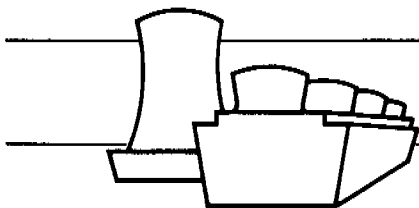


Cooling Water Problems

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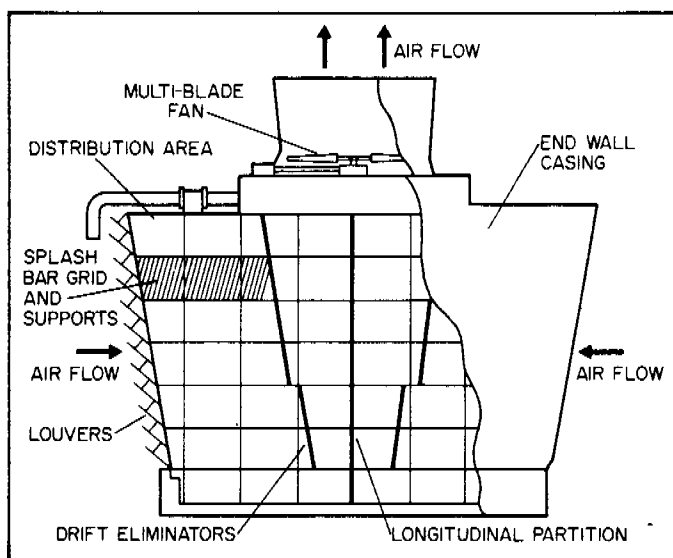


COOLING WATER PROBLEMS

Introduction

Water, as it circulates through the cooling water system, draws heat from the processes and expels it at the cooling tower into the air. As the water is cooled,

evaporation takes place which increases both the amount of dissolved solids within the water and the potential problems of corrosion, scaling and fouling.



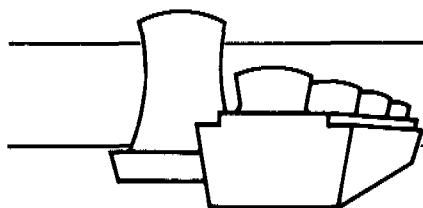
Typical cooling tower.

As water falls through the tower, air and water are intimately mixed to obtain the greatest efficiency in the removal of heat from the water. During this process, oxygen is absorbed into the water which is retained in the basin and circulated through the system. This too can significantly increase corrosion potential within the cooling operation. Corrosion, scale and fouling are all interdependent. Each of these three independently, or in combination, can significantly reduce cooling efficiency.

In this unit we will look at the problems that typically are experienced in cooling water systems. We will look at corrosion and its causes, how ions can combine to reduce heat transfer by producing scale and fouling, both organic and inorganic. We will also look at corrosion and scale inhibitors and the role they play in the cooling water system operation.

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No. 91-1145

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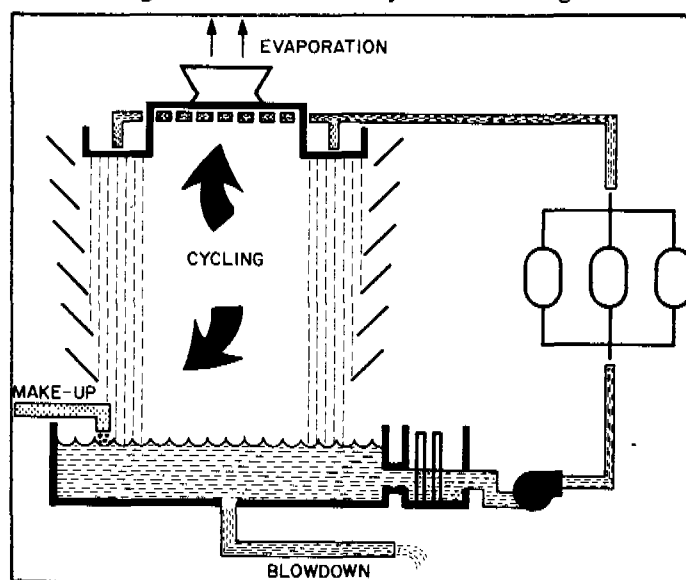
COOLING WATER PROBLEMS

The Cooling Water System

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of 14th Judicial District Court
No. 91-1145

SL 000489

In cooling tower operations, as evaporation takes place, ions in the makeup water become concentrated in the circulating water. As this process continues, dissolved and suspended solids concentrate, and if left unchecked, can create severe problems of both scale and fouling. Blowdown is a way of controlling the level



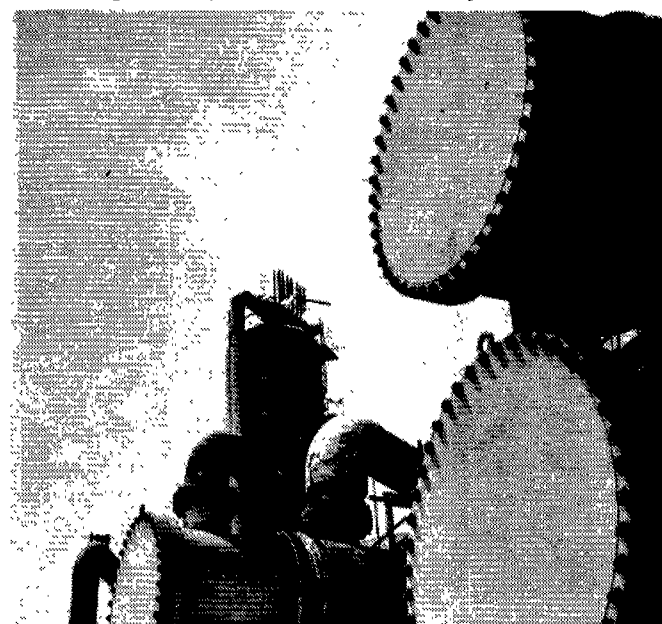
Blowdown controls the level of suspended and dissolved solids in the system.

