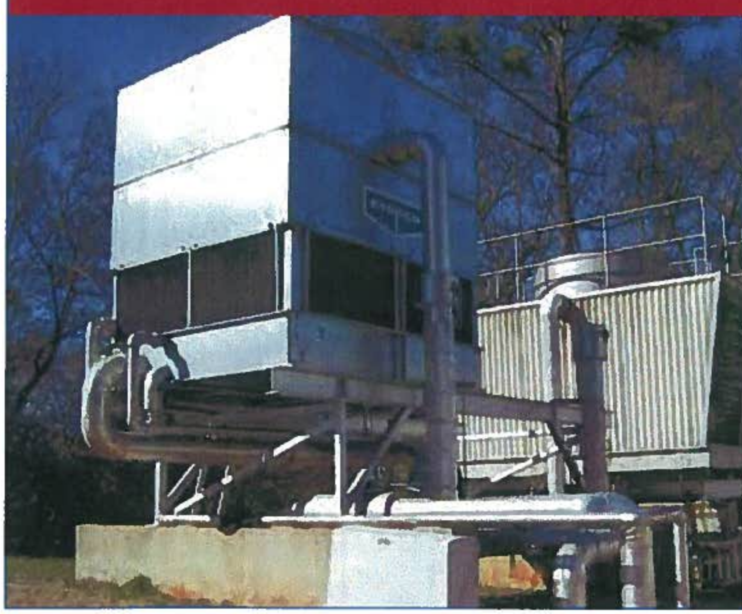
Table of Contents

Mechanical Systems



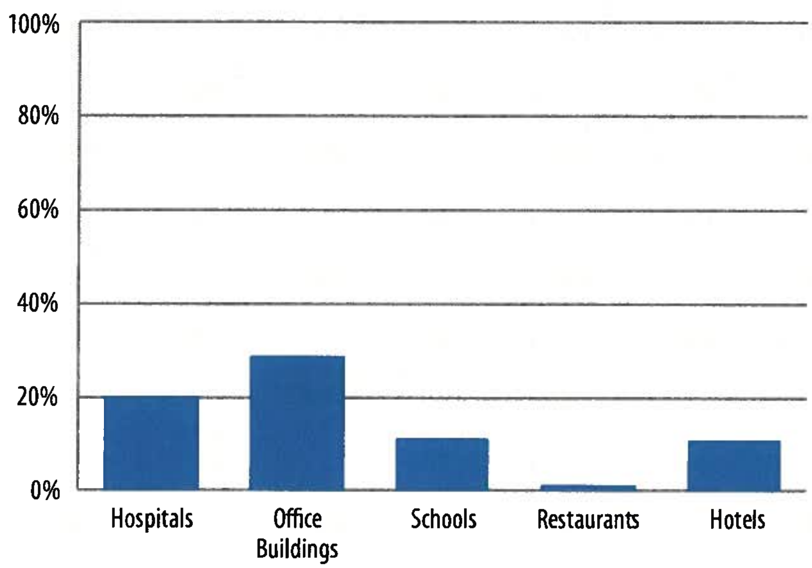
EPA WaterSense

6.1 Introduction to Mechanical Systems

EPA WaterSense

Mechanical systems are used in nearly every type of commercial and institutional facility to provide building heating and cooling. Some facilities also use mechanical systems to cool specific pieces of equipment, such as vacuum pumps, X-ray equipment, and ice machines. In many instances, these mechanical systems use water as the heat transfer medium. As a result, the use of water for building and equipment heating and cooling can be significant, in some cases as much as 30 percent of the total water use within a facility, as shown in Figure 6-1 for various commercial facility types.[1]

Figure 6-1. Water Use Attributed to Mechanical Equipment for Heating and Cooling in Various Commercial Facility Types



Common mechanical systems that use water as the heat transfer medium include single-pass cooling, cooling towers, chilled water systems, and boiler and steam systems. When looking to reduce mechanical system water use, facilities should first eliminate single-pass cooling or reuse that water, then evaluate other cooling and heating systems to maximize efficiency. Single-pass cooling systems use water to remove heat and cool specific pieces of equipment. However, after the water is passed through the equipment, it is typically discharged to the sewer, rather than being re-cooled and recirculated. In some cases, single-pass cooling can be the single largest water user at a facility, using approximately 40 times more water to remove the same heat load than a cooling tower operating at five cycles of concentration.[2]

[1] Created from analyzing data in: Schultz Communications. July 1999. *A Water Conservation Guide for Commercial, Institutional and Industrial Water Users*. Prepared for the New Mexico Office of the State Engineer. www.ose.state.nm.us/wucp_ici.html; Dziegielewski, Benedykt, et al. American Water Works Association (AWWA) and AWWA Research Foundation. 2000. *Commercial and Institutional End Uses of Water*; 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; AWWA. *Helping Businesses Manage Water Use—A Guide for Water Utilities*.

