Controlling Condensate Corrosion in Marine Boiler Systems

Condensate is steam that has been returned to its liquid state. Steam, which is manufactured in the boiler, is used for various shipboard processes. After the steam is used, it is condensed to water and returns to the preboiler system through a series of pipes and condensate return equipment. Depending on the plant, the condensate system can be fairly small or very extensive in size. As water returns to the boiler from plant processes that are distant from the boiler, contamination by process materials or leakage in the system can occur.

Control of the condensate system is critical to the overall operation of the boiler. If the condensate system is not protected, corrosion results. Corrosion eats away at the metal in the pipes and equipment in the system. This can cause leaks in process equipment that can result in a process shutdown.

Corrosion forms iron and copper compounds that are returned back into the boiler. These deposits then cause a decrease in boiler efficiency and ultimately result in a blown boiler tube and boiler shutdown.

Pure condensate is important for maximum boiler efficiency in terms of heat value and energy. The more condensate that is returned, the less heat is needed for the feedwater, thus saving energy.

Sources of Impurities

Contamination of a condensate system can come from any number of sources in the system.

Dissolved solids can be present due to carryover. These include hardness salts, chloride, sulfate, etc. Oil and other organics are due to leaks in the system, or they may be found when steam contacts a process stream and returns with the other condensate. Iron and copper impurities are almost always due to corrosion in the condensate system.

Causes of Condensate Corrosion

Iron and copper contamination in condensate result from corrosion of metal surfaces in various sections of the condensate system. Corrosion of iron and copper occurs because of dissolved gases forming or entering the system. The two principal gases that cause corrosion in condensate systems are dissolved carbon dioxide and dissolved oxygen.

The major source of carbon dioxide is the thermal breakdown of feedwater alkalinity in the form of carbonate and bicarbonate. The corrosive effect of carbon dioxide dissolved in condensate systems is a general overall loss of metal below the surface of the condensate. These problems may be found throughout the system or in isolated locations. Because the metal is thinnest in threaded areas, they are most susceptible to carbonic acid attack. However, bottom grooving of horizontal pipe is also a problem.

Oxygen can be present in the system from a poorly functioning deaerator, air in-leakage to the condensate system via vacuum points in the system, from vented condensate receivers or surge tanks. Intermittent process operation is another source for oxygen pickup.
Dissolved oxygen is present to some degree in practically all makeup water. Unless removed, dissolved oxygen is carried by the feedwater into the boiler. The oxygen flashes off from the boiler water and is carried along with the steam. This is probably the most critical source of oxygen in the condensate system. The oxygen, flashed with the steam, is present when condensation first occurs – the time when the metal is most susceptible to attack. Oxygen can also leak into the condensate via absorption into the condensate in atmospheric systems, with raw water inleakage, and as air drawn in through small leaks when the system is under a vacuum.

Severe pitting caused by oxygen attack can frequently be found at or just below the liquid surface in partially filled vessels and pipes, and at points above the surface where condensate droplets are formed.

Large amounts of oxygen are kept from operating systems by mechanical deaerating or heating the feedwater and then adding a chemical oxygen scavenger.

**Controlling Condensate Corrosion**

The most effective way to control the corrosion in condensate return line systems is to control or eliminate the concentration of the corrodent keeping in mind the following:

- Oxygen can usually be reduced from feedwater by good mechanical deaeration and chemical treatment.
- Condensate tanks should be covered to minimize air intrusion and insulated to keep the condensate temperature as high as possible to reduce the solubility of oxygen.
- Proper lay-up procedures should be implemented to keep the entire system air free.
- Leaks into the condensate system should be repaired properly and promptly.

**Mechanical Factors**

There are several mechanical factors that directly influence the corrosion potential of a condensate system.

**Equipment Operation and Maintenance**

The proper operation and maintenance of equipment are among the most critical mechanical factors influencing the corrosion potential of a condensate system. Equipment such as heat exchangers, pumps, steam traps, condensers and pretreatment equipment must be kept in good operating order or contaminants will enter the system.

**Proper Construction Materials**

Materials of construction must be selected to do the job within the environment in which they are expected to work. Carbon steel is the most frequently used material.

**System Design**

Undersized piping and/or oversized pumps can lead to excessive velocities within the system. The can cause erosion corrosion directly or can act to strip away potentially passivating films. Poor system drainage and open condensate receivers are other design factors that affect the corrosion process.

**Chemical Factors**

Although mechanical methods can reduce the dissolved corrosive gases to very low levels, chemical treatment is needed to complete the job. Volatile additives are materials used most frequently used.

**Neutralizing Amines**

Neutralizing amines are used to prevent after-boiler corrosion caused by low pH. They volatilize into the steam, are distributed throughout the system, and at the point of condensation, dissolve in the condensate, reacting with and neutralizing the carbonic acid and raise condensate pH. The two most commonly used neutralizing amines are morpholine and cyclohexylamine.

To be effective, a neutralizing amine must volatilize into the steam for thorough distribution throughout the system. Volatility is denoted by the distribution ratio. The distribution ratio is the ratio of amine in the steam to the amine in the condensate at the points of condensation.

$$\text{DR} = \frac{\text{PPM Amine in Vapor Phase (Steam)}}{\text{PPM Amine in Liquid Phase (Condensate)}}$$
Amines with a distribution ratio of more than one have more amine in the steam than in the water; the converse is true for ratios less than one.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>DR at 0 psig</th>
<th>DR at 600 psig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morpholine</td>
<td>0.4:1</td>
<td>1.3:1</td>
</tr>
<tr>
<td>Cyclohexylamine</td>
<td>4.0:1</td>
<td>6.6:1</td>
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</tbody>
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Morpholine, which is the amine used in SLCC-A™ condensate corrosion inhibitor, AGK® 100 boiler and feedwater treatment, and DREWPLEX® AT boiler water treatment, has the greatest potential to condense in the first condensate formed, at which time it will neutralize any carbon dioxide dissolved in this same first condensate. It can offer the greatest protection in relatively small systems.

The relatively low distribution ratio of morpholine will result in a low loss through steam venting of deaerating equipment. Conversely, cyclohexylamine, which has a relatively high distribution ratio, travels farther in the steam and reaches areas beyond those in which steam first condenses.

Because neutralizing inhibitors return to the boiler with the condensate, they can be recycled. This is an important consideration in their use because the only loss is through non-returned condensate, steam released to the atmosphere or consumed in the plant processes, or through slight venting losses in the deaerating equipment.

Neutralizing amines are easy to feed and simple to control. They are often applied with other internal treatments. Measurements of condensate pH are used to control the feed of neutralizing amines.

The disadvantages of neutralizing amines are few. Although they effectively control carbonic acid attack, they are ineffective against corrosion due to dissolved oxygen. Where oxygen removal in the condensate system is desired, DREWPLEX OX corrosion inhibitor containing diethylhydroxylamine, more commonly known as DEHA, can be used. DEHA is very volatile and when dosed to the feedwater for oxygen removal, it passes through the boiler and into the condensate system where any remaining DEHA will remove oxygen and also contribute to condensate pH neutralization. In some cases, the contribution to condensate pH neutralization may reduce or eliminate the need for a separate neutralizing amine such as SLCC-A™ condensate corrosion inhibitor.