PERFORMANCE ANALYSIS OF COOLING TOWER IN PROCESS INDUSTRY

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ABSTRACT

The performance of Cooling Towers is of massive importance for a large number of process industries that must depend upon Cooling Towers as their only means of waste heat rejection. But still, the performances of Cooling Towers have been problematic. Normally they are used to dissipate heat from heat sources to the heat sink. The cooling of hot liquid wastage and process water is required from reuse and environmental point of view. The effectiveness of Cooling Tower relies on flow rates of air and water temperature. In this evaluation of the performance of Cooling Towers the cooling tower located at one of the unit of M/s. Aarti Industries Ltd. The aim is to analyze the performance of Cooling Tower and give the optimum solution that would reduce the monitoring input.

Keyword: - *Cooling Tower, Wet Bulb Temperature, Induced Draft etc….*

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1 Introduction

Cooling tower is an essential and useful part for many process plants. The essential purpose of a cooling tower is to remove heat into the surrounding. It represents a relatively dependable and economical means of rejecting low-grade heat from cooling water. To fill up again water lost to evaporation the make-up water source is used. Hot water from heat exchangers is received by cooling tower. The water departures from the cooling tower which is return to the heat-exchangers or to other sections for additional cooling. Fig. 1 represents the prototypical closed loop cooling tower system.

