(IJRST) 2016, Vol. No. 6, Issue No. I, Jan-Mar **e-ISSN: 2249-0604; p-ISSN: 2454-180X**

PERFORMANCE EVALUATION AND OPTIMISATION OF CROSS FLOW COOLING TOWER

***R.Immanual, **Dr.S.Rajakumar,**

**PG student: Department of Mechanical Engineering,*
Regional centre, Anna university Tirunelveli Region,Tirunelveli, India
*** Assistant Professor: Department of Mechanical Engineering,*
Regional centre, Anna university Tirunelveli Region,Tirunelveli, India

---

ABSTRACT

In this paper the cross flow cooling tower in DCW Limited was studied. The performance factors of the cooling tower analyzed by experimental data's and the thermodynamic analysis of it by using the first law of thermodynamics is carried out. Mathematical model based on heat and mass transfer principle is solved using stepwise integration method. The mathematical model is used to find the outlet condition of water and air, which will be further used in Energy analysis. Simulation on the tower is carried out to investigate its performance on variable conditions which not possible in experimental analysis in the plant. The model is validated with experimental results and error is within 3.6%. From this paper one can easily understand how to analyse the performance of cross flow cooling tower in industries using data recorded and by mathematical model.

Keywords: cross flow cooling tower; stepwise integration method; mathematical model; Energy analysis; experimental analysis.

INTRODUCTION

In Diesel power plant, the mechanical components in the engine section will damage due to high temperature at the working condition. This heat can be removed from this system. It will be done using oils. The heat extracted by the oil will also removed to the environment then only it will circulates again and cools the engine parts. To remove the heat from the oil, heat exchangers are used. In the heat exchanger, the water gains the removed heat from the oil. This water liberates its heat into the environment by direct contact with the air in the cooling tower. So many types of cooling tower available but here we see near by the description of cross flow mechanical induced draught cooling tower. In which the water spread on the splash fill material at the upper surface of the tower by means of nozzles, and the air contact with the water comes between louvers of the cooling tower so the water and air meet at right angles to each other. For induced draught system, the fan is located at the highest point of the tower. Ebrahim Hajidavalloo reference [1] predicts the thermal behavior of an existing cross flow tower under variable wet bulb temperature by a conventional mathematical model and the available fill characteristic curve of the tower. According to his prediction, the wet bulb temperature increases means the come near range of evaporation loss are decreases at constant dry bulb temperature. Montri Pirunkaset [2] in his studies he applied the stepwise integration method for two conditions. In first condition if we have in the mind of the inlet and outlet temperatures of water, flow rates of the entering water and air, and the inlet wet bulb temperature are known means it is possible to calculate the value of the volumetric heat transfer co-efficient. In the second condition if we know the volumetric heat transfer co-efficient for the entire fill, the flow rates of the entering air and water, the inlet dry bulb and inlet wet bulb temperatures and the hot water temperature are known. We can predict the outlet water temperature and the outlet air temperature. Tawsif Mahmud [3] studied experimentally the heat transfer phenomena between water and air by direct contact in a cross flow cooling tower model. Their experiments were conducted in a splash type packing of 10inch high and consist of four stages. Each packing provides 11.5inch x 1.75inch cross section area. He gives the experimental setup and procedure to support out the analysis. From his observations the range of the cooling tower increases with the increase of air velocity approach decreases with the raise in air velocity. Evaporation loss increases with the increase of air velocity. Cooling capacity increased slowly with the increase in air velocity. Xiantai wen [4] develops a correlation expression of the heat transfer co-efficient by regression method using experimental study of cross flow heat source tower. At validation of this correlation, which gives only 3% of error according to his studies both airflow and liquid flow rate have significant effect on heat transfer co-efficient, however the influence of inlet air temperature and inlet liquid temperature is small. A.S. Pushnov [5] determines the effect of the pressure drop coefficient of regular film – droplet – film and droplet type packing has on the efficiency of the return water-cooling process in cooling tower. According to the Sunil [6] studies, a suitable water distribution across the plane area of the cooling tower can increase efficiency of natural draft cooling towers in the performance of cooling tower increases when the packing is vertically oriented. M.Prasad [7] presented the method to take the place of the fill in cooling tower by economic way. In his studies he analyze all the individual cell half in a multi-cell cross flow cooling tower and predicts its present fill characteristic's then find the deviation between the fill characteristic's at the design stage to present stage. If the deviation is more the fill is replaced. Mushtaq Esmael Hassan [8] express similarities in the thermal performance of existing counter flow-cooling tower with the new design cross flow cooling tower. This comparison evaluated at distinct operating conditions such as variation's of weather, different water to air flow ratio. The results show that the cross flow-cooling tower has high performance in the heat transfer process. However, it requires large size compared with existing counter flow tower. Arash [9] studied a new type of cooling tower with rotational splash type packing. In which the thermal performance of cooling tower with and without rotational packing's are compared according to this study when increasing packing rotational velocity cooling water range, heat rejected from water, tower characteristics are increases, but it does not attract the water evaporation rate significantly. Eitidal-Al-Bassam [10] studies the cooling tower present in the Airport commercial building at the Kuwait International Airport. According to this variable frequency drive can satisfy the variable load requirements and thereby, consume minimum energy of the cooling tower fan motors. Fisenko [11] presented a new two dimensional mathematical model of the performance of a cross flow cooling tower. From the analysis, it's found that the main parameter which affects the thermal efficiency of cross flow cooling tower is the average droplet radius. R.Shakeri [12] predicts the thermal behaviors at the cooling tower in Khuzestan steel company under the present operating conditions by using the two mathematical models. One is the conventional Merkel model and the other is Halasz's model comparing the mathematical model results with the experimental results, which shows that Halasz's model gives more accurate predictions for high flow ratio cell half but the Merkel prediction for all cell half are reasonable. Thirapong Muangnoi [13] presented performance characteristics of a new type of water-jet cooling tower using experiments and numerical simulations. This characteristic predicts that the energy and second law efficiency are normally sensitive to reasonable variation in droplet diameter. Water to airflow rate ratio and tower spray zone neigh but do not respond greatly to reasonable variation in droplet velocity and air velocity. This tower use a high pressure water spray nozzle to induce a co-current air steam into the tower so that neither fill nor fan are required. J.C. Kloppers [14] presented how to solve the governing equations of the cross flow evaporative process which are derived from first principles according to the Poppe, Merkel and e-NTU methods. Ravindra Kirar [15] presented a CFD analysis of induced draught cross flow cooling tower at three different inlet angles. From this when the air inlet angle decreases the effectiveness will be decreases. Pushpa B [19] evaluates the performance of thermal power station cooling tower. According to this if the inlet air temperature is higher means the evaporation rate will also increases and inlet water temperature increases the rate of heat loss will also increases. Lilian Mello [21] presented mass transfer coefficient as function of the air and water flow rates. This correlation formed by using a pilot study of cross flow cooling tower with nominal capacity of 90kw and GRT package (polypropylene grid fill block).H. Inazumi[22] proposes the mean enthalpy driving force in a cross flow cooling tower calculated by a graphical method. He also gives one numerical example of the calculation.

