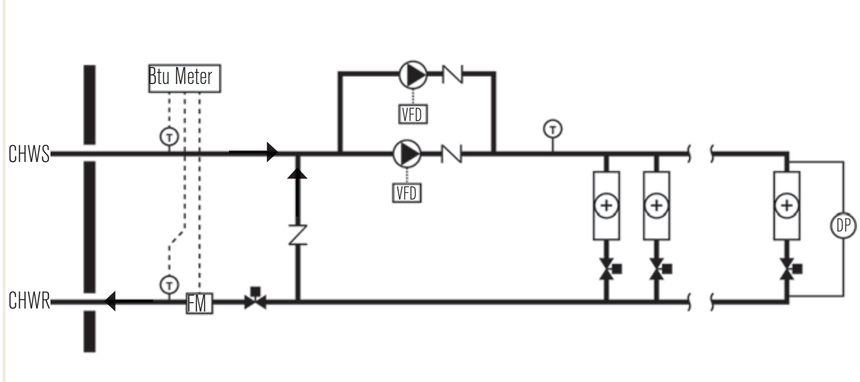
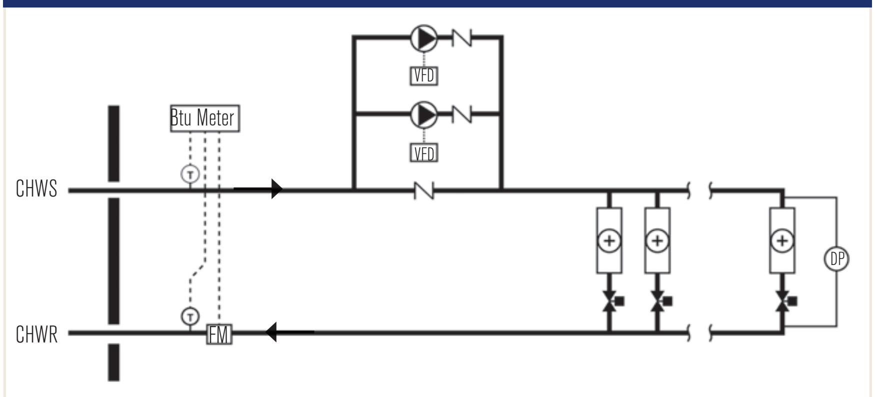


FIGURE 3 Non-decoupled direct building connection.



Control of the building pump can be provided with a differential pressure transducer in the building chilled water loop. The differential pressure setpoint should be reset based on most demanding coil chilled water valve position. The building pump only should be used when the central plant chilled water distribution system cannot meet the required differential pressure setpoint.

The non-decoupled approach maximizes Δ*T* while providing stable temperature and humidity control.

Concluding Remarks

The methods in which buildings, air handlers and terminal devices are designed to work with chilled water systems frequently have the greatest impact in optimizing chiller water system Δ*T*. Hopefully, these tips can help designers and chilled water plant operators improve chilled water system performance.

References

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2. Taylor, S. 2011. "Optimizing design & control of chiller plants." *ASHRAE Journal* (12).
3. District Cooling Best Practice Guide. 1st Edition 2008, International District Energy Association.■