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Review Article

Experimentation on Cooling Tower: Material Balance, Efficiency and Packed Height

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ABSTRACT

Operation of heat exchangers, condensers and many reactors involving heat changes calls for sound supply of water at adequate temperature. Cooling towers thus are integral part of utility section, sometimes they are the most important one. Humidification is the process in which the moisture or water vapor or humidity is added to the air without changing its dry bulb (DB) temperature. Cooling and humidification processes are one of the most commonly used air conditioning applications for the cooling purposes. Natural circulation, forced circulation and induced draft cooling towers are used according to requirement as they have their own advantages and disadvantages. Natural draft towers have least operating cost and operate with natural circulation of air. Forced and induced draft towers need electricity for blowing or forcing air. In the current investigations efficiency of forced draft cooling tower is analyzed. Also material balances and packed height of column are computed.

Key words: Efficiency, dry bulb temperature, wet bulb temperature, adiabatic saturation, humidification.

INTRODUCTION

Cooling tower is very important utility in the chemical and allied industries. Water from processing industries is at higher temperature. It is required to be cooled before disposal as per regulatory norms. Also many processes need water at low temperatures (5-20^{o}C). Operation of heat exchangers, condensers and many reactors involving heat transfer calls for sound supply of water at adequate temperature.

Cooling towers, thus are integral part of utility section, sometimes they are the most important one. Humidification is the process in which the moisture or water vapor or humidity is added to the air without changing its dry bulb (DB) temperature. Cooling and humidification processes are one of the most commonly used air conditioning applications for the cooling purposes. Natural circulation, forced circulation and induced draft cooling towers are used according to requirement as they have their own advantages and disadvantages. Natural draft towers have least operating cost and operate with natural circulation of air. Forced and induced draft towers need electricity for blowing or forcing air. Many investigators have studied and investigated cooling towers for mass and energy balance analysis and design aspect. [1-3] Work is also reported on thermal design of the cooling towers. Investigations are also reported on aspects such as optimization and performance enhancements of cooling towers. [4-6] Hyperbolic cooling towers are also investigated and still continue to be import area of research. [7-9] In the current investigations efficiency of forced draft cooling tower is analyzed. The calculation for material balance and column height is carried out with simple conventional equations.

EXPERIMENTAL SETUP

Experimental studies were carried out on cooling tower in chemical engineering department of DattaMeghe College of Engineering, Airoli.

Fig.1: Cooling tower

METHODOLOGY FOR FORCED DRAFT COOLING TOWER

Experiments were carried out at different temperatures and water flow rates.

Table 1: Inlet air readings

Q (mol/sec)	Wet bulb temp. (°C)(Tw)	Dry bulb temp. (°C)(Tg1)
12.5	27	30
11.11	21	26
10	29	30

Table 2: Outlet air readings

Q (mol/sec)	Wet bulb temp. (°C)(T_W)	Dry bulb temp. (°C)(T_{G1})
12.5	27	28
11.11	25	28
10	25	29

Table 3: Water inlet and outlet temperatures

Water inlet Temp. (T_{L1}) (°C)	Water outlet Temp (T_{L2}) (°C)
32	22
34	23
32	26

CALCULATIONS

Absolute Humidity (h):

From the psychometric chart the absolute humidity we get is:-

Inlet air humidity (h_1) =0.023 gm. of water vapour/m^3 vol. of air

Outlet air humidity (h_2) = 0.021 gm of water vapour/ m^3 vol. of air

Enthalpy (H):

$H_1=C_p\,(T_{G1}-T_o)+h_1\lambda$

Where

C_p= specific heat of water =4.19 KJ/kg℃

T_{G1} = inlet air dry bulb temperature $=\frac{30+26+30}{3}=28.67$℃

T_o=inlet air temperature =25℃

λ= latent heat of vaporization of water =2264.76 kJ/kg

$\therefore H_1$ = [4.19 X (28.67-25)] + (2264.96 X 0.023)

$\therefore H_1 = 67.47$ kJ/kg

$\therefore H_2$ = [4.199 X (28.33-25)] + (2264.96 x 0.021)

$\therefore H_2 = 61.51$ KJ/Kg

Efficiency$=\frac{H_1}{H_{s1}}$

= 67.47/104

= 0.6488

= 64.88%

Mass Balance:

$[L\ C_L X\ (T_{L2}-T_{L1})] = [G\ X\ (H_2-H_1)]$

Where,

L = water flow rate (ml/sec) = 11.2 ml/sec

C_L = Specific heat of water =4.19 kJ/kg

T_{L2} = water outlet temp (°C)

T_{L1} = water inlet temp (°C)

H_2 = Enthalpy of outlet air (kJ/kg)

H_1 = Enthalpy of inlet air (kJ/kg)

G = Air flow rate (m^3/sec)

$\therefore$ [11.2 $X10^{-3}$X 4.19 X (25.33-32037)] = [G X (61.51- 67.47)]

$\therefore$G = 0.0578 kg/sec

Packing Height (z):

Z = $H_G X N_G$

Where,

$$H_G = \frac{G}{k_{ya}\,XM_B} = \frac{0.0578}{8.25*10^{-3}*28.97} = 0.2418\ m$$

From Fig.2,

$N_G = 0.1575$
$\therefore z = 0.2418 * 0.1575$
$\therefore z = 0.0381\ m$
$\therefore z = 3.81\ cm$

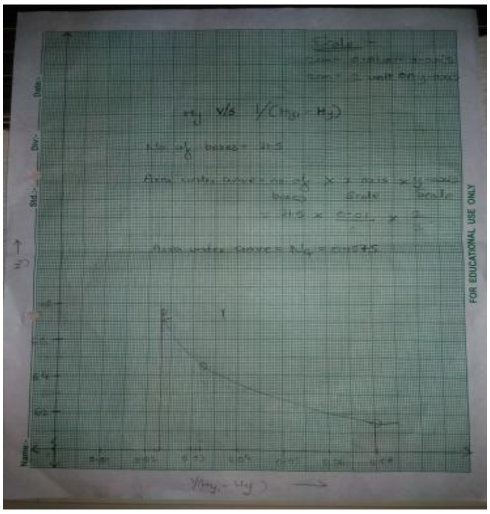

Fig. 2:H_y verses $1/(H_y{*}\text{-}H_y)$

RESULTS

Using the experimental data which we get from running our setup we calculate the following:
Absolute humidity of inlet air (h1) = 0.023 gm of water vapour/m^3 volume of air
Absolute humidity of outlet air (h2) = 0.021 gm of water vapour/m^3volume of air
Inlet air Enthalpy (H1) = 67.47 kJ/kg
Outlet air Enthalpy (H2) = 61.51 kJ/kg
Gas flow rate (G) = 0.0578 kg/sec
Packing height (z) = 3.81 cm

CONCLUSION

Efficiency of cooling tower was found to be 64.88 percent. The errors in measurements can be the reason for this. One more and important reason is the leakage in the tower. Though, efforts were made to minimize the leakage, still considerable error is caused in flow rate measurement and efficiency due leakage. Evaporative losses also cause loss in efficiency and significant error measurements.

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