Oxygen Attack in Steam and Condensate Systems

Many STEAM Users find that their Condensate System Piping is under Corrosion Attack And Don't really know why! The Main TWO Culprits are *AIR* and *Lower Return Temperatures*!

Read Here and See Why this is Happening:

Chapter 19 - Condensate System Corrosion (Reprinted Courtesy GE)

Problems caused by iron and copper corrosion in condensate systems are not restricted to piping and equipment damage or to the loss of high-quality water and heat energy when condensate is lost. If returned to the boiler, corrosion products and process chemicals from corrosion-caused leaks contribute to the formation of damaging boiler deposits, boiler carryover, and steam-driven equipment deposits. Their presence reduces system reliability and increases operation and maintenance costs.

CORROSION OF IRON

Iron corrodes in water even in the absence of oxygen. An iron oxide surface acts like a car battery, with the surface divided into microscopic anodes (+) and cathodes (-). In condensate systems, iron acts as an anode so that it is oxidized (i.e., gives its electrons to the cathode). The cathode in pure water is a proton or hydrogen ion (H^+). When iron metal is oxidized, electrons are passed from the iron surface to hydrogen ions as shown in the reactions below.

Oxidation:

Fe	«	Fe^{2+}	+	$2e$
iron		ferrous ion		electrons

Reduction:

$2H^+$	+	$2e$	«	H_2
hydrogen ion		electrons		hydrogen gas

Overall:

Fe	+	$2H^+$	«	Fe^{2+}	+	H_2
iron		hydrogen ion		ferrous ion		hydrogen gas

The fate of the ferrous ion (Fe2+) depends on condensate temperature, pH, and flow conditions. At low temperatures, Fe^{2+} reacts with water to form insoluble ferrous hydroxide, $Fe(OH)_2$. If the condensate stream velocity is high enough, colloidal $Fe(OH)_2$ is swept into the water and car-ried downstream to deposit elsewhere. In low-flow areas of the condensate system, $Fe(OH)_2$ deposits near the oxidation site, forming a porous oxide layer.

At temperatures above 120°F the deposited ferrous hydroxide reacts further to form surface-bound magnetite (Fe_3O_4) crystals.

$3Fe(OH)_2$	«	Fe_3O_4	+	$2H_2O$	+	H_2
ferrous hydroxide		magnetite		water		hydrogen gas

At even higher temperatures (above 300°F), Fe^{2+} spontaneously forms magnetite without first forming $Fe(OH)_2$. This magnetite forms a nonporous, tightly adherent layer on the metal surface.

$3Fe^{2+}$	+	$4H_2O$	«	Fe_3O_4	+	$4H_2$
ferrous ion		water		magnetite		hydrogen gas

In most condensate systems, two or three forms of iron oxide are present. In pure water, a tightly adherent magnetite layer is formed, which is indicative of a well passivated iron surface. In the absence of contaminants, this oxide layer greatly retards any further oxidation reactions.

Oxygen Corrosion of Iron

In the presence of high oxygen, the corrosion process described above is modified and greatly accelerated. Dissolved oxygen replaces hydrogen ions in the reduction reaction. The reactions are as follows:

Oxidation:

Fe	«	Fe^{2+}	+	2e
iron		ferrous ion		electrons

Reduction:

O_2	+	2e	«	O_2
oxygen		electrons		oxide ion

Overall:

Fe	+	O_2	+	$2H^+$	«	Fe^{2+}	+	H_2O
iron		oxygen		hydrogen ion		ferrous ion		water

This reaction occurs more readily than the direct reaction between iron and protons. Therefore, corrosion rates are accelerated in the presence of oxygen.

Two types of corrosion can occur with oxygen present. The first, generalized corrosion on the metal surface, causes a loss of metal from the entire surface. The second, oxygen pitting (Figure 19-1), causes a highly localized loss of metal that results in catastrophic failure in a short time.

Oxygen pitting begins at weak points in the iron oxide film or at sites where the oxide film is damaged. Instead of growing along the metal surface, the corrosion penetrates into the surface, effectively drilling a hole into (or through) the metal.

Pits are active only in the presence of oxygen. There is a visible difference between active and inactive pits. An active oxygen pit contains reduced black oxide along its concave surface, while the surrounding area above the pit is covered with red ferric oxide. If a pit contains red iron oxide, it is no longer active.

Sources of Oxygen. Oxygen usually enters the condensate by direct absorption of air as we have in open condensate return tanks. It can also flash over with the steam when the feedwater contains oxygen. With effective mechanical deaeration and chemical oxygen scavenging, all but a trace of oxygen is eliminated from boiler feedwater, so this source is not significant in most systems.

In a good steam system design, the air-condensate contact is minimized or eliminated to prevent oxygen absorption. The condensate receiving tank can be designed with a cover to reduce air contact and a steam heating coil within the tank to elevate condensate temperature and thereby reduce oxygen solubility.

Under certain conditions, gross oxygen contamination of the condensate may be unavoidable. For example, condensate from warm-up steam for equipment used only intermittently should not be saved. Its dissolved oxygen attacks systems between the point of condensation and the deaerating heater. This contaminated condensate can return large amounts of corrosion products to the boiler.

In most cases, proper feedwater deaeration and elimination of air infiltration into the condensate substantially reduce oxygen corrosion