



PDHonline Course M248 (3 PDH)

Managing Water Consumption in Cooling Systems

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2020

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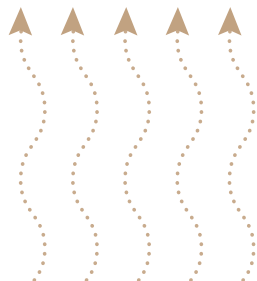
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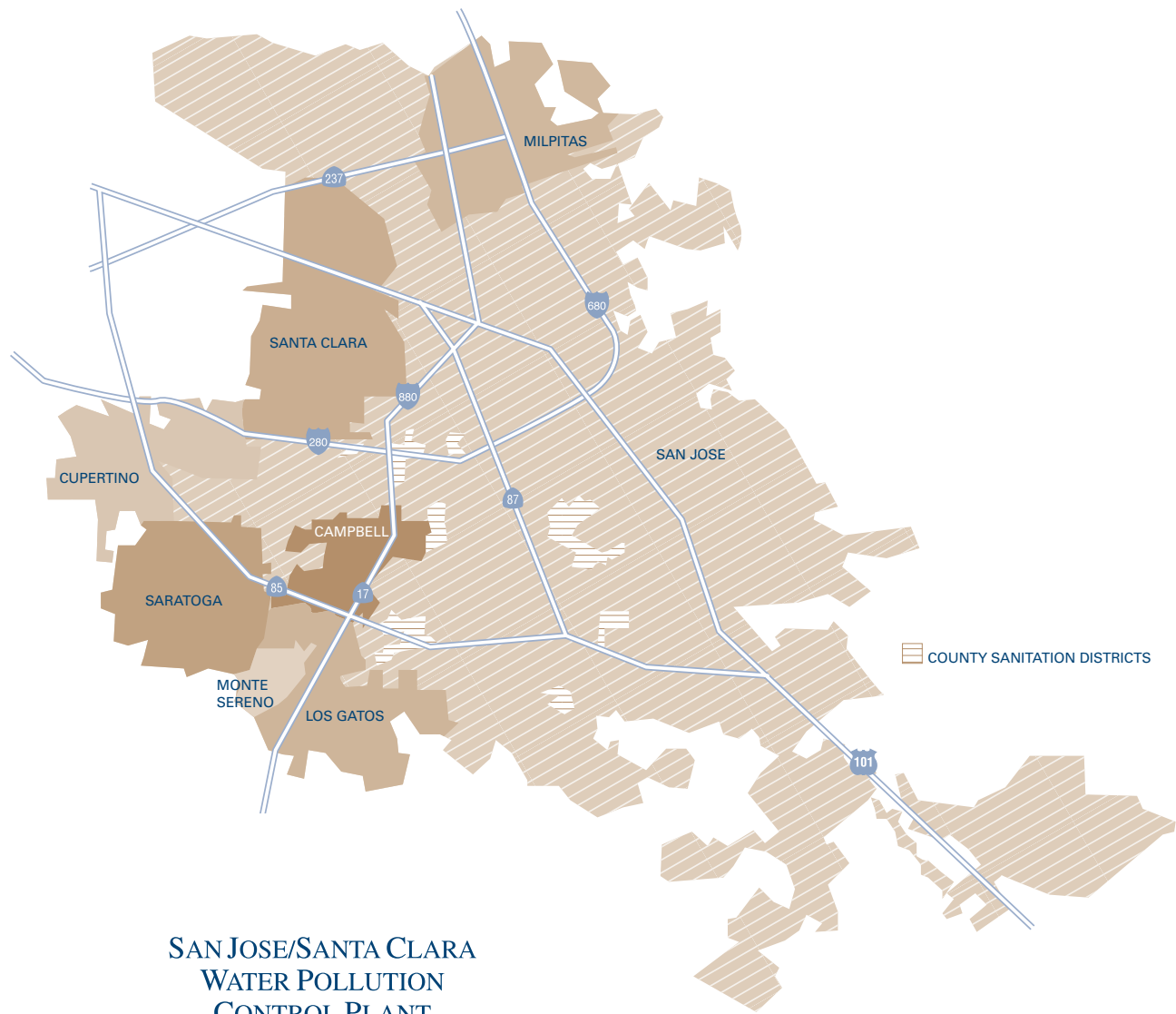
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Guidelines for Managing Water in Cooling Systems

For Owners, Operators, and Environmental Managers





SAN JOSE/SANTA CLARA WATER POLLUTION CONTROL PLANT

The Plant is owned by the Cities of San José and Santa Clara, and is operated by the San José Environmental Services Department on behalf of the tributary agencies.

Tributary Agencies

- Burbank Sanitary District
- Cupertino Sanitary District
- City of Milpitas
- Santa Clara County Sanitation Districts No. 2 – 3
- Sunol Sanitary District
- West Valley Sanitation District
 - Serving:
 - City of Campbell
 - Town of Los Gatos
 - City of Monte Sereno
 - City of Saratoga

Acknowledgments

Development of this guideline has been supported by:

San Jose/Santa Clara Water Pollution Control Plant and the City of San José Environmental Service Department.

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It should be noted that the ideas presented in these Guidelines are not intended as an endorsement by the City of San José or the San Jose/Santa Clara Water Pollution Control Plant of any particular method, process or product. They are suggestions for your consideration.

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Introduction

In today's fast-paced markets, knowing where to focus cost reduction efforts is essential for remaining competitive. The production line is often the primary focus of cost reduction analysis. But a good environmental manager—given the necessary support from an organization's leadership—can help reduce costs by optimizing support operations, such as those that rely on water. Attention to water conservation is good business. It has a direct impact on the bottom line: less water consumed means less water purchased, less water treated, and less water discharged.

Cooling systems are often a good candidate for water reductions. Whether the outcome is optimizing the use of costly potable water or changing the feed water to a recycled source, modifying the way a cooling system operates can mean big water savings. In turn, this savings results in lower water and sewer bills and decreased waste treatment cost for a facility. Maximizing water efficiency can also support a company seeking to protect its future growth, where limitations to capacity are a challenge.

Why We are Asking Customers to Reduce Discharges

The San Jose/Santa Clara Water Pollution Control Plant is one of the largest advanced wastewater treatment facilities in California. It treats and cleans the wastewater of over 1,500,000 people that live and work in the 300-square mile area encompassing San José, Santa Clara, Milpitas, Campbell, Cupertino, Los Gatos, Saratoga, and Monte Sereno.

The Plant seeks to protect the salt marsh habitat of two endangered species by preventing its “fresh water” effluent from converting saltwater marsh to fresh water marsh. As a result, the Plant fosters flow reduction measures that will reduce discharges of treated and clean effluent to the Bay. The Plant has achieved lower flows by:

- Communicating the importance of water conservation and protection of the Bay to residences and businesses;
- Implementing water conservation measures with industry;
- Promoting the installation of Ultra Low Flush Toilets; and
- Providing recycled water for irrigation and industrial uses through the South Bay Water Recycling (SBWR) program.

Using this Guide

This guide examines three strategies for maximizing water efficiency in cooling systems:

- Optimizing operation by minimizing water and chemical usage,
- Reusing other waters at a facility as source water, and
- Using South Bay Water Recycling water as an alternate water source.

The guide focuses on cooling towers as the most common type of cooling system component where water savings can be realized. It begins with a discussion of the operational basics of a cooling tower, such as function and water use. The guide provides the necessary steps to successfully implement water conservation measures and includes considerations related to water quality, ongoing operations, and vendor involvement.

These guidelines are intended to support the needs of facility owners, cooling system operators, and environmental managers. Along the way, the special icons (as shown at left) draw attention to money-saving ideas and special notes.

Cooling system operations are different for each company, and what works in one situation may not necessarily work in another. However, with careful analysis, facilities are likely to achieve high performance with less waste from cooling systems, without adversely impacting the cooling system equipment. In doing so, facilities create the opportunity to save water, save money, and participate in the protection of our South Bay environment.

Icons



Take Special Note
or Caution



Money-Saving Ideas

1 Understanding the Principles of Operation

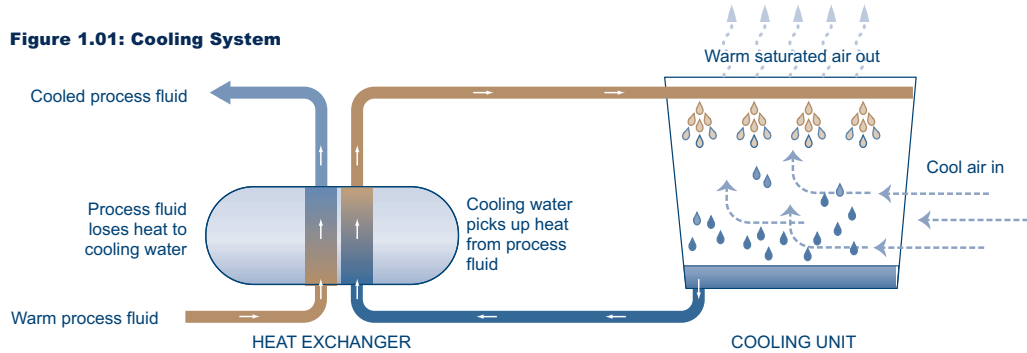
Cooling Systems Basics

SECTION HIGHLIGHTS

- Cooling systems are composed of two components: a **heat exchanger** and a **cooling unit**.
- The **heat exchanger** allows cooling water to remove heat from production and facility equipment or fluids without direct contact.
- The **cooling unit** removes the heat gained from the contact of cooling water with hot equipment and fluids in the heat exchanger. The heat is removed from the returning cooling water by transferring the heat to air through evaporation.
- **Splash and film fill** are the two types of packing materials inside the cooling towers that improve the contact of air and water to increase cooling inside the tower.

A cooling system, shown in Figure 1.01, consists of a heat source (called a heat exchanger) and a cooling unit (a cooling tower or an evaporative condenser).

Figure 1.01: Cooling System

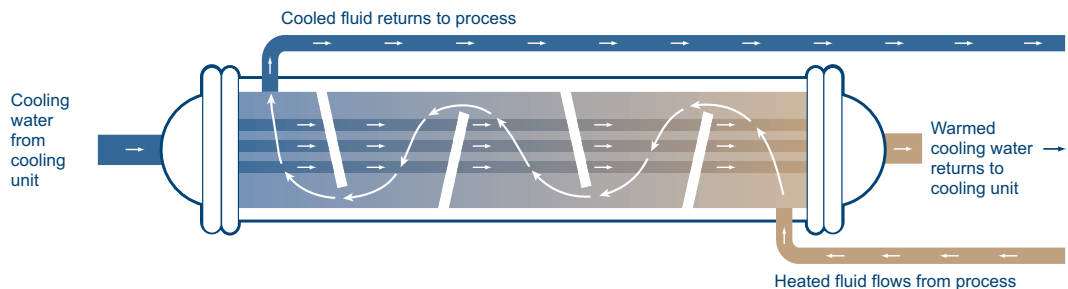


Heat Exchangers

A heat exchanger, shown in Figure 1.02, allows cool media, usually water, to contact and cool production and facility equipment or fluids.

A heat exchanger can take the form of production equipment, air conditioning units, distillation columns, or heat exchanger units.

Figure 1.02: Cooling System Heat Exchanger



Cooling Units

The purpose of a cooling system is to transfer heat from one source or medium to another. In a cooling system with a cooling tower, cool water is pumped away from the cooling tower and is circulated through hot equipment (usually through a separate piping system in a heat exchanger). A heat exchange occurs: the equipment is cooled, and the water from the cooling tower becomes warmer. The warmed water then returns back to the cooling tower. In the cooling tower the warmed water is sprayed downward, and air is blown upward with a fan. As the warm water droplets contact the air, some of the water droplets evaporate, and the air absorbs the heat released from this evaporation—thereby lowering the temperature of the remaining water.

An outside source of water, commonly referred to as “makeup water,” adds more water to the system to make up for evaporation and other water losses. Then the water is recirculated back to the heat exchanging equipment and the process is repeated.

Typical Cooling Systems

Information in this booklet usually refers to one of two significantly different designs of evaporative cooling water systems. Those systems are **Evaporative Condensers** and **Cooling Towers**. All of the systems discussed here cool a circulating stream of water by evaporating a portion of it. Evaporative Condensers keep water that is being evaporated for heat removal isolated from fluid being circulated for heat transfer from the process. Cooling towers circulate the same fluid (water) to accomplish both heat transfers. Illustrations and schematics for typical cooling tower configurations are shown below.

Counter Flow Induced Draft Cooling Tower

Counter Flow Induced Draft Cooling Tower

In counter flow induced draft cooling towers, the water being cooled moves from the top down through the tower, while air is "pulled" in the "counter direction," from the bottom up.

