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Choices to Decrease Cooling Tower Water Wastage in Fertilizer Plants (Lagging KPIs)

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Abstract

Water recognizes our planet gap with all the others we think about. There are numerous districts where our freshwater assets are lacking to meet natural needs and thus we all associated with inquire about discover approaches to evacuate these imperatives. We face various difficulties in doing that, particularly since 1965, the paper Water reserve Exploration has assumed a significant profession in revealing and scattering existing study. This paper recognizes the issues confronting water today and future research expected to more readily advise the individuals who endeavor to make a progressively manageable and attractive future. In fertilizer lagging key performance indicators at cooling tower water wastages addressed by experimentally to overcome the evaporation, blow-down and make-up water losses from maximum (576) to minimum 288 level to promote environment sustainability.

Key words: water resource Management; cooling tower; make up water; evaporation rate; blow-down; water conservation.

1. Introduction

Intact at main thesis paper title " Assessment Lagging Performance Indicators of cooling Tower Water Wastage at Refiner (Parco) and Possible up-gradations to Eco Design for water Conservation" Chances to advance the cooling water framework can be found in decrease of cooling water necessities, in improving the productivity of the cooling water treatment, and in improving the cooling tower plan.

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Generous reserve funds can be accomplished through a point by point examination of the cooling water circle and its clients. The target of this paper is to feature the favorable circumstances and burdens of various alternatives to limit cooling water utilization. Moreover, fixed and variable expenses are assessed to break down the effect of these adjustments. In Pakistan and different countries, individuals are doing combating over the issue of water insufficiency while three-fourths of the earth is included by water. Because of the water deficiency, individuals spur us to monitor water and save the earth, life. The study of different researcher trying to mitigate the future generation water crisis as the prediction concept accepted concept developed by Merkel 1925 [8] the Author at its first research paper focused at future concern water crisis i.e. Contribute, feel and realizes the needs to control the water losses at different industries refinery, Fertilizer power plant and Construction. Water consumed in huge amount in the form of Cooling tower where losses are greater than recycling. In 1995 new development in air cooled steam condensing [8] and state water resources control board SWRCB 1975. The water conservation under guidance of $\in$co advance approaches Baker, D [1] at Evaporation section by Control of different water behavior changes. The relations up b/w air and water vapor, Enthalpy Curve indicates the massive amount of water conservation at major industrials (Fertilizers, Refinery) 40 million m3/year as compared to refinery for Environment Sustainability. Many assumptions and approximation were used to simply the development of the final Eco approached phenomena of Evaporation losses. It has been tried do minimize the intent of obtaining Error using the modification where as accuracy may be Scarified probably not understood. The reason is steps do arrive at final decision as the objective is to point out desired limits of accuracy after conducting test trial to determine what accuracy is attained i.e. degree of precision. The method developed to overcome the difficulties. In [8] Merkel. The evaporation losses neglected i.e. not Considered conservative while Zivi et at [15] Consider Evaporation losses, so Reference [9] and pastor [10] mollified, analyzed Markel [8] model at accuracy level. Reference [14] also consider water losses at Cooling Avower of water circulation system later on discussed by [6] i.e. include NTU methods and compare NTU models So in Collusion water outtet temperature of cooling tower [8] Markel model is used while for heat transfer (accuracy). Reference [4] proposal is more effective for counter flow cooling towers. Evaporation losses under equilibriums of air with water i.e. reformulated NTU under non linearity of humidity ratio and Enthalpy Curve by cheng-Qin and his colleagues [3]. The factor (0.9) Lewis [7] and Simpson Sherwood [13] Correlated experiment. So heat transfer is due to latent heat i.e. 60% Prasad [12] flow eT. It has been observed by different scientist (researcher) developed mathematical model for prediction the performance of lagging indicators of cooling tower water wastage. Analytical model the author keeps in mind the correlation of mass transfer, heat transfer coefficient and thermal, moisture effectiveness i.e.

$$\mathrm{ET}=\frac{\mathrm{Tair\ Out}-\mathrm{Tair\ Inlet}}{\mathrm{Twateranlet}-\mathrm{Tair\ Inlet}}$$

The Evaporation rate related as heat load at tower $Qtower$ i.e. equal to head load on the condenser $Qcond$

$$Qtower = Qcond = \mathrm{Wcire\ x\ Cp\ x\ (Th\text{-}Tc)}$$

$$\mathrm{Wevap} = Qtower\ \frac{Flatent}{hfg}$$

hfg = Latent heat of vaporization ($^{Btu}/_{lbm}$)

Flateut = fraction of total heat (0.9)

It has been observed that evaporation loss increases with increase in air flow rate. This indicates that at high air flow rate, the ambient the air-water interface rapidly. Therefore reducing the humidity gradient between interface and ambient air and by maintaining a higher potential for mass transfer, it is found that increasing the mass flow rate increase the evaporation loss also evaporation loss increase by increase in water temperature. So it means partial pressure of water is dependent on the temperature and consequently higher potential for mass transfer i-e increases evaporation loss. While evaporation loss decrease with increase in air specific humidity ratio, this happen because higher humidity ratio implies higher vapor pressure of air and consequently lower potential mass transfer, water loss by evaporation increases with longer water flow rate due to high water flow rates there will be less reduction in water temperature as driving potential for mass transfer is high. So remember ambient air temperature doesn’t have effect on the evaporation loss as shown in figures. We should change our negative behavior patterns into constructive ones and spread mindfulness among individuals about the significance of clean water. We should advance the less use and sparing of clean water to keep up the progression of life on the earth. Earth is the main known planet right now life is conceivable simply because of the accessibility of water and oxygen. Water is most significant need of life for all the living creatures on the earth. Without water nobody can exist in any event, for a day. We additionally realize that there is less level of clean water implies drinking water accessible on the earth. Ecological Frameworks Investigation is an orderly research of the effect of human activities on the earth and environments. It comprises of the methodology of logical inquiry utilizing numerical strategies and models inside the structure of a systematized logical way to deal with taking care of complex issues.

