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Evaluation of Bio-Fouling Effect in Cooling Tower by Chemical Treatment

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Abstract: The main aim of this work is to check the bio fouling in cooling tower and its effect on power generation. The way to reduce bio fouling is necessary issue within the thermal power station, as it results in reduction of the heat transfer rate and ultimately reduction in the power generation rate of plant. So as to attenuate the energy consumption in process plant equipped with device network. In various branches of chemical industries fouling builds up on heat transfer surfaces is a heat transfer equipment burning extra fuel to compensate for a reduced heat recovery accepting reduction of plant output due to periodic equipment cleaning and recovering the cost of cleaning interventions. Microbiological fouling can cause energy losses and loss of tower efficiency. The pilot plant is very useful in the thermal power plant to test the cooling water and then it is used in the thermal power plant to reduce the losses due to the bio fouling. In large power plant they having pilot plant with PLC system and microprocessor with highly accurate sensors. It will give very accurate and direct digital readings on screen.

Key Words- Cooling Tower, Bio-fouling, Chemical treatment

I. INTRODUCTION

The condenser in the power plants will increase the effectiveness of the power plant by reducing exhaust pressure of steam below atmosphere. Water cooling towers are major users of water worldwide. Industrial development has resulted in an increase in the use of water for cooling tower operations. This has led to an expansion of the demand for water and natural resources, particularly in onset countries such as China, India and South Africa. [1] The availability of fresh water for use in industrial cooling water systems is becoming increasingly limited. Alternative lower quality water sources for industrial cooling are thus of growing interest. However, cooling tower performance is strongly related to the intake water quality, which may lead to undesirable outcomes due to inappropriate cooling water management.[2, 3] A cooling tower could be a heat rejection device that removes unwanted heat to the encompassing through the chilling of a water stream to a lower temperature. This heat transfer instrumentation could use to evaporation of water to eliminate heat and cool the operating liquid to close the wet bulb air temperature. In the thermal power plant condensing the steam from the turbine outlet is done by the condenser. To condense this steam we supply it to the condenser and the water absorbs the heat of steam and gets heated to high temperature. This water is then cooled in cooling tower. The heat transfer at the condenser is full of variety of things out of that bio fouling is vital issue as a result of the water needed in the cooling system is received from the stream, sea, lake etc. and it contains a number of organisms, the temperature of cooling water cycle within the cooling system is useful for growth of the organisms. We tend to design pilot plant to check bio fouling result, and process the ways for the management the bio fouling.

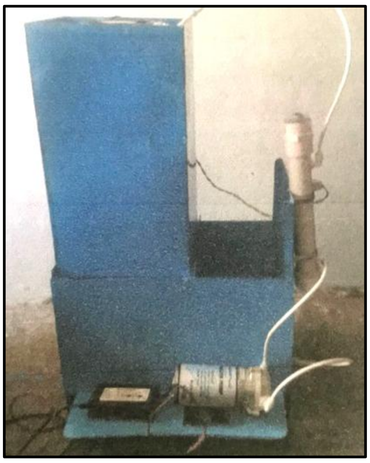

Fig. 1 Experimental Set up

Water cooling utilizing natural waters is typically used for cooling large industrial facilities such as power plants. The cooling water cycles are susceptible to biofouling and scaling, which may reduce heat transfer capacity and enhance corrosion. [4] We design pilot plant to study bio fouling effect, and defining the strategies for the control of the bio fouling. In the power plant for controlling the bio fouling they have chemicals which are intermittently mixed with cooling tower water but they select the proportion of these chemicals on their past experience. It is necessary to check water quality intermittently and use correct proportion of chemicals. So the setup of pilot plant is very useful to study the bio- fouling characteristics for each sample of water. The chemical mixed water first tested in pilot plant and then used in actual cooling tower. It is helpful to reduce the bio fouling effect in actual thermal power plant. So it is important to have pilot plant for each power plant.

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Controlling of microorganism growth and bio fouling

The common method which is universally used for killing algae and to prevent slime coating of condenser tubes is chlorination of the cooling water.

