



Title of Paper-Case Study on Corrosion Phenomenon in Water Wall Tubes of Boiler in Thermal Power Plants

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ABSTRACT

Thermal power plants contribute about 75% of the total installed capacity of electric power generating stations. In worldwide energy sector, total 37% of electricity is produced by combustion of coal. Boiler tube failure is one of the main reason of forced Outages at coal fired thermal power plants. With ever increasing demand for electricity, it is very necessary for the power plants to generate electricity without any failure or forced outages. This paper illustrates cause & effect analysis of corrosion failure in water wall tubes of boiler. The data pertaining to corrosion failure of water wall tubes for one of Thermal Power Plant in Rajasthan State of last ten years is referred. In spite of maintaining the very good water chemistry in water cycle of thermal power plant, a corrosion phenomenon takes place in the water wall tubes. The product of corrosion in the feed water system goes into the water wall tubes of boiler and gets deposited on the internal surface of it. It leads to corrosion and ultimately the tube failure. To achieve the almost zero tube failure in water wall of high pressure boilers, post-operational chemical cleaning is essential at the frequent intervals or at the time of shut down of the plant to reduce corrosion failure of tubes. This paper will discuss the phenomena of corrosion failure in water walls tubes of the boiler & its remedial measures to achieve near zero tube failure.

KEYWORDS

Feed water system, Corrosion, Water wall, Overheating, Wall Thinning

INTRODUCTION

This paper deals with the phenomenon of corrosion failure in water wall tubes of boiler in thermal power plants. Much of this work is based on the theory and particularly on experimental tests performed on water wall tube, sample taken from Kota super thermal power plant. Our aim is to minimize the failure of water wall tubes due to corrosion which is highly important in the thermal power plant. The saturation temperature of boiler water varies from 260 – 380 °C depending upon the boiler pressure. The capacity of these boilers varies from 110 MW to 500 MW, whereas the heat flux varies from 210-310 kw/m². These boilers are generally drum type and a few once through types. Water wall tubes of these boilers are made of carbon steel or low alloy steel. Demineralised water is used in these boilers with proper boiler water treatment; TSP is used in most of the boiler to maintain the pH where deposition of corrosion products and salt concentration takes place on the internal surface of water wall tubes. Thermal conductivity of this deposit is very low (about 3 W/m°C) in comparison of carbon steel (about 50 W/m°C), thus significantly reduces the heat transfer and increases the outer metal temperature. Frequent tube failure has been observed in old boilers ran more than 130,000 hours due to internal localized corrosion. Tube failure investigation indicates that the main reason of water wall tube failure is either due to hydrogen damage or caustic corrosion or overheating or the effect of all.

Corrosion Mechanism

Corrosion is the deterioration of a material as a result of its interaction with its surroundings and can occur at any point or at any time. Water wall tubes in most of the fossil-fired boiler are made of carbon steel. In pure DM water, or in very dilute acid or alkaline solutions at boiler temperature, it normally corrodes very slowly to form the black iron oxide known as magnetite (Fe₃O₄). The overall reaction is:

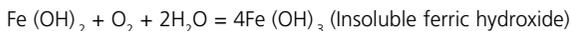
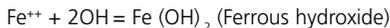


Figure1:-Visualization of water wall failure tubes

Corrosion processes not only influence the chemical properties of metal or metal alloys, but also generate changes in their physical properties and mechanical behaviors and their microstructure. Hydrogen damage (Hydrogen embrittlement) failure occurs when pH value of feed water is very low. For proper working, pH value of feed water must be 6.8 to 7.2, at low pH value; feed water is more acidic in nature, at low pH value hydrogen atom react with the tube material and make the methane gas which removes the carbon from metal which ultimately weak the surface of tube. Corrosion due to dissolved & suspended solids such as calcium and magnesium are present in the water in form of carbonate, bicarbonate, sulphate and chlorides with the conversion of water into steam in boiler, solids are left behind which concentrate the remaining water. As the temperature of feed water increase scale formation tendency also increases Thus at higher temperature, these salts are deposited inside the tube in the form of scale. Thus we can say Ca. & Mg salts are the major sources of scale formation due to low solubility. These scale formed are further hardened by silica present in water. Allowable value of dissolved O₂ in feed water is 0.007 ppm; its presence is highly objectionable as it is corrosive to iron. It causes corrosion and pitting of water lines. Gaseous O₂ dissolved in wa-

ter reacts with the transvestite atomic H₂ on cathodic area of metallic surface destroys the film by depolarization and pursuit the corrosion to continue. Corrosion problem due to dissolved O₂ can be completely solved by deaeration of water. Another effect of dissolved O₂ is to oxidize the ferrous hydroxide, which is soluble in water to ferric hydroxide, which is insoluble in water, which ultimately creates no. of problems i.e. velocity reduction, scaling problem etc.

The reaction takes place is as follows: -



The corrosion of the less noble member of a pair of metals, which are joined together, is called "Galvanic Corrosion." Such type of corrosion occurs in the heavy humidity area like in power station situated near the sea. In sea, feed water conditions are conducive at high temperature it create the corrosive action in tube surface. Caustic embitterment is due to the formation of caustic alkalinity, which deposited on the surface of the tube in the form of scale. The scale of this caustic soda reacts with the metal and damages the welding joints, which are weak in nature. If the salt concentrated under the deposit is having high pH due to concentration of caustic from TSP dosing, it start dissolution of protective magnetite (Fe₃O₄) layer on the evaporator tube wall inner surface and form sodium ferrite (NaFeO₂) and sodium ferroate (Na₂FeO₂) as shown in the equation.



