

### **Overview**

Cooling towers are used in a variety of commercial and institutional applications to remove excess heat. They serve facilities of all sizes, such as office buildings, schools, supermarkets, and large facilities, such as hospitals, office complexes, and university campuses. Cooling towers dissipate heat from recirculating water that is used to cool chillers, air conditioning equipment, or other process equipment. By design, they use significant amounts of water.

Cooling towers often represent the largest use of water in institutional and commercial applications, comprising 20 to 50 percent or more of a facility's total water use. However, facilities can save significant amounts of water by optimizing the operation and maintenance of cooling tower systems.<sup>4</sup>



Cooling towers

Cooling towers work by circulating a stream of water through systems that generate heat as they function. To cool the systems, heat is transferred from the systems to the water stream. This warm water is then pumped to the top of the cooling tower, where it is sprayed or dripped through internal fill (i.e., a labyrinth-like packing with a large surface area). Fans pull or push air through the tower in a counterflow, crossflow, or parallel flow to the falling water. As some of the water is evaporated, the heat is removed.<sup>5</sup> The remaining cooled water is recirculated back through the systems to repeat the process.

The thermal efficiency and longevity of the cooling tower and its associated water loops

depend upon the proper management of water recirculated through the tower. Water leaves a cooling tower system in four ways: evaporation, blowdown or bleedoff, drift, and leaks or overflows.

#### **Evaporation**

Evaporation is the primary function of the tower and is the method that transfers heat from the cooling tower system to the environment. The quantity of evaporation is not typically targeted for water-efficiency efforts because it controls the cooling process, although improving the energy efficiency of the systems that use the cooling water will reduce the evaporative load on the tower. The rate of evaporation from

<sup>4</sup> North Carolina Department of Environment and Natural Resources, et al. May 2009. *Water Efficiency Manual for Commercial, Industrial and Institutional Facilities*. Page 39. savewaternc.org/bushome.php.

⁵ Ibid.

a cooling tower is typically equal to approximately 1 percent of the rate of recirculating water flow for every 10°F in temperature drop that the cooling tower achieves.<sup>6</sup>

#### **Blowdown or Bleed-Off**

When water evaporates from the tower, dissolved solids (e.g., calcium, magnesium, chloride, silica) are left behind. As more water evaporates, the concentration of total dissolved solids (TDS) increases. If the concentration gets too high, the TDS can cause scale to form within the system or can lead to corrosion. The concentration of TDS is controlled by removing (i.e., bleeding or blowing down) a portion of the water that has high TDS concentration and replacing that water with make-up water, which has a lower concentration of TDS. Carefully monitoring and controlling the quantity of blowdown provides the most significant opportunity to conserve water in cooling tower operations. Blowdown can be conducted manually using a batch method, in which blowdown is initiated, and make-up water is fed to the system for a preset time to decrease the concentration of TDS. It can also happen automatically through a control scheme that initiates blowdown and make-up when the TDS concentration reaches a preset point.

#### Drift

A small quantity of water can be carried from the tower as mist or small droplets known as "drift." Drift loss is small compared to evaporation and blowdown and is controlled with baffles and drift eliminators.

Drift can vary from 0.05 to 0.2 percent of the flow rate through the cooling tower.<sup>7</sup> Modern drift eliminators can reduce this loss to less than 0.005 percent, which would be negligible.

#### **Leaks or Overflows**

Properly operated towers and associated piping should not have leaks or overflows. However, an overflow drain is provided within the tower in case of malfunction and subsequent overflow. Most green codes require overflow alarms.

The water used by the cooling tower is equal to the amount of make-up water that is added



Cooling tower

to the system. The amount of make-up water needed is dictated by the amount of water that is lost from the cooling tower through evaporation, drift, blowdown, and leakage, as illustrated by Equation 6-3.

<sup>6</sup> Schultz Communications. July 1999. A Water Conservation Guide for Commercial, Institutional and Industrial Users. Prepared for the New Mexico Office of the State Engineer. Page 60. www.ose.state.nm.us/wucp\_ici.html.

7 Ibid.

#### Equation 6-3. Cooling Tower Make-Up Water (gallons)

#### = Evaporation + Drift + Blowdown + Leaks and Overflows

Where:

- Evaporation (gallons)
- Drift (gallons)
- Blowdown (gallons)
- Leaks and Overflows (gallons)

See Figure 6-2 for an illustration of the water being recirculated, added to, or lost from a cooling tower.

