6.4 Chilled Water Systems

Overview

Chilled water systems remove heat by passing recirculated cold water through equipment. They are often used in place of single-pass cooling because the water is recirculated, rather than being discharged, to the drain. Chilled water systems are often used to cool air passing through air handling units, but they can also be used to cool a number of systems, including:

- Air compressors
- Air conditioners
- Hydraulic equipment
- CAT scanners
- Degreasers
- Welding machines
- Vacuum pumps
- X-ray equipment
- Ice machines

Water can be used to transfer heat loads within a chilled water system in two ways, as illustrated in Figure 6-4. First, water can be recirculated as a heat transfer fluid between the chiller and the equipment to be cooled. This water is contained in a closed loop, and no water is gained or lost when the system is operating properly. Second, the chiller, or refrigeration unit, might use water or air to remove heat from the refrigeration condenser. These types of chillers are referred to as water-cooled or air-cooled units.

A chiller's cooling capacity is measured in tons of refrigeration, a metric used to represent the amount of heat that can be extracted by the system in a 24-hour period. Small systems (i.e., 40 to 50 tons of refrigeration and below) are often designed as air-cooled systems because they are less expensive, although the energy consumption of air-cooled systems is usually significantly higher, especially as the systems approach 500 tons. In addition, the space required for air-cooled systems greater than 500 tons becomes impractical in many applications. Since air-cooled systems are used in limited applications and use air instead of water as the cooling mechanism, they are not the focus of this section.[12]

Water-cooled units tend to be more energy-efficient than air-cooled units, particularly in larger facility applications.[13]

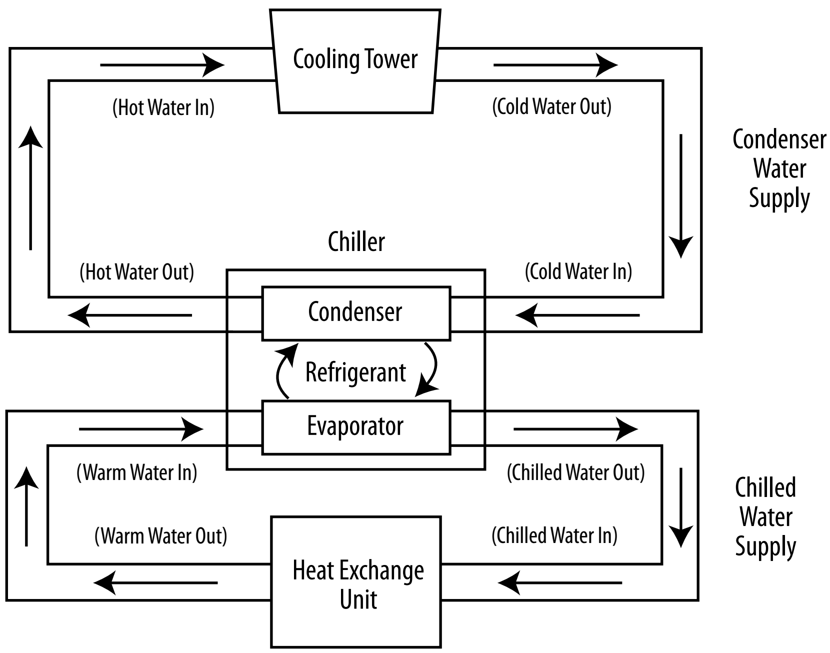
As shown in Figure 6-4, there are four main stages of operation in a water-cooled chilled water system:

- First, chilled water at a temperature between 38° and 45°F is pumped through heat exchange units to transfer heat from equipment. By removing heat, the chilled water temperature typically rises 10° to 20°F.

[12] Koeller and Company and Riesenberger, James. January 2006. *A Report on Potential Best Management Practices—Commercial-Industrial Cooling Water Efficiency*. Prepared for the California Urban Water Conservation Council. Page A-5. www.cuwcc.org/products/pbmp-reports.aspx.
[13] *Ibid*.