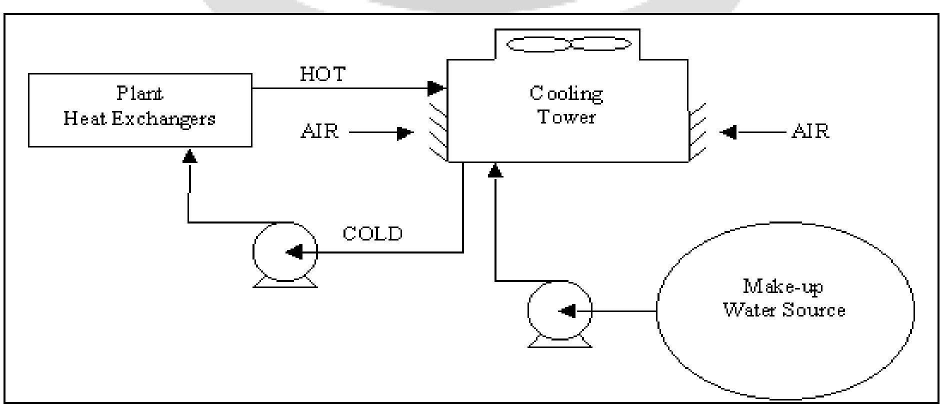

Fig- 1 Power Plant Layout

1.1 Classification of Cooling Tower

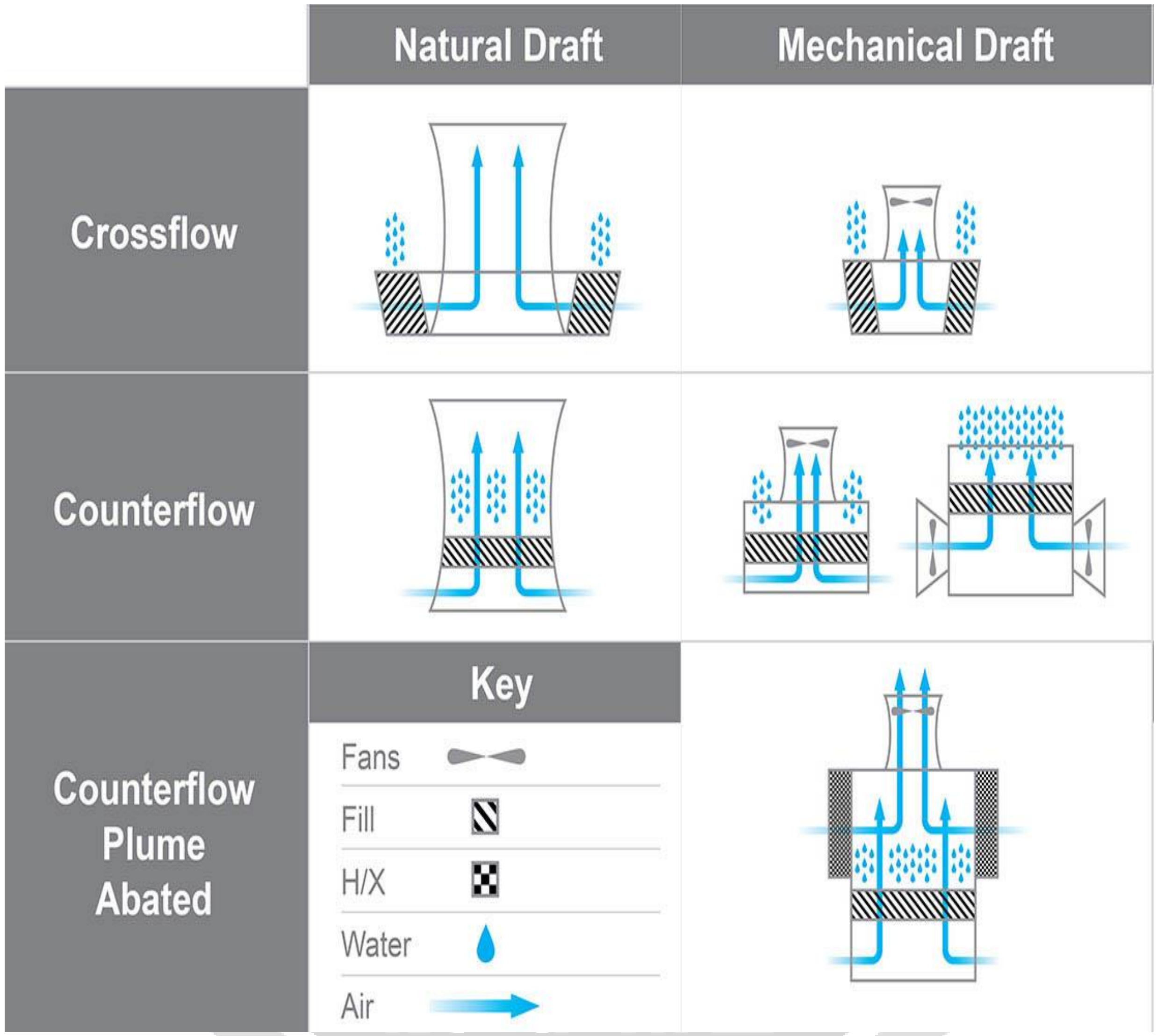

Fig- 2 classification of cooling Tower

Cooling towers can be classified into two main types: Natural draft and Mechanical draft.

Natural draft cooling towers use very huge chimneys, which is made up of concrete, to placed air through the channel. Due to the huge size of these towers, they are basically used for water flow rates higher than 45,000 m^3/hr. The utility power station uses these types of towers. A mechanical draft tower uses large fans. The large fan is sucking or force air across circulated water. To increase the contact time between the water and the air and to maximize heat transfer between water and air, the water drop down above fill surfaces is used. Cooling speed of Mechanical draft towers rely upon their fan diameter and speed of operation. Since, these type cooling towers are much widely used.

2 Literature Review

B. Bhavani Sai, et al,[1] has done a work on **"DESIGN OF COOLING TOWER"** in this research-paper description of induced-draft cooling tower of counter-flow type having effectiveness, characteristics, efficiency are calculated. The required data has been acquired from the mechanical-draft cooling tower. It is used for evaporation of which some quantity of water is evaporated into air stream. From this following parameters are considered: Cooling Range, Approach to a WBT, Mass flow-rate of water, WBT, Air Velocity through tower, Height of Tower

He has work on cooling tower approach of 32° C to 28° C and Range of 40° C to 32° C. And on this basis he had calculated thermal calculations of cooling tower.

Ronak Shah, et al,[2] has done a work on **"THERMAL DESIGN OF COOLING TOWER"** in this research-paper it give detail description of this device which is used to evaporate heat from power generation source. Refrigeration and Air Conditioning it offers a best alternative in location where cooling water cannot be obtain easily from natural sources. Thermal performance of cooling tower can be increase using different techniques.
During the evaporation the necessary heat is taken from the water which condenses the water returns to original basin water temperature and water is recirculate, The dissolved salt is evaporated in the quantity of water which isn't been evaporated, due to this salt consolidation is increased. To prevent the salt consolidation becoming too high, a quantity of water is taken of for the disposal and thereby making fresh water supply to recompense for the loss of evaporated water and draw-off water.