[2] U.S. Environmental Protection Agency and U.S. Energy Department, Energy Efficiency and Renewable Energy, Federal Energy Management Program. May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Page 4. www1.eere.energy.gov/femp/program/labs21_bmp.html.

All facilities should be on the lookout for single-pass cooling, which is often a hidden but rather significant water use associated with certain heating, air conditioning, and refrigeration equipment; hydraulic equipment; CAT scanners; X-ray equipment; vacuum pumps; ice machines; and wok stoves.

Like single-pass cooling systems, cooling towers also use significant quantities of water by design. Cooling towers dissipate heat from recirculating water that is used to cool chillers, air conditioning equipment, or other process equipment. After assessing whether single-pass cooling can be eliminated, facilities should focus next on ensuring that the cooling tower is properly maintained to minimize the need for make-up water. Facilities can also consider alternative sources of water for cooling tower make-up to significantly reduce the demand for potable water.

In many cases, cooling towers are used in conjunction with chilled water systems to remove heat by passing recirculated cold water through equipment. 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 other systems or specific pieces equipment. Chilled water systems and/or cooling towers can be found in relatively small facilities, such as office buildings, schools, and supermarkets and in large facilities, such as hospitals, office complexes, and university campuses. Energy-efficiency measures should be used to decrease the load of the entire system to significantly reduce water used in both chilled water systems and cooling towers.

Boiler and steam systems are used in large building heating systems for heating water or to produce steam for industrial processes, cooking, or other operations. For example, hospitals might have central steam systems to supply steam for sterilization, while large commercial kitchens use them to operate combination ovens, steam cookers, and steam kettles. Other types of facilities might use boilers to supply hot water. Returning steam condensate back to the boiler is an important first step in improving water efficiency of boiler and steam systems.

Section 6: Mechanical Systems of *WaterSense at Work* provides an overview of and guidance for effectively reducing the water use of:

- Single-pass cooling
- Cooling towers
- Chilled water systems
- Boiler and steam systems

Single-Pass Cooling Case Study

To learn how the U.S. Environmental Protection Agency's Mid-Continent Ecology Division Laboratory in Duluth, Minnesota, eliminated single-pass cooling and reduced its potable water use by 90 percent, read the case study in Appendix A.

6.2 Single-Pass Cooling

EPA WaterSense

Overview

Single-pass or once-through cooling systems use water to remove heat and cool equipment components. After water is passed once through a coil within or casing around a piece of equipment, the water is discharged to the sewer. Types of equipment that use single-pass cooling include:

- Point-of-use chillers or other refrigeration systems
- Condensers
- Air compressors
- Air conditioners
- Hydraulic equipment
- CAT scanners
- Degreasers
- Welding machines
- Vacuum pumps
- X-ray equipment
- Ice machines
- Wok stoves

Vacuum pumps, X-ray equipment, ice machines, and wok stoves use water for processes in addition to the water used for single-pass cooling. Such equipment and its associated water use, apart from single-pass cooling, are discussed in other sections within *WaterSense at Work*.

Eliminating single-pass cooling offers a significant opportunity for water savings. Single-pass systems use approximately 40 times more water to remove the same heat load than a cooling tower operating at five cycles of concentration.[3] Many types of equipment cooled with single-pass water can be replaced with air-cooled systems.

For equipment that requires cooling with water, installing an air-cooled, point-of-use chiller or converting to a recirculating water system that makes use of a process water chiller and/or a cooling tower will eliminate single-pass cooling.

The International Association of Plumbing and Mechanical Officials *2010 Green Plumbing & Mechanical Code Supplement*, which establishes requirements for green building and water efficiency applicable to plumbing, prohibits the use of single-pass cooling. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings* (ASHRAE Standard 189.1) also prohibits the use of single-pass cooling.

[3] U.S. Environmental Protection Agency and U.S. Energy Department, Energy Efficiency & Renewable Energy, Federal Energy Management Program. May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. Page 4. www1.eere.energy.gov/femp/program/labs21_bmp.html.

