HVAC Water Systems

Waterside Free Cooling

Summary

Free cooling utilizes the evaporative cooling capacity of a cooling tower to indirectly produce chilled water for use in medium temperature loops, such as process cooling loops and sensible cooling loops. Free cooling is best suited for climates that have wetbulb temperatures lower than 55°F for 3,000 or more hours per year. It is most effectively applied to serve process and/or sensible cooling loops that between 50°F–70°F chilled water.

Table 1. Free Cooling Application

At least 3000 hours per year where wet bulb temperature is below:	Applicability
55°F	Process cooling water
45°F	Process cooling, sensible cooling
35°F	All chilled water use

1. Assumes process cooling water is between 60 to 70°F.
2. Assumes sensible cooling water is between 50 to 55°F.

Principles

- Chilled water systems use chillers that typically operate at 0.5 to 0.7 kW/ton in a partial load regime while free cooling systems typically operate at 0.05 to 0.15 kW/ton.

- A flat plate heat exchanger is used to isolate the chilled water loop from the open tower condenser water. With few exceptions, tower water is not reliably clean enough for use directly in the cooling loop.

- The approach temperature on a cooling tower is critical for best results. A low approach temperature on the tower is critical to achieve the highest energy savings.

- A traditional chiller is used to provide cooling during hot periods and as an always-available emergency backup. For a portion of the year, free cooling offers a non-compressor based backup to the traditional chiller.

Approach

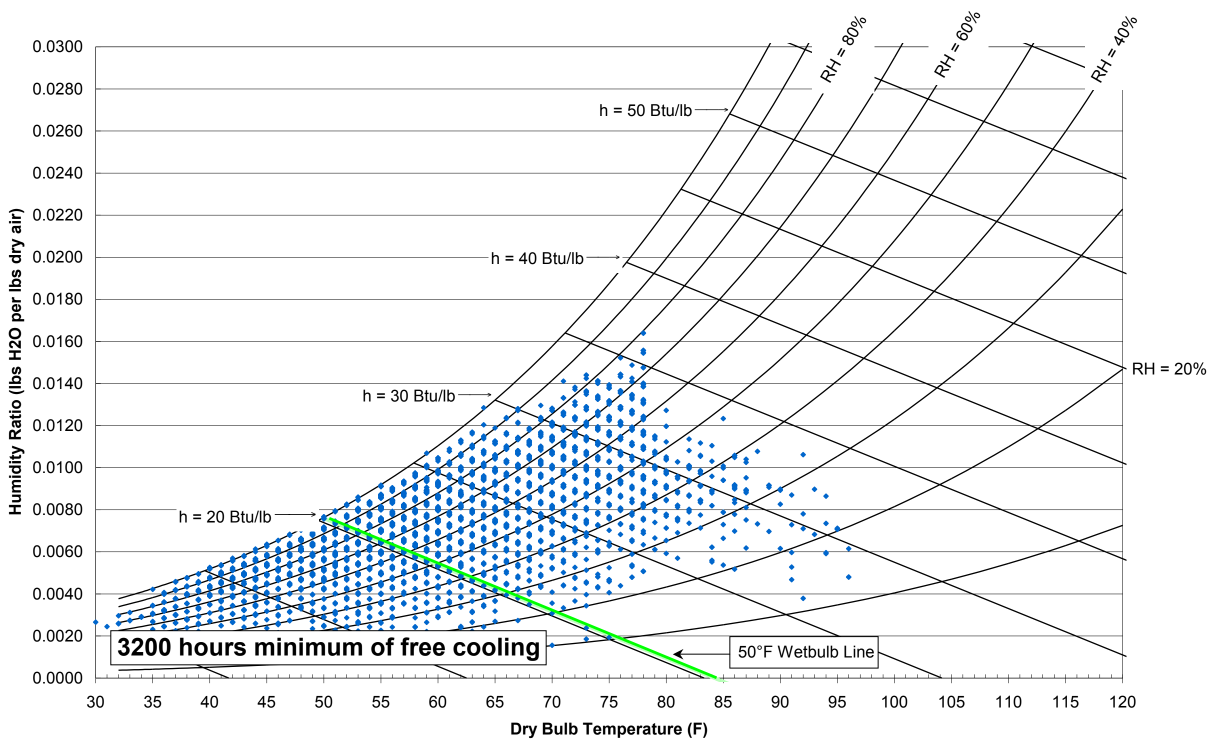
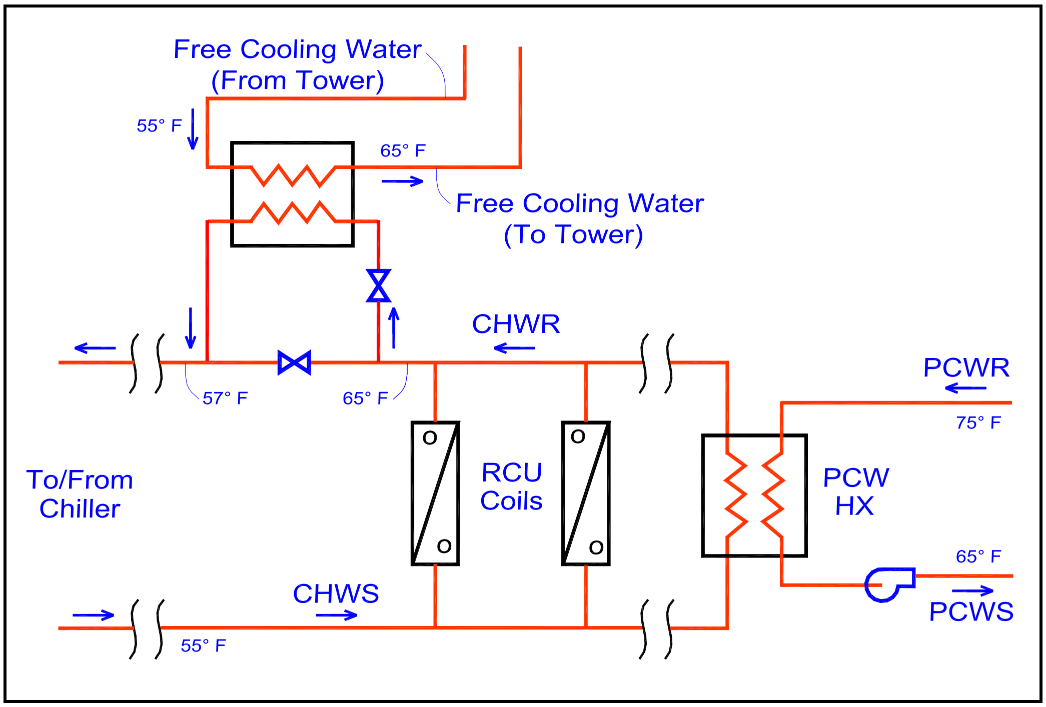


