
Steven T. Taylor

Tips to Reduce Chilled Water Plant Costs

BY STEVEN T. TAYLOR, P.E., FELLOW ASHRAE

A chilled water plant can be conceptually well designed but implemented in a manner that unnecessarily increases first costs, sometimes substantially. Here are a few tips to reduce the first costs of a chilled water plant without reducing performance.

Tip 1: Piping and Pumps

Figure 1 shows a chilled water plant with primary-only pumping. Conceptually the design is fine, and in fact the primary-only design is a good step in reducing plant costs since it is less expensive than primary-secondary pumping.[1] But the designer of this plant unnecessarily increased first costs.

First, "reverse return" piping was provided for both condenser water and chilled water systems. Reverse return, where the first device supplied is the last returned, is a piping scheme intended to self-balance hydronic systems, but more importantly, to keep the pressure drop across modulating two-way control valves relatively low and equal among all valves as they open and close with changing loads. It can be an effective technique to improving controllability of large (high pressure drop) variable flow hydronic distribution systems.[2]

But in this case, the valves at each chiller are essentially two-position and the difference in pressure across each valve is very small even if the system is direct-return (first supplied, first returned) and was not manually balanced. A balanced direct-return piping system will result in the same flow rates across each chiller as the reverse-return design regardless how many chillers were enabled. So there is absolutely no value in performance to reverse-return in this application, yet it substantially increases first costs.

Another often expensive design concept is to gang pumps together and pipe all the pumps first to a larger common pipe before distributing the supply water to the chillers. In this example, the common pipe size is 12 in. (nominal 300 mm) on the chilled water side and 14 in. (nominal 350 mm) on the condenser water side. It is not uncommon to see all the pumps squished into a corner of the chiller room. There is little synergy to ganging pumps next to each other yet doing so can increase first costs and reduce space around the pumps for maintenance.

Figure 2 shows the same plant as *Figure 1* but instead of reverse-return and ganged pumps, the pumps are aligned with chillers and are piped into a common header on the discharge side of the pump and also on the discharge side of the condensers. (The discharge side of the evaporators is the same as that in *Figure 1*.) This design still allows any pump to serve any chiller, but it shortens piping runs and it reduces pipe sizes because there is no common pipe that sees the total system flow.

On the condenser water side, all pipes are 10 in. (nominal 250 mm)—the 14 in. (nominal 350 mm) common pipe is eliminated. Similarly, the 12 in. (nominal 300 mm) chilled water piping at the discharge of the pump to the evaporators is eliminated; all pipes are 8 in. (nominal 200 mm). First costs are substantially reduced with no impact on performance.

This layout also usually reduces the footprint of the plant, reducing the floor area required for the chiller room. In fact, locating the equipment as close together as possible is key to the first cost savings. *Figure 3* shows a floor plan of the plant shown schematically in *Figure 2*. The chilled and condenser

Steven T. Taylor, P.E., is a principal of Taylor Engineering in Alameda, Calif. He is a member of SSPC 90.1 and chair of TC 4.3, Ventilation Requirements and Infiltration.

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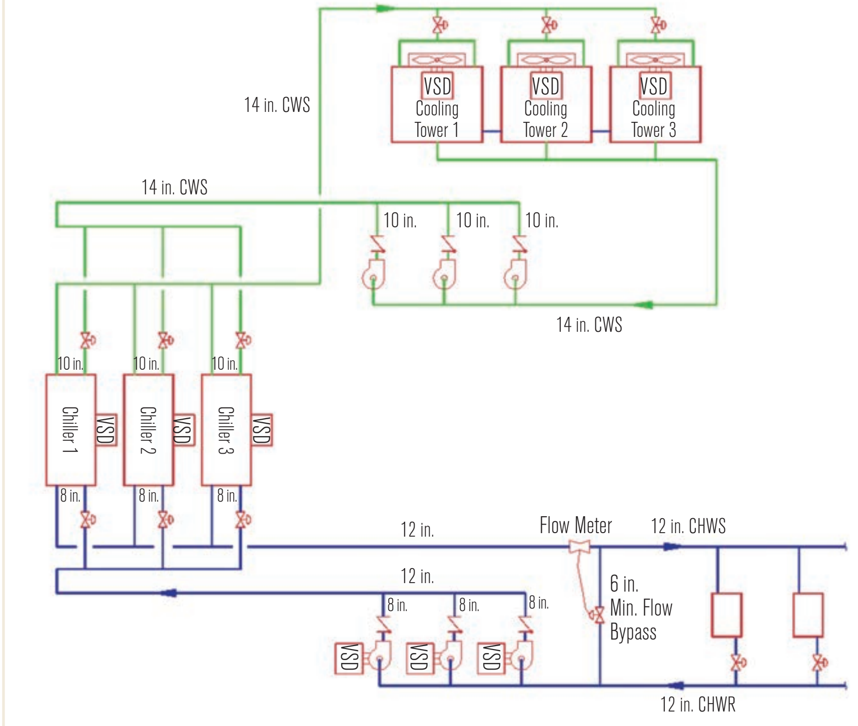
water pumps align with the chillers but are offset to provide tube-pull space and piping connections between the pumps. This is a very compact layout but it still provides adequate maintenance access for all equipment.