DATA'S COLLECTED

The site selected for this project is DCW limited Captive power plant, at Sahupuram in Tuticorin district of Tamilnadu in India. In this a Mechanical draught Cross flow cooling tower with two cells is present. So, data required for assessment of performance is taken from this tower. Data on inlet air temperature, inlet water temperature, airflow rate, water flow rate relative humidity were collected from the tower for calculation of range, approach, effectiveness, percentage of water loss. For this Calculations Formulae used from basic cooling tower formulae [26].Mass flow rate of water and air are 90 kgs^{-1},70kgs^{-1} respectively.

Sr. No.	DATE	TIME	(T_{wi})(°C)	(T_{wo})(°C)	(T_{di})(°c)	RH (%)
01.	10/09/2015	11.00am	47	33	36	54
02.	10/09/2015	02.00pm	48	33	36	53
03.	10/09/2015	04.00pm	48	32	36	53
04.	10/09/2015	08.00pm	46	32	34	60
05.	15/09/2015	05.00am	52	33	27	71
06.	15/09/201	10.00am	54	34	36	49

	5					
07.	15/09/2015	04.00pm	56	34	35	51
08.	15/09/2015	11.00pm	52	33	27	71
09.	16/09/2015	11.00am	53	34	37	49
10.	16/09/2015	02.00pm	53	34	38	45
11.	16/09/2015	03.00pm	53	33	27	69
12.	16/09/2015	05.00pm	53	33	27	70

