"EXPERIMENTAL AND NUMERICAL ANALYSIS OF THERMAL BEHAVIOUR OF COUNTER FLOW COOLING TOWER"

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Abstract - *In this paper performance analysis of cooling tower were conducted. Performance of tower is of a great importance. For this study, experiments were conducted for fixed mass flow tare of water and then for fixed inlet temperature and from experimental data effectiveness and evaporation losses were calculated. As it was a small capacity of cooling tower that meant for only study purpose a high effectiveness of 64% were achieved for range of 33.8˚C and a small amount of water loss of 1% obtained for range 5.7˚C. Theoretical EL was also calculated from carrier's equation and with the help of steam table and was compared with the practical EL. The comparison b/w them shows the difference is marginal. It was observed that performance of tower depends on so many parameters, like range, approach, design & material of tower etc. Effectiveness and EL of tower is function of range & influences it most among all other parameters.*

***Key Words*: Cooling Tower, Heat exchanger, Counter flow, effectiveness.**

1. INTRODUCTION

Cooling Tower is a special type of direct type of contact heat exchanger that is broadly and efficiently used in various fields. Cooling Tower is a necessary part of thermal power plant , fertilizer plant ,chemical plant etc. Mostly used Cooling Tower is of counter flow type. There is need to cool the hot water in thermal power plant and various plants and the Cooling Tower brought revolution in this field. It is an important evaporative, direct contact, counter flow heat exchanger. The main function of tower is to increase the efficiency of power plant by lowering the temperature of outlet water. It direct use the atmospheric air to cool the hot and warm air. The first law of thermodynamic is rely on the energy conservation principle. The concept of energy balance is based on Enthalpy. Which is described and referred as: $H = U+PV$; $\Delta H = Q - W$

Where;
H=Enthalpy; ΔH=Change in heat;
P=Pressure; Q=Heat;
V=volume. W=Work.

As per conservation law of energy following can be concluded:

$$\sum \Delta H_{in} = \sum \Delta H_{out}$$

Hence,
By obtaining different enthalpies, the analysis of various, and all important aspect of cooling tower can be conducted.

2. EXPERIMENTAL SET-UP

This experimental set-up is of small capacity and meant for only study and research purpose. Various reading was taken carefully and according to the needs. The reading taken by changing mass flow rate & keeping the inlet water temperature constant and another reading was taken by changing inlet temperature & keeping mass flow rate constant. Various reading was taken by varying the parameter and important parameter like effectiveness, range, approach, evaporation loss (practical and theoretical) related to cooling tower performance was calculated.

2.1 SPECIFICATION OF TOWER

Table -1: Dimensions of set-up Equipment

Sr.No.	Name of components	Specification
1.	Cooling Tower	Cross sec.0.15mx0.15m Height:0.75m
2.	Wire mesh packing	Aluminium expanded wire mesh
3.	Blower	Centrifugal blower,power-3H.P.
4.	Pipe diameter(d_2)	50mm
5.	Diameter of orifice (d_1)	25mm
6.	Coefficient of discharge	0.60

2.2 UTILITY REQUIRED

1. Water supply, 2. Drain, 3. Electricity supply: 1 Phase, 220V AC, and 3 kW. 4. Floor area of 1.2m x 1m.

2.3 EXPERIMENTAL PROCEDURES

1. Fill the tank with water, set the temperature with the help of D.T.C. also, and switch on the warmer.
2. Switch on siphon and blower after wanted temp. is accomplished.
3. Set the stream rate of water and air.
4. Record the stream rate of water and manometer perusing after consistent state accomplished.
5. Record different temp.
6. Stages 3 to 5 might be rehashed for various water and wind stream rates inside operational range.

Fig -1: Laboratory Experimental set-up

3. PRECAUTIONS & MAINTENANCE INSTRUCTIONS

1. Warmer ought not to be exchanged on before filling the water in warming tank.

2. Siphon ought not to be exchanged on at low voltage.

3. Water in warming tank ought to be appropriately depleted after trial is finished.

4. Cotton coat over the wet bulb game plan ought to be in its place appropriately.

5. Wet bulb jug ought to be loaded up with water before beginning the analysis.

4. EXPERIMENTATION: READING & CALCULATIONS

Keeping inlet water flow rate fixed as 50 LPH and varying inlet water temperature, different temp is noted as below.