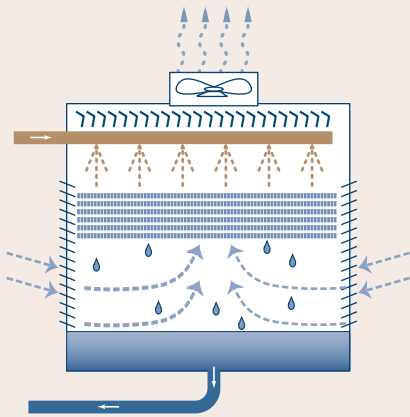
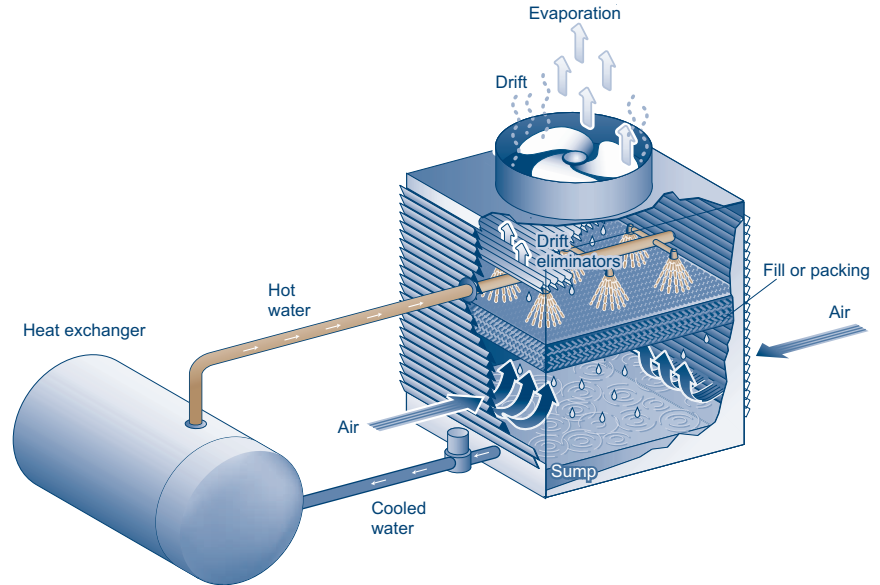


Figure 1.03: Counter Flow Induced Draft Cooling Tower



Cross Flow Induced Draft Cooling Tower

Cross Flow Induced Draft Cooling Tower

In cross flow induced draft cooling towers, the water being cooled moves from the top down through the tower, while air moves "across" through the water flow and then out the exhaust. Air is moved by fans, blowers, or natural draft.

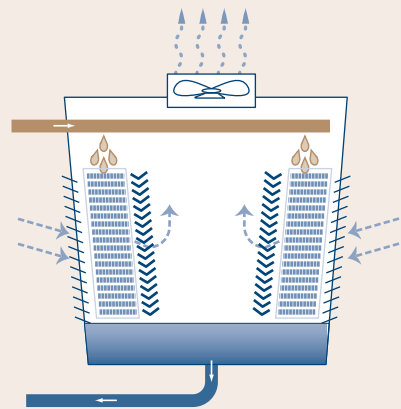
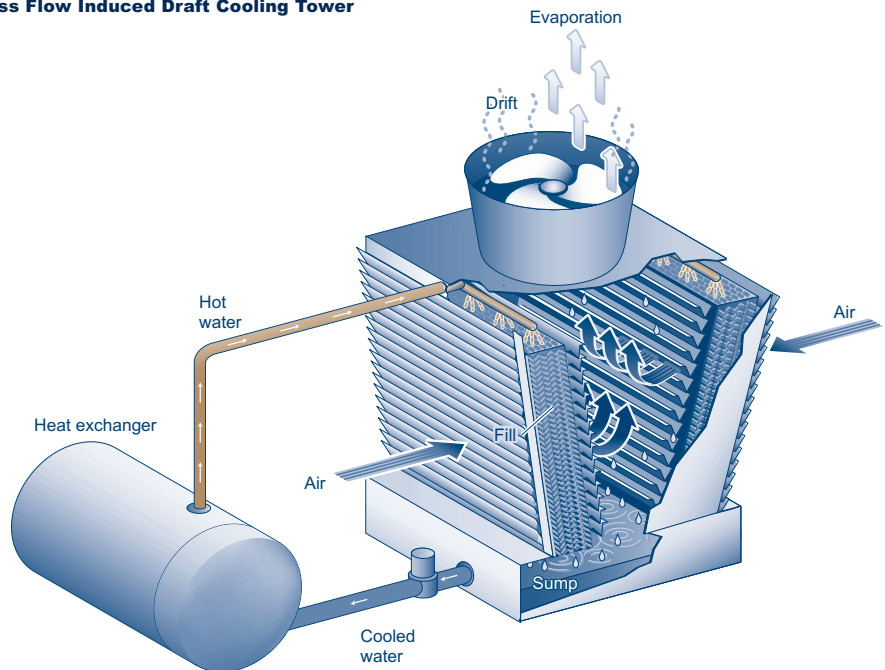


Figure 1.04: Cross Flow Induced Draft Cooling Tower



Packing Materials

Some cooling towers have slats of wood or plastic that are horizontally and vertically separated in a staggered pattern. These slats are known as splash fill. Hot water falls onto a cooling tower distribution deck and then splashes down onto the top slats before cascading down to the lower slats. The splashing causes the water to disperse into droplets thereby increasing the contact of

water and air. Other cooling towers use film fill made of corrugated plastic sheets that have been joined into blocks that have a honeycombed appearance. Hot water falling onto the distribution deck forms a surface film as it channels through the fill down to the cooling tower basin. Both splash and film fill are known as the **packing materials** of the cooling towers.

Forced Draft Cooling Tower

Forced Draft Cooling Tower

In forced draft cooling towers, air is "pushed" through the tower from an inlet to an exhaust. Downward direction for movement of the water being cooled is shown here.

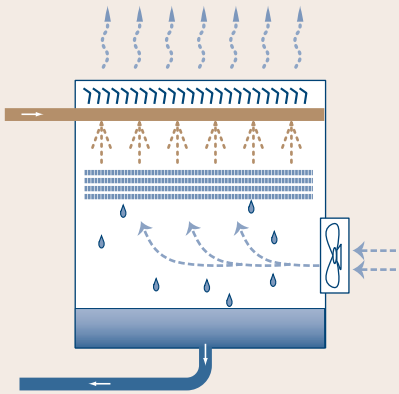
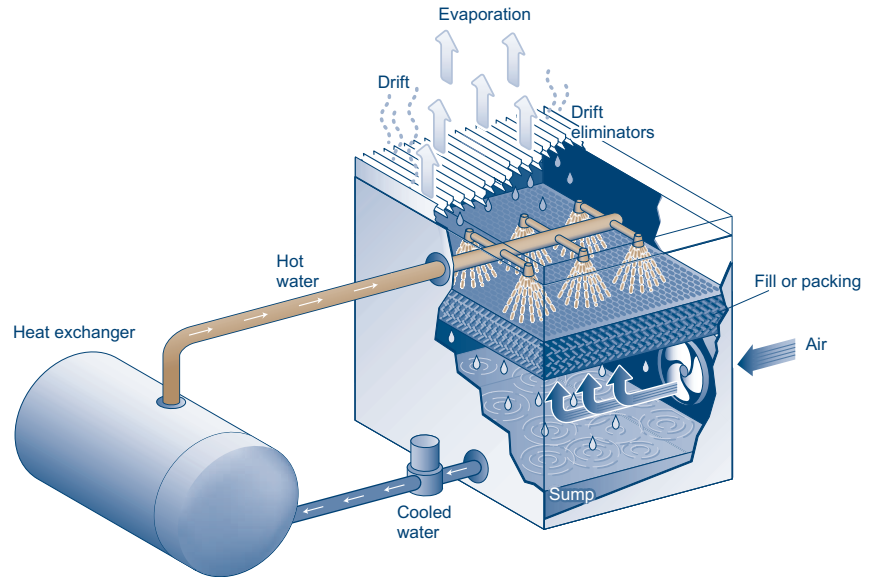


Figure 1.05: Forced Draft Cooling Tower



Evaporative Condenser Cooling Unit

Evaporative Condenser Cooling Unit

In evaporative condenser cooling units, the fluid that removes heat from the process is kept isolated from the water used for evaporative cooling. The cooling water is never circulated to the process it cools. Some systems use condensable fluids or refrigerants for transferring heat.

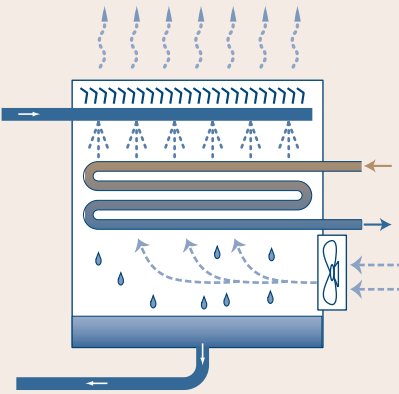
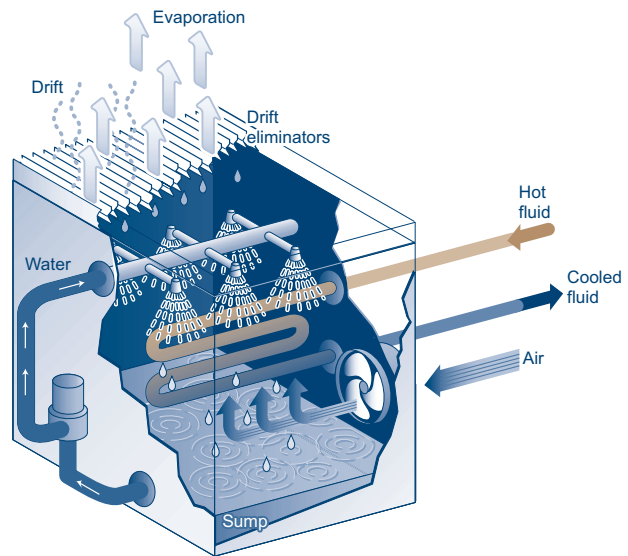


Figure 1.06: Evaporative Condenser Cooling Unit

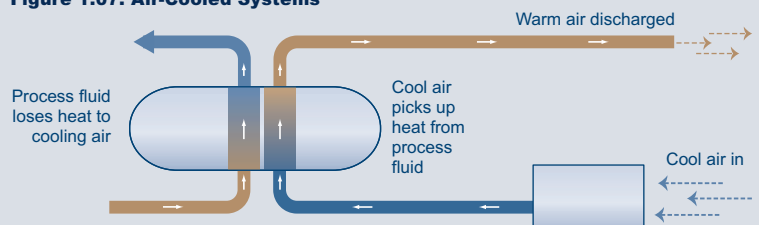


Air-Cooled Systems

An air-cooled system (also referred to as mechanical refrigeration) uses cool air instead of water in the heat exchanger; therefore, there is no cooling tower.

Although air-cooled systems perform as effectively as water-cooled systems, these systems use energy less efficiently and may require more space to handle equivalent cooling loads. Cost evaluation should compare the capital, energy, and reduced space costs to the water savings.

Figure 1.07: Air-Cooled Systems



Water Use in Cooling Towers

SECTION HIGHLIGHTS

The previous section described the basic equipment used to transfer heat from process equipment and fluids. This section quantifies how much water is used in the cooling system to achieve this goal.

- **Blowdown** is a portion of the concentrated cooling tower water intentionally discharged from the cooling tower to maintain an acceptable water quality in the cooling tower.
- **Makeup water** is the new water added to compensate for the volume of water lost through evaporation, blowdown, and other water losses.
- The **cycle of concentration** is the number of times the solids content of the cooling water is increased in multiples of itself, such as twofold, threefold, etc.
- Cooling towers use large amounts of water and are excellent opportunities to conserve water.

Evaporation

The purpose of a cooling tower is to transfer heat from the cooling water to the air by evaporation. Cooling towers usually cool circulated water 10°F in air conditioning systems and 15°F to 30°F in power plants and in manufacturing facilities such as electronics, chemical plants, etc.

As a rule of thumb, for each 10°F that the circulated water needs to be cooled, one percent of the cooling water is evaporated in the cooling tower.

The following example uses this relationship to estimate the evaporation rates for various circulated cooling water temperature reductions.

Equation 1.01

$$\text{EVAPORATION RATE} = \text{Recirculated Flow Rate} \times (\text{Warm Water Temperature} - \text{Desired Cool Temperature}) \times 0.01/10^\circ\text{F}$$

(1% evaporation per each 10°F temperature reduction)

Example 1a

A cooling tower system currently circulates water at the rate of 1,000 gallons per minute (gpm) and the cooling tower needs to cool the warmed water exiting the heat exchanger from 90°F to 80°F degrees (or reduce the temperature of the water by 10°F).

To determine evaporation rate, apply **Evaporation Rate Formula** (Equation 1.01):

$$\text{Evaporation Rate} = \text{Recirculated Flow Rate} \times (\text{Warm Water Temperature} - \text{Desired Cool Temperature}) \times .01/10^\circ\text{F}$$

Evaporation Rate = 1,000 gpm X (90°F - 80°F) X 0.01/10°F = **10 gpm**

Therefore, for the given 1,000 gpm circulated water, 10 gpm needs to be evaporated to reduce the warm water from 90°F to 80°F.

Table 1.01 shows the gallons of water evaporated daily, monthly, and yearly; to achieve 10°F, 20°F, and 30°F changes in water temperature.

Table 1.01

Temperature Reduction	Water Evaporated		
	Per Minute	Per Day	Per Year
10°F	10 gal	14,400 gal	5,256,000 gal
20°F	20 gal	28,800 gal	10,512,000 gal
30°F	30 gal	43,200 gal	15,768,000 gal

*System operates 24 hours/day, 365 days/year

Cooling Tower Capacity

Cooling Towers are usually described by their tons of cooling capacity.

The cooling capacity indicates the rate at which the cooling tower can transfer heat.

One ton of cooling is equal to 12,000 BTUs (British thermal units) per hour, or 200 BTUs per minute.

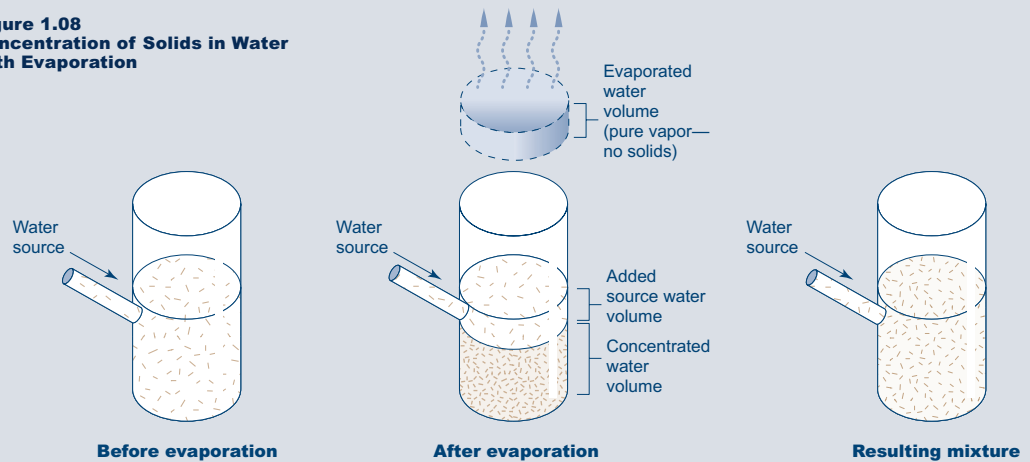
Cooling tower capacities at commercial, industrial, or institutional facilities typically range from as little as 50 tons to as much as 1,000 tons or more. Large facilities may be equipped with several large cooling towers.