of suspended and dissolved solids in the system. **Blowdown** is defined as any water lost (intentional or nonintentional) from the system containing the concentrated solids. Cycles in the tower are maintained by controlling the amount of water that is discharged from the system.



The problem trio: corrosion, scale and fouling.

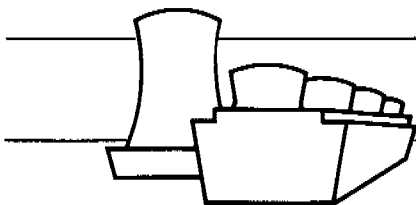
At this point, we should redefine our problem trio: corrosion, scale and fouling. **Corrosion** is an electrochemical reaction between oxygen, water and exposed metal surfaces. **Scale** is a crystalline deposit formed by combining ions in the water and depositing the resulting scale on the surface of exchangers or water lines. **Fouling** is described as suspended solids such as mud, silt and other debris, corrosion products or biological deposits found in the system.



Efficiency depends upon:

- cleanliness of the exchanger
- water velocities
- temperatures

In the cooling system, the heat exchanger is the workhorse of the entire operation. Heat is transmitted through the metal surfaces of the tubes to the water, carried back to the cooling tower and discharged to the air. Corrosion, scale and fouling can all create problems in heat transfer efficiency. The efficiency relates to the heat transfer rate of the exchanger and depends upon the cleanliness of the exchanger, water velocities, and temperatures throughout the unit. Changes in any of these parameters can drastically affect the overall heat transfer coefficient (heat transfer rate) in the heat exchanger. In the next sections, we will look at each of our problem trio in more detail.

