Corrosion Control in Chilled Water Pipes

In Pharma companies a pin hole in the chilled water pipeline would mean partial closure of the manufacturing facility and loss in production. Quite often a sample taken from chilled water pipeline is reddish in colour due to rusting. BacComber Treatment has

successfully protected Chilled Water pipelines at nominal cost without any consumables. It is a fit-and-forget system successfully in use for over 5 years in Indian HVAC industry.

This article examines the following issues:

- The Corrosion Cell
- Effect of dissolved gases on corrosion

Chilled Water Pipe Protection

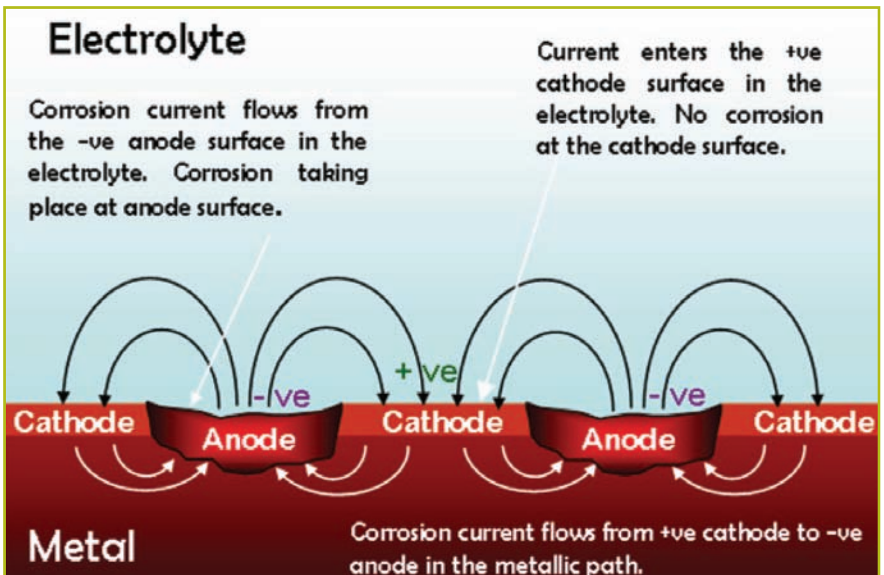
A large pharmaceutical company has 2.5 km long chilled water pipe branching all over their different production units. The header size was 28″. They had corrosion problem with dissolved Fe level as high as 100 ppm. They installed the BacComber ULF system on the common header. Within three months the dissolved Fe came down to less than 1 ppm. With BacComber Ultra Zinc System their pin holes corrosion was controlled excellently without further interruption in production.

- The mechanism of corrosion due to dissolved oxygen
- Chilled Water Systems: Open Loop and Closed Loop
- Pitting corrosion
- BacComber Corrosion Control for Chilled Water Pipes
- BacComber Ultrazinc for pitting corrosion
- Removal of Corrosion Products from the Chilled Water Tank
- Slime Control in Chilled Water Pipes.

The Corrosion Cell

Corrosion is an electro-chemical process. A typical corrosion cell is shown below:

The four essential components involved are:



Corrosion Cell

- Both anode and cathode must be present
- There must be a difference in electrical potential between anode and cathode
- A metallic electrical path must be present to connect anode and cathode
- The anode and cathode must be submerged in an electrolyte, which is electrically conductive

The corrosion cell can only function when all the above four conditions are met. If any one of the four conditions is not met, the corrosion cell cannot function and no corrosion will take place.

The area where electrical potential is more negative is called an anode, and electrically more positive area is called a cathode. Electric current will leave the (anode) metal surface, flowing through the electrolyte and enter the surface of the electrically more positive area (cathode). When current leaves the anode surface, the anode surface will corrode. There is no corrosion at the cathode surface where the current enters.

Effect of dissolved gases on corrosion

Dissolved gases in water can be divided into two groups.

- Gases such as oxygen or nitrogen remain in its non-ionic molecular state when dissolved in water.
- Gases such as carbon dioxide can be in both the ionic and non-ionic form when dissolved in water. When dissolved in ionic form, compounds such as carbonic acid will form and they change many properties of water including pH.

$$CO_2 + H_2O \leftrightharpoons H_2CO_3$$

$$H_2CO_3 \leftrightharpoons H^+ + HCO_3^-$$

$$HCO_3^- \leftrightharpoons H^+ + CO_3^{2-}$$

The solubility of these gases is mainly determined by two factors:

- Partial pressure

Henry's law gives the relationship between partial pressure above the liquid and the gas solubility.