Operation, Maintenance, and User Education

As a first step, identify all equipment using single-pass cooling and follow these tips to minimize or eliminate this water use:

- Use the minimum flow rate required to cool the system recommended by the manufacturer.
- Install solenoid valves that shut off single-pass cooling water when the equipment is turned off.
- 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.
- Keep coil loops clean to maximize heat exchange.
- If single-pass cooling cannot be eliminated, consult the *Section 8: Onsite Alternative Water Sources* to identify methods of reusing single-pass cooling water in other applications.

Retrofit Options

For maximum savings, eliminate single-pass cooling by modifying equipment to recirculate cooling water. This can be achieved by installing a closed-loop recirculation system that will reuse cooling water instead of discharging it. A dedicated air-cooled, point-of-use chiller can be added to most cooling systems to reject heat and allow the cooling water to be reused. Alternatively, at some facilities, the single-pass cooling water can be replaced with water from an existing recirculating chilled water loop or cooling tower water loop, which are mechanical systems used to remove heat from the water.

If single-pass cooling water cannot be eliminated through cooling water recirculation, consider installing an automatic control that stops cooling water flow when the equipment is not in use or no heat load is present. This retrofit will not entirely eliminate water use, but it will minimize unnecessary water use.

Replacement Options

When possible, replace single-pass, water-cooled equipment with air-cooled equipment. Air-cooled equipment uses no water for cooling purposes. If considering air-cooled equipment as a replacement, evaluate the potential energy use of the equipment in addition to the water use to ensure that the cost benefit from water savings is not offset by an increase in energy use.

For detailed replacement options for specific equipment using single-pass cooling, refer to the *WaterSense at Work* sections covering vacuum pumps, X-ray equipment, ice machines, and wok stoves.

6.2 Single-Pass Cooling

Savings Potential

Single-pass cooling can be eliminated by retrofitting the existing equipment with a recirculating system or replacing with air-cooled equipment.

Potential savings can be estimated by measuring the existing cooling water discharge with a gallon bucket and stopwatch and determining how often the cooling water flows (e.g., how many hours per day and days per year). Many applications of single-pass cooling water flow continuously. To estimate facility-specific water savings and payback, use the following information.

Current Water Use

To estimate the current water use of existing equipment cooled with single-pass water, identify the following information and use Equation 6-1:

- Flow rate of the discharge water from the equipment cooled with single-pass water.
- Average daily use time. This will vary by facility and the type of equipment cooled with single-pass water.
- Days of facility operation per year.

Equation 6-1. Single-Pass Cooling Equipment Water Use (gallons per year)

= Single-Pass Cooling Equipment Flow Rate x Daily Use Time x Days of Facility Operation

Where:

- Single-Pass Cooling Equipment Flow Rate (gallons per minute)
- Daily Use Time (minutes per day)
- Days of Facility Operation (days per year)

Water Savings

Replacing existing equipment cooled with single-pass water with an air-cooled system or retrofitting with a recirculating cooling water system will entirely eliminate discharge water use, as shown in Equation 6-2.

Equation 6-2. Water Savings From Retrofitting or Replacing Single-Pass Cooling Equipment (gallons per year)

= Current Water Use of Single-Pass Cooling Equipment

Where:

- Current Water Use of Single-Pass Cooling Equipment (gallons per year)

Payback

To calculate the simple payback from the water savings associated with replacing existing equipment cooled with single-pass water, consider the equipment and installation cost of the replacement option, the water savings as calculated using Equation 6-2, and the facility-specific cost of water and wastewater.

If single-pass cooling is eliminated by replacing equipment with air-cooled models, facilities might see an increase in energy usage. The increased energy use, depending upon how significant, might increase the payback time and decrease replacement cost-effectiveness.

Additional Resources

EPA and DOE, Energy Efficiency & Renewable Energy, Federal Energy Management Program. May 2005. *Laboratories for the 21st Century: Best Practices, Water Efficiency Guide for Laboratories*. www1.eere.energy.gov/femp/program/labs21_bmp.html.

6.3 Cooling Towers

EPA WaterSense

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.[4]

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.[5] 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 bleed-off, 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

[4] 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.*

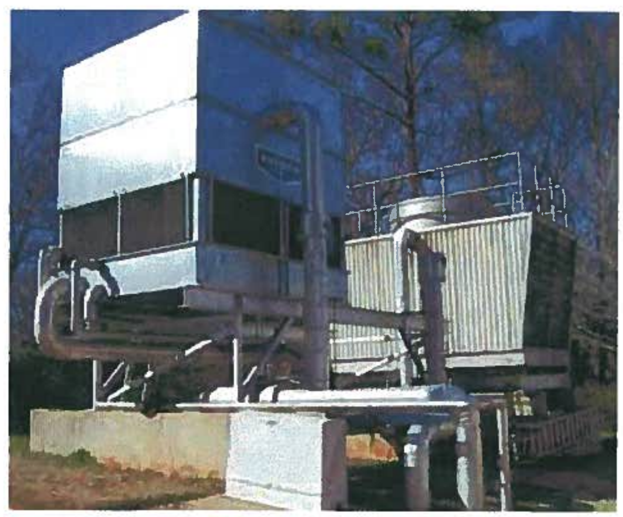
a cooling tower is typically equal to approximately 1 percent of the rate of recirculating water flow for every 10°F in temperature drop that the cooling tower achieves.[6]