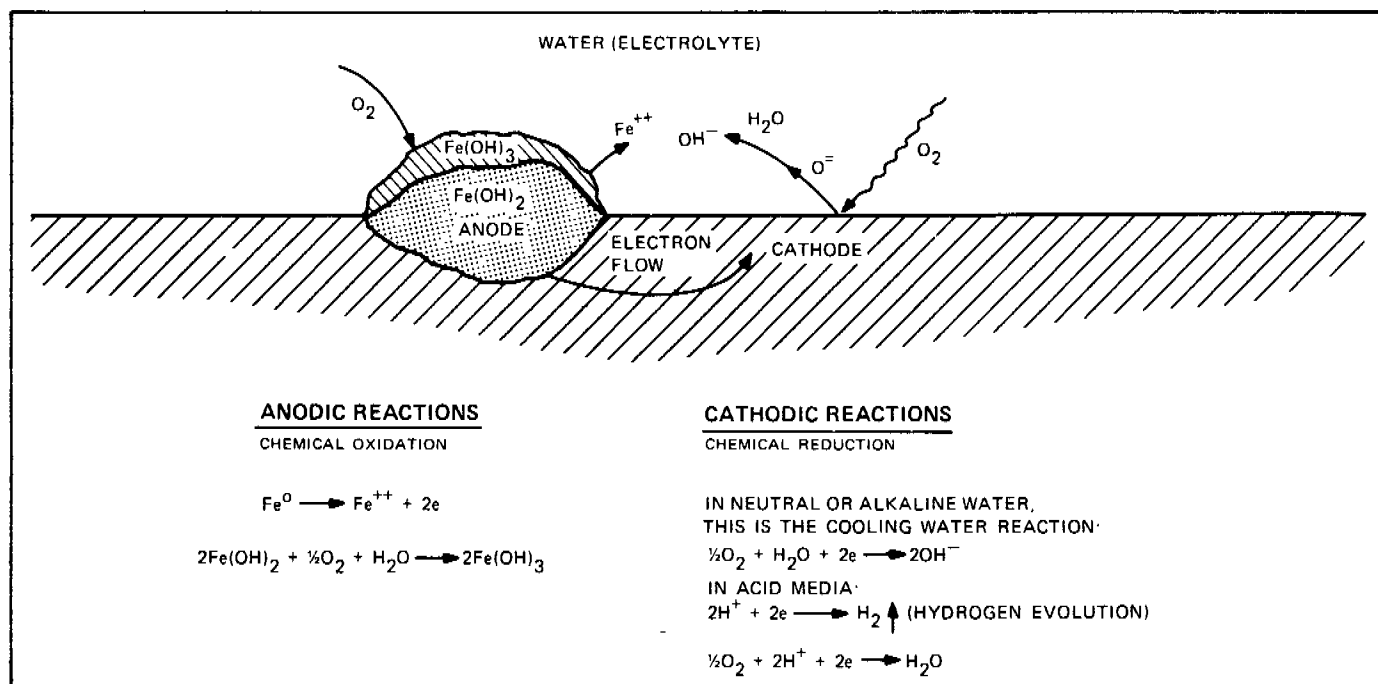


COOLING WATER PROBLEMS

Corrosion

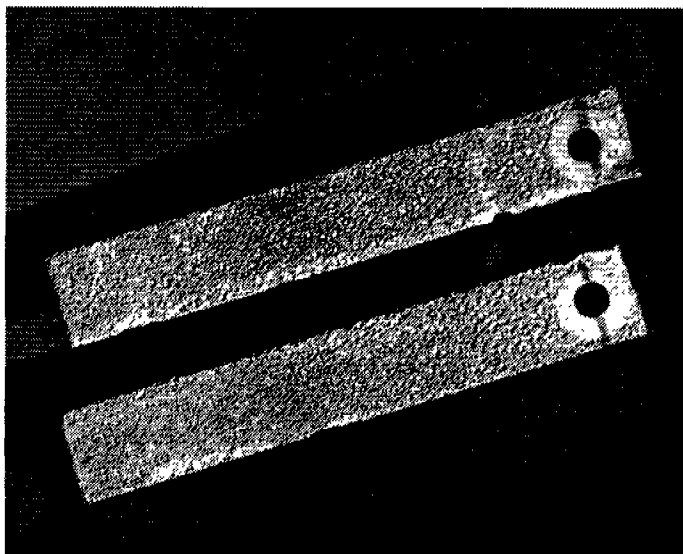
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of 14th Judicial District Cou
No. 91-1145

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Classic corrosion cell.

In the cooling tower operation, oxygen is absorbed in the water as the tower water splashes through the fill and is intimately mixed with air. **Corrosion** is an electrochemical reaction between the metal and the water to which it is exposed. As can be seen in the

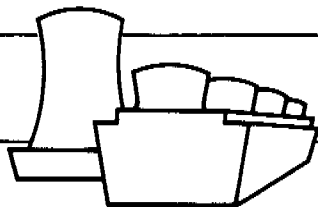


Pitting can cause failures in a short period of time.

drawing, electrons flow from the anode of the corrosion cell to the cathode, where hydroxide ions are produced by the reaction. Oxygen reacting with the metal surface forms iron hydroxides which then build up at the surface or are solubilized and washed away into the system. Corrosion can continue until the metal thins and finally collapses.

Corrosion in the cooling system can take the form of both general thinning (uniform overall corrosion) and/or pitting. Oxygen produces an easily identified corrosion in the form of small pits or depressions. Intense corrosion at a single point causing a deep penetration of the metal is called **pitting**. When pitting corrosion occurs loss of metal can be more detrimental than if the loss is uniform over a large area. Pitting is more severe than general corrosion since this type of corrosion can cause failures in a short period of time.

Even greater current flow can be experienced if two dissimilar metals are in contact with one another and in contact with water. This additional difference in potential is called **galvanic corrosion**. The use of dissimilar metals in cooling water systems is a common



COOLING WATER PROBLEMS

Corrosion (Cont'd.)

problem. Examples of this are the use of brass valves in a steel pipe system or admiralty tubes in a steel tube sheet. As can be seen in this table of galvanic series, the higher the metal appears in the list, the easier it corrodes. Lower metals resist corrosion more.

(In the section on corrosion control, we will discuss the use of sacrificial anodes and the role they play in the control of galvanic corrosion in the cooling water system.)

Corrosion is a complex mechanism and can be affected by pH, conductivity, temperature and velocities. The understanding of the interrelationships of all these parameters and how they affect the overall corrosion rates in your cooling tower system is the responsibility of your BETZ man. He will help to sort out and recommend proper action and control limits for your cooling tower system operations.

TABLE OF GALVANIC SERIES

Corroded End
(anodic, or least noble)

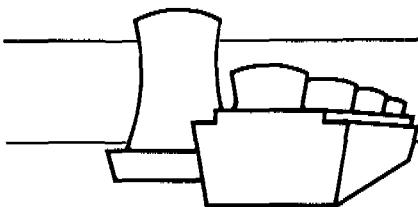
Magnesium
Magnesium alloys
Zinc
Aluminum 2S
Cadmium
Aluminum 17ST
Steel or Iron
Cast Iron
Chromium-iron (active)
Ni-Resist
18-8-Cr-Ni-Fe (active)
18-8-3-Cr-Ni-Mo-Fe (active)
Hastelloy C
Lead-tin solders
Lead
Tin
Nickel (active)

Inconel (active)
Hastelloy A
Hastelloy B
Brasses
Copper
Bronzes
Copper-nickel alloys
Titanium
Monel
Silver Solder
Nickel (passive)
Inconel (passive)
Chromium-iron (passive)
18-8-Cr-Ni-Fe (passive)
18-8-3-Cr-Ni-Mo-Fe (passive)
Silver
Graphite

Protected End
(Cathodic or most noble)

SL 000491

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of 14th Judicial District Court
No. 91-1145