To chill 100 pounds of water by 10°F, one pound of water must be vaporized (converted from a liquid state to a gas). In the English measurement system, 1,000 BTUs are required to evaporate one pound of water. However, the ambient temperature and humidity also impact the heat transfer rate as well.

Makeup Water and Blowdown

Any water source has various levels of dissolved or suspended solids. When water evaporates from the system, these solids are left behind, causing the remaining cooling tower water to become more concentrated. In order to continue to recirculate the same volume of water back through the cooling system, more source water needs to be added to the system. Again, this source water contains solids. Therefore, although the source water helps to dilute the concentrated recirculated stream, the fact that the source water also contains some solids results in a net increase in concentration of solids in the recirculated stream. Therefore, as the system recirculates the water in the cooling tower, the water's impurities become more and more concentrated as shown in Figure 1.08.

Figure 1.08
Concentration of Solids in Water with Evaporation



In Figure 1.08, the first container is the water before evaporation. In the second container, some of the water has evaporated. The bottom layer represents the volume of water left over after this evaporation. The top layer represents the source water added to make up for water volume lost to evaporation. Altogether, the resulting mixture has the same volume of water as the first container but contains more solids and is, therefore, more concentrated.

Concentrated solids can build up in the form of scale, causing blockages and corrosion to the cooling system materials. Also, the multiplication of algae and other biological matter can lead to corrosion, plugging of film fill, and eventually collapse of film fill.

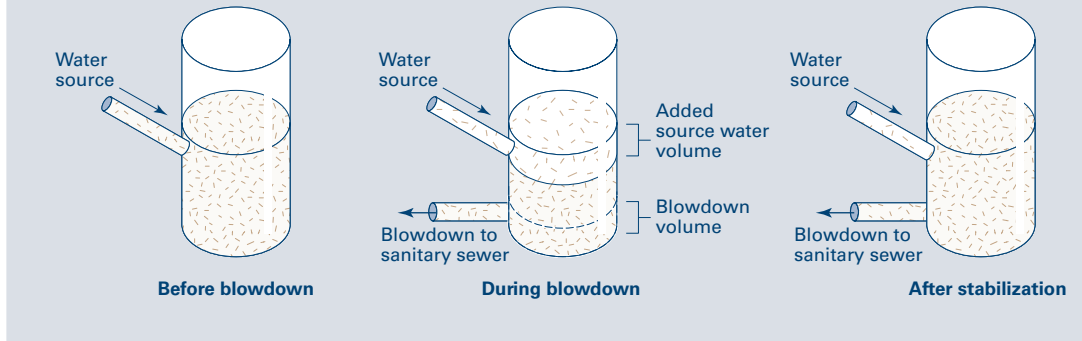
The solids and biological matter must be removed from the system before their concentrations reach levels that cause serious damage. Water treatment can reduce the impact of the solids and biological matter, however, after a certain point impurities become too concentrated for the water to be reused cost-effectively. The maximum acceptable level for these materials are site specific for each cooling tower due to several variables that will be discussed in the next section.

To stay below this maximum acceptable concentration and to maintain the tower's water balance, new water needs to be added to the cooling tower (called makeup water) and a portion of the concentrated cooling tower water needs to be discharged from the cooling tower (called blowdown or bleed). See Figure 1.09, next page.



In the past, some cooling systems did not recirculate cooling tower water. This practice, known as **ONCE-THROUGH COOLING**, is no longer allowed for systems using potable water. Most cooling towers range from four to six cycles of concentration.

Figure 1.09
Blowdown Process



In Figure 1.09, the first container is the mixed result after evaporation, as shown in Figure 1.08. In the second container, the bottom layer represents the volume of concentrated cooling water to be removed from this container as blowdown and the top layer represents the volume from the original water source added to make up for the water lost through blowdown. The third container shows the stabilization of this process as water is evaporated, blown down, and made up continuously.

Therefore, blowdown reduces the amount of solids and biological matter in the cooling tower by removing a portion of the concentrated solids. “Fresh” makeup water then dilutes the remaining cooling tower water by replacing the water volume lost through blowdown, evaporation, drift (water droplets that escape through the plume of the cooling tower), and other losses, such as leaks.

Cycles of Concentration

A **cycle of concentration** occurs when the water balance of evaporation, makeup water and other losses concentrates the cooling tower’s solids by a multiple of the makeup water. For instance, when the solids concentration in the tower has doubled or tripled its concentration over that of the makeup water, then there are two or three cycles of concentration. See Table 1.02 for an example of a cooling tower water balance at various cycles of concentration.

Equation 1.02

$$\text{NUMBER OF CYCLES OF CONCENTRATION} = \text{Cooling Water Concentration} \div \text{Makeup Water Concentration}$$

Table 1.02

Water Quality and Cycles of Concentration (CoC)						
Water Status	Conductivity	Total Hardness mg/l as CaCO ₃	Calcium Hardness	Total Alkalinity*	pH**	Silica mg/l
Makeup Water	600	300	150	200	7.5	5
2 CoC	1,200	600	300	400	8.0	10
4 CoC	2,400	1,200	600	800	8.5	20
6 CoC	3,600	1,800	900	1,200	8.8	30
10 CoC	6,000	3,000	1,500	2,000	9.0	50

*with no chemical treatments such as acid **pH is estimated; it may be higher or lower.

When the cycle of concentration is left at **one** (i.e. not concentrated), all water left in the tower after evaporation needs to be removed as blowdown. This is called **single pass** or **once-through cooling** and is **PROHIBITED** in the area served by the San Jose/Santa Clara Water Pollution Control Plant.

This unpolluted water is wasted when it is discharged directly to the sanitary sewer system. In the examples on page 4, this would mean discharging the entire 990 gpm that was not evaporated. That is 1,425,600 gallons per day!

If the cycle of concentration is increased, only a portion of water is discharged as blowdown and the rest is recirculated with more new water to make up for the water loss in the blowdown. The following equations quantify the relationships of blowdown, evaporation, and the cycles of concentration based on mass balancing:

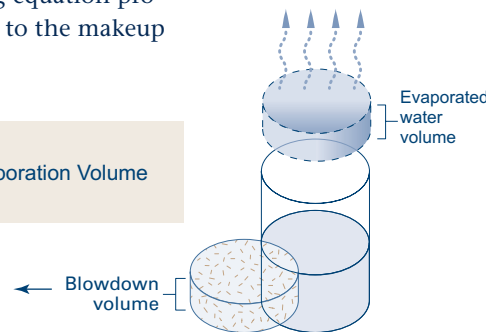
Equation 1.03

$$\text{BLOWDOWN VOLUME} = \text{Evaporation Volume} \div \left[\text{Number of Cycles of Concentration minus 1} \right]$$

To quantify the makeup volume, a volume-balancing equation provides the relationship of blowdown and evaporation to the makeup water volume.

Equation 1.04

$$\text{MAKEUP VOLUME} = \text{Blowdown Volume} + \text{Evaporation Volume}$$



Example 1b illustrates the large volumes of water cooling towers can use. This creates opportunities for appropriate conservation measures to achieve significant water savings.

Example 1b

Continuing with example 1a from page 4, where a 1,000 gpm cooling tower resulted in 10 gpm of evaporation for 10°F of cooling:

Applying Blowdown Volume Formula (Equation 1.03):	Applying Makeup Volume Formula (Equation 1.04):
$\frac{\text{Evaporation Volume}}{\text{Number of CoC minus 1}}$	$\text{Blowdown Volume} + \text{Evap Volume}$
Blowdown = 10 gpm ÷ (2 - 1) = 10 gpm	Makeup = 10 gpm + 10 gpm = 20 gpm

Table 1.03

Cooling Tower Water Balance at 10° Intervals
1,000 gpm Circulating Rate, Two Cycles of Concentration

Temperature Reduction	Circulation Rate	Total Evaporation		Total Blowdown (goes to sanitary sewer)		Total Makeup (from water supply)	
		per minute	per day	per minute	per day	per minute	per day
10°F	1,000 gpm	10 gpm	14,400 gpd	10 gpm	14,400 gpd	20 gpm	28,800 gpd
20°F	1,000 gpm	20 gpm	28,800 gpd	20 gpm	28,800 gpd	40 gpm	57,600 gpd
30°F	1,000 gpm	30 gpm	43,200 gpd	30 gpm	43,200 gpd	60 gpm	86,400 gpd

LEAKS

Usually water volume losses due to leaks in the cooling system are insignificant. However, if leaks are substantial, the water balance equation needs to include the volume of water loss due to leaks, as shown in Equation 1.05. Unintentional water loss may result from mechanical leaks,

drift or spray from the cooling tower, or basin overflow. Drift occurs when water droplets are carried out of the cooling tower by the air flowing through the tower.

Equation 1.05

$$\text{MAKEUP} = \text{Evaporation} + \text{Blowdown} + \text{Leaks}$$

Losses due to drift can be kept small in a properly maintained cooling tower and virtually eliminated with drift eliminators.

Water Conservation Measures

SECTION HIGHLIGHTS

- Water savings of over 40% may be achieved by optimizing the cooling system’s cycles of concentration.
- As long as the water’s quality is acceptable, any process water can be used in a cooling tower, saving money for both water purchased and wastewater discharged.
- SBWR is another cost-effective alternative for replacing potable water in a cooling tower and has proven to be an acceptable alternative where it is available.

Described below are the various strategies for maximizing water efficiency in cooling systems. How to evaluate the applicability of these strategies to a given facility is examined in Chapter 2.

Increasing Cycles of Concentration

Increasing the cycles of concentration to optimize water use is the most common water conservation measure for cooling towers. Determining the optimum number of cycles of concentration is a balancing act between the reduced chemical, water, and sewage costs at higher cycles of concentration versus the increased risk of scale formation. Usually, cooling towers using makeup water with the least amount of solids should be operated at the higher cycles of concentration. However, water with too few solids also brings the risk of corrosion and, therefore, has its own associated chemical treatment costs. Example 1c illustrates water savings from increasing the cycles of concentration.


Example 1c

For the same-sized cooling system as discussed in Examples 1a and 1b (i.e., 1,000 gpm with 10°F temperature reduction) how much water can be saved by increasing the cycles of concentration (CoC)?

Table 1.04

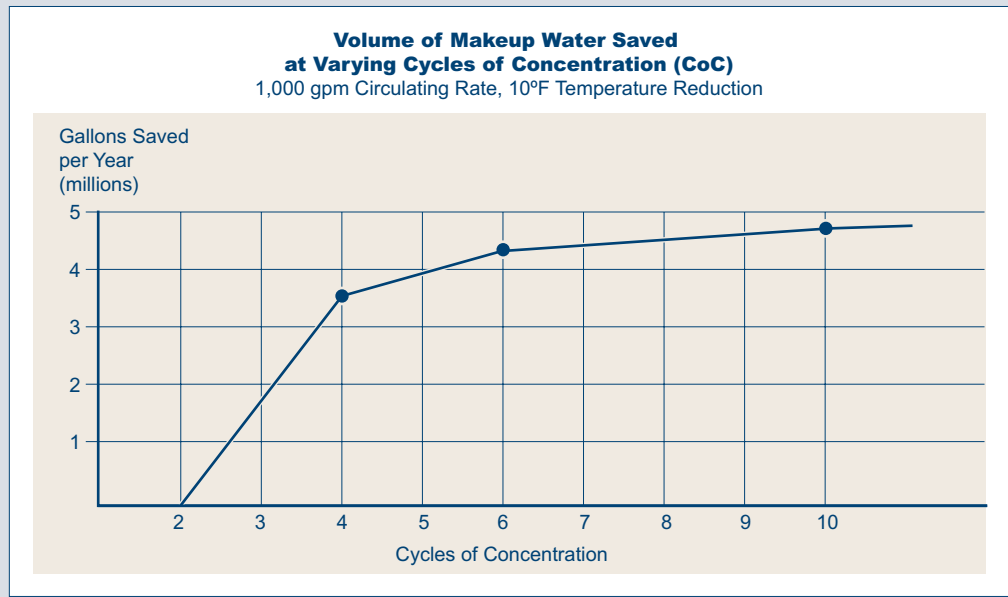
Cooling Tower Water Use: Varying Cycles of Concentration (CoC)						
1000 gpm Circulating Rate, 10°F Temperature Reduction						
Cycles of Concentration (CoC)	Evaporation: 1% (10°F temp reduction)	Blowdown (Evap ÷ [CoC - 1])	Water Added to System (GALLONS)			% of Water Saved
			per minute	per day	per year	
2	10 gpm	10.0 gpm	20 gpm	28,800	10,512,000	—
4	10 gpm	3.3 gpm	13.3 gpm	19,152	6,990,480	33.5%
6	10 gpm	2.0 gpm	12 gpm	17,280	6,207,200	41%
10	10 gpm	1.1 gpm	11.1 gpm	15,984	5,834,160	44.5%

Note that with higher cycles of concentration, analysis of the water quality in the cooling tower becomes more critical.

