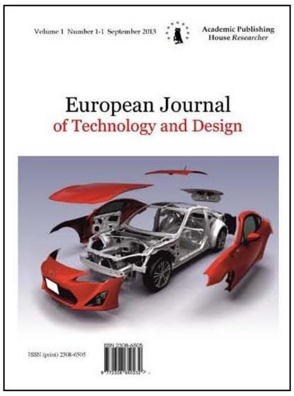

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Prevent Corrosion in Cooling Towers: Finding the Optimum Amount of Makeup Water and the Outlet Water Stream, Experimentally

[1] Farzaneh Safari
[2] Alison Zamanpour
[3] Aghil Reihany
[4] Sara Farah
[5] Farshad Farahbod

[1-3, 5] Islamic Azad University, Firoozabad, Fars, Iran
Department of Chemistry, Firoozabad Branch
[1] E-mail: f_safarii90@yahoo.com
[2] E-mail: zamanpour.a@gmail.com
[4] Islamic Azad University, Marvdasht, Fars, Iran
Department of Chemical Engineering, Marvdasht Branch
E-mail: sfarahmand2005@gmail.com
[5] E-mail: mf_fche@iauf.ac.ir

Abstract

In this work, problems related to the corrosion and sedimentation in cooling tower and the decrease in the amount of evaporation rate are investigated experimentally, using loop test which is similar to the cooling tower system. The input and output water stream in the loop test are analyzed in different time intervals, different amount of evaporation, different amount of the outlet water and make up water stream. The first analyzes indicate on the increase in the amount of dissolved material, concentration cycle and also the increase in the amount of evaporation rate and consequent corrosion problems and sedimentation. However, adjusting the amount of makeup water and the water outlet provides the acceptable results. Changes in conditions due to each analyze are illustrated in curves.

Keywords: $FeCl_3$; $Fe_2(So_4)_3$; $Al_2(SO_4)_3$.

Introduction

Literature review

Marquis Brenhardet et al. in 2014, have been studied the effect of heat operation and the rate of cooling process on properties of light sediment. They produced light seed from clay, in the laboratory. Experimental results were investigated in material resistance and micro structure of material after different heat working and different velocity of cooling. Feng hiwang et al in 2014 studied about the recycled cooling water system in petrochemical industry in experimental scale. This cooling water system was used before wastewater flocculation process in treatment unit. Reverse osmosis mechanism was used before the treatment process. They presented the optimum dosage of four coagulants of polymer acryl amide. This includes anionic poly acryl amid, cationic poly acryl amide, nonionic poly acryl amide and hydrophobic poly acryl amide which is invented in the laboratory using coagulation and flocculation. Xia lung sung et al in 2012 investigated about the raman structural complementation. This was a thining operation of multilayer graphene in helium hydrogen discharge arc during rapid cooling. They presented the decrease in the number of layers and structural disorders in multilayer grapheme in discharge arc of helium-hydrogen mixture were done by fast cooling processes. They investigated the appropriate mixing parameters of helium-hydrogen mixtures, the effect of high cooling velocity in forming, morphology and structural disorders of initial colly.

Erika makenzy et al in 2013, investigated the dual evaporation cooling systems and evaluated the remained water operation in urban sector. They used the summation of electrical charges in water (directly or indirectly) for 15 years in 6 different zones of mountain in California for three cooling water towers in conduction system. Yung Hu et al in 2013 investigated a cooling tower operation. They investigated on the angle of baios changes in ferromagnetic and non feromagnetic using in cooling process. They showed there is no need to the angle depends on the baios changes in low operation temperature in cooling process. The principle of this presentation is simulated based on the Monte Carlo:

Loop test and the operation

Figure 1. A schematic of loop test.

Method and experimental instruments

The amount of ions cause water hardness in the inlet stream of cooling tower is measured due to the standards and the results are reported. Some of the used equipments are shown in Figure 2.

a b c d

Figure 2. a. Spectrophotometer
b. Electrode Probe CDC401
c. Electrode Probe C301pH
d. Moltimeter

Equations and Calculations

pH value is measured by one electrode. Electrode is an electrochemical sensor which includes one identifier electrode and one reference electrode.

