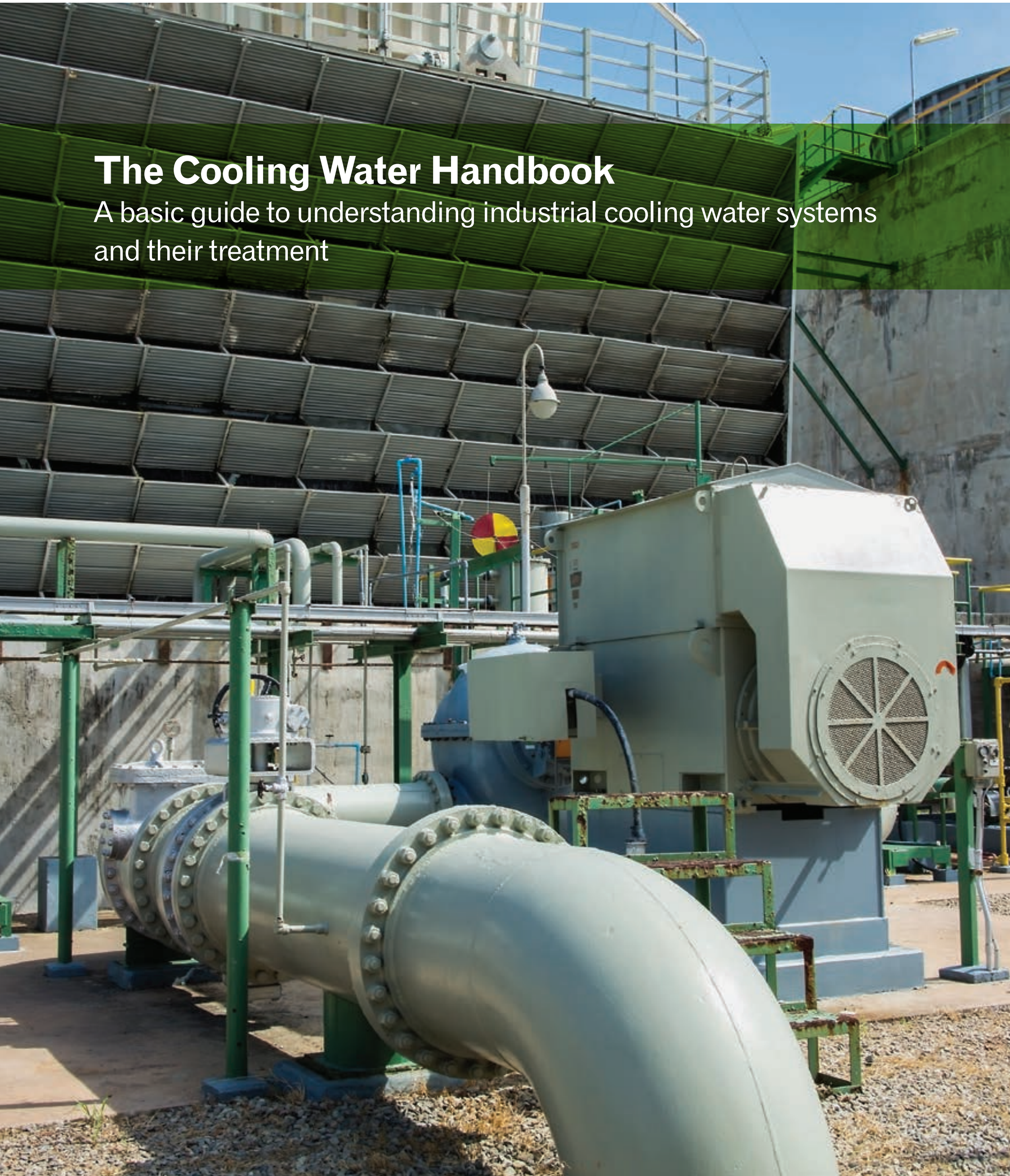
Buckman

The Cooling Water Handbook

A basic guide to understanding industrial cooling water systems and their treatment