- The water that has absorbed heat is sent to the chiller to re-cool. Inside the chiller, an evaporator with refrigerant inside removes heat from the chilled water loop. As the refrigerant absorbs the excess heat, it expands and becomes a gas.
- The refrigerant gas is then sent to a compressor prior to passing through a condenser, where heat is removed by the condenser water loop and the refrigerant gas returns to the liquid phase. Condenser water is typically between 80° and 85°F when it is sent through the chiller condenser and rises in temperature 10° to 20°F after it has removed the heat from the refrigerant.[14]
- In the final stage, the condenser water is re-cooled in a cooling tower.

Figure 6-4. Water-Cooled Chilled Water System



In water-cooled chilled water systems, the condenser water is typically recirculated to give off heat through evaporation. Cooling by evaporation can occur in either an open cooling tower, where the condenser water is open to the atmosphere, or in a closed-loop evaporative cooler, where the condenser water is not open to the atmosphere. Both cooling towers and evaporative coolers are installed outdoors to mechanically circulate air used to cool condenser water. Refer to *Section 6.3: Cooling Towers* for more information on cooling towers.

Alternatively, single-pass cooling systems can be used, which rely on a source of freshwater supply for condenser cooling water, which is ultimately discharged. In small systems, the discharge might be to the sewer, but in large systems, it might be discharged to a local body of water depending upon the discharge permit. Single-pass cooling systems should be avoided if the water goes to the sewer after it is used.

[14] *Ibid*. Page A-2.

6.4 Chilled Water Systems

There are several main components of a chilled water system: chillers, pumps, heat exchangers, piping, and valves. The systems used to cool condenser water (e.g., a cooling tower) are auxiliary to the chilled water system.

Chillers are central to the chilled water system design. Chillers contain a refrigerant used to remove heat from the chilled water loop and a compressor to compress the refrigerant. Proper sizing of chillers is determined by evaluating the peak load and cooling load profile of the facility or process. Improper sizing of chillers can lead to undersized units that are unable to cool equipment or oversized units that do not operate efficiently.

Some facilities might require multiple chillers or cooling towers to meet equipment cooling needs. In the case of multiple chillers or cooling towers, there might be several options for the way in which the system is staged. For example, if multiple cooling towers are installed, they could be plumbed in parallel to allow for condenser water to pass through multiple cooling towers.

The efficiency of a chilled water system is dictated by its net useful refrigerating effect, or its ability to remove heat, compared to the energy supplied to do so. A system that removes more heat per unit of supplied energy is considered more efficient than a comparable system.

There are no federal standards for the efficiency of a chilled water system; however, the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) ASHRAE 90.1-2007 *Energy Standard for Buildings Except Low-Rise Residential Buildings* has minimum required efficiencies for water chillers and is specified in several local and state building codes.[15]

Operation, Maintenance, and User Education

Because chilled water systems are complex systems, the efficiency of the system as a whole is dependent upon the combined performance of each individual component. Considering the interaction between components helps ensure optimum energy and water savings from efficient operation and maintenance measures.[16]

Prior to implementing any operation and maintenance efficiency measures, the potential energy savings should be evaluated using the University of Massachusetts Amherst Center for Energy Efficiency & Renewable Energy's Chilled Water Systems Analysis Tool.[17,18] The tool was developed for facility personnel to evaluate potential changes to existing chilled water systems and can be used to calculate the potential energy-saving—and inherently water-saving—opportunities that exist from the measures listed below. The maximum water efficiency can be reached by reducing energy use, since it reduces the overall cooling load on the system.

[15] American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE). 2007. ASHRAE 90.1-2007 *Energy Standard for Buildings Except Low-Rise Residential Buildings*.

[16] U.S. Environmental Protection Agency (EPA) and U.S. Energy Department's (DOE's) ENERGY STAR. *Building Upgrade Manual, Chapter 9: Heating and Cooling Upgrades*. www.energystar.gov/index.cfm?c=business.bus_upgrade_manual.

