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"Experimental Investigation To Improve the Performance of Fluidized Bed Cooling Tower for Various Configurations"

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***Abstract* - Over a last decade, great strides have been in improving the performance of conventional cooling towers. Heat is dissipated from the surface of a body of water by convection, evaporation and radiation. The heat is largely due to evaporating cooling. The driving force is difference in enthalpy rather than in temperature. The water temperature tends to approach the wet bulb temperature rather than the dry bulb temperature of air. This offers an inherent advantage in making it possible to cool the water to a temperature lower than the dry bulb temperature. This cooling is accomplished by a combination of the sensible heat transfer and evaporation of a small proportion of water. High contact efficiencies are reported for the three phase counter current, fluidized bed in the other applications make it attractive to apply the fluidized bed technology in the field of cooling water.**

Fluidization is the phenomenon by which the solid particles are made to behave like a fluid through contact gas or liquid or both. This principle in the development of three phase fluidized bed cooling tower. The turbulent and random motion of solids which shows vigorous result in high heat and mass transfer coefficients as they are complex in nature, it is difficult form of mathematical simulation programs. Therefore an experimental investigation has been conducted towards these directions.

The present work deals with the methods to improvement in the performance of the wet cooling tower with fluidized bed for various configurations with that of the cooling tower without fluidized bed. The prototype model of forced draft fluidized bed cooling tower and forced and induced draft fluidized bed cooling tower is designed, fabricated, assembled and finally carry out the tests for the performance. The results shows the improvement in cooling capacity, range with the use of fluidized bed with forced draft and forced & induced draft system compare to non-fluidized cooling tower.

INTRODUCTION

In thermal power plant the prime mover is steam driven. The energy released by combustion of fuel is used to generate steam at high pressure in boiler, which is used to spin a steam turbine which in turn drives an electrical generator. Steam coming from the turbine is condensed in a condenser and recycled to where it was heated. The thermal power plants works as per the Rankine cycle. The greatest variation in the design of thermal power stations is due to the different fossil fuel resources generally used to heat the water. Some prefer to use the term energy center because such facilities convert forms of heat energy into electrical energy. Certain thermal power plants also are designed to produce heat energy for industrial purposes of district heating, or desalination of water, in addition to generating electrical power. Globally, fossil fuelled thermal power plants produce a large part of man-made CO_2 emissions to the atmosphere, and efforts to reduce these are many, varied and widespread. Almost all coal, nuclear, geothermal, solar thermal electric and waste incineration plants, as well as many natural gas power plants are thermal. Natural gas is frequently combusted in gas turbines as well as boilers. The waste heat from a gas turbine can be used to raise steam, in a combined cycle plant that improves overall efficiency. Power plants burning coal, fuel oil, or natural gas are often called fossil-fuel power plants. Some biomass-fueled thermal power plants have appeared also. Non-Nuclear thermal power plants particularly fossil fueled plant, sometimes referred to as Conventional power plant.

TYPES OF COOLING TOWERS

This section describes the two main types of cooling towers: the natural draft and mechanical draft cooling towers.

Natural draft cooling tower

The natural draft or hyperbolic cooling tower makes use of the difference in temperature between the ambient air and the hotter air inside the tower.

As hot air moves upwards through the tower (because hot air rises), fresh cool air is drawn into the tower through an air inlet at the bottom. Due to the layout of the tower, no fan is required and there is almost no circulation of hot air that could affect the performance. Concrete is used for the tower shell with a height of up to 200 m. These cooling towers are mostly only for large heat duties because large concrete structures are expensive.

There are two main types of natural draft towers:

Cross flow tower : air is drawn across the falling water and the fill is located outside the tower.

Counter flow tower : air is drawn up through the falling water and the fill is therefore located inside the tower, although design depends on specific site conditions.

MECHANICAL DRAFT COOLING TOWER

Mechanical draft towers have large fans to force or draw air through circulated water. The water falls downwards over fill surfaces, which help increase the contact time between the water and the air - this helps maximize heat transfer between the two. Cooling rates of mechanical draft towers depend upon various parameters such as fan diameter and speed of operation, fills for system resistance etc.

There are two types of mechanical draft cooling tower

i. Forced draft cooling tower
ii. Induced draft cooling tower

LITERATURE SURVEY

Several investigation and experiments are carried out on Fluidized bed cooling tower. Some of the technical aspects that are considered to carry out the present work are from the following Literature survey.

