water efficiency

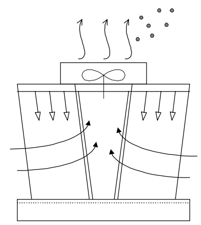
Water Management Options

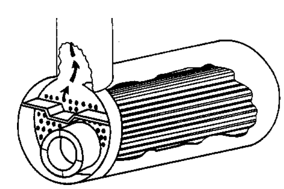
Cooling and Heating

Background

The use of cooling towers represents the largest reuse of water in industrial and commercial applications. Cooling towers offer the means to remove heat from air conditioning systems and from a wide variety of industrial processes that generate excess heat. While all cooling towers continually reuse water, they still can consume 20 to 30 percent of a facility's total water use. Optimizing operation and maintenance of cooling tower systems can offer facility managers significant savings in water consumption.

Cooling Tower



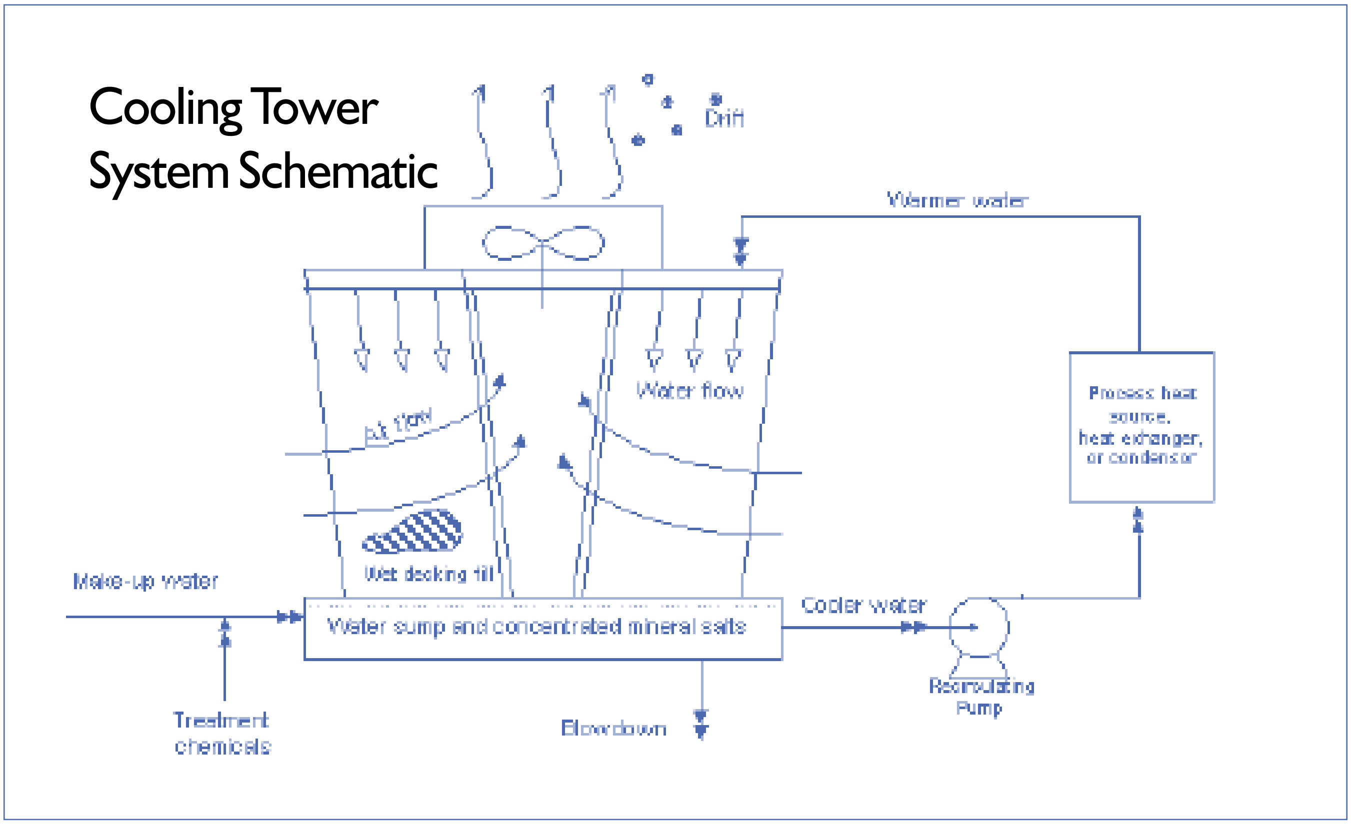


Boiler

Cooling Tower Design

Warm water is recirculated continuously from a heat source, such as an air conditioning system or process equipment, to the cooling tower. *(See Figure 1.)* In most cooling tower systems, warm water (or water to be cooled) is pumped to the top of the tower where it

Figure 1



is sprayed or dripped through internal fill materials called wet decking. The wet decking creates a large surface area for a uniform thin film of water to be established throughout the tower. Air is blown through falling water over the wet decking to cause evaporation. Fans pull air through the tower in a counterflow, crossflow, or parallel flow to the falling water in the tower. Fore most efficient cooling, the air and water must mix as completely as possible.

Evaporation

Cooling occurs in a tower by the mechanisms of evaporative cooling and the exchange of sensible heat. The loss of heat by evaporation (approximately 1,000 Btu per pound of water) lowers the remaining water temperature. The smaller amount of cooling also occurs when the remaining water transfers heat (sensible heat) to the air.