[17] University of Massachusetts Amherst, Center for Energy Efficiency & Renewable Energy (CEERE), Industrial Assessment Center (IAC). Chilled Water Systems Analysis Tool (CWSAT). www.ceere.org/iac/iac_assess_tools.html.

[18] DOE, Energy Efficiency & Renewable Energy (EERE). October 2005. *Improving Chilled Water System Performance: Chilled Water System Analysis Tool (CWSAT) Improves Efficiency*. www1.eere.energy.gov/manufacturing/tech_deployment/pdfs/chiller_tool.pdf.

Optimizing Chiller Efficiency

To optimize chiller efficiency, consider the following:

- Use controls to monitor the capacity of the chiller and turn chillers on or off as necessary, depending upon the cooling demand of equipment connected to each chiller.
- The smaller the temperature difference between the chilled water and condenser water loop, the higher the chiller efficiency. Therefore, raising the chilled water temperature and lowering the condenser water temperature will improve efficiency. Such temperature adjustments can only be made within the constraints of outside conditions. The chilled water temperature will be constrained by the cooling load. A condenser water return temperature 5° to 7°F above the ambient wet bulb temperature is optimal.[19]
- Apply variable speed control to circulation pump motors.[20]
- Inspect chillers regularly to remove any scale buildup, which can decrease the heat-transfer efficiency of the chiller.

Reducing Demand on Chilled Water System

WaterSense at Work includes a number of best management practices for technologies that might be connected to the chilled water loop. Optimizing these products or systems can reduce the load on the chilled water system, which will, in turn, reduce the load on the cooling tower.

Optimize Cooling Tower Efficiency

To optimize cooling tower efficiency, consider the following:

- Refer to *Section 6.3: Cooling Towers* to ensure that the cooling tower is operating most efficiently in order to deliver cooled condenser water to the chilled water system.
- If the facility has multiple cooling towers that are plumbed in parallel, run condenser water over as many cooling towers as possible at the lowest possible fan speed.[21]

Retrofit Options

With proper preventative maintenance, chilled water systems have a typical lifetime of 20 years or longer. Therefore, it is often practical to retrofit individual system components, rather than the whole system. However, the functioning of the overall system should still be considered. The effect of an individual component retrofit on

[19] Pacific Gas and Electric Company. January 2006. *High Performance Data Centers: A Design Guidelines Sourcebook*. hightech.lbl.gov/datacenters-bpg.html.
[20] University of Massachusetts Amherst, CEERE, IAC, *op. cit*.
[21] EPA and DOE's ENERGY STAR, *op. cit*.

other system component performance should be evaluated prior to performing the retrofit. By using University of Massachusetts Amherst Center for Energy Efficiency & Renewable Energy's Chilled Water Systems Analysis Tool,[22,23] facility managers can evaluate which of the following retrofit options are the best.

Water-Related Retrofits

For retrofit options that involve water reduction, consider the following:

- Install a make-up water meter on the chilled water loop, which will allow for leaks to be easily identified.
- Insulate the pipes on the chilled water loop to ensure that the chilled water does not absorb unnecessary heat, therefore requiring more water to cool.

Energy-Related Retrofits

In addition retrofit opportunities to increase the water efficiency of a chilled water system are in many cases directly related to reducing energy use by reducing the overall cooling load on the system. Consider the following energy-related retrofits in addition to the retrofit options discussed in University of Massachusetts Amherst's Chilled Water Systems Analysis Tool. For additional information on increasing the energy efficiency of existing chilled water systems, review Energy Design Resources' *Chilled Water Plant Design Guide*[24] and the U.S. Environmental Protection Agency (EPA) and U.S. Energy Department's (DOE's) ENERGY STAR® *Building Upgrade Manual*.[25]

Replacing Pump Valves

- Standard valves can be replaced with low-friction valves to reduce flow resistance in the chilled water loop, thereby reducing pump energy use.
- For valves that control flow by inducing a pressure drop, consider removing the valves or eliminating their use by keeping the valve open. These types of valves can be replaced by using variable-speed controls, trimming the impeller, or staging pumps instead.