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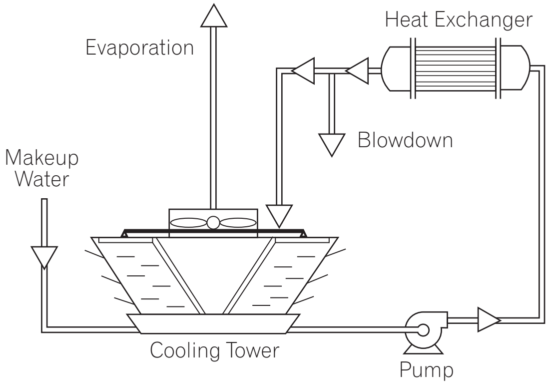
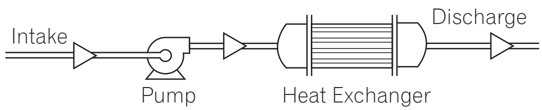
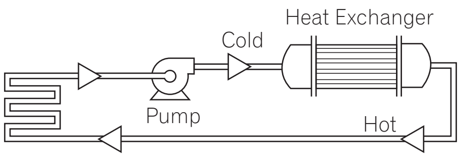


Once-Through System



Closed Recirculating System



An Introduction to Cooling Water

Water works for us

Water is used around the world in industrial applications because it has a number of valuable properties. It's non-toxic. It's readily available in many parts of the world. Its flow can be controlled easily through pressure or gravity. And, perhaps most important for cooling water systems, it provides a high level of ***thermal conductivity***, the ability to absorb heat and transport it away.

When we use water to lower the operating temperature of equipment or entire plants, it is called cooling water. Industries such as power, pulp and paper, oil and gas, ethanol, steel, mining, leather and manufacturing operations of every description depend on water for cooling.

And against us

Water is extremely good at dissolving substances and distributing them throughout itself. That's good when you want to deliberately dilute and mix chemicals. It's not so good when unwanted impurities are dissolved.

Surface waters used to supply cooling systems are open to the greater environment and can contain a wide variety of organic suspended matter that causes microbiological fouling. Ground water, while protected from some of the contaminants surface waters face, can contain high amounts of corrosion-causing metals, such as manganese and iron.

When unwanted compounds build to the point that solubility is no longer possible, scale forms. When algae and bacteria enter the system, water temperatures and nutrients can quickly aid in their growth, reducing water quality, fouling system surfaces and promoting corrosion.

That’s why proper treatment is important

Because water is so good at dispersing minerals and helping living things grow, water in cooling systems must be specially treated and monitored. The goal is water that runs free and clean, maximizing its ability to absorb heat and carry it away, so your systems stay cool.

The key is **water treatment optimization**—the ability to not only apply the right chemistries but also to constantly monitor and control water quality to keep it balanced at all times. By monitoring pH, water temperature, electrical conductivity, microbiological activity, corrosion, chemistry levels and other variables, your plant can be proactive. That not only helps keep contaminants from growing in your system but also helps you grow the bottom line. The right program can:

- Increase production
- Reduce downtime
- Lower operating and chemical costs
- Reduce your operation’s impact on the planet

Types of Cooling Systems

Treatment of cooling water will be different depending upon the kind of system in use. Here are the basic types:

Once-through

A once-through cooling system pumps water into equipment where it passes over a hot surface in order to cool it. The water then exits the equipment, taking heat with it. Simple and effective in a wide range of applications, this system can be undermined by the quality of the raw water. Lakes and rivers can bring in suspended matter and pollutants. Well waters can contribute large amounts of iron and scale-forming materials. Because water is only used once, a large amount of water is required.

Open recirculating

This system sends cooling water out of the equipment and into a pond or cooling tower, which is open to the atmosphere. Here evaporation occurs, removing heat along with the evaporated water. As a result, the remaining water cools. It is then combined with makeup water, which replaces the evaporated water, and is sent through the system again. Open-recirculating systems have become prevalent as water has become scarcer and environmental restrictions have been placed on bleedoff discharge.

Closed recirculating

All water used to carry heat away from equipment is run through a heat exchanger, which is cooled by air, mechanical refrigeration or a separate open cooling water system. There is no evaporation or makeup water required, so contamination—and the maintenance that results—is less likely. Since the same water is used over and over, water and sewage costs are lower and environmental compliance is easier. Many once-through systems have been converted to closed systems for this reason.