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.[7] Modern drift eliminators can reduce this loss to less than 0.005 percent, which would be negligible.



Cooling tower

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 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.

[6] 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.*

6.3 Cooling Towers

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

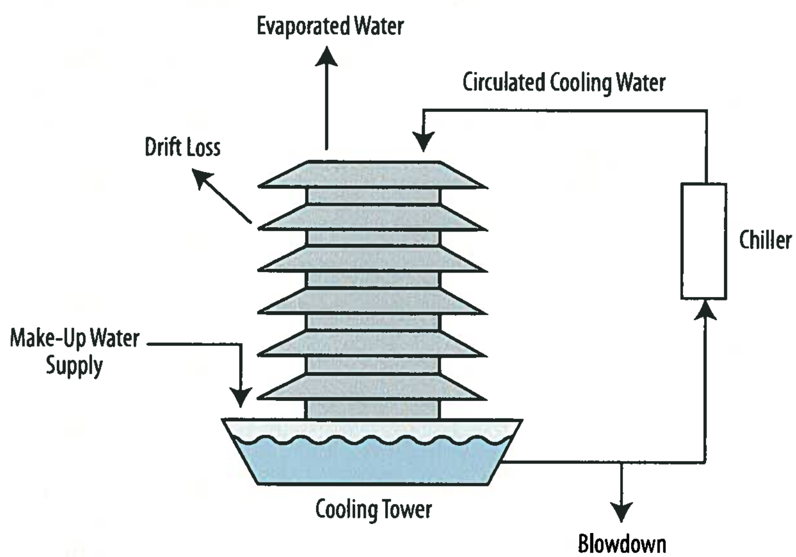
= Evaporation + Drift + Blowdown + Leaks and Overflows

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 blowdown 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.[8] 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

[8] 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 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 microSiemens 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 blowdown, 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.[9] 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.

[9] *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

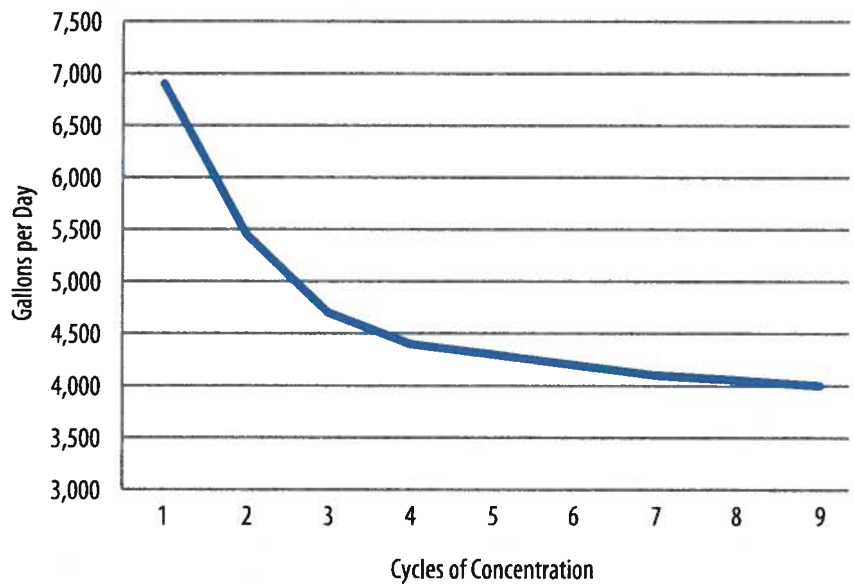
Significant water savings can be achieved by improving the cooling tower management approach. A key mechanism to reduce water use is to maximize the cycles of concentration. Table 6-1 shows the percentage of make-up water savings that can be expected by increasing a cooling tower's cycles of concentration, denoted as the concentration ratio (CR).[10] Figure 6-3 further illustrates this point by showing how increasing cycles of concentration can decrease water use in a 100-ton cooling tower.[11] 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.

