

# Cooling Towers: Understanding Key Components of Cooling Towers and How to Improve Water Efficiency



Source: Paul Johnston-Knight

## Introduction

Federal laws and regulations require Federal agencies to reduce water use and improve water efficiency. Namely, Executive Order 13514 *Federal Leadership in Environmental, Energy, and Economic Performance*, requires an annual two percent reduction of water use intensity (water use per square foot of building space) for agency potable water consumption as well as a two percent reduction of water use for industrial, landscaping, and agricultural applications. Cooling towers can be a significant source of water use for both of these categories of water use at Federal facilities. To realize potential savings it is essential for Federal agencies understand the key components of cooling towers and how to improve water efficiency of the system as a part of a comprehensive approach to water management.

### In this Fact Sheet:

- Introduction
- Overview
- Structure
- Basic Cooling Tower Terms
- Types of Towers
- Important Properties of Water
- System Calculations
- Factors That Limit Cycles of Concentration
- System Concerns
- Treatment Options

## Overview

Cooling towers are an integral component of many refrigeration systems, providing comfort or process cooling across a broad range of applications. They are the point in the system where heat is dissipated to the atmosphere through the evaporative process, and are common in industries such as oil refining, chemical processing, power plants, steel mills, and many different manufacturing processes where process cooling is required. They are also commonly used to provide comfort cooling for large commercial buildings including airports, office buildings, conference centers, hospitals, and hotels.

Cooling tower structures vary greatly in size and design, but they all function to provide the same thing: liberation of waste heat extracted from a process or building system through evaporation of water. In technical terms, cooling towers are engineered and designed based on a specified cooling load, expressed in refrigeration tons.<sup>(1)</sup> The cooling load is determined by the amount of heat that needs to be extracted from a given process or peak comfort cooling demand. The cooling tower must be adequately sized to reject this same amount of heat to the atmosphere.

Cooling towers are used to reject heat through the natural process of evaporation. Warm recirculating water is sent to the cooling tower where a portion of the

water is evaporated into the air passing through the tower. As the water evaporates, the air absorbs heat, which lowers the temperature of the remaining water. This process provides significant cooling to the remaining water stream that collects in the tower basin where it can be pumped back into the system to extract more process or building heat, thereby allowing much of the water to be used repeatedly to meet the cooling demand.

The amount of heat that can be rejected from the water to the air is directly tied to the relative humidity of the air. Air with a lower relative humidity has a greater ability to absorb water through evaporation than air with a higher relative humidity, simply because there is less water in the air. As an example, consider cooling towers in two different locations—one in Atlanta, Georgia, and another in Albuquerque, New Mexico. The ambient air temperature at these two locations may be similar, but the relative humidity in Albuquerque on average will be much lower than that of Atlanta's. Therefore, the cooling tower in Albuquerque will be able to extract more process or building heat and will run at a cooler temperature because the dry desert air has a greater capacity to absorb the warm water.

Cooling towers can be split into two distinct categories: open circuit (direct contact) and closed circuit (indirect) systems. In open circuit systems the recirculating water returns to the tower after

(1) One ton of refrigeration is equal to 12,000 Btu/hour.

gathering heat and is distributed across the tower where the water is in direct contact with the atmosphere as it recirculates across the tower structure. Closed circuit systems differ in that the return fluid (often water, or sometimes water mixed with glycol) circulates through the tower structure in a coil, while cooling tower water recirculates only in the tower structure itself (see Figure 1). In this case, the return fluid is not exposed directly to the air.

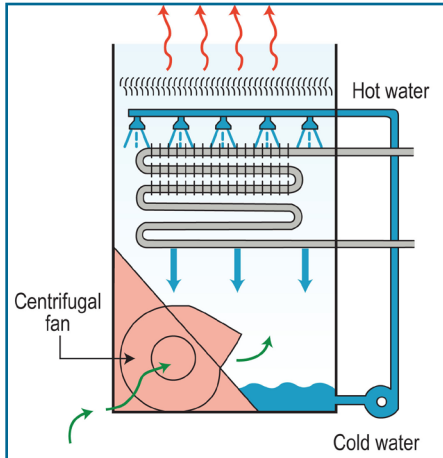


Figure 1. Example of a Closed Circuit Cooling Tower.

## Structure

Cooling towers are the primary component used to exhaust heat in open recirculating cooling systems. They are designed to maximize air and water contact to provide as much evaporation as possible. This is accomplished by maximizing the surface area of the water as it flows over and down through the tower structure. Figure 2 illustrates the

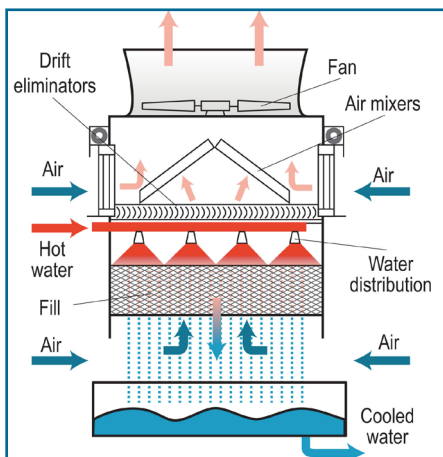


Figure 2. Overview of Cooling Tower Structure Components.

different components of a cooling tower structure.

First, the water is distributed evenly across the top of the cooling tower structure. Tower distribution decks can be a series of spray nozzles oriented up or down (like a landscaping sprinkler system) to uniformly distribute the water over the tower structure. In some cases, the distribution deck may just be a series of holes through which the water falls onto the tower structure. Regardless the distribution deck must uniformly apportion the recirculating water across the tower structure. Broken nozzles or plugged orifices will impede uniform distribution across the tower structure, negatively impacting the overall heat exchange capacity of the system.