The chlorination has established a satisfactorily experience record as effective treatment in controlling accumulation of biological slimes. The chlorine treatment consists of injecting liquid chlorine or compounds in to the water. The injecting liquid chlorine or chlorine compound solution combines with water to form a chlorine solution. The solution is feed in to the condensing water system, usually at the tower outlet or circulating pump inlet. Nearly all forms of algae are killed by exposure of 1 to 2 parts of free chlorine per million. Interment feed of chlorine is usually as effective as a continuous feed and is more economical also.

II. LITERATURE REVIEW

1. Jameel-Ur-Rehman Khan et. al. [5] investigated, in their paper, that fouling of cooling tower fills is one in every of the foremost vital factors affecting its thermal performance, that reduces cooling effectiveness and capability with time. In this paper, the fouling model given unfair treatment the experimental information on fill fouling, is employed to analyze the danger primarily based thermal performance of the cooling. It's verified that utility of the cooling reduces significantly with an occasional risk level (p =0.001); there's concerning 6% decrease in utility for the given fouling model. The sensitivity analysis of the cooling is investigated for each rating and design calculation for various values of mass rate ratios.

2. Youliang Che et. al. [6] discussed in there paper, that performance of cooling towers is considerably affected by environmental conditions, particularly by cross winds. Several studies looked as if it would investigate the result of cross winds on cooling system performance, and steered counter measures against cross winds.

3. Manuel Lucas et. al. [7] suggested that, water drift discharged from cooling towers is objectionable for many reasons, mainly of drift depend totally on the few components water distribution system and drift agent. The configuration of those thinks to human health hazards. And extreme averaged changes of 38.66% in terms of cooling system concert are obtained among the two water systems.

4. S.D. Ruth et. al. [8] concludes in there paper, that a large range of materials and industries area unit full of the intense problem of microorganism fouling of built surfaces that get contact with natural water. This is due to the formation of bio film consisting of aquatic bacteria, algae and other microorganisms. Bio fouling is that the term familiar describes the unwanted development of microorganism growth on the surface connected with natural waters which end up in unacceptable performance or reduced time period of equipment. Bio films cause fouling of heat exchanger/ condenser tubes, pipelines, water boxes etc. in cooling water system of many industries. The formation of bio film adversely results on performance of cooling system.

5. M. Legay et. al. [9] studied qualitatively in there paper by visual observations and quantitatively by overall heat transfer constant and fouling thermal resistance calculations that ultrasound could be a powerful tool to get rid of resistant paint layers in an exceedingly double pipe device. Later ultrasound exposure at minimal obtainable power, most paint may be far from the zone subjected to structure vibrations. The cleanup method starts at the antinodes of the supersonic wave and expands to any or all the vibratory length as confirmed by the analysis. Crafty of the fouling thermal resistance and overall heat transfer constant seem to be sensible ways in which to gauge quantitatively the cleanup method. It had been displayed definitely that the general heat transfer constant may be found up to its initial worth, i.e. the one in all a clean device, once regarding 30 min ultrasound exposure and 45 min for a pipe painted on each surfaces.

III. DESIGN OF PILOT COOLING TOWER PLANT

Microorganisms are found everywhere in nature. In air, water and soil are scattered and they are crucial role in the health of humans and animals. Many microorganisms are beneficial, while others are pathogenic. Life and activity of microbial processes are effective in many industries. Microorganisms that are present in the water cooling system that can be bad effects on the corrosion and deposition create operational efficiencies. This paper discusses problems caused by micro-organisms in the corrosion of iron will take. Since water of cooling towers are the good conditions for the growth of organisms from their troubles and problems, and methods used to control them will express.

