



Effect of Corrosion on Heat Transfer through Boiler Tube

Eng. Waleed A. Dirbas

Department Of Mechanical Engineering,

KING ABDULAZIZ UNIVERSITY, Jeddah – Saudi Arabia

Abstract

Boiler treatment chemistry has been shown to be critical in maintaining clean heat transfer surfaces and minimizing corrosion in higher pressure industrial boilers. Monitoring boiler feed water contamination, especially iron and copper, from condensate leakage and upsets is a critical parameter required to maintain control parameters which promote passivation and clean heat transfer surfaces. Hydrogen analysis has also been shown to detect FAC (Flow Assisted Corrosion) and UDC (Under Deposit Corrosion) subsequently monitor corrective procedures. Hydrogen analysis remains the only dynamic continuous monitoring technique available for corrosion monitoring in feed water and boiler systems.

Introduction

Hydrogen analysis has been a useful monitoring technique for the identification and, in many cases, the quantification of in service boiler corrosion. It can be a useful tool for detecting waterside corrosion processes before damage to failure occurs in boiler system components. Since availability and reliability of boiler plants are key components for increasing operational life expectancy, periodic hydrogen analysis can be used for evaluating the water chemistry and the potential impact of the chemical treatment program. This technique, when coupled with oxygen and sodium studies and iron and copper feedwater and boiler blowdown analysis, provides evaluation tools for feedwater, boiler and steam cycle determinations. Also, the copper and iron testing can be used to evaluate corrosion in the condensate system.

Boiler tube damage to failure can occur as a result of internal boiler corrosion. It is frequently caused by the breakdown or inability to form a stable protective magnetite film at the boiler tube metal surface. The protective magnetite film is often referred to as the passive film which grows and forms naturally under normal operating conditions in the boiler, producing magnetite and hydrogen. As a result, the boiler has often been described as a thin passive magnetite film surrounded by a steel frame. The objective of a boiler corrosion protection program is to maintain the passive film intact, thereby protecting the steel frame. If the magnetite film is destroyed or if its formation is interrupted, corrosion of the base metal occurs rapidly.

Literature Review

Boiler tube failures are a major cause of forced outages in the power production industry. As a means for improving asset availability, many power generation executives are making significant capital investments in new tube bundles. While full tube wall thickness may reduce the frequency of leaks, varying operating conditions can accelerate deterioration of the new tubes. New tubes made of commonly accepted materials, including carbon and stainless steels, are not necessarily designed to withstand the current operating variables of today's power generation industry. Reduced reliability due to corrosion attack is one of the main problems in boiler systems costing billions of dollars per year.

Possible factors of cracking:

- High tension
- Higher heat load
- Corrosion on the material
- Product defects
- Tensile Crack due to improper alignment

Observations in visual inspection

1. Rust caps were seen on the tube surface



Fig.1: Rust for tube

2. Black color sediments were seen on the bottom bed

Assumption

Assuming that corrosion forms on the metal leads to penetrate the thickness of metal body.

Exploring observation No.01

- Rust is an iron oxide, usually red oxide formed by the redox reaction of iron and oxygen in the presence of water or air moisture.
- The key reaction is the reduction of oxygen
 $O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$
- Rust consists of hydrated iron(III) oxides $Fe_2O_3 \cdot nH_2O$ and iron(III) oxide-hydroxide ($FeO(OH)$, $Fe(OH)_3$).
- Different type of corrosion can be seen in boilers.

1. Galvanic corrosion

Occurs when a metal or alloy is electrically coupled to a different metal or alloy. The most common type of galvanic corrosion in a boiler system is caused by the contact of dissimilar metals, such as iron and copper.



Fig.2: Galvanic corrosion

2. Caustic corrosion

Occurs when caustic is concentrated and dissolves the protective magnetite (Fe_3O_4)Iron, in contact with the boiler water, forms magnetite and the protective layer is continuously restored.