 *Increasing the cycles of concentration from two to four as in Example 1c would save over 3.5 million gallons of water per year while accomplishing the same amount of cooling!*

Example 1c (continued)

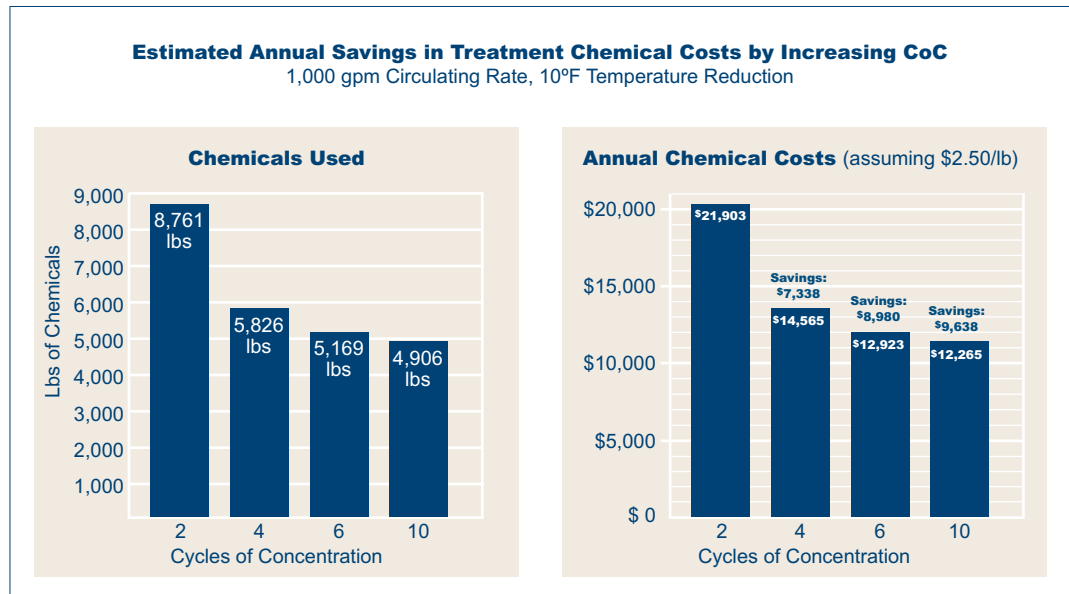
Figure 1.10



Reduction in Treatment Chemical Costs

The 1,000 gpm cooling system evaluated in the examples above can be expected to use 8,761 pounds of treatment chemicals per year at two cycles of concentration. By reducing the amount of makeup water, fewer pounds of treatment chemicals are required. Increasing the cycles of concentration from two to four could save \$7,338 per year in chemical costs; increasing the cycles of concentration from two to six could save \$8,980 per year. (Assumes chemical costs at \$2.50/lb, and maintenance of 100 ppm treatment in the cooling tower water.)

Figure 1.11



Reusing Water from Other Processes

Water replacement with water used from other processes (especially if the cycles of concentration are optimized) can bring the greatest savings for cooling towers. Each gallon of water reused in cooling towers to replace potable water saves on both the costs of the potable water replaced and fees for discharging the process water to the sanitary sewer. In addition, it saves any existing unused sewer and water capacity for company growth and defers additional fees for expansion of collection and treatment facilities.

Any process water can be reused in the cooling tower system, provided the water quality is acceptable. Examples of water to be considered for reuse include softener rinse, condensate, reverse osmosis reject, acid wash neutralization water, and rinse water from electronics manufacturing.

Using SBWR Recycled Water


Throughout California and other states, facilities are substituting recycled water for potable water as cooling tower makeup. In this area, the San Jose/Santa Clara Water Pollution Control Plant treats and disinfects municipal wastewater to produce a high quality effluent that meets the California Code of Regulations Title 22 California Water Recycling Criteria. The South Bay Water Recycling (SBWR) Program is the wholesaler of this highly treated water—known as recycled water—and oversees the development and implementation of recycled water use in this area. SBWR water is currently available to many facilities in San José, Santa Clara, and Milpitas. Additions to the distribution network continue to be made so that this water is available to an increasing number of facilities.

Recycled water is approved for many uses. In fact, California has adopted water conservation regulations under Title 22 requiring that potable water be replaced with recycled water wherever it is available. Thus, recycled water is being used for irrigation; and in evaporative cooling systems, refineries, utility power plants, and manufacturing facilities. This includes air conditioning, electronics, and process cooling operations. It also includes uses as makeup water for boilers and closed water systems.



Using recycled water in cooling towers saves money, since it costs an average of 50% less than potable water, depending on the water retailer. Cooling tower operators may need to increase the volume of water discharged and reduce the number of cycles of concentration when replacing potable water with recycled water. The combined costs of water purchased plus water discharged should still be reduced. Optimizing the cycles of concentration of recycled water will be required to glean the most cost reduction benefits.

Wastewater Discharge Regulations

 Note: ALL cooling towers must blowdown to the sanitary sewer system, and NOT the storm sewer system. If you are discharging to the storm sewer system, then you have an ILLICIT CONNECTION. You must cease operations immediately, and plumb your cooling tower to the sanitary sewer system.

Cooling water systems can discharge substances that may be harmful to the aquatic plants and animals that live in creeks and the San Francisco Bay. These substances may also cause problems for the San Jose/Santa Clara Water Pollution Control Plant (Plant), which must keep them out of the sewer to comply with state and federal requirements to reduce toxic discharges to the Bay and to reduce emissions of toxic air pollutants. In order for the Plant to achieve compliance with the concentration limits on plant effluent discharged to the San Francisco Bay, local discharge limits are developed for all industrial discharges to the sanitary sewer.

Regulations

The Plant provides service to the communities of San José, Santa Clara, Milpitas, Cupertino, Campbell, Los Gatos, Monte Sereno, Saratoga, and adjacent unincorporated areas. All agencies discharging to the Plant have adopted local ordinances for their service area containing the discharge restrictions shown in Table 1.05.

Table 1.05

San Jose/Santa Clara Water Pollution Control Plant Discharge Limits for Interfering Substances	
No person shall discharge, cause, allow or permit to be discharged into the sanitary sewer system or any part thereof, any industrial waste containing any of the following toxic substances exceeding the concentrations set forth below:	
Pollutant	Maximum Allowable Concentration (mg/l)
Antimony	5.0 mg/l
Arsenic	1.0 mg/l
Beryllium	0.75 mg/l
Cadmium	0.7 mg/l
Chromium, total	1.0 mg/l
Copper	2.7 mg/l
Cyanides	0.5 mg/l
Lead	0.4 mg/l
Manganese	35.0 mg/l
Mercury	0.010 mg/l
Nickel	2.6 mg/l
Phenol & derivatives	30.0 mg/l
Selenium	2.0 mg/l
Silver	0.7 mg/l
TTO	2.13 mg/l
Xylene	1.5 mg/l
Zinc	2.6 mg/l

The Bay Area Air Quality Management District prohibits the use of hexavalent chromium chemicals in cooling towers.

In December 1995, the California Department of Pesticide Regulations enacted prohibitions on the sale and use of tributyltin-containing cooling water additives in the San Francisco Bay area. This action was taken to protect Bay water quality.



There are several tributyltin-containing products registered in California for use in recirculating cooling water systems. However, these products are prohibited in the nine bay area counties of San Francisco, Santa Clara, San Mateo, Alameda, Contra Costa, Solano, Napa, Marin, and Sonoma.

2

Evaluating Water Reduction Alternatives

The following list summarizes the steps necessary to optimize the cycles of concentration for a cooling tower and evaluate current cooling water source replacement. Each step will be explained in greater detail.

1. Evaluate the cooling system.
2. Determine the water quality constituents and concentrations limits for cooling system protection:
 - Evaluate all water source constituents.
 - Determine the water quality constituents at various cycles of concentration.
 - Determine upper limits for water quality constituents.
3. Evaluate water treatment requirements.
4. Choose monitoring and maintenance requirements during and after changes.
5. Create a plan to change chemistry or flow rates, if problems occur.



Note: Any water source can be evaluated using these steps. It is not the water source, but the effect the water source's constituents have on the cooling system that matters. Protection of the cooling system is the first priority.

Step 1: Evaluate the Cooling System

SECTION HIGHLIGHTS

- Protecting the cooling system is the first priority when evaluating any change in chemical, structural, water optimization, or water source replacement project.
- Always check to make sure that the cooling tower materials, temperatures, flow rates, and type of cooling tower packing are compatible with the water quality of the proposed cooling tower water at different cycles of concentration.

Cooling System Composition

Matching the cooling system materials, design, and operation with the water treatment program and water quality is essential for protecting the cooling water contacted equipment. Thus, the water quality within the cooling system will determine what water treatment program should be used.

The most common heat exchangers contain a number of tubes enclosed in a cylindrical shell. Heat exchangers can have 25 to 1,000 tubes. Tube diameters range from 3/8" to 3/4" and lengths from a few feet to fifty feet. The tubing material is very thin (1/16" or less), for efficient heat transfer, but requires good protection from corrosion and deposits.

If the cooling water is in the inner tube and the process fluid is in the outer shell, it is called **tube-side cooling**. If the cooling water is in the outer shell and the process fluid is in the inner tube, it is called **shell-side cooling**.

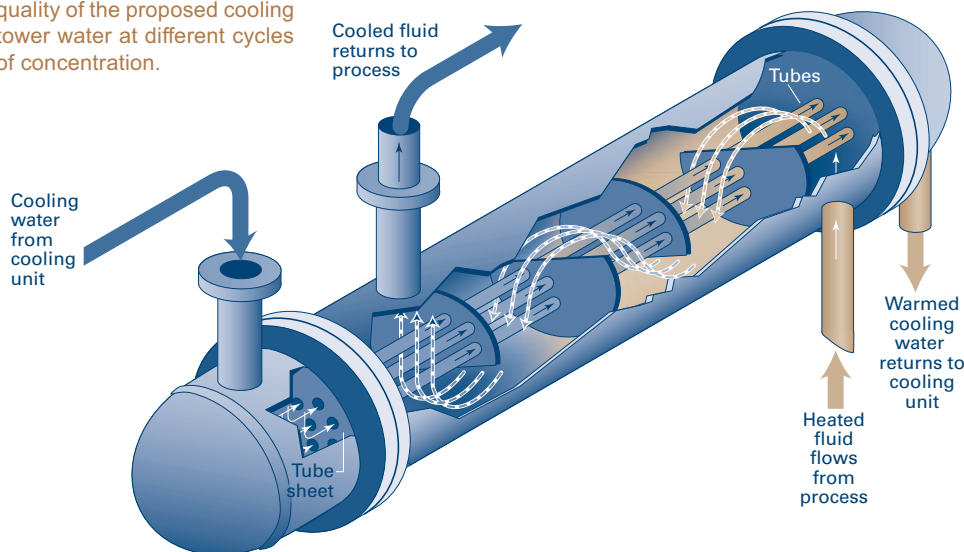


Figure 2.01:
Heat Exchanger



Always check with the cooling system's manufacturing specifications when evaluating any system.

Cooling System Materials

- Cooling towers are constructed of wood, plastic, metal, and fiberglass.
- The cool water is usually sent via mild steel, PVC, fiberglass, or stainless steel piping to heat exchangers, chillers, coils, and/or jacketed vessels (usually copper or stainless steel, seldom mild steel).
- The heat exchangers (i.e., chillers, jacketed vessels, etc.) are often constructed with copper, copper alloy, stainless and galvanized steel tubes.
- Although water boxes — the covers at either end of the exchanger — and support plates are often made of mild steel, as are tube sheets and water lines, copper lines are also commonly used. (Figures 1.03 – 1.06 and Figure 2.01)
- When the tubes are made of a copper alloy such as Admiralty brass (copper-nickel alloy) or of stainless steel, the tube-sheet might be made of Muntz metal (a copper zinc alloy) or coated carbon steel to lessen the potential for galvanic corrosion between tube and sheet.

Corrosion can also be reduced through the use of alternative construction materials, such as stainless steel, plastic or non-corrosive coating. Carbon steel is usually less expensive but is subject to rapid corrosion and requires a good corrosion/deposit control treatment system. *All types of metals under the right circumstances can corrode or scale.* Different types of metals corrode for different reasons, so knowledge of the metals in the system is a must.

Table 2.01

Effect of Water Quality Parameters on Cooling System Component Materials	
Type of Material	Effect of Water Quality Parameters
Galvanized Iron (Cu and Zn coating)	Susceptible to corrosion (white rust) from: (a) high dissolved solids, particularly chlorides and heavy metals, or (b) pH levels below 6.5 or above 8.5.
Stainless Steel	Susceptible to corrosion, usually at lower rates than for mild steel. Corrosion can be due to high dissolved solids — primarily chlorides that can cause stress corrosion cracking (SCC) or severe pitting. Chloride levels above 200 mg/l in contact with 304-SS are of concern when deposit-forming conditions exist. (Chlorides concentrate under deposits.) However, 1,000 mg/l chloride levels do not cause 304-SS corrosion if surfaces are free of deposits. The 316-SS alloy can tolerate chloride levels of 5,000 mg/l chloride levels when deposit-forming conditions exist, and 30,000 mg/l when surfaces are free of deposits. Biomass deposits, particularly from sulfate-reducing bacteria and iron-depositing bacteria, can cause rapid pitting of stainless steel. Chemical water treatment can effectively minimize or eliminate this potential. Maintaining a positive oxidant level will benefit the integrity of the protective oxide film on stainless steels and will reduce biomass accumulation. The water treatment program can also prevent deposits and help keep stainless steel surfaces clean. Nitrates are known to reduce stainless steel corrosion.
Mild Steel	Susceptible to corrosion from: (a) high total dissolved solids, usually chlorides, (b) any deposit-forming constituents such as suspended solids, biomass, scale, and (c) heavy metals, such as copper. Effective water treatment and operational changes can eliminate or minimize corrosion caused by these conditions. Operational changes include increased flow rates and periodic flushing of heat exchangers. Ammonia does not contribute directly to steel corrosion (but rather indirectly through increases to biomass).
Copper alloys including Admiralty Brass and Muntz metal	Susceptible to corrosion from: (a) ammonia and (b) high dissolved solids, usually chlorides and deposit-forming constituents such as suspended solids. Ammonia above 0.5 mg/l as NH ₃ can cause cracking of brass (Admiralty), severe corrosion of copper alloys, and contributes to biomass that can cause corrosion to copper alloy under deposits. The cracking of brass can be rapid and severe. Even chloramines (chlorine plus ammonia) can cause cracking. The use of copper corrosion inhibitors such as TTA (Tolytriazole or BZT (Benzotriazole) reduce but do not totally eliminate cracking. The use of BBT (Butylbenzotriazole) is still more effective, but does not totally eliminate cracking. Copper-nickel alloys (90/10 and 70/30) are resistant to cracking. Water treatments can minimize or eliminate other contributors to copper alloy corrosion.
Wood	Needs to be protected from decay or chemical attack.
Plastics	Should be corrosion-resistant, but needs to be kept clean and free of deposits to prevent clogging, etc. Plastic film in particular needs to be kept clean and free of biomass buildup.

