Study Performance of Forced Draft Counter Flow Cooling Tower

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Abstract— Cooling towers constitute an important component of industrial process equipments and are widely used in the field of air conditioning. In this study the performance of cooling tower used in central cooling system is studied as experimental work and carried out at residential area in the city of Erbil.

This work includes the estimation of the number of transfer units for the cooling tower of interest and the effect of outside conditions such as air temperature and the inlet water temperature of the cooling tower. Experimental work includes study the changing of air temperature and effect of water to air flow ratio from (0.2-1.9) and from (0.2-1.35). The second condition, range and approach to the result obtained such as (number of transfer unit, heat load, air and water effectiveness, and water loss through the tower, then effect of performance of the tower.

The experimental results show the number of transfer unit is increasing by increasing the water to air flow ratio and decreases the approach. The properties of air (temperature, vapor pressure, enthalpy and humidity) are increased by increasing the water to air flow ratio and there was no affect of approach. The effectiveness of water and air increased by increasing the water to air flow ratio. Increasing the range leads to an increase of many variables and parameters such as number of transfer unit, water and air properties, and heat load through the tower.

The conclusion: the experimental results of this work comparing with previous work, it has shown good agreement compatible results with them.

Keywords—Cooling Tower, Performance, Forced Draft Counter.

1. INTRODUCTION

Most air conditioning system and industrial production processes need cooling of the working fluid to operate efficiently and safely .Refineries ,steel mills ,petrochemical manufacturing plants, electric utilities, and paper mill and rely heavily on efficient temperature control .

Cooling water system control these temperatures by transferring heat form hot process fluids into cooling water [1].The use of water as a cooling medium has been long established ,but its importance, in an industrial sense ,was emphasized with the introduction of steam power. Historically, the first pack designs were random timber to be followed rapidly by ordered timber splash bars. The concept of filming water ,as opposed to splash or concrete ,originated in England in the 1930. The introduction of plastic packing dates from the 1950, but this was confined to mechanical-draft towers until the 1970, when experiments started with plastic packs in natural draft cooling towers. Plastic-impregnated is used in certain eastern countries in air-conditioning towers ,but has been unsuccessful in the west. In most cases the changes have due to economics ,but water quality and type of process can significantly affect the selection in individual cases[2].Materials for cooling tower construction are usually selected to resist the corrosive water and atmospheric conditions. Wood has been used extensively for all static components except hardware . Metals steel with galvanized zinc is used for small and medium-sized installations .Hot dip galvanizing after fabrication is used for larger elements .Hot dip galvanizing and cadmium and zinc plating are used hardware. Brasses and bronzes are selected for special hardware ,fittings, and tubing material. Stainless steels are often used for sheet metal [3].

Joe A.sirena [4]Thermo-fluid dynamic efficiency values obtained with available experiment results acquired from commercial fills, and it can be concluded that this efficiency is not a function of the height of the fill.

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Yasar Islamoglu[5] studied the ability of an artificial neural network model to evaluate the thermal performance of a cooling tower, which used in the heating, ventilating, and air conditioning industries to reject heat to the atmosphere is examined. It is concluded that a well-trained neural network provides fast, accurate, and consistent results, making it an easy-to-use tool for preliminary engineering studies.

Bilal A. Qureshi, [6] predicted that evaporation losses is significant because water in cooling towers is cooled primarily through the evaporation of portion of the circulating water, which causes the concentration of dissolved solids and other impurities to increase. The predicted values are in good agreement with experimental data as well as predictions made by an accurate mathematical model.

Jorge Facaq[7] focused on computational data analysis of heat and mass transfer in an indirect contact cooling tower. The computational fluid dynamics (CFD) model uses as boundary conditions the temperatures of the tubes obtained by a correlation model. The available mass transfer correlations for indirect cooling towers presented and compared with a correlation obtained from (CFD) simulations. In the present work the design conditions used, such as inlet and outlet water temperature, inlet air wet bulb and dry bulb temperature, and water to air flow rate on the performance of forced draft counter flow cooling tower.

2. THEORETICAL ANALYSIS

A cooling tower cools water by combination of heat and mass transfer. The water to be cooled is distributed in the lower by spray nozzles, splash bars, or film-type fill, which exposes a very large water surface area to atmospheric air[3].