Bhupeshkumar Yadav, et al,[3] has done a work on **"EXPERIMENTAL STUDY OF THE PERFORMANCE OF THE COOLING TOWER"** in this research-paper Cooling tower is an important component of refrigeration and air-conditioning. Temperature of hot water stream is reduced and thus it is release to the surrounding. It contains main working aim and principle of cooling tower and various parameters like Approach, Effectiveness, Evaporation loss and Range. For large capacity system water is used as a cooling media for condenser, so temperature of water rises so it can be cooled for use again. For cooling device is used known as cooling tower. The surface of cooling tower is fabricated of MS sheet. Front side is provided with Perspex sheet for visualization. Hot water is induced from the top. So that water can be distributed over the zigzag shape wire-mesh packing.

Y. A. Li And M. Z. Yu, et al,[4] has done a work on **"THE DEVELOPMENT OF A MATHEMATICAL MODEL WITH AN ANALYTICAL SOLUTION OF THE COUNTERFLOW CLOSED CIRCUIT COOLING TOWERS"** in this research-paper description of counter-flow close circuit cooling tower are developed the latest cooling tower have important features like pure water, low noise, safety, energy effective. Performance curve of cooling tower is taken and it is predominantly calculated so that outlet temperature of cooling water varies with spray water flow-rate. The cooling water in this device is released to air which is being polluted due to which cooling capacity of refrigerator decreases. So it is necessary to develop a new cooling tower that not only cools water but also keep cooling water being polluted. From theory and experiment study it has been concluded that cooling capacity of cooling water increases by increasing the spray water-rate at a same time it has little effect on cooling capacity.

Xinming Xi, et al,[5] has done work in **"OPTIMAL DESIGN OF LARGE SCALE DRY COOLING WATER WITH CONSIDERATION OF OFF-DESIGN OPERATION".** Many factors can influence the performance and design of indirect air cooling system of power-plant. By optimization a tower with finer structure is used conduct thermal analysis of influence of ambient temp., speed of wind and saturated exhaust flow-rate on back pressure of turbine.

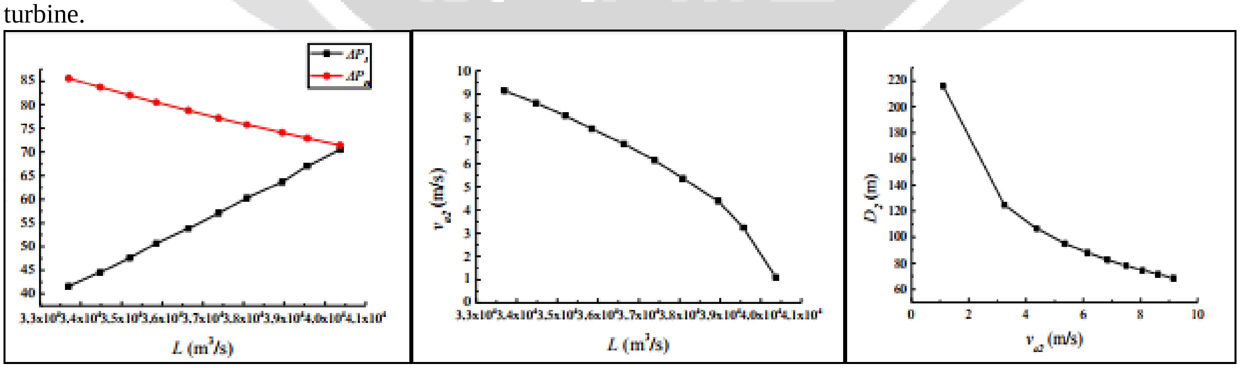

Fig- 3 The relationships between $\Delta P_1, \Delta P_H$ & L, v_{a2} & L, D_2 & v_{a2}