Specialized

A specialized cooling system might utilize compression or absorption-type refrigeration or air conditioning systems, which can be used to cool both processes and work spaces. It might utilize a cooling coil below the deck of the cooling tower. Or it might include the use of industrial air washers in which air is filtered, sprayed and then forced through a series of mist eliminators. Each system has its own unique risks for fouling and must be treated accordingly.

Scale

Common cooling water issues

Cooling water has many enemies. Sometimes they work alone. In other instances, they team up and compound the problem. For example, algae growth creates the perfect environment for corrosion to take hold. Here's a quick look at the major sources of cooling water fouling.

Scale

Scale and scalelike deposits include calcium carbonate, calcium phosphate, magnesium silicate, silica and other mineral compounds. They build up on heat exchanger tubes, reducing heat transfer. In sufficient amounts they can restrict water flow. When heat transfer is reduced, efficiency of production is reduced and the quality of products can be compromised. Equipment can suffer damage from overheating. Scale can cause expensive downtime for cleaning or repair, resulting in lost revenue. In addition, scale and scalelike deposits can accelerate corrosion.

Corrosion

Corrosion occurs when electrically charged particles flow through metal components, causing the metal to oxidize and eventually lose thickness. Corrosion causes pitting and leaks in cooling systems and can lead to the replacement of pipes, pumps, heat exchanger tubes and even entire cooling towers. Iron oxide, especially, contributes to fouling and deposition, which interfere with heat transfer. Downtime for equipment repair or replacement is always costly.

Corrosion

Organic fouling

Mud, sand, silt, clay, biological matter and even oil can enter the system through its makeup supply or from the air. These suspended materials can accumulate and settle in the system, blocking flow and reducing efficiency. Oil film can reduce heat transfer and encourage the growth of microorganisms.

Microbiological deposits

Biofilms severely restrict heat transfer. Slime masses bind inorganic and organic foulants and plug systems. Algae and fungi cause extensive plugging and fouling of heat exchanger tubes, water lines, tower spray nozzles, distribution pans, screens and fill. Microbiological fouling also contributes to under-deposit corrosion as well as the growth of corrosion-causing bacteria.

Foam

Cascading water, the continuous recycling of contaminants and a high concentration of foam stabilizers can cause foam to overflow the tower sump, blow off the towers or even cause an airlock in the water pumps. Worst of all, foam concentrates deposit-forming materials, increasing the chance of fouling in the system.

Basic cooling water treatment

Treatment can be divided into four steps:

- Audit and assessment
- Cooling water pretreatment
- Chemical applications
- Monitoring

Audit and assessment

Before effective treatment can be provided, a thorough assessment of conditions in your cooling water system must be made. Experienced field engineers backed by laboratory resources can audit your system, perform accurate tests to measure water quality and trouble-shoot problems. Some common tests include:

- ATP testing
- Corrosion failure analysis
- Biocide efficacy
- Water and mass balances
- On-site physical audits by industry experts
- Computer modelling
- Deposit analysis
- Biofilm and dispersion analysis

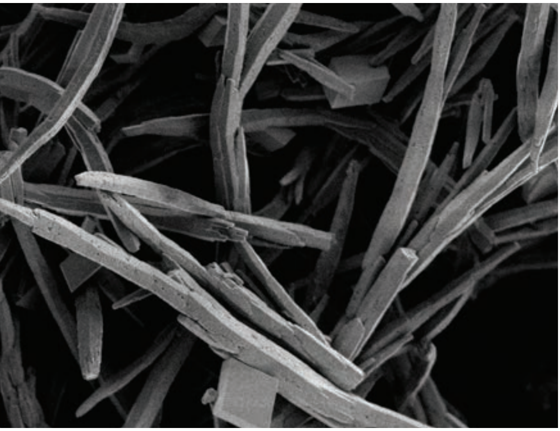
Cooling water pretreatment

Pretreatment for cooling systems includes:

- Modification of the water composition – clarifiers and cold-lime softening equipment remove suspended solids, organics and/or hardness that are present in the makeup water or in recycled cooling water
- Removal of suspended solids in the cooling water – side-stream filtration removes solids but doesn't alter the chemical composition of the cooling water

Chemical applications

To control scale, corrosion, microbiological fouling, and foam, water quality must be maintained at all times, and the right microbicides must be applied in just the right doses. That takes a delicate balance of chemistries and application expertise.



