MARLEY

applications engineering

Performance Impacts of Flow and Range

15°F vs. 10°F RANGE

Overview

Traditionally, chillers were designed specifically to handle 3 gpm/ton, but improvements in chiller efficiency and increased use of variable speed drives on pumps and fans present opportunities to make design changes to condenser water systems. To take advantage of these improvements, the optimum condenser-water flow rate and ΔT must be determined. Recent product developments and review of case studies have begun to shift the industry away from the typical 3 gpm/ton (10°F ΔT), leading to lower flow rates and greater differences in entering and exiting water temperatures. This approach can be used when upgrading a building's heat rejection capacity without changing existing piping (and incurring substantial costs).

Background

Cooling towers are frequently used in conjunction with condensing units in a refrigeration cycle. Small water-cooled condensers are often designed to be counterflow heat exchangers where the hot, high-pressure refrigerant flows in the opposite direction from the cold water from the cooling tower within the heat exchange loop. For this reason, the entering temperature of the cold water to the condenser is the driver in heat rejection from the refrigerant. Larger water cooled condensers often flow the refrigerant across the cold water tube bundles, allowing for less subcooling of the refrigerant compared to smaller, counterflow designs. **Figure 1** shows a schematic of the two loops feeding a chiller.

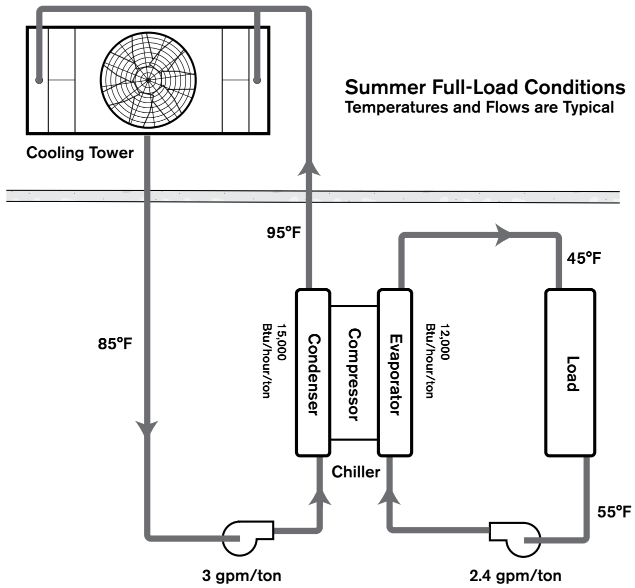

Figure 1 *Summertime heat load for a refrigeration cycle rejecting heat with a cooling tower utilizing 3 gpm/ton.*

By increasing cooling tower range when optimizing a chilled water design, the first cost and energy usage can be reduced. An *ASHRAE Journal* article, "Optimizing Design & Control Of Chilled Water Plants Part 3: Pipe Sizing and Optimizing", presents the case in which the life cycle cost is reduced roughly 3% by utilizing 2 gpm/ton. Before adopting this approach, always check with the condenser and other equipment manufacturers to confirm that the unit accepting heat from the process fluid/refrigerant can handle a larger temperature range in the cold-water loop.

The benefits of increasing range and decreasing flow are:

- Smaller cooling tower and/or cooling tower fan motor
- Smaller pipe diameters
- Smaller pump and/or pump motor
- Smaller VFD

Be mindful of potential changes in chiller selection or chiller operating costs which can impact the initial equipment investment cost.

Total Heat Rejection

A mechanical draft, open circuit cooling tower is a specialized heat exchanger in which two fluids (air and water) are in direct contact with each other to induce the transfer of heat.

