Journal of Farayandno – Vol. 20 – No. 89 (2025): pp. 57-76

National Iranian Oil Refining and Distribution Company
(NIORDC)

Journal of Farayandno

Research Paper

DOI: 10.22034/farayandno.2025.2055693.1995

Monitoring the physicochemical parameter and investigating the causes of destruction for thermal power plant steam cycle

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Received: 1 Jan 2025 **Accepted:** 20 May 2025

1. ABSTRACT

In this study, the effective parameters in the water-steam cycle of a thermal power plant including feed water, blowdown, saturated steam, and condenser are investigated. According to the XRD and XRF analysis of the deposits from the blowdown and the internal deposits of the boiler, the type of corrosion that occurred in this power plant are investigated. Based on the performed experiments, the pH, TDS, and electrical conductivity of the saturated steam ater are about 9, 3.66 ppm, and 5 µS/cm, respectively. The results of these studies indicate that the oxygen content is high which leads to pitting corrosion and separation of the magnetite protective layer. As a result, overheating of the pipes ahappen due to the accumulation of deposits in the pipes. Moreover, the XRD and XRF analyses of the internal deposits of the boiler and the deposits in the blowdown indicate the presence of hematite phase which confirms the presence of excess oxygen and the conversion of the magnetite coating layer to hematite and its separation from the surface. In order to prevent overheating of waterwall pipes, it is recommended to use appropriate alternative fuels, improve the chemical regime of the circulating water, improve fuel quality, and conduct periodic and regular acid washing.

Keywords: Thermal Power Plant, Physicochemical Parameters, Boiler, Blowdown, Corrosion.

2. INTRODUCTION

Typical steam generation systems consist of pre-boiler sections (deaerator heaters, piping, pumps, stage heaters, and economizers), steam generating section (boiler, superheaters, and reheaters), post-steam generating section (process equipment, steam pipes, and condensate traps), and condensate section (pipes, flash tanks, pumps, and condensate storage tanks) [1].

Corrosion in steam generation systems has led to major problems and issues in industries including refineries, power plants, gas plants and petrochemical plants. Corrosion in boilers is affected by factors such as the concentration of carbon dioxide, ammonia, oxygen and how these species are controlled, as well as chloride and hydroxide anions and high concentrations of chemicals in the boiler water. Control of water-soluble gases (oxygen and carbon dioxide) in more advanced steam generation systems leads to reduced corrosion of the inner wall of boiler tubes. Alkali embrittlement, pitting corrosion, and hydrogen embrittlement are among the common corrosion mechanisms in steam generation systems [2].

The results of the previous research and studies indicate that the control of corrosion in the boiler is seriously and fundamentally affected by the quality of the boiler feed water. If the pH parameter and the deposition conditions are well controlled, the main factor of corrosion before and inside the boiler is attributed to oxygen

Please Cite This Article Using:
Esmaeilpour, M., Ghahraman Afshar, M., Yousefpour, A., Kazemnejadi, A., Ghaseminejad, H., “Monitoring the Physicochemical Parameter and Investigating the Causes of Destruction for Thermal Power Plant Steam Cycle”, Journal of Farayandno – Vol. 20 – No. 89, pp. 57-76, In Persian, (2025).

level. The formation of corrosion products and oxygen-induced corrosion led to heavy costs in boiler maintenance. Therefore, monitoring and controlling the oxygen concentration in the boiler is very important. In order to prevent oxygen corrosion in the boiler, the oxygen concentration should be reduced to a few ppb and controlled at these low values [3].