COOLING WATER PROBLEMS

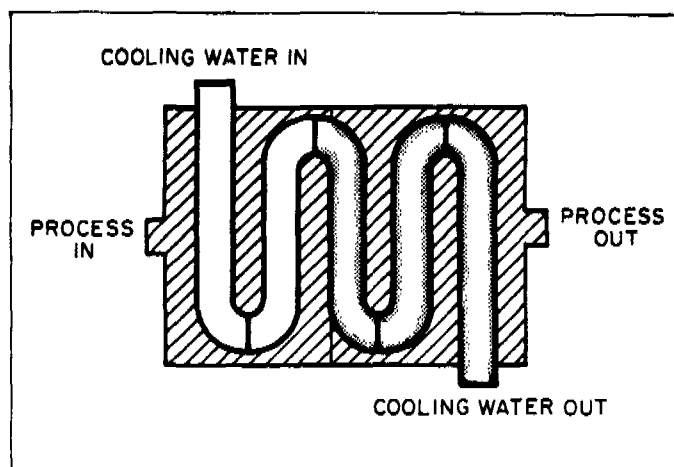
Scale

Scale, when discussed in cooling water systems, is defined as a deposit of a crystalline nature. It is formed by a combination of cations and anions in a fixed ratio to form a deposit. It generally forms at a metal surface in a reasonably uniform manner.

In the cooling tower system, many ions can combine to form potential scales. Calcium scale is the most common. Calcium combines with carbonate or sulfates depending on ion concentrations, temperatures and conductivity. A scientist named Langelier developed an index to predict the solubility of calcium carbonate in water. This index predicts the tendency of calcium carbonate to either come out of solution or remain soluble within the framework of the cooling water control program. One way of controlling potential calcium carbonate deposition problems is to maintain calcium carbonate concentrations, total dissolved solids, and pH within a negative Langelier saturation index. Many times this approach is not feasible based on water characteristics and the desire to optimize corrosion control. An alternative is to add a deposit control agent capable of preventing calcium carbonate.

Calcium carbonate and calcium sulfate exhibit an unusual chemical characteristic. Usually salts become

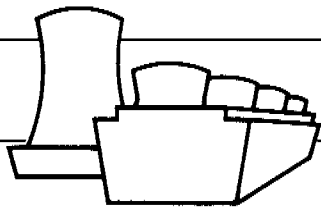
more soluble as the temperature is increased. In the case of calcium carbonate and calcium sulfate, however, as temperature increases their solubility *decreases*. This means the potential for problems is greater in the hottest part of the system—heat exchange units, where it is critical to maintain clean heat transfer surfaces.



As water temperature increases, calcium carbonate becomes less soluble and the potential for deposition increases.