Table 1 Collected Data

TOWER CHARACTERISTIC RATIO

In general, the cooling tower performance assessed in terms of the Tower characteristic ratio [18]. For most of the cooling tower this ratio is given by its vendor. For this cooling tower this ratio is not present. If we know the tower characteristic ratio then only we can proceed into the mathematical modeling. Tower characteristic Ratio is determined from Tower Thermal Design formula using the present conditions mostly. From the [17] formulae the characteristic value find as KaV / L = 1.96624.This Tower characteristic ratio value is for counter flow working at this configuration. To calculate cross flow tower characteristic from the counter flow characteristic using Fujita [24] relation, The cooling tower characteristic value as 2.2438.This value can be acceptable Range according to the Hasalaz [23] and Experimental Study of Mohamed [16][20].

MATHEMATICAL MODELING

Mathematical modeling for this cross flow tower is based on stepwise integration method [27]. For this analysis the Fill material is divided into number of cells according to number of water passages and air passages to the tower. When the value is known for KaV for the entire fill, the flow rates of the entering air and water, the inlet dry bulb and inlet wet bulb temperatures and the hot water temperature are given, it is possible to predict the outlet water temperature and the outlet air Enthalpy by the stepwise integration method. However, the procedure for prediction of the outlet temperatures of the water and air requires an iterative calculation. A cross-flow cooling tower can be divided into n cells. Water enters the top of the fill at an inlet temperature and flows through the nozzles, while air enters the left side of the fill.If the divided air passages (m) and the divided water passages (n) were known, a value of KaV for each cell can be calculated using Equation 4. For this tower the fill divided into four water passages and three air passages Therefore, the total number of cells present is twelve.

$$(KaV)_{cell} = \frac{KaV}{m.n} \qquad (01)$$

The energy balance in the first cell,

Water Side: $\dot{Q} = L_{cell} \times C_w \times (T_1 - T_{1,5})$ (02)

Air Side: $\dot{Q} = G_{cell} \times (h_{1,2} - h_{ainlet})$ (03)

$$\dot{Q} = (KaV)_{cell} \times \left(\frac{(h_{si} + h_{so})}{2} - \frac{(h_{ainlet} + h_{1,2})}{2} \right) \quad (04)$$

The enthalpy of the saturated air can be calculated from ,

$h_s = 4.7926 + 2.568T - 0.029834\,T^2 + 0.0016657\,T^3$ (05)

Outlet air enthalpy of cell can be calculated from,

$$h_{1,2} = \frac{G \times h_{ainlet} + 0.5 \times (KaV)_{cell} \times (h_{si} + h_{so} - h_{ainlet})}{0.5 \times (KaV)_{cell} + G} \quad (06)$$

The outlet water temperature of the first cell can be calculated from,

$$T_{1,5} = T_1 - \frac{G \times (h_{1,2} - h_{ainlet})}{L \times C_w} \quad (07)$$

Using these formulae how to predict the outlet conditions of Water and air is given in the flow chart, using Excel spreadsheet follow the flow chart easily predicts the outlet conditions of water and air.