As the water falls from the distribution deck, the surface area is further expanded in the fill section. Older tower systems may feature splash bars made of plastic, fiberglass, or wood that serve to break the falling water into tiny droplets. In recent years, many different forms of labyrinth-like packing or film fill have been incorporated. The closely packed nature of film fill causes the water to travel through this portion of the tower in thin streams, improving thermal efficiency and the evaporation rate, thereby increasing heat rejection (see Figure 3).

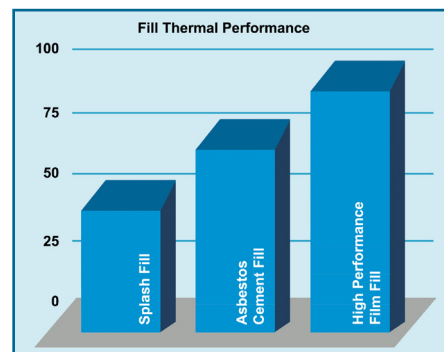


Figure 3. Relative Thermal Performance of Different Types of Fill.

There are several variations of film fill geometries commercially available, and though they do greatly increase the heat rejection rate over splash-type fills, they are also much more susceptible to fouling, scaling, and microbiological growth (these are discussed in greater

detail in the System Concerns section). Development of any of these problems greatly reduces the cooling efficiency and in severe cases can collapse portions of the tower fill or tower structure. To avoid this, film fill should be inspected routinely to ensure it is clean and free of debris, scale, and biological activity.

To minimize losses due to drift and help direct airflow into the tower, louvers and drift eliminators are commonly used. Louvers are most often seen along the sides of the tower structure, while drift eliminators reside in the top section of the tower to capture entrained water droplets that may otherwise leave through the stack. Damaged or incorrectly oriented louvers along with damaged drift eliminators will lead to excessive losses due to drift from the tower structure. Therefore, louvers and drift eliminator sections should be routinely inspected and repaired to ensure optimal water usage.

After the water passes through the fill it cascades down to a collection basin at the base of the tower structure. From the basin the cold water can be pumped back into the system to extract process or comfort cooling needs and begin the cycle all over again.

By design, cooling towers consume large volumes of water through the evaporation process to maintain comfort cooling or process cooling needs, although they use significantly less water than similar capacity once-through cooling systems. Because the evaporative loss is water containing little to no dissolved solids, the water remaining in the cooling tower becomes concentrated with dissolved solids, which can lead to scaling and corrosive conditions. To combat these problems, water with high total dissolved solid content must be drained from the system via “blowdown.” The associated losses caused by blowdown, evaporation, drift, and system leaks must be accounted for by system make-up requirements. Figure 4 illustrates these water system flow locations in generic terms.

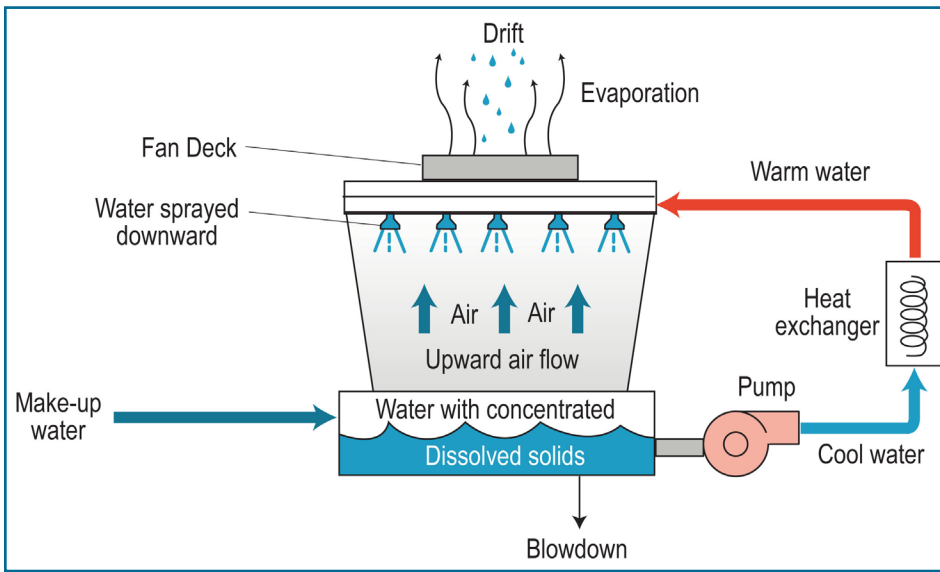


Figure 4. Illustration of Water Flow Across a Cooling Tower.

**Basic Cooling Tower Terms**

**Blowdown** – Water discharged to remove high mineral content system water, impurities, and sediment.

**Cycles of Concentration** – Technical term used to describe the mass flow relationship between the amount of system feed water and the amount of blowdown sent down the drain. Also referred to as concentration ratio, cycles of concentration correlates to the effective use of water in your system to provide heating or cooling needs. High cycles of concentration are directly related to low levels of water loss from your system.

**Dissolved Solids** – The amount of dissolved minerals present in the water.

**Drift** – Droplets of water entrained in the air leaving the top of the tower, or blown from the side of the tower by crosswinds.

**Make-up** – Water supply needed to replace all losses due to evaporation, leaks, or discharge in cooling systems.

**Types of Towers**

**Cooling Towers** – Cooling towers are classified by the direction of air flow (counter-flow or cross-flow) and the type of draft (mechanical or natural).