Figure 2 – corrosion observed in water wall tube

Case Study: - Front Water Wall Tube No: 5&6 of unit #1

A case study is made on tubes no 5 & 6 of water wall at unit no.1 of kota super thermal power station and details of various test conducted on these water wall tubes are collected to perform a case study. The test results are compared against established limits and conclusions are drawn. The results of chemical analysis conducted are shown in tabular format. During In -Situ metallographic replicas were taken which shows the micro-structural degradation due to corrosion attack on sample tubes.



Figure3- Corrosion observed on water wall tube

IN-SITU Metallography

The tube was transverse sectioned and micro examined at the failed region. It showed severe external wastage and wall thinning from OD surface towards ID surface. Oxidation of the edges are observed at the failed region. The microstructure of the tube at the failed shows polygonal grains of ferrite & pearlite. Opposite to the failed region and on a ring section a little away from the failed region, similar microstructure is observed. Microstructure shows ferrite grains along with bainite/pearlite. Spheriodization of pearlite is observed. At few places fine bainitic structure is observed. Spheriodization of pearlite is observed. Microstructure shows fine dendrites of ferrite with bainite at weld.

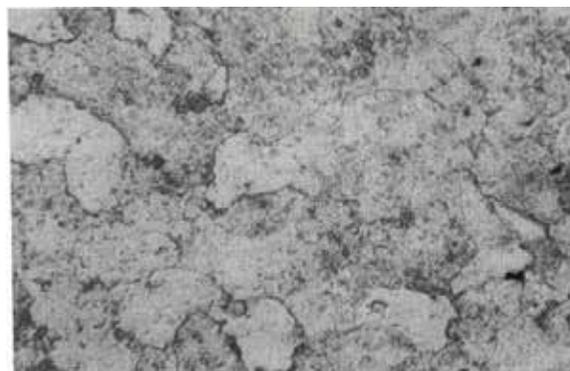


Figure 4:-Microstructure of front water wall tube no: 5

(A) Chemical Analysis:- Water Wall Tube deposit composition(% by wt)		
1	Silica (SiO ₂)	2.3
2	Iron Oxide (Fe ₃ O ₄)	88.5
3	Copper (Cu)	1.7
4	Calcium Oxide (CaO)	4.3
5	Manganese Oxide (MgO)	3.0
6	Phosphate (P ₂ O ₅)	Traces
7	Sodium Oxide (Na ₂ O)	Traces
(B) DEPOSIT QUANTITY(mg/cm²)		
Front Water Wall		39.67

In tube no 6, some pitting are there and pitting is probably the most destructive form of corrosion that affects the water side of boiler tubes. Only a few pits are present and most of the surface is unattacked. In other cases, the pits cover most of the surface, and as a further extreme, the pits all run together and the corrosion takes the form of uniform attack. The frequency of the pits is determined to a large extent by the degree of acidity or alkalinity of the water. Acidity and alkalinity are dependent upon the amount of hydrogen-ion concentration found in the water. Both would be expressed in

terms of the pH scale. A strong acid solution -- strong muriatic or sulfuric acid is rated as 1; a strong alkaline solution -- concentrated caustic soda is rated as 14. A neutral water has a pH value of 7. Below a pH of 5, the water is actually sufficiently acid.

Conclusion

The failure of the tube no 5 is attributed to external metal wastage and subsequent wall thinning. Hence immediate chemical cleaning is required. since the water wall deposit quantity is comparatively high, it is recommended to carry out deposit density measurement of tubes during next available outage ,the presence of copper (1.7%) in the deposit indicates pre boiler corrosion and subsequent deposition on water wall tubes ,water chemistry guidelines have to be measured and monitored properly to minimize the pre boiler corrosion ,Visual examination of water wall tubes no 6 revealed deposits on tube surfaces, normal pitting also noticed. Corrosion observed on tubes in furnace and hopper zone area. No misalignment found visually. Visual inspection of water wall tubes revealed surface deposition and normal scaling. Misalignment observed on tube surface. Distortion /deformation were also noticed. From analysis of observations taken for corrosion of water wall tubes, it could be concluded that corrosion is the major cause of failure. Various N.D.T. (Non-Destructive Techniques) are useful to determine the performance of water wall tubes & therefore reduce outages. Visual inspection of this intermediate tube surfaces revealed scaling and corrosion at bend areas. Misalignment was also observed in some of the tube coils. No any other physical damage or discontinuity observed, selective tubes are being replaced, Examination showed heavy oxide scale and corrosion on the surface of tubes. No other abnormality found visually, for analysis of corrosion failure in water wall tubes, various data's were obtained and analysis tables were prepared for this tube by conducting various tests. Methods of corrosion failure control depend on type of corrosion encountered. The most common cause of corrosion are dissolved solids and under deposit attack& low pH, and these factors can be controlled by maintenance of proper pH and alkalinity levels, control of oxygen and boiler feed water contamination, reduction of mechanical stresses, operation within design specifications, especially for temperature and pressure, proper precautions during start-up and shutdown, effective monitoring and control, Effective corrosion control monitoring is essential to ensure boiler reliability. Lastly we can say that by knowing the various aspects of water wall tubes failure, efficiency of power plant can be increased by reducing outage due to corrosion in water wall tube and ultimately reducing the cost of electricity.

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