

CORROSION IN DRY KILN PIPING

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INTRODUCTION

Corrosion in dry kiln piping causes a large amount of piping replacement every year. The causes of this corrosion are due to various reasons in the boiler water chemistry and operation of dry kilns. The types of corrosion in dry kilns are the following:

1. *Uniform Corrosion* - Usually due to low pH problems such as carbonic acid formation.
2. *Pitting Corrosion* - Due to dissolved oxygen in the system.
3. *Galvanic Corrosion* - Caused by joining two dissimilar metals such as zinc and iron.
4. *Erosion Corrosion* - Due to high velocities in the piping caused by design. This problem usually occurs in pipe elbows or other restrictions. It physically removes the metal and thins the pipe wall.
5. *External Corrosion* - Usually occurs when the piping is buried and/or lies in water that accumulates around the pipes. The dissolved oxygen or low pH kiln water corrodes the outside of the pipe.

For the purposes of this paper, we are most concerned with the effects of corrosion inside the piping and methods used to prevent this corrosion. Since this corrosion occurs when the steam condenses to condensate, we will center this discussion on the condensate return piping.

FACTORS THAT INFLUENCE CORROSION

Corrosion in the piping is due to several factors, and only some of these factors can be controlled. With proper water treatment, the corrosion rates can be minimized to less than three mils per year. These factors are listed below.

Temperature

As the graph in Figure 1 shows, corrosion rates are dramatically increased as the temperature increases. Above 180° F (which is the case in dry kilns) corrosion rates increase dramatically if the water is not properly treated. Since the condensate temperature has to be kept above 180° F, temperature is not a controllable cause. Each 15° F rise in temperature approximately doubles the rate of corrosion reactions.

Velocity

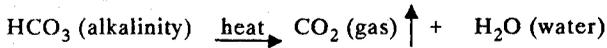
The higher the velocity in the return system, the more corrosion will occur in the system. This factor also cannot be easily controlled. Higher velocity removes the corrosion products which naturally retard corrosion.

pH

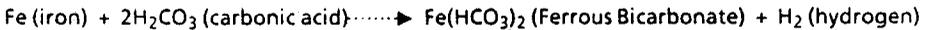
When the pH is low (below 7.0) in the system, the corrosion rates are dramatically increased. This factor can be corrected by adding the proper chemicals to raise the pH to the alkaline range (above 7.0) or by adding chemicals which prevent the low pH water from attacking the metal.

Carbon Dioxide

This is the major cause of corrosion in the steam/condensate return system. The breakdown of the makeup water alkalinity in the boiler is the source of the carbon dioxide by the following reaction:



The carbon dioxide (CO_2) is a gas and goes off with the steam. When the steam condenses, the carbon dioxide dissolves in the water to produce carbonic acid.



This reaction is accelerated at a pH of 5.9 or less. Corrosion caused by carbonic acid will occur below the waterline and is identified by channeling or grooving of the metal wall. Carbonic acid corrosion is prevented by:

- A. Chemical treatment
- B. Removal of carbon dioxide (CO_2) at the boiler deaerator
- C. Removal of alkalinity in the makeup water by demineralizer or dealkalizer

Oxygen

Oxygen causes corrosion in condensate systems by pitting the metal out of the piping via individual corrosion cells. Oxygen corrosion is not as common as carbonic acid corrosion because it is usually removed at elevated feedwater temperature in the deaerator and/or with an oxygen scavenger such as sodium sulfite.

Oxygen is about 8 to 10 times more corrosive than carbon dioxide. The two gases combined in condensate are very corrosive.

Oxygen corrosion occurs wherever moisture occurs so it is found both above and below the waterline in the piping. Severe oxygen corrosion occurs in vacuum return systems due to high amounts of oxygen. Leaks permit air to be drawn in the system. Corrosion due to oxygen also occurs in systems operating intermittently. There is no simple solution for this problem. Higher oxygen concentrations in the system will increase the corrosion rate in the system as shown in Figure 2.