**Mechanical Draft Towers** – Mechanical draft towers have air forced through the structure by a fan. The air flow can be pushed through

by fans located at the base of the tower (referred to as forced draft), or pulled through by fans located at the top of the tower (referred to as induced draft). Induced draft towers tend to be larger than forced draft units.

**Natural Draft Towers** – Natural draft towers are designed to move air up through the structure naturally without the use of fans. They use the natural law of differing densities between the ambient air and warm air in the tower. The warm air will rise within the chimney structure because of its lower density drawing cool ambient air in the bottom portion. Often times these towers are very tall to induce adequate air flow, and have a unique shape giving them the name “hyperbolic” towers (see Figure 5).



Figure 5. Hyperbolic Cooling Towers (Source: Victor Vizuz).

**Cross-Flow Towers** – Cross-flow cooling towers are structured so that air flows horizontally across the falling water (see Figure 6). This design provides less resistance for the air flow, thereby reducing the fan horsepower required to meet the cooling demand. These towers usually feature gravity-fed water distribution decks that are either open and uncovered, or that are covered to limit algae growth and debris from getting into the distribution deck. Gravity-fed distribution decks have evenly spaced openings that the water drops through to be spread across the tower fill.

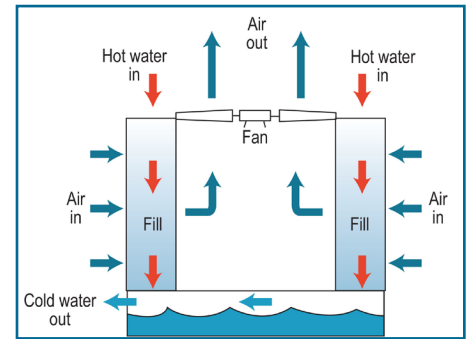


Figure 6. Example Cross-flow Cooling Tower.

**Counter-flow Towers** – Counter-flow cooling towers have upward air flow that directly opposes the downward flow of the water providing very good thermal efficiency because the coolest air contacts the coolest water (in the bottom section of the tower structure).

**Important Properties of Water**

A primary consideration for the operation of the cooling tower system is the water quality of the make-up source. Differing sources present differing challenges. Surface water sources include lakes, rivers, and streams, while groundwater sources consist of wells or aquifers. Depending on the location, surface water sources will have seasonal variations and can carry high levels of suspended silt and debris that cause fouling if not removed by pre-filtration systems. Groundwater sources don’t have the seasonal variations that surface water sources have, but depending on the geology of the region, they can have high levels of dissolved minerals that contribute to scale formation or corrosion in the



cooling system. Recently, water reuse has become popular and many cooling systems are being supplied reclaimed effluent or discharge water from other processes. While water reuse is a wise resource option, consideration should be made regarding the quality of the water and how that will impact the efficient operation of the cooling system, and the system's ability to meet the required cooling demand.

Whether the source water is surface, ground, or reuse, in nature there are a few basic water quality considerations that should be understood.

**pH** – pH is a measurement of how acidic or how alkaline a substance is on a scale of 0 to 14. A pH of 7.0 is neutral (the concentration of hydrogen ions is equal to the concentration of hydroxide ions), while measurements below 7.0 indicate acidic conditions, and measurements above 7.0 indicate basic or alkaline conditions. The pH scale is logarithmic (each incremental change corresponds to a ten-fold change in the concentration of hydrogen ions), so a pH of 4.0 is ten times more acidic than a pH of 5.0 and one hundred times more acidic than a pH of 6.0. Similarly, a pH of 9.0 is ten times more basic or alkaline than a pH of 8.0 and one hundred times more alkaline than a pH of 7.0.

**Hardness** – Hardness refers to the presence of dissolved calcium and magnesium in the water. These two minerals are particularly troublesome in heat exchange applications because they are inversely soluble – meaning they come out of solution at elevated temperatures and remain soluble at cooler temperatures. For this reason calcium and magnesium-related deposits will be evident in the warmest areas of any cooling system, such as the tubes or plates of heat exchangers, or in the warm top regions of the cooling tower fill where most of the evaporation occurs.

**Alkalinity** – Alkalinity is the presence of acid neutralizing, or acid buffering minerals, in the water. Primary contributors to alkalinity are carbonate ( $\text{CO}_3^{2-}$ ), bicarbonate ( $\text{HCO}_3^-$ ), and hydroxide

(OH<sup>-</sup>). Additional alkaline components may include phosphate ( $\text{PO}_4^{3-}$ ), ammonia ( $\text{NH}_3$ ), and silica ( $\text{SiO}_2$ ), though contributions from these ions are usually relatively small.

**Conductivity** – Conductivity is a measurement of the water's ability to conduct electricity. It is a relative indication of the total dissolved mineral content of the water as higher conductivity levels correlate to more dissolved salts in solution. Conversely, purified water has very little dissolved minerals present meaning the conductivity will be very low.

## System Calculations

To properly operate and maintain a cooling tower, there needs to be a basic understanding of the system water's use. Water use of the cooling tower is the relationship between make-up, evaporation, and blowdown rates. There are a couple simple mathematical relationships between the blowdown rate, evaporation rate, make-up rate, and cycles of concentration of a cooling tower that are very useful to understand the principal flow rates. The first relationship illustrates the overall mass balance consideration around a given cooling tower:

$$(1) \text{ Make-up} = \text{Blowdown} + \text{Evaporation}$$

In this case, the blowdown accounts for all system losses including leaks and drift, except for evaporation.

