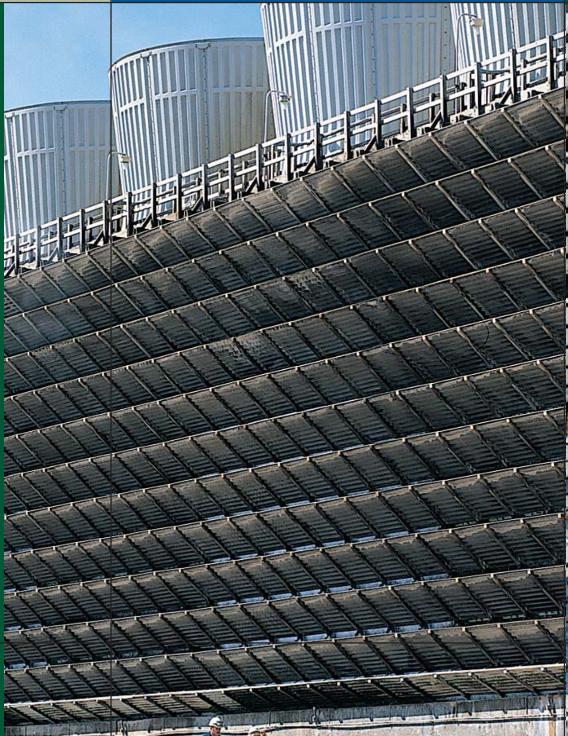
NALCO

Essential Expertise
for Water, Energy and Air.℠

Cooling Water Treatment



Contents

Cooling Water Systems: An Overview

Why Water is Unique

Water is a unique molecule with basic properties that make it ideal for cooling water applications. For example, it is safe, easy to handle, widely available, and inexpensive in most industrialized regions of the world. Water is a more efficient heat transfer medium than many other materials, especially compared to air.

Water is often called the universal solvent – a property that can cause unwanted side effects for industrial applications. Water can dissolve many substances, including gases like oxygen and carbon dioxide. As a result, water can cause corrosion of metals used in cooling systems. As water concentrates in cooling systems, dissolved ions may exceed the solubility of some minerals and form scale. The life-giving properties of water can also encourage bacterial growth that can foul system surfaces. These problems require proper treatment and control to maintain the value of a cooling water system to the process it serves.

Cooling water systems are an integral part of process operations in many industries. For continuous plant productivity, these systems require proper chemical treatment and preventive maintenance.

Why are Cooling Water Systems Needed?

Most industrial production processes need cooling water for efficient, proper operation. Refineries, steel mills, petrochemical plants, manufacturing facilities, food plants, large buildings, chemical processing plants, and electric utilities all rely on the cooling water system to do its job. Cooling water systems control temperatures and pressures by transferring heat from hot process fluids into the cooling water, which carries the heat away. As this happens, the cooling water heats up and must be either cooled before it can be used again or replaced with fresh makeup water. The total value of the production process will be sustained only if the cooling system can maintain the proper process temperature and pressure. The cooling system design, effectiveness and efficiency depends on the type of process being cooled, the characteristics of the water and environmental considerations.

Why is Treatment and Control Important?

The cooling system operation can directly affect reliability, efficiency, and cost of any industrial, institutional, or power industry process. Monitoring and maintaining control of corrosion, deposition, microbial growth, and system operation is essential to provide the optimum Total Cost of Operation (TCO). The first step to achieve minimum TCO is selecting an appropriate treatment program and operating conditions to minimize system stresses. One such treatment program is Nalco 3D TRASAR cooling water technology optimization software. Another step is implementation of an appropriate monitoring program to evaluate system conditions and treatment program performance. The final step is use of Nalco 3D TRASAR® technology to control system stress, optimize operating conditions and maintain program parameters to minimize TCO.

Why is Monitoring Important?

Monitoring is an integral part of any industrial water treatment program. It is used to determine treatment effectiveness and to establish the optimum level of treatment that is most cost effective, with respect to energy, water and chemical usage.

The purpose of corrosion monitoring is to assess or predict corrosion behavior of the system. Basically, there are two objectives to monitoring:

1. To obtain information on the condition of the operational equipment
2. To relate this information to the operating variables (i.e., pH, temperature, water quality, chemical treatment). Meeting these objectives will provide the following results:
   - Increased life of the plant
   - Improved quality of the plant's product
   - Maintenance predictation needs at plant
   - Reduced plant's operating cost

Corrosion monitoring is standard practice in the water treatment industry. The plant engineer can use this information to predict equipment life. Monitoring helps the engineer identify significant factors responsible for corrosion problems and assures implementation of solutions.

Corrosion monitoring is a diagnostic tool. It provides information for the solution of corrosion problems. Knowledge of corrosion trends can be very valuable. Frequently, several variables might appear to be significant, and the ability to correlate corrosion rates with a single variable under specific conditions can be vital. As a logical extension of diagnostic capabilities, corrosion monitoring is used to assess the effectiveness of a solution to a specific water treatment problem.

Why is more than One Type of Monitoring Method Recommended?

Corrosion monitoring can be used to provide operational information. If corrosion can be controlled by maintaining a single variable (i.e., temperature, pH, chemical treatment) within limits previously determined, then that variable can be used to predict changes in corrosion patterns as the limits are exceeded in both a positive and negative direction. An extension of this technique is to use a monitored variable to control chemical addition directly through automatic feed systems.

The particular corrosion monitoring technique selected depends upon its applicability to the system and the information being sought. Some monitoring techniques provide:

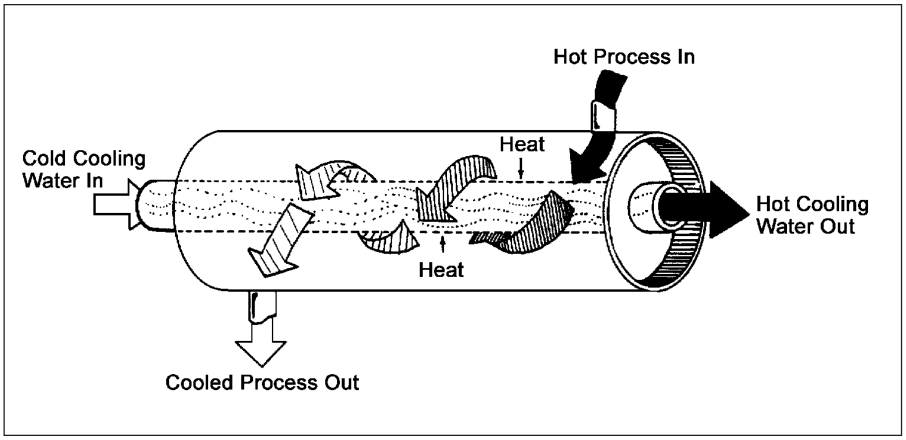
- Information that is effective instantaneously
- A measure of average corrosion rates
- A measure of total corrosion or the remaining thickness
- Information on the overall system

No one monitoring technique will provide all the necessary data to properly evaluate the efficacy of the treatment program. More than one technique may be necessary to monitor a particular system.

Most corrosion monitoring techniques are best suited to situations where corrosion is of a general nature, but some techniques provide at least some information on localized attack, such as pitting.

What is Involved in the Cooling Process?

Cooling involves the transfer of heat from one substance to another. The substance that loses heat is said to be cooled, and the one that receives the heat is referred to as the coolant. All cooling systems rely on this give and take action, with water being the most widely used coolant.



Heat Transfer Principle

How Does Cooling Water Impact Total Cost of Operation (TCO)?

Production processes or building cooling use significant amounts of energy. The cooling system removes the unwanted heat. When the cooling system cannot remove the heat efficiently, the entire process suffers and costs increase (see chart below). In addition, if the cooling system operation is not optimized, excess water, wastewater, and energy costs result.

Why is Water Used for Cooling?

Several factors make water an excellent coolant:

- It is normally plentiful, readily available, and inexpensive
- It is easily handled and safe to use
- It can carry large amounts of heat per unit volume, especially compared to air
- It does not expand or compress significantly within normally encountered temperature ranges
- It does not decompose

Cost/kWH (Cost/kWh) (U.S. Dollars)	10 mil (0.254 mm) Thickness	50 mil (1.27 mm) Thickness	100 mil (2.54 mm) Thickness
$.04	$8,800/yr	$42,200/yr	$80,400/yr
$.06	$13,200/yr	$63,300/yr	$120,600/yr
$.08	$17,600/yr	$84,400/yr	$160,800/yr

Energy costs wasted by calcium carbonate deposits of varying thickness in a 1000 ton (12.7 GJ/h) chiller running 24 h/d, 365 d/yr.

What are the Sources of Cooling Water?

Fresh water – This is the primary source of makeup for cooling water systems. Fresh water can be surface water (rivers, streams, reservoirs) or ground water (shallow or deep well waters). In general, ground water supplies are more consistent in composition, temperature, and contain less suspended matter than surface water supplies, which are directly affected by rainfall, erosion, and other environmental conditions. Ground water sources frequently contain soluble iron or manganese which can cause fouling in cooling systems if not removed. These are much less common in surface water.