N. Sisupalan and K. N. Seetharamu[1], has been carried out the experimental investigation on heat transfer and pressure drop in fluidized bed cooling tower analysis on a counter flow three phase fluidized bed cooling tower (FBCT) with different static bed heights. The efficient static bed heights for the present tower is found to be between 11 cm to 13 cm. the pressure drop is observed is in the order of 0.6 mm of water column per cm of static bed heights within the range of parameter investigated

A.Grandov, A.Doroshenko, I.Yatskar[6], has carried out the experimental investigation on the Cooling towers with fluidized beds for contaminated environment.

The present work provides the information under which the fluidized bed cooling tower can be used (contaminated water and air). The results of experimental research into the hydrodynamic and heat and mass exchange processes have been listed in the wide range of water and air velocities with bed elements of different densities. The work suggests the regimes and designs of small ventilating cooling towers.

Hisham El-Dessouky[7], has investigated the experiment on thermal and hydraulic performance of a three-phase fluidized bed cooling tower.

An experimental study was made of the thermal and hydraulic characteristics of a three-phase fluidized bed cooling tower. The experiments were carried out in a packed tower of 200 mm diameter and 2.5 m height. The packing used was spongy rubber balls 12.7 mm in diameter and with a density of 375 kg/m^3.

The tower characteristic was evaluated. The experimental results indicate that the tower characteristics KaV/L increases with increases in the bed static height and hot water inlet temperature and with decreases in the water/air mass flux ratio. It is also shown that the air-side pressure drop increases very slowly with increases in air velocity. The minimum, fluidization velocity was found to be independent of the static bed height.

Summary

By observing all the above studies, the theme for present work has been arrived. The present work is all about increasing the efficiency of cooling tower by using different configurations.

OBJECTIVES

This section describes how the performance of cooling powers can be assessed. The performance of cooling towers 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 evaluation, following parameters are considered.

- Wet bulb temperature of air.
- Dry bulb temperature of air.
- Cooling tower inlet water temperature.
- Cooling tower outlet water temperature.
- Exhaust air temperature.
- Electrical readings of pump and fan motors.
- Water flow rate.
- Air flow rate.

The main objective of the project is to show the improvement in the performance of the Wet-cooling tower with fluidized bed with that of the cooling tower without fluidized bed. A prototype model of forced draft fluidized bed cooling tower is designed, fabricated, assembled and finally carry out the tests for the performance.
The parameters to be evaluated are as follows,

a) Range: This is the difference between the cooling tower water inlet and outlet temperature. A high CT Range means that the cooling tower has been able to reduce the water temperature effectively, and is thus performing well. The formula is:
CT Range (°C) = [CW inlet temp (°C) – CW outlet temp (°C)]

b) Approach: This is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. The lower the approach the better the cooling tower performance. Although, both range and approach should be monitored, the `Approach' is a better indicator of cooling tower performance.

CT Approach (°C) = [CW outlet temp (°C) – Wet bulb temp (°C)]

c) Effectiveness: This is the ratio between the range and the ideal range (in percentage), i.e. difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach). The higher this ratio, the higher the cooling tower effectiveness.
CT Effectiveness (%) = 100 x (CW temp – CW out temp) / (CW in temp – WB temp)

d) Cooling capacity: This is the heat rejected in kcal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.

e) Evaporation loss: This is the quantity of water carried away by the cooling air.

DESIGN AND FABRICATION

The design of fluidized bed cooling tower is done based on the following parameters.

In order to maintain the L/G ratio from an approximate ratio between 0.5 to 5.5 as obtained from the literature review. 1 HP pump and a 3 H P centrifugal blower are selected as they give flow rates to maintain the required L/G ratio.

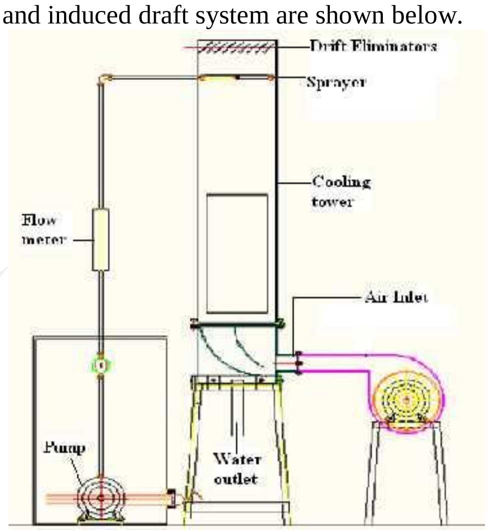
The air flow rate is obtained from the control panel of the blower setup. water flow and temperature are measured by using water flow meter and control unit respectively.