The second principal relationship defines cycles of concentration in terms of make-up flow and blowdown flow:

$$(2) \text{ Cycles of Concentration} = \text{Make-up} \div \text{Blowdown}$$

This equation can be rearranged to either of the following to solve for the make-up rate or blowdown rate:

$$(3) \text{ Blowdown} = \text{Make-up} \div \text{Cycles of Concentration}$$

$$(4) \text{ Make-up} = \text{Cycles of Concentration} \times \text{Blowdown}$$

If the evaporation rate and cycles of concentration are known, the blowdown rate can then be determined by substituting equation 4 into equation 1:

$$(5) \text{ Cycles of Concentration} \times \text{Blowdown} = \text{Blowdown} + \text{Evaporation}$$

Solving for blowdown:

$$(6) \text{ Blowdown} = \text{Evaporation} \div (\text{Cycles of Concentration} - 1)$$

Also, if the blowdown rate and cycles of concentration are known, the make-up rate can be determined by solving equation 4, and then the evaporation rate can be determined by solving equation 6 for evaporation:

$$(7) \text{ Evaporation} = \text{Blowdown} \times (\text{Cycles of Concentration} - 1)$$

## Factors That Limit Cycles of Concentration

Increasing cycles of concentration saves water because it essentially means that water is being recirculated longer through the system before being blown down. But as levels of dissolved minerals elevate with higher cycles of concentration, scaling and corrosion potential also increase. All dissolved minerals have a saturation limit that, if exceeded, will lead to scale formation.<sup>(2)</sup> Additionally, high levels of dissolved minerals (high cycles of concentration) increases the water's tendency to be corrosive (corrosion is discussed in greater detail below). Chemical and mechanical treatment programs allow the thresholds of scaling tendencies and corrosion to be pushed; however, limits still persist necessitating management of dissolved minerals (conductivity) levels through elimination of high mineral content water through blowdown. The following section discusses these concerns in greater detail.

## System Concerns

Cooling towers are dynamic systems because of the nature of their operation and the environment they function within. Tower systems sit outside, open to the elements, which makes them susceptible to dirt and debris carried by the wind. Their structure is also popular for birds and bugs to live in or around, because

(2) Scaling will occur predominantly in the heat exchangers and in the fill-section of the tower structure, but may also occur in the piping or on the tower distribution deck.

of the warm, wet environment. These factors present a wide range of operational concerns that must be understood and managed to ensure optimal thermal performance and asset reliability. Below is a brief discussion on the four primary cooling system treatment concerns encountered in most open-recirculating cooling systems.

**Corrosion** – Corrosion is an electrochemical or chemical process that leads to the destruction of the system metallurgy. Figure 7 illustrates the nature of a corrosion cell that may be encountered throughout the cooling system metallurgy. Metal is lost at the anode<sup>(3)</sup> and deposited at the cathode.<sup>(4)</sup> The process is enhanced by elevated dissolved mineral content in the water and the presence of oxygen, both of which are typical of most cooling tower systems.

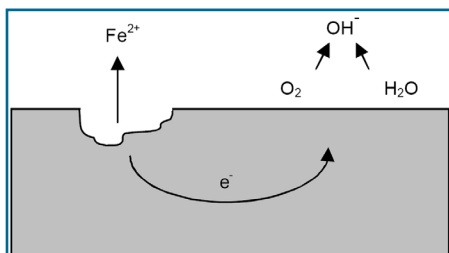


Figure 7. Example of a Corrosion Cell.

There are different types of corrosion encountered in cooling tower systems including pitting, galvanic, microbiologically influenced (Figure 8), and erosion corrosion, among others (expanded discussion is available at [www.gewater.com/handbook/cooling\\_water\\_systems/ch\\_24\\_corrosion.jsp](http://www.gewater.com/handbook/cooling_water_systems/ch_24_corrosion.jsp)). Loss of system metallurgy, if pervasive enough, can result in failed heat exchangers, piping, or portions of the cooling tower itself.

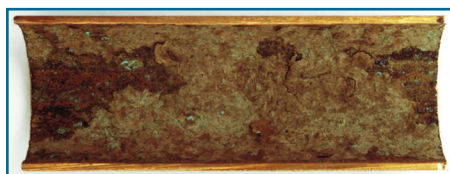


Figure 8. Microbiologically Influenced Corrosion (Source: Taprogge GmbH).

**Scaling** – Scaling is the precipitation of dissolved minerals components that have become saturated in solution. Figure 9 illustrates calcium carbonate scale collecting on a faucet head. Factors that contribute to scaling tendencies include water quality, pH, and temperature. Scale formation reduces the heat exchange ability of the system because of the insulating properties of scale, making the entire system work harder to meet the cooling demand. An expanded discussion for scaling is available at [www.gewater.com/handbook/cooling\\_water\\_systems/ch\\_25\\_deposit.jsp](http://www.gewater.com/handbook/cooling_water_systems/ch_25_deposit.jsp).



Figure 9. Calcium Carbonate Scale (Source: Hustvedt).

**Fouling** – Fouling occurs when suspended particles fall out of solution forming deposits. Common foulants include organic matter, process oils, and silt (fine dirt particles that blow into the tower system, or enter in the make-up water supply). Factors that lead to fouling are low water velocities<sup>(5)</sup>, corrosion, and process leaks. Fouling deposits, similar to scale deposits, impede the heat exchange capabilities of the system by providing an insulating barrier to the system metallurgy. Fouling in the tower fill can plug film fill reducing the evaporative surface

area, leading to lower thermal efficiency of the system.