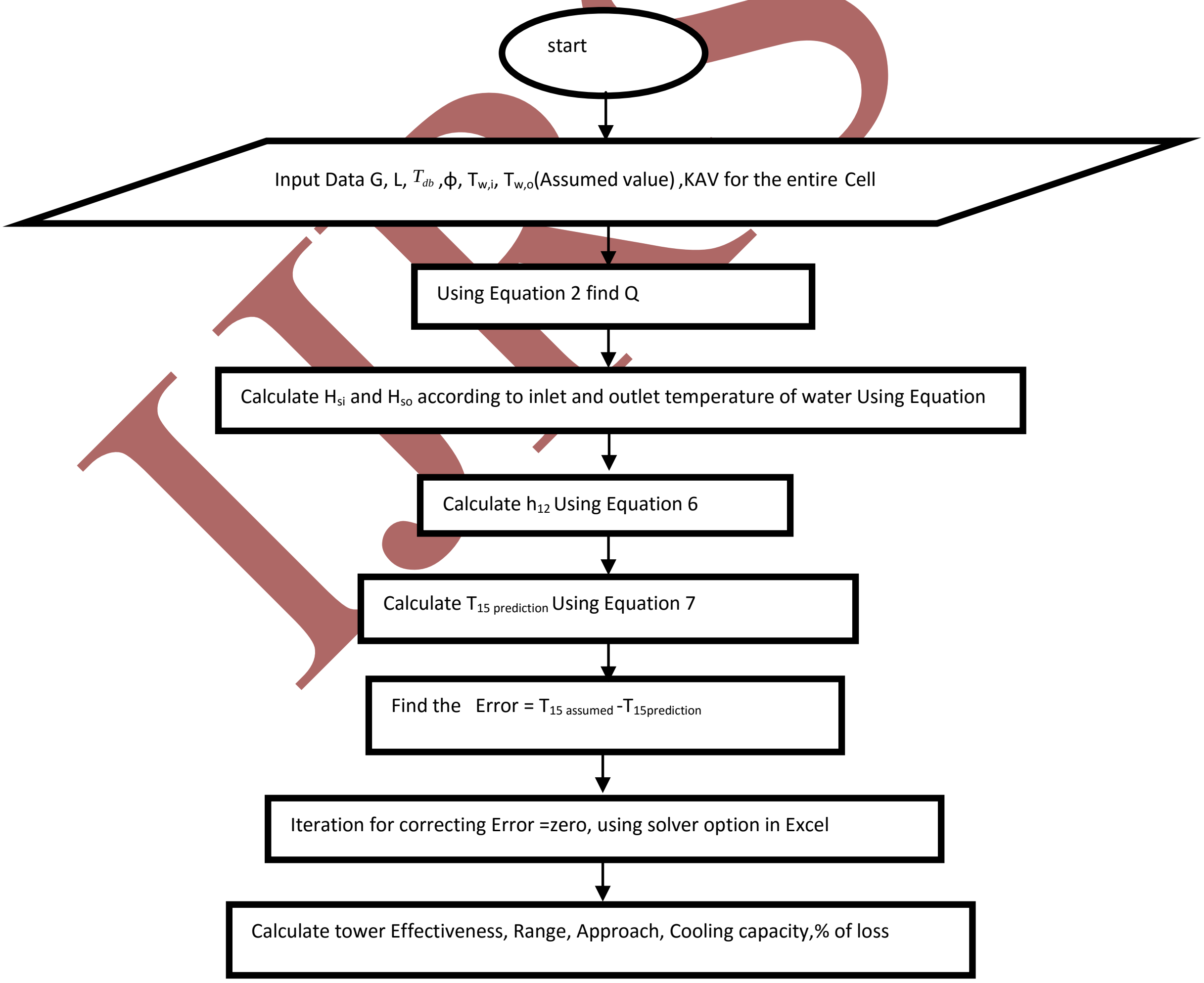

Figure 1 Flowchart for mathematical modeling

(IJRST) 2016, Vol. No. 6, Issue No. I, Jan-Mar e-ISSN: 2249-0604; p-ISSN: 2454-180X

RESULTS AND DISCUSSION

From the experimental analysis from figure 1, when the relative humidity increases the effectiveness decreases. Figure 2, shows that the variation of effectiveness according to inlet water temperature the randomness of the graph is due to the variation of the environmental condition at the site. In figure 3 shows that in most of the cases when the inlet air-dry bulb temperature increases the water, evaporation rate also increases, when the air relative humidity increases the water evaporation rate decreases. Figure 4 shows the results from mathematical model, which show the variation of outlet water temperature according to inlet water temperature at different flow ratio’s from this we can understand that at low flow ratio the outlet water temperature is low at higher flow ratio the outlet water temperature will be high. Figure 5 shows the variation of percent loss of water according to inlet water temperature it shows that at low flow ratio the percentage of loss of water lower compared to high flow ratio. When the inlet water temperature increases the percentage of water loss also increases. Figure that at low flow ratio, the cooling tower will give more effectiveness. When the inlet water temperature increases the effectiveness slightly increases.