Membrane voltage changes due to the changes in pH value of solution. Usual electrodes are made as the membrane voltage in pH=7 equals to zero millivolt. Electrical pH is measured using an electrode.

$$pH = -\log [H^+] \quad (1)$$
$$pH = -\log [H^+] = -\log [10^{-7}] = 7 \quad (2)$$

The unit of Water electrical conductivity is mho/cm, the unit of electrical resistance is ohm and since the electrical conductivity is reverse of resistance, so its unit is mho/cm. This unit represents a large number so usually the unit of micromho/cm is used instead of mho/cm which is smaller about 10^{-6} order. Pure water electrical conductivity is 0.056 µmho/cm.Also, micromho/cm is called microzimens/cm. The values of electrical conductivity and total dissolved solids are as follows:

$$EC = 2\,TDS \quad (3)$$

a. The increase in the value of electrical conductivity or in the amount of total dissolved solids increases the rate of corrosion in water. On the other hand the rate of corrosion in the sample with higher electrical conductivity is higher than other sample which has the same oxygen content and pH value.

b. The increase in the values of electrical conductivity, decreases the salt in water

Iron in the sample is in form of ferro and ferric. Iron measurement is due to FeΠ or ferro. FeΠ and total amount of iron can be determined using method of colorimetric with orthofenantroil consequently the amount of Ferric can be determined.

$$\text{Total Iron} = [Fe^{2+}] + [Fe^{3+}] \quad (4)$$
$$[Fe^{3+}] = \text{Total Iron} - [Fe^{2+}] \quad (5)$$

The amount of ferric in sample is regenerated into ferro type using amino-hydroxide and HCl, determining the total amount of iron. HCl and concentrated HNO3 are used preventing the iron leakage, if the time interval between sampling and experiment is too long. 1 ml of each acid is sufficient for 1 liter of solution to decrease the amount of pH below 4. Acetate buffer is used adjusting the pH of solution, usually. Total alkalinity of water includes hydroxide radicals, carbonates and sometimes phosphates, borates and silicates. The alkalinity of hydroxide includes magnesium hydroxide, Sodium hydroxide, Calcium hydroxide, magnesium oxide and calcium oxide. The most important components of water carbonates includes: Calcium carbonate, Sodium carbonate and magnesium carbonate. The most important types of usual bicarbonates in water are: bicarbonate ion, Sodium bicarbonate, Magnesium bicarbonate. The applied identifiers used in determination of water alkalinity are phenol ftallyn and methyl orange. The summation amount of phenol ftallyn and methyl orange alkalinity is called total alkalinity and is shown with symbol of T.

$$T = P + M \quad (6)$$

M is symbol of the amount of consumed acid neutralize bicarbonates, P is the amount of consumed acid to neutralize hydroxide and carbonate and T denotes the total alkalinity, in Equation 6.

Performance calculations

The only role of cooling tower is cooling the warm water. The whole process is defined as follow; cooling water circulates in operation units and absorbs heat and this flow becomes warm and recycled to the cooling tower to be cool contacting with the air which flows in the tower. Considerable amount of heat transfers from the water to the cooling air through this process and cools the water and heat the air. This is responsible of 20 to 30 percentage of the evaluated amount of total process cooling. The remained fraction of cooling is from evaporation of about 1 to 2 percentage of recycled water. About

1000 BTU energy is consumed to evaporate the 1 lbm of water. The amount of consumed heat in BTU, is provided from the total heat in this water stream.

