



EXPERIMENTAL INVESTIGATION OF INDUCED DRAFT COOLING TOWER

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ABSTRACT

A cooling tower is an enclosed device for the evaporative cooling of water by contact with the air. Cooling tower is a heat rejection device. Common applications include cooling the circulating water used in Steel plants, Oil refineries, Petrochemical, Chemical plants, Thermal power stations and HVAC systems for cooling buildings. The efficiency and the effectiveness of cooling tower is depend on number of parameter like inlet air angle, inlet and outlet temperature of air and water, inlet air rate, water flow rate, fill materials, fan speed etc. Every industry has its own aim to minimizing the losses in every equipment running within it and how to improve growth rate. The Steel producing plant have its own method to cool the hot water. Hence this paper studied about Induced draft cross flow cooling tower. This work represents a case study which is carried out at Steel producing plant to increase the plant efficiency by analyzing and minimizing the losses occurs in cooling tower.

KEYWORDS: Cooling Tower, Optimization of Flow, Cross Flow Cooling Tower, L/G Ratio.

1. INTRODUCTION:

Water plays very important role as a coolant in processing industries. Recirculation is therefore, essential and cooling tower provides a means by which hot water is cooled with air. As consult with cooling tower the primary task is to reject heat into the atmosphere. They represent a relatively inexpensive and dependable means of removing low-grade heat from cooling water and its operation is based on evaporative cooling as well as exchange of sensible heat. During evaporative cooling in a cooling tower, a small quantity of the water that is being cooled is evaporated in a moving stream of air to cool the rest of the water. Also when warm water comes in contact with cooler air, there is sensible heat transfer whereby the water is cooled. Shortly cooling tower is an apparatus use to reduction the hotness of a water stream through expelling high temperature from water and transmitting it to the air. Generally cooling towers are classified into natural and mechanical draft cooling towers. In natural draft cooling tower the flow is carried out with naturally without any aid of agency to fluid flow whereas, the mechanical draft cooling tower is use of external agent to force down the flow of fluid. The Mechanical draft cooling towers further divided into forced and induced draft cooling tower. Generally induced draft cooling towers are used in steel producing plants to remove heat absorbed in circulating cooling water. The performance of cooling tower can be affected by effect of crosswind condition and change in atmospheric temperature. So that's many types of cooling tower are available but here we see near by the description of cross flow mechanical induced draft cooling tower. In which the water spread on the splash fill material at the upper surface of the tower by means of nozzles, and the air contact with the water comes between louvers of the cooling tower so the water and air meet at right angles to each other. For induced draft system, the fan is located at the highest point of the tower. R. Immanuel [2] studied the performance factors of the cooling tower analyzed by experimental data's and the thermodynamic analysis of it by using the first law of thermodynamics is carried out and can easily understand how to analyze the performance of cross flow cooling tower in industries using data recorded and by mathematical model. Manas Patil, Sanket Patil, Prashant Patil, Suneet Mehta [1] studied the performance study, working principle, and analysis of induced draft cooling tower, which is one of the deciding factors used for increasing the power plant efficiency. Umakanta B, C.N Nataraj [3] studied that the goal is to recognize the few methods for enhancing proficiency of cooling tower. In this investigation examination of a few figuring with respect to the cooling tower. Krishna Vishwakarma, Arpit Bhojar, Sahil Laroekar, Vaibhav Hote, Sourabh Bhudhbaware [4] studied the comparison and parametric investigation of the cooling system model in the logic tree and the results are summarized as tables and charts. The objective is to identify the several ways of improving efficiency of cooling tower. These are some studied recently carried out apart from this we were studied the DCW type of induced draft cross flow cooling tower by changing mass flow rate, how was impacting on the performance of it. This study makes theoretical approach to rich out different result that makes useful to improving and imparting on cooling tower.