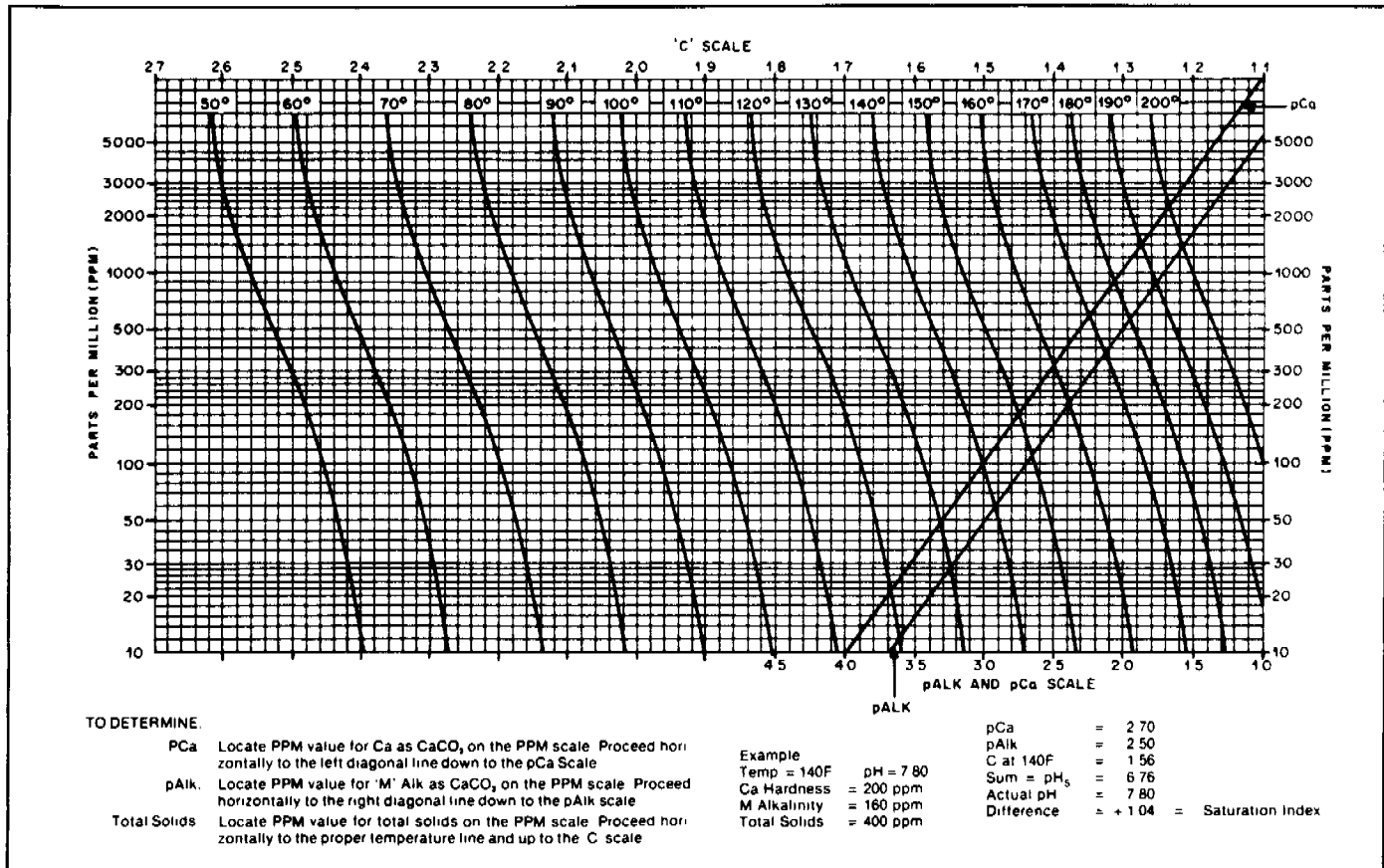
SL 000492

CONFIDENTIAL:
Subject to Protective Order
of 14th Judicial District Court
No. 91-1145



COOLING WATER PROBLEMS

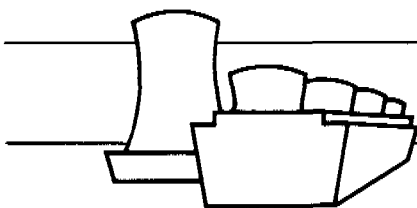
Scale (Cont'd.)



The Langelier Index is used to predict the solubility of calcium carbonate in water.

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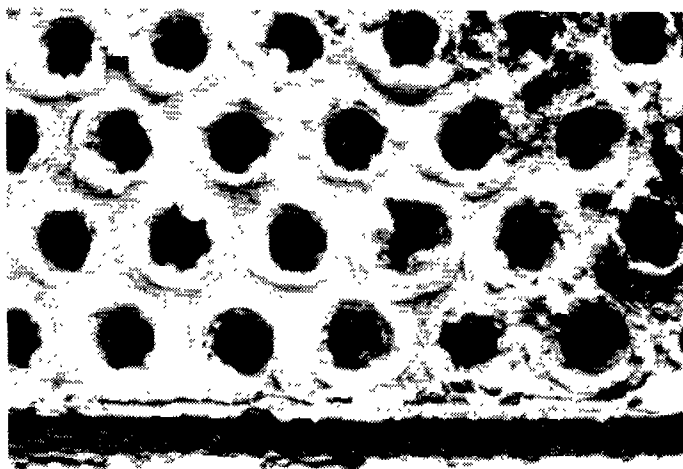
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Subject to Protective Order
of 14th Judicial District Court
No. 91-1145



COOLING WATER PROBLEMS

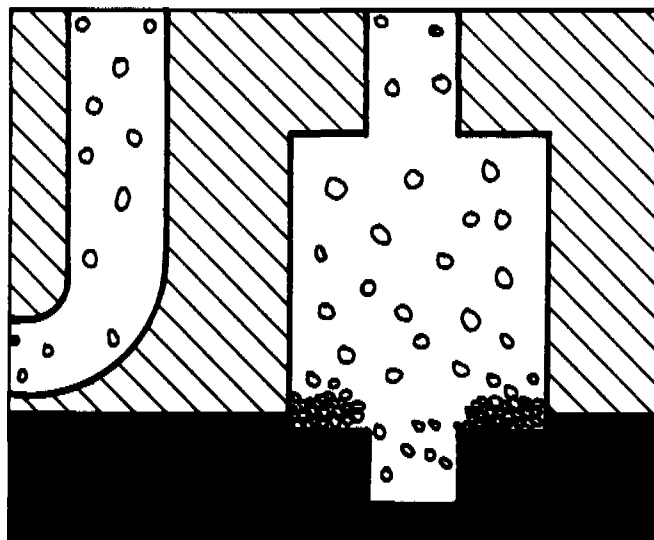
Fouling

Fouling in the cooling water system is generally described as the accumulation of organic or inorganic materials, which are of a suspended nature, in the bulk water. Biological slimes or algae, corrosion products, and other suspended materials can foul heat exchangers. Suspended solids can enter the tower in a number of ways. If makeup water contains suspended solids, these become concentrated during the cooling tower operation. As air passes through the tower, it is scrubbed by the water and any dust or particles carried in the air are scrubbed into the water. In addition, microorganisms carried by the air have a prime breeding area in the cooling water system because of its warmth and humidity.



Severely fouled heat-exchanger.

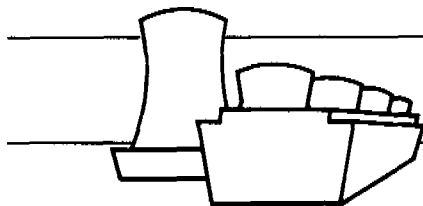
Fouling caused by inorganic deposits is subject largely to flow velocities since these materials are carried in the water and any decrease in velocity, as may be seen in a shell-side exchanger, allows these materials to deposit out in the system. In the case of organic, microbiological activity, these particles can be found throughout the cooling water system. Control of these types of potential foulants in the cooling water operation is discussed in another section.



Fouling is often a problem in low flow areas of the system.

SL 000494

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Subject to Protective Order
of 14th Judicial District Court
No. 91-1145



COOLING WATER PROBLEMS

Corrosion Control

Corrosion is defined as the destruction of metal by chemical or electrochemical reactions with its environment. Corrosion inhibitors used in cooling water systems are classified as passivators. These types of inhibitors form a passive metal oxide or film on the metal surface. Combinations of chromate, phosphates and zinc are most commonly used as inhibitors.

