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Monitoring of physicochemical parameters and sediments of the cooling tower of the Heller power plant: investigating the causes of destruction and providing suggested solutions to reduce corrosion

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1. ABSTRACT

Preventing corrosion and reforming the energy model are the main priorities of the industry, especially the electricity industry and power plants in the country. Therefore, monitoring and evaluating structural components, equipment, process units, and facilities for corrosion monitoring is of great importance in order to improve asset efficiency and increase life, while reducing replacement costs and increasing safety. Since corrosion can always cause major damage in power plant facilities, the ability to test or monitor corrosion of key equipment such as cooling cycles and condensers in thermal power plants is of great importance. For this purpose, the levels of anions, cations, and effective parameters of the power plant cooling cycle water must be continuously and regularly monitored. Therefore, in this study, we will first examine and evaluate the effective parameters in the water cycle of the dry cooling system (Heller) of a selected power plant. Then, based on the analysis of the sediment under the condenser of the dry cooling tower (XRF and XRD tests), we will examine the type of corrosion that has occurred and present suggested solutions to control and reduce corrosion. The results of this study show that the lack of control of parameters such as pH and oxygen are the main causes of the intensification of aluminum corrosion, and changing the chemical regime by using corrosion inhibitors such as molybdate, triazoletolyl, and hydrazine (removal of oxygen) has a significant effect on controlling and reducing corrosion in the dry cooling system of this power plant.

Keywords: Power plant, physicochemical parameters, cooling system sedimentation, Heller Tower, corrosion, XRD and XRF analyses

2. INTRODUCTION

Cooling-water chemistry is a critical factor in the reliability and service life of power-plant equipment. Corrosion can cause material loss, unplanned outages, reduced heat-transfer efficiency, and higher maintenance requirements, while dissolved oxygen, ionic impurities, pH, temperature, and deposits can accelerate degradation. Recent studies have examined the effects of pH and environmental conditions on aluminum-alloy corrosion and the performance of protective systems [1,2]. In parallel, practical studies on power-plant cooling-water chemical regimes have emphasized the need for continuous monitoring and appropriate inhibitor selection [3,4]. However, the present work differs from studies focused mainly on laboratory corrosion behavior by combining field monitoring of the circulating water in an operating Heller system with mineralogical and elemental characterization of actual condenser sediment. The objective was therefore to determine the dominant water-chemistry and deposit-related factors associated with corrosion, identify the principal

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affected material, and develop operationally applicable measures for controlling corrosion in the selected dry cooling system [5].

3. MATERIALS AND METHODS

Samples were collected from the demineralized make-up water, the circulating water of the dry Heller tower, the wet cooling-tower circuit, and the heat-exchanger inlet. pH, electrical conductivity (EC), total dissolved solids (TDS), temperature, and salinity were measured using a HANNA HI 2300 instrument. Calcium was determined by atomic absorption according to Standard Method 3500 B-Ca, while sodium and potassium were measured by flame photometry. Inductively coupled plasma optical emission spectrometry (ICP-OES; PerkinElmer Optima 5300 DV) was used for dissolved cation analysis. A condenser sediment sample was examined by XRF (X-PERFORM) to determine its elemental/oxide composition and by XRD (Bruker D8 AXS, Cu Kα radiation, $\lambda = 1.5418$ Å) to identify crystalline phases. The analytical results were interpreted together with the operating conditions and the materials of construction of the cooling circuit, including aluminum components in the dry tower and copper-containing condenser components.

4. RESULTS AND DISCUSSION

The dry cooling circuit exhibited a marked change in water chemistry relative to the demineralized make-up water. The pH values were approximately 7.61 for the dry-tower circulating water and 7.57 for the wet-tower water, while the dry circuit contained 31 ppm TDS and an EC of 6.06 μS/cm. Most importantly, ICP-OES analysis showed 260 ppb aluminum in the dry-tower circulating water, compared with concentrations below the detection limit in the make-up water. Zinc and copper were present at much lower levels (14.18 and 4.3 ppb, respectively), and iron was below 10 ppb. These results indicate that the dominant material-degradation signal in the dry circuit was aluminum dissolution rather than extensive corrosion of the other monitored metals.