C = k x P

Where,

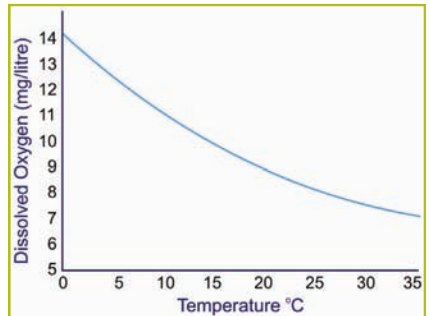
C is the concentration of gas in the liquid

p is the partial pressure of the gas above the liquid

k is the Henry's constant

- Temperature

Besides the partial pressure, colder temperature will dissolve more gases whereas hotter water will dissolve fewer gases.



Oxygen solubility in water at various temperatures

The presence of oxygen and carbon dioxide can affect directly the corrosion rate of mild steel in water. The effect of these dissolved gases must be taken into consideration when designing corrosion protection. It is important to maintain the water pH value at high level.

The mechanism of corrosion due to dissolved oxygen

As mentioned earlier, corrosion is an electro-chemical process. Several small cathodes and anodes on steel surfaces are created due to several factors such as:

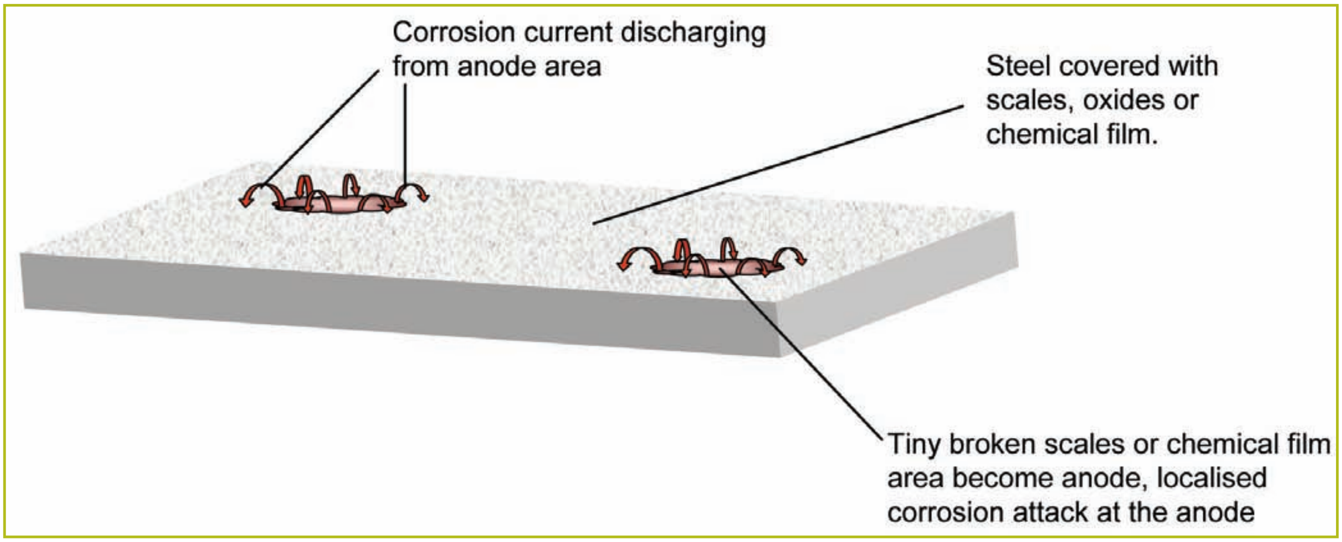
- Stress differences on the steel surface
- Discontinuity in oxide films
- Difference in aeration