Chromate and phosphate are considered **anodic inhibitors** since they react and restrain the reaction that occurs at the anode of the corrosion cell. Chromate and phosphate function by promoting a passive iron oxide film at the anodic site. Substantial amounts of anodic inhibitor are required if this is the only form of protection used in the cooling corrosion control program. To further protect the system, cathodic inhibitors are used.



Anodic Reaction

Cathodic inhibitors are those which restrain the



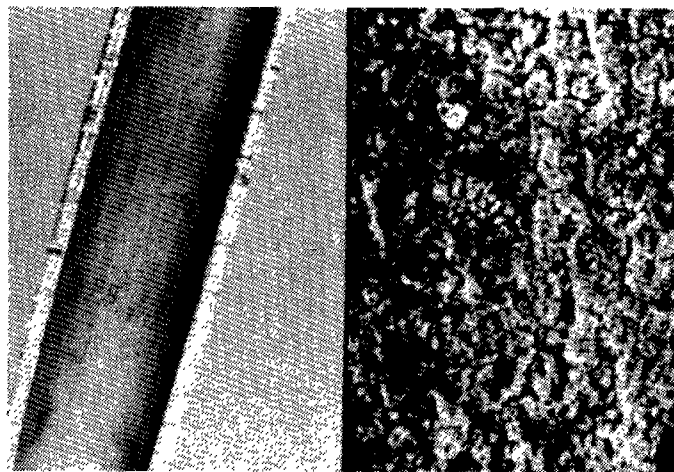
Corrosion

cathodic reaction. Salts of metals such as zinc form moderately insoluble hydroxides at the cathodic site. Calcium carbonate and calcium phosphate also act as cathodic inhibitors.



Cathodic Reaction

The ideal cathodic inhibitor is one which develops a protective film of minimum thickness and which precipitates evenly in both the hot and cold sections of the system without interfering with heat transfer efficiencies.

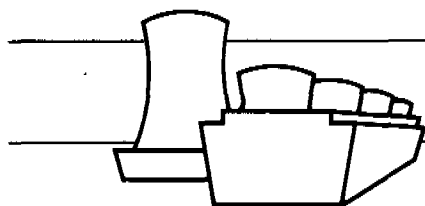


Test heat exchange tube and electron photomicrograph of surface coated with iron oxide film.

Other parameters can affect corrosion protection. These are pH, chloride and sulfate concentrations, temperatures, and water velocities. All of these parameters must be considered in the development of an overall water treatment program for the cooling water system.

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Subject to Protective Order
of 14th Judicial District Court
No. 91-1145

SL 000495

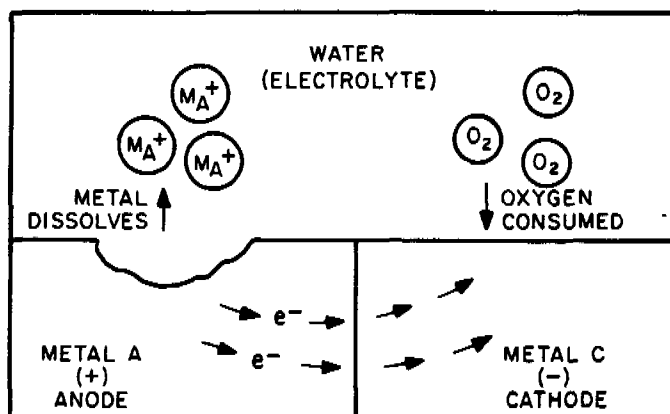


COOLING WATER PROBLEMS

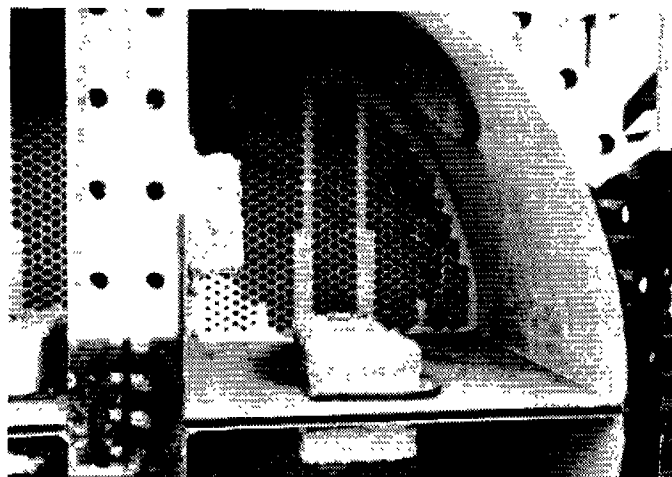
Galvanic Corrosion

Galvanic corrosion is defined as the destruction of metal caused by contact of dissimilar metals.

In the case of cooling systems, it is typical to use a steel tube sheet with Admiralty tubes. This type of interface creates an electrical current similar to the corrosion cell that has been discussed. In this case, the steel (being less noble as can be seen in the galvanic series) would corrode. The electromotive series or galvanic series cannot be interpreted as a precise indication of galvanic action. Dissimilar metals, temperature and the ion concentrations can affect the rate of galvanic metal destruction.



Galvanic corrosion is caused by contact of dissimilar metals.