#### Figure 6-2. Cooling Tower System



A key parameter used to evaluate cooling tower operation is cycles of concentration (sometimes referred to as "cycles" or "concentration ratio"). The concentration ratio is the ratio of the concentration of TDS (i.e., conductivity) in the blowdown water divided by the conductivity of the make-up water. Since TDS enter the system in the make-up water and exit the system in the blowdown water, the cycles of concentration are also approximately equal to the ratio of volume of make-up water to blow-down water. See Equations 6-4 and 6-5.

#### **Equation 6-4. Cooling Tower Cycles of Concentration**

= Conductivity of Blowdown Water ÷ Conductivity of Make-Up Water

Where:

- Conductivity of Blowdown Water (parts per million of TDS)
- Conductivity of Make-Up Water (parts per million of TDS)

#### **Equation 6-5. Cooling Tower Cycles of Concentration**

#### = Make-Up Water ÷ Blowdown Water

Where:

- Make-Up Water (gallons)
- Blowdown Water (gallons)

To use water efficiently in the cooling tower system, the cycles of concentration must be maximized. This is accomplished by minimizing the amount of blowdown required, thus reducing make-up water demand. The degree to which the cycles can be maximized depends on the water chemistry within the cooling tower and the water chemistry of the make-up water supply. As cycles of concentration are increased, the amount of TDS that stays within the system also increases.

Facilities often employ a water treatment vendor to monitor the cooling tower, add chemicals to the system to control scaling and chemical buildup, and maximize the cycles of concentration. Critical water chemistry parameters that require review and control include pH, alkalinity, conductivity, hardness, microbial growth, biocide, and corrosion inhibitor levels.<sup>8</sup> Controlling these parameters allows water to be recycled through the system longer, thereby increasing cycles of concentration. Controlling blowdown using an automatic scheme allows a better opportunity to maximize cycles of concentration, as the TDS concentration can be kept at a more constant set point.

Equations 6-4 and 6-5 can also be used to determine if there is a leak, overflow, or excessive drift. Since the equations assume that the water lost to drift and overflow is negligible, if cycles of concentration are calculated using both equations and the results from Equation 6-5 are higher than that from Equation 6-4 by more than 10 percent, the cooling tower might be losing water due to one of these malfunctions.

In addition to carefully controlling blowdown and checking for unexpected losses, facilities can also reduce potable water demand from cooling towers. Water from other equipment within a facility can sometimes be recycled and reused for cooling

<sup>8</sup> North Carolina Department of Environment and Natural Resources, et al., op. cit., Page 44.

tower make-up with little or no pre-treatment, including air handler condensate (i.e., water that collects when warm, moist air passes over the cooling coils in air handling units). This reuse is particularly appropriate because the condensate has a low mineral content and is generated in greatest quantities when cooling tower loads are the highest. For additional sources of water that could be used as cooling tower make-up water, refer to *Section 8: Onsite Alternative Water Sources*.

## **Operation, Maintenance, and User Education**

For optimum cooling tower efficiency, there are a number of operations, maintenance, and user education strategies to consider, such as maintaining system energy efficiency, monitoring the cooling tower's water chemistry and flow, choosing a water treatment vendor, maximizing cycles of concentration in the tower, and paying close attention to water chemistry reports.

#### **Maintaining System Energy Efficiency**

To maintain the system energy efficiency, consider the following:

- Implement energy-efficiency measures to reduce the heat load to the tower. As the heat load is reduced, cooling tower water use will be commensurately reduced.
- Implement a comprehensive air handler coil maintenance program. Dirty coils can increase the load on the chilled water system used to maintain building temperatures. Increased load on the chilled water system will increase the load on the evaporative cooling process, requiring more make-up water for the cooling tower.
- Properly maintain and clean heat exchangers, condensers, and evaporator coils to prevent scale, biological growth, and sediment from building up in the tubes.
- Properly insulate all piping. Insulate chillers and storage tanks, if installed.
- When cooling specific equipment using the cooling tower water loop or chilled water system, use the minimum flow rate required to cool the system recommended by the manufacturer. In addition, regularly check operation of the water control valve so that cooling water only flows when there is a heat load that needs to be removed.