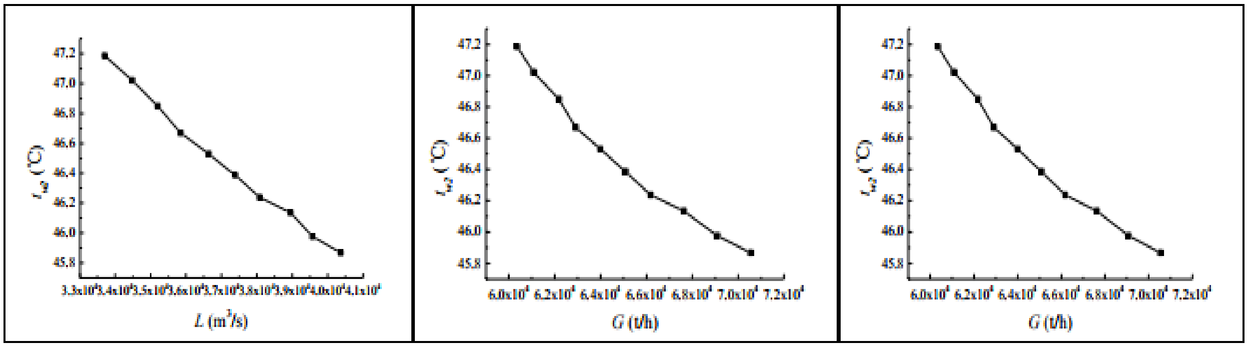

Fig- 4 The relationships between t_{W2} & L, v_{a2} & G, t_{W2} & G

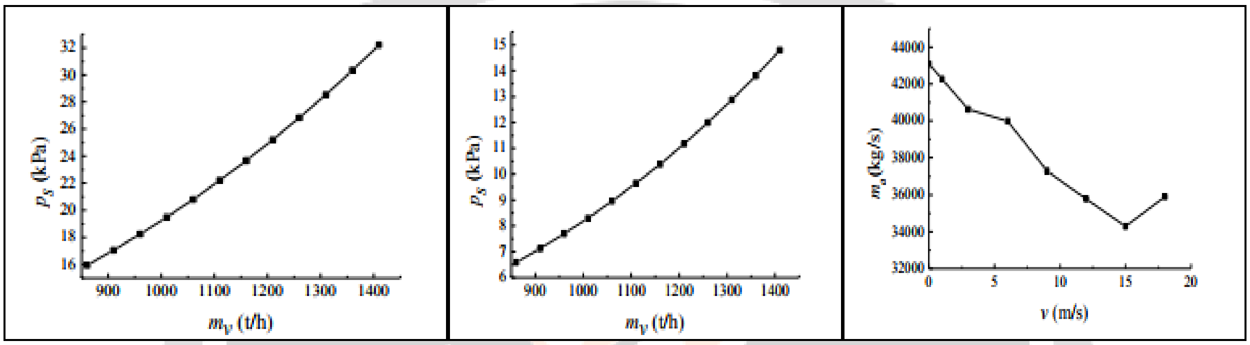

Fig- 5 The relationships between P_s & m_v for $t_a = 31°C$, P_s & m_v for $t_a = 12°C$, m_a & v

Xioni Qi, et al,[6] has done work in **"EXERGY BASED PERFORMANCE ANALYSIS OF A SHOWER COOLING TOWER".** In typical cooling tower fills material act as a media of heat and mass transfer through which waste is rejected from the system, In fill fouling is the important factor affecting thermal performance which reduces its efficiency on the other end salt deposition performance of cooling tower declines after an interval of time.