The amount of heat rejection rate can be calculated using **Equation 1.** In an open circuit cooling tower, the specific heat, or heat capacity (Cp), is constant for water under constant pressure. In a closed circuit fluid cooler, this value could change slightly with freeze protection additives. However, for a given singular system, Cp will be a constant.

$$\dot{Q} = \dot{M} C_p \Delta T \tag{1}$$

$\dot{M}$ = Mass rate of circulating fluid lb/hr
C_p = Specific heat of the fluid Btu/(lb °F)
$\Delta T = T_{HW} - T_{CW}$ °F
T_{HW} = Temperature of fluid entering cooling tower °F
T_{CW} = Temperature of fluid leaving cooling tower °F
$\dot{Q}$ = Heat Rejection Btu/hr

In order to size the heat rejection range for 15°F instead of 10°F, the difference in entering and exiting water must be considered. If heat rejection is considered equivalent, we can solve for the change in flow rate utilizing **Equation 1.** We can also use this for another ΔT.

$$\dot{M}_1 C_p(10°F) = \dot{M}_2 C_p(15°F)$$

$$\dot{M}_1(10°F) = \dot{M}_2(15°F)$$

$$\dot{M}_1(10°F) / (15°F) = \dot{M}_2$$

$$\dot{M}_2 = 2/3 \times \dot{M}_1$$

If a cooling tower is sized at 900 gpm with a 10°F range, then the equivalent heat load with a 15°F range would require only 600 gpm. This assumes a negligible change in specific heat for water at all temperatures.

Effects on the System – Tower Performance

Generally, cooling towers reject heat more easily with lower flow rates and higher ranges. In some cases, by changing the design range and flow to accommodate the 15°F range, cooling tower selection decreases in box size and/or fan power. It is worth considering potential savings on up-front equipment costs by designing the cooling system to accept the higher temperature range and lower flow rate. **Table 1** shows the fan horsepower needed on the same box size for closed and open circuit conditions. Note this may vary on a case-by-case basis.

Case	Power hp	ΔT °F	Cold Water °F	Circuit Type	Capacity	Coil Pressure Drop psi
1	15	10	85	open	100.0%	n/a
	10	15	85	open	108.5%	n/a
2	45	10	85	closed	100.0%	20.4
	37.5	15	85	closed	107.8%	9.4

Table 1: *Power consumption for 10°F and 15°F range in closed and open circuit cooling towers. Note that excess capacity will result in lower approach temperatures*

Case 1 shows two open circuit cooling towers of same box size, one utilizing a smaller fan motor to reject the same amount of heat with excess capacity.

Case 2 shows two closed circuit cooling towers (fluid coolers) of same box size and coil size, one utilizing a smaller fan motor and providing less pressure drop across the coil.

It is also advisable in a closed circuit cooling tower to maintain turbulent flow through the coil. This ensures even cooling of fluid within the coil and eliminates the potential of a temperature gradient. Flowrate should not fall below the closed circuit cooling tower manufacturer's stated minimum flow rate to avoid inconsistent heat transfer and incorrect predicted performance.

Condensers

Confirm with the chiller manufacturer that a larger range and lower flow is acceptable. When the range is increased on the cold-water side of the condenser, generally, the condensing fluid saturation temperature will increase directly with the leaving water temperature of the cold-water side (tower side) of the condenser. This is to provide equivalent heat transfer potential between the two fluids. In order to increase to saturation temperature, but operate at the same temperature through the evaporator, the refrigerant will need to increase in pressure between the two operating points. This will cause the compressor to work harder. The offset of pumping, piping, and fan power cost on the cooling tower side often offsets some of the operational increase in the chiller, but not always. At peak conditions this increase could be more expensive. It is important to review the part load vs. operating hours per year to determine whether the increased range will be more economical.

Making these changes does not impact the load or the amount of heat rejection in the system. The only things that change are the operating temperatures and/or pressures and where energy is being used/conserved.

Conclusion

- Increasing range and decreasing flow to reject the same heat load within a cooling tower can reduce both initial costs and operational costs over the life of the cooling tower.
- Decreasing flow to the cooling tower will decrease the pump head necessary to pump the water/glycol solution through the system.
- Decreased flow to a closed circuit cooling tower (fluid cooler) may create "laminar flow" for a particular selection. This negatively affects performance and consistency. It is advisable to maintain turbulent flow through the coil in a closed circuit cooling tower.
- Always confirm with the water cooled condenser manufacturer that a larger range and lower flow can be utilized with the condenser. Some models may not handle the pressure change of the lower flow and higher ΔT.

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