#### Monitoring the Cooling Tower's Water Chemistry and Flow

Monitor the cooling tower's water chemistry and flow by considering the following:

- If available, have operations and maintenance personnel read the conductivity meter and the make-up and blowdown flow meters regularly to quickly identify problems and determine when to make adjustments.
- Keep a detailed log of make-up and blowdown quantities, conductivity, and cycles of concentration and monitor trends to spot deterioration in performance.

• Make sure the tower fill valve cuts off cleanly when the tower basin is full to minimize wasted water from leaks.

#### **Choosing a Water Treatment Vendor**

When considering a water treatment vendor, select one that focuses on water efficiency. Request an estimate of the quantities and costs of treatment chemicals, volumes of make-up and blowdown water expected per year, and the expected cycles of concentration that the vendor plans to achieve. Select a vendor that can achieve high cycles of concentration while keeping costs for chemicals low.

#### **Maximizing Cycles of Concentration**

In addition, to maximize cycles of concentration, consider the following:

- Calculate and understand the cooling tower's cycles of concentration. Check the ratio of make-up water to blowdown water. Then check the ratio of conductivity ity of blowdown water and make-up water. Use a handheld conductivity meter if the tower is not equipped with permanent conductivity meters. These ratios should match the target cycles of concentration. If both ratios are not roughly the same, check the tower for leaks. If the tower is not maintaining target cycles of concentration, check the conductivity controller, the make-up water valve, and the blowdown valve for proper operation.
- Work with the cooling tower water treatment vendor to maximize the cycles of concentration. Many systems operate at two to four cycles of concentration, while six cycles or more might be possible. Increasing cycles from three to six reduces cooling tower make-up water by 20 percent and cooling tower blowdown by 50 percent.
- Work with the water treatment vendor to add chemicals to the system to control scaling and chemical buildup. Critical water chemistry parameters that require review and control include pH, alkalinity, conductivity, hardness, microbial growth, biocide, and corrosion inhibitor levels.
- When increasing cycles of concentration, ensure that discharged water meets allowable water quality standards.

#### **Reading Water Chemistry Reports**

The water treatment vendor should produce a report every time he or she evaluates the water chemistry in the cooling tower. When these reports are received, read them to ensure that monitoring characteristics, such as conductivity and cycles of concentration, are within the target range. By paying proper attention to the water chemistry reports, problems within the system can be identified quickly.

# **Retrofit Options**

To improve the efficiency of an existing cooling tower, some retrofit options are available, including: installing meters and control systems to help facility managers monitor water use; improving the tower's water quality to increase cycles of concentration; using onsite alternative sources of water to replace potable make-up water; and taking steps to reduce biological growth.

#### **Installing Meters and Control Systems**

When installing meters and control systems, consider the following:

- To automatically control blowdown, install a conductivity controller, which can continuously measure the conductivity of the cooling tower water and will initiate blowdown only when the conductivity set point is exceeded. Working with the water treatment vendor, determine the maximum cycles of concentration that the cooling tower can sustain, then identify and program the conductivity controller to the associated conductivity set point, typically measured in micro-Siemens per centimeter (μS/cm), necessary to achieve that number of cycles.
- Install automated chemical feed systems on large cooling tower systems (more than 100 tons). The automated feed will monitor conductivity, control blow-down, and add chemicals based on make-up water flow. These systems minimize water and chemical use while protecting against scale, corrosion, and biological growth.
- If not already present, install flow meters on make-up and blowdown lines. Meters can be installed on most cooling towers for less than \$1,000.<sup>9</sup> Refer to the previous "Operation, Maintenance, and User Education" section for recommendations on how to use the meters once they are installed.
- Consider contacting the water utility to determine if the facility can receive a sanitary sewer charge deduction from the potable water lost to evaporation. If the utility agrees to provide this deduction, calculate the difference between the city-supplied potable make-up water and the blowdown water that is discharged to the sanitary sewer.

#### **Improving Cooling Tower Water Quality**

To improve the cooling tower water quality, consider the following:

- To cleanse the cooling tower basin water and help the system operate more efficiently, install a rapid sand filter or high-efficiency cartridge filter on a sidestream taken from the cooling tower basin. This system will filter out sediments within the basin water and return it to the cooling tower. This is especially helpful if the cooling tower is subject to dusty conditions.
- Install a water softening system on the make-up water line if hardness (e.g., calcium and magnesium) limits the ability to increase cycles of concentration.

