Study and Investigation Analysis of Significant Aspects of Mechanical Draft Cooling Tower Performance

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ABSTRACT

Cooling tower is an integral part of every industries central Air Conditioning plant which have water cooled condenser. Basically cooling tower are heat rejection devices used to transfer heat from hot water to the atmosphere air. In this project first we have a review study is carried out to investigate different types of cooling towers, their application, performance, usage and working principles, which can be useful in the HVAC plants as well as other energy stations. A number of investigations have been considered to reveal differences between the used cooling towers. The process parameters such as inlet Air Wet bulb Temperature, Flow rate of Water and fills porosity have more influence on Thermal performance of cooling tower. The Temperature of outlet water is maintained nearest to inlet air wet bulb temperature to obtain the best Thermal Performance of cooling tower. Finite element method is one of the powerful numerical techniques to solve the complex physical phenomenon that are governed by the differential equations.

The performance parameters like range, approach, cooling capacity, evaporation loss liquid to gas ratio have been evaluated when the plant is operated at full load and part load under the same water flow rates. Effectiveness of the cooling tower can be increased up to 20% by optimizing the liquid to gas ratio (L/G) of the cooling tower. Likewise other parameters such as range, tower characteristic ratio can also be increased considerably. In this paper present the calculate thermal design data by practical reading which effect the performance of cooling tower and for assembly model of cooling tower using fusion360. For taking practical reading temperature sensor and thermocouple is used.

Keyword: - *Investigation, Performance, Counter Flow, Cooling Tower, induced draft, approach, cooling capacity, evaporation loss, and water flow rate, Autodesk fusion 360.*

NOMENCLATURE:

- Di-Inside diameter of pipe
- M_{w1}-Mass of water circulated in cooling tower
- CTA-Cooling Tower Approach
- CTR -Cooling Tower Range
- M_a-Mass of Air
- V_a -Volume of Air tower
- η- Effectiveness of Cooling Tower
- HL-Heat Loss by Water
- HG-Heat Gain
- DL-Drift Losses
- EL-Evaporation Losses

- WL -Windage Losses
- M_{mak} - Mass of Makeup Water
- K -Mass transfer co-efficient

1. INTRODUCTION

A Cooling Tower is a heat rejection device that extracts waste heat to the atmosphere by cooling a stream of hot water in the tower. This type of heat rejection is termed "evaporative" because it allows a small portion of the water being cooled to evaporate into a moving air stream and thereby provides significant cooling to the rest of that water stream. The heat that is transferred from the water stream to the air stream raises the air's temperature and its relative humidity to 100%, and this air is discharged to the atmosphere.
In present research work, the factors affecting the performance like environmental conditions, cooling water quality have been studied on Induced draft cooling tower of 320TR central chillers plant. Square structures that can be over 2.5 meters (8.20 ft) Height and 2.5 meters (8.20 ft) length and width with its outer diameter of outlet water pipe size is 450mm (17.71 inches) and its capacity is 80 TR(as in the adjacent fig. no 03).

1.1 COOLING TOWER

Cooling towers are heat exchangers which are used to dissipate large heat loads to the atmosphere. It is equipment used to reduce the temperature of a water stream by extracting heat from water and

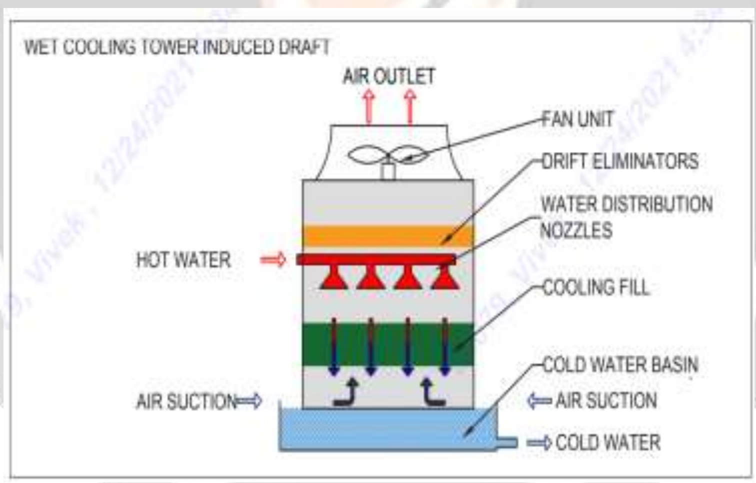

Fig. 1: Induced Draft Cooling Tower.

Emitting it to the atmosphere. They are used in a variety such as power generation and refrigeration. Cooling towers are designed for industrial plants for various purposes and sizes to provide cool water. Typically, a condenser of a power plant and or of heating ventilation, and air conditioning (HVAC) system is cooled by water.