FIGURE 1 Expensive chilled water plant.



Tip 2: Cooling Tower Makeup And Level Control

Typically, makeup water to cooling towers is provided by domestic or industrial water piped to a float valve in each tower basin. Float valves, which are similar to those in tank-type toilets, are not very reliable—they tend to get stuck open and leak. An alternative is to install an electronic level switch in each tower basin wired to an electric slow-closing solenoid makeup water valve.

Another novel makeup water system design is summarized as follows:

- No makeup water connection or assembly is provided with the cooling towers.
- The cooling tower equalizers are fitted with shut-off valves at each cell and a standpipe is installed in the common equalizer pipe as shown in *Figure 4*. The standpipe is open at the top and is fitted with an analog level sensor, such as a conductivity type, silicone diaphragm type, or sonar type. This is tied to the building energy management and control system (EMCS). The level of water in the standpipe is the same as the cooling tower basins for any basin open to the equalizer. A basin that is valved off and drained, e.g., for cleaning, has no impact on the level sensor reading.
- Makeup water is piped through a slow-closing valve to the condenser water system in either the supply or return piping to the tower—it does not matter which, provided the makeup water pressure is higher than that in the piping and there are no automatic valves or check valves between the connection point and the towers. Typically, the connection will be indoors near the chillers. The valve is wired to the EMCS.

FIGURE 2 Less expensive chilled water plant.