Figure 1. Psychrometric Chart for San Jose, California

Free cooling operates on the principle that during cool weather conditions, particularly at night for 24 hour operation facilities, process cooling water can be produced by the cooling tower alone, bypassing the energy intensive chiller entirely. Free cooling reduces or eliminates the chiller's power consumption while efficiently maintaining strict temperature and humidity requirements. Free cooling can also offer an additional level of redundancy by providing a non-compressor cooling solution for portions of the year.

For application beyond medium temperature loops, use of a chilled water reset is an integral part of optimizing free cooling. A chilled water reset increases the chilled water supply setpoint during mild conditions when lower temperature chilled water is not required to meet cooling needs and, conveniently, when the cooling towers are able to produce the lowest temperature free cooling water. It is often possible to configure cooling tower systems to isolate an idle tower during cool (far below design conditions) weather for use as a free cooling tower. A redundant tower can also be configured to serve free cooling since a free cooling system is inherently considered to be an intermittent cooling source.

A cooling tower utilized for free cooling should be selected to provide an approach temperature (*Leaving Tower Water Temperature minus Wet Bulb Temperature*) between 5 and 8°F. A lower approach temperature generally results in a physically larger tower since more surface area in the tower is required for the heat rejection process. A variable speed drive (VSD) for the fan motor should be used in a free cooling tower to minimize on-off cycling and maximize controllability to maximize energy savings.



CHWS/R – Chilled Water Supply /Return
PCWS/R – Process Cooling Water Supply/Return
HX – Heat Exchanger

Figure 2. Free Cooling Loop Schematic

Free cooling requires that the cooling tower produce low temperature water, often lower than a chiller will accept for condenser water. There are two common design approaches to address this concern. One option is to hydraulically isolate a tower and dedicate it to free cooling only. This is the best approach, but requires careful piping configuration and control valve placement and operation. A redundant backup tower can be provided with automatic isolation valves and used for free cooling use. Since free cooling operates during low temperature weather conditions, the chilled water plant load is often low enough that even non-backup towers are available for free cooling use provided the proper automatic valving is implemented.

The other common solution is to share a single condenser water loop and towers between free cooling and the chillers by running the loop at a low, free cooling temperature and providing a bypass at the chillers. The chiller-side bypass is used to mix warm condenser water leaving the chiller with the low temperature condenser water to produce a suitable condenser water supply temperature. The bypass is controlled in a manner similar to bypasses provided at the cooling tower to control the minimum condenser water temperature. Locating the bypass at the chiller end of the loop instead of at the cooling tower brings low temperature water into the main plant area, in many cases greatly reducing the cost of piping to implement free cooling. Providing such a bypass mixing valve arrangement also ensures that starting up the chillers during cold temperatures with a cold tower sump can be done reliably. This approach is popular in retrofit situations or where the pipe run to the cooling towers is too long to economically allow a second set of pipes for free cooling. Some efficiency is lost by producing lower temperature water for the chillers than is used, but typically this is far outweighed by the reduced chiller compressor energy consumption.