Salt water and wastewater – Because of environmental considerations, water cost, and water availability, some plants are now using salt water and wastewater treatment plant effluents as sources of cooling water. Close attention to design and treatment of cooling systems using these sources of water is critical for reliable performance and long life.

What are Some Important Properties in Cooling Water Chemistry?

Conductivity – A measure of water's ability to conduct electricity. In cooling water, it indicates the amount of dissolved minerals in the water. Conductivity is measured in µS/cm (microSiemens/cm) and can vary from a few for distilled water to over 30,000 µS/cm for sea water.

pH – Gives an indication of the relative acidity or basicity of water. The pH scale runs from 0 to 14, with 0 representing maximum acidity and 14 representing maximum basicity.

Alkalinity – In cooling water, two forms of alkalinity play a key role. These are carbonate ions (CO_3^{-2}) and bicarbonate ions (HCO_3^{-}). The alkalinity acts as a buffer to charges acidity or basicity.

Hardness – Refers to the amount of calcium and magnesium ions present in the water. The hardness in natural waters can vary from a few parts per million (ppm) to over 800 ppm.

The pH Scale

	Relative Concentration of Hydrogen Ions Compared to Distilled Water	pH =	Examples of Solutions at this pH
	10,000,000	pH = 0	Battery acid, strong acid
↑	1,000,000	pH = 1	Hydrochloric acid secreted by stomach lining
More Acidic	100,000	pH = 2	Lemon juice, vinegar
	10,000	pH = 3	Grapefruit, orange juice, soda
	1,000	pH = 4	Tomato juice, acid rain
	100	pH = 5	Soft drinking water, black coffee
	10	pH = 6	Urine, saliva
Neutral	1	pH = 7	"Pure" water
	1/10	pH = 8	Sea water
	1/1000	pH = 9	Baking soda
	1/1,000	pH = 10	Great salt lake, milk of magnesia
More Basic	1/10,000	pH = 11	Ammonia solution
	1/100,000	pH = 12	Soapy water
↓	1/1,000,000	pH = 13	Bleaches, oven cleaner
	1/10,000,000	pH = 14	Liquid drain cleaner

Why are These Water Chemistry Properties Important in Cooling Water Systems?

These key water chemistry properties have a direct impact on the four main problems of cooling water systems; corrosion, scale, fouling, and microbial contamination. These properties also affect the treatment programs designed to control the problems.

Conductivity – Cooling water treatment programs will function within specific ranges of conductivity. The range will be dependent upon the particular cooling water system's design, characteristics, and the type of chemical program.

pH – Control of pH is critical for the majority of cooling water treatment programs. In general, metal corrosion rate increases when pH is below recommended ranges. Scale formation may begin or increase when pH is above recommended ranges. The effectiveness of many biocides depends on pH; therefore, high or low pH may allow the growth and development of microbial problems.

Alkalinity – Alkalinity and pH are related because increases in pH indicate increases in alkalinity and vice versa. As with pH, alkalinity below recommended ranges increases the chances for corrosion; alkalinity above recommended ranges increases the chances for scale formation. When corrosion and scale problems exist, fouling will also be a problem.

Hardness **–** Hardness levels are usually associated with the tendency of cooling water to be scale forming. Chemical programs designed to prevent scale can function only when the hardness level stays within the specified range. Some corrosion control programs require a certain hardness level to function correctly as corrosion inhibitors, so it is important to make sure hardness levels are not too low in these programs.

What are the Cooling Water Systems?

There are really only three basic designs:

1. Open recirculating systems
2. Once-through systems
3. Closed recirculating systems

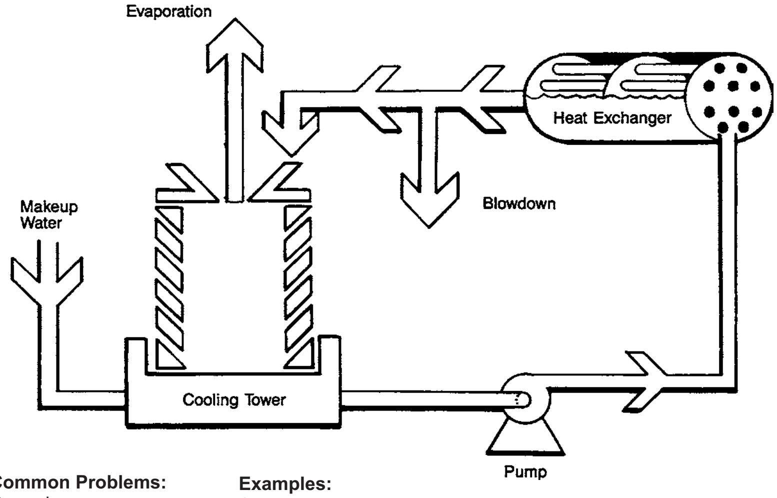
How are These Three Systems Different?

Open recirculating systems are the most widely used industrial cooling design. These systems consist of pumps, heat exchangers, and a cooling tower. The pumps keep the water recirculating through heat exchangers. It picks up heat and moves it to the cooling tower where the heat is released from the water through evaporation. Because of evaporation, the water in open recirculating systems undergoes changes in its basic chemistry. The dissolved and suspended solids in the water become more concentrated.

In once-through systems, the cooling water passes through heat exchange equipment only once. The mineral content of the cooling water remains practically unchanged as it passes through the system. Because large volumes of cooling water are used, these systems are used less often than recirculating systems. Seasonal temperature variation of the incoming water can create operational problems. Temperature pollution of lakes and rivers by system discharge is an environmental concern.

Closed recirculating systems use the same cooling water repeatedly in a continuous cycle. First, the water absorbs heat from process fluids, and then releases it in another heat exchanger. In these systems, an evaporative cooling tower is not included. Often used for critical cooling applications or when water temperature below ambient is required, as in a chilled water system.

OPEN RECIRCULATING SYSTEM

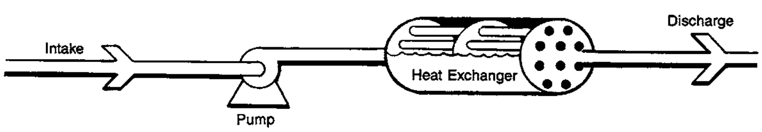


Common Problems:
Corrosion
Fouling
Scale
Wood Decay
Microbiological Contamination

Examples:
Spray Ponds
Cooling Towers
Evaporative Condensers

Amount of Water Used: Moderate

ONCE-THROUGH SYSTEM

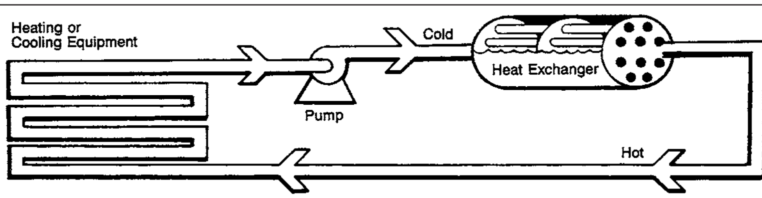


Common Problems:
Corrosion
Fouling
Scale
Microbiological Contamination

Examples:
Potable Water Systems
Process Water
General Service

Amount of Water Used: Extremely Large

CLOSED RECIRCULATING SYSTEM



Common Problems:
Corrosion
Fouling
Leakage
Microbiological Contamination

Examples:
Diesel Engine Jackets
Automobile Radiators
Chilled Water Systems

Amount of Water Used: Negligible

Does the Type of Cooling System Affect Treatment Application Principles?

Yes. The choice of treatment is dependent on the type of system.

In an ***open recirculating system***, more chemical must be present because the water composition changes significantly through evaporation. Corrosive and scaling constituents are concentrated. However, treatment chemicals also concentrate by evaporation; therefore, after the initial dosage, only moderate dosages will maintain the higher level of treatment needed for these systems.

In a ***once-through system***, protection can be obtained with relatively few parts per million of treatment, because the water does not change significantly in composition while passing through equipment. Treatment can be challenging because even small treatment dosage can be a large quantity of chemical because of the large volume of water used.

In a ***closed recirculating system***, water composition remains fairly constant. Ideally, there is very little loss of either water or treatment chemical. Softened or demineralized water and high treatment dosages can be used without a significant cost impact, because systems are ideally filled once and minimal water is lost from the system.

Cooling Water Problems and Solutions

The following four problems are normally associated with cooling water systems.

1. CORROSION

Manufacturing of common metals used in cooling systems, such as mild steel, involves removing oxygen from the natural ore. Cooling water systems are an ideal environment for the reversion of the metal to the original oxide state. This reversion process is called corrosion.