1.2 COOLING TOWER PERFORMANCE

The important parameters, from the point of determining the performance of cooling towers, are:

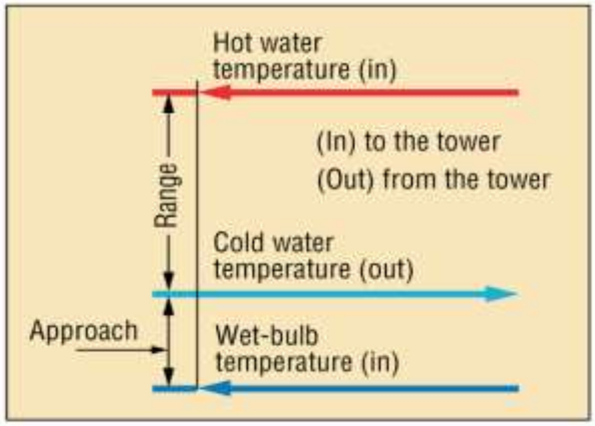

Fig. 2: Range and Approach

1. "Range" is the difference between the cooling tower water inlet and outlet temperature.(see figure 2)
2. "Approach" is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. (see figure 2)
3. Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is Range / (Range + Approach).
4. Cooling capacity is the heat rejected in Kcal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.
5. Evaporation loss is the water quantity evaporated for cooling duty.

   *Evaporation Loss (m3/hr) = 0.00085 x 1.8 x circulation rate (m3/hr) x (T1-T2)

   T1-T2 = Temp. Difference between inlet and outlet water.
6. Cycles of concentration (C.O.C) is the ratio of dissolved solids in circulating water to the dissolved solids in makeup water.
7. Blow down losses depends upon cycles of concentration and the evaporation losses and is given by relation: Blow Down = Evaporation Loss / (C.O.C. – 1)
8. Liquid/Gas (L/G) ratio, of a cooling tower is the ratio between the water and the air mass flow rates. Against design values, seasonal variations require adjustment and tuning of water and air flow rates to get the best cooling tower effectiveness through measures like water box loading changes, blade angle adjustments. Thermodynamics also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air.

2. METHODOLOGY

2.1 DESIGN OF COOLING TOWER

INPUT DATA

T1- temperature of hot water circulating in cooling tower	42°C
T2-Outlet temperature of hot water circulating in cooling tower	35° C
Volume of Circulating Water Circulated in Cooling– Tower	10.8 m3 /Hr
Ta1-Inlet temperature of air-30°C	30°C
Ta2 - Outlet temperature of air-	37°C

Wet-Wet Bulb Temperature-	30°C
Relative Humidity-	70%
H-Height of cooling tower	2.5M
D-Diameter of cooling tower	2.5M

Table 1: Technical specification

Ha1-Enthalpy of air at30°C inlet temperature	99KJ/Kg
Ha2 - Enthalpy of air at outlet temperature	143 KJ/Kg
W1-Specific humidity of air at inlet temperature	0.0252
W2-Specific humidity of air at outlet temperature	0.0391
Vs1-Specific volume of air at inlet temperature	0.908– m3 /Kg
Specific Heat Of water (Cpw)	4.186 Kj/Kg.k
R-Constant	0.287 KJ/Kg.K
Vs2-Specific volume of air at outlet temperature	0.951– m3 /Kg
Hw1-Enthalpy of water at inlet temperature 42°C	175.8Kj/Kg
Hw2 -Enthalpy of water at outlet temperature	35°C- 146.6– Kj/Kg
ρ -Mass density of water	1000 kg/m3

Table 2: Data from Psychometric Chart and Steam Table

2.2 THERMAL DESIGN CALCULATION

Cooling Tower Approach (CTA)

CTA: Cooling Tower Outlet Temperature–WBT
CTA: 35 – 30
CTA: 5°C

Cooling Tower Range (CTR)

CTR: T1 – T2
CTR: 42°C – 35°C
CTR: 7°C

Now, Mass of water circulated in cooling tower
M_{W1}= Volume of circulating water **x** Mass density of water
M_{w1} = 10.8 x 1000
M_{w1} = 10800 Kg / hr

Heat Loss by Water (HL)

HL: M_{w1}x C_{pw} x (T_1 – T_2)
HL: 10800 x 4.186 x (42 - 35)
HL: 316461.6 KJ/hr

Volume of Air Required (V)

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

$$V = \frac{(31641.6 \times 0.908)}{[(143.83 - 99.73) - (0.0391 - 0.0252) \times 4.186 \times 35}$$

$$V = \frac{287347.13}{42.06}$$

V= 6831.83m^3/hr

Heat Gain by Air (HG)