Fig.3: Caustic corrosion

3. Acidic corrosion

Low makeup or feedwater pH can cause serious acid attack on metal surfaces in the preboiler and boiler system. Even if the original makeup or feedwater pH is not low, feedwater can become acidic from contamination of the system



Fig.4: Acidic corrosion

4. Hydrogen embrittlement

Hydrogen embrittlement is rarely encountered in industrial plants. The problem usually occurs only in units operating at or above 1,500 psi

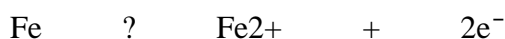


Fig.5:Hydrogen embrittlement

5. Oxygen attack

Without proper mechanical and chemical DE aeration, oxygen in the feed water will enter the boiler. Much is flashed off with the steam; the remainder can attack boiler metal. Oxygen is highly corrosive when present in hot water. Even small concentrations can cause serious problems. Because pits can penetrate deep into the metal, oxygen corrosion can result in rapid failure of feed water lines, boiler tubes, and condensate lines. Additionally, iron oxide generated by the corrosion can produce iron deposits in the boiler. Oxygen corrosion may be highly localized or may cover an extensive area. It is identified by well-defined pits or a very pockmarked surface. The pits vary in shape, but are characterized by sharp edges at the surface. Active oxygen pits are distinguished by a reddish brown oxide cap (tubercle). Removal of this cap exposes black iron oxide within the pit. Oxygen attack is an electrochemical process that can be described by the following reactions:

Anode:



Cathode:



Overall:



The influence of temperature is particularly important in feed water heaters. A temperature rise provides enough additional energy to accelerate reactions at the metal surfaces, resulting in rapid and severe corrosion.

At 60°F and atmospheric pressure, the solubility of oxygen in water is approximately 8 ppm. Efficient mechanical deaeration reduces dissolved oxygen to 7 ppb or less. For complete protection from oxygen corrosion, a chemical scavenger is required following mechanical deaeration.

Major sources of oxygen in an operating system include poor deaerator operation, in-leakage of air on the suction side of pumps, the breathing action of receiving tanks, and leakage of undeaerated water used for pump seals.

The acceptable dissolved oxygen level for any system depends on many factors, such as feed water temperature, pH, flow rate, dissolved solids content, and the metallurgy and physical condition of the system. Based on experience in thousands of systems, 3-10 ppb of feed water oxygen is not significantly damaging to economizers. This is reflected in industry guidelines.

The ASME consensus is less than 7 ppb (ASME recommends chemical scavenging to "essentially zero" ppb)

TAPPI engineering guidelines are less than 7 ppb

EPRI fossil plant guidelines are less than 5 ppb dissolved oxygen



Fig.6: Over firing

6. Carbon dioxide attack

Observation No 01 will be due to the Oxygen attack on the tube body. Suspecting dissolved oxygen in boiler water will damage the tube.

Mechanical conditions affecting corrosion

1. Caustic Embrittlement

Caustic embrittlement (caustic stress corrosion cracking), or intercrystalline cracking, has long been recognized as a serious form of boiler metal failure. Because chemical attack of the metal is normally undetectable, failure occurs suddenly-often with catastrophic results.

For caustic embrittlement to occur, three conditions must exist:

- The boiler metal must have a high level of stress

- Mechanism for the concentration of boiler water must be present
- The boiler water must have embrittlement-producing characteristics

2. Fatigue Cracking

Fatigue cracking (due to repeated cyclic stress) can lead to metal failure.

3. Steam Side Burning

Steam side burning is a chemical reaction between steam and the tube metal. It is caused by excessive heat input or poor circulation, resulting in insufficient flow to cool the tubes. Under such conditions, an insulating superheated steam film develops. Once the tube metal temperature has reached 750°F in boiler tubes or 950-1000°F in super heater tubes (assuming low alloy steel construction), the rate of oxidation increases dramatically; this oxidation occurs repeatedly and consumes the base metal. The problem is most frequently encountered in diffracted beam in side fire boilers.

4. Erosion

Erosion usually occurs due to excessive velocities. Where two-phase flow (steam and water) exists, failures due to erosion are caused by the impact of the fluid against a surface.

5. Metallic Oxides forming in Boiler Systems

❖ Iron Oxide Formation

Iron oxides present in operating boilers can be classified into two major types

1. The first and most important is the 0.0002-0.0007 in. (0.2-0.7 mil) thick magnetite formed by the reaction of iron and water in an oxygen-free environment. This magnetite forms a protective barrier against further corrosion. This magnetite consists of two layers. The inner layer is relatively thick, compact, and continuous. The outer layer is thinner, porous, and loose in structure
2. The second type of iron oxide in a boiler is the corrosion products, which may enter the boiler system with the feedwater. These are frequently termed "migratory" oxides, they are not usually generated in the boiler. This layer is very porous and easily penetrated by water and ionic species.