STEPS IN DESIGN OF COOLING TOWER-

1. Heat removal rate/Heat transfer rate (Q_h)

Heat transfer rate shows that what quantity of heat that impassive from the warm water,

Initially we assume heat removal rate as an 8000 KJ/hr.

$$Q_h = 8000 \text{ KJ/hr}$$
$$= \frac{8000}{60}$$
$$= 133.33 \text{ KJ/min}$$
$$= 2.22 \text{ KW}$$

2. Range (Cooling Range)

It ranges from 5.6 to 16.7 ℃

We assume 8.3 ℃ as a cooling range. This is a standard value for counter flow cooling tower.

3. Cooling water Flow Rate

The heat absorb by the cold water is given by equation

$Q_h = m_w C_w \Delta T$

Where m = mass flow rate of cold water

C_w = specific heat of water in KJ/Kg°k

= 4.187 KJ/Kg°k

ΔT = Temperature difference of cooling water

$Q_h = m_w C_w \Delta T$

$133.33 \text{ KJ/min} = m_w C_{pw} \Delta T$

$133.33 = m_w \times 4.187 \times 8.3$

$$m_w = \frac{133.33}{4.187 \times 8.3}$$

$m_w = 3.836$ Kg/min

$$= \frac{3.386}{\rho} \text{ m}^3\text{/min}$$

$$= \frac{3.386}{1000} \quad \text{… (For water } \rho = 1000 \text{ Kg/m}^3)$$

$= 3.83 \times 10^{-3}$ m³/min= 3.83 LPM $\approx$ 4 LPM

4. Cooling Tower Water mass velocity (V_w)

It ranges from 81.5 to 203.7 LPM/m^2
For flat sheet pack we are assuming 122 LPM/m^2
V_w = 122 LPM/m^2
= 0.122 m/min

5. Water-Air mass loading ratio (R)

$$R = \frac{Gw}{Ga}$$

Usually it ranges from 1.5 to 2
We select R= 2

6. Air mass Velocity

$$R = \frac{Gw}{Ga}$$

$$2 = \frac{12.2}{Ga}$$

G_a = 244 LPM/m^2

7. Cooling Tower base area

$$A = \frac{Qf}{Gw}$$

$$= \frac{4}{122} = 0.03278 \text{ m}^2 \approx 0.04 \text{ m}^2 = 400 \text{ cm}^2$$

For considering heat transfer losses we increase area to 625 cm^2 and selecting square cross section for cooling tower.

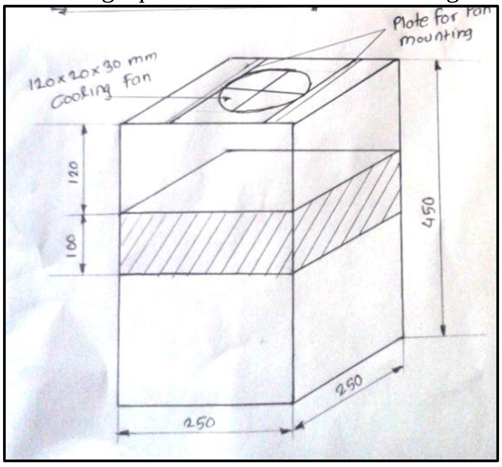


Fig.2 cooling tower

$l \times b \times t$ =450 × 250 × 250 (mm)
Material for cooling tower sheet is Galvanized Iron

8. Design ambient temperature

We assume ambient temperature = 28.3 ℃

9. Design relative humidity (RH)

Assume RH = 0.83

10. Cooling water inlet temperature

Depending on heat exchanger optimal operational condition: Power plant Condenser inlet temperature is 43.3 ℃ generally.

11. Cooling water outlet temperature

Range = cooling water outlet temperature – cooling water inlet temperature
8.3 = Tco – Tci
= Tco – 28.3
Tco = 36.6 ℃

HEAT EXCHANGER DESIGN

Heat exchanger used is a tube in tube type heat exchanger in which inside tube is consider as a hot tube inserted in cold water.
Material for inner tube is carbon steel

Thermal conductivity of steel = 48W/m°k
H_i = water convective heat transfer coefficient (free) = 600W/m^2°k
H_o=water convective heat transfer coefficient (forced) = 5000W/m^2°k