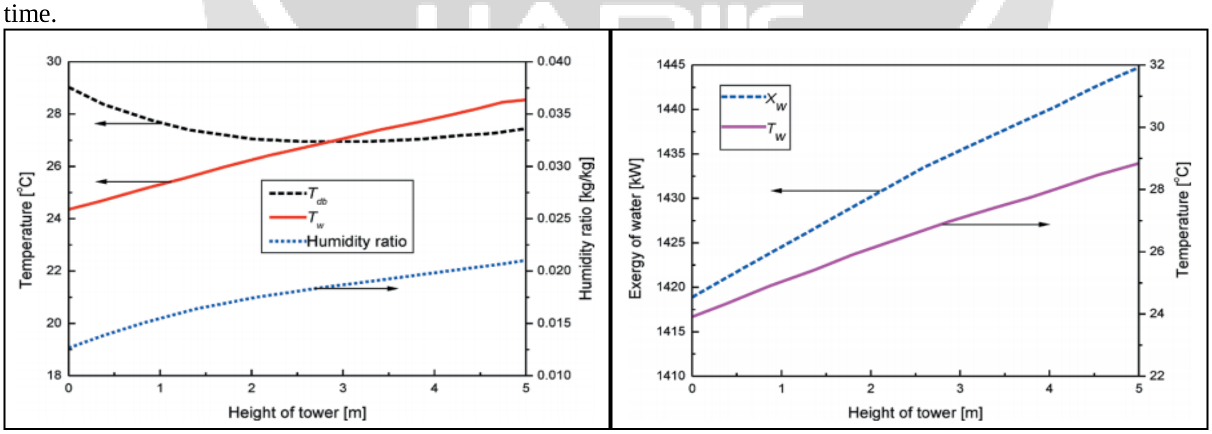

Fig- 6 Temperature profiles of Humidity, water and air ratio profile through the SCT & Exergy of water temperature profiles through the SCT

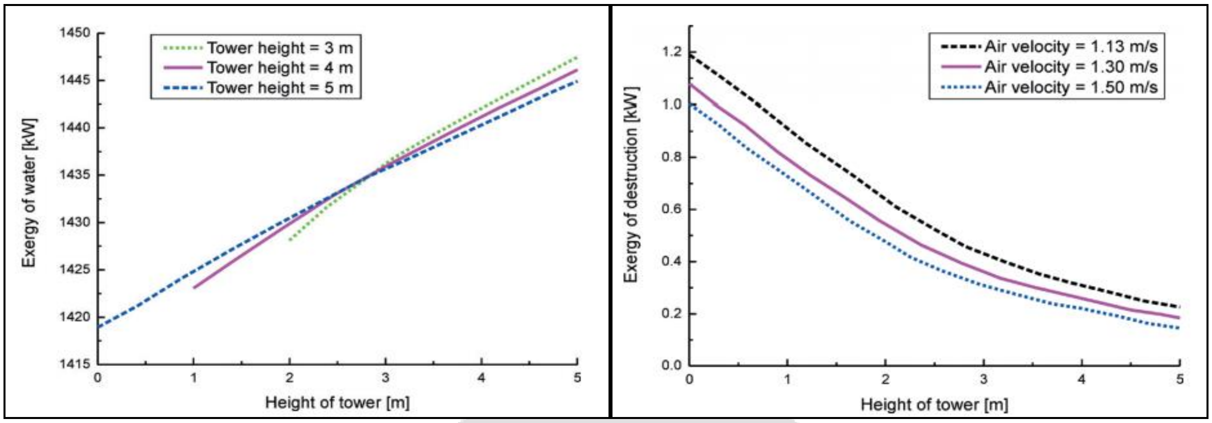

Fig- 7 Effect of tower height on water Exergy through the SCT & Effect of air velocity on Exergy destruction through the SCT (Diameter is 15 mm)

J.smrekar,et al,[7] has done work in **"METHODOLG OF EVALUATION OF COOLING TOWER PERFORMANCE-PART 1:DESCRIPTION OF METHODOLOGY"** in this relation between device power output and performance is established .In his methodology empirical model are focused the methodology is available on real data from power-plant and cooling tower small maintenance at the cooling tower has problem of broken passages, plug sprayers, growing algae which reduces heat and mass transfer of cooling tower their by reduces the efficiency.

Table 1: Nominal value of Steam Turbine

Parameters	Nominal values
Revolution/min-1	3000
Power/MW	345
Pressure of fresh steam/bar	177
Pressure of reheated steam/bar	42
Temperature of fresh steam/°C	537
Temperature of reheated steam/°C	537

Table 2: Nominal value of Condenser

Parameters	Nominal values
Heat transfer area/m3	17,100
Condenser tubing/mm	1
Nominal pressure/bar	0.05
Cooling water mass flow/(t/h)	35,300
Condensate Mass flow/(t/h)	588
Cooling water temperature rise/°C	8

J.smrekar, et al,[8] has done work in **"METHODOLOGY FOR EVALUATION OF COOLING TOWER PERFORMANCE –PART 2:APPLICATION OF METHODOLOGY AND COMPUTATIONAL ASPECTS OF POPPE EQUATION**". The device not only increase the cooling tower efficiency but also increase the power input as function of cooling tower temperature and load. In typical power-plant half of the energy convey by fuel is rejected, thus improvement in heat rejection may contribute in saving of fuel as the flow of energy supply is large.