Cooling Water Temperature and Cooling Water Flow Rates

In determining the heat exchanger performance and life, it is important to know “design” versus “actual” cooling tower inlet and exit temperatures as well as water velocities within the heat exchanger tubes. Some compounds have an inverse solubility at high temperatures (above 140°F) which can cause increased scale formation. “Pinching back” or reducing the flow rates through a heat exchanger can aggravate this situation. Because equipment designers usually incorporate one or more factors to accommodate less-than-ideal heat transfer conditions, heat exchangers are frequently over-designed so that the operation at the anticipated cooling water flow rates would lower the process fluid temperature below acceptable values. As a result, operators reduce the cooling tower water flow rates to certain heat exchangers as a means of controlling process temperatures.

Lower flow rates will always mean higher temperatures and increased potential for deposits. Microorganism growths in heat exchanger tubes are also very velocity-dependent. Biofilms increase at lower flow rates. On the other hand, too high a flow rate may cause erosion and corrosion.

With shell-side cooling, it is impossible to maintain a higher water velocity between the tubes and the support plate. At lower cooling water velocities, or in stagnant regions, deposits can occur from suspended solids or inorganic scale. Deposits can contribute to under-deposit corrosion; therefore, tube-side cooling is preferred.

Types of Cooling Tower Packing

Splash fill is less prone to plugging than film fill, but needs a greater volume to achieve the same effect. Film fill needs to be protected from biomass accumulation. Too much biomass not only reduces the effectiveness of the fill, but can also collapse the fill from its weight if left to accumulate.

Step 2: Determine Water Quality Constituents

SECTION HIGHLIGHTS

The water added to the cooling system can be reused process water, recycled water, potable water, or combinations of all these sources.

- The water qualities of any potential source water combinations need to be determined.
- The water quality of individual and combined potential water sources is calculated and the flow rates for evaporation, makeup, blowdown, and leaks are determined for different cycles of concentrations.
- Finally, the upper limits for water quality concentration are determined.

Evaluating Water Quality

All water, regardless of its source (e.g., reused or recycled waters), contains various constituents at different concentrations. Identification of these constituents helps to determine their impact on the water use in the cooling tower. Some constituents can be very beneficial, while others need to be handled by specific water conditioning or chemical treatment. Knowledge and understanding are needed to assure successful water conservation and use. The quality and quantity of available reused water(s) must be evaluated to determine:

- Is it suitable “as is” for adding to the cooling water system
- Does it require further treatment prior to use, and
- Will the water quality require a change in the water treatment program?

The chemistry of any given source of water will impact the structures and operation of all types of cooling towers. Operations at higher cycles of concentrations increase the potential for equipment scaling, corrosion, and fouling unless some type of treatment is implemented. A typical cooling water system makeup water quality analysis can provide substantial information regarding potential corrosion and deposition problems. Therefore, to compare the operational impacts of using different types of water sources in cooling towers, monitoring the chemistry is required.

Table 2.02 is an example of a water survey for several water sources, either for comparison or for mixing water. For example: Water Source #1 could be “Reverse Osmosis Reject,” Water Source #2 could be “Rinsewater from Plating Process,” Water Source #3 could be “recycled water,” Water Source #4 could be “potable water,” etc. If water sources are to be mixed, the resulting mixture needs to be determined. The next section will discuss the calculations necessary to determine the volume and concentration when combining water sources.

Table 2.02

Survey of Water Sources				
	Water Source #1:	Water Source #2:	Water Source #3:	Water Source #4:
Water Supply				
Volume, (gpm)	_____	_____	_____	_____
Continuous, (Yes, No)	_____	_____	_____	_____
Periodic, (Yes, No)	_____	_____	_____	_____
Usual Water Quality Constituents				
Conductivity	_____	_____	_____	_____
Hardness, total	_____	_____	_____	_____
Hardness, Calcium	_____	_____	_____	_____
pH	_____	_____	_____	_____
Silica	_____	_____	_____	_____
Total Alkalinity	_____	_____	_____	_____
Total Dissolved Solids (TDS)	_____	_____	_____	_____
Total Suspended Solids (TSS)	_____	_____	_____	_____
Less Usual Water Quality Constituents				
Ammonia	_____	_____	_____	_____
Biological Oxygen Demand (BOD)	_____	_____	_____	_____
Chloride	_____	_____	_____	_____
Copper	_____	_____	_____	_____
Other heavy metals	_____	_____	_____	_____
Fluoride	_____	_____	_____	_____
Hardness, Magnesium	_____	_____	_____	_____
Iron	_____	_____	_____	_____
Nitrate	_____	_____	_____	_____
Organics (TOC)	_____	_____	_____	_____
Phosphate	_____	_____	_____	_____
Zinc	_____	_____	_____	_____

Determining Water Quality: Mixed Water Sources

After determining the water quality of different water sources, decisions to blend different water sources can be made, if required. The following section describes and provides examples of the method for calculating concentrations of various parameters when mixed.

For well blended water sources, the mass of any constituent whose concentration is known, is calculated from:

Equation 2.01

MASS	=	Concentration	x	Volume
M	=	C	x	V

For water with more than one source, the total mass of a constituent whose concentration is known, is calculated from summing masses from each source:

Equation 2.02a

	TOTAL MASS	=	Mass of the first source	+	Mass of the second source	...	+	Mass of the last source
	M_T	=	M_1	+	M_2	...	+	M_n

Calculations for mixing or blending may be simpler if the CV term is not converted into actual units of mass.

Equation 2.02b

$$C_T V_T = C_1 V_1 + C_2 V_2 \dots + C_n V_n$$

Constituent concentrations can be calculated, rearranging Equation 2.01 to the following:

Equation 2.03a

	TOTAL CONCENTRATION	=	Total Mass	÷	Total Volume
	C_T	=	M_T	÷	V_T

Constituent concentrations in cooling water are usually expressed in parts per million (ppm), or milligrams per liter (mg/l). Cooling water volumes are usually expressed in gallons. A complex conversion is required to get an expression of mass that we can use. The concentration for a mixture equals:

Equation 2.03b

$$C_T = (C_1 V_1 + C_2 V_2 \dots + C_n V_n) \div V_T$$

Total volume equals the sum of water from all sources:

Equation 2.04

	TOTAL VOLUME	=	Volume from the first source	+	Volume from the second source	...	+	Volume from the last source
	V_T	=	V_1	+	V_2	...	+	V_n

Example 2a

Table 2.03 lists the concentration and volume of water to be mixed as a source for a cooling tower. What is the TDS (Total Dissolved Solids) concentration of the blended sources?

STEP 1: Calculate the CV term for each source stream to determine the total mass of dissolved solids.

Table 2.03

Calculating Total Volume and Mass				
Water Sources	TDS Concentration (mg/l)	x	Volume (gpd)	C _i V _i = M _i
1 Scrubber Water	1,000 mg/l		1,000 gpd	1,000,000
2 Process C	570 mg/l		2,000 gpd	1,140,000
3 RO Reject	2,400 mg/l		100 gpd	240,000
4 Process Water A	459 mg/l		600 gpd	275,400
5 Process Water B	234 mg/l		5,000 gpd	1,170,000
TOTAL			8,700 gpd	3,825,400

Eq. 2.04

Eq. 2.02b

STEP 2: Use Equation 2.03b to calculate the TDS concentration for the mixture.

<i>Total Mass</i>		<i>Total Volume</i>		<i>Total Concentration</i>
3,825,400 (mg/l, gal/day)	÷	8,700 (gal/day)	=	440 mg/l

STEP 3: Use Equation 2.01 and an appropriate conversion factor to calculate the daily TDS mass of the mixture in a common unit of measure.

<i>Total Mass</i>		<i>Conversion Factor</i>		<i>Total Mass</i>
3,825,400 (mg/l, gal/day)	x	(8.34 x 10 ⁻⁶)	=	31.9 lbs per day

Example 2b

The XYZ Company has a cooling tower for which they would like to use a blend of potable water and recycled water. They receive potable water with a TDS concentration of 300 ppm. They can also connect to the local system for recycled water, which has a TDS level of 800 ppm. To keep their operating parameters relatively consistent, they would like to maintain a concentration of 600 ppm in the cooling system make up water. What should the ratio of potable water to recycled water be?

With the conservation of mass **Equation 2.02b**, and the total volume from **Equation 2.04**, $V_T = V_1 + V_2$, we know that:

$$C_1V_1 + C_2V_2 = C_T(V_1 + V_2)$$

We are looking for the ratio of V_1 (potable) to V_2 (recycled).

$$C_1V_1 + C_2V_2 = C_T V_1 + C_T V_2$$

Equation 2.05

$$(C_1 - C_T) V_1 = (C_T - C_2)V_2$$

$$V_1 \div V_2 = (C_T - C_2) \div (C_1 - C_T)$$

For our example, $V_1 \div V_2 = (600 - 800) \div (300 - 600) = 2/3$

Therefore, you need to add 2 gallons of potable water for every 3 gallons of recycled water to be used.

A survey of the reused water sources and whether water flow is continuous or intermittent will be needed to determine the available quantity of reused water. An additional survey like the one shown in Table 2.04 will determine the quality of reused water.

Determining Water Quality: Cycles of Concentration

After the water quality for all water sources to be considered is analyzed, combined, and tabulated, then each parameter needs to be multiplied by various cycles of concentration. The calculation method is simple. Each parameter must be multiplied by the number of cycles of concentration as shown in Example 2c.

Example 2c

A water source has TDS of 400 mg/l, a conductivity of 800 ohms, and chlorine level of 50 mg/l. What are the concentrations of these parameters at different cycles of concentration?

Each water quality parameter is multiplied by the number of cycles of concentration. For example: at 2 cycles of concentration the TDS is 800, at 4 cycles of concentration the TDS is 1,600, etc.

Table 2.04

Water Quality at Varying Cycles of Concentration (CoC)						
Parameter	Initial Water Quality	Water Quality at 2 CoC	Water Quality at 4 CoC	Water Quality at 6 CoC	Water Quality at 8 CoC	Water Quality at 10 CoC
TDS	400 mg/l	800 mg/l	1,600 mg/l	2,400 mg/l	3,200 mg/l	4,000 mg/l
Conductivity	800 ohms	1,600 ohms	3,200 ohms	4,800 ohms	6,400 ohms	8,000 ohms
Chlorine	50 mg/l	100 mg/l	200 mg/l	300 mg/l	400 mg/l	500 mg/l



Although this section does provide actual concentrations, they may not be applicable to your system and should only be considered a **starting point** in the investigation of the appropriate cooling tower chemistry.

The following must all be considered and consulted when making decisions on the appropriate cooling tower chemistry:

- Materials in the cooling system
- The temperature range
- The cooling tower flow rates
- The packing materials
- Manufacturers specifications

Table 2.05 describes different chemical parameters in water sources, their effect at different concentrations, and typical water chemistry additions to counteract corrosion, deposits and biofouling potentials

Determining Upper Water Quality Limits

Now that the concentration of various parameters are known at different cycles of concentration, the water quality parameters must be evaluated to see what type of treatment may be needed.