Iron can enter the boiler as soluble ferrous ions and insoluble ferrous and ferric hydroxides or oxides. Oxygen-free, alkaline boiler water converts iron to magnetite, Fe_3O_4 . Migratory magnetite deposits on the protective layer and is normally gray to black in color.

❖ Copper Oxide Formation

A truly passive oxide film does not form on copper or its alloys. In water, the predominant copper corrosion product is cuprous oxide (Cu_2O).

6. Metal Passivation

The establishment of protective metal oxide lay-errs through the use of reducing agents (such as hydrazine, hydroquinone, and other oxygen scavengers) is known as metal passivation or metal conditioning.

Result:

Observation No.01 rust caps forms on the tube surface will be due to the dissolve oxygen in boiler feed water. That oxygen leads to corrosion of metal surfaces inside the boiler.

Observation No.02 black colour particulate generates will be due to the effect of steam side burning and type two migrant iron oxides sedates on the bottom of boiler bed.

Discussion:

Many factors influence the corrosion rate of alloys:

- Temperature
- PH
- Oxygen concentration
- Amine concentration
- Ammonia concentration
- Flow rate

1. Temperature dependence results from faster reaction times and greater solubility of oxides at elevated temperatures. Maximum temperatures specified for various alloys range from 200 to 300°F.
2. pH Control

Maintenance of proper pH throughout the boiler feedwater, boiler, and condensate systems is essential for corrosion control. Control of pH is important for the following reasons:

- ❖ corrosion rates of metals used in boiler systems are sensitive to variations in pH
 - ❖ low pH or insufficient alkalinity can result in corrosive acidic attack
 - ❖ high pH or excess alkalinity can result in caustic gouging/cracking and foaming, with resultant carryover
- speed of oxygen scavenging reactions is highly dependent on pH levels

The corrosion rate of carbon steel at feedwater temperatures approaches a minimum value in the pH range of 9.2-9.6. It is important to monitor the feedwater system for corrosion by means of iron testing. In systems that use deionized water makeup, small amounts of caustic soda or neutralizing amines can be used.

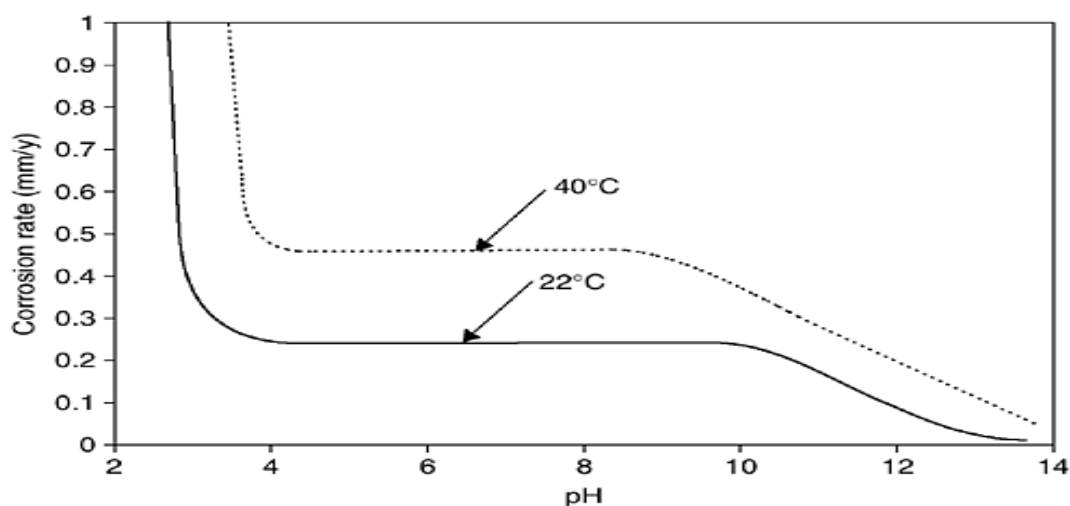


Fig.7: Ph Vs. Corrosion rate

3. Oxygen Control

Chemical Oxygen Scavengers. The oxygen scavengers most commonly used in boiler systems are sodium sulfite, sodium bisulfite, hydrazine, catalyzed versions of the sulfites and hydrazine, and organic oxygen scavengers, such as hydroquinone and acerbate.