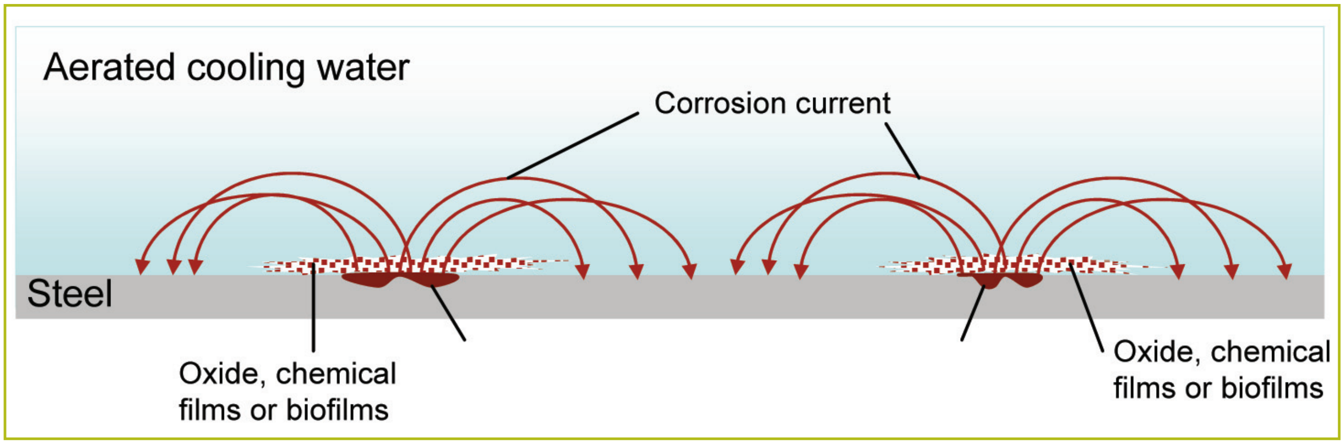
At these anode and cathode areas, the following reaction will take place.

Anode: Fe → Fe^{++}+ 2e- (Metal loss)

Cathode: $\frac{1}{2}O_2 + H_2O$ + 2e-2OH^- (No metal loss, becomes alkaline. Excessive current can cause hydrogen evolution)

The hydroxide present will react





further in water to form ferrous hydroxides:

$Fe^{2+} + 2OH^{-} \rightarrow Fe(OH)_2$

When ferrous hydroxide is further converted into the oxide in the water, depending on the energy available either Hematite (Fe_2O_3) or Magnetite (Fe_3O_4) will form.

Fe_2O_3 Hematite

- This iron oxide layer is porous allowing water, oxygen etc to migrate through or from the steel surface. This action is not that free as without the hematite oxide layer.
- The hematite oxide film does not adhere well on the steel surface as a result of its continual oxide film expansion.

Fe_3O_4 Magnetite

It is therefore not a good corrosion protective film.

- This layer in its pure form is slightly magnetic and adheres very tightly to the steel surface.
- The magnetite layer once formed will retard further reaction and reach a stable thickness showing good oxide film stability.
- The protective continuous magnetite oxide films growth rate will follow the parabolic law and its protecting power is directly proportionate to its thickness.

Chilled Water Systems: Open loop and Closed loop

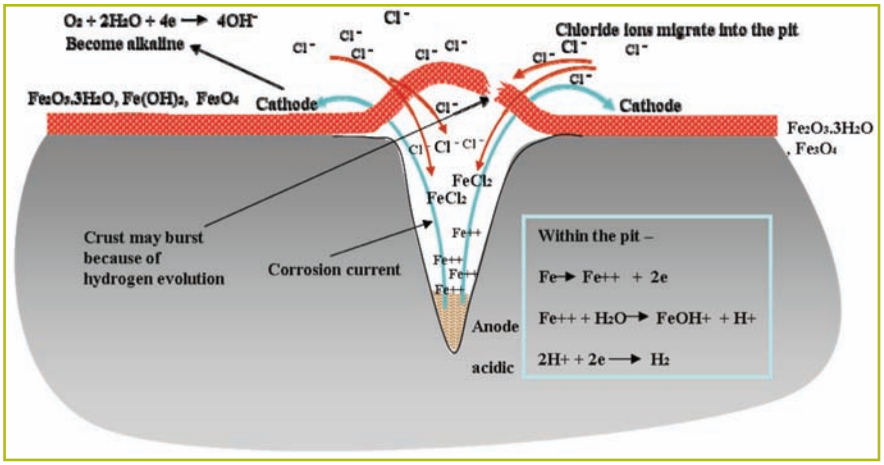
It is therefore important to understand the water temperature and pressure to design a corrosion control system with ULF treatment. There are two types of chilled water systems:

- Closed Loop: It is assumed that there is no replenishment of oxygen in the system. But in practical situations there is often leakage & oxygen replenishment takes place.
- Open Loop: gases come in contact with chilled water and oxygen gets replenished frequently. This may happen because of:
  - Air vents in the system in hot or cold wells
  - Sometimes due to leakage in a 'closed' system

In an open loop chilled water line the DO (dissolved oxygen) level in the chilled water is much higher than the room temperature water.