2. SCALE

Minerals such as calcium carbonate, calcium phosphate, and magnesium silicate are relatively insoluble in water and can precipitate out of the water to form scale deposits when exposed to conditions commonly found in cooling water systems.

3. FOULING

The deposition of suspended material in heat exchange equipment is called fouling. Foulants can come from external sources such as dust around a cooling tower or internal sources such as by-products of corrosion.

4. BIOLOGICAL CONTAMINATION

Cooling water systems provide an ideal environment for microbial organisms to grow, multiply, and cause deposit problems in heat exchange equipment. Microbial growth can strongly influence corrosion, fouling, and scale formation, if not controlled properly.

Macrofouling can occur in once-through cooling systems or water intakes in lakes and rivers. Various species of clams, mussels, and other marine organisms can attach to the piping, reducing water flow and increasing corrosion.

Scale deposits and corrosion products on tube surfaces reduce heat transfer efficiency, increase energy costs, and reduce equipment life.

What are the Effects of These Problems?

If not properly controlled, these problems can have a direct, negative impact on the value of the entire process or operation. Examples of problems that corrosion, deposition, and biological fouling can create are as follows:

- Increased maintenance cost
- Equipment repair or replacement cost
- More frequent shutdowns for cleaning and replacement of system components
- Reduced heat transfer efficiency and therefore reduced energy efficiency of the process being cooled
- Increased fuel costs for power generation plants
- Increased energy consumption by refrigeration chillers
- Possible product yield reduction or even plant shutdown
- Product quality problems and increased product rework
- Environmental compliance problems
- Increased greenhouse gas emissions due to higher energy use

Proper program selection and system control methodology are essential to maximizing the value of the cooling system to the operation of any facility. The proper system management to control cooling system stresses will optimize TCO.

CORROSION

What is Corrosion?

Corrosion is an electrochemical process by which a metal returns to its natural oxide state. For example, mild steel is a commonly used metal in cooling water systems that is very susceptible to corrosion. Corrosion causes loss of metal thickness or even penetration of tube walls which can cause leakage of process fluids into the cooling water or vice versa. Corrosion is generally a greater concern with the more common, lower cost materials like mild steel.

How does Corrosion take Place?

For corrosion to occur, a corrosion cell, consisting of an anode, a cathode, and an electrolyte must exist. Metal ions dissolve into the electrolyte (water) at the anode. Electrically charged particles (electrons) are left behind. These electrons flow through the metal to other points (cathodes) where electron-consuming reactions occur. The result of this activity is the loss of metal and often the formation of a deposit.

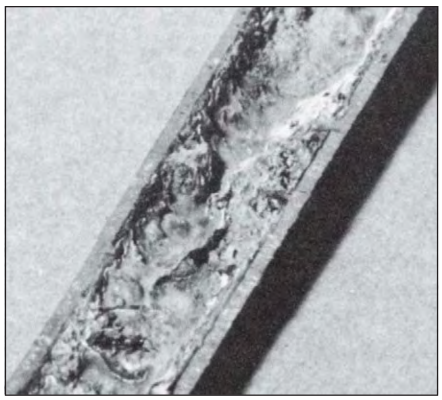
Are Copper, Aluminum Alloys, and Stainless Steel Subject to Corrosion?

In general, these metals corrode more slowly than mild steel. However, in some waters, these metals may be subject to severe localized (or pitting) attack. In addition, dissolved gases, such as hydrogen sulfide (H_2S) or ammonia (NH_3) are frequently more destructive to these metals than to mild steel.

What are the Different Types of Corrosive Attack?

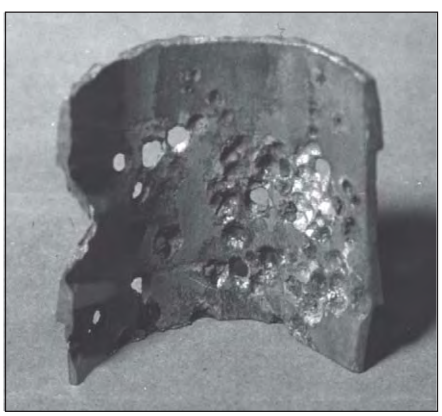
Many different types of corrosion exist, but the most common are characterized as general, localized or pitting, and galvanic.

General attack exists when the corrosion is uniformly distributed over the metal surface. The considerable amount of iron oxide produced by generalized attack contributes to fouling problems and reduces system efficiency.



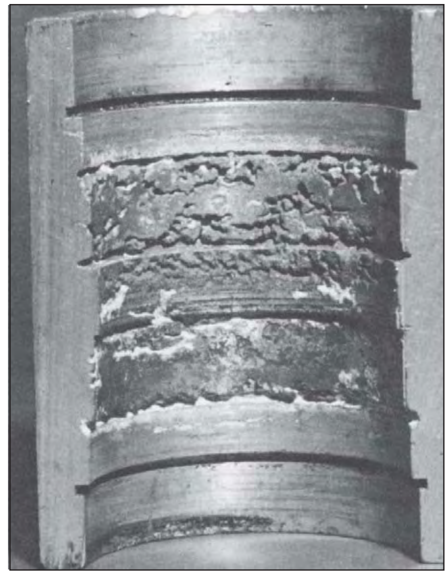
General corrosion

Localized (or pitting) attack exists when only small areas of the metal corrode. Pitting is the most serious form of corrosion because the action is concentrated in a small area. Pitting may perforate the metal in a short time.



Localized corrosion (pitting)

Galvanic attack can occur when two different metals are in contact. The more active metal corrodes rapidly. Common examples in water systems are steel and brass, aluminum and steel, and zinc and steel. If galvanic attack occurs, the metal named first will corrode.



Severe galvanic attack on steel adjacent to nozzle holes where brass nozzles had been inserted

What Water Characteristics Affect Corrosion?

The most important factors are:

- Oxygen and other dissolved gases
- Dissolved and suspended solids
- Alkalinity or acidity (pH)
- Velocity
- Temperature
- Microbial activity

How Does Oxygen Affect Corrosion?

Oxygen dissolved in the water is essential for the cathodic reaction to take place. Dissolved oxygen drives the cathodic reaction by accepting electrons from the metal. This allows more metal to dissolve at the anode.

How do Dissolved and Suspended Solids Affect Corrosion?

Dissolved solids can affect the corrosion reaction by increasing the electrical conductivity of water. As the dissolved solids concentration increases, so does the conductivity, and the likelihood of corrosion is greater. Dissolved chlorides and sulfates are particularly corrosive. Suspended solids can influence corrosion by erosive or abrasive action, and they can settle on metal surfaces to set up localized corrosion cells.

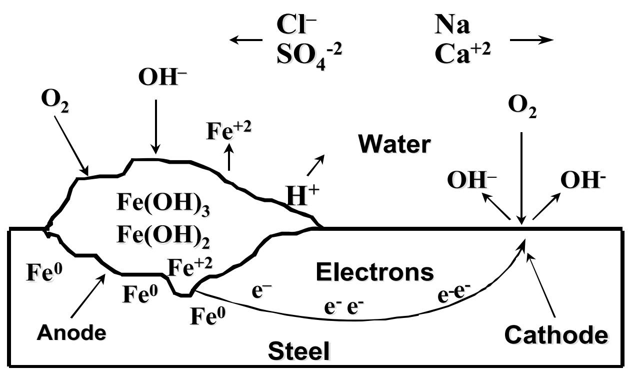
ANODE: Neutral Metal → Soluble Metal Ion + Electrons

$$Fe^0 \longrightarrow Fe^{+2} + 2e^-$$

CATHODE: Oxygen + Electrons + Water → Soluble Ion

$$1/2\ O_2 + 2e^- + H_2 \longrightarrow 2(OH^-)$$

The Corrosion Cell



Electrochemical corrosion cell and reactions that occur at the anode and cathode

How does Alkalinity or Acidity Affect Corrosion?

Acidic and slightly alkaline water can dissolve metal and the protective oxide film on metal surfaces. More alkaline water favors the formation of the protective oxide layer.

How Does Water Velocity Affect Corrosion?

High-velocity water increases corrosion by transporting oxygen to the metal and by carrying away corrosion products at a faster rate. High velocity can also cause erosion of metal surfaces, any protective films on the metal, and oxides. Copper alloys, which are softer than steel alloys, are more susceptible to erosion corrosion. When water velocity is low, deposition of suspended solids can establish localized corrosion cells, thereby increasing corrosion rates.

How Does Temperature Affect Corrosion?

Below 160°F (71°C), every increase in temperature of 18°F (10°C) causes corrosion rates to double. Above 160°F (71°C), additional temperature increases have relatively little effect on corrosion rates in cooling water systems, partly because the oxygen concentration in water is reduced at high temperatures.

How Does Microbial Growth Affect Corrosion?

Microbial growth promotes the formation of corrosion cells. In addition, the byproducts of some organisms, such as hydrogen sulfide from anaerobic corrosive bacteria are corrosive to many metals.

What Methods are Used to Prevent Corrosion?