1. Model of heat exchanger

$$Q = \frac{\Delta T}{Rth}$$

$$= \frac{To - Ti}{Rth}$$

$$R_{th} = \frac{1}{hiAi} + \frac{\ln(Ro/Ri)}{2\pi LK} + \frac{1}{hoAo}$$

Where h_i = inner convective heat transfer coefficient of water (free)
= 600W/m^2°k
A_i = Inner area of tube
h_o= water convective heat transfer coefficient(forced)
= 5000W/m^2°k
A_o = outer area of tube
R_o = outer radius of tube
R_i = Inner radius of tube
K = thermal conductivity of tube material
= 48W/m°k
L= length of tube

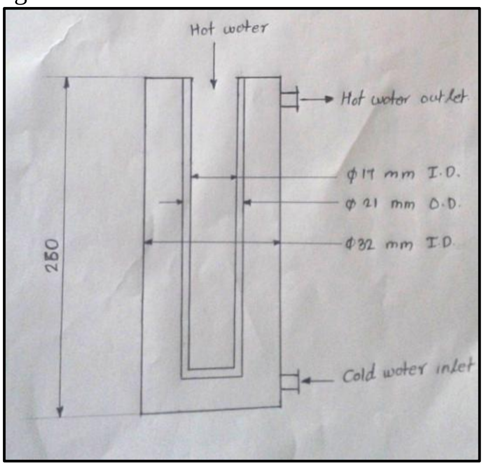


Fig. 3 heat exchanger

$A_i = \pi Di \times L$ = 3.142 × 17 × 10^{-3} × 250 × 10^{-3} = 0.01335 m^2

$A_o = \pi Do \times L$
= 3.142 × 21 × 10^{-3} × 250 × 10^{-3}
= 0.01649 m^2

$$R_{total} = \frac{1}{600 \times 0.01335} + \frac{\ln(10.5/8.5)}{2 \times 3.14 \times 48 \times 0.250} + \frac{1}{5000 \times 0.01649}$$

= 0.1248 + 2.8 × 10^{-3} + 0.0121
= 0.1397

Similarly by considering overall heat transfer co efficient

$$Q_h = UA\Delta T = \frac{\Delta T}{Rth}$$

UA = $\frac{1}{R}$

U = $\frac{1}{RA}$

U_i = overall heat transfer coefficient based on inner area. Then,

$U_i = \frac{1}{RAi} = \frac{1}{0.1397 \times 0.01335}$ = 536.19 W/m^{2}°k

U_o = overall heat transfer coefficient based on outer area, Then

$U_o = \frac{1}{RAo} = \frac{1}{0.1397 \times 0.01649}$ = 434.093 W/m^{2}°k

2. Volume of water inside the tube

V = area × length

$= \frac{\pi}{4} \times (0.017)^2 \times 0.250$

$= 5.6752 \times 10^{-5}$ m^3

ρ_w = 1000 Kg/m^3

$m_w = \rho_w \times V = 1000 \times 5.6752 \times 10^{-5} = 0.0567$Kg

Heat rejected by the hot water inside the tube = m×Cp× ΔT

Where,

m = mass of hot water

= 0.0567 kg

Cp = 4.187 KJ/Kg°k

ΔT = temperature difference of the hot water measured by thermometer

3. PUMP SELECTION

The maximum designed discharge for pilot plant is 4 LPM but for economic consideration we select 1.8 LPM discharge pump from manufacturing catalogue

4. TANK SIZE

The size of tank is 450 × 300 × 300 mm

Volume of tank = 450 × 300 ×= 0.450 × 0.30 × 0.30 = 0.0405 m^3 = 40.5 litter

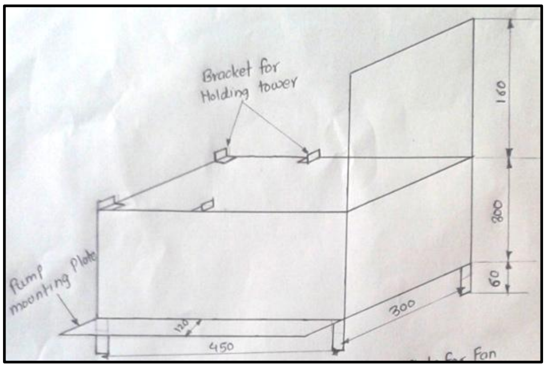


Fig. 4 cooling tower tank

5. FAN

Fan is required to force air to flow upward from cooling tower to absorb heat from the water and evaporate some of water