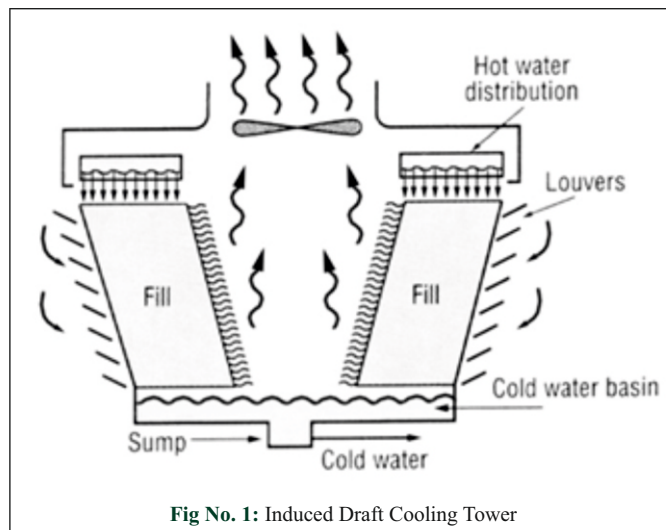


Fig No. 1: Induced Draft Cooling Tower

1.1 Cooling Tower Performance Parameters:

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

- i) "Range" is the contrast among the cooling-tower water gulf and vent temperature. A great CT Choice implies that the cooling-tower has possessed the capacity to lessen the water-temperature successfully, and is subsequently presentation admirably.

$$CT\ Range\ (^{\circ}C) = [CW\ inlet\ temp\ (^{\circ}C) - CW\ outlet\ temp\ (^{\circ}C)]$$

- ii) "Approach" is the contrast among the cooling- tower's outlet icy water temperature and surrounding wet knob temperature. Albeit, together variety and methodology ought to be checked, the Approach is a superior pointer of cooling-tower's execution.

$$CT\ Approach\ (^{\circ}C) = [CW\ outlet\ temp\ (^{\circ}C) - Wet\ bulb\ temp\ (^{\circ}C)]$$

- iii) "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 Effectiveness = Range / (Range + Approach).

- iv) "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.

- v) "Evaporation Loss" is the water quantity evaporated for cooling duty and, theoretically, for every 10, 00,000 kcal heat rejected, evaporation quantity works out to 1.8 m³. An empirical relation used often is

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.

vi) "Cycles of concentration" (C.O.C) is the ratio of dissolved solids in circulating water to the dissolved solids in makeup water.

vii) "Blow Down Losses" depend upon cycles of concentration and the evaporation losses and is given by relation:

$$\text{Blow Down} = \text{Evaporation Loss} / (\text{C.O.C} - 1)$$

viii) "Liquid/Gas (L/G) Ratio", 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:

$$L(T_1 - T_2) = G(h_2 - h_1)$$

Where, L/G = liquid to gas mass flow ratio (kg/kg)

h_2 = enthalpy of air-water vapor mixture at exhaust wet-bulb temperature (KJ/kg)

h_1 = enthalpy of air-water vapor mixture at inlet wet-bulb temperature (KJ/kg)

2. METHODOLOGY:

Table shows the technical data about induced draft cross flow cooling tower used in steel producing plant.

Table no. 1: Induced Draft Cooling Tower Details

Type	DCW Induced Draft Cross Flow
Tower Model	457-202
No. of Cells	02
No. of towers	01
Design Circulating Water Flow	600 m ³ /hr
I/L (Hot) water temp	47 °C
O/L (Cold) water temp	35 °C
Wet bulb temperature	27 °C
Drift Loss	1.8
Evaporation Loss	8.49
Blowdown Loss	2.83
STRUCTURAL DETAILS	
Fans per Cell	1
Total Number of Fans	2
Overall Tower Dimensions L × W (M)	10 × 5
Overall Tower Height (M)	5
MATERIAL OF CONSTRUCTION	
Frame work Members	Wood
Casing	RCC
Filling	PVC Film type
Support	RCC
Louvers	Material None
Fan Deck	Steel
Cold water basin material	RCC
Furnished By	PAHARPUR Cooling Tower Ltd.
COOLING TOWER FAN	
Number	One per cell
Type	Axial Flow propeller type
Manufacturer	PAHARPUR Cooling Tower Ltd.
No. of Blades	09
Diameter (M)	3.658
Fan Speed (RPM)	75
Tip Speed (M/Sec)	14.36
Fan, Driver output	40 HP
Blade Material	GRP

2.1 Data collected:

The hot water temperature to the tower and cold water temperature from the tower checked in each hour a day given below:

Table No. 2: Data Collected From Industry

Sr. No	M _r (Mass of water at inlet m ³ /hr)	T ₁ (Inlet cooling Temperature)	T ₂ (Outlet cooling Water Temperature)	T _{ai} (air inlet wet bulb Temperature)	T _{ao} (Air outlet wet bulb Temperature)
1.	900	37.2	32.52	22.86	32.5
2.	900	41.2	32.82	29.96	38.1
3.	900	36.2	31.82	30.41	36.1
4.	925	38.2	31.32	30.06	35.1
5.	950	37	31.52	29.43	33.2

2.2 Cooling tower actual performance calculation:

As we know cooling tower is used to remove heat and minimize water usage. The relative humidity of the incoming air plays a great role in determining the rate of heat transfer and that relative humidity assumed to be 70%. The findings of one typical trial pertaining to the Cooling Towers of a Steel producing Plant is given below.