Table 2 Measured values (Manometer reading:16 mm)

Sr. No	Water Temp.⁰C		Air Inlet Temp.⁰C		Air outlet temp.⁰C	
	Inlet (T_5)	Outlet (T_6)	DBT (T_1)	WBT (T_2)	DBT (T_3)	WBT (T_4)
1.	30	24.3	17.4	15.7	29.1	28.2
2.	40	28.4	18.6	15.9	33.4	33.3
3.	50	30.0	18.8	16.0	40.8	38.6
4.	60	32.8	19.0	16.1	48.1	43.0
5.	70	36.2	19.9	16.5	53.6	49.3

Table 3 Measured values (Keeping inlet temp. fixed as 55 ˚C and varying inlet water flow rate in LPH. Manometer reading: 20 mm)

Sr. No	Inlet water flow rate(LPH)	Water outlet temp(⁰C)	Air Inlet Temp.⁰C		Air outlet temp.⁰C	
			DBT (T_1)	WBT (T_2)	DBT (T_3)	WBT (T_4)
1.	28	26.8	19.8	16.8	42.0	40.6
2.	36	28.4	19.8	16.8	42.8	41.6
3.	44	29.3	19.8	16.8	43.0	42.1
4.	52	31.7	19.9	16.9	43.6	42.8
5.	60	33.4	19.9	16.9	44.4	42.9

Table 4 Results for Effectiveness

Sr.No	Range(⁰C)	Effectiveness
1.	5.7	39.86%
2.	11.6	48.13%
3.	20.0	58.82%
4.	27.2	61.95%
5.	33.8	63.17%

Table 5 Range & Evaporation loss (%)

Sr.No	Range(⁰C)	Effectiveness
1.	5.7	1.00
2.	11.6	2.149
3.	20.0	3.705
4.	27.2	5.00
5.	33.8	6.26

Table 6 Results of Evaporation losses

Sr. No	Inlet water mass flow rate(LPH)	Range (˚C)	Evaporation loss(kg/hr)	Evaporation loss(%)
1.	28	28.2	1.4628	5.224
2.	36	26.6	1.774	4.928
3.	44	25.7	2.094	4.7613
4.	52	23.3	2.2446	4.3166
5.	60	21.5	2.40	4.00

Table 7 Results of theoretical evaporation losses

Sr. No	Inlet water mass flow rate(LPH)	Water outlet temp.(°C)	Theoretical Evaporation Loss(kg/hr)	Practical Evaporation Loss(kg/hr)
1.	28	26.8	0.9031	1.4628
2.	36	28.4	0.9752	1.7740
3.	44	29.3	1.0131	2.0940
4.	52	31.7	1.0622	2.2446
5.	60	33.4	1.0627	2.4000

5. RESULTS & DISCUSSIONS

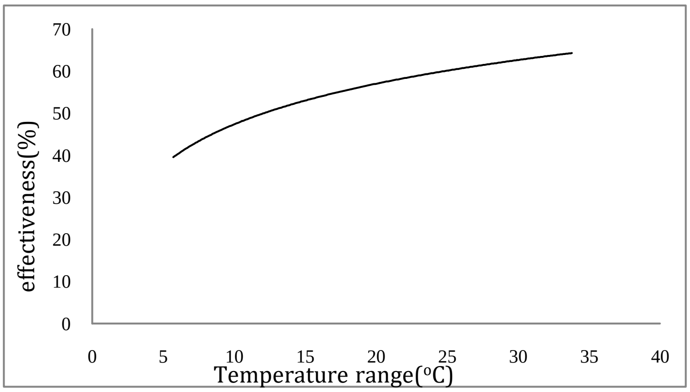

Figure 1: Graph b/w effectiveness (%) & temperature range (˚C).

Effectiveness is strongly depended on range of cooling tower & it is directly proportional to temperature range. As resulting graph indicating the increasing slope of effectiveness (%) with range (˚C),it means when the ranges of tower is increased that results in increment in effectiveness of tower. At initial stage when range is increased effectiveness is also increased but slop of increment is greater than that of later stage. Different effectiveness calculated from various ranges are plotted here and that shows direct proportionality relationships b/w both of them. Hence range is a strong function of efficiency of cooling tower.

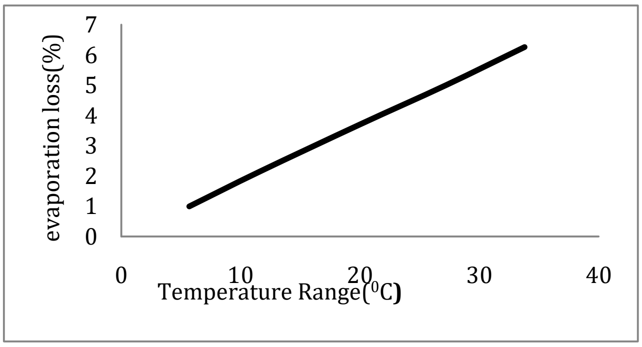

Figure 2: Graph b/w Evaporation loss(%) & Range(˚C) for fixed flow rate.