The rate of evaporation is about 1.2 percent of the rate of flow of the recirculating water passing through the tower for every 10 F decrease in water temperature achieved by the tower. The decrease in water temperature will vary with the ambient dew point temperature (DPT). The lower the dew point, the greater the temperature difference (ΔT) between water flowing in and out of the tower. Another rule of thumb for estimating the rate of evaporation from a cooling tower is as follows: evaporation equals three gallons per minute (gpm) per 100 "tons" of cooling load placed in the tower. The term "ton," when used to describe cooling tower capacity, is equal to 12,000 British thermal units (Btu) per hour of heat removed by the tower. When the dew point temperature is low, the tower air induction fans can be slowed by using a motor speed control or merely cycled on and off, saving both energy and water evaporation losses.

FIGURE 2

CONCENTRATION RATIO

$$\frac{\text{TDS of blowdown}}{\text{total dissolved solid (TDS) of make-up water}}$$

OR

$$\frac{\mu\text{mhos of blowdown}}{\text{specific conductance } (\mu\text{mhos}) \text{ of make-up}}$$

Blowdown

Blowdown is a term for water that is removed from the recirculating cooling water to reduce contaminant buildup in the tower water. As evaporation occurs, water contaminants, such as dissolved solids, build up in the water. By removing blowdown and adding fresh makeup water, the dissolved solids level in the water can be maintained to reduce mineral scale build-up and other contaminants in the tower, cooling condensers, and process heat exchangers. Thermal efficiency, proper operation, and life of the cooling tower are related directly to the quality of the recirculating water in the tower.

Water quality in the tower is dependent on makeup water quality, water treatment, and blowdown rate. Optimization of blowdown, in conjunction with proper water treatment, represents the greatest opportunity for water efficiency improvement. Blowdown can be controlled manually or automatically by valves actuated by timers or conductivity meters.

Drift losses

Drift is a loss of water from the cooling tower in the form of mist carried out of the tower by an air draft. A typical rate of drift is 0.05 to 0.2 percent of the total circulation rate. Reduction in drift through baffles or drift eliminators will conserve water, retain water treatment chemicals in the system, and improve operating efficiency.