Corrosion can be prevented or minimized by one or more of the following methods:

- When designing a new system, choose corrosion-resistant materials to minimize the effect of an aggressive environment.

- Apply protective coatings such as paints, metal plating, tar, or plastics.
- Protect cathodically, using sacrificial anodes or other methods such as impressed current.
- Add protective film-forming chemical corrosion inhibitors that the water can distribute to all wetted parts of the system.

Material Costs to Replace or Retube Chillers				
Tons (GJ/h)	Centrifugal Retubing	Centrifugal Chiller	Absorption Retubing	Absorption Chiller
250 (3.2)	$ 20,000	$ 78,000	$ 38,000	$ 136,000
500 (6.3)	$ 36,000	$ 128,000	$ 70,000	$ 205,000
750 (9.5)	$ 52,000	$ 176,000	$ 98,000	$ 272,000
1,000 (12.7)	$ 68,000	$ 224,000	$ 130,000	$ 330,000
1,500 (19)	$ 99,000	$ 315,000	$ 195,000	$ 450,000

How do Chemical Corrosion Inhibitors Work?

Chemical inhibitors reduce corrosion by interfering with the corrosion mechanism. Inhibitors usually affect the corrosion reactions at either the anode or the cathode.

Anodic corrosion inhibitors establish a protective film on the anode. These inhibitors can be effective, although they can be dangerous; if insufficient anodic inhibitor is present, the entire corrosion potential occurs at the remaining unprotected anodic sites. This causes severe localized (or pitting) attack.

Cathodic corrosion inhibitors form a protective film on the cathode. These inhibitors reduce the corrosion rate in direct proportion to the reduction of cathodic reaction.

General corrosion inhibitors protect by filming all metal surfaces whether anodic or cathodic.

What Inhibitors are Commonly Used for Cooling Water Systems?

Mainly anodic

- Molybdate
- Orthophosphate
- Nitrite
- Silicate

Mainly cathodic

- Phosphino Succinic Oligomer (PSO)
- Bicarbonate
- Polyphosphate
- Zinc

General

- Soluble oils
- Triazoles for copper

What is the Cost of Corrosion?

Corrosion can increase costs of any process. It causes fouling that reduces heat exchange efficiency and reduces the process efficiency. If severe enough, corrosion can cause failure of an exchanger, requiring either retubing or replacement. This has direct cost for the equipment being replaced and costs to shut down the process while repairs are completed (see Material Costs Chart above).

What is the Most Important Factor in an Effective Corrosion Inhibitor Program?

Consistent control of both the corrosion inhibitor chemicals and the key water chemistry characteristics is essential for effective corrosion control. No program will work without proper application of treatment and system control.

While daily monitoring of water chemistry and product dosage can be effective, continuous monitoring and control will provide the best results. 3D TRASAR technology provides the means to continuously monitor the system stresses and automatically respond to any changes in the system, thereby controlling corrosion stresses at the optimum level for lowest TCO. With 3D TRASAR technology, the cooling system can provide its optimum value to the total operation of the facility.

SCALE

What is Scale?

Scale is a dense coating of predominantly inorganic material formed from the precipitation of water-soluble constituents. Some common scales are:

- Calcium carbonate
- Calcium phosphate
- Magnesium silicate
- Silica

Why Does Scale Form?

Scale results when dissolved ions in the water exceed the solubility of a given mineral.

Four principal factors determine whether or not a water is scale forming:

1. Temperature
2. Alkalinity or acidity (pH)
3. Amount of scale-forming material present
4. Influence of other dissolved materials, which may or may not be scale-forming

How do These Factors Increase the Amount of Scaling?

As any of these factors change, scaling tendencies also change. Most salts become more soluble as temperature increases. However, some salts, such as calcium carbonate, become *less soluble* as temperature increases. Therefore, they often cause deposits at higher temperatures.

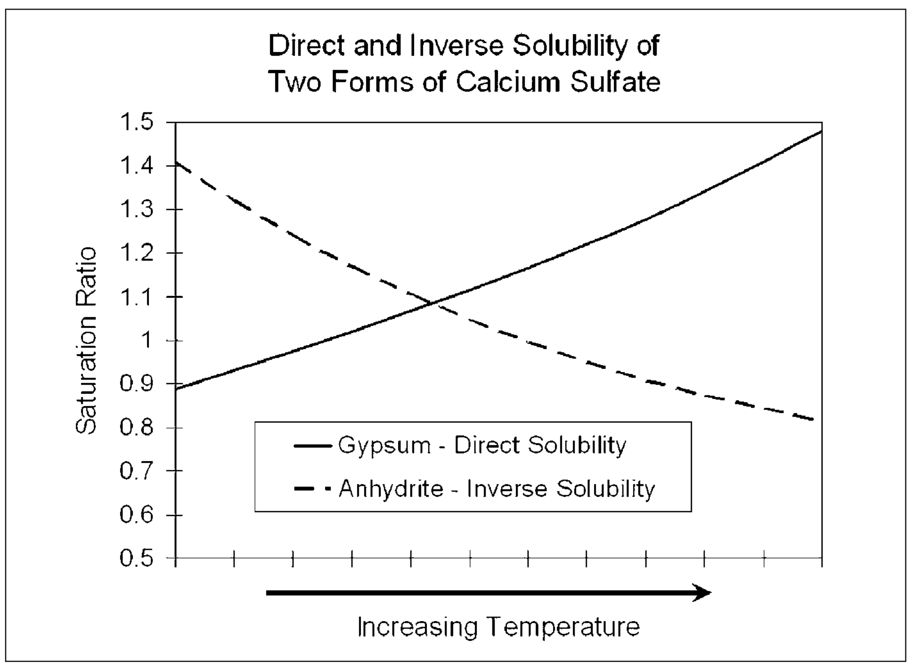
Calcium carbonate scale

A change in pH or alkalinity can greatly affect scale formation. For example, as pH or alkalinity increases, calcium carbonate decreases in solubility and eventually precipitates on system surfaces. Some materials, such as silica (SiO_2), are less soluble at lower alkalinity.

When the amount of scale-forming material dissolved in water exceeds its saturation point, scale may result. In addition, other dissolved solids may influence scale-forming tendencies. In general, higher levels of scale-forming dissolved solids increase the chance of scale formation.

How Does Temperature Affect Mineral Solubility?

Some minerals are more soluble as temperature increases. This is called direct or normal solubility. Other minerals are less soluble as temperature increases. This is called inverse solubility. The chart below shows two examples. One of normal direct solubility, another of inverse solubility.



Direct and inverse solubility of cooling water scale-forming minerals

How Can Scale Formation Be Controlled?

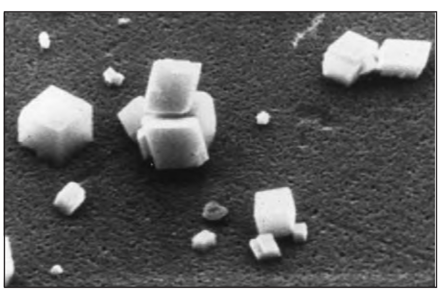
There are four basic means to control scale:

1. Limit the concentration of scale-forming minerals by controlling concentration ratio or by removing the minerals before they enter the system. "Concentration ratio" is the ratio of dissolved solids in the blow-down to dissolved solids in the makeup.

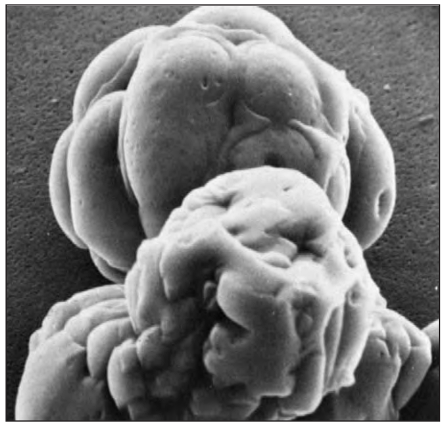
2. Feed acid to keep the common scale-forming minerals (such as calcium carbonate) dissolved. Most, but not all, minerals are more soluble at lower pH.

3. Make mechanical changes in the system to reduce the chances for scale formation. Increased water flow and exchangers with larger surface areas are examples.

4. Treat with chemicals designed to prevent scale.



"Normal" calcium carbonate (calcite) crystals (magnified 2000X)



Treatment with a polyacrylate yields distorted calcium carbonate crystals that grow very slowly (magnified 2000X)

How Do Chemical Scale Inhibitors Work?

Threshold inhibition chemicals prevent scale formation by keeping the scale-forming minerals in solution and not allowing the crystallization process to begin. Kinetic inhibitors modify the crystal structure of scale, which significantly reduces the speed of growth of deposit.

When new crystals are formed in solution, dispersant polymers can prevent deposition by keeping these particles suspended in the same manner as preventing fouling.

What are Some Common Scale-Control Chemicals?

Organic phosphates, polyphosphates, and polymeric compounds can act as both threshold inhibitors and kinetic inhibitors.