The graph b/w evaporation loss and range establish a relation which is shown in the above figure. The figure tells directly that the slope of graph is of increasing trends, establishing relation of direct proportionality. As range increases evaporation loss is also increasing in a same trend, the slop is almost a straight line. At various value of ranges respective evaporation losses are calculated in percentages & graph is plotted which is shown above. The graph b/w ranges and evaporation losses says that evaporation loss is highly depended on range & directly proportional to it. As it is an undesirable parameter and should be as small as possible, should be less than 5% for optimum result. Here the calculated practical evaporation loss is within range of 1% to 6%, which is a reasonable result.

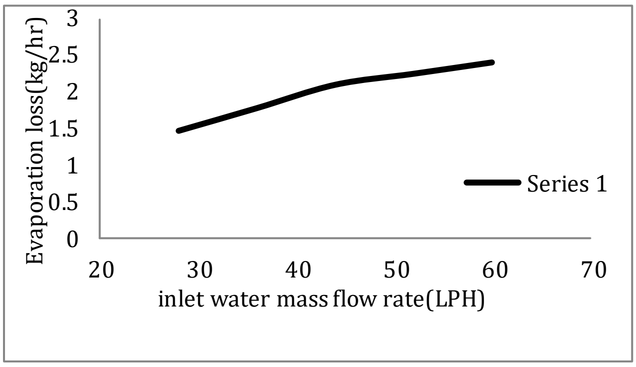

Figure 3: Graph b/w Evaporation loss (kg/hr) & Inlet water flow rate (LPH).

Evaporation losses in kg/hr are calculated from respective inlet water flow rate in LPH. The relationship b/w them is related by drawing graph inlet water flow rate v/s evaporation losses as above. The graph simply indicates & shows that evaporation loss in kg/hr is function of flow rate of water. The result & graph shows that evaporation loss in kg/hr is directly proportion to inlet mass flow of water. As water flow rate increases that leads to increment in evaporation loss in kg/hr also. The nature of graph is of increasing slope and a straight line.

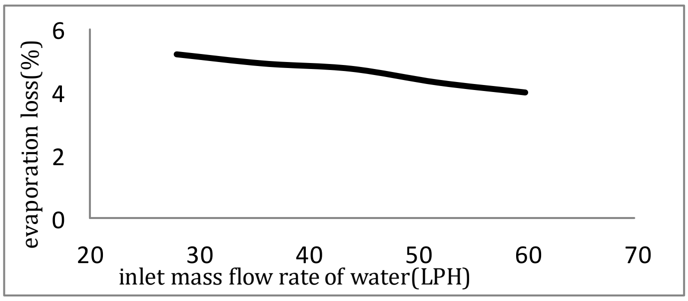

Figure 4: Graph b/w Evaporation loss (%) & Inlet water flow rate(LPH).

Evaporation losses in percentage is calculated from the measured values & when relation is established between evaporation losses(%) and water flow rate(LPH) nature of graph shown is of decreasing slope, It means when mass flow rate of water increases evaporation loss in % decreases. Although the graph b/w evaporation loss in kg/hr v/s inlet water flow rate in LPH provides the sign of positive slope, while when losses is calculated in term of % and graph is drawn then it gives the opposite nature than of kg/hr.

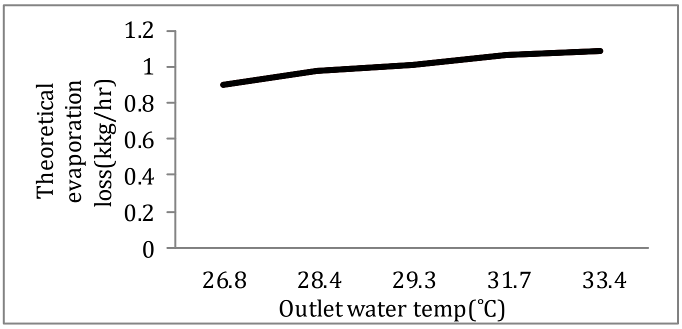

Figure 5: Graph b/w Evaporation loss (kg/hr) & Water outlet temp.(˚C).

Theoretical evaporation loss is calculated from Carrier's equation. With the help of this formula and steam table different evaporation loss at respective parameter is obtained, and a relation b/w evaporation loss and outlet water temp is drawn. Although the trend of graph is of positive slope but slope is marginal i.e. very little.