Photomicrograph of $Ca_3(PO_4)_2$ scale

Fighting Scale

Scaling in cooling water systems can be prevented using four basic approaches:

1. Limit the concentration of critical ions by maintaining concentrations that are lower than those required to cause scaling. This can be accomplished by pretreatment of the water or by limiting the tower cycles of concentration.

2. Reduce alkalinity with acid. This removes carbonate and bicarbonate by converting them to CO_2. Since the carbonate level is controlled, the potential for calcium carbonate is restricted.

3. Alter system design or operation. Scaling potential can be altered by altering the system's mechanical operation. Options include:

- Increasing cooling water velocity, which keeps the water cooler
- Using compressed air to "air rumble" the heat exchanger inlet water on a periodic basis to dislodge and remove scales and deposits
- Modifying the exchanger design so that the cooling water is on the tube side, promoting higher velocity
- Changing the metallurgy of the heat transfer surface. Mild steel heat transfer surfaces will scale under conditions where copper and other alloys will not, due to corrosion and surface roughness
- Reducing the heat flux, either by reducing the process load or by increasing heat exchanger size and, as a result, reducing metal surface temperature and bulk water temperature

4. Apply chemical deposit inhibitors. There are several types that act in distinctly different ways to control deposits.

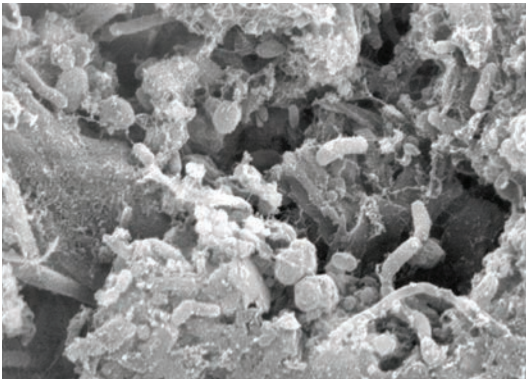
Fighting Corrosion

Fighting corrosion involves controlling certain water properties, including pH, oxygen, temperature, water velocity, suspended solids, and dissolved solids. Dissimilar metals and

process leaks can also lead to corrosion and must be addressed.

The methods used to minimize corrosion in cooling water systems include:

- Use of corrosion-resistant materials in the system's construction
- Application of inert barriers
- Use of sacrificial anodes
- Adjustments to water chemistry
- Prevention of scale and microbiological fouling which can lead to corrosion
- Application of chemical corrosion inhibitors



Biofilm

Fighting Microbiological Fouling

Cooling water systems are constantly inoculated with microbes from the makeup water, process contamination and the air. Controlling microbiological fouling depends upon effective control of all these parameters:

Water quality—organic contaminants, such as oil and grease, fertilizers, food products and byproducts, dust and silt from the air, leaves, and suspended solids have a major effect on the potential for microbial growth.

pH—changes in pH, in the range of 6.5–9.5, do not significantly affect microbial growth rates in cooling water treatments.

Water velocity—the flow rate of cooling water is a critical factor, particularly in areas of low velocity such as in shell-side heat exchangers, where debris can settle out and provide favorable conditions for microbial activity.

Biocide treatment—The application of biocides, by either slug or continuous addition, is used to control the level of microbes, depending on a specific plant's requirements. Underfeeding a biocide can rapidly lead to rebounds in the population of microorganisms or may not provide sufficient kill to ensure adequate control.

Biofilm control—Removal or control of the biofilm on system surfaces is critical. While bulk water concentration of microorganisms raises the potential for re-inoculation and health hazards, biofilm raises the potential for corrosion.