3. MATERIALS AND METHODS

Important and analyzable parameters in water samples of the steam-water cycle of the power plant such as ions in the sample are required to be accurate measurement in the laboratory. Therefore, the analyses related to each ion are performed using standard methods commonly used in the world. All required chemical materials and solvents are purchased from Sigma Aldrich and used without additional purification. Measurements of pH, electrical conductivity (EC) and water hardness (TDS) parameters are performed with a HANNA HI2300 device. In order to measure magnesium and calcium ions, the standard 3500 Mg-B and 3500 Ca-B and atomic absorption method are used, respectively. Moreover, the flame photometer method according to the standard 3500-K and 3500-Na are used for measuring potassium and sodium ions. The concentration of sulfate and chloride ions are determined by barium titration (standard SMWW4110 test) and Mohr titration (standard Cl4500 test). The concentration of phosphate, fluoride, nitrite and nitrate anions are determined by UV-Vis method and standard SMWW 4110 method. In order to determine the concentration of cations, a Perkin-Elmer DV5300 ICP-OES analyzer is used. X-ray diffraction analysis of sediment samples is performed with a Bruker AXS D8 instrument with Cu Kα radiation (λ= 1.5418). The conditions for performing XRF boiler scale and boil blowdown scale test is depended on the sampling method and sample uniformity. This analysis is performed semi-quantitatively. In this test, the sample is first dehumidified at 110 ^{o}C and then the sample is subjected to a loss on ignition (LOI) measurement test at 950 ^{o}C for 1.5 hours.

4. RESULTS AND DISCUSSION

In the X-ray diffraction of deposits in boiler and boiler blowdown of the steam-water cycle power, the presence of peaks with diffraction angles 18.27^{o}, 30.1^{o}, 35.60^{o}, 43.05^{o}, 53.40^{o}, 56.94^{o}, 62.40^{o} and 73.95^{o} are assigned to Miller indices (111), (220), (311), (400), (422), (511), (440) and (553), respectively. These peaks confirm the presence of Fe_3O_4 particles in the deposit (Crystalline face-centered cubic Fe_3O_4 NPs (JCPDS file No. 19-0629)). Moreover, the presence of peaks with diffraction angles of 24.15, 33.16, 35.61, 40.86, 49.93, 54.04, 58.10, 62.40 and 64.45 are assigned to Miller indices (012), (104), (110), (113), (024), (116), (018), (214) and (300), respectively. These peaks are consistent with the standard XRD pattern for α-Fe_2O_3 hematite particles (JCPDS 33-0644) [4].

Therefore, the presence of Fe_3O_4 in the sediment is justified having information that in the MWT chemical control regime the protective layer is magnetite. However, a closer examination of the X-ray diffraction of the sediments shows that in addition to Fe_3O_4 (magnetite) particles, specific peaks related to Fe_2O_3 (hematite) particles are also visible. With the increase in the thickness of the protective layer and the presence of excess oxygen (outside the standard limit according to the results of online monitoring, the oxygen level is higher than the permissible limit [5].

XRF testing is performed using the reference standard ASTM E 1621-21 through sample preparation by grinding. The results of chemical analysis by XRF are reported based on the weight percentage of the constituent elements and compounds. The XRF results indicate a high percentage of iron oxides in the boiler and blowdown deposits of Unit 1 which a significant amount of is associated with Fe_2O_3. These deposits are formed by the reaction between excess oxygen (more than 5 ppb) and the Fe_3O_4 protective layer. The presence of hematite phase in the deposits confirms the presence of excess oxygen which leads to pitting corrosion in the steam drum, feedwater pipes and economizer.

5. CONCLUSION

Considering the importance of monitoring and preventing corrosion in the power industry, especially in the country's power plants, implementing monitoring and surveillance programs to increase the efficiency and life of equipment has attracted significant attention. Therefore, considering the corrosion that occurred in the boilers of the steam power plant, the effective parameters of water and steam of this power plant such as condenser water, saturated steam, blowdown, and boiler feed water of the power plant unit are investigated in the present work.

The results of these investigations indicate that the oxygen content is high which leads to pitting corrosion, separation of the magnetite protective layer. As a result, overheat of the tubes occurs due to the accumulation of deposits in the tubes. XRD and XRF analyses of the internal deposits of the boiler and the deposits in the blowdown are performed. According to the data, the presence of hematite phase confirms the presence of excess oxygen and the conversion of the magnetite coating layer to hematite and its separation from the surface.

In order to prevent overheating of waterwall tubes, it is recommended to use suitable alternative fuels, improve the chemical regime of circulating water, improve fuel quality and conduct periodic and regular acid washing. Moreover, corrosion caused by FAC is observed in the inlet pipes to the economizer header, boiler feedwater pipes, and economizer inlet pipes. This type of corrosion may be prevented by controlling the concentration of dissolved oxygen in water, increasing the pH of the water in the economizer area, and using high-alloy steels (containing chromium, molybdenum, or copper) such as A213(T11) and A213(T22).

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