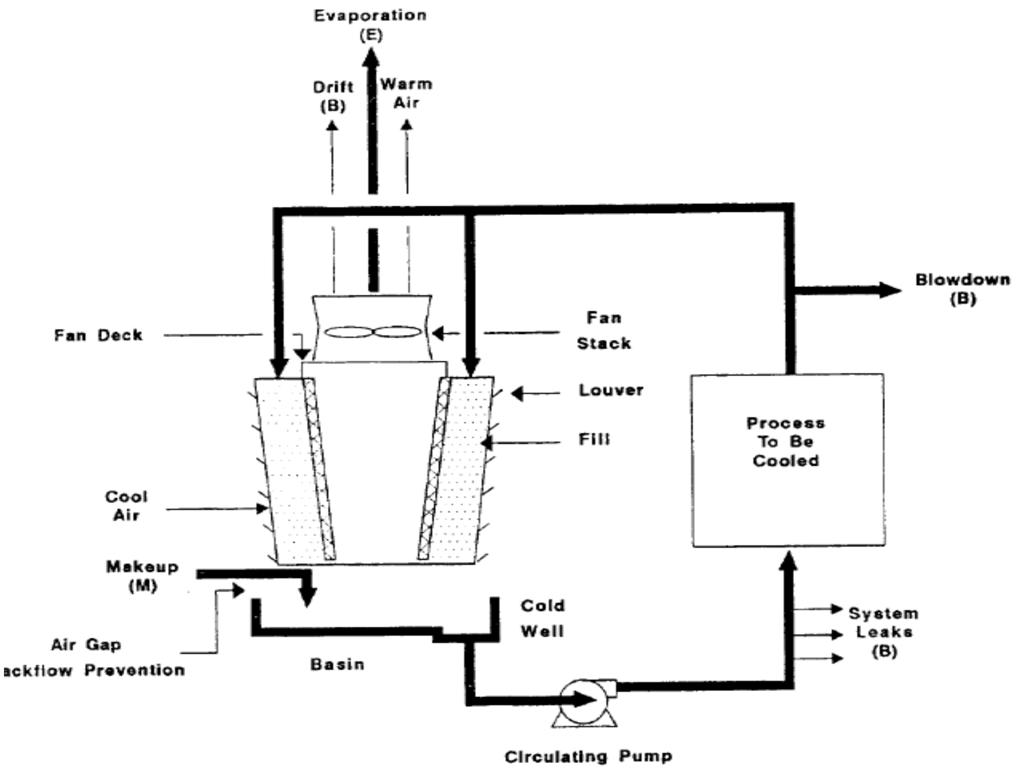


Figure 3. The location of the makeup water and lost water in the simple cooling water system.

Results and Discussion

The amounts of sedimentation factors in the cooling tower are measured and shown in follow Figures and are reported in this section.

Investigation of pH value

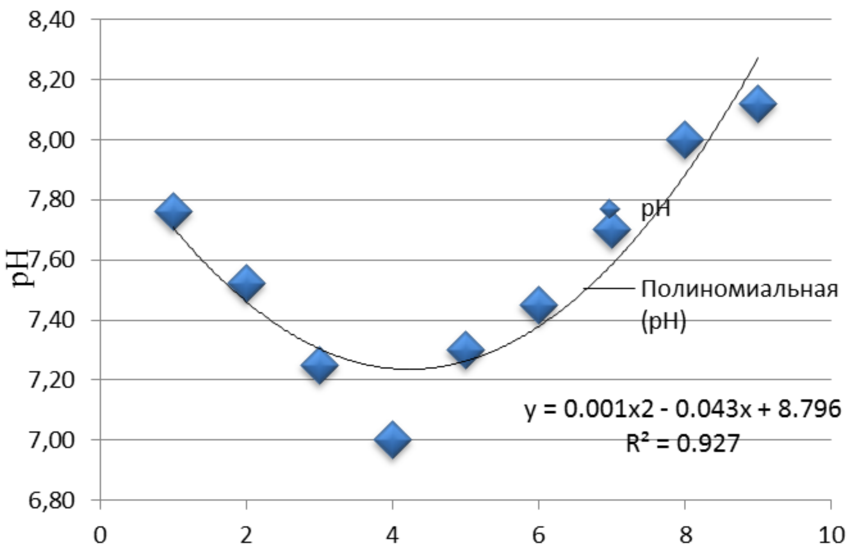


Figure 4. The pH value analyze curve

Figure 4 shows the curve of pH analyzes which are observed from changes in pH parameter. pH shows the concentration of hydrogen ion in water and it changes between 7.2 to 8.2. Although, the increase in the amount of changes is observed due to the curve but the accuracy of the measured pH in different time intervals can be investigated considering the near results and also regression value. This parameter is proportional with phosphate directly and reversely with chloride. So, the decrease in the amount of pH in the middle of curve the amount of phosphate decreases and the amount of chloride increases. Since the changes in pH values are standard then no sedimentation and no corrosion in loop test system is obtained.