#### Microbiological Activity –

Microbiological activity is microorganisms that live and grow in the cooling tower and cooling system. Cooling towers present the perfect environment for biological activity due to the warm, moist environment. There are two distinct categories of biological activity in the tower system. The first being planktonic, which is bioactivity suspended, or floating in solution. The other is sessile biogrowth, which is the category given to all biological activity, biofilms, or biofouling that stick to a surface in the cooling system. Biofilms are problematic for multiple reasons. They have strong insulating properties, they contribute to fouling and corrosion, and the bi-products they create that contribute to further micro-biological activity. They can be found in and around the tower structure, or they can be found in chiller bundles, on heat exchangers surfaces, (see Figure 10), and in the system piping. Additionally, biofilms and algae mats are problematic because they are difficult to kill. Careful monitoring of biocide treatments, along with routine measurements of biological activity are important to ensure bio-activity is controlled and limited throughout the cooling system.<sup>(6)</sup>

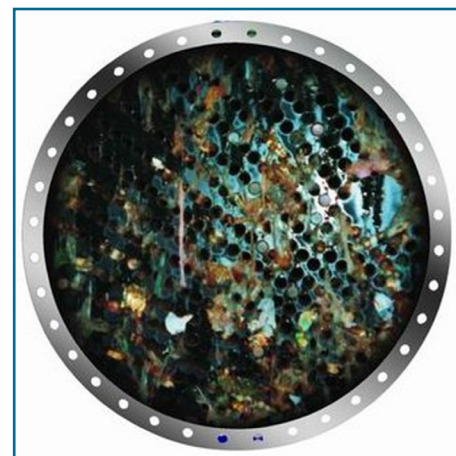


Figure 10. Biofouled Heat Exchanger (Source: Taprogge GmbH).

(3) The anode in a corrosion cell is defined as the site where metal is lost from the system structure and goes into solution.

(4) The cathode in a corrosion cell is defined as the site where the metal lost at the anode is deposited.

(5) Low water velocities may occur in poorly designed or improperly operated heat exchangers, in the cooling system piping, or in locations across the tower fill where uniform distribution is not maintained.

(6) Beyond the operational and mechanical problems bioactivity causes in cooling tower systems, there is a human health issue if the system develops a specific bacterium known as Legionella. For more information regarding Legionella and Legionnaires' disease go to [www.cdc.gov/legionella/patient\\_facts.htm](http://www.cdc.gov/legionella/patient_facts.htm).

## Treatment Options

Traditional water treatment programs are designed and implemented to account for the system concerns outlined above. This ensures the tower system operates optimally and achieves the needed cooling requirement. These programs consist of chemical additives including corrosion inhibitors, dispersants, scale inhibitors, and biocides that function to protect the cooling system and keep heat exchange surfaces clean and free of deposits or bio-films. When this is accomplished, maximum cycles of concentration can be achieved, and the cooling system can be operated at peak efficiency both in terms of water use and energy use. Beyond traditional water treatment programs there are options to build upon the current program, improve the current program, or replace the current program.

**Water Modeling** – Software platforms provide the ability to model the system’s scaling tendencies, corrosion characteristics, and view optimal chemical application (also referred to as “dosing”). This can be a powerful tool to better understand if the system is operating at the maximum cycles of concentration possible, to see problem points in the system (low flow velocity, high temperature heat exchangers, for example), and to see impacts of varying water characteristics. Additionally, these modeling platforms allow a facility to review the potential impact of integrating water reuse resources, altering chemical treatment programs, or variations to certain operational parameters such as pH set-point. In some cases, local and regional water treatment professionals may have the capability to supply similar modeling results as a part of your existing water treatment program or for a consulting fee.

**Green Chemistries** – “Green” chemistry programs exist primarily to replace traditional treatments that have been deemed harmful for environmental reasons. “Green” chemistries often don’t result in improved thermal efficiency or reduced water consumption, but provide environmental compliance and reduced discharge of harmful or illegal substances.

Examples of “green” chemistry programs include polysilicate corrosion inhibitors (used for many years in potable water systems), polyaspartic acid dispersants, and hydrogen peroxide for biocide applications. Another biocide that received the 1997 Environmental Protection Agency (EPA) Green Chemistry Award is THPS – tetrakis (hydroxymethyl) phosphonium sulfate.<sup>(7)</sup>

**Automation** – Automation systems are available providing a broad range of capacities to control single or multiple parameters in the cooling system such as conductivity and blowdown control, pH control, and real-time chemical monitoring and dosing.

Blowdown controllers are available from several different commercial suppliers and offer a range of control points from simple conductivity/blowdown control, to timed or meter relay chemical dosing. Many of them incorporate water meter inputs and alarm relays if threshold measurements are exceeded.

Blowdown controllers offer continuous monitoring and control of the blowdown of the tower system. This ensures high conductivity is avoided, minimizing scaling and corrosive conditions and minimizes excessive blowdown which wastes water. Figures 11 and 12 provide two opposing trends – one showing manual

blowdown control and the other showing blowdown controlled with a conductivity controller. The charts illustrate the impact of implementing blowdown controllers, revealing conductivity rates that stay much closer to the ideal set point compared to manual control.