What is the Most Important Factor in Scale Control?

As with corrosion, control of scaling stresses is the only way to ensure that scale formation does not become a problem. It is essential to have an effective treatment program and control methodology to maintain optimum conditions in the system. This is best done by continuous monitoring of important variables and control of the operational variability of the system with 3D TRASAR control. If not controlled, scale can reduce the energy efficiency of any process served by the cooling system.

FOULING

What is Fouling?

Fouling is the accumulation of solid material, other than scale, in a way that hampers the operation of plant equipment or contributes to its deterioration.

Examples of common foulants are:

- Dirt and silt
- Sand
- Corrosion products
- Natural organics
- Microbial masses
- Aluminum phosphates
- Iron phosphate

Aluminum phosphate and iron phosphate could be considered scale forming minerals. However, these minerals have been called foulants historically because they are most common in phosphate treated systems where the makeup is clarified with aluminum (Al) or iron (Fe) salts. Carryover of trivalent Al or Fe generally causes a mixed phosphate/suspended solids agglomeration in solution that settles out like a foulant.

What Influences Fouling in a Cooling System?

The most important factors influencing fouling are:

- Water characteristics
- Temperature
- Flow velocity
- Microbial growth
- Corrosion
- Contamination

How Do Water Characteristics Affect Fouling?

Most waters contain suspended materials that can cause a significant fouling problem under certain conditions. The amount of suspended material directly affects the amount of fouling that can occur on system surfaces. Lower dissolved solids reduces fouling potential and higher amounts increase the fouling potential.

How Does Temperature Affect Fouling?

Increasing temperature increases the fouling tendency. Because heat transfer surfaces are hotter than the cooling water, they accelerate fouling.

How Does Flow Rate Affect Fouling?

At low flow rates, 1 ft/s (0.3 m/s) or less, fouling occurs due to natural settling of suspended material. At higher flow rates, 3 ft/s (0.9 m/s) or more, fouling can still occur, but usually at a lower rate so that accumulation is less severe.

Impact of Intercooler Fouling on Compressor Energy Consumption

If a compressor intercooler is fouled, the gas temperature entering the next compression stage will increase. The compressor motor horsepower (kW) requirement increases as inlet air temperature increases. The rule of thumb for the horsepower (kW) increase is as follows:

- ◆ A 10°F increase in inlet gas temperature to a compressor increases horsepower requirement by 2%
- ◆ A 10°C increase in inlet gas temperature to a compressor increases kW requirement by 3.6%

How Does Microbial Growth Affect Fouling?

Microorganisms can form deposits on any surface. In addition, corrosive or iron-depositing bacteria cause or utilize corrosion products, respectively, which subsequently deposit as voluminous foulants. All microbial colonies act as a collection site for silt and dirt, causing a deposit of different foulants.

How Does Corrosion Affect Fouling?

Corrosion can form insoluble corrosion products that migrate and mix with debris, process contamination, or microbial masses to aggravate fouling.

How Does Process Contamination Affect Fouling?

Material that leaks from the process side of heat exchange equipment can cause serious fouling problems in several ways:

- Depositing as insoluble products
- Providing nutrients for microorganisms and causing severe microbial growth
- Reacting with scale or corrosion inhibitors to form insoluble foulants

Fouling of a heat exchanger tube bundle

How can Fouling be Controlled?

Fouling can be controlled mechanically or by the use of chemical treatments. The best method of control depends upon the type of fouling. Control of fouling in the cooling system involves three major tactics:

1. ***Prevention –*** The best approach is to prevent foulants from entering the cooling system. This may include mechanical changes or addition of chemicals to clarify makeup water.

2. ***Reduction –*** Take steps to remove or reduce the volume of foulants that unavoidably enter the system. This may involve sidestream filtering or periodic tower basin cleaning.

3. ***Ongoing Control –*** Take regular action to minimize deposition of the foulants in the system. This can include adding chemical dispersants and air rumbling or back flushing exchangers.

How Do Chemical Inhibitors Work?

Charge reinforcement and wetting agent dispersants act to keep foulants in suspension, preventing them from settling on metal surfaces, or helping to remove fouling deposits that have already formed. The charge reinforcement dispersants cause the foulants to repel one another by increasing the electrical charges they carry. The wetting agents make the water wetter (reduce surface tension), inhibiting new deposit formation and possibly removing existing deposits. This action keeps the particles in the bulk water flow, where they are more likely to be removed from the system, either through blowdown or filtration.

What Kinds of Chemicals are Normally Used?

Charge reinforcers – Anionic polymers

Wetting agents – Surfactants

Impact of Deposits on Steam Condenser Efficiency

The rule of thumb for surface condensers is:

- For every 1 inch Hg increase in backpressure, steam consumption (fuel cost) increases roughly 1-2% for the same electrical output.
- For every 1 kPa increase in backpressure, steam consumption (fuel cost) increases roughly 0.3-0.7% for the same electrical output.

If boiler capacity limitations do not allow increased steam flow to compensate for turbine backpressure increase, there will be a loss of electrical output capacity.

What is the Most Important Factor in Reducing Fouling?

Continuous control of the mechanical, operational, and chemical (MOC) aspects of the system and treatment program is the only way to reduce fouling. It is essential to have an effective treatment program and control methodology to maintain optimum conditions in the system. This is best done by continuous monitoring of important variables and control of the operational variability of the system with 3D TRASAR control. If not controlled, fouling can reduce the energy efficiency of any process served by the cooling system.

BIOLOGICAL PROBLEMS

What is Microbial Contamination?

The uncontrolled growth of microorganisms can lead to deposit formation that contributes to fouling, corrosion, and scale. The accompanying table lists troublesome microorganisms and the problems they create.

What are Microbial Slimes?

Microbial slimes are masses of microscopic organisms and their waste products. These slime layers are usually sticky and effective in trapping foulants present in the bulk water.

How do Slime Layers Impact Cost of Operation?

Microbial slime, like other fouling materials, reduces the efficiency of heat transfer. In fact, microbial slime is more insulating than other common deposits (see the Impact of Deposits chart). The slime can trap other deposits, making the problem worse.

How do Microorganisms Enter a Cooling Water System?

There are two primary modes of entry of microorganisms into cooling water systems. One is the makeup water in which microorganisms are already present. Another is via airborne microorganisms that are blown into the cooling tower.

What Factors Contribute to Microbial Growth?

The most important factor is the degree of microbial contamination being introduced into a system. Next in importance are:

1. ***Nutrients –*** For instance, hydrocarbons or other carbon sources can serve as food for slime-forming organisms.

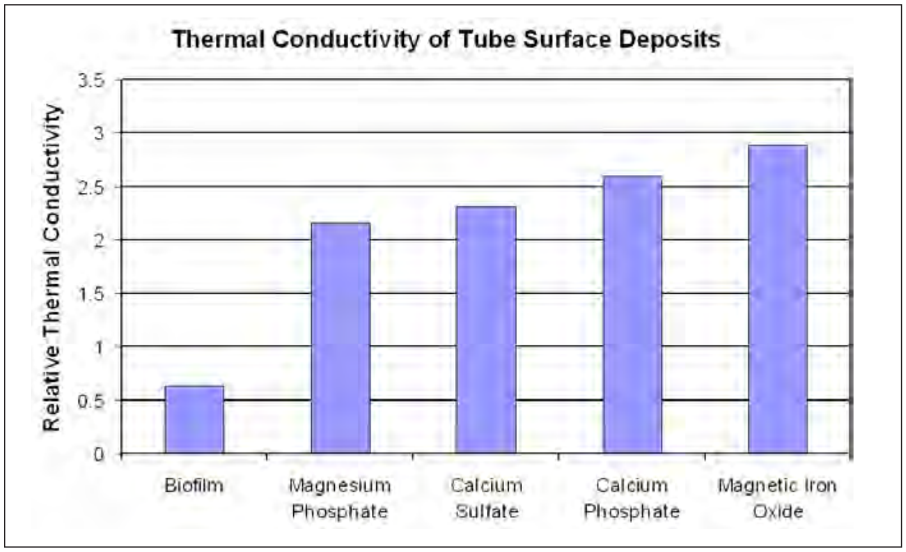
2. ***Atmosphere –*** Organism growth depends upon the availability of oxygen or carbon dioxide.

3. ***Location –*** Such factors as the amount of light and moisture may significantly affect growth rates.

4. ***Temperature –*** Organisms that make up slime tend to flourish between 40 and 150°F (4.4 and 65.6°C).

What is *Legionella*?

Legionella is a group of bacteria present in all natural waterways and biofilms. About half of the *Legionella* species can produce a pneumonia-like infection in humans (Legionellosis). It is named from an outbreak of Legionellosis that took place at a Legionnaires' convention in Philadelphia in 1976, where 200 people became ill and 34 died.