Table 2.05

Impact of Water Quality Parameters on Cooling Systems	
Water Quality Parameter	Impact on Cooling System
Hardness (A measure of the combined calcium and magnesium concentrations)	Although both can contribute to scale, calcium is particularly troublesome because certain calcium salts exhibit an inverse solubility in water. Magnesium is usually not as much of a problem unless the silica levels are also high. This could result in magnesium silicate scale in the heat exchangers. Unlike most salts in solution, which become more soluble with increasing temperature, calcium carbonate becomes less soluble with increasing temperature.
Alkalinity (Alkalinity is a measure of water's ability to neutralize acids.)	Bicarbonates normally represent the major portion of the measured alkalinity, although under certain conditions, appreciable amounts of carbonate and hydroxide alkalinity may also be present. Alkalinity is an important means of predicting calcium carbonate scale potential.
Silica	Can produce difficult-to-remove scale deposits. Pretreatment or sidestream filtration is often required if the silica levels are above 150 ppm (as SiO ₂).
Total Suspended Solids (TSS) (Consists of undissolved material such as silt, sand, fine clay, and vegetation.)	Unlike dissolved solids, not all suspended solids enter the cooling system with the makeup water. Some might be generated as corrosion and scale byproducts or from air/water contact. Suspended solids can adhere to biofilms and cause under-deposit corrosion. TSS can be controlled through pretreatment, sidestream filtration or through use of deposit control agents.
Ammonia	An ideal nutrient for many microorganisms, it can promote biofilm development and growth in the heat exchangers and cooling tower fill. It is also extremely corrosive to copper alloys (even those well passivated with chemicals). There have been documented cases of stress corrosion cracking in copper alloys from ammonia concentrations as low as 2.0 ppm. Ammonia also can combine with chloride to form chloramines that are one tenth the effectiveness of free chlorine residual. Chloroamines are also quite volatile and are stripped from the water as it passes the tower, negating any disinfecting affect. Ammonia also can reduce or negate some non-oxidizing biocides such as glutaraldehyde. (Bromine is a more cost-effective biocide than chlorine if ammonia is present.)
Phosphate	Concentration levels equal to or less than 4.0 mg/l may not be a concern if the pH is controlled between 7.0 and 7.5 and there is a sufficient amount of dispersant. At this level the phosphate might also provide a mild steel corrosion protection since phosphate is a common anionic inhibitor (although the system should not rely on recycled water as the only source for corrosion protection since the levels may fluctuate). At higher concentrations (calcium greater than 1,000 mg/l and phosphate greater than 20 mg/l) there is a potential for calcium phosphate scaling in the heat exchangers, especially at high heat loads and low cooling water flow rates. Therefore, close monitoring of blowdown is required. Phosphate can also act as a nutrient for biofilms.
Chloride	Can be corrosive to most metals, especially mild steel. A chloride limit of 300 ppm is often used for stainless steel, but limits for other metals may go as high as 1,000 ppm.
Iron	May be a concern if it combines with phosphate to form undesirable foulants. It may also deactivate specialized polymers used to inhibit calcium phosphate scaling. Recycled water may have a high concentration at 0.12 to 0.32 of iron. Specialized treatment of iron is expected to be required for this concentration.
Biological Oxygen Demand (BOD)	Reflects the organic content for biological organisms and the associated demand for oxidizing biocide in addition to the amount used for bio fouling control.
Nitrates and Nitrites	Can provide additional mild steel corrosion control at levels above 300 mg/l in the concentrated cooling water. Can contribute to reductions in stainless steel cracking and pitting erosion. Nitrates do not attack copper alloys or protect them from corrosion.
Zinc	Can assist phosphates and nitrates in reducing mild steel corrosion rates and pitting tendencies. Levels in cooling water above 0.5 mg/l are beneficial, but levels above 3.0 mg/l can contribute to deposits.

Table 2.05 (continued)

Impact of Water Quality Parameters on Cooling Systems	
Water Quality Parameter	Impact on Cooling System
Organics	Can act literally as fertilizer for microorganisms. Water-soluble cationic polymers can react with some anionic treatment biocides, as well as some scale and corrosion inhibitors.
Fluoride	At 10 ppm or more can combine with calcium to cause scale formation.
Heavy Metals (e.g. Cu, Ni, and Pb)	Copper and nickel can plate out on steel, causing localized galvanic corrosion that can rapidly penetrate thin steel heat exchanger tubes.

Step 3: Evaluate Cooling System Water Treatment

SECTION HIGHLIGHTS

Cooling tower treatment can be both chemical and physical.

Corrosion, deposition, and microbiological growths are controlled through chemical treatments such as:

- Controlling contact on surfaces through inhibitors
- Keeping ions in solutions with solubilizing agents
- Preventing solids from contacting each other by dispersants and surfactants
- Using oxidizers to kill bio-masses.

Chemical Treatment

Treatment for cooling towers can be both chemical and physical. It is most common for chemical treatment programs to be used for controlling corrosion, deposition, and microbiological growths. Prior to installing a chemical treatment system, or introducing a new chemical treatment agent, contact your local fire department's hazardous materials unit for regulatory, reporting, and permitting requirements.

Corrosion Control (Inhibitors)

Corrosion is an electrochemical process in which metals are oxidized by transferring electrons from an anodic site to a cathodic site. Cathodic inhibitors reduce the amount of cathodic surface available and anodic inhibitors reduce the amount of anodic surface available. Sometimes both types of inhibitors are needed to prevent corrosion. Phosphates, zinc salts, molybdates, and polysilicates are typical mild steel corrosion inhibitors, while organic nitrogen-based compounds (azoles) are copper alloy corrosion inhibitors.

Deposition Control

Several different types of deposits can form in cooling water systems, necessitating different approaches for control:

DEPOSITION INHIBITOR CONTROL focuses on either solubilizing agents to prevent scale from precipitating or crystal modifiers to alter the nature of precipitate to prevent adhesion to surfaces.

DISPERSANTS AND SURFACTANTS are charged molecules that adsorb suspended solids and cause a mutual repulsion, which keeps solids as smaller particles.

ACID, PHOSPHONATES AND WATER-SOLUBLE POLYMERS are typical mineral scale inhibitors.

Deposition control is particularly critical in systems with high levels of calcium hardness.

Microbiological Growth Controls

The hydroxyl radicals (OH^\cdot), hydrogen peroxide (H_2O_2) and hypochlorite (bleach) (OCl^-), and chlorine gas (Cl_2) are oxidizers that kill microbiological growths.

Of the above mentioned compounds, sodium hypochlorite is the easiest and the safest to handle. Typically, a 13% solution of sodium hypochlorite (NaOCl) is used to destroy microorganisms.



Hydrogen peroxide is in a liquid form and can burn the skin on contact.

Hydroxyl radicals and chlorine gas require extraordinary care in handling and use due to their high potential for health hazards. Therefore, microorganisms should be kept at a minimum in cooling towers and other similar devices whenever possible.


Oxidizing biocides irreversibly oxidize protein groups, resulting in loss of normal enzyme activity and death. Non-oxidizing biocides are also available.

Ozone, hydrogen peroxide, and hydroxyl radicals may also be used to control the growth of microorganisms. All of these chemical compounds are strong oxidizing agents.

Typical microbiological control chemicals include chlorine and bromine compounds, or ozone, as well as a variety of toxic organic compounds such as “quats,” aldehydes, organo-sulfurs, bromine-based organics, and others. Note: “quats” refers to quaternary amine compounds that are more bacteriostatic than bactericidal (i.e. they inhibit the growth of microorganisms, but do not kill them).

Surfactants also help biocides reduce biofilms.

Some conditioning chemical additives and their recommended maximum concentrations are shown in Table 2.06.

 Water treatment chemicals can contribute considerable nutrients, e.g.:

- Phosphate corrosion inhibitors
- Organic polymers as scale inhibitors
- Dispersants
- Surfactants
- Ammonia containing compounds such as copper corrosion inhibitors TTA, BZT, BBT
- Some scale inhibitors
- Some biocides, etc.

Therefore, a good bio-control program is important—no matter what the water source.

Table 2.06

Conditioning Chemical Additives		
Conditioning Chemical	Use	Recommended Maximum Concentration**
Organophosphates (phosphates)*	Control scaling for steel	20 mg/l as PO ₄
Orthophosphates, Polyphosphates	Inhibit corrosion and control scaling	20 mg/l as PO ₄
Sodium silicate	Inhibit corrosion	100 mg/l as SiO ₂
Aromatic triazoles	Inhibit corrosion	2-4 mg/l
Molybdates [†]	Inhibit corrosion	40 mg/l as molybdenum
Non-oxidizing biocides such as: • Isothiazolin ^{††} • Dibromonitripropionamide (DBNPA) • Quaternary amines	Inhibit biological growth	
Oxidizing Biocides • Chlorine • Bromine	Inhibit biological growth	0.5 mg/l

* Requires close monitoring of blowdown and dispersant to prevent calcium phosphate scale.

** If corrosion protection of the cooling system requires high chemical dosing rates that result in concentrations of inhibitors that exceed these recommended maximum levels, the system should be thoroughly investigated to determine the cause. Any problems should be corrected.

† Molybdates are acceptable for discharge to the San Jose/Santa Clara Water Pollution Control Plant, but may be prohibited in other service areas.

†† Copper is often used as a stabilizer in isothiazolin biocides. Because the presence of copper is typically not noted on the Material Safety Data Sheet (MSDS), chemical analysis data should be obtained before use. Such data may be obtained from the vendor, the San Jose/Santa Clara Water Pollution Control Plant, or other industrial dischargers. Copper-containing additives must not be used.

ADVANTAGES

- Higher cycles of concentration.
- Low initial capital cost.
- Low operating cost.
- Well-understood method of treatment.

DISADVANTAGES

- Possible safety hazard.
- Possible damage to system.

Sulfuric Acid pH Control Treatment

Adjusting pH by feeding sulfuric acid to the cooling tower water helps control scale buildup in cooling tower systems.



When using sulfuric acid, make sure to take the necessary safety precautions:

Before using sulfuric acid, all personnel working in the area should be trained in its use and what to do in the event of an accident.

Workers handling sulfuric acid must be equipped with eye and skin protection and exercise caution to prevent bringing the acid into contact with skin or eyes.

If the acid is fed through an automatic system, check it often to prevent acid overdoses that could severely damage the system.

Low alkalinity waters are more susceptible to corrosion damage by overfeeding acid than high alkalinity waters.

The advantages and disadvantages of using sulfuric acid are summarized at left.

ADVANTAGES

- High cycles of concentration possible.
- Elimination of microorganisms from the cooling tower's media and heat exchanger surfaces.
- Increased air volume rate passing through the cooling tower. Maximized surface area for the air/water interface, which in turn yields an increased heat transfer rate.

DISADVANTAGES

- High capital investment.
- Complex system, possibly requiring outside contractor for maintenance.
- Limited effectiveness at water temperatures above 90° F.
- Additional labor required to maintain the ozone unit.
- Possible health hazard.
- Additional energy costs.

Ozonation

Ozone, one of the most powerful oxidizing agents available, has been used for many years as a disinfecting agent for water supplies. Ozonation controls viruses and bacteria by rupturing the cell membrane and killing the microbes in the water. Ozone treatment also may control corrosion by oxidizing the inorganics and soluble ions that cause corrosion. Its effectiveness in controlling scale, and possibly removing existing scale, is still being evaluated.



Ozone in large quantities is toxic, and strict safety precautions must be observed to protect plant workers from excessive exposure.

A typical ozonation unit consists of an air compressor, an ozone generator, a diffuser or contactor, and a control system. Ozone is produced when cool, dry air (or pure oxygen gas) is passed through a high voltage field (~1200 Volt), between two electrodes to convert oxygen (O₂) to ozone (O₃). Additionally, the reaction is "activated" with the addition of ultra-violet light. The ozone that is created then proceeds out of the ozone generator through piping into a fine bubble diffuser or equivalent device so that it is introduced into the cooling tower recirculation stream. The fine bubble diffuser allows high concentrations of ozone to be present in the water stream, approximately 500 ppm.

Ozone is not stable, and after about 20-30 minutes it either reacts with compounds present in the immediate area or it dissociates back into oxygen. The rate of degradation increases rapidly at temperatures above 90° F, and therefore, careful consideration should be given before attempting to apply ozone to systems where the water temperature exceeds 90° F.

The advantages and disadvantages of ozone are summarized at left. Many ozone manufacturers offer leasing agreements that include maintenance and allow the user to test the system without a large capital investment.

ADVANTAGES

- Reduced possibility for fouling.
- Higher operating efficiency.
- Reduced maintenance.

DISADVANTAGES

- Moderately high initial capital investment.
- Limited effectiveness for dissolved solids removal.
- Additional energy costs for pumping.
- Additional maintenance and servicing of a new pretreatment system

Other Types of Treatment**Side Stream Filtration**

A sidestream filtration system is particularly effective where the turbidity of the supply water is high, airborne contaminants such as dust or oils are common, or the cooling water passages are small and susceptible to clogging. Filtration systems remove particles or suspended solids in the recirculating water, enabling the system to operate more efficiently with less maintenance. However, the sidestream filtration unit must be maintained on a regular basis.

Typical cooling tower filtration systems continuously draw water from the basin, filter out the suspended particulate, and return the filtered water to the tower. The most common types of filters are **rapid sand filters** and **high efficiency cartridge filters**.

Although filtration can be accomplished at any point, the most efficient way is to draw water from the center of the basin, pass it through the filter, and return the filtered water to the basin through spray nozzles or perforated piping arranged so that any sediment is swept to the filtration system collection point. By pumping from the bottom of the cooling basin, greater amounts of suspended particulates and precipitants can be removed. Filtration rates typically range from approximately 5 percent of the total circulation rate to as much as 20 percent for systems where particulates are a problem.

The advantages and disadvantages of a filtration system are summarized at left.

Partial Softening of Makeup Water

Partial softening of the makeup water prior to its introduction to the cooling tower is an effective pretreatment method to increase cooling tower efficiency. Partial softening reduces water hardness, alkalinity and silica. In this method the water is treated with lime or a combination of lime and soda ash to precipitate the ions contributing to hardness and alkalinity. The precipitate is removed by filtration. Partial softening is used to treat water with moderate to high hardness and alkalinity in the range of 150 to 500 ppm as CaCO_3 .

Other Considerations**Increasing Cycles of Concentration**

An operator may be able to go from two to ten cycles of concentration, but the treatment program must recognize the increase in mineral content and be adjusted to prevent any adverse impact on the cooling water equipment. A possible change in treatment would be the use of scale inhibitors discussed previously. Other approaches such as partial softening of the makeup water or the use of acid addition may also be considered. The additional costs of these chemicals need to be evaluated when analyzing for the potential cost savings. Typically, additional dispersants and phosphates need to be added to the cooling tower basin in order to prevent precipitation of chemical compounds.

When acids are not used to control pH, lower levels of phosphate, such as 5 to 10 mg/l (ppm) are used, and supplemented with molybdates and/or zinc salts for mild steel corrosion control.

Reusing Water

Internally generated process waters often have very good cooling water quality. The following examples illustrate water use options and considerations:

- Rinse water from the semiconductor manufacturing industry is usually ultrapure, and may have a purity of 18 megohm resistivity, i.e. containing nearly no detectable levels of ions. However, water low in *Total Dissolved Solids* (TDS) may be corrosive and may need corrosion inhibitors. This water source can be used by itself or can be blended with water that has a high TDS concentration to yield an intermediate TDS concentration.