2.1 Cooling Tower Theory

Baker and Shryock [8] developed the following theory:

\[ K. a. V / G = \frac{dh_a}{(h-h_a)_{avg}} \]  
\[ K. a. V / L = \frac{C_p}{du} \left( (h-h_a)_{avg} \right) \]  

Effectiveness is the percentage between the actual heat transferred to maximum possible heat transfer [9]:

\[ \varepsilon = \frac{q_{act}}{q_{max}} \]  

The maximum heat transfer must be removed from the water as the following [10].

\[ \varepsilon_w = \frac{(t_1-t_2)}{(t_1-t_{w1})} \]  

The maximum heat transfer become when the enthalpy of exit air equal to the enthalpy of water inlet.

The air effectiveness is also as following:

\[ \varepsilon_a = \frac{(h_a-h_{a2})}{(h_1-h_{a1})} \]  

The heat load is:

\[ Q = G \left( h_{a2}-h_{a1} \right) \]  

3. EXPERIMENTAL WORK:

The experimental work for this study was carried out at residential area in the city of ERBIL-IRAQ. The system used in this study is counter flow forced draft cooling tower. The cooling tower is connected to the condenser of chiller of air-condition system closed system as shown in figure (1).
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4. RESULTS AND DISCUSSION

4.1 Variation properties through counter flow cooling tower by changing (L/G).

Figure (2) shows the relationship between (L/G) and number of transfer unit (K.a.V/L) at constant range and inlet air condition. It showed the (NTU) is increasing with increasing (L/G).

Figure (3) show no variant in (NTU) based on both (K.a.V/G) and (K.a.V/l).

Figure (4) shows an increase of air effectiveness with water temperature for (L/G) values greater than one while it decreases at values of (L/G) because water flow rate increase.

Figure(5) shows the heat load is directly proportion with (L/G) at constant inlet air condition and range.

Figure(6) shows an increase of water effectiveness with increase of water temperature at (L/G) greater than one, while it decrease for values of (L/G) less than one this due to an increase of water flow rate compared with air.

4.2 Variation properties through counter flow Cooling tower by changing the inlet conditions

Figures (7 and 8) shows variation of (NTU) in different inlet air conditions, as increasing inlet air condition the (NTU) is increased because the approach is decreasing.

Figure (9) shows variation of water effectiveness with water temperature, air effectiveness is increasing with increasing water temperature this due to an increase in enthalpy change of air and decreasing the driving force between interfacial enthalpy and air enthalpy.

5. CONCLUSION

From the results of this study, it was observed that:

1- The (number of transfer unit, effectiveness of air & water) increase by increasing the inlet condition and not effect on the heat load for constant (L/G) and range.

2- The (number of transfer unit, effectiveness of air & water, and heat load) increases by increasing the range for constant inlet air condition and (L/G) and range.

3- The (number of transfer unit) is very small or not be senses if (L/G) is less than one for constant inlet air condition and (L/G) and range.

4- The effectiveness of water is decreased by increasing water temperature if (L/G) is less than one, for constant inlet air condition and range.

5- The (number of transfer unit) is increased by decreased the approach, for constant inlet air condition and range.

6- The (K.A.V/L) is greater than (K.A.V/G) if (L/G) is less than one, and (K.A.V/L) is less than (K.A.V/G) if (L/G) is greater than one and they equals if (L/G) is equal to one.

REFERENCES

Nomenclature

a  Area of interface (m²/m³)
Cₚₜ  Specific heat of water (KJ/Kg.k°)
d  Change
G  Air mass flow rate (Kg/sec)
h  Enthalpy (KJ/Kg)
K'  Unit conductance, mass transfer, interface to air stream (Kg/m².s)
L  Inlet water mass flow rate (Kg/sec)
Q  Heat transfer rate (Watt)
T  Temperature (°C)
V  Cooling volume (m³)

Subscripts
1  Inlet (air or water)
2  Outlet (air or water)
a  air
avg.  Average
w  water
Wa  Wet bulb

GREEK SYMBOLS

£  EFFECTIVENESS
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Figure (2): Variation of \((K.a.V/L)\) with \((L/G)\) at different approach at constant inlet condition and range.

Figure (3): Variation of \((K.a.V/G)\) with \((L/G)\) at different approach at constant inlet condition and range.

Figure (4): Variation of air effectiveness with water temperature at different \((L/G)\) at constant inlet air condition and range.

Figure (5): Variation of heat load with \((L/G)\) at constant inlet air condition and range.

Figure (6): Variation of water effectiveness with water temperature at different \((L/G)\) at constant inlet air condition and range.

Figure (7): Variation of \((K.a.V/G)\) with water temperature at different inlet air condition at constant \((L/G)\) and range.

Figure (8): Variation of \((K.a.V/G)\) with water temperature at different inlet air condition at constant \((L/G)\) and range.

Figure (9): Variation of heat load with \((L/G)\) at different inlet air condition and at constant range.