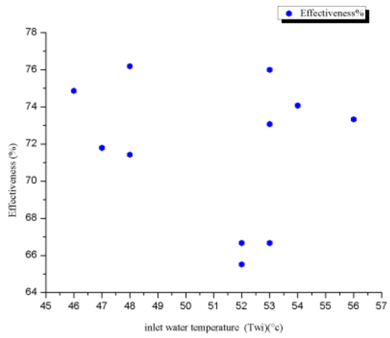

Figure 2 Experimental analysis results between tower Effectiveness and Relative humidity

Figure 3 Experimental analysis results between tower Effectiveness and

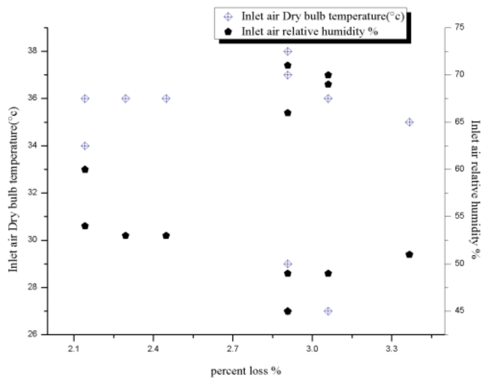

Figure 4 Experimental analysis results between Inlet dry bulb temperature, Inlet air Relative humidity and percent of water loss

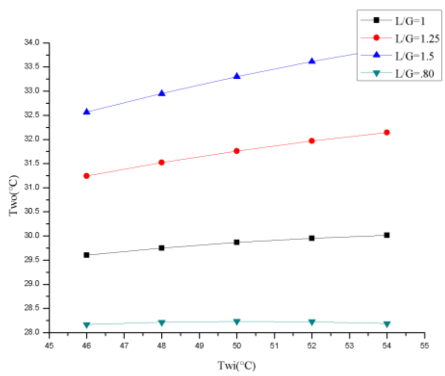

Figure 5 Model Results between inlet water temperature and outlet water temperature at different flow ratio

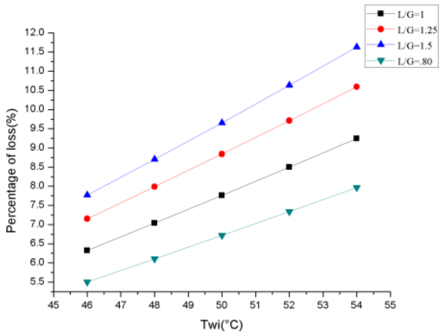

Figure 6 Model Results between inlet water temperature and Percentage of water loss at different flow ratio

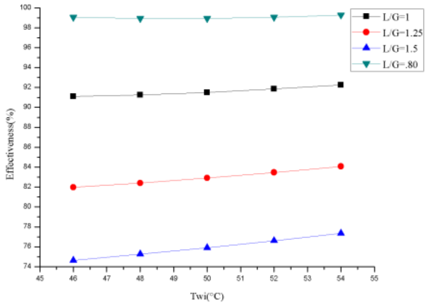

Figure 7 Model Results between inlet water temperature and Effectiveness at different flow ratio

CONCLUSIONS

Performance of DCW limited power plant analyzed by experimental collected data at site operation. That shows that at the present condition it will give best effectiveness at low relative humidity, high wet bulb temperature and it slightly depends on inlet water temperature. To reduce the Water evaporation increase wet bulb temperature, at constant wet bulb decrease the dry bulb temperature, increase the relative humidity. From the collected data, the tower characteristic ratio calculated. Mathematical model is used to predict the performance of cooling tower, which cases not done in experimental analysis. That model is validated and it shows that only 3.6% Error occur. From that model, Outlet temperature decreases at low flow ratio and at low inlet water temperature, Percentage of water loss is decreases at low flow ratio and at low inlet water temperature and Effectiveness increases at low flow ratio and at high inlet water temperature are predicted.

REFERENCES

R. Shakeri, E. Hajidavalloo, M. A. Mehrabian,"Thermal performance of cross flow cooling towers in variable wet bulb temperature", International Journal of Energy Conversion and Management,vol. 51, no. 6, pp. 1298-1303, 2010.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

Montri Pirunkaset,Simulation of a "Counter-Flow and Cross-Flow Cooling Tower by the Stepwise Integration Method",Kasetsart J. Nat. Sci 2010;44:972-981.

T. Mahmud, Md. K. Islam,B.Salam, "Experimental study of forced draft cross flow wet cooling tower using splash type fill", International conference on Mech Eng and Renewable Energy(ICMERE)2013.

X. Wen, C. Liang, X.Zhang, "Experimental study on heat transfer coefficient between air and liquid in the cross-flow heat-source tower".Building and Environment 2012;57:205-213.

