Performance and Optimisation of Cooling Tower by Employing Nylon Net as Fill Material

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Abstract— Cooling water or processed water is the need of any industry. It requires cooling water. Cooling water is one of the major constituent of industry's annual electricity bills. This situation raise the need for research in techniques employed for functioning of cooling tower. Our project entitled Optimisation and Performance of Cooling Tower by Employing Nylon Net as Fill Material is undertaken as a part of development and improvement of cooling tower. This paper presents how the energy consumption of evaporative cooling tower can be reduced without affecting the performance of cooling tower. This type of cooling tower utilizes the principle of direct evaporative cooling. The position of inlet hot water nozzle results in increase heat transfer rate due to more time circulation of water. For increasing the travelling length of circulation of water, we used different types of patterns of nylon net such as zig-zag pattern, full length zig-zag pattern and vertical parallel pattern. This type of direct spray type evaporative cooling tower has an advantage of reduced maintenance because of elimination of matrix required for induced draft type cooling tower.

Key words: Cooling Tower, Temperature

I. Introduction

In today's scenario of depleting natural resources, such as coal, gasoline and other resources has caused an emergence and application of various technologies reducing impact on depletion and improvement in efficient use of non-renewable resources. As such, electricity generation is important and as well as vulnerable. The thermal power stations are to be modified and upgraded with emerging research in various components of the plant of which, one is a cooling tower.

A cooling tower is a heat rejection device, which gives out waste heat to the atmosphere through the cooling of a water stream to a lower temperature. The type of heat rejection in a cooling tower is termed "evaporative" in that it allows a small portion of the water being cooled to evaporate into a moving air stream to provide significant cooling to the rest of that water stream. The heat from the water stream transferred to the air stream raises the air's temperature and its relative humidity to 100%, and this air is discharged to the atmosphere. Evaporative heat rejection devices such as cooling towers are commonly used to provide significantly lower water temperatures than achievable with "air cooled" or "dry" heat rejection devices, thereby achieving more cost-effective and energy efficient operation of systems in need of cooling. The smallest cooling towers are designed to handle water streams of only few gallons of water per minute supplied in small pipes like those might see in residence, while the largest cools hundreds of thousands of gallons per minute supplied in pipes as much as 15 feet (about 5 meters) in diameter on large power plant. Cooling towers vary in size from small roof-top units to very large hyperboloid structures that can be up to 200 meters tall and 100 meters in diameter, or rectangular structures that can be over 40 meters tall and 80 meters long. Smaller towers are normally factory-built, while larger ones are constructed on site.

II. Design Considerations of Cooling Tower

This section describes how the performance of cooling tower is assessed. The performance of cooling tower is evaluated to assess present levels of approach and range against their design values, identify areas of energy wastage and to suggest improvements.

During the performance evaluations, portable monitoring instruments are used to measure the following parameters:

1) Wet bulb temperature of air
2) Dry bulb temperature of air
3) Cooling tower inlet water temperature
4) Cooling tower outlet water temperature
5) Exhaust air temperature
6) Electrical readings of pump and fan motors
7) Water flow rate
8) Air flow rate

III. Theme of the Project

The working of the cooling tower is based on the evaporative cooling of water. The hot water is cooled by the flow of air. Theoretically the hot water can be cooled up to the wet bulb temperature of air. Most of the cooling tower introduces the hot water at the top of the cooling water in the form of spray. The water falls on the porous fill medium. The fill is made up of either plastic or wood. The plastic fills are preferred because of no maintenance. The atmospheric air is introduced at the bottom of tower and exit at the top. The air is introduced with the help of fan. The cooling tower may be forced draught if the fan is located at the bottom and induced draught if the fan is located at the top.

With conventional design the range of 8 -10˚C can be obtained and the approach is not less than 5 – 7˚C. The limited performance of conventional design is because of the fact that the surface area available for evaporative cooling is less and also the velocity of air when it passes through the fill drops because of its resistance to air flow. If we try to increase surface area the velocity of air will drop. In this project we have decided three models of cooling towers with different arrangements of nylon net. Three models of cooling towers are as described below;

A. Model with Cross Zig-Zag Pattern

The model consists of tower made from mild steel angle frame of size 2.5”×2.5” and 11 feet high. The several rows of cross-ribs are provided in the frame. With the help of this cross ribs five small zig-zag patterns of nylon net is formed in vertical pattern. The header consists of five branches of pipe with a hole in it. Each pipe is placed on the top of zig-zag net. The water from hole of these pipes falls on the zig-zag pattern of nylon net. The water after falling on the net partly will trickle along the slope of the net and partly will cross the net. The water is collected in the basin at the bottom. The model of cooling tower is as shown in the figure.