<sup>9</sup> Ibid.

#### **Using Appropriate Onsite Alternative Water Sources**

Use onsite alternative water sources where appropriate and feasible (see *Section 8: Onsite Alternative Water Sources* for more information). Work with the water treatment vendor to ensure that the alternative sources identified are a good match for the cooling tower, considering the water chemistry of the source and water quality needs of the cooling tower.

#### **Reducing Biological Growth**

Install covers to block sunlight penetration. Reducing the amount of sunlight on tower surfaces can significantly reduce biological growth such as algae. Controlling algae growth can help increase cycles of concentration and improve water quality in the tower.

### **Replacement Options**

Since replacing a cooling tower involves significant capital cost, facilities should first implement all efficient operation and maintenance procedures and perform any retrofits available to optimize the current cooling tower's management scheme. After exhausting all efficient management practices and considering the costs and benefits of a new tower, new cooling tower designs and improved materials can provide additional water and energy savings.

## **Savings Potential**

Significant water savings can be achieved by improving the cooling tower management approach. A key mechanism to reduce water use is to maximize the cycles of concentration. Table 6-1 shows the percentage of make-up water savings that can be expected by increasing a cooling tower's cycles of concentration, denoted as the concentration ratio (CR).<sup>10</sup> Figure 6-3 further illustrates this point by showing how increasing cycles of concentration can decrease water use in a 100-ton cooling tower.<sup>11</sup> Each facility should determine the maximum cycles of concentration it can achieve depending upon the quality of the make-up water supply and other facility-specific characteristics.

<sup>10</sup> *Ibid*. Page 42.

<sup>11</sup> Texas Water Development Board. November 2004. Water Conservation Best Practices Guide. Page 148. www.twdb.state.tx.us/conservation/municipal/plans/.

New Concentration Ratio (CRf)												
Initial Concentration Ratio (Cri)		2	2.5	3	3.5	4	5	6	7	8	9	10
	1.5	33%	44%	50%	53%	56%	58%	60%	61%	62%	63%	64%
	2.0	-	17%	25%	30%	33%	38%	40%	42%	43%	44%	45%
	2.5	-	-	10%	16%	20%	25%	28%	30%	31%	33%	34%
	3.0	-	-	-	7%	11%	17%	20%	22%	24%	25%	26%
	3.5	-	-	-	-	5%	11%	14%	17%	18%	20%	21%
	4.0	-	-	-	-	-	6%	10%	13%	14%	16%	17%
	5.0	-	-	-	-	-	-	4%	7%	9%	10%	11%
	6.0	_	_	_	_	_	_	_	3%	5%	6%	7%

Table 6-1. Percent	of Make-Ur	Water Saved by	v Maximizing	<b>Cycles</b> of	Concentration
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### **Additional Resources**

Alliance for Water Efficiency. Introduction to Cooling Towers. www.a4we.org/cooling\_tower\_intro.aspx.

Cooling Technology Institute. www.cti.org.

DOE, Energy Efficiency & Renewable Energy (EERE), Federal Energy Management Program (FEMP). February 2011. *Cooling Towers: Understanding Key Components of Cooling Towers and How to Improve Water Efficiency*. www1.eere.energy.gov/femp/ program/waterefficiency\_bmp10.html#resources. East Bay Municipal Utility District. 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. www.ebmud.com/for-customers/ conservation-rebates-and-services/commercial/watersmart-guidebook.

EPA and DOE, EERE, FEMP. May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. www1.eere.energy.gov/femp/program/labs21\_bmp.html.

North Carolina Department of Environment and Natural Resources, et al. May 2009. *Water Efficiency Manual for Commercial, Industrial and Institutional Facilities*. Pages 39-48. savewaternc.org/bushome.php.

Schultz Communications. July 1999. A Water Conservation Guide for Commercial, Institutional and Industrial Users. Prepared for the New Mexico Office of the State Engineer. Pages 60-65. www.ose.state.nm.us/wucp\_ici.html.

Texas Water Development Board. November 2004. *Water Conservation Best Practices Guide*. Pages 145-149. www.twdb.state.tx.us/conservation/municipal/plans/.