Biofilms are more insulating than other types of heat exchanger deposits (Source: N. Zelver, et al, CTI Paper TP239A, 1981)

Is *Legionella* a Concern in Cooling Water?

Periodically, cases of Legionellosis have been reported and treated. The primary source of the bacteria causing the infection is man-made systems such as cooling towers, spas/whirlpools, vegetable misters, decorative fountains, and other aerosol producing sources.

How do *Legionella* Grow in Cooling Systems?

Legionella can live and multiply as a parasite in protozoa. As they multiply, *Legionella* will burst the protozoa and be released into the water. *Legionella* can survive in biofilms that provide a source of complex nutrients. Some believe that *Legionella* may be able to multiply within biofilms even outside of host protozoa.

How can *Legionella* be Controlled?

No biocide is specific for *Legionella*. However, traditional oxidizing biocides such as chlorine and bromine have proven effective in controlling *Legionella* in cooling systems. A program that includes non-oxidizing biocides together with oxidizers is also effective. Key elements of any program are proper control of biocide dosages, monitoring microbial levels in the system, and maintaining a clean system. These are part of a complete *Legionella* risk reduction management plan.

How can the Bacterial Population of Cooling Water be Determined?

The Differential Microbial Analysis (DMA) is a widely used set of laboratory tests that offers a profile of many microorganisms found in cooling water systems. DMA testing is not performed as frequently as on-site testing (like dip-slides described later) but it is an important part of an effectively

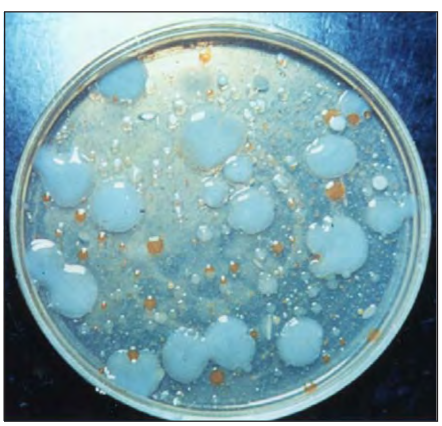
PRINCIPAL CLASSES OF TROUBLESOME MICROORGANISMS

CLASSIFICATIONS		DESCRIPTION	COMMON PROBLEMS
BACTERIA			
Filamentous			
Sulfur depositing	*Streptomyces*	Stringy, slippery, gray or gray-green	Fouling
Iron depositing			
Corrosive			
Desulfovibrio	*Clostridium* (spore forming)	Black granular appearance glows beneath slime or deposit	Corrosion Formation of gases
Non-Spore forming			
Flavo bacterium *Alcaligenes* *Pseudomonas*	*Achromobacter* *Aerobacter* Mucoids	Gelatinous, flocculant substance resembling mucus, may be colored	Fouling Formation of gases Protect corrosive bacteria
Spore forming			
B. subtilis *B. cereus*	*B. megatherium* *B. mycoides*	Gelatinous, may be stringy, rope like, may be colored.	Fouling Protect corrosive bacteria
Pathogenic			
Legionella		Live inside protozoa. Proliferate in dirty systems	Can cause a pneumonia-like illness in susceptible individuals
FUNGI (Spore forming)			
Molds			
Aspergillus *Penicillium* *Trichoderma*	*Cladosporium* *Mucon*	Stringy, fluffy or matted, normally colorless but may be green	Wood decay Formation of corrosion cells Fouling
YEASTS			
Monilia *Oospora* *Torula*	*Endomyces* *Rhodotorule*	Leathery, rubbery or resembling mucus, may be colored or colorless	Formation of corrosion cells Fouling
ALGAE			
Chroococcus *Oscillatoria* *Chlorococcus*	*Ulothrix* *Navicula* *Fragilaria*	Loose slimy or rubbery green or blue-green, found only in sunlight.	Fouling Protect corrosive bacteria

managed microbial control program. It should be done periodically, with the frequency dependent on the level of microbial problems.

The DMA provides important information about the microbiology of the cooling system. It can differentiate many of the bacteria in the Principal Classes chart by growing them on agar plates. Other organisms, like algae, protozoa, and fungi, can be determined by microscopic observation.

One disadvantage of the DMA is that it monitors only planktonic bacteria, or those floating in the water. It is the sessile bacteria on the exchanger surfaces that impact the heat transfer efficiency of the system. Estimates indicate that 90% of the bacteria in cooling systems is on system surfaces. The 3D TRASAR Bio-Control technology (described later) can monitor microbial activity of both sessile and planktonic organisms. This is why an effective, continuous monitoring and control program is essential for optimum results in cooling systems.



Example of bacterial cultures from cooling water system grown on an agar plate as part of a DMA

Can Slime Cause Scale Formation?

Yes. Slime can cause or accelerate the rate of scale formation. Slime can degrade treatment chemicals, rendering them ineffective. When deposits form, heat transfer is reduced. This causes possible production cutbacks and higher energy cost.

Can Slime Cause Fouling?

Slime masses themselves are foulants. They provide excellent sites for the deposition of other foulants. Other microorganisms and suspended solids can add to the already existing fouling deposit.

Can Slime Cause Corrosion?

Certain organisms, such as, sulfate-reducing bacteria generate corrosive hydrogen sulfide which can cause severe pitting on metal surfaces. In addition, slime can accelerate corrosion by depositing on the metal and preventing protective film formation. Slime layers can also cause under-deposit corrosion.

Do Organisms Affect Specific Areas in a Cooling System?

Generally, microbial organisms form colonies at points of low water velocity. Heat exchangers are, therefore, subject to microbial growth and slime formation; cooling towers may have algae growth on the deck and fungal rot in the wood structural components.

What Factors must be Considered in Planning an Effective Microbial Control Program?

The most important factors are:

- Types and quantities of microbial organisms
- Microbial trouble signs such as wood rot, slime deposits, and algae on the tower deck
- Operating characteristics of the system, such as temperature, flow rate, and water composition
- Types of equipment employed, such as cooling towers or spray ponds
- Sources of contamination, such as organisms and nutrients carried into the system

Each system must be evaluated and treated on an individual basis, because each system has its own unique microbial profile.

How Are Microbial Treatments Selected?

Microbial treatments are selected by first analyzing representative water and slime samples to determine the types of organisms present. Based on this information, plant personnel input, and on-site product testing, a treatment strategy is selected. Treatment programs may be altered should any critical changes take place.

What Types of Chemicals are used for Microbial Control?

Three general classes of chemicals are used in microbial control:

1. Oxidizing biocides
2. Non-oxidizing biocides
3. Biodispersants

Each class functions uniquely to provide effective microbio control.

Energy Efficiency Lost in Fouled Chiller Condenser

The rule of thumb for the relationship of increased refrigerant temperature to power consumption for compression refrigeration systems is given by these relationships:

- For every 1°F increase in refrigerant condensing temperature, horsepower requirements increase 1%
- For every 1°C increase in refrigerant condensing temperature, kW requirements increase 1.8%

Microbial contamination on a tube sheet

What Are Oxidizing Biocides?

These biocides oxidize important cellular components in microorganisms, resulting in death of the organisms. They can be applied continuously or on a slug basis. Gaseous chlorine and liquid sodium hypochlorite (bleach) are the most widely used oxidizer products.

Another oxidizer used in many applications is bromine-based treatment, which is available as a solid or liquid. Bromine offers several performance and safety advantages over gaseous chlorine and sodium hypochlorite. Most systems can be effectively treated with bromine-based biocontrol compounds.

What Are Non-Oxidizing Biocides?

Non-oxidizers perform differently than oxidizers. They are organic compounds that react with specific cell components within a microbe to ultimately destroy that cell.

What Are Biodispersants?

Biodispersants do not kill organisms. They loosen microbial deposits, which upon detachment from a metal surface, are flushed away with the bulk cooling water. They also expose new layers of microbial slime or algae to the attack of oxidizing biocides. In addition to removing biodeposits, biodispersants are also effective in preventing biofilm formation from taking place.

What is Macrofouling?

Macrofouling is the attachment of complex organisms like clams and mussels to piping and other surfaces of a cooling system. It is most common in once-through cooling systems or water intakes using surface water, like lakes, rivers, or oceans.

Does Water Source Affect Type of Macrofouling Organism?

Macrofoulants exist in freshwater, seawater, and brackish waters. Examples of the various mollusks responsible for cooling water macrofouling in seawater and brackish water systems are barnacles, bryozoans, oysters, and brown, blue, and green-lip mussels. In fresh water systems, the most common species are the Asiatic clam, zebra mussel, gastropod, and bryozoans.

What is the Cost of Macrofouling?

Macrofouling costs are estimated to be in the billions of dollars on an annual basis for industries throughout the world. Most of this cost is related to plugged lines, reduced water flow, under-deposit corrosion, damage to pumps, and the high cost of mechanical cleaning.

How do Macrofouling Organisms Get into a System?