More robust automation platforms are also available from several manufacturers that provide system-wide monitoring and dosing. These platforms are scalable depending on the need, but offer conductivity/blowdown control, pH control, real-time chemical monitoring and dosing, continuous corrosion monitoring, web-enabled reporting, and alarm relays. The benefit of these systems is tightened control of the various control points of the water treatment program, not only eliminating excessive water use and high cycle conditions, but also controlling chemical residuals and treatment dosing based on real-time corrosion and scaling indices. In trend terms, similar results to the conductivity improvements shown by Figures 11 and 12 can be achieved on chemical treatment residuals, pH set point and acid feed, biocide dosing, and corrosion monitoring. Figures 13 and 14 illustrate the performance improvement real-time dosing achieves on chemical residuals, ensuring the proper dosage of corrosion and scale inhibitors at all times and eliminating overfeed or underfeed of

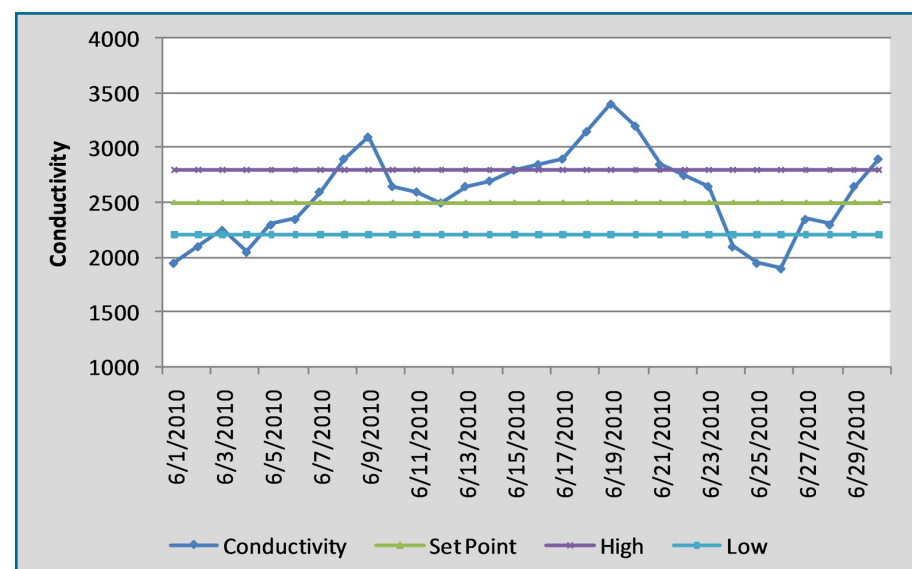


Figure 11. Conductivity Trend for Manual or Timed Blowdown Control.

(7) To view the details of the THPS Green Chemistry Award go to [www.epa.gov/gcc/pubs/pgcc/winners/dgca97.html](http://www.epa.gov/gcc/pubs/pgcc/winners/dgca97.html). The complete list of recipients for the EPA's Green Chemistry Awards is available at [www.epa.gov/gcc/pubs/pgcc/past.html](http://www.epa.gov/gcc/pubs/pgcc/past.html).



these products. These platforms offer web-enabled reporting interfaces so operators and maintenance staff can view tower performance remotely. Additionally, alarms for out-of-compliance measurements can be sent via email or text message alerting maintenance or operations personnel so corrective actions can be taken.

**Filtration** – Filter systems are nothing new to industrial water systems, and have been used as pre-treatment in many different applications for many years. In recent years, side-stream filtration systems have become popular among many water treatment professionals. They function to remove suspended solids, organics, and silt particles down to 0.45 microns from a portion or all of the system water on a continual basis, thereby reducing fouling, scaling and microbiological activity. This allows the cooling system to work more efficiently and often reduces the amount of water blown down. However, the net impact on water consumption must consider the fact that these platforms require back-washing to clean the filter system. The amount of water used to regenerate the filter system should be added to the water lost due to evaporation and blowdown.

**Softening** – Softeners function to remove hardness (calcium and magnesium) from the make-up water, or can be incorporated as a side-stream system to soften a portion of the water continuously. This effectively manages (or eliminates) the amount of calcium and magnesium in the tower bulk water, thereby reducing the scaling potential of calcium and magnesium related deposits. By reducing or eliminating the scaling potential of calcium and magnesium, higher attention should be given to corrosion monitoring and the corrosive characteristics of the water. Calcium and magnesium function naturally as corrosion inhibitors, so if they are minimized or removed from the water, the corrosive conditions will increase putting more importance on the corrosion management program and tighter requirements on pH and alkalinity control.

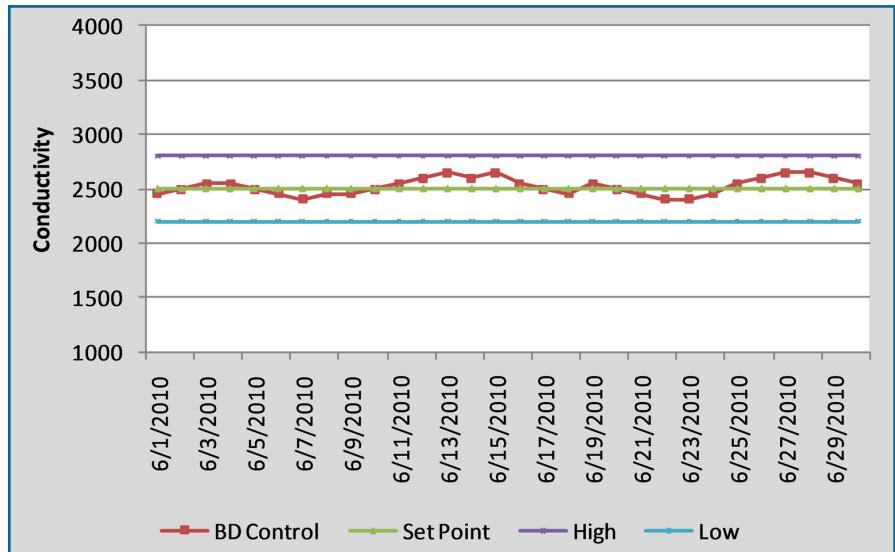


Figure 12. Conductivity Trend for a System Using a Blowdown Controller.