Observations:

- Inlet cooling water temperature = 37.2 °C
- outlet cooling water temperature = 32.52 °C
- Air inlet wet bulb temperature = 22.86 °C
- Air outlet wet bulb temperature = 27.77 °C
- Air inlet dry bulb temperature = 27.1 °C
- Air outlet dry bulb temperature = 32.5 °C
- Enthalpy for Inlet wet bulb temp = 67.73 KJ/Kg
- Enthalpy for Outlet wet bulb temp = 88.63 KJ/Kg
- Dissolved solids in circulating water = 185 ppm
- Dissolved solids in makeup water = 46 ppm
- Circulating water flow rate = 900 m³/hr

✓ Range:

$$\begin{aligned} \text{CT Range (oC)} &= [\text{CW inlet temp (oC)} - \text{CW outlet temp (oC)}] \\ &= [37.2 - 32.5] \\ \text{Range} &= 4.7 \text{ °C} \end{aligned}$$

✓ Approach:

$$\begin{aligned} \text{CT Approach} &= [\text{CW outlet temp (oC)} - \text{Wet bulb temp (oC)}] \\ &= [32.5 - 22.8] \\ \text{Approach} &= 9.7 \text{ °C} \end{aligned}$$

✓ Effectiveness:

$$\begin{aligned} \text{Cooling Tower Effectiveness} &= (\text{Range} / (\text{Range} + \text{Approach})) \times 100 \\ &= 4.7 / 4.7 + 9.7 \times 100 \\ \text{Effectiveness} &= 32.63 \% \end{aligned}$$

✓ Cooling capacity:

$$\begin{aligned} \text{Cooling capacity} &= \text{Mass flow rate of water} \times \text{Cw} \times \text{Temperature difference} \\ &= 250 \times 4.187 \times 4.7 \\ \text{Cooling capacity} &= 4898.8 \text{ KJ/Sec} = 1171.96 \text{ Kcal/hr} \end{aligned}$$

✓ Evaporation loss:

$$\begin{aligned} \text{Evaporation losses in m}^3/\text{hr} &= 0.00085 \times 1.8 \times \text{Mass Flow rate (m}^3/\text{hr)} \times (T_1 - T_2) \\ &= 0.00085 \times 1.8 \times 900 \times 4.7 \\ \text{Evaporation loss} &= 6.47 \text{ m}^3/\text{hr} \end{aligned}$$

✓ Cycles of Concentrations (COC):

$$\begin{aligned} \text{C.O.C} &= \text{TDS of Cooling Water} / \text{TDS of Makeup Water} \\ &= 185 / 46 \\ \text{C.O.C} &= 4.02 \end{aligned}$$

✓ Blow down losses:

$$\begin{aligned} \text{Blow down} &= \text{Evaporation Loss} / \text{C.O.C} - 1 \\ &= 6.47 / 4.02 - 1 \end{aligned}$$

$$\text{Blow down loss} = 2.14 \text{ m}^3/\text{hr}$$

✓ Drift Losses : Assume 0.15 % of Mass Flow Rate

$$\begin{aligned} &= 0.0015 \times 900 \\ \text{Drift Loss} &= 1.35 \text{ m}^3/\text{hr} \end{aligned}$$

✓ Make-up water required:

$$\begin{aligned} \text{Total losses in circulating water} &= \text{Evaporation losses} + \text{Blow down losses} + \text{Drift losses} \\ &= 6.47 + 2.14 + 1.35 \end{aligned}$$