Bed materials are used to increase performance of cooling tower by increasing the time of contact between air and water. The bed material used is spherical thermo coal balls of 4 to 5.5 cm diameter. The bed size of 25cm is maintained in the cooling tower duct.

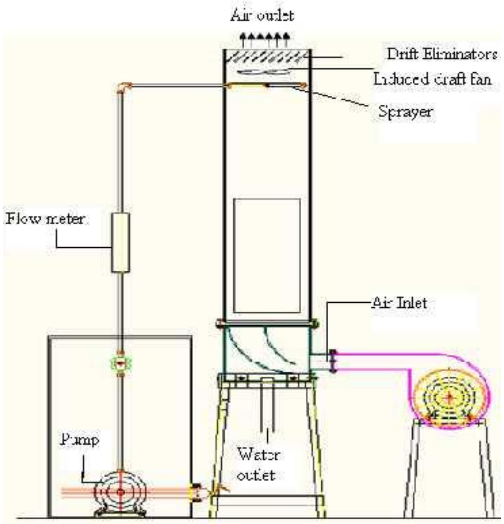
The drift eliminators are used to decrease the amount of water carried away by cooling air. The drift eliminators are placed at the top of the tower. The drift eliminators are made of GI sheet or glass.

Induced draft fan is used in designing forced and induced draft system.

The line diagram of forced draft system and forced and induced draft system are shown below.



Line diagram of FBCT (forced draft system)[5]



Line diagram of FBCT (forced and induced draft system)[5]

EXPERIMENTAL RESULTS AND DISCUSSION

The following parameters are considered in the experiments conducted on cooling tower.

i. L/G ratio is maintained between 0.5-5.5.
ii. The temperature changes of hot water at inlet are neglected.
iii. The inlet temperature of cooling air is assumed to be constant.
iv. Fluid friction inside the tower during experimentation is neglected.
v. The pressure loss in pipes is neglected.

By considering above parameters the following readings are obtained.
T_1-Inlet air temperature
T_2-Outlet air temperature
T_3-Inlet water temperature
T_4-Outlet water temperature
T_5-Temperature of water at tank
T_6-Wet bulb temperature

The results are presented in table mentioned below.

CONCLUSION

1. The range of cooling tower increases with increase in flow rate irrespective of configuration of cooling tower (fluidized system with forced draft or induced & forced draft system).
2. The use of fluidized bed cooling tower increases the cooling rate by 50 % compared to normal cooling tower.
3. The increase in inlet temperature of water decreases the effectiveness as same quantity of air is available for cooling for all operating temperatures of cooling tower.
4. As L/G ratio decreases, the cooling rate increases.
5. The effectiveness of cooling tower is increased by 30 to 40% for combination of forced and induced draft system compare to that of forced draft.
6. The cooling capacity is increased by 30 to 40% for combination of forced and induced draft system compare to that of forced draft. Compared to non fluidized system, the cooling capacity is increased by 90 to 110%.
7. For optimum utilization of fluidized bed the flow rate of cooling air should be increased.
8. In forced draft and induced draft combine system, the water carried away by cooling water is almost doubled compare to that of forced draft system.

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Results for 12 LPM

With bed materials (forced draft configuration)
Ambient wet bulb temp-= 27^0C
Specific heat of water C_{pw}= 4.186 kJ/kg-k

T_1 ^0C	T_2 ^0C	T_3 ^0C	T_4 ^0C	T_5 ^0C	T_6 ^0C	Range ^0C	Approach ^0C	Effectiveness %	Cooling capacity J/Sec	Water carried away cooling air Kg of water/hr
17	37	45	41	45	30	4	15	26.66	2009.28	10.40
17	36	47	43	47	30	4	17	23.52	2009.28	10.83
18	37	49	45	49	30	4	19	21.10	2009.28	10.75

With bed materials (combination of forced and induced draft cooling tower)
Ambient wet bulb temp-= 27^0C
Specific heat of water C_{pw}= 4.186 kJ/kg-k

T_1 ^0C	T_2 ^0C	T_3 ^0C	T_4 ^0C	T_5 ^0C	T_6 ^0C	Range ^0C	Approach ^0C	Effectiveness %	Cooling capacity J/Sec	Water carried away cooling air Kg of water/hr
20	28	45	40	45	26	5	14	35.71	2511.6	18.72
21	32	47	32	47	29	5	13	38.46	2511.6	27.97
20	37	49	44	49	42	5	12	41.66	2511.6	