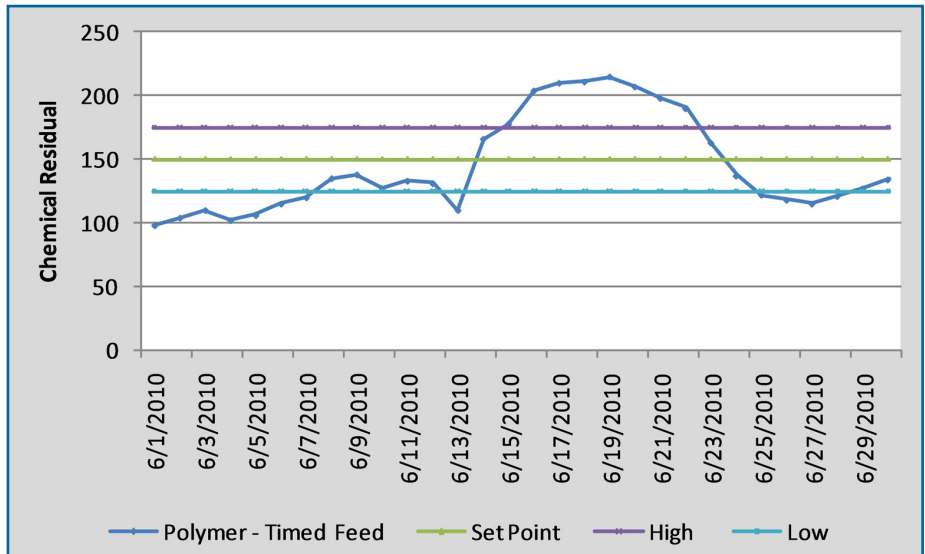


Figure 13. Chemical Residuals Trend for Timed Feed.

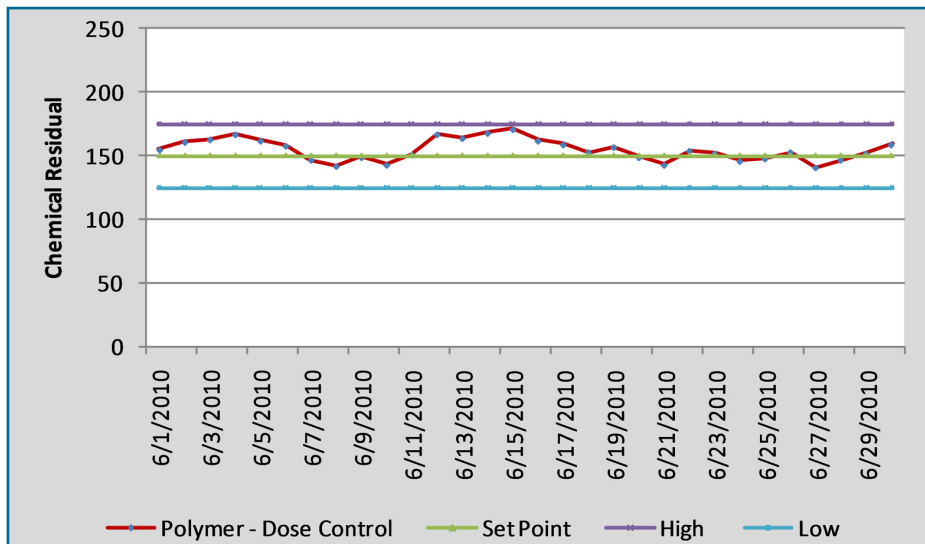


Figure 14. Chemical Residuals with Real-Time Dosing.

**Chemical-free Platforms** – In recent years many innovations have been made in systems that provide chemical-free treatment replacements to traditional treatment platforms. These include systems that are singular in their target treatment, such as ozone<sup>(8)</sup> and ultraviolet biocide systems. These systems are very effective disrupting and eliminating biological activity in the treatment zone, are flexible across a broad pH range, have low operating costs, and no undesirable byproducts. These systems treat an isolated point in the system, so far-reaching parts of the cooling system may have bioactivity due to extended distances from the treatment application point. Additionally, sessile bioactivity in the system beyond the point treatment may not be affected by the ozone and ultraviolet treatments.

There are also other types of comprehensive chemical-free platforms and the market has evolved, offering many different types of platforms, which currently have varying degrees of success in the commercial marketplace. Several have been available for many years, but the evolution of the differing technologies has allowed for many more platforms to be developed.<sup>(9)</sup> The exact mechanisms used to alter the water's characteristics vary from platform to platform, including electromagnetic and hydrodynamic principles as point treatments to control scaling and corrosion along with microbiological activity. Systems that employ electromagnetic principles feature a treatment zone where an electric field courses through the flow of the recirculating water creating a "seeding" mechanism for dissolved minerals, principally calcium carbonate (also known as calcite). The seeding process creates a location for other dissolved minerals to agglomerate, or come out of solution, and then be removed via in-line filtration systems that follow the treatment system. The pulses of electricity also behave to counter

bioactivity by damaging cell walls of potential microbes that pass through the treatment zone. Corrosion is controlled naturally by these systems as they allow the water to run at elevated pH levels, or alkaline conditions.