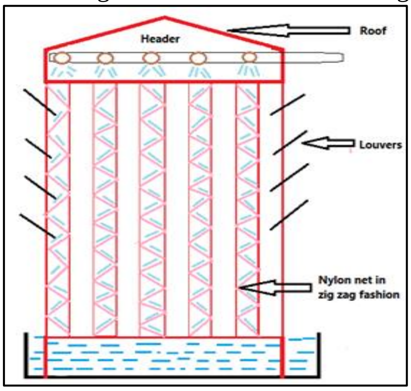

Fig. 1: Setup of a zig-zag pattern by nylon net.

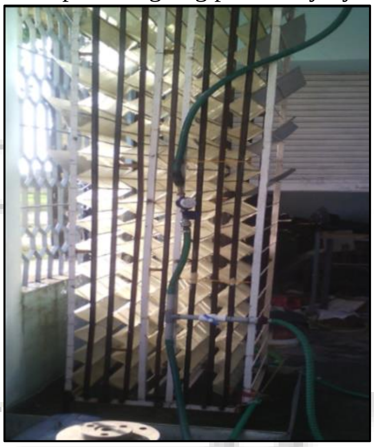

Fig. 2: Experimental setup of cross zig-zag pattern.

B. Model with Full Length Zig-Zag Net Pattern

The model consist of single large zig-zag pattern of nylon net. The slope of the net is less than in model with cross zig-zag pattern. Hence the amount of water flowing along the slope of the net will be less and more water will drop down in the form of droplets crossing the nylon net. The model of cooling tower is shown in the figure.

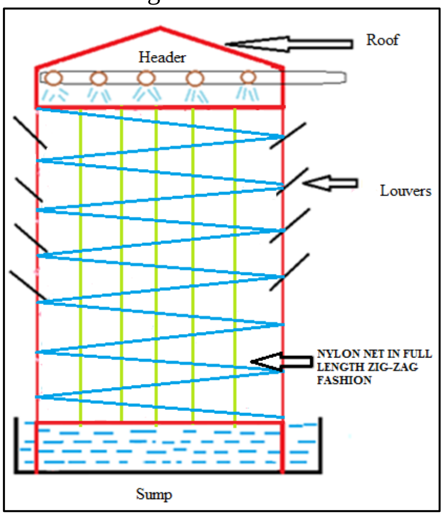

Fig. 3: Setup of full length zig zag pattern

Fig. 4: Experimental setup of full length zig-zag pattern.

C. Model with Vertical Nylon Net

The model consist of straight vertical net aligned from top and arranged parallel to each other. The water is allowed to descend down along the net. The water flows down without any obstruction as in other patterns. The model of cooling tower is shown in the figure.

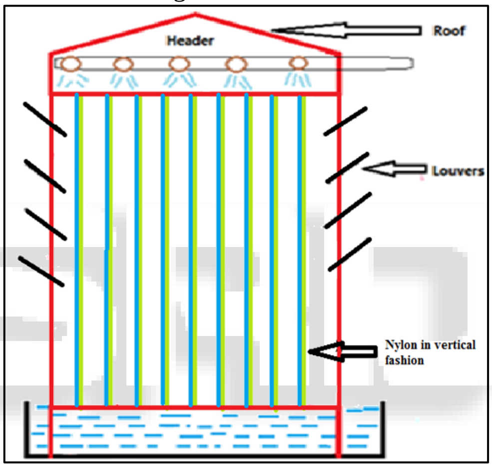

Fig. 5: Setup of Vertical Pattern by Nylon Net

IV. EXPERIMENTAL SETUP

The experimental set up is as shown in figure.

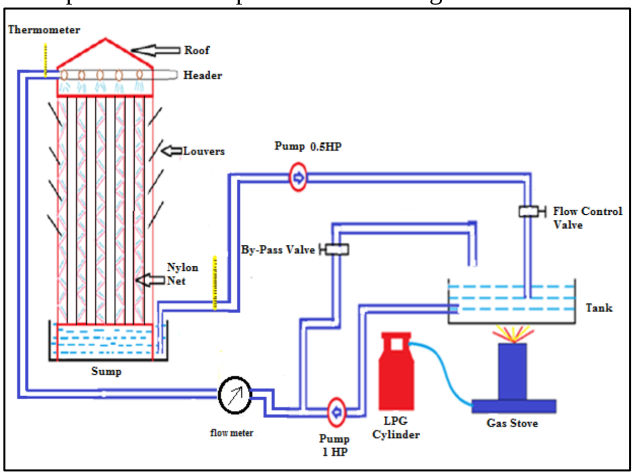

Fig. 6: A Typical Experimental Setup

The water is heated in the container with the help of gas stove. The heated water is feeded into the inlet header with the help of pump. The by-pass with valve is provided to adjust the flow rate of heated water to the inlet header of cooling tower. The water from the cooling tower is collected in the water basin at the bottom. The water from the basin is pumped back into the container for heating with the help of pump. The thermometer is provided in the both pipeline to measure the temperature of outlet and inlet water from cooling tower. The valve is provided to control the flow rate.