[10] *Ibid*. Page 42.
[11] Texas Water Development Board. November 2004. *Water Conservation Best Practices Guide*. Page 148. www.twdb.state.tx.us/conservation/municipal/plans/.

Table 6-1. Percent of Make-Up Water Saved by Maximizing Cycles of Concentration

Initial Concentration Ratio (Cri)	New Concentration Ratio (CRf)										
		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%

Figure 6-3. Cooling Tower Water Usage at Various Cycles of Concentration for a 100-Ton Tower



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/.

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]

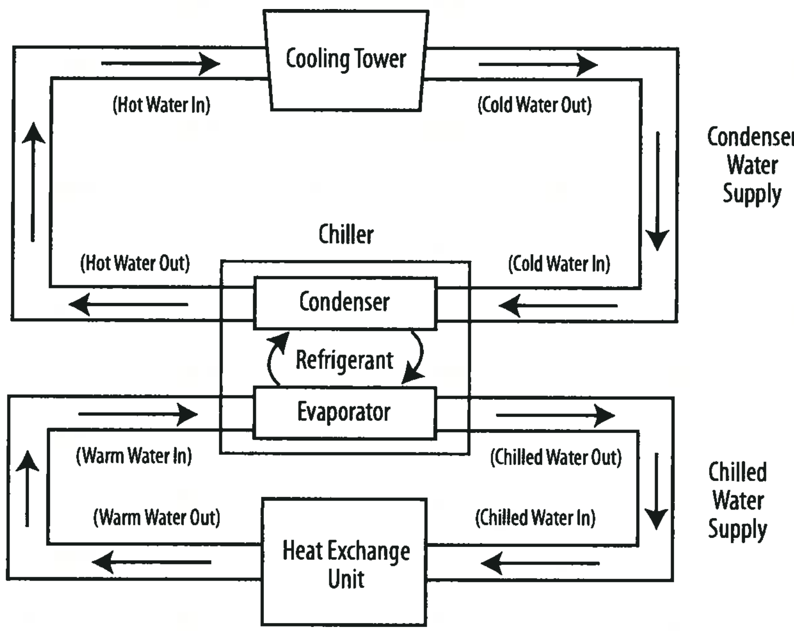
As shown in Figure 6-4, there are four main stages of operation in a water-cooled chilled water system:

- 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.

6.4 Chilled Water Systems

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.

6.5 Boiler and Steam Systems

Overview

Boiler and steam systems are used in large building heating systems for heating water or to produce steam for industrial processes, cooking, or other operations. Hot water boilers are a subset of commercial and industrial boilers used to heat water. Steam boilers, which include water-tube and fire-tube systems, produce steam by boiling water. Low-pressure boilers are used most for commercial applications and heating water, while high-pressure boilers are more common for power generation and industrial processes.[27]

Hot Water Boilers

Hot water boilers are used to provide hot water for bathing, laundry, dishwashing, or similar operations. Unlike steam boilers, however, they do not produce steam. Instead, hot water boilers essentially act as commercial- or industrial-scale water heaters.[28]

Hot water boiler distribution systems can be open or closed. Open systems provide hot water to end uses, such as hand washing, bathing, and laundry. These can either be direct-supply systems or have loop piping, whereby the hot water is recirculated back to the hot water boiler. Open systems are typically found in food service or laundry operations. Recirculating systems are most commonly used in applications that need hot water instantaneously, such as hotels.

Closed systems are often used for heating buildings. Hot water is circulated in a closed loop for space heating, using either air heat-exchange or hydronic floor-heating systems. Water in closed-loop systems is typically treated to prevent corrosion and scaling. Additional water is needed only to make up for leaks and periodic additions.[29] Because water efficiency isn't a primary concern for hot water boiler systems, they are not discussed further in this section.