6. NOZZLE OR SPRAY

To spray are provided with small holes to discharge water in to the cooling tower. In this pilot plant, we use two small sprays.

IV. EXPERIMENTAL METHODOLOGY AND CALCULATIONS

Sr. no.	Time in sec	Temp. in °C (sample 1)	Temp. in °C (sample 2)	Temp. in °C (sample 3)	Temp. in °C (sample 4)
1.	0	80	80	80	80
2.	30	59	64	62	60
3.	60	46	49	48	47
4.	90	39	42	41	40
5.	120	34	36	36	35
6.	150	32	33	33	33
7.	180	30	32	31	30
8.	210	29	31	30	30
9.	240	28	30	30	29

The water which is tested is first filled in tank. Then the hot water which is at 80 ℃ is filled in the heat exchanger inner tube. The thermometer is dipped in the tube. Pump is then start. The reading of temperature of hot water is taken after 30 sec each interval. After getting this temperature for different time intervals we calculate heat transfer for each time interval.

Plot the result of test on graph paper

A) Heat transfer vs. time

The heat transfer rate calculation:

The heat rejected by hot water at a particular time is given by equation

$Q_h = m \times Cp \times \Delta T$

$\Delta T = T_1 - T_2$

T_1 = initial temp of hot water

T_2 = temp of hot water at a particular time

Sample calculation

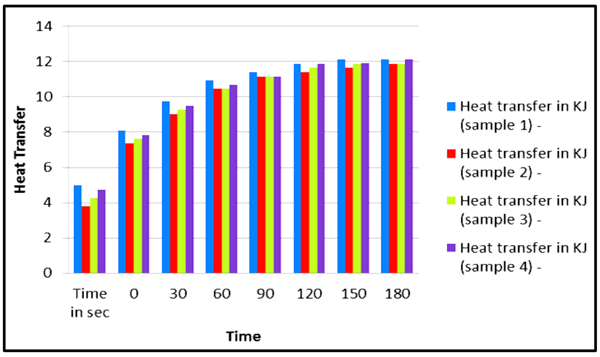
For sample 1, reading 2

$Q_h = m \times Cp \times \Delta T$

=0.0567×4.187×(80-59)

=4.985 KJ

Sr. no	Time in sec	Heat transfer in KJ (sample 1)	Heat transfer in KJ (sample 2)	Heat transfer in KJ (sample 3)	Heat transfer in KJ (sample 4)
1	0	-	-	-	-
2	30	4.985	3.798	4.273	4.74
3	60	8.07	7.359	7.596	7.83
4	90	9.73	9.02	9.258	9.49
5	120	10.92	10.445	10.44	10.68
6	150	11.39	11.157	11.157	11.15
7	180	11.87	11.39	11.63	11.87
8	210	12.10	11.63	11.87	11.89
9	240	12.10	11.87	11.87	12.10



V. CONCLUSION

Cooling water systems are ideal spots for microscopic organisms to grow. Bacteria, algae and fungi are the most common microbes that can cause serious damage to cooling water systems. The pilot plant is very useful in the thermal power plant to test the cooling water and then it is used in the thermal power plant to reduce the losses due to the bio fouling. Because in today's world the efficiency is very important, that means we will produce anything with minimum consumption of resources is important. By selecting this problem for the project we are getting the knowledge of thermal power plant, how it work and the cooling tower cycle. So it is very helpful to us in future to work with highly growing power sector of India. In large power plant they having pilot plant with PLC system and microprocessor with highly accurate sensors. It will give very accurate and direct digital readings on screen

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