When adult organisms in the water source spawn, juvenile organisms called veligers are produced. The veligers are free floating organisms and may be drawn into the water intake of a plant or a once-through system. The veligers can attach to system surfaces and grow into adult mollusks.

How can Macrofouling be Controlled?

Macrofouling is very difficult to control completely. Local environmental regulations are a key factor when choosing a control approach. The two general strategies to treat macrofouling are prevention and eradication. A comparison of these two methods is shown in the table.

Method	Advantages	Disadvantages
Eradication	Treatment needed only 1-3 times per year	Under-deposit corrosion can occur where mollusks attach to the system
	Potentially lower chemical cost	Potentially higher maintenance cost to remove mollusk shells
		Mollusks can cause flow restriction
Prevention	No mollusk shells to remove	Potentially higher chemical cost
	Lower potential for under-deposit corrosion from mollusks in system	Must treat more often, generally throughout warm-weather months
	Generally helps to provide better overall biological control in the system	Potentially higher capital costs

Methods comparison for control of macrofouling.

TOTAL COOLING SYSTEM MANAGEMENT

A Total Treatment Program

To have the most successful cooling water treatment program requires all of the following elements.

1. Optimized chemical treatment and automated system control programs must be combined.
2. Plant personnel – including operators, supervisors, engineers, and managers – must understand the value of the cooling water system in relation to production and must be committed to maintain and control the program.
3. Monitoring and control must be continuous and must utilize the proper techniques, equipment, and supplies.
4. A complete system approach combining all of these aspects will optimize TCO.

What are the Steps to Develop a Total Treatment Program?

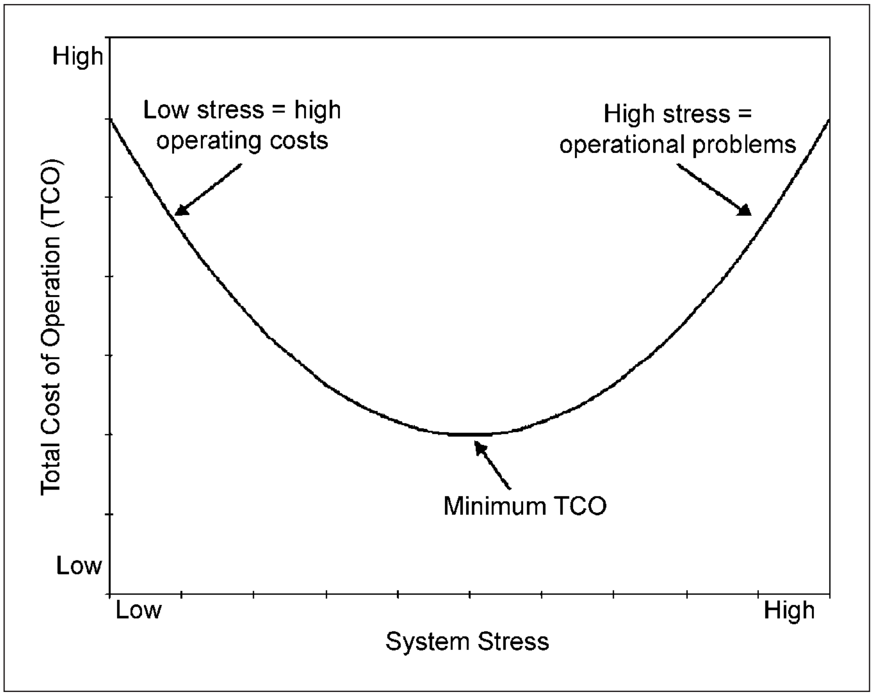
The steps to optimize TCO of a cooling system are:

1. Complete cooling system survey to understand the system dynamics, operating variability, and system stresses
2. Pretreatment of any new or recently cleaned system with special chemical corrosion inhibitors
3. Selection of treatment program using 3D TRASAR® optimizer software to select the best program based upon system operating conditions and known system stresses.
4. Implementation of performance monitoring program to evaluate heat transfer efficiency, corrosion control, deposition control, and microbial control
5. Use of analytical testing, both routine on-site testing and periodic lab analyses, to confirm optimum operation
6. Use 3D TRASAR technology to control system parameters and treatment program application to optimize system stresses, minimize system discharge, and provide the lowest TCO

These steps will be described on the following pages.

How Does the Cooling System Add Value to Production Processes?

Energy, water, and discharge costs have a direct impact on the bottom line of any production facility or large building. Energy intensive processes, like the cooling system or heat exchange equipment, can have a significant effect on the value produced by any facility.



Optimization of Total Cost of Operation (TCO) requires optimization of treatment program and system conditions to balance system stress. Low stress can be a low concentration ratio, for example. High stress can be high temperature or low water velocity in heat exchangers

Optimizing treatment programs to reduce and control corrosion, deposition, and microbial fouling can improve energy transfer throughout the cooling system, thereby increasing the efficiency of the entire process. Optimizing cooling system operation can add value to the process. Here are some of the key aspects to this value contribution:

Treatment and operating costs – Optimizing all aspects of the treatment program and system operating conditions to the optimum stress level will minimize costs of cooling system operation. The minimum TCO provides lowest water, energy, treatment, and maintenance costs for any cooling system.

Product quality – Cooling system temperatures that are too hot can have a negative effect on product quality. Poor product quality may require rework to meet product specifications or may have to be scrapped. Maintaining optimum conditions reduces this impact and adds value to the product.

Production efficiency – Fouling of heat exchangers can reduce production capacity, thereby reducing the total value of the product that is produced. Corrosion can cause loss of product from leaks in the system or contamination of a product. Lost product directly impacts production value. In severe cases, deposition, corrosion or microbial fouling can cause system shut down.

The costs associated with poor plant reliability or availability can quickly dwarf those associated with loss of efficiency of operation. A process shutdown resulting from a fouled heat exchanger causes lost production in addition to the costs of cleaning or repair. Sometimes, a shutdown from water-related failures can cripple an entire plant. In large, integrated facilities, these costs can easily reach millions of dollars. Finally, in most cases, safety, efficiency, and reliability are inextricably linked.

What is the First Step to a Value-Based Treatment Program?

A complete system survey is needed to fully understand the system and processes well enough to identify areas where the cooling system operation can add value to the process.

A thorough survey will cover the mechanical, operational, and chemical aspects of the entire system to collect information. The survey can identify areas of system stress that must be treated by the program and controlled through effective monitoring and control.

What is Pretreatment?

Pretreatment is the preparation of the cooling water system to ensure that the treatment program can work effectively from startup.

Why is Cooling Water System Pretreatment Needed?

New systems or existing ones being returned to service can contain significant amounts of contaminating material. Films of oil or grease, spots of rust, or dirt and sand always remain in newly constructed systems. These materials do not represent faulty construction; they result from conditions existing during construction.

In systems taken off-line, deposits can be present as the result of scale, corrosion, fouling, or microbial contamination. If these materials are not removed through effective pretreatment, the subsequent chemical program will not be as effective.

What are the Steps in System Preparation and Start-Up?

A successful cooling water system protection program requires the following preparation and start-up procedures.

1. System cleaning
2. Application of special pretreatment chemicals
3. Initial high dose application of corrosion inhibitors
4. Ongoing application of corrosion inhibitors at maintenance levels

Does Water Flushing or Hydrotesting Remove New System Contaminants?

Water flushing or hydrotesting may reduce contaminants, but not to any great extent. In addition, the untreated water and the unprotected metal surfaces react to form additional corrosion products or active corroding surfaces.

What Effect does Acid Cleaning have on a Cooling System?

Acid removes corrosion products and some mineral contaminants, but has little effect upon organic materials. With improper application, acid may attack system metal and cause severe metal attack. Improper flushing will leave metal surfaces in a highly reactive state, which makes them especially vulnerable to corrosion attack.

When should Pretreatment Chemicals be Applied?

Pretreatment chemicals can be applied immediately after hydrotesting. The sooner a system is pretreated after construction, the more complete protection it will have. The same applies for equipment that has been taken off-line. Pretreatment should take place as soon as possible after the necessary maintenance has been done and the unit is ready to go back in service.

Once Pretreatment is Done, What is Next?

The selection of the optimum treatment program and best monitoring and control methodology will provide the best value to any operation. This can be divided into three steps:

1. Program selection and optimization based upon system stress
2. Implementing system monitoring, for both performance and control
3. Using 3D TRASAR technology for automated control of system stress and optimization of TCO

How can the Optimum Program be Selected?

Industrial water systems operate under stress. When stress is too high, deposition, corrosion, and microbial fouling result. When stress is too low, water and chemicals are wasted.

The goal: optimize the level of system stress by optimizing the treatment program and operational conditions. This will minimize operating cost and operational problems caused by variation of stress levels.

Product selection and optimization must evaluate the system stresses and the variability of the system. Advanced computer software can be used to select and optimize a treatment program for a particular system and the stresses in that system. The benefits of optimization software include rapid evaluation of alternative treatment programs, varying treatment dosages, and fluctuating system conditions on cooling system performance.