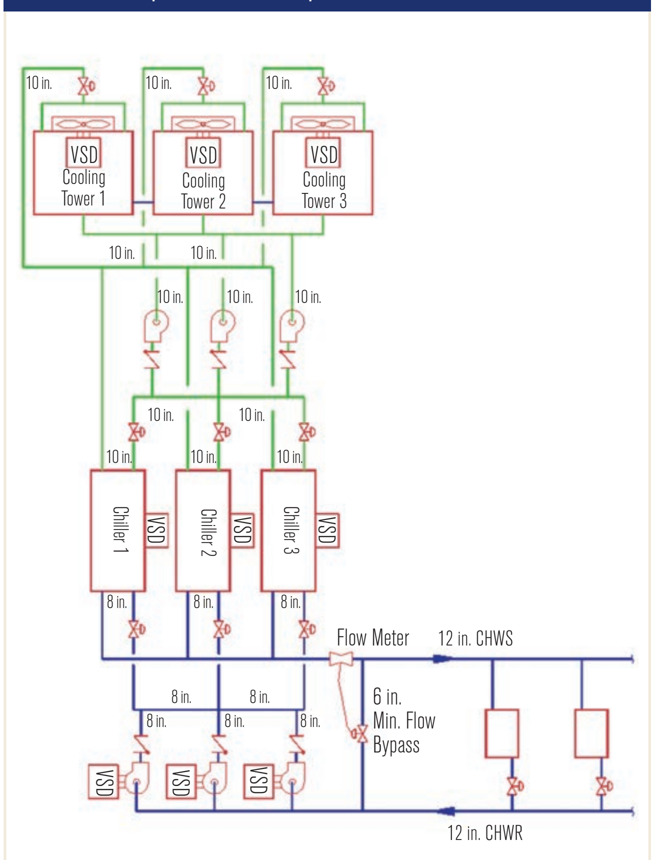
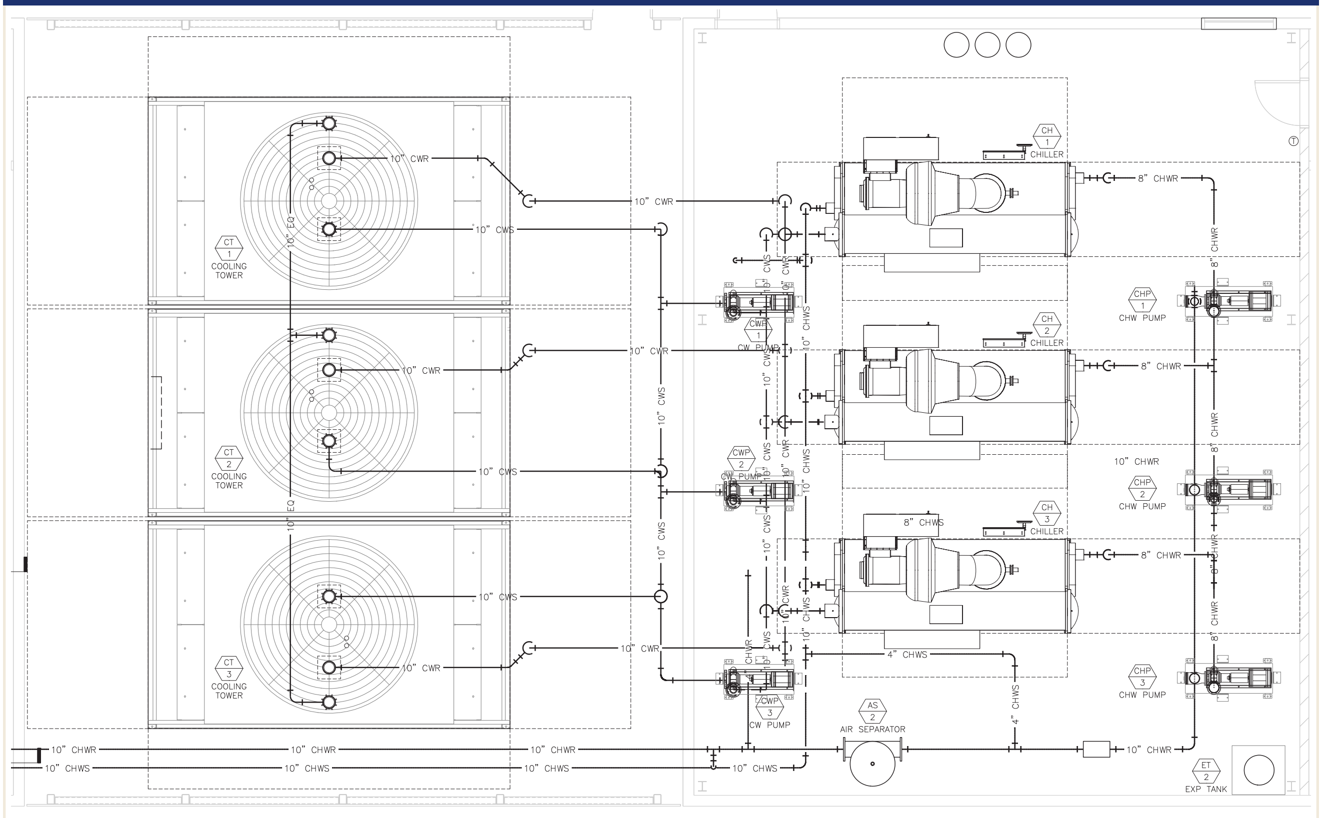


FIGURE 3 Chilled water plant floor plan.

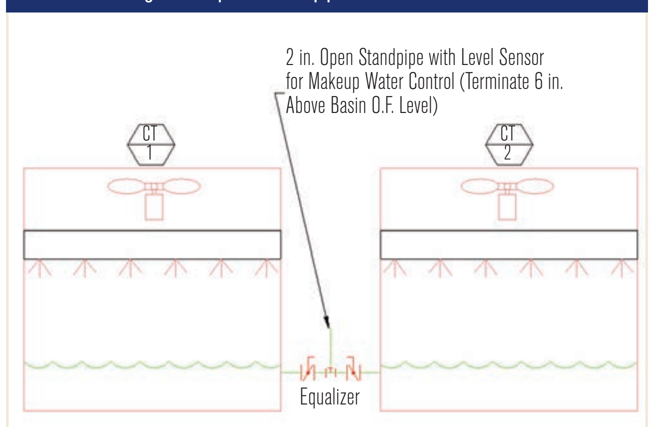


- The level sensor is programmed in the EMCS to open the makeup water valve as required to maintain the tower basin water level within the tower manufacturer's recommended range whenever the condenser water pumps are on. It can also be programmed to provide high and low level alarms.