$$\text{Total Losses} = 9.96 \text{ m}^3/\text{hr}$$

$$\text{Total make up water required} = 909.96 \text{ m}^3/\text{hr}$$

✓ **Liquid/Gas (L/G) Ratio:**

$$L(T_2-T_1) = G(h_2-h_1)$$

$$L/G = (h_2-h_1) / (T_2-T_1) = (88.63-67.73) / (27.77-22.86) = 20.9 / 4.91$$

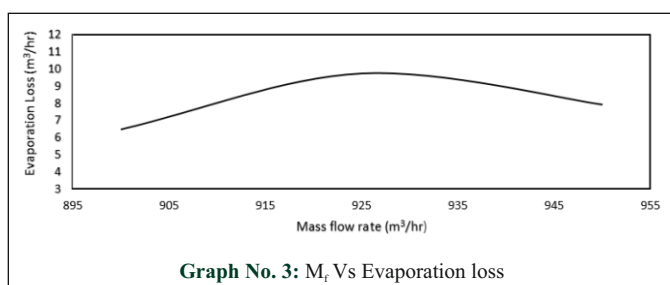
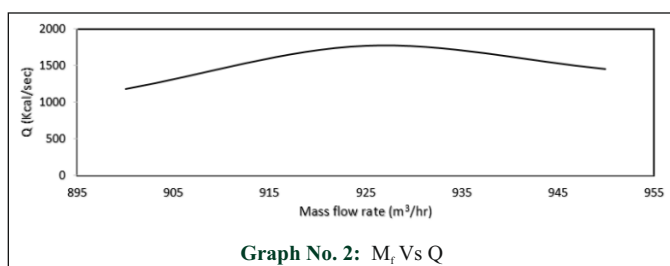
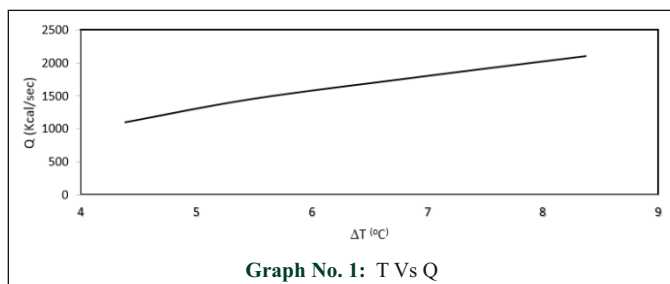
$$L/G \text{ Ratio} = 4.25$$

3. RESULTS AND DISCUSSION:

The result of theoretical analysis are shown in table no.3, the graphs shows the changes of cooling capacity and the evaporation loss with respective to mass flow rate and range.

Table No. 3: Results

Mass of water at inlet (M_f , m ³ /hr)	Range ΔT (°C)	Cooling Capacity Q (Kcal/sec)	Evaporation loss (m ³ /hr)	Blow down Loss (m ³ /hr)	Drift Loss (m ³ /hr)
900	4.68	1171.96	6.44	2.14	1.35
900	8.38	2098.5	11.53	3.84	1.35
900	4.38	1096.83	6.03	2.01	1.35
925	6.88	1770.7	9.73	3.24	1.38
950	5.48	1448.53	7.9	2.63	1.42

**4. CONCLUSION:**

We can conclude that there is difference between the theoretical and practical work. The scope of understanding will much more in practical work is done and we get much more knowledge as well as experience of doing a work. Were we studied the induced draft cross flow type cooling tower, according to increase in flow rate the cooling capacity will increased in some extent it depends on range. Apart from this the climatic condition also effects on performance. The rate of evaporation loss depend on cooling capacity and flow rate that were increased gradually. To make optimum condition of mass flow rate that will results in improving cooling capacity as well as minimizing the losses. The exercise carried out at Steel Industry.

REFERENCE:

1. Manas M. Patil, Sanket J. Patil, Prashant S. Patil, Suneet J. Mehta, "Design and Analysis of Cooling Tower", International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, p-ISSN: 2395-0072, Volume: 05, Issue: 02 | Feb-2018.
2. R. Immanuel, Dr.S.Rajakumar, "Performance Evaluation and Optimisation of Cross Flow Cooling Tower", International Journal of Research in Science and Technology (IJRST) 2016, e-ISSN: 2249-0604, p-ISSN: 2454-180X, Vol. No. 6, Issue No. 1, Jan-Mar.
3. Umakanta.B, C.N.Natraj, "Study of Induced Draft Cooling Tower Performance Analysis in Captive Power Plant", International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, p-ISSN: 2395-0072, Volume: 04 Issue: 08 | Aug -

2017.

4. Krishna S. Vishwakarma, Arpit S. Bhojar, Saahil K. Larokar, Vaibhav V. Hote, Saurabh Bhudhbaware, "Study the factors on which efficiency of cooling tower can be critically acclaimed (A case Study)", K. S. Vishwakarma et al. Int. Journal of Engineering Research and Applications, ISSN : 2248-9622, Vol. 5, Issue 4, (Part -3) April 2015, pp.73-79.
5. Vishnu s Kumar, Reji Mathews, "Performance Analysis and Optimization of Cooling Tower." International Journal of Scientific and Research Publications, Volume 8, Issue 4, April 2018, ISSN 2250-3153, pp. 225-237.