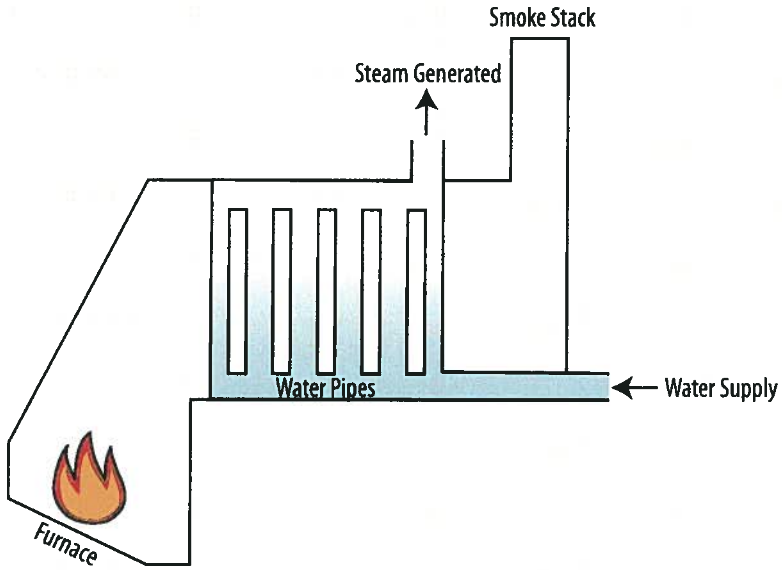
Water-Tube Boilers

Water-tube boilers (see Figure 6-5) are used for high-pressure boiler applications. In these systems, water circulates through tubes that are indirectly heated by fire. Exhaust gases remain inside the boiler shell and pass over tube surfaces to heat the water. The heated water then rises as steam to be used for cooking, as process steam, or for other operations. Water-tube boilers are lighter by design and thus able to withstand higher pressures. They are also capable of high efficiencies and generating saturated or superheated steam.

[27] East Bay Municipal Utility District (EBMUD). 2008. *WaterSmart Guidebook—A Water-Use Efficiency Plan Review Guide for New Businesses*. Pages THERM10-14. www.ebmud.com/for-customers/conservation-rebates-and-services/commercial/watersmart-guidebook.
[28] *Ibid.*
[29] *Ibid.*

6.5 Boiler and Steam Systems

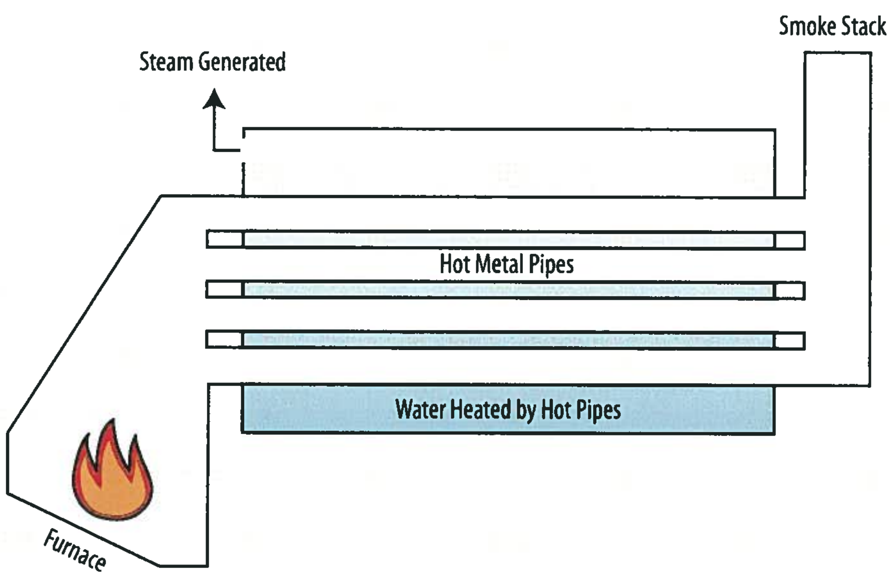
Figure 6-5. Water-Tube Steam Boiler Configuration



Fire-Tube Boilers

The most common type of steam boiler is the fire-tube boiler (see Figure 6-6).[30] In this type of system, a gas- or oil-fired heater directs heat onto a series of tubes that are immersed in water, which transfers heat to the water, generating steam.

Figure 6-6. Fire-Tube Steam Boiler Configuration



[30] *Ibid.*

In both types of steam boiler configurations, as the steam is distributed, its heat is transferred to the ambient environment and, as a result, it recondenses to water. This condensate is then either discharged to the sewer or captured and returned to the boiler for reuse. If the condensate is discharged to the sanitary sewer, most codes require it to be cooled to an acceptable temperature before discharging. The hot condensate is typically tempered with cool water to meet the temperature discharge requirements.

As the water is converted to steam, dissolved solids, such as calcium, magnesium, chloride, and silica, are left behind. With evaporation, the total dissolved solids (TDS) concentration 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., blowing down) a portion of the water that has a high concentration of TDS and replacing that water with make-up water, which has a lower concentration of TDS. Some boiler operators practice continuous blowdown by leaving the blowdown valve partially open, requiring a continuous feed of make-up water.