Pitting Corrosion

Pitting corrosion normally starts from points under the deposit or breakage in coating or oxide film. In the case of presence of dissimilar metals, pitting corrosion will be accelerated. When the pitting corrosion starts at the anode surface, the electrical potential at the anode is more negative than the cathode and corrosion current will discharge from the anode to the cathode. The anode surface will become more concentrated with Fe ions as the



current leaves the surface and the cathode will become more OH^- concentrated or more alkaline. Because of the physical condition in the deposit-covering pit, the positive Fe ions cannot be removed readily from the pit by the bulk solution and created the tendency to attract the negative ions.

Of all the negative ions, chloride has the best ability to penetrate the scale or deposit and start reacting with the ferrous ions, the pH in the pit therefore become lower or electrically become even more negative due to the production of hydrogen ions.

The corrosion process is therefore accelerated further in the pit and further pits through the metal. The general corrosion rate of mild steel in water is about 20~50 mpy for unprotected steel for cooling water system. In case of pitting corrosion, it can reach even up to 120 mpy.

BacComber corrosion control for Chilled water Pipes

In the BacComber treated water, the ULF input energy will promote the formation of magnetite. However, the depolarization effect of dissolved oxygen will discourage its formation. As a result, the surface layer, which is in constant contact with water where supply of dissolved oxygen is readily available the iron corrosion product, is the red rust hematite Fe_2O_3. However, the layer beneath the hematite lacks oxygen and the magnetite formation reaction will proceed. In the closed loop chilled water and boiler condition, the supply of oxygen is minimum. As a result, the magnetite formation reaction will proceed, and the top layer of iron oxide in the closed loop chilled water is usually magnetite instead of the hematite. BacComber corrosion control is very effective for chilled water system where black steel pipe is generally used. It has been proven that BacComber corrosion control is more effective in many installations especially those having severe corrosion problem due to earlier chemical treatment.

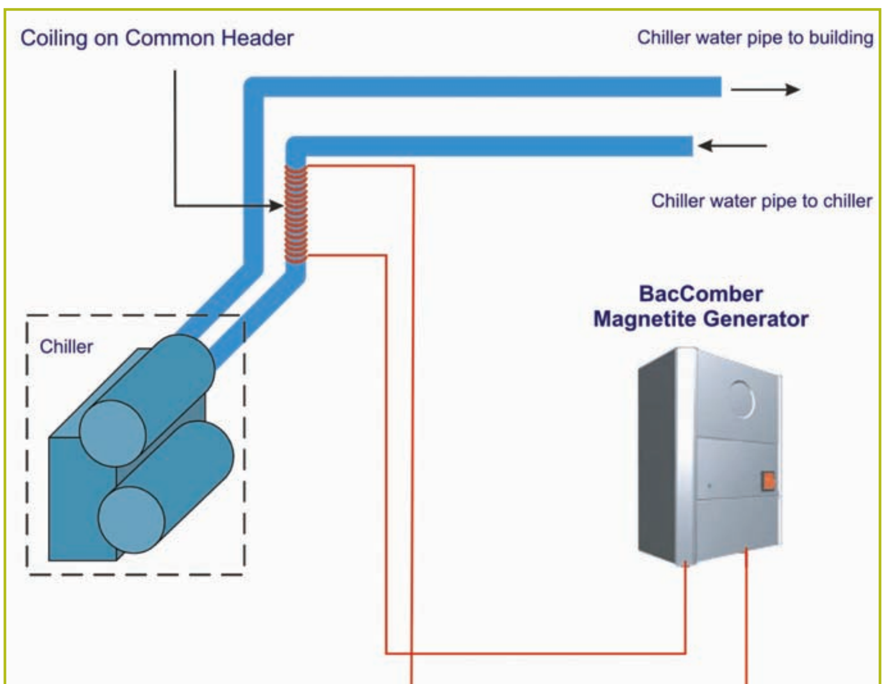
Closed Loop System

The closed loop chilled water system is common in HVAC chilled waters system and basically the chilled water system is fully enclosed and not in direct contact with the atmosphere. The common possible source of oxygen supply is through the new water replenishment. Usually small amount of water is replenished due to leakages at pump seal etc.

Open Loop System

In the case of open looped chilled water system, constant exchange of oxygen with the atmosphere will constantly take place. In fact the amount of dissolved oxygen in the chilled water system is much higher than those in cooling water. In this situation, corrosion design similar to cooling water shall be adopted and in fact extra ULF capacity will be

Black Magnetite layer behind red rust scrapped off



Schematic

Typical

needed due to the higher dissolved oxygen level in chilled water.