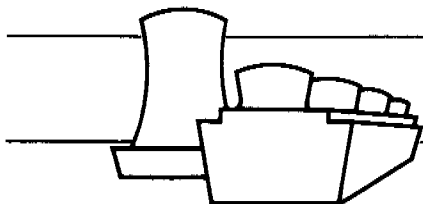
Heat exchanger with sacrificial anodes.

To control the potential problems created by galvanic coupling, frequently **sacrificial anodes** are used. In many cases, magnesium or zinc anodes are placed in the heads of exchangers of cooling water systems. These sacrificial anodes dissolve, being higher in the electromotive series, and they are corroded in preference to steel tube sheet which appears lower in galvanic series.* If not addressed galvanic corrosion can be a serious problem in a cooling tower system.

*See chart in Cooling Tower Problems—Corrosion Section MAR206 C-3.

SL 000496

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Subject to Protective Order
of 14th Judicial District Court
No. 91-1145



COOLING WATER PROBLEMS

Scale Control

Temperature, rate of heat transfer, calcium sulfate, magnesium, silica, alkalinity, dissolved solids and pH of the water are all factors affecting scale formation. Control of scale can be accomplished by the control of alkalinity, pH and ion concentrations through the use of blowdown. This type of control can be inefficient, since water losses increase operating cost and decrease the efficiency of the operation of the cooling system. Softening the makeup water to the cooling system is an additional alternative, but this many times is not economically feasible with the large volumes of water required in cooling water systems.

The usual method for inhibiting calcium carbonate and scale deposits, while still allowing economical operation of the cooling system in terms of cycles, is by the use of acid and deposit control agents. Deposit control agents prevent crystal growth and scale formation by distorting the crystal structures as they are formed. This will allow higher concentrations of calcium in the system without the fear of deposition in the hot heat transfer areas.

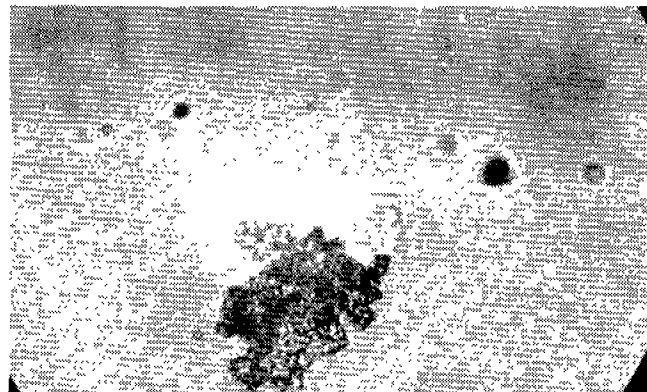
The use of phosphonates and polymers to accomplish deposit control is demonstrated in the three photomicrographs on this page. As you can see, the crystal structures are significantly distorted and the potential for deposition is substantially reduced.

SL 000497

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Subject to Protective Order
of 14th Judicial District Court
No. 91-1145



Pure CaCO_3 , 450 magnifications.

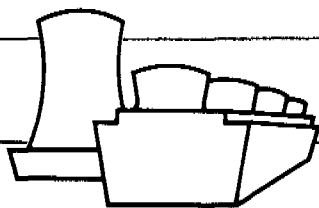


Distorted CaCO_3 crystals with phosphonate treatment.



Distorted CaCO_3 crystals with polymer phosphonate blend.

Use of deposit control agents can effectively control scale.



COOLING WATER PROBLEMS

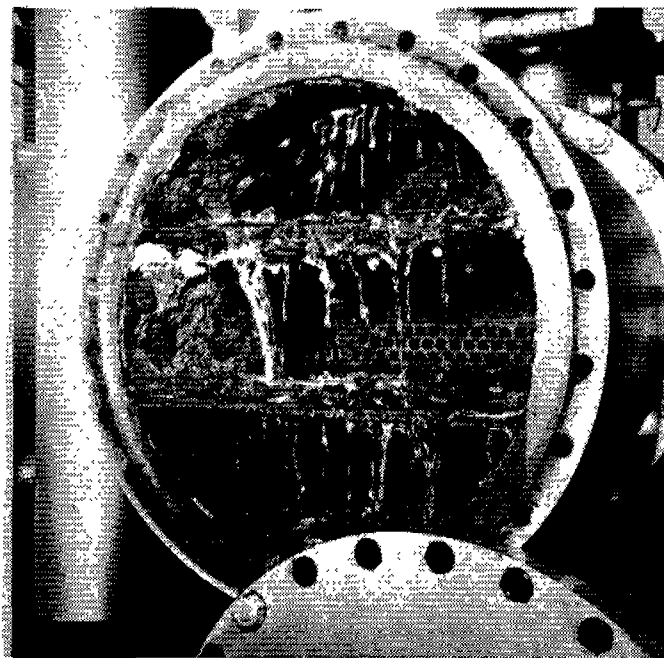
Fouling Control

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Subject to Protective Order
of 14th Judicial District Court
No. 91-1145