Make-up water

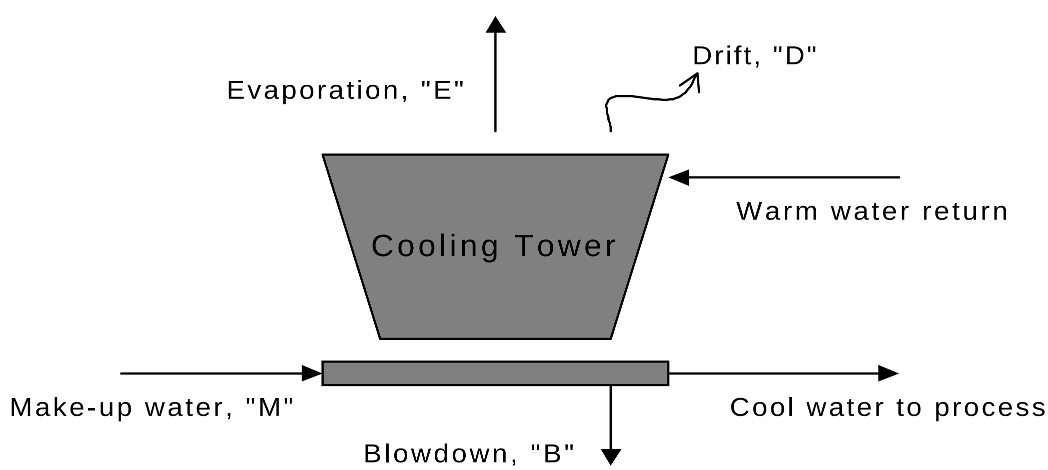
Makeup water is water added to the cooling towers to replace evaporative, blowdown, and drift losses. The amount of make-up water added directly affects the quality of water in the systems. The relationship between blowdown water quality and make-up water quality can be expressed as a "concentration ratio" or a "cycle of concentration." *(See Figure 19.)* The most efficient use occurs when the concentration ratio increases and blowdown decreases.

Water balance

A simple water balance on a cooling tower system can be determined if three of the four following

FIGURE 3

Cooling Tower Water Balance



Water Balance: M = E + B + D

Concentration Ratio: CR = B Quality / M Quality

FIGURE 4

Percent of Make-up Water Saved

Initial Concentration Ratio (Cr_i) \ New Concentration Ratio (CR_f)	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	——-	17%	25%	30%	33%	38%	40%	42%	43%	44%	45%
2.5	——-	——-	10%	16%	20%	25%	28%	30%	31%	33%	34%
3	——-	——-	——-	7%	11%	17%	20%	22%	24%	25%	26%
3.5	——-	——-	——-	——-	5%	11%	14%	17%	18%	20%	21%
4	——-	——-	——-	——-	——-	6%	10%	13%	14%	16%	17%
5	——-	——-	——-	——-	——-	——-	4%	7%	9%	10%	11%
6	——-	——-	——-	——-	——-	——-	——-	3%	5%	6%	7%

parameters are known: make-up, evaporation, drift, and blowdown. *(See Figure 20 for a description.)*

Blowdown Optimization

Water consumption of cooling towers can be reduced significantly by minimizing blowdown in coordination with an integrated operation and maintenance program. Blowdown is minimized when the concentration ratio increases. Typical concentration ratios are 2-to-3, and generally can be increased up to six or more.

Some states have passed laws governing the quality level in a cooling tower as an attempt to promote efficient cooling tower water use. For example, the State of Arizona requires that the total dissolved solids (TDS) of blowdown water be 2,000 ppm or greater for a new large cooling facility whose total

$$V = M_i \times \frac{CR_i - CR_f}{(CR_i)(CR_f - 1)}$$

V = volume of water conserved
M_i = initial make-up water volume (before modification)
CR_i = concentration ratio before increasing cycle
CR_f = concentration ratio after increasing cycles

cooling capacity is greater than 250 tons or three million Btu.

The volume of water saved by increasing the cycles of concentration can be determined by this equation: For example, increasing concentration ratio from two to six will save 40 percent of the initial make-up water volume. Table 21 allows users to easily estimate potential water savings.