Many factors affect the speed of the sulfite-oxygen reaction. These factors include temperature, pH, initial concentration of oxygen scavenger, initial concentration of dissolved oxygen, and catalytic or inhibiting effects. As temperature increases, reaction time decreases; in general, every 18°F increase in temperature doubles reaction speed. At temperatures of 212°F and above, the reaction is rapid. The reaction proceeds most rapidly at pH values in the range of 8.5-10.0.

Oxygen Level Monitoring. Oxygen monitoring provides the most effective means of controlling oxygen scavenger feed rates. Usually, a slight excess of scavenger is fed. It is also necessary to test for iron and copper oxides in order to assess the effectiveness of the treatment program. The amount of chemical fed should be recorded and compared with oxygen levels in the feed water to provide a check on the control of dissolved oxygen in the system.

For low- and medium-pressure systems, sulfite residuals should be in excess of 20 ppm.

In parallel to chemical deaeration system mechanical deaerators must be used. If the temperature in feed water tank drops below 60°C dissolved oxygen in feed water increases rapidly.

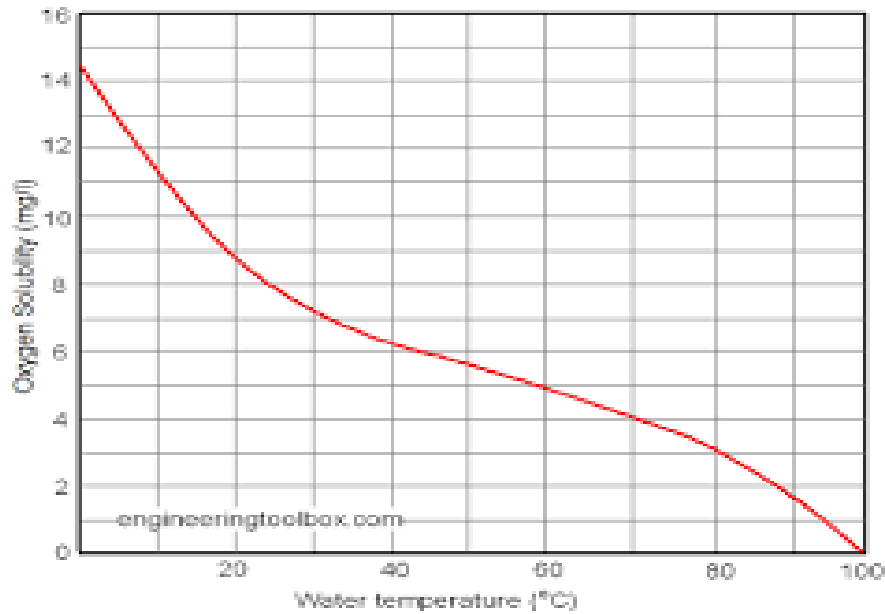


Fig.8: Oxygen Solubility

Deaerators can be installed in variety of forms, direct feedback of steam line, Electric heaters or in form of economizers.

To prevent the steam side burning of boiler flame must be focused parallel to the fume tube. Overheating protectors switches, beam collimators were used for preventing the diffraction of beam.

Conclusion and Recommendation

- Direct monitoring of dissolved oxygen meter should be fixed to the feed water tank to the monitoring dissolve oxygen level. The ASME consensus is less than 7 ppb (ASME recommends chemical scavenging to "essentially zero" ppb)



- The deaerator storage system must be fixed to the feed water tank and threshold temperature should be maintained while storing the feed water.

- Flame must be focused parallel fire throwing to prevent steam side burning of boiler.
- DE chlorination system should install to remove free chlorine in feed water to prevent further formation of ferrous chlorides.
- Annually water draining, conditioning and two step inspection in boiler tank recommended for all boilers.
- For proper boiler maintenance, storing purpose should be based on COCHRAN American Standard Guidelines to prevent rust formation.

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