Although understanding corrosion can be complicated, it can be summed up in three steps:

- A. Loss occurs from the anode side of the metal. Iron (Fe^0) is lost to the water side and becomes oxidized to Fe^{2+} ion.
- B. As the Fe^{2+} ion is formed, two electrons flow to the cathode area of the steel.
- C. Oxygen in the water completes the electric circuit by using the two electrons to form OH ions.
 - (1) Anode Reaction- $\text{Fe}^0 \rightarrow \text{Fe}^{2+} + 2e^-$
 - (2) Cathode Reaction- $1/2\text{O}_2 + \text{H}_2\text{O} + 2e^- \rightarrow 2(\text{OH}^-)$

The final corrosion product of the above reaction is ferric oxide. Every metal surface has anodes and cathodes due to surface formations, stresses, etc.

In the absence of oxygen, the hydrogen in the water will react with the iron to promote corrosion. The corrosion product of this reaction is ferrous hydroxide, $\text{Fe}(\text{OH})_2$, in low temperature systems. In dry kiln systems, at any temperatures above 120°F , the corrosion product ferrous hydroxide, $\text{Fe}(\text{OH})_2$, is converted to magnetite, Fe_3O_4 .

Other Dissolved Gases

Other dissolved gases such as ammonia or hydrogen sulfide, which rarely occur, can cause corrosion. Ammonia is very corrosive to copper piping in the presence of oxygen. Ammonia can be present from the decomposition of hydrazine (an oxygen scavenger) or the steamline treatment amines.

SOLUTIONS TO CONTROL CORROSION IN DRY KILN CONDENSATE PIPING

The main sources of corrosion in the piping are dissolved gases, such as oxygen, and acidic water caused by condensing the carbon dioxide to carbonic acid in the condensate. Several solutions can be proposed to solve these problems.

Deaeration

The boiler system should be designed with a proper operating deaerator to scrub all of the feedwater before going to the boiler. This would remove the majority of gases like oxygen and carbon dioxide. An oxygen scavenger should be fed to the boiler water system to remove all traces of oxygen in the boiler water.

Dealkalization

If the boiler makeup water is very high in alkalinity, a dealkalizer may be warranted to prevent the formation of carbon dioxide per the above reaction. This option usually requires a high amount of capital cost to the boiler system.

Chemical Treatment of Condensate Corrosion

Two classes of chemical amines are used to control condensate corrosion--neutralizing amines and filming amines.

The properties of neutralizing amines vary with respect to their neutralizing ability and their distribution throughout the steam system. They may be used alone or in combination with each other to get the best results. The chemicals used as neutralizing amines are:

- (1) Morpholine
- (2) Diethylaminoethanol
- (3) Amino Methyl Propanol
- (4) Cyclohexylamine
- (5) Ammonia
- (6) Any combination of the above

Unlike neutralizing amines, filming amines do not neutralize acidity or raise pH. They form a non-wettable barrier which prevents the corrosive condensate from actually contacting the metal and dissolving it. They are polar amines. One part of the molecule attaches to the metal itself. Filming amines can handle oxygen corrosion much better than neutralizing amines since they prevent the oxygen from contacting the metal. Filming amines can be fed with neutralizing amines to achieve low corrosion rates. The chemicals used as filming amines are:

- (1) Octadecylamine
- (2) Emulsion forms of filming amines

Filming amine has to be fed continuously to prevent the condensate from washing the film away.

TESTING AND FEEDING

Neutralizing Amines

Usually these are fed directly to the boiler with the other chemicals. They volatilize in the boiler and carry with the steam. The dosage is monitored by maintaining the condensate pH between 8.0 and 8.5 with a colorimetric pH kit. Iron levels should be below 0.05 ppm. The pH is often monitored at various points in the system.

Filming Amines

It is preferable to feed filmers directly to the steam header going to the dry kiln. The boiling point of some filming amines is higher than the boiler water. The filmers should be injected with a quill to the steam header using a chemical pump feed system. In existing systems, the gradual introduction of filming amines is recommended to avoid the rapid removal of corrosion products. Fast removal of rust will plug traps and strainers.

The dosage is monitored by maintaining the pH between 6.5 to 8.0. A filming amine test can be run to keep the level between 0.1 to 0.5 ppm. Iron levels in the condensate should be below 0.05 ppm.

CORROSION COUPONS

Corrosion coupons should be installed on a regular basis to monitor results of the amine program. Carbon steel coupons should be installed on a 30 to 90 day basis and sent to your water treatment supplier's lab for a corrosion rate study. A corrosion coupon study should be done on the system at least once a year. Since your water treatment supplier usually does this at no charge, checking the system twice a year is recommended in a kiln system to monitor the corrosion rate.