Similarly, systems employing hydrodynamic cavitation impact the water's characteristics to control scaling, corrosion, and biological activity. Instead of imparting electromagnetic principles to accomplish these ends, hydrodynamic cavitation impacts the water mechanically by rapid changes in pressure and mechanical collision in the treatment zone. Again, scaling is controlled through the seeding mechanism of calcium carbonate (calcite) formation, which in turn collects any other dissolved minerals nearing their respective saturation points and removes them through in-line filtration. Low pressure zones strip the passing water of CO<sub>2</sub>, maintaining naturally alkaline conditions to control corrosion. Lastly, the cavitation process ruptures cell walls of microbes passing through the treatment zone, thereby managing bioactivity in the cooling systems.

These systems and many others like them have case studies and testimonials posted to demonstrate successful replacement of standard treatment options, including energy savings and water efficiency gains. They offer the advantage of reduced or eliminated need for treatment chemicals and have had many successful installations with documented improvements. However, some installations have had difficulty depending on the water quality, especially where the natural tendencies of the source water lean toward corrosive conditions. Furthermore, point treatments may have some difficulty with systems that are extensive and have far reaching-pipe runs or heat exchangers that are a substantial distance from the treatment system itself.

**Water Reuse** – Water reuse options vary depending on the nature of water uses from site to site along with a broad range of other considerations, including local and regional water reuse laws and the availability of an adequate reuse resource. The concept is relatively simple: take discharge water from one application, apply sufficient treatment to it if needed, and then use it as a make-up water resource for the cooling tower system. Two examples of reuse are collecting the condensation from air-handlers and then pumping them back to the tower system make-up, or implementing a reverse osmosis system on the cooling tower blowdown. The condensed water that collects in air handlers is an excellent resource of high quality make-up water for the tower system. Because it is condensation, by nature it will be relatively pure, and therefore will not require much additional treatment to make it sufficient for using as tower make-up water.<sup>(10)</sup> These systems are not difficult to engineer, nor are they typically very capital intensive.<sup>(11)</sup>

Reverse osmosis (RO) systems (similar to Figure 15) are common in many

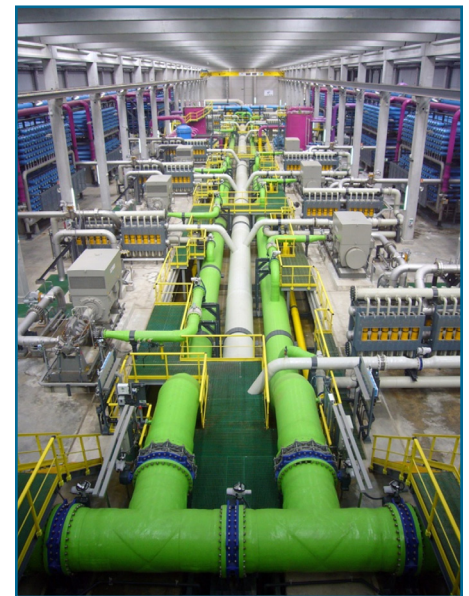


Figure 15. Desalination Plant Using Reverse Osmosis Technology (Source: James Grellier).

(8) Ozone is a reactive form of oxygen that has strong oxidizing characteristics making it very effective at controlling microbiological activity.

(9) This document features mechanisms of a few different available systems and is not intended to be a comprehensive overview of all commercially available chemical-free water treatment systems. The purity of the water will increase its natural abilities as a solvent and stagnant water systems are ideal for bioactivity. Care should be taken when considering the materials of construction for the collection and distribution system and if needed a small amount of biocide may be needed to minimize bioactivity. Additionally, the corrosion program for the tower system will need to be reviewed or modeled to ensure proper corrosion control steps are taken to protect system metallurgy.

(11) For more information on condensate recovery systems a case study is available at [www.femp.energy.gov/program/waterefficiency\\_csstudies.html](http://www.femp.energy.gov/program/waterefficiency_csstudies.html).



applications including desalination, industrial pre-treatment platforms, and applications where the purity requirements for water are very high. In the case of water reuse from a tower system, the blowdown water would be sent directly into an RO system, which would purify a portion of the water (the permeate flow) and concentrate the bulk of the dissolved minerals into a smaller waste

stream (the concentrate flow) that would be discharged from the system. These systems can be difficult to operate correctly, and are expensive to purchase and operate. However, locations where water resources are limited or discharge permits prohibit excessive cooling tower blowdown, RO platforms are a consideration to minimize the overall losses from a cooling system.

## Where to Get More Information

FEMP Water Efficiency:  
[www.femp.energy.gov/program/waterefficiency.html](http://www.femp.energy.gov/program/waterefficiency.html)

Cooling Technology Institute:  
[www.cti.org/](http://www.cti.org/)

American Society of Heating,  
Refrigeration, and Air-Conditioning  
Engineers:  
[www.ashrae.org/](http://www.ashrae.org/)

American Society of Mechanical  
Engineers:  
[www.asme.org/](http://www.asme.org/)

If questions remain, contact:

Will Lintner  
Federal Energy Management Program  
(202) 586-3120  
[William.Lintner@ee.doe.gov](mailto:William.Lintner@ee.doe.gov)

Brian Boyd  
Pacific Northwest National Laboratory  
(509) 371-6724  
[Brian.Boyd@pnl.gov](mailto:Brian.Boyd@pnl.gov)

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### EERE Information Center

1-877-EERE-INFO (1-877-337-3463)  
[www.eere.energy.gov/informationcenter](http://www.eere.energy.gov/informationcenter)

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