Microbiological fouling

Chemical applications (continued)

Chemistries for microbiological control

Chemicals used to control microbial populations can be grouped in three general classes based on their mode of action:

- Oxidizing biocides—these break down organic substances and kill microorganisms, including bacteria, in cooling waters
- Non-oxidizing biocides—these control microbiological activity by interfering with cell structure and function
- Biodispersants—these break up and disperse deposits, such as slimes and biofilm

Chlorine and bromine are oxidizers often used to control microbiological activity. In many cases, bromine can be more effective than chlorine gas. A process called Target Bromination uses sodium bromide and a safe, easy-to-handle source of chlorine, such as industrial sodium hypochlorite, to rapidly produce hypobromous acid instead of the hypochloromous acid produced using chlorine gas. Benefits include:

- Stability under alkaline conditions
- Efficacy against a wide variety of biofoulants
- Rapid reaction rate
- Reduced corrosivity to system metallurgy
- Reduced fouling potential
- Lower environmental impact

High organic demand

In systems with high organic demand, both chlorine and bromide become less effective and, because more has to be used, less cost efficient. In this situation, an alternative low-oxidizing chemistry, such as Oxamine®, can be used. Unlike bromine and chlorine, its oxidative strength is low enough that only minimal amounts react with extraneous organic matter in cooling water, making it more effective at disrupting microbiological activity.

Fighting Foam

Excess foam can damage the surfaces of objects around and below the tower and spread bacteria. Fortunately it can be controlled by defoamers, a system blowdown to remove contaminants, the mitigation of environmental dirt, or adjusting the chemical feed or alkalinity in the water.

Cart filter fouling

Foam

Monitoring

The more control you have over your cooling water treatment program, the better you can control fouling, plant efficiency and costs. You should be able to look to your chemical company for advanced monitoring technology that can conduct precise on-line measurements of key microbiological control parameters and deliver the data to you in real time. This system should also be able to provide feedback directly to your automated biocide feed unit to keep your system in optimum balance.

EZe Monitor® equipment

Buckman OnSite® dashboard interface provides quick access to continuous reporting and valuable insight into the customer's internal processes.

Taking the heat off your operating budget

This handbook has been provided to you by Buckman, a leading supplier of cooling water treatment chemistries and services around the world. You can rely on us for unsurpassed support in all of these critical areas:

Cooling tower

- Microbiological control
- Biocide efficacy
- Enhanced filtration systems
- ATP testing
- Deposition removal, control, and monitoring
- Blowdown reduction to conserve water

Closed loop

- Scale and corrosion prevention
- Successful management of multi-metal systems
- Procedures to extend equipment life and reduce costs

Chiller

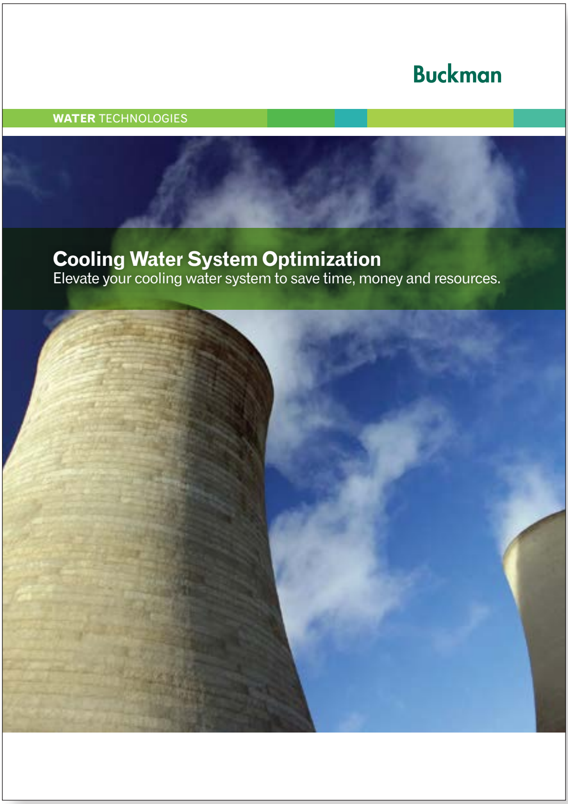
- Corrosion failure analysis
- Control and monitoring of corrosion, scale, and deposition

Feed systems

- Troubleshooting and optimization
- Accurate, effective, and easy-to-install feed equipment
- Water usage reduction through control and cycle enhancement
- Optimization of pump-off/direct chemical feed systems
- Application of blended products, reducing the number of products needed

Learn more

To learn about our latest treatment and monitoring technologies for cooling water treatment, contact a Buckman representative, request our Cooling Water System Optimization brochure, and visit **buckman.com**.



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Commitment makes the best chemistry.

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