L.Lu,et al,[9] has done work in **"A UNIVERSAL ENGINEERING MODEL FOR COOLING TOWERS"** in this formulation of counter-flow and cross-flow cooling towers are prepared .It has the benefits of and new input variables and better description. There are no iterative calculations required.

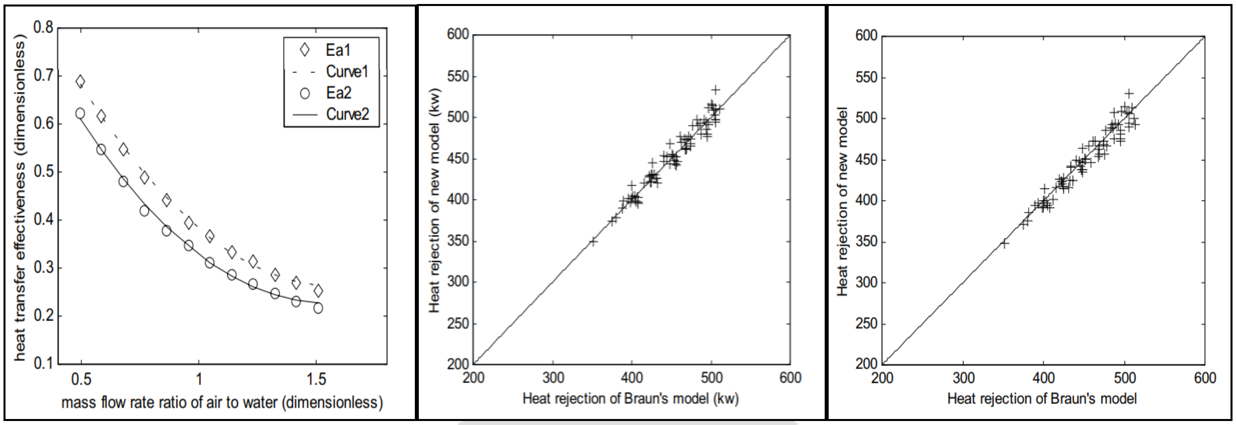

Fig- 8 Comparison of HT effectiveness of two models, Counter-flow type Cooling Tower models & Cross-flow type Cooling Tower models

R. Ramkumar, et **al,**[10] has done work in **"THERMAL PERFORMANCE OF FORCED DRAFT COUNTER FLOW WET COOLING TOWER WITH EXPANDED WIRE MESH PACKING"** This research-paper presents an experimental examination of the thermal performance of forced-draft counter-flow wet cooling tower with expanded wire mesh type packing. The packing used in this work is wire mesh with vertical [VOWMP] and horizontal [HOWMP] orientations. The packing have 1.25 m height and having a zigzag form. From the experiments there is concluded that the vertical orientation of the packing increase the performance of the cooling tower.

3 Calculation

3.1.1 COOLING TOWER APPROACH:

$$CTA = (\text{Outlet temperature of water}) - (\text{Wet Bulb temperature.}(^0C))$$

3.1.2 COOLING TOWER RANGE:

$$CTR = (\text{Inlet Temperature of water}) - (\text{Outlet temperature of water}(^0C))$$

3.1.3 MASS OF WATER:

$$MW = (\text{Mass flow rate}) \times (\text{Density of water(kg/hr)})$$

3.1.4 HEAT LOSS BY WATER:

$$H_L = H_W \times C_{pw} \times (T_1 - T_2)$$

Where, T_1 = inlet temp of water (°C)
T_2 = outlet temp of water (°C)

3.1.5 VOLUME OF THE AIR REQUIRED (V):

$$V = \frac{H_L \times V_{s1} \times C_{pw} \times (T_1 - T_2)}{(H_{a2} - H_{a1}) - \{(W_2 - W_1) \times C_{pw} \times T_2\}}$$