Replacing Pumps

- Standard or oversized pumps can be replaced with more efficient pumps. Pumps typically reach peak efficiency when they are approximately 75 percent loaded, but they are less effective if they are fully or under loaded.

[22] University of Massachusetts Amherst, CEERE, IAC, *op. cit*.
[23] DOE, EERE, *op. cit*.
[24] Energy Design Resources. December 2009. *Chilled Water Plant Design Guide*. www.energydesignresources.com/resources/publications/design-guidelines/design-guidelines-cooltools-chilled-water-plant.aspx.
[25] EPA and DOE's ENERGY STAR, *op. cit*.

Replacement Options

Replacing a chilled water system involves significant capital cost and involves many design considerations. Before replacing an existing chilled water system, first consider implementing efficient operation and maintenance and procedures and performing any retrofits available to optimize the current chilled water system. After considering the costs and benefits of installing a new chilled water system, if the facility plans to do so, the design process should take into account all system components. Facility managers and design professionals should consult design guides for efficient chilled water systems.

Because chillers are central to chilled water system design, replacing an existing chiller might allow for efficiency improvements. If the existing chiller is inefficient, and the potential energy and cost savings merit a replacement, both water and energy efficiency should be considered as part of the planned design. Water-cooled systems are typically the most efficient option for larger facilities with cooling towers. Alternate technologies, such as ground source heat pumps, can also be more energy- and water-efficient than traditional chiller and cooling tower technology. Choose a system that will operate most efficiently under typical load conditions. For most cooling loads less than 100 tons, air cooling is just as cost-effective as a water-cooled system. An analysis of the total cost of cooling with air versus cooling towers should include the cost of the water, wastewater, water treatment to prevent scale and corrosion, and labor needed to operate a cooling tower versus the 0.2 to 0.3 kilowatt-hour/ton-hour savings realized with chilled water/cooling tower/chiller systems.

Savings Potential

Chilled water systems are completely closed loops and thus consume no water when operating properly with no leaking components. However, if cooling towers are used to operate the refrigeration loop, the tower requires approximately 2.0 gallons per hour of evaporation for each ton of cooling.[26] By improving the efficiency of the chilled water system, the heat load on the cooling tower can be reduced, thereby reducing the evaporative cooling load and the water use of the system as a whole.

Additional Resources

DOE, Energy Efficiency & Renewable Energy. October 2005. *Improving Chilled Water System Performance: Chilled Water Systems Analysis Tools (CWSAT) Improves Efficiency*. www1.eere.energy.gov/manufacturing/tech_deployment/pdfs/chiller_tool.pdf.

Energy Design Resources. December 2009. *Chilled Water Plant Design Guide*. www.energydesignresources.com/resources/publications/design-guidelines/design-guidelines-cooltools-chilled-water-plant.aspx.

EPA and DOE's ENERGY STAR. *Building Upgrade Manual, Chapter 9: Heating and Cooling Upgrades*. www.energystar.gov/index.cfm?c=business.bus_upgrade_manual.

[26] Conservation Mechanical Systems, Inc. *Water Use in Cooling Towers*. www.conservationmechsys.com/wp-content/siteimages/Water%20use%20in%20Cooling%20Towers.pdf.

Koeller and Company and Riesenberger, James. January 2006. *A Report on Potential Best Management Practices—Commercial-Industrial Cooling Water Efficiency*. Prepared for The California Urban Water Conservation Council. Page A-2. www.cuwcc.org/products/pbmp-reports.aspx.

Pacific Gas and Electric Company. January 2006. *High Performance Data Centers: A Design Guidelines Sourcebook*. hightech.lbl.gov/datacenters-bpg.html.

University of Massachusetts Amherst, Center for Energy Efficiency & Renewable Energy, Industrial Assessment Center. *Chilled Water Systems Analysis Tool*. www.ceere.org/iac/iac_assess_tools.html.