The advantages of this design include:

- Makeup water piping need not be piped to each cell and generally need not be piped outdoors. This is a particular advantage in freezing climates since it obviates the need for heat tracing and insulating the makeup water piping.
- The analog sensor provides control as well as high and low level alarms with setpoints easily adjusted in software. False alarms are virtually eliminated; when level switches are provided at each cell for alarming, a false alarm is generated if the cell is drained for cleaning.
- Float valves are eliminated.
- Costs are lower than electronic makeup water controls, especially if they include high and low level alarms to the EMCS. Costs are also typically lower than float valve makeup water when the system has more than two cells and in freezing climates.

FIGURE 4 Cooling tower equalizer standpipe.



Tip 3: Valves

Chilled water plants, within the plant itself, should have only two kinds of valves for flow isolation and balance: butterfly valves for large piping (typically 3 in. [nominal 80 mm] and larger) and ball valves for smaller piping. These are not only the least expensive types of valves, they also are the easiest to use since they require only a quarter turn to open and close (unlike globe and gate valves) and they may be used for balancing (unlike gate valves). They are also physically smaller than other valve types. Valves to avoid and/or are not needed include:

- **Globe and gate valves.** They provide no advantages over butterfly and ball valves and they cost more and require more space.
- **Calibrated balancing valves.** Most plants are almost self-balancing simply because their compact size does not result in large differences in pressure drop across each evaporator or condenser. Even if no balancing is done, the plant generally will work fine—a small difference in chilled water or condenser water flow among chillers and towers has only a small impact on plant performance. What little balancing is needed can be accomplished by modulating the condenser/evaporator isolation butterfly valves to cause the pressure drop across the condenser/evaporator to be the same among the chillers (or proportionally the same if chillers are not all the same). Cooling tower balancing is almost never an issue and there is no need to create equal flow to each cell; the cells with excess flow will create warmer water and the ones with low flow will create colder water, but when they are mixed, the resulting temperature is almost exactly the same as it would be if the cells had equal flow.
- **Flow limiting valves (aka, flow control valves).** These valves should never be used in the chilled water plant. There are times when exceeding design flow is actually desired. For example, a chiller plant with degrading chilled water ΔT can be more efficient if higher flow is allowed to be forced through operating chillers rather than start another.[3] Exceeding the chiller manufacturer's maximum flow rate is rarely an issue because pressure drop increases with the square of the flow and pumps seldom have the capability to force this much water through the evaporator or condenser.
- **Multipurpose (aka, "triple-duty") valves.** These valves, typically located at pump discharges, provide three functions in one: shut-off valve, check valve, and flow measurement/balance. But they are hard to use as shut-off valves since they are multi-turn rather than quarter turn and a wrench is required; they generally do not include handles. They can also be hard to repair since they cannot isolate themselves. For these two reasons, building operators generally very much dislike multipurpose duty valves. When sized the same as the pipe size, as is typical, flow measurement is often not possible; they must be undersized to provide accurate flow readings which adds to pressure drop. Flow balancing is also not needed at the pump; it can and should be done at the heat exchangers and throttling flow for balance is not required at all if the pump has a variable speed drive. Finally, cost savings versus a check and butterfly valve are minor or nonexistent.

Conclusions

One would think that a chilled water plant that has "x" chillers and pumps and provides "y" tons of cooling capacity would cost about the same no matter how it is ultimately designed and configured. But that is not the case; first costs can vary substantially depending on the details. Hopefully, these three tips can help designers minimize central plant first costs.

References

1. Taylor, S. 2002. "Primary-only vs. primary-secondary variable flow systems." *ASHRAE Journal* (2).

2. Taylor, S., J. Stein. 2002. "Balancing variable flow hydronic systems." *ASHRAE Journal* (10).

3. Taylor, S. 2002. "Degrading chilled water plant Delta-t: causes and mitigation." *ASHRAE Transactions* 108(1). ■