From a water-efficiency standpoint, installing and maintaining a condensate recovery system to capture and return condensate to the boiler for reuse is the most effective way to reduce water use. Recovering condensate:

- Reduces the amount of make-up water required.
- Eliminates or significantly reduces the need to add tempering water to cool condensate before discharge.
- Reduces the frequency of blowdown, as the condensate is highly pure and adds little to no additional TDS to the boiler water.

In addition, since the steam condensate is relatively hot, when it is added back to the boiler, it requires less energy to reheat to produce steam again.

Proper control of boiler blowdown water is also critical to ensure efficient boiler operation and minimize make-up water use. Insufficient blowdown can lead to scaling and corrosion, while excessive blowdown wastes water, energy, and chemicals. The optimum blowdown rate is influenced by several factors, including boiler type, operating pressure, water treatment, and quality of make-up water. Generally, blowdown rates range from 4 to 8 percent of the make-up water flow rate, although they can be as high as 10 percent if the make-up water is poor quality with high concentrations of solids.[31,32]

Blowdown is typically assessed and controlled by measuring the conductivity of the boiler make-up water compared to that in the boiler blowdown water. Conductivity provides an indication of the overall TDS concentration in the boiler. The blowdown percentage can be calculated as indicated in Equation 6-6. The boiler water quality is

[31] U.S. Energy Department (DOE), Energy Efficiency & Renewable Energy (EERE). January 2012. *Minimize Boiler Blowdown.* www1.eere.energy.gov/industry/bestpractices/pdfs/steam9_blowdown.pdf.

[32] DOE, EERE. January 2012. *Return Condensate to Boiler.* www1.eere.energy.gov/manufacturing/tech_deployment/pdfs/steam8_boiler.pdf.

often expressed in terms of cycles of concentration, which is the inverse of the blowdown percentage.[33]

Equation 6-6. Boiler or Steam System Blowdown Percentage (percent)

= Conductivity of Make-Up Water ÷ Conductivity of Blowdown

Where:

- Conductivity of Make-Up Water (milligrams per liter of TDS)
- Conductivity of Blowdown (milligrams per liter of TDS)

Controlling the blowdown percentage and maximizing the cycles of concentration will reduce make-up water use; however, this can only be done within the constraints of the make-up and boiler water chemistry. As the TDS concentration in the blowdown water increases, scaling and corrosion problems can occur, unless carefully controlled.

The amount of make-up water required is a key driver of the overall water use of the boiler. Make-up water quantity is dictated by the amount of water that is lost from the system, particularly steam condensate that is discharged and not returned to the boiler, and the amount of blow down, as illustrated in Equation 6-7.

Equation 6-7. Boiler or Steam System Make-Up Water (gallons)

= Condensate Loss + Blowdown

Where:

- Condensate Loss (gallons)
- Blowdown (gallons)

By recovering steam condensate and carefully controlling the amount and frequency of blowdown, boiler water and energy use can be significantly reduced.

Operation, Maintenance, and User Education

There are a number of ways to improve water efficiency of boiler and steam systems by changing operation, maintenance, and user education techniques. Best management practices include: maintaining boilers, steam lines, and steam traps; choosing a water treatment vendor that focuses on water efficiency; reading meters and water chemistry reports to closely monitor water use; minimizing blowdown; and improving make-up water quality to increase cycles of concentration.

[33] North Carolina Department of Environment and Natural Resources, et al. May 2009. *Water Efficiency Manual for Commercial, Industrial and Institutional Facilities.* Pages 49-52. savewaternc.org/bushome.php.

Maintaining Boilers, Steam Lines, and Steam Traps

When maintaining boilers, steam lines, and steam traps, consider the following:

- Regularly check steam and hot water lines for leaks and make repairs promptly.
- Regularly clean and inspect boiler water and fire tubes.
- Develop and implement an annual boiler tune-up program.
- Provide proper insulation on piping and the central storage tank to conserve heat.
- Implement a steam trap inspection program for boiler systems with condensate recovery. When steam traps exceed condensate temperature, this inspection can reveal whether the trap is leaking condensation. Monitor temperature using an infrared temperature device.[34] Repair leaking traps as soon as possible.[35]

Choosing a Water Treatment Vendor

When choosing 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. Choose a vendor that can minimize water use, chemical use, and cost, while maintaining appropriate water chemistry for efficient scale and corrosion control.

Reading Meters and Water Chemistry Reports

When reading meters and water chemistry reports, consider the following:

- If available, have operations and maintenance personnel read the make-up and condensate return flow meters regularly to quickly identify leaks or other problems.
- Ensure the water treatment vendor produces a report every time he or she evaluates the water chemistry in the boiler. 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.