The maximum concentration ratio at which a cooling tower can still properly operate will depend on the feedwater quality, such as pH, TDS, alkalinity, conductivity, hardness, and microorganism levels. The use and sensitivity of a cooling system also will control how much blowdown can be reduced. Scale, corrosion, fouling, and microbial growth are four critical parameters that must be controlled in cooling towers. Minimum blowdown rates must be determined in tandem with the optimum water treatment program for the cooling tower.

Controlling Blowdown

To better control the blowdown and concentration ratio, facilities can install submeters on the make-up water feed line and the blowdown line. Submetering allows operators to carefully control water use. In some areas, evaporative water loss, as determined by submetering and water balances, can be subtracted from local sewer charges. Submeters can be installed on most cooling towers for less than $1,000. Blowdown can be conducted manually or automatically. Recirculating water systems are blown down when the conductivity of the water reaches a preset level. Typically, this is done in a batch process, blowing down sizable water volumes. A better approach is to use a conductivity controller to continuously bleed and refill water in the system. Continuous systems maintain water quality at a more consistent level without wide fluctuations in TDS.

Cooling Tower Water Treatment

Almost all well-managed cooling towers use a water treatment program. The goal of a water treatment program is to maintain a clean heat transfer surface while minimizing water consumption and meeting discharge limits. Critical water chemistry parameters that require review and control include pH, alkalinity, conductivity, hardness, microbial growth, biocides, and corrosion inhibitors.

Depending of the quality of the make-up water, treatment programs may include corrosion and scaling inhibitors, such as organophosphate types, along with biological fouling inhibitors. These chemicals normally are fed into the system by automatic feeders on timers or actuated by conductivity meters. Automatic chemical feeding tends to decrease chemical dosing requirements.

Sulfuric "Acid" Treatment

Sulfuric acid can be used in a cooling tower water to help

Practical guidance for working with a service contractor

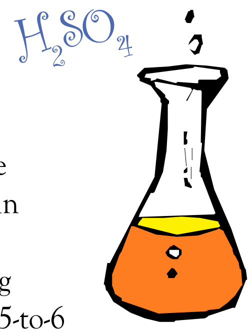
- Work closely with your chemical vendor or contracted service provider to reduce blowdown. Because reducing blowdown also reduces chemical purchasing requirements, facility personnel must keenly set up performance-based service contracts.
- Require vendors to commit to a predetermined minimum level of water efficiency. Have them provide an estimate of projected annual water and chemical consumption and costs.
- Tell your vendor that water efficiency is a priority, and ask about alternative treatment programs that will help reduce blowdown.

When purchasing chemicals for treating cooling tower water, have the chemical vendor explain the purpose and action of each chemical. Your vendor should provide a written report of each service call. Be sure the vendor explains the meaning of each analysis performed, as well as the test results.

CASE STUDY

Bayer Corp. in Clayton, North Carolina, substantially reduced city water consumption for cooling towers by reusing the "reject" stream from their reverse osmosis (RO) water treatment process. By reusing the RO "reject" water to replace cooling tower evaporative losses, Bayer is saving 10 million gallons of city water per year.

control scale buildup. When properly applied, sulfuric acid will lower the water's pH and help convert the calcium bicarbonate scale to a more soluble calcium sulfate form. In locations in Southern California and Phoenix, facilities are able to operate cooling towers at a concentration ratio of 5-to-6 using sulfuric acid treatment.



Important precautions need to be taken when using sulfuric acid treatment. Because sulfuric acid is an aggressive acid that will corrode metal, it must be carefully dosed into the system and must be used in conjunction with an appropriate corrosion inhibitor. Workers handling sulfuric acid must exercise caution to prevent contact with eyes or skin. All personnel should receive training on proper handling, management, and accident response for sulfuric acid used at the facility.

Side Stream Filtration

In cooling towers that use makeup water with high suspended solids, or in cases where airborne contaminants such as dust can enter cooling tower water, side stream filtration can be used to reduce solids build-up in the system. Typically five to 20 percent of the circulating flow can be filtered using a rapid sand filter or a cartridge filter system.