V. TESTING PROCEDURE

1) First dry bulb temperature and wet bulb temperature for ambient air are noted down.
2) The water in container is heated with the help of gas stove.
3) The inlet and outlet pump are started and flow rate of the pump are adjusted, so that inlet and outlet flow rate are equal and the water level in the heating container remains same. The flow rates are adjusted with help of valves in the by-pass line and outlet line.
4) When the temperature of water in inlet and outlet line are stabilized i.e. does not change with time. The temperature are noted down.
5) The flow rate from the water flowmeter is noted down.
6) Supply of gas is increased and again the temperature are allowed to stabilize and temperature re recorded again.
7) The procedure is repeated up to the maximum possible temperature.

VI. OBSERVATIONS

Sr. No	Ambient air temp (°C)		Cooling water temp (°C)		Water meter reading (Liters)	Time for water meter readier (sec)	Discharge m^3/hr
	DBT	WBT	Inlet	Outlet			
1	25	18	30	29	142	600	1.422
2	25	18	30	28	77	600	1.374
3	25	18	30	28	98	600	0.822
4	28	19	20	28	130	600	0.846
5	28	19	33	29	128	600	0.84
6	28	19	34	29	135	600	0.84
7	28	19	34	29	126	600	0.852
8	28	19	35	30	129	600	0.792
9	28	18	35	30	117	600	0.804
10	28	18	36	30	134	600	0.78
11	28	18	36.5	30.5	121	600	0.756
12	28	18	36.5	31	119	600	0.744
13	28	18	37	31	117	600	0.75
14	29.5	18	38	31	118	600	0.732
15	29.5	18	38	31	116	600	0.744
16	29.5	18	39	31	119	600	0.756
17	29.5	18	39	31.5	120	600	0.756
18	29.5	18	39.5	32.5	117	600	0.69
19	29.5	18	40	32.5	126	600	0.738
20	29.5	18	41	33	108	600	0.984
21	29.5	18	41	33	120	600	0.942
22	30	19	42	33	123	600	0.792
23	30	19	42	33.5	130	600	0.78
24	30	19	43	33.5	125	600	0.762
25	30	19	43	33.5	116	600	0.696
26	30	19	44	34	120	600	0.648
27	31	18	44	34	131	600	0.684
28	31	18	45	33	109	600	0.864
29	31	18	46	33.5	119	600	0.858
30	31	18	47	34	122	600	0.858

Table 1: For Cross Zig-Zag Pattern.

Sr. No	Ambient air temp (°C)		Cooling water temp (°C)		Water meter reading (Liters)	Time for water meter reading (sec)	Discharge m^3/hr
	DBT	WBT	Inlet	Outlet			
1	25	19	29	28	237	600	1.422
2	25	19	28	27	229	600	1.374
3	25	19	31	27	137	600	0.822
4	28	18	32	28	141	600	0.846
5	28	18	32	28	140	600	0.84
6	28	18	34	28	140	600	0.84
7	28	18	35	28.5	142	600	0.852
8	29	19	35	29	132	600	0.792
9	29	19	36	29.5	134	600	0.804
10	29	19	36.5	30	130	600	0.78

11	29	19	36.5	30	126	600	0.756
12	30	19	37.5	30.5	124	600	0.744
13	30	19	37.5	30.5	125	600	0.75
14	30	19	38	31	122	600	0.732
15	30.5	18	38	31	124	600	0.744
16	30.5	18	40.5	31	126	600	0.756
17	30.5	18	42	32	126	600	0.756
18	31	19	40.5	32	115	600	0.69
19	31	19	40.5	32	123	600	0.738
20	31	19	41	32	164	600	0.984
21	31	19	41	32.5	157	600	0.942
22	31	19	42	33	132	600	0.792
23	31	19	43	33	130	600	0.78
24	31	19	43	33.5	127	600	0.762
25	31.5	18	44.5	34	116	600	0.696
26	31.5	18	45.5	34.5	108	600	0.648
27	31.5	18	47	34.5	114	600	0.684
28	31.5	18	46	35	144	600	0.864
29	31.5	18	46	35	143	600	0.858
30	31.5	18	47.5	36	143	600	0.858

Table 2: For Full Length Zig-Zag Pattern.