Investigation in electrical conductivity

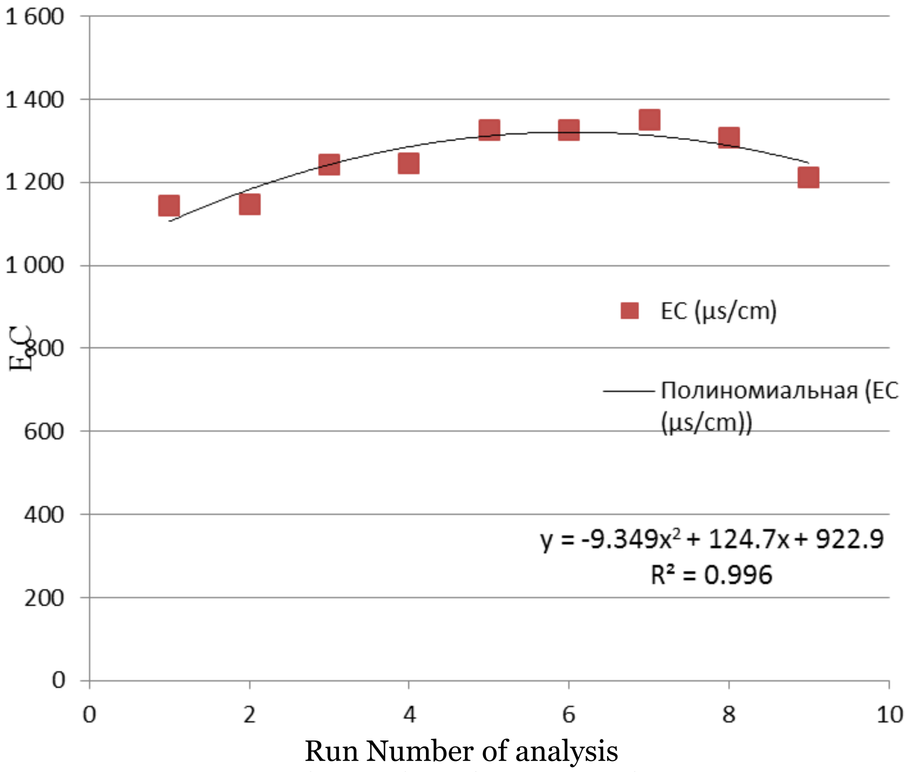
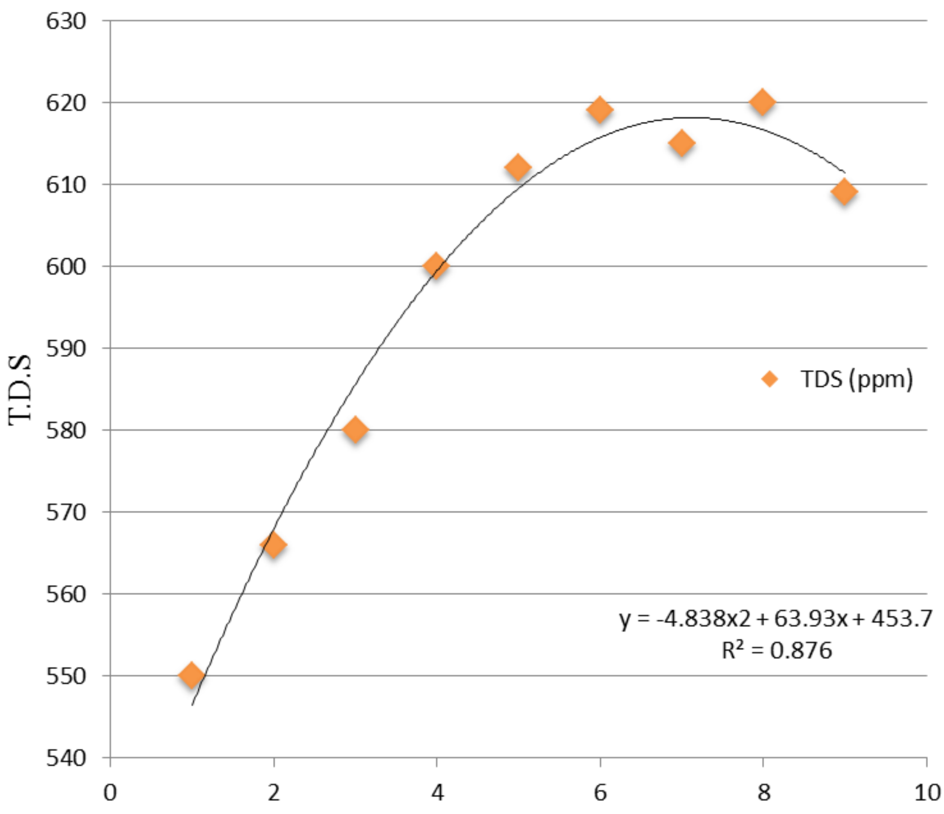


Figure 5. Electrical conductivity analyze curve

Figure 5 shows the analyze results of water electrical conductivity. Water conductivity shows the transmission ability of electrical current transfer in water. The existed ions in water make the electrical current transfer possible. So, there is a relation between electrical conductivity and the concentration of total dissolved solids in water. According to the obtained results of EC in the Figure 5, in the initial middle of curve, the changes in parameter are between 1100 to 1400 μz/cm. The increasing trend of curve shows the increase in the amount of dissolved solids in water which may lead to the increase in the amount of total hardness, sedimentation load and different corrosion types in system. However, the decreasing trend of results is obtained considering the second part of the curve, the amount of dissolved solids decreases and there is not any malfunction of sedimentation and corrosion in the system.