Why is Monitoring and Control Important?

Changes in cooling system stress are based on many factors, many beyond the control of the cooling system operators. For instance, makeup water phosphate concentrations may change without warning, creating a scaling condition. Or a process leak may result in microbial contamination. To be successful, a cooling water treatment program must be able to:

- Determine and measure the key parameters related to system stress
- Detect upset conditions and take an appropriate, automatic, and corrective action to compensate
- Deliver value by communicating with system users to permit proper follow-up and troubleshooting

What Tools are Available For Monitoring and Control?

Simple, easy-to-use manual tests are available for measuring parameters such as conductivity, pH, alkalinity, hardness, chlorine, and chemical treatment concentrations. The necessary control tests must be consistently run and corrective action taken when a variable is out of specification. Control is the foundation of every successful treatment program.

Although wet chemistry testing is still commonly used in the water treatment industry and certainly has value, automation plays a critical role in cooling system operation and control. Nalco's 3D TRASAR program automates much of the routine testing formerly done by system operators, freeing them to do more valuable work. On-line, continuous monitoring of key system parameters, recording the data and reporting it in a useful format, gives cooling system operators access to the data they need to prevent problems, minimize costs, and find areas for improvement.

Nalco's powerful VANTAGE® V100 Data Management and SPC Software gives system users the tools they need to successfully troubleshoot and improve their system operations. Nalco's VANTAGE V100 Data Management and SPC Software simplifies data analysis. Users spend less time manipulating data and more time using the information gathered to improve system operations or troubleshoot problems.

What are some Methods for Performance Monitoring in a Cooling System?

***Microbial Analysis* –** Most commonly, dip-slides (small cultures of living, planktonic bacteria) are used to assess the efficacy of a microbial control program 24-48 hours after sampling the water. As with corrosion coupons, this method is widely used and has its place in cooling water programs. They are selective for certain kinds of bacteria and offer a quantitative measure of microbial activity. A full DMA analysis, as described earlier, should be done periodically to verify on-site test results.

Corrosion coupons inserted into the cooling system can provide an accurate indication of corrosion rates.

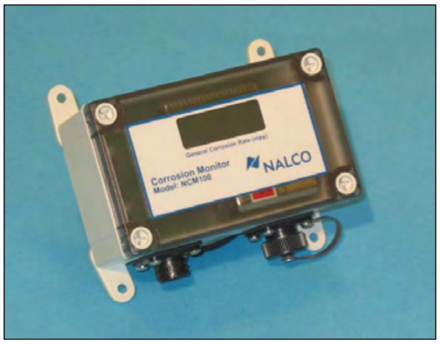
***Corrosion Coupons* –** Corrosion coupons are the standard method for corrosion rate measurement in cooling systems. These small, pre-weighed metal samples are exposed to the cooling water for a specified period of time – usually 30-120 days – removed from the system and weighed. The weight loss correlates to a corrosion rate in mils per year (mpy) or micrometers per year (µm/yr).

***Corrosion Test Rack* –** A corrosion test rack evaluates the effectiveness of corrosion inhibition programs on non-heat transfer surfaces. It provides for proper installation and use of multiple corrosion coupons and NCM100 probes.

***The Nalco Corrosion Monitor (NCM100)* –** As valuable and ubiquitous as corrosion coupons are, they really only reveal average corrosion over a long period of time. The instantaneous effects of fluctuations in conditions or the impact of an upset cannot be easily evaluated with corrosion coupons.

Instantaneous, continuous measurement of corrosion rates is possible using the Nalco Corrosion Monitor (NCM100). These small, inexpensive devices can be placed in the cooling system to provide constant corrosion rate information. This instantaneous monitoring can show the effect of system variability or upsets on corrosion rates.

The NCM100 technology is also incorporated into the 3D TRASAR program. When upsets occur, alarms can be sent to system users. Corrosion rate data can be correlated with other operational data, providing the information needed to locate the problem and correct it before damage occurs.

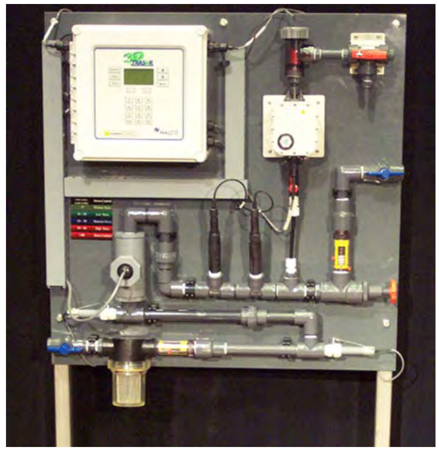


The Nalco Corrosion Monitor (NCM100) provides continuous corrosion rate measurements and can be configured to handle numerous metallurgies.

What is best Practice for Monitoring and Control of Cooling Systems?

Optimum performance can be achieved through on-line control of cooling system parameters. Nalco 3D TRASAR technology can monitor a number of important parameters, including product dosage, active polymer residual in the system, scaling stresses, and microbial activity. Using the data collected, the 3D TRASAR equipment can manage the system stress level to the optimum point.

3D TRASAR Corrosion Control is provided by a key chemical inhibitor, PSO, an organic phosphate compound that does not degrade in the presence of chemical or other system stresses, and provides excellent corrosion control across a broad range of conditions. The 3D TRASAR controller does not control corrosion rate directly. Corrosion rate is dependent on too many variables to be able to



Nalco's 3D TRASAR program, combines sophisticated equipment, innovative chemistries, advanced software, and new services to provide total cooling system control. By managing a cooling system based on the stresses placed upon it, 3D TRASAR technology minimizes Total Cost of Operation (TCO) and prevents operational problems.

control corrosion only with the inhibitor dosage alone corrosion rate is detected and recorded every 6 seconds.

3D TRASAR Scale Control monitors and controls the scaling stresses in a cooling tower system. Scaling stresses are determined by measuring the action of inhibitors on scale formation and particulate dispersancy and using a special algorithm to calculate the Nalco Scale Index (NSI). The NSI then allows control of either scale inhibitor dosage or cooling system concentration ratio to minimize the impact of scaling stresses in a cooling tower system.

The Nalco 3D TRASAR program advances the state-of-the-art in microbial monitoring for many cooling systems. 3D TRASAR Bio-Control uses an innovative Bio-Reporter, a compound that reacts with an enzyme produced by living organisms. The Bio-Reporter fluoresces at different wavelengths in its reacted and unreacted forms. Both wavelengths can be measured by the modular fluorometer in the 3D TRASAR controller. 3D TRASAR Bio-Control detects changes in the level of bio-activity in the cooling system and applies oxidizing biocides to compensate for increased activity. The level of bio-activity is detected by measuring the ratio of reacted to unreacted Bio-Reporter flowing through the controller (and the rate at which the ratio changes). 3D TRASAR technology is the only cooling system microbial control method that reacts to actual bio-activity, both planktonic and sessile, and applies microbial control agents in response.

What is the Role of Plant Personnel in Proper Monitoring and Control of the Cooling Water System?

Plant operating and supervisory personnel need to understand the importance of water treatment to overall plant operations. Proper training of all cooling water personnel is the best method for achieving a successful treatment program.

3D TRASAR technology helps plant personnel do their jobs better, faster, and with less effort. Alarms are sent to any device capable of receiving a text message when upsets occur and control actions are taken. This frees plant personnel from routine monitoring duties, but ensures they know when their attention is needed. Your Nalco Sales Engineer provides training in both the day-to-day methods of control and the fundamentals of a successful cooling water treatment program.

NALCO'S PHILOSOPHY: BUILDING VALUE

We create value for our customers by developing and implementing innovative, differentiated solutions that are financially, technically, and environmentally sustainable. We have also helped our customers to continuously improve their environmental performance through better resource management and control of emissions.

We are committed to being the proven, global leader in each area of our business, process improvement focused, or water treatment oriented, by providing dynamic, integrated solutions that improve our customers' products and optimize their operations.

Nalco works to meet its customers' needs by listening to the customer, identifying key concerns, nurturing relationships, and creating new technologies and applications. The Nalco Sales Engineer is key to achieving these goals as consultant, problem-solver, on-site expert and business partner.

Nalco on-site Sales and Service Engineers are backed by our global research groups, support teams, infrastructure, and best practices.

NALCO COMPANY OPERATIONS

North America: ***Headquarters –*** 1601 West Diehl Road • Naperville, Illinois 60563 • USA
Energy Services Division – 7705 Highway 90-A • Sugar Land, Texas 77487 • USA
Europe: Ir.G.Tjalmaweg 1 • 2342 BV Oegstgeest • The Netherlands
Asia Pacific: 2 International Business Park • #02-20 The Strategy Tower 2 • Singapore 609930
Latin America: Av. das Nações Unidas 17.891 • 6° Andar 04795-100 • São Paulo • SP • Brazil

www.nalco.com

Bulletin B-34