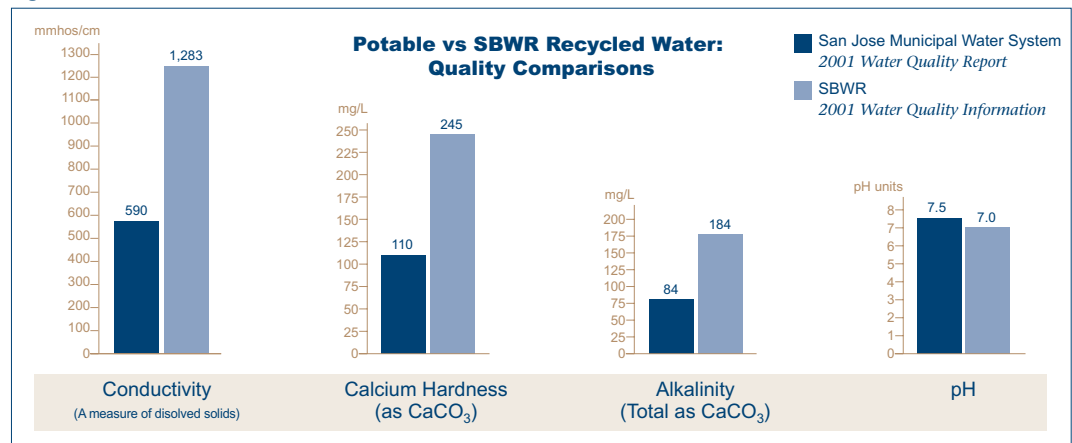
- Ion exchange softener rinse typically does not require any additional treatment before reuse as an alternative makeup water source for cooling towers. However, the higher chloride should be considered when designing the chemical treatment program.
- Reverse Osmosis (RO) reject water will contain three or more times the mineral content of the RO feed water. However, since the quantity added to the cooling system is usually much smaller than the makeup requirements, it is usually blended with other more dilute water sources. Therefore, there is usually very little impact with this reuse water. If only RO reject is used there is often a benefit since it is likely softer (less hardness) and may contain some low pH or scale inhibitors used to keep the RO membranes scale free, reducing the cooling water chemical requirements.

SBWR Recycled Water Quality

Adequate testing, control, and performance monitoring must be maintained in order to assure good system operation and protection. The use of recycled water depends on the final water quality in the cooling system, the systems metallurgy, the levels of nutrients present, and the operating conditions in the cooling components. Recycled water can contribute to corrosion, but the presence of phosphates and nitrates can provide mild steel corrosion control. All increased corrosives, except ammonia, can be reduced or eliminated with water treatment chemicals under good control.

Figure 2.02 compares key components in SBWR recycled water and an example of local potable water to provide an understanding of how these waters can be used. Proper treatment is needed to protect cooling water equipment from deposits and corrosion.

Figure 2.02



Conductivity is an approximate measure of ionic concentration. As water quality constituents contributing ions change, conductivity settings used for system control have to be adjusted.

As the concentration of calcium increases, so does its likelihood of precipitating out of solution. Potential scaling can be controlled through the use of pretreatment, scale inhibitors or deposit control agents.

SBWR recycled water has higher alkalinity levels than potable water. Alkalinity is an important means of predicting calcium carbonate scale potential. Adjusting the pH through acid addition to shift the ionic equilibrium to favor bicarbonate can aid in controlling the potential for calcium carbonate scaling.

SBWR recycled water has essentially the same pH as potable water.

Comparing Basic Treatment Options

Table 2.07 is an example of how small a change in water treatment is needed if using a different water source; in this case, potable water versus SBWR recycled water. Table 2.07 lists four basic water treatment programs. The primary differences in the treatment programs are that **Basic #2 and #4** treatments use acid to control pH while **Basic #1 and #3** do not include acid treatment. When no acid is used, additional scale inhibitor may be needed.

Table 2.07

Typical Cooling Water Treatment Programs for Potable and SBWR Water				
Treatment to Control	Potable Water		SBWR Recycle Water Makeup	
	Basic #1 Water Treatment (No Acid)	Basic #2 Water Treatment (With Acid)	Basic #3 Water Treatment (No Acid)	Basic #4 Water Treatment (With Acid)
Scale	Polymers/ Phosphonates	Polymers/ Acid	Polymers	Polymers
Mild Steel Corrosion	Phosphate	Phosphate	None*	None*
Copper Corrosion	Azole	Azole	Azole	Azole
Bio-organisms	Biocides	Biocides	Biocides	Biocides

* Since recycled water contains phosphate and nitrate, additional mild steel corrosion inhibitor may not be needed.

Step 4: Monitoring and Maintenance

SECTION HIGHLIGHTS

Proper operation of any cooling system is dependant on a regular monitoring and maintenance program implemented by a trained cooling system operator or system expert.

A small change in water treatment along with water testing, adequate control, and performance monitoring may allow the use of SBWR recycled water in the cooling system.

Quick operator response to problems is aided by the use of automatic monitoring and alarm systems.

A regular maintenance program using brushes, high-pressure water, or steam can reduce or eliminate the use of harsh chemicals for cleaning.

Updated Spill Response Plans and Material Safety Data Sheets should be available to all employees at all times.

System Monitoring

A regular monitoring and maintenance program is essential to ensure the proper functioning of any cooling system. The system vendor should provide a preventive maintenance schedule specifically for your cooling systems. If you do not have a trained cooling system operator on staff, you should obtain the services of a system expert (a reputable cooling systems service vendor, a Certified Operating Engineer, or an industrial water treatment specialist) to monitor and maintain your systems.

Routine chemical testing of both cooling and the makeup water is an important part of system monitoring. Regular chemical tests should include the following parameters:

Table 2.08

Maintenance Monitoring Parameters		
Daily Testing of Cooling Tower Water	Regular Testing of Makeup Water and Cooling Tower Water	Additional Testing for Recycled Water
Copper	Hardness, Total Calcium	Chlorides
Iron	Silica	Ammonia
Zinc	Conductivity	Phosphate
Carbon Dioxide	Biological Colonies < 10,000	
Chlorine, Bromine or Ozone (if used)		
pH		
Conductivity		

Compare test results to guidelines (see Diagnostic Indicators Table 2.10, page 27) and past results to evaluate current operational changes.

Many of these parameters can be measured with a field test kit (conductivity and pH are especially easy to measure). For others, especially metals, it is easier and more accurate to send a sample of the cooling water to a lab for analysis.

Monitoring Equipment

- Makeup water volumes can be checked using an **in-line totalizer** for daily flow rates, and a **rotameter** for instantaneous flow rates. Additionally, the flow rate in the piping may be measured with a **magnetic flow meter**. Note that these devices need to be calibrated and are subject to error. In-line flow meters can clog and foul with suspended particles and microorganism and thus give an inaccurate flow value.
- System piping should be checked with a **flow meter** or by calculating velocity from pumping rate and pipe diameter.
- **Deposition monitors**, utilizing a heated surface that simulates what is occurring in the heat exchangers, are available and are used occasionally.
- **Record and photograph or videotape** appearances to maintain a record of equipment condition.

Microbiological Monitoring Requirements

Monitoring the levels of microbiological organisms in cooling water is usually accomplished by growing them on a test “strip,” often called a “dip” slide. This strip has a growth media enabling the microbiological organisms to grow and be counted relative to a millimeter of cooling water. This testing is done at the facility.

Testing strips are available for total bacteria, and specific microbiological organisms such as corrosive bacteria, i.e., sulfate-reducing bacteria. They are also available for fungus.

Acceptable levels of microorganisms are site specific. However, common guidelines are to maintain:

- Algae and fungus: none or few (usually reported as “none,” “few,” or “many”)
- Total bacteria: 10,000 or less cfu/ml*
- Corrosive bacteria: zero cfu/ml*

**These values are colony-forming units (cfu) per milliliter of cooling water.*

The biobox is a good instrument to watch for accumulation of solids. It is especially helpful if you have shell side heat exchangers. This is a Plexiglas® box with a series of plates that show visually what is going on in the system. Another instrument is a biofouling tube. This is a piece of stainless steel pipe about 10 feet in length with pressure taps at each end. If a biofilm starts to build up, the pressure drop will increase.



Total bacteria tests will NOT identify Legionella bacteria. Testing for Legionella bacteria is done by sending cooling water samples to a laboratory specializing in this type of testing.

Prevention of Fouling Due to Scale or Deposits

Fouling from scale or suspended solids can occur throughout the system, affecting both heat exchangers and cooling towers. Scale is controlled with solubilizing agents that prevent precipitation or crystal modifiers that alter the precipitate so it does not adhere to system surfaces. Chemical dispersants are added to keep solids as smaller particles that remain suspended until discharged in the blowdown. Sludge fluidizers are used to control settling by attracting small particles into larger but sparsely packed particles that cannot form a hard deposit. Monitoring of suspended solids on a regular basis will give indication of potential problems.

Automated controls allow cooling systems to adjust rapidly to changing conditions, while maintaining system stability and operating efficiency. Using a good chemical feed system can prevent problems such as:

- High chemical costs from overfeeding,
- Corrosion of metals from overfeeding of acidic or oxidizing chemicals,
- Corrosion from underfeeding protective chemicals.

The use of an automatic monitoring and alarm system, with or without automatic controls, is encouraged, as these systems facilitate quick operator response to problems. Note that when using automated systems with probes that detect specific constituents in the cooling tower basin, the probes must be kept clean and free of any film or contamination. Additionally, such probes should be calibrated against a known standard to ensure proper system performance.

The schedule in Table 2.09 shows a minimum monitoring program. This schedule should be adequate for most small and medium sized systems using a potable water supply. More extensive monitoring may be required for the largest systems and for those systems using reused or recycled water.

Table 2.09

Recommended Monitoring Schedule		
<ul style="list-style-type: none"> • Visually inspect the equipment to verify that it is working properly. • Check to see if additive chemical supply is adequate. • Investigate any system anomalies or changes since the last inspection. 		
Daily	Monthly	Other
<ul style="list-style-type: none"> • Record the daily volumes of makeup and blowdown water. (During the winter, volumes should be checked and recorded at least weekly.) Significant variations in daily flow may give early warning of system malfunctions. • Check conditioning chemical dosage. • Check pH, temperature, and conductivity. Significant variation from normal values may indicate malfunctions or need for additive feed rate adjustment. • Perform chemical and biological testing on cooling system water. Compare results to the values in Table 2.10. • Inspect surfaces contacted by cooling waters for deposits and algae. • Clean heat exchanger surfaces on a daily basis to minimize buildup of anaerobic microorganisms. "Air Rumble" heat exchangers with compressed air to remove biological film. 	<ul style="list-style-type: none"> • Inspect the system, checking for proper equipment function and physical evidence of corrosion. • Check corrosion rate. • Check water velocity in system piping. 	<ul style="list-style-type: none"> • Determine scaling and suspended solids when opening chiller tubes or other heated surfaces of heat exchangers. • Corrosion rates should be checked quarterly using corrosion coupons, corrosion rate meters, or other monitoring devices. The coupons are also examined after cleaning for pitting or localized attack. • Examine any opened piping or strainers. • Replace heat exchangers and piping on an as-needed basis.

Values in the Diagnostics Indicators Table 2.10 are guidelines for typical systems. Ask your vendor or a cooling system expert for system-specific guidance. Diagnostic Indicators may indicate a significant problem. A reputable cooling system service vendor, a Certified Operating Engineer, or an industrial water treatment specialist should evaluate systems with these problems.

Table 2.10

Diagnostic Indicators for Cooling Systems		
Indicator	Possible Problem	Possible Solution
Metals: Copper > 0.25 mg/l Iron > 1.0 mg/l Zinc > 0.5 mg/l OR Measured corrosion rates: Copper > 0.2MPY Mild steel piping > 3 MPY Mild steel Hx tubing > 0.5 MPY Galvanized steel > 4 MPY	<ul style="list-style-type: none"> • High corrosion rate • Inadequate chemical dosage control • Use of conditioning chemicals containing copper or zinc 	<ul style="list-style-type: none"> • Improve corrosion protection through use of an additive or by other means • Improve additive dosage control and/or monitoring • Eliminate use of additives containing copper or zinc • Consider replacing copper components or piping
Additives: Chlorine > 0.5 mg/l Ozone > 0.2 mg/l	Overuse of these oxidizing chemicals <ul style="list-style-type: none"> • Leads to high corrosion rates 	<ul style="list-style-type: none"> • Reduce or stabilize additive dosage • Improve monitoring • Install an automatic conductivity probe controlled oxidizing agent feed system.
Carbon dioxide > 5 mg/l	Copper oxide protection is inhibited	<ul style="list-style-type: none"> • Raise pH
pH < 7.0	Inadequate pH control	<ul style="list-style-type: none"> • Implement pH control • Check dosage of low-pH additives
Water velocity: > 3 feet/sec @ >150°F > 5 feet/sec @ 120°F > 8 feet/sec @ <90°F	Leaks or system failure <ul style="list-style-type: none"> • High rate of corrosion of copper piping; could cause leaks or system failure 	<ul style="list-style-type: none"> • Reduce recirculation rate • Increase line size • Replace copper elements with nonmetallic parts or other non copper parts
Conductivity outside the manufacturer's recommended range	System operation not optimized <ul style="list-style-type: none"> • Possible misuse of additives • Improper blowdown rate 	Investigate: <ul style="list-style-type: none"> • System settings • Chemical dosing rates • Blowdown system operation
The water consumption rate has increased greatly.	The heat load to the system has greatly increased. <ul style="list-style-type: none"> • Possible massive system leak. 	<ul style="list-style-type: none"> • Check if additional heat load has been added on the system today. • Check the system for leaks. Inspect sanitary sewer and storm sewer manholes on site for unusually high flows.