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

$$HG = \frac{6831.83 \times [(143.83 - 99.73) - (0.0391 - 0.0252) \times 4.186 \times 35}{0.908}$$

$$HG = \frac{287346.75}{0.908}$$

HG = 316461.Kj/hr

Mass of Air Required (M_a)

$$M_a = \frac{\text{Volume of air required}}{\text{Specific volume of air at inlet tempreture}}$$

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

$$M_a = \frac{6831.83}{0.908}$$

M_a = 7524.04 Kg / hr

The Quantity of Make-Up Water

$$M_{mak} = \frac{V \times (W_2 - W_1)}{V_{s2}}$$

$$M_{mak} = \frac{6831.83 \times (0.0391 - 0.0252)}{0.951}$$

M_{mak} = 99.85 Kg/hr

Now, taking Evaporating loss in calculation

M_{mak} = 99.85 x [1 + (1.44 / 100)]

M_{mak} = 101.28 Kg/hr

M_{mak} = 101.28 / 60

M_{mak} = 1.68 Kg / min

Effectiveness of Cooling Tower

$$\eta = \frac{(T1 - T2)}{(T1 - WBT)}$$

$$\eta = \frac{(42 - 35)}{(42 - 30)}$$

η = 58.33%

2.3 DIFFERENT TYPES OF LOSSES GENERATED IN COOLING TOWER

Drift Losses (DL)

Drift losses are generally taken as 0.10 % (Perrys chemical engineering hand book) of circulating water.

DL = 0.10 x M_{w1} / 100
DL = 0.10 x 10800 / 100
DL = 10.8 Kg / hr

Windage Losses (WL)

Windage losses are generally taken as 0.005(Perrys chemical engineering hand book) of circulating water.

WL = 0.005 x M_{w1}
WL = 0.005 x 10800
WL = 54 Kg / hr

Evaporation Losses (EL)

Evaporation losses are generally taken as 0.00085(Perrys chemical engineering hand book) of circulating water.

EL = 0.00085 x mw1 x (T1 – T2)
EL = 0.00085 x 10800 x (42 - 35)
EL = 64.26 Kg / hr

Water balance equation for cooling tower is
M = WL + EL + DL
M = 54 + 64.26 + 10.8
M = 129.06 Kg / hr

2.4 DESIGN MODEL OF COOLING TOWER

A. Assembly joint of cooling tower using Fusion 360 and make different parts.

B. Based on the obtained specifications (size and dimensions), the cooling tower model has been prepared in Autodesk fusion360 2021 3d modeling software.

Fig. 3: Practical of Cooling Tower

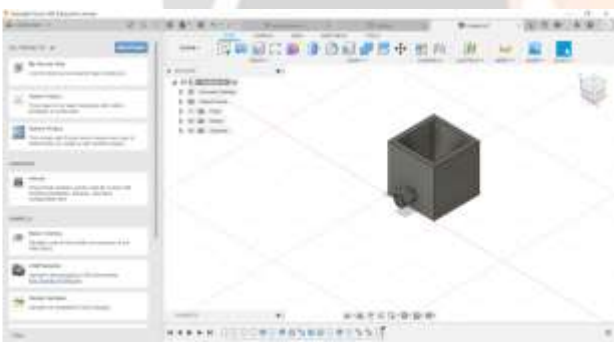

Fig. 4: Isometric Model using Fusion 360

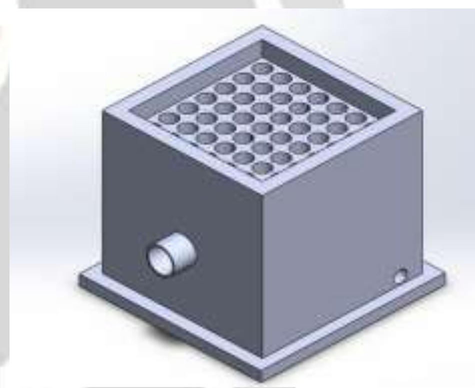

Fig. 3: Isometric View of Cooling Tower Model

3. CONCLUSION

For a Square FRP cooling tower stack, the model effectively predicts the air and water outlet temperature, fan control prerequisites, cosmetics water necessities, and gulf air and water mass stream rate. Increment in wet knob temperature of gulf air causes increment in air and water outlet temperature and lessening in the vanishing misfortunes. The execution parameters like range, approach, cooling limit, vanishing misfortune, fluid to gas proportion have been assessed when the plant is worked at full load. This check was led with information of induced draft counter stream cooling tower in HVAC central control plant.

The results clearly demonstrate that on basis of thermal design calculations with an increase in inlet water mass flow rate for the same fill porosity, the surface area required both for convection and evaporation is reduced, resulting in higher water outlet temperatures and reduced heat transfer rates.

The design of cooling tower is closely related to cooling tower characteristics which is unique for a particular tower and loading factor which depends on hot water temperature.

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