Total dissolved solids



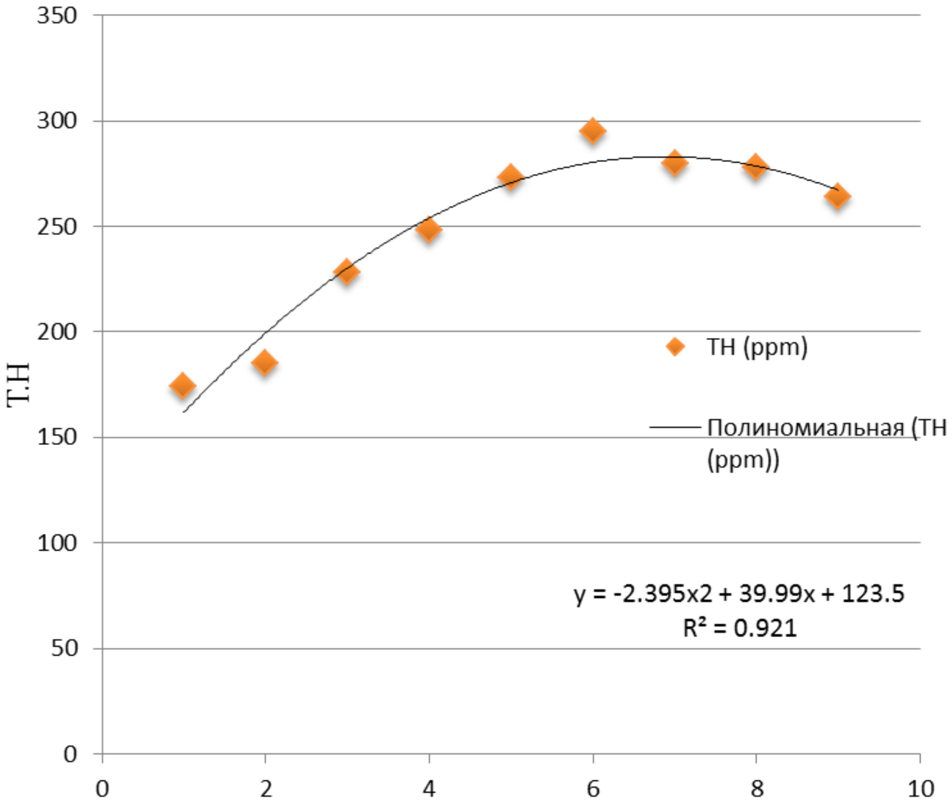
Run Number of analysis

Figure 6. Total dissolved solid analysis curve

Figure 6 show the analysis of total amount of solids in water which is the total dissolved solid contaminants in water indicates the total concentration of all ions in water. The measurement unit of TDS is mg/lit. According to the changes in TDS parameter, the changes are ranged in 55 to 620 mg/lit at the first stage of the changes curve. This increase shows the increase of total amount of solids in water. This increases the amount of total hardness and the increase in the amount of sedimentation and corrosion in system. However, this malfunction is solved using the increase in the concentrated cycle and the test loop inlet water and also the increase in the outlet water. Then the other results are acceptable.

Total hardness investigation

Figure 7 shows the results of total hardness analysis. The total hardness includes the amount of Calcium and Magnesium ions in water. So, the total amount of water hardness is a portion of total dissolved solids in water. Total hardness is the main factor of sedimentation. The measuring unit of total hardness is mg/lit as $CaCO_3$. Totally, the concentration process in system changes the effective total hardness parameter in system. The increase in the amount of pH, EC and TSS increases the amount of Calcium and magnesium ions and this change in concentration leads to the higher sedimentation and also higher evaporation rate. The downtrend of total hardness curve is obtained considering the precise amount of outlet water and concentration cycle, finally.



Run Number of analysis

Figure 7. Total hardness analysis curve

Conclusions

In this investigation, the factors in hard water which causes precipitation and corrosion are considered. The parameters which affect precipitation in cooling process are measured and evaluated due to loop test. Totally, the results show that the acquisition process is done with aforementioned analysis at the undesirable conditions of the loop test. So, due to the analysis the amounts of outlet water make up water and the rate of evaporation can be determined to prevent the precipitation in loop test. This also avoids corrosion. Also, phosphate should be injected in system before the proper conditions for bacterial growth is observed.

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