Maintenance

Nearly all facilities conduct maintenance on the cooling towers in one form or another over the course of the year. During such maintenance, the cooling towers are normally not operating. Typical maintenance may include but not be limited to: cleaning or changing the media, re-packing the media, cleaning the cooling tower's basin, preventative maintenance of the cooling tower's pumps and fans, installing more efficient electric motors, and expanding the cooling system. Such "planned" maintenance may occur anywhere from quarterly to annually.

Cleaning

Regular maintenance and cleaning with brushes, pressurized water, or steam can eliminate the need for cleaning with harsh chemicals. Cleaning should be done quarterly or on the schedule recommended by a system expert. When cleaning, the following points should be considered.

- When using chemicals, high pressure water, or physical scrubbing to clean a cooling system, test wastewater for compliance with local discharge limits (see Table 1.05, page 11 — *San Jose/Santa Clara Water Pollution Control Plant Discharge Limits for Interfering Substances*) prior to disposal into the sanitary sewer. Contact the San Jose/Santa Clara Water Pollution Control Plan for more information on discharge requirements.
- Cooling system cleaning should always be done while the system is off line, instead of by adding chemicals while the system is in normal operation mode.
- After cleaning, the cooling system should be treated with a prefilming agent to reduce corrosion. Prefilming chemicals such as phosphates or triazoles coat the metal surfaces with a protective layer. Prefilming can extend a cooling system's lifetime.



Wastes from cooling tower cleaning (including filter backwash) should never be discharged to a street, gutter, rooftop, or storm drain. Wastewater that does not meet sewer discharge limits must be treated prior to discharge, or taken off site for disposal. Any solids should be collected and managed as solid waste, not washed down the drain.

All employees should be trained in:

- Proper use of personal protective equipment: safety glasses, respirators, protective clothing.
- Proper chemical handling, storage, and disposal.
- Water conservation techniques.
- Reading and understanding of Material Safety Data Sheets.
- Spill response.

Keep your facility's Spill Response Plan updated and available to employees at all times. Material Safety Data Sheets must be available to all employees.

Materials Management

Obtain a Material Safety Data Sheet for each chemical used or stored in your facility. If applicable, determine whether you can use less toxic substitutes.

- Order minimum amounts of materials and chemicals. This practice reduces waste and leftover materials when procedures are changed, expiration dates pass, and spills occur, as well as minimizing severe problems in emergencies (fire, earthquake, etc.).
- Maintain a current and accurate chemical inventory, and use a first-in, first-out materials management policy (i.e., use the materials in the order that they were received) to make sure stockpiled materials do not expire before use.
- Inspect containers of raw materials closely for leaks and punctures or tears before acceptance of deliveries.
- Standardize the types of fluids and cleaning solutions used in the cooling towers. Using the same fluids for as many applications as possible facilitates reuse, recycling, treatment, storage and disposal.
- Whenever possible, select suppliers who provide fresh chemicals and pick up used solutions and empty containers for recycling.

3

Implementing a Cooling System Project

In addition to water quality and treatment chemistry, there are other important considerations for implementing changes to your cooling system.

Cost/Benefit Analysis

A cost/benefit analysis is a useful tool in analyzing the financial impact of cooling tower projects. A thorough evaluation of all project and operating costs is necessary to properly review the costs of the proposed changes. Reductions in energy, water, wastewater discharge, and treatment can offset the costs to design, install, and maintain onsite water in cooling towers. Using available financial incentives helps reduce the total cost of the project.

Examples of cost/benefit calculations are presented in Tables 3.01 and 3.02.

Table 3.01

Estimated Net Project Costs (NPC)				
	Item(s)	Quantity	Unit Cost	Total Cost
<u>COSTS:</u>				
Design Labor				
In-house				
Consultants				
Installation Labor				
New Equipment				
Purchased Materials				
Spare Parts				
Shipping				
Sales tax				
Permits				
Planning and Building				
Occupancy				
Hazardous Materials				
Hazardous Wastes				
Utility Connection Fees				
Electricity				
Water (potable)				
Recycled Water				
Sewage Collection and Treatment				
Lost Production Time				
Maintenance Training				
Other				
			Costs, Subtotal	_____
<u>CREDITS:</u>				
Financial Incentives				
Equipment Salvage/Resale				
Other				
			Credits, Subtotal	(_____)
ESTIMATED NET PROJECT COST (NPC)				_____

Table 3.02

Estimated Annual Operating Costs (AOC)		
	Before Project (AOC _{BP})	After Project (AOC _{AP})
ANNUAL COSTS:		
Labor		
Operations	_____	_____
Maintenance	_____	_____
Administrative	_____	_____
Waste Treatment	_____	_____
Laboratory Support	_____	_____
Parts	_____	_____
Utilities		
Electricity	_____	_____
Potable Water	_____	_____
Recycled Water	_____	_____
Sewer Service and Use	_____	_____
Chemicals		
Treatment Chemicals	_____	_____
Waste Treatment	_____	_____
Conditioning Chemicals	_____	_____
Permits	_____	_____
Insurance	_____	_____
Training	_____	_____
Other	_____	_____
Costs, Subtotal	_____	_____
ANNUAL CREDITS:		
Reclaimed Chemicals	_____	_____
Tax Savings from Depreciation	_____	_____
Other	_____	_____
Credits, Subtotal	(_____)	(_____)
ANNUAL OPERATING COSTS (AOC), TOTAL	_____	_____

The costs of energy, water, and wastewater discharge services vary by provider and from community to community. See *Resources*, page 33, for contact information to aid in determining the project’s utility rates.

Simple Payback Period

The Payback period can be used to help evaluate financial impacts of proposed changes. The simple payback period is calculated by dividing the initial investment or Net Project Cost (NPC), from Table 3.01, by the change in Annual Operating Costs (AOC), from Table 3.02 (before and after the project). Use available financial incentives to help reduce the length of the pay-back period. (See *Financial Incentives*, page 32.)

It should be noted that the simple payback period does not account for costs of borrowing, the time value of money, etc.

Equation 3.01

$$\text{PAYBACK PERIOD} = \text{NPC} \div (\text{AOC}_{\text{BP}} - \text{AOC}_{\text{AP}})$$

Permits and Requirements

When replumbing your facility to change the source water for your cooling system, contact your local building official for permits or requirements. In some instances, there may be special requirements for reusing process water in cooling systems.

Using recycled water requires a permit from South Bay Water Recycling (SBWR). During that permit process, SBWR staff procures project approval from the California Department of Health Services and ensures that the project meets state requirements for the proper use of recycled water. Review of your project would include:

- Proper labeling of all piping to distinguish lines carrying recycled water.
- Proper separation of potable and recycled waters and assurance that there is no backflow into potable water supply lines.
- Inclusion of high-efficiency drift eliminators for cooling towers.
- Proper signage in areas where recycled water is used.

SBWR staff is available throughout the process of connection to the recycled water system. For details on connection requirements and the connection process, contact SBWR at (408) 945-3000.

Upgrading or Building a New Facility

When selecting, installing, or replacing a cooling system, the following points should be considered:

- Closed rather than open systems.
- Systems fabricated from or coated with non-metallic or non-corrosive materials (stainless steel, anodized aluminum, or plastics) whenever possible.
- Non-copper piping for water supply, drain, and system circulation lines (especially in open systems).
- Installing flow meters for makeup water (each water source) and blowdown.
- Re-using wastewater generated at your site as cooling water.
- All water discharges must be plumbed to the sanitary sewer.
- New cooling systems must recirculate water. Installing a new non-recirculating (also known as “single-pass” or “once through”) cooling system is prohibited.
- Analyzing process water needs early in the facility design. Separate “process” from potable water supplies to minimize construction costs for second and third water sources, then pipe to equipment or systems.
- Installing evaporative coolers with pumps to recirculate cooling water. Cooling towers, evaporative condensers, and coolers are three major categories of water use.
- Evaluating alternative physical and chemical cooling water treatments that will minimize the amount of bleed-off or lost process water, occurring during each re-circulation of the cooling system.

New cooling system owners assume the burden of meeting any local wastewater flow discharge limits, which may be more stringent in the future. Plan ahead by evaluating the use of recycled water in your cooling system.

Hiring a Contractor

Most facilities contract with a commercial water treatment firm to supply the chemicals and, in some cases, manage their use.

Contracting for maintenance and chemical services is frequently done, especially when equipment protection services require special skills or training. Choose from the service providers who use proven conservative service practices and also address your priorities for water and chemical efficiency. Set a policy that water conservation is an important element of your cooling tower water treatment requirements. Review the following points and incorporate them into your service contracts or bidding process.

- Require service providers to prepare and submit projections for volumes of blowdown water as well as quantities and costs of chemicals.
- Require service providers to submit written explanations of their control decisions. Ask for the control purpose of each chemical that is used. Compare their control methods to these guidelines. Ask for clarification of all terms.
- Ask the service provider to describe any controls and changes needed to incorporate alternative water sources other than potable water.
- Ask them to estimate the cost for increasing cycles of concentration to different levels. Have them provide breakdowns and written explanations of these costs.
- Whenever possible, select suppliers who provide fresh chemicals, and collect used solutions and empty containers for recycling.

Financial Incentives



To encourage water efficiencies, the San Jose/Santa Clara Water Pollution Control Plant offers financial incentives to companies who make equipment changes that reduce wastewater discharge. Cooling tower reuse projects and upgrades are ideal candidates for the program. The program, Water Efficient Technologies (WET), offers rebates up to \$50,000 per project, based on flow reduction and project costs.

The criteria to qualify for the rebate are straightforward: apply before you begin the project, and document pre- and post-project water uses. The rebate will be based upon the reduction in discharge. Examples of cooling tower projects include reuse of RO Reject in cooling towers, reuse of acid waste neutralization wastewater in cooling towers, cooling tower ozonation and equipment upgrades to increase cycles of concentration. For more information on WET call (408) 945-3700 or visit www.slowtheflow.com.

Resources

Compliance and Water Quality Protection

- San Francisco Bay Regional Water Quality Control Board (510) 622-2300
www.swrcb.ca.gov/rwqcb2/
- Watershed Protection
San Jose/Santa Clara Water Pollution Control Plant (408) 945-3000
www.ci.san-jose.ca.us/esd/
- City of San José, Fire Prevention — Hazardous Materials Inspection (408) 277-4659
- City of Santa Clara, Hazardous Materials Administration (408) 615-4960
- City of Milpitas, Hazardous Material Permit (408) 586-3365
- Santa Clara County, Hazardous Materials Compliance Division (408) 299-6930
- Central Fire District, Fire Prevention — Hazardous Materials (408) 378-4010

Water Suppliers and Recycled Water

- City of Milpitas Community Services (408) 586-2600
www.ci.milpitas.ca.gov/
- City of Santa Clara Water Department (408) 615-2300
cho.ci.santa-clara.ca.us/40915.html
- Great Oaks Water Company (408) 227-9540
www.greatoakswater.com/index.html
- San Jose Water Company (408) 279-7900
www.sjwater.com
- San Jose Municipal Water System (408) 277-4036
www.sjmuniwater.com
- South Bay Water Recycling (408) 945-3000
www.ci.san-jose.ca.us/sbwr

Energy and Water Conservation

- City of Santa Clara Water Department (408) 615-2300
cho.ci.santa-clara.ca.us/40915.html
- Pacific Gas and Electric Company, Business Customer Center (800) 468-4743
www.pge.com/003_save_energy/rebates_index.shtml
- Santa Clara Valley Water District, Conservation Hotline (408) 265-2607, ext. 2554
www.valleywater.org
- Water Efficiency Technologies
San Jose/Santa Clara Water Pollution Control Plant (408) 945-3700
www.slowtheflow.com



References

Major portions of text and materials were developed from presentations made by and papers authored by Puckorius & Associates.

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2. *Reclaimed Water As Cooling Tower Makeup For Refinery/Petrochemical Plants – Southern California's Activities and Time Table*, Cooling Tower Institute Paper No: TP95-15, 1995.
3. *Cooling Tower & Reuse Workshop*, presented at the San Jose/Santa Clara Water Pollution Control Plant, 1999.
4. *A Practical Guide to Water Recycle-Reuse*, Technical Bulletin PA092, presented at Corrosion NACEExpo 97, 1997.
5. *Effectively Evaluating Cooling Water Treatment Programs*, Technical Bulletin PA056, presented at NACE Corrosion 88 Conference, 1988.
6. *Conservation Wastewater Reuse for Industrial Cooling Water Systems*, *Industrial Water Treatment*, pp. 43 – 47, September/October 1991.
7. *Municipal Wastewater Reuse for Cooling, Implications and Proper Treatment*, Water Reuse Symposium IV.

Conservation and environmental compliance information was adopted from guidelines by the City of San José, and regional wastewater treatment/recycling facilities in the South San Francisco Bay area.

1. *Cooling Water Systems, Management Guidelines for Water Protection*, Regional Water Quality Control Plant, serving the communities of East Palo Alto, Los Altos, Los Altos Hills, Mountain View, Palo Alto, and Stanford, 1996.
2. *Cooling Water Systems, Management Guidelines for Water Quality Protection*, East Bay Municipal Utility District Special District 1, serving the communities of Oakland, Emeryville, Albany, Alameda, Berkeley, Piedmont and Stege Sanitary District, January 1998.
3. *Using Recycled Water in Cooling Towers and Condensers*, City of Sunnyvale Department of Public Works/Environmental Division, Sunnyvale, 1998.
4. *Water Conservation Guide for Cooling Towers*, City of San José, Environmental Services Department, December 1992.
5. *Water Conservation Guide for New Construction*, City of San José, Environmental Services Department, December 1992.



SAN JOSE/SANTA CLARA
WATER POLLUTION
CONTROL PLANT

In accordance with the Americans with Disabilities Act, City of San José Environmental Services Department materials can be made available upon request in alternative formats, such as large print, audio tape or computer disk. Requests may be made by calling (408) 277-5533 (V) or (800) 735-2929 (CRS).