Normal corrosion rate for a condensate return system is 3 mils per year (a mil being 0.001 inches) or less. Excessive corrosion rates will rapidly decrease the life of the condensate return system (traps, piping, etc.)

CONCLUSIONS

Corrosion in dry kiln piping is due to several variables in the system. Some of these variables can be controlled by

- (a) proper deaeration of the boiler feedwater,
- (b) removing the dissolved gases by pretreatment equipment such as a dealkalizer,
- (c) proper equipment design with proper venting, steam traps, no connecting of dissimilar metals, etc.
- (d) proper chemical treatment to prevent low pH condensate and oxygen corrosion.

Corrosion can never be totally eliminated but it can be reduced to a minimum. It should be monitored on a regular basis with corrosion coupons to insure that the above solutions to the problems are being properly applied.

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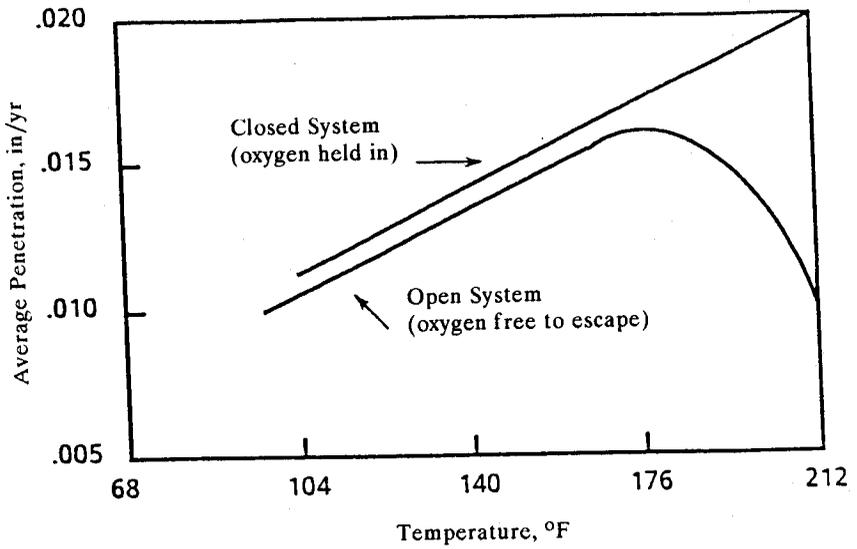


Figure 1. High temperature boosts corrosion except where oxygen is free to escape. (From "Corrosion Report," Power, December 1956.)

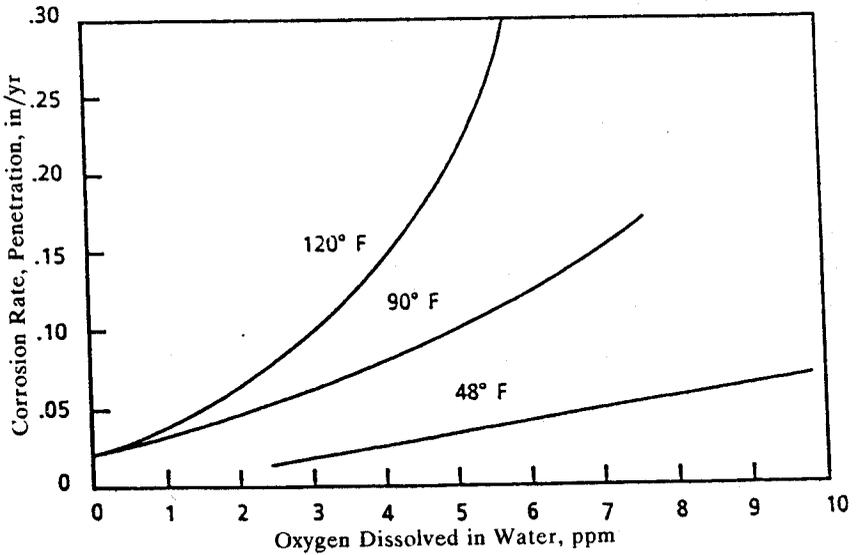


Figure 2. Effect of oxygen concentration on corrosion at different temperatures.