A.S. Pushnov, "The Effect the Pressure Drop of Regular Packings Has on the Return Water Evaporation Cooling Efficiency in Cooling Towers".Therm Eng 2013;vol.60,no.6,pp.426-428.

S. J. Kulkarni, A. k. Goswami, "Studies and Experimentation on Cooling Towers: A Review". International Research journal of Eng and Tech Aug 2015;vol 2:279-282.

Prasad M. "Economic upgradation and optimal use of multi-cell cross flow evaporative water cooling tower through modular performance appraisal".Appl Therm Eng 2003;24:579–93.

M. E. Hassan, K. H. Gubban, "A comparison between the counter and cross flow cooling tower for thermal power plants", Journal of university of Thi-Oar June 2006;no.1,1vol 2:15-22.

A. M. Lavasani, Z. N. Baboli, M. Zamanizadeh, M.Zareh, "Experimental study on the thermal performance of mechanical cooling tower with rotational splash type packing", Energy Conversion and Management 2014; vol 87:pp 530-538.

E. Al-Bassam,"The Impact of Installing Variable Frequency Drives for Cooling Towers in Kuwait on Energy Consumption",2015:535-539.

S. P. Fisenko, A. A. Brin, "Simulation of a cross-flow cooling tower performance", International Journal of Heat and Mass Transfer 2007;vol 50: 3216-3223.

R. Shakeri, M A Mehrabian, E. Hajidavalloo,"Thermal and fouling characteristics of cross-flow wet cooling towers under mixed weather conditions",Part E:J. Process Mech Eng 2009;vol 223:215-224.

T. Muangnoi, W. Asvapoositkul, P. Hungspreugs, "Performance characteristics of A Downward Spray Water-Jet Cooling Tower", Applied Therm Eng 2014,doi:10.1016/j.applthermaleng.2014.04.019.

J. C. Kloppers, D.G. Kroger, "A critical investigation into the heat and mass transfer anlaysis of crossflow wet-cooling towers".Numerical Heat Transfer, Part A, 2004;46:785-806.

R. Kirar, D. Vaghela, H. Patel, "Optimization of Air Inlet For Increase The Effectiveness Of Induced Draught Cross Flow Cooling tower", International Journal of Engineering Research and Technology 2013;vol 2:1-4.

M M Abo Elazm, A F Elsafty, "Theroretical and Experimental study of a cross-flow Induced-Draft cooling tower", Thermal Science 2009;vol 13.no.4:pp 91-98.

Ronak Shah, Trupti Rathod, "Thermal Design Of Cooling Tower", International Journal Of Advanced Engineering Research And Studies, vol.1,pp.26-29/April-June,2012.

Mohiuddin AKM, Kant K. Knowledge base for the systematic design of wet cooling towers. Part II: fill and other design parameters. Int J Refrig 1996;19(1):52–60.

Pushpa B. S, Vasant Vaze, P. T. Nimbalkar, "Performance Evaluation Of Cooling Tower In Thermal Power Plant - A Case Study Of Rtps,Karnataka", International Journal Of Engineering And Advanced Technology , vol.4, no.2, pp.110-114,December 2014.

E. T. White, G. P. Lees, R. Broadfoot, "Performance model for cross-flow cooling towers". Proc.Aust.Soc.Sugar Cane Technol., 2000;22:474-481.

L. Mello, T. Song, J L de Paiva, "Management of a cooling Tower System by Experimental Characterization".

Inazumi H, Kageyama S. A successive graphical method of design of a cross flow cooling tower.chem Eng Sci 1974;30:717-21

Halasz B. Application of a general non-dimensional mathematical model to cooling towers. Int J Therm Sci 1999;38:75–88.

(IJRST) 2016, Vol. No. 6, Issue No. I, Jan-Mar e-**ISSN: 2249-0604; p-ISSN: 2454-180X**

Fujita, T.,Tezuka,S. Calculations on Thermal performance of mechanical draft cooling towers ASHRAE Trans (1986) 92 274-287)

Hasegawa, Cooling tower Thermal design mannual,cooling tower Technical site for Daeil aqua co.,ltd.for cooling tower Engineers,Operators and purchasers.

Coolingtowers Bureau of energy efficiency, available on www.bee-india.nic.in

Stoecker, W.F. and J.W. Jones. 1983. Refrigeration and Air Conditioning. 2nd Edition. TATA McGraw-Hill Publishing Company Ltd., New Delhi.443 pp.