BacComber System for Chilled Water consists of a BacComber Magnetite Generator which generates ULF waves through a coil wound around the steel pipe of the common header. The typical installation for a closed loop system is shown herein.

The installation is carried out on a common header. A portion of the insulation is removed (about 1 m) and cable is coiled on the metal pipe. It is connected to the BacComber Magnetite Generator. The insulation is put back. There is no consumable. It is fit-and-forget.

BacComber Ultrazinc Corrosion Control

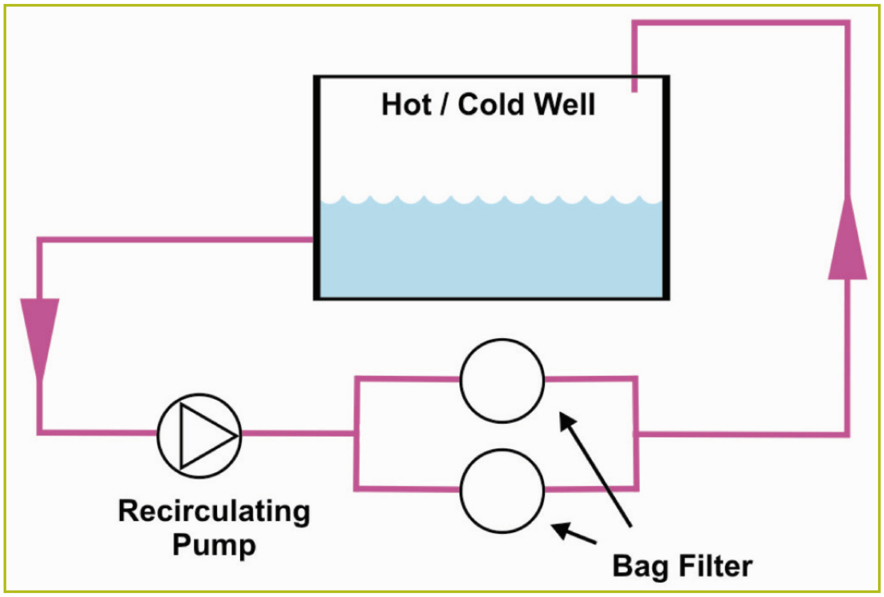
In situation where dissimilar metals corrosion is involved, BacComber Ultrazinc corrosion control system must be used. Enhanced by the ULF system, zinc ions are released into the water system to control corrosion.

It can be used for the following corrosion control-

- Dissimilar metal corrosion
- Pitting corrosion for steel
- Dead end or stagnant water corrosion.

Cuprous oxides on the copper surface are electrically conductive. Therefore, under the bimetallic connection condition, the cuprous oxide film cannot act as a Cathodic inhibitor to stop the flow of corrosion current. On the other hand, the Ultrazinc ions can act as Cathodic inhibitor.

For pitting corrosion, the BacComber Ultrazinc will deposit at the pit mouth and will control further corrosion in the pit.



Removal of Corrosion Products from the Chilled Water Tank

It is advisable to remove the corrosion products from the chilled water system, especially in the open loop system. This is done very effectively using filtration system. The typical layout is shown below:

This filtration system has helped in making dark brownish water into clear water when combined with the BacComber Corrosion Control system.

Slime Control in Chilled Water Pipes

In certain cases the water from chilled water is observed to be slimy. The slime impedes heat transfer. Even a thin layer of bio-film or slime can have a huge loss in energy. The table here shows the energy loss compared to $CaCO_3$ (hard scale).

Material	Thickness (mm)	Energy Loss (%)
$CaCO_3$	0.03	27
Bio-film (slime)	0.01	30

This is now easily solved using BacComber ULF Emitters which control reproduction of bacteria dramatically without any biocides or consumables. When the water is clear and without slime the heat transfer efficiency goes up. BacComber ULF Emitters could be installed either in the open well or in-pipe using a section of non-metallic pipe.

Summary

It is extremely important to control corrosion in Chilled Water pipelines since the rate of corrosion is much higher than in condenser water. BacComber ULF System offers a easy fit-and-forget solution which is extremely economical and takes care of various issues that arise in different applications. ■

N S Rao is Managing Director of Ecospec India Pvt Ltd. He graduated from IIT, Bombay and is a member of ISHRAE. He has been associated with HVAC industry for over two decades. Also, he is involved for 8 years in BacComber Treatment of Cooling Tower water in India.