Where, H_{a1} =Enthalpy of air at inlet temp. (KJ/Kg)
H_{a2} =Enthalpy of air at outlet temp. (KJ/Kg)
W_1 =Specific humidity of air at inlet temp. (Kg/Kg of air)

W_2 =Specific humidity of air at outlet temp. (Kg/Kg of air)

3.1.6 HEAT GAINED BY AIR (HG):

$$H_G = \frac{\{V \times [(H_{a2} - H_{a1}) - \{(W_2 - W_1) \times C_{pw} \times T_2\}]\}}{V_{s1}}$$

where, V_{s1} =specific volume of air at inlet (m^3/Kg)

3.1.7 MASS OF AIR (Ma):

$$M_a = \frac{V}{V_{s1}}$$

3.1.8 MAKE UP WATER:

$$M_{make} = \frac{\{V \times \{W_2 - W_1\}\}}{V_{s2}}$$

Where, V_{s2} =Specific volume of air at outlet (m^3/Kg)

3.1.9 VELOCITY OF WATER IN PIPE (VW):

$$V_W = 10 \times \left\{\frac{\pi}{4} \times D^2\right\}$$

Where, D = Inside diameter of Pipe

3.1.10 COOLING TOWER CHARACTERSTICS:

$$\frac{K_a V}{M_{w1}} = \left[\frac{(T_1 - T_2)}{4}\right] \times \left[\left(\frac{1}{\Delta h_1}\right) \times \left(\frac{1}{\Delta h_2}\right) \times \left(\frac{1}{\Delta h_3}\right) \times \left(\frac{1}{\Delta h_4}\right)\right]$$

$$\Delta h_1 = \text{Value of } H_w - H_a \text{ at } T_2 + 0.1(T_1 - T_2)$$

$$\Delta h_2 = \text{Value of } H_w - H_a \text{ at } T_2 + 0.4(T_1 - T_2)$$

$$\Delta h_3 = \text{Value of } H_w - H_a \text{ at } T_1 - 0.4(T_1 - T_2)$$

$$\Delta h_4 = \text{Value of } H_w - H_a \text{ at } T_1 - 0.1(T_1 - T_2)$$

3.1.11 COOLING TOWER EFFICIENCY:

$$\eta = \frac{T_1 - T_2}{T_1 - WBT}$$

3.1.12 COOLING TOWER EFFECTIVENESS:

$$\varepsilon = \frac{T_1 - T_2}{T_1 - T_{a1}}$$

Where, T_{a1} =inlet temp. of air (°C)

3.1.13 DIFFERENT TYPES OF LOSSES:

• DRIFT LOSS (DL)

$$DL = \frac{(0.20 \times M_W)}{100}$$

• WINDAGE LOSS (WL):

$$WL = \frac{0.005}{M_{w1}}$$

• EVAPORATIVE LOSS:

$$EL = 0.00085 \times M_w \times (T_1 - T_2)$$

• BLOW DOWN LOSS:

$$BL = \frac{EL}{Cycles - 1}$$

$$\text{No.of Cycles} = \frac{\text{XC}}{\text{XM}}$$

Where, XC = concentration of solids in circulating water
XM = concentration of solids in make-up water

WATER BALANCE EQUATION:

$$M = WL + EL + OL$$

$$\frac{XC}{XM} = \frac{M}{M - EL}$$

4 CONCLUSIONS

In this paper a methodology for evaluation of Cooling Tower performance and different literature survey from different research paper is presented. Cooling Tower is used to reduce the temperature of hot fluid stream. It is mainly used in air conditioning plant, Chemical Plants etc. The design of cooling tower is closely related to tower characteristics and different types of losses generated in cooling tower. Main factors that affect thermodynamic performance of the counter flow closed circuit cooling tower are spray water, air flow rate and air wet bulb temperature if its structure is designed. Evaporation loss and Effectiveness are two important performance parameters of Cooling Tower. Cooling Tower performance increases with increase in air flow rate and characteristics decreases with increase in water to air mass ratio. In Vertical Orientation Wire-Mesh Packing the water droplets are split into fine size compared with Horizontal Orientation Wire-Mesh Packing. So, the Vertical Orientation Wire-Mesh Packing is having better performance than Horizontal Orientation Wire-Mesh Packing in Cooling Tower.

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