Sediment characterization supported the water-chemistry findings. XRF showed that Fe_2O_3/Fe_3O_4 accounted for about 75.16 wt.% of the analyzed sediment, with Al_2O_3 at 2.32 wt.% and smaller fractions of CaO, MnO, ZnO, CuO, SiO_2, SO_3, P_2O_5, Na_2O, and Cr_2O_3. XRD identified magnetite (Fe_3O_4) as a major crystalline phase, while other iron-oxide phases were also indicated. The high proportion of iron oxides demonstrates that oxidation and corrosion products were actively transported into the condenser circuit. The presence of aluminum oxide and the elevated dissolved aluminum concentration further indicate degradation of aluminum surfaces in the dry tower. Excess oxygen and inadequate pH control can destabilize the protective oxide layer on aluminum; turbulence and flow-accelerated corrosion can then promote removal or leaching of oxide products. Contact between aluminum and more noble metals such as copper may additionally create galvanic cells and locally accelerate aluminum corrosion. These observations are consistent with the need for integrated control of water chemistry and material interactions rather than reliance on a single corrosion-control measure.

Based on the combined analytical evidence, the principal control strategy should include maintaining the dry-tower circulating-water pH in the range of 8.2–8.5, minimizing excess dissolved oxygen through suitable mechanical or chemical deaeration, and applying an appropriate inhibitor program. In the investigated system, the use of molybdate together with TTA, with oxygen removal using hydrazine, was identified as an effective chemical regime for controlling aluminum corrosion. Additional measures include periodic inspection and cleaning of aluminum fins, removal of deposits and contaminants, electrical isolation or design control at dissimilar-metal interfaces, and protective surface treatments where appropriate. These measures should be implemented as part of a continuous monitoring program rather than as isolated corrective actions.

5. CONCLUSION

Field monitoring and XRD/XRF characterization demonstrated that aluminum corrosion is a major degradation mechanism in the investigated Heller dry-cooling circuit, with 260 ppb dissolved aluminum and substantial aluminum- and iron-oxide products in the condenser sediment. The evidence indicates that pH control, excess oxygen, material interactions, and flow conditions jointly influence corrosion. Maintaining pH at 8.2–8.5, removing excess oxygen, and applying a controlled inhibitor regime based on molybdate and TTA are recommended as the principal mitigation measures. Future work should focus on long-term monitoring of water chemistry and corrosion indicators to verify the effectiveness and stability of the proposed regime under seasonal operating conditions.

6. REFERENCES

[1] Shi, C., Li, Z., Tang, Y., Chen, J., Lei, B., An, H., Wang, S., Liu, G., and Shao, Y., “Multi-Factor Coupling Effects on the Electrochemical Corrosion Behavior and Mechanism of 7A04 Aluminum Alloy,” Surfaces and Interfaces, In Press, 2026.

[2] Hao, M., Tan, H., Yang, W., Yue, D., Gao, L., Wang, Z., and He, C., “Effect of pH on long-term corrosion protection of Zn doped MgAl-LDHs coatings by in situ growth on 5052 aluminum alloy,” Surfaces and Interfaces, 64, 2025.

[3] Chinisaz, M., Soleimani, M., Esmaeilpour, M., and Ghahraman Afshar, M., “Application of novel chemical regimen in a thermal power plants’ cooling tower,” Energy Reports, 15, pp. 109010, 2026.

[4] Yousefpour, A., Mehdizadeh, M., Ghaseminejad, H., Esmaeilpour, M., Abdi, N., Valaee, M., and Esmaeilzadeh, M., "Investigating corrosion caused by improper operation in CWT regime of a combined cycle power plant; Causes and solutions," Energy Equipment and Systems, 13, pp. 35–57, 2025.
[5] Electric Power Research Institute (EPRI), "Comprehensive Cycle Chemistry Guidelines for Combined Cycle/Heat Recovery Steam Generators (HRSGs)," Technical Report, 2013.