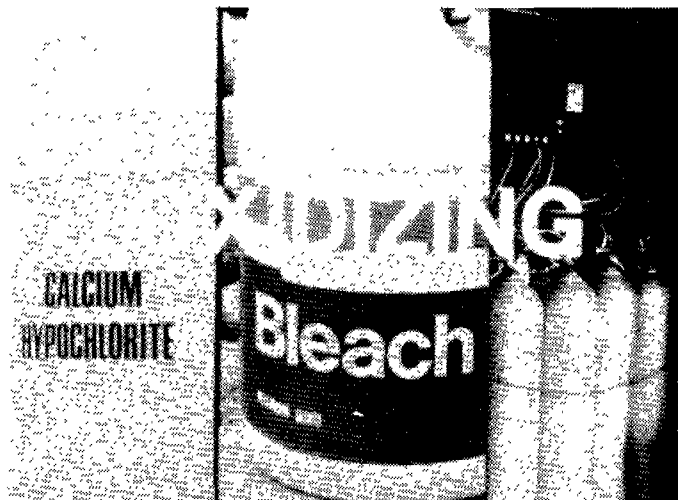
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Fouling is categorized generally in terms of organic and inorganic deposition within the cooling water system. Inorganic deposition many times is associated with the amount of suspended solids or corrosion products present in the circulating water system. Velocities become critically important in the control of deposits of this nature. Many times **side-stream filters** are used to remove suspended solids and corrosion products and reduce the potential for deposition. Where this is not possible, polymers are used to control the deposition and to maintain the particles in suspension. These materials can allow for somewhat higher suspended solids, but even these materials in critically low flow areas of shell-side exchangers can be less efficient.

Organic or biological control in the cooling water system is a vital part of an overall treatment program. **Biological fouling** in an open recirculating system is the result of excessive growth and development of different lower forms of life, namely algae, fungi or bacteria. These types of deposits can severely reduce heat transfer efficiency if not controlled.

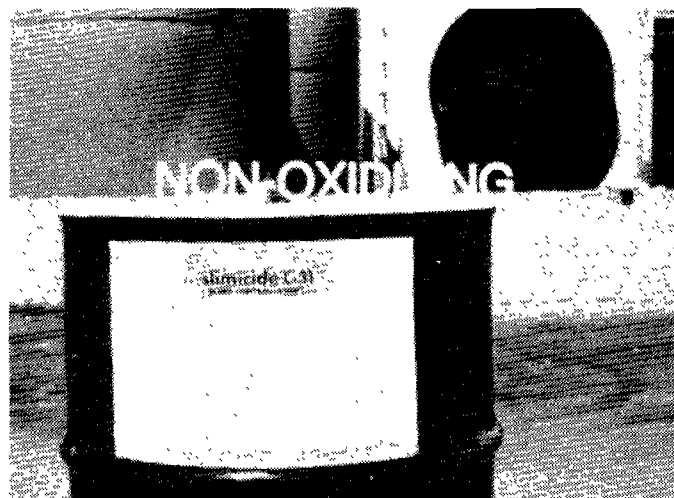


Heat exchanger with a serious biological fouling problem.



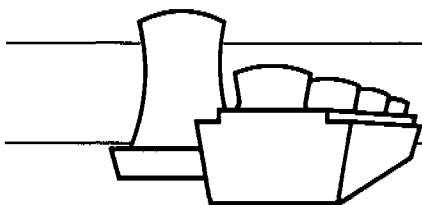
Oxidizing biocides include calcium hypochlorite, sodium hypochlorite, and gaseous chlorine.

Biological control materials are generally designated as oxidizing or nonoxidizing biocides. **Chlorine** is an example of an oxidizing biocide. Low doses of free chlorine within the cooling tower system effectively kill most microorganisms contacted for a short period



Non-oxidizing biocides are often used for shock treatments.

of time. The amount of chlorine required to control microbiological activity in an individual system is governed by the following factors: quantity of a makeup water in a tower, the amount and type of



COOLING TOWER PROBLEMS

Fouling Control (Cont'd.)

contact with the atmosphere, the nature and quantity of system contaminants, cooling tower treatment program, and type of biological contamination. The efficiency of chlorine strongly depends on the pH of the cooling system.

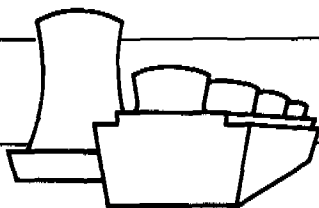
N n-oxidizing biocides are generally used as a shock-type treatment. These compounds react with the microorganisms to either prevent their reproduction

or to kill the original organisms contacted. These types of materials generally are not consumed by contaminants or oxygen in the system so they remain in the system until they pass out with the blowdown and therefore provide a significant period of time for controlling microbiological activity.

The selection of a biocide program is determined largely by the nature of the system itself.

SL 000499

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of 14th Judicial District Court
No. 91-1145



COOLING WATER PROBLEMS

Review Questions

1. Blowdown in the cooling water system is designed to control the _____ solids and the _____ solids in the circulating water.
2. Corrosion is defined as an _____ reaction between oxygen, water and the exposed metal surfaces.
3. _____ is a more severe type of corrosion than general corrosion, since this type of corrosion can cause failures in a short period of time.
4. Scale when discussed in a cooling water system is defined as a deposit of a _____ nature.
5. _____ saturation index is an indication of whether calcium carbonate will remain soluble or precipitate in the cooling water system.
6. Fouling is generally described as organic or inorganic materials which are _____ in the water.
7. The ideal corrosion inhibitor would form a _____ coating of a minimum thickness.
8. To protect a system from galvanic corrosion, _____ anodes are generally used.
9. Phosphonates and polymers are used to _____ the crystal structure as they are formed.
10. _____ is an example of an oxidizing biocide.

SL 000500

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No. 91-1145