Rapid sand filters can remove solids as small as 15 microns in diameter while cartridges are effective to remove solids to 10 microns or less. Neither of these filters are very effective at removing dissolved solids, but can remove mobile mineral scale precipitants and other solid contaminants in the water. The advantages of side stream filtration systems are a modest reduction in scale formation and fouling, which allows longer periods between major maintenance.

Ozone

Ozone can be a very effective agent to treat nuisance organics in the cooling water. Ozone treatment also is reported to control the scale by forming mineral oxides that will precipitate out to the water in the form of sludge. This sludge collects on the cooling tower basin or in a separate tank. Ozone treatment consists of an air compressor, an ozone generator, a diffuser or contactor, and a control system. The initial capital costs of such systems are high but have been shown to provide payback in 18 months.

Magnets

Some vendors offer special water treating magnets that alter the surface charge of suspended particles in cooling tower water. The particles help disrupt and break loose deposits on surfaces in the cooling tower system. The particles settle in a low velocity area of the cooling tower — such as sumps where they can be mechanically removed. Suppliers of these magnetic treatment systems claim that magnets will remove scale without conventional chemicals. Also, a similar novel treatment technology, called an electrostatic field generator, can be investigated and validated.

Alternative Sources of Make-up Water

Some facilities may have an opportunity to reuse water from another process for cooling make-up water. Water reuse from reverse osmosis reject water, wastewater from a once through cooling process, or from other clean wastewater streams in the plant are examples. In some cases, treated effluent can be used as cooling tower make-up if the concentration ratio is maintained conservatively low. Similarly, blowdown streams may be suitable for use as process water in some applications

It has been reported that municipal wastewater effluent from tertiary treatment may be suitably used as make-up water. In these reuse applications, reports of phosphate scale formation was problematic where water softening pretreatment was not also employed.

Eliminate Once-Through Cooling

Many facilities use "once-through" water to cool small heat generating equipment. Once-through cooling is a very wasteful practice because water is used only one time before being sewered. Typical equipment that can be using once-through cooling includes: vacuum pumps, air compressors, condensers, hydraulic equipment, rectifiers, degreasers, X-ray processors, welders, and sometimes even air conditioners. Some areas of the country prohibit the use of once-through cooling practice. Option to eliminate once-through cooling are typically very cost effective. They include:

- Connect equipment to a recirculating cooling system. Installation of a chiller or cooling tower is usually an economical alternative. Sometimes excess cooling capacity already exists within the plant that can be utilized.
- Consider replacing water-cooled equipment with air-cooled equipment. One example is switching from a water-cooled to an air-cooled ice making machine.
- Reuse the once-through cooling water for other facility water requirements such as cooling tower make-up, rinsing, washing, and landscaping. ♦

CASE STUDY

Eliminating Once-Through Cooling

A small medical equipment manufacturer in Arden, North Carolina, was using a continuous tap water flow of 12 gpm to cool a 20-horsepower vacuum pump. After a water efficiency audit, the company installed a chiller water recirculating system. The company is now saving 6.6 million gallons of water per year, an estimated $30,500 annual savings in water and sewer costs.

FIGURE 5

Summary of Cooling Tower Water Efficiency and Treatment Options

Option	Advantages	Disadvantages
Operation improvements to control blowdown and chemical additions	Low capital costs Low operating costs Low maintenance requirements	None
Sulfuric acid treatment	Low capital cost Low operating cost Increased concentration ratio	Potential safety hazard Potential for corrosion damage if overdosed
Side stream filtration	Low possibility of fouling Improve operation efficiency	Moderately high capital cost Limit effectiveness on dissolved solids Additional maintenance
Ozonation	Increased concentration ratio Reduced chemical requirements	High capital investment Complex system Possible health issue
Magnet System	Reduced scale Reduced or eleminated chemical usage	Novel technology Controversial performance claims
Reuse of water within the facility	Reduces overall facility water consumption	Increased fouling potential Low concentration ratios required Possible need for additional water pretreatment

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