Sr. No	Ambient air temp (°C)		Cooling water temp (°C)		Water meter reading (Liters)	Time for water meter reading (sec)	Discharge m^3/hr
	DBT	WBT	Inlet	Outlet			
1	32	21	32.5	31	169	600	1.014
2	32	21	32	31	157	600	0.942
3	32	21	32.5	31	121	600	0.726
4	32	21	33	31	125	600	0.75
5	32	21	33	31	122	600	0.732
6	32	21	34	31	117	600	0.702
7	32	21	36	31	121	600	0.726
8	32	21	39	31.5	107	600	0.642
9	32	20	35	32	136	600	0.816
10	32	20	35	32.5	130	600	0.78
11	32	20	36	32.5	120	600	0.72
12	33	20	37	32.5	138	600	0.828
13	33	20	37	32.5	125	600	0.75
14	33	20	38	32.5	123	600	0.738
15	35	20	39	33	115	600	0.69
16	35	20	39.5	33	115	600	0.69
17	35	20	40	33	100	600	0.6
18	35	20	41	33.5	85	600	0.51
19	35	20	42.5	34	120	600	0.72
20	36	21	42.5	34	120	600	0.72
21	36	21	42	34	125	600	0.75
22	36	21	43	34.5	156	600	0.936
23	36	21	44	35	130	600	0.78
24	36	21	44	35	111	600	0.666
25	36	21	44.5	35	133	600	0.798
26	36	21	44.5	35	137	600	0.82
27	35	21	45.5	35	135	600	0.81
28	36	21	46	35	126	600	0.756
29	36	21	46	36	126	600	0.756
30	36	21	46	36	128	600	0.768

Table 3: For Parallel Vertical Net Pattern.

VII. RESULT

1) Considering an average of all temperatures, taking into account temperature of 35°C for all the setups, we have,
   - For Cross Zig-Zag Pattern,
     - At inlet temp. of 35°C ,the range is 6°C and approach is 17°C for the flow rate 0.123 m3 /hr.
   - For Full Length Zig-Zag Pattern,

  – At inlet temp. of 35°C ,the range is 6°C and approach is 18°C for the flow rate 0.132 m3 /hr.
– For Parallel Vertical Net Pattern,
  – At inlet temp of 35°C, the range is 5°C and approach is 15°C for the flow rate 0.133 m3 /hr.

2) From the above results of the patterns described, it is Desirable to employ Cross Zig-Zag Pattern of net as fill material to achieve effective cooling and saving in consumption of power.

VIII. ADVANTAGES

1) The elimination of fans and blowers in cooling towers can cause considerable saving in cost of setups and maintenance.
2) Installation of nylon net patterns as fill material can provide efficient heat exchange as air and water is influenced by large suface area due to obstructions.
3) The setup of cooling tower is simple and more space can be utilized for cooling of the water as nets provide maximum heat exchange between air and water.

IX. DISADVANTAGES

1) The maintenance and replacements of nylon nets after a specific period of time causes increase in cost.
2) The initial setup of the cooling tower may require accurate designs and proper installations of net which serve the whole purpose.

X. FUTURE ENHANCEMENTS

1) Nylon Nets can be replaced by substitute synthetic resin material which would last longer in life as compared to nylon nets.
2) Various designs apart from the above can be employed and similar cooling towers can be constructed.
3) This tower can be utilized in other energy producing plants.

XI. CONCLUSION

In this paper, the need for development in the existing technologies and their advantages over the traditional ones is described by the modifications in the fill material used for cooling in a cooling tower. The quality and quantity of power generated in any plant would boost its economical as well as socio-economic conditions. In turn the various designs employed can be tested for various capacities of cooling towers and advancements in the same can prove the plant with maximum efficiency.

The various problems such as maintenance of blowers, water collection method can be eliminated totally by use of patterns of fill in the cooling tower. Thus by such implementation the overall saving in power required to drive the components is reduced and thus can strengthen the production and eliminate waste of water.

REFERENCES

[1] A.S.Kaiser, M.Lucas, A. Viedma, B. Zamora, "Numerical model of evaporative cooling processes in a new type of cooling tower", international journal of heat and mass transfer 48,986-999.
[2] Bilal A Qureshi, Syed M Jubair, "A complete model of wet cooling towers with fouling in fills, applied thermal engineering."
[3] Chengqin Ren, Hongxing Yang, "An analytical model for the heat and mass transfer processes in indirect evaporative cooling with parallel/counter flow configurations", international journal of heat and mass transfer 49.
[4] Jorge Fac~ao, Armando Oliveira, "Heat and mass transfer correlations for the design of small indirect contact cooling towers," Applied Thermal Engineering 24(2004) 1969-1978.
[5] M.S. SODHA, S.P. SINGH, R.L. SAWHNEY, Evolution of design patterns of Direct Evaporative Coolers, hiding and Environment, Vol. 30,No. 2,pp. 287-291, 1995.
[6] We have also used the following links,
https://www.wikipedia.com
https://www.cti.org
https://www.baltimoreairoil.com/coolingtowers