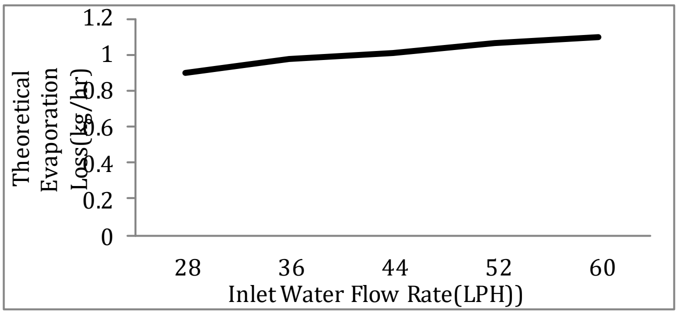

Figure 6: Graph b/w Theoretical evaporation loss(kg/hr) & Inlet water flow(LPH).

Another relationship of theoretical evaporation loss is shown here with inlet flow of water. From figure it can be predicted that theoretical evaporation loss is also shows some relation with inlet water flow rate. The nature of graph is positive but the slope is only marginal.

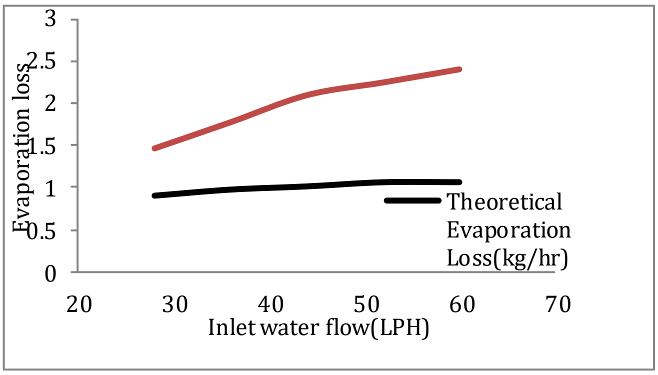

Figure 7: Graph b/w Evaporation loss(kg/hr) & Inlet water flow(LPH).

Above results shows comparison between theoretical evaporation loss & practical evaporation loss (kg/hr) with respect to inlet water flow rate(LHP). Of course there is difference b/w theoretical and practical losses this because in the calculation of theoretical losses some natural phenomenon is not considered, like surrounding ambient temp and relative humidity. The graph predicts that slope of practical loss is more than that of theoretical losses. Practical losses variation with water flow rate is of increasing order & has a positive slope, while theoretical losses seems to be almost a const line having marginal variation with inlet flow rate of water.

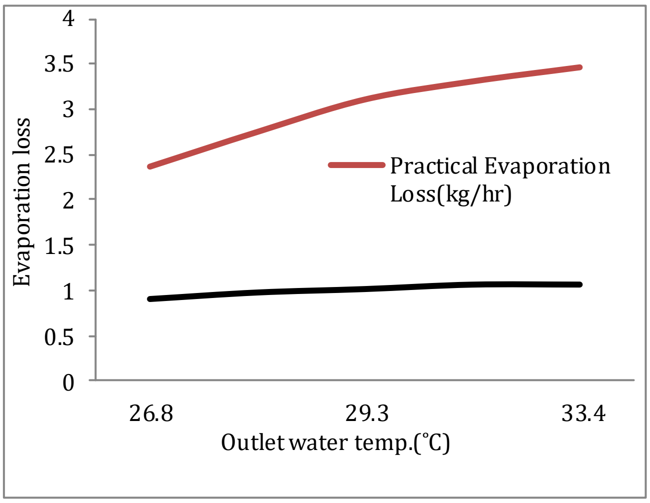

Figure 8: Graph b/w Evaporation loss(kg/hr) & Outlet temperature(°C).

The variation of evaporation losses both theoretical & practical (kg/hr) with outlet temp of water is shown above. Graph is similar to earlier graph, variation of evaporation losses with inlet water flow rate. Both graphs show the same pattern. Hence it can be said that the variation of theoretical & practical evaporation losses with respect to mass flow rate and outlet temp are similar in nature.

6. CONCLUSIONS

1. Effectiveness of tower is a strong function of range & proportional to it.
2. Evaporation losses (%) in both cases is function of range with increasing slope nature.
3. Evaporation losses (kg/hr) v/s inlet water flow rate shows incremental graph, while losses (%) v/s inlet flow rate of water shows decremental graph.
4. Variation of theoretical evaporation loss with inlet flow rate & outlet temp are of same nature with marginal slope.
5. The variation of theoretical & practical evaporation losses with outlet temp & inlet flow rate is of same nature, the graph plotted is almost same in both cases.

7. FUTURE SCOPE

1. At present the efficiency of practical working cooling tower is about 70%-75% but in future a high effectiveness of about 80%-85% may be achieved.
2. Water loss in the form of vapour in tower may also further reduced to optimal minimum level that may be negligible in compare to supplied water. At present practical EL is 1-5% but in future it might be expected to be as small as 0.01%.

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