Minimizing Blowdown

To minimize blowdown, consider the following:

- Calculate and understand the boiler's cycles of concentration. Check the ratio of conductivity of blowdown water to the make-up water. Use a handheld conductivity meter if the boiler is not equipped with permanent conductivity meters. This ratio should match the target cycles of concentration.

[34] *Ibid.*
[35] DOE, EERE, Federal Energy Management Program. July 1999. *Steam Trap Performance Assessment: Advanced technologies for evaluating the performance of steam traps*. www1.eere.energy.gov/femp/pdfs/FTA_SteamTrap.pdf.

- Work with the water treatment vendor to prevent scaling and corrosion and optimize cycles of concentration.

Improving Make-up Water Quality

To improve make-up water quality, consider the following:

- Consider pre-treating boiler make-up water to remove impurities, which can increase the cycles of concentration the boiler can achieve. Water softeners, reverse osmosis systems, or demineralization are potential pre-treatment technology options. Refer to *Section 7.2: Water Purification* for more information.
- When increasing cycles of concentration, ensure that discharged water meets allowable water quality standards.

Retrofit Options

To improve the efficiency of an existing boiler and steam system, consider retrofitting the system by recovering steam condensate and installing meters and control systems to monitor water use.

Recovering Steam Condensate

When recovering steam condensate, consider the following:

- Install and maintain a condensate recovery system to return condensate to the boiler for reuse.
- Where condensate cannot be returned to the boiler and must be discharged to the sanitary sewer, employ an expansion tank to temper hot condensate rather than adding water to cool it.

Installing Meters and Control Systems

When installing meters and control systems, consider the following:

- Install an automatic blowdown control system, particularly on boilers that are more than 200 horsepower, to control the amount and frequency of blowdown rather than relying on continuous blowdown.[36] Control systems with a conductivity controller will initiate blowdown only when the TDS concentrations in the boiler have built up to a certain concentration.
- If not already present, install flow meters on the make-up water line and the condensate return line to monitor the amount of make-up water added to the boiler. Refer to the previous "Operation, Maintenance, and User Education" section for recommendations on how to use the meter once it is installed.

[36] EBMUD, *op. cit.*

- Install automated chemical feed systems to monitor conductivity, control blowdown, and add chemicals based on make-up water flow. These systems minimize water and chemical use while protecting against scale buildup and corrosion.

Replacement Options

Because replacing a boiler involves significant capital costs, first implement efficient operations and maintenance procedures and perform any retrofits available to optimize the current boiler's management scheme. After exhausting all efficient management practices, consider the costs and benefits of boiler replacement.

Boiler replacement options will vary depending upon the size of the facility and existing equipment. Conduct an energy audit to help reduce heating loads; ensure the boiler system is appropriately sized; and identify whether it is possible to reduce the boiler size. When looking to replace an existing boiler, consider installing a small summer boiler, distributed system, or heat-capture system for reheating or dehumidification requirements. Also, consider alternative technologies such as heat pumps.

Savings Potential

Significant water savings can be achieved by improving the boiler system management scheme. A key mechanism to reduce water use is to maximize the cycles of concentration. Installing an automatic blowdown control system is one way to minimize blowdown and maximize cycles of concentration. Switching to an automatic control system can reduce a boiler's energy use by 2 to 5 percent and reduce blowdown by as much as 20 percent.

Additional Resources

American Society of Mechanical Engineers. 1994. *Consensus Operating Practices for Control of Feedwater/Boiler Water Chemistry in Modern Industrial Boilers.*

Council of Industrial Boiler Owners (CIBO). November 1997. *CIBO Energy Efficiency Handbook.* www.cibo.org/pubs/steamhandbook.pdf.

DOE, Energy Efficiency & Renewable Energy. January 2012. *Minimize Boiler Blowdown.* www1.eere.energy.gov/industry/bestpractices/pdfs/steam9_blowdown.pdf.

DOE, Energy Efficiency & Renewable Energy. January 2012. *Return Condensate to Boiler.* www1.eere.energy.gov/industry/bestpractices/pdfs/steam8_boiler.pdf.

DOE, Energy Efficiency & Renewable Energy, Federal Energy Management Program. July 1999. *Steam Trap Performance Assessment: Advanced technologies for evaluating the performance of steam traps.* www1.eere.energy.gov/femp/pdfs/FTA_SteamTrap.pdf.

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.

North Carolina Department of Environment and Natural Resources, et al. May 2009. *Water Efficiency Manual for Commercial, Industrial and Institutional Facilities*. Pages 49-52. 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. Page 68. www.ose.state.nm.us/wucp_ici.html.