Added costs for a waterside economizer result from controls, heat exchangers, pump, and piping. In a typical critical facilities installation, no additional cooling tower capacity is required.

Both existing and new cleanroom facilities can benefit from free cooling. Cleanroom facilities are typically designed to be able to handle a peak load. Peak loads only occur 2 to 5% of the time in a year. Cooler weather along with lower wetbulb temperatures allow existing facilities to retrofit chilled water plants to provide free cooling. The common use of medium temperature process or sensible cooling loops integrates very well with free cooling. Re-piping, particularly using the chiller-side bypass approach, and/or adding valves and controls is usually cost effective. New facilities, on the other hand should be designed with the concept in mind. Added cost for free cooling is minimal and paybacks are short when such a system is accommodated in the initial design stage.

Real World Experiences (Benchmarking Findings/Case Studies)

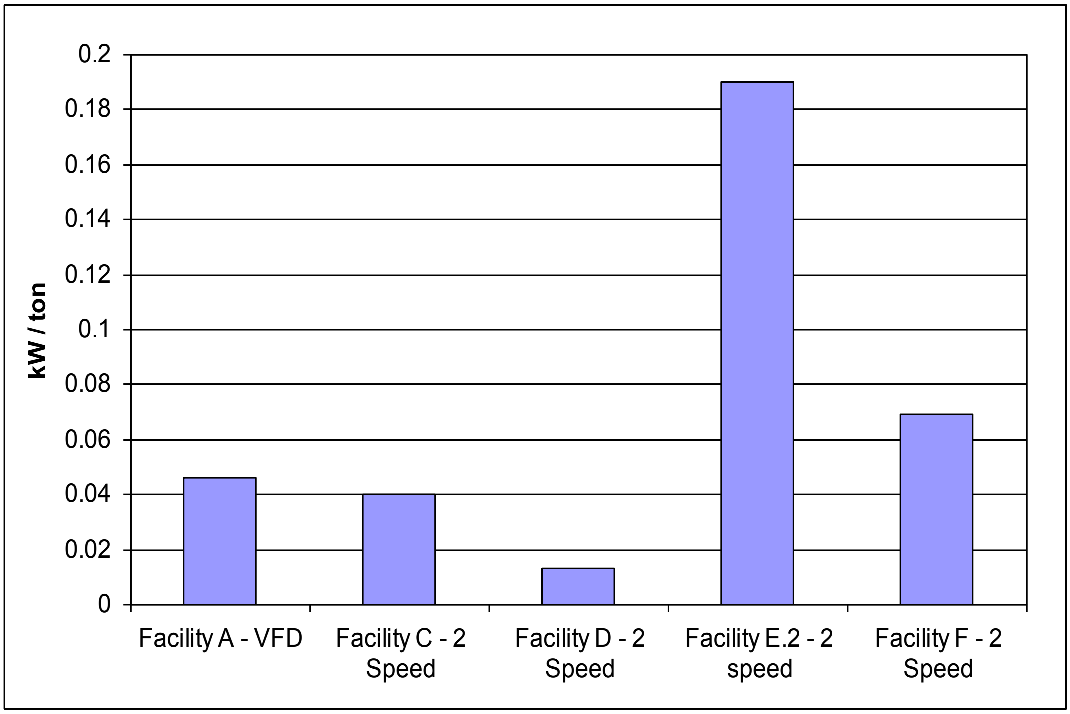


Figure 3. Cooling Tower Benchmarked Data

Figure 3 shows the LBNL Benchmarking project data collected on cooling towers at participating cleanroom facilities. The efficiency of cooling towers is evaluated by comparing the cooling tower fan energy to the chilled water system output. The cooling towers were operating between 0.013 and 0.19 kW per ton with an average efficiency of 0.07 kW/ton. Chillers typically operate at 0.5 to 0.7 kW/ton in a partial load regime. By using a cooling tower operating at 0.07 kW/ton for free cooling, approximately 90% of energy can be saved when the chillers are bypassed entirely.

The implementation of free cooling at Facility C, an 80,000 sf facility consisting of 17,000 sf of ISO Class 5 and 6 cleanrooms was evaluated in the benchmarking study. The facility had 900 tons of installed cooling capacity and was measured to be operating at an average of 561 tons. With the excess cooling tower capacity, a heat exchanger to isolate the condenser water from the process cooling loop, a minimal amount of piping and controls would be required to implement free cooling. An annual energy savings of 1,140 MWh and a payback of 1.2 years were projected.

Related Best Practices

Chilled Water Plant Controls	Variable Speed Chillers
Dual Temperature Cooling Loops	Cooling Tower/Condenser Optimization

References

1)

Resources

-