1.2 Research Question

1. What materials are used in the cooling system, temperature, flow rate and operating hour?
2. What is the source water quality?
3. What is the treatment system if source quality is problematic?
4. How can the optimal concentration period be calculated in order to reduce water and chemical use?
5. What potable water back up is?
6. What is the monitoring system of make-up and blow-down water quality?
7. What are desired performance factors for cooling tower? 1-chemical doing, 2- cycle of Concentration (COC).

2. Material and Methods

Moisture air is a binary mixture of dry air and water vapor. The amount of water vapor in the moisture air varies from zero (dry air) to a maximum that depends temperature and pressure. The later condition refers to saturation. The equilibrium between moisture air and condensed water phase. The molecular weight of water is 18.01528. The gas constant for water vapor is 1545.32/18.01528=85.778ft bf/lbR the gravity is assumed

32.1740ft/sec2

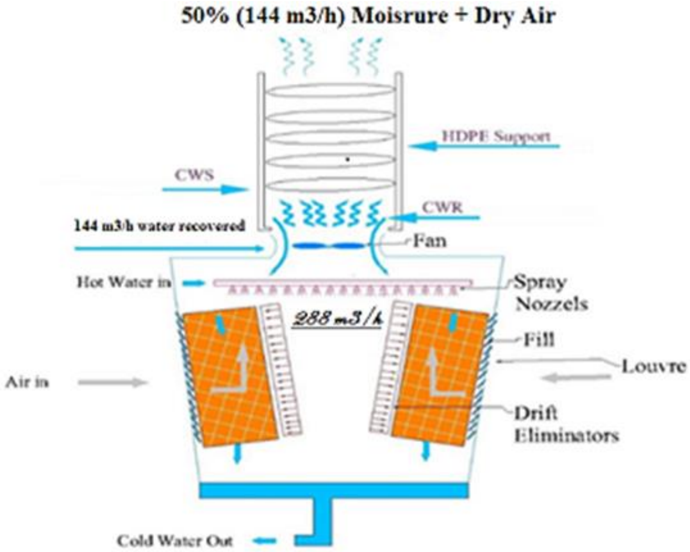

Figure 1: Advance Eco Approach

The cooling tower outlet exhaust contains 288m3/h water contents that Being waste into atmosphere, author in his previous paper recovered. These evaporation losses into 50% by applying or considering the exhaust in natural cylinder which contain cooling water supply of cold water inside the tubes, condensation and humidity differences from saturation to dry with the help of cooling coils and natural draft, the recovered vapors size increased and return at inlet cooling water hot distribution channel to increase the CT efficiency of water conservation and helping to achieve outlet water temperature of CT. the phenomena explained below mathematical calculations.

Humidity ratios = ratio of mass of H_2O vapor/ratio of mass of dry air

Specific humidity = mass of H2O vapor/total mass of the moisture air

Absolute humidity = mass of H_2O vapor/total volume of moisture air

Saturation humidity = moisture humidity/

Degree of saturation = air humidity/saturated air humidity

Relative humidity = mole fraction of H_2O vapor/mole fraction of air saturated

Enthalpy of moisture air = partial enthalpy of dry air + saturated water vapor

Air specific volume=1/air density=1/0.0723lb/ft3=13.8224ft3/lb dry air

So here RH is zero relative Humidity (dry air condition) so k=heat transfer coefficient

3. Heat & Mass Transfer

$Q = K \times S \times (h^W - h^a)$ ....1 [8]

For mass evaporation of small portion of water & sensible heat transfer b/w the air and H_2O in a counter flow cooling tower.

Total Heat Transfer Btu/h

K= overall enthalpy transfer coefficient $lb/hr.ft^3$

S= heat transfer surface= $(a \times v)\,ft^3$ =area of transfer surface x effective tower volume

$h^W = enthalpyofair - watervapormoisture..atbulkwatertemperature\,Btu/lbdryair$

$h^a = enthalpyofair - watervapormoistureat$
$WBT\ Btu/\ lbdryair$

So equation 1 can be written as

$$dQ = d\left[K \times S \times (h^w - h^a)\right]$$

$$= K \times (h^w - h^a) \times ds$$

The heat transfer rate from water side

$Q = C_w \times L \times Range$ Where

$C_w =$ Specific heat of water=1

$L =$ Water flow rate therefore

$$dQ = d\left[Cw \times L \times (t_{w2} - t_{wl})\right]$$

$$dQ = Cw \times L \times dtw$$

So the heat transfer rate from air side is

$$Q = G \times (h_{a2} - h_{a1})$$

Where G=air mass flow rate

Than

$dQ = d[G \times (h_{a2} - h_{a1})]$ so

$dQ = G \times dha$ Than the relationship of

$$K \times (h_w - h_a) \times ds = G \times dha \mapsto or = K \times (h_w - h_a) \times ds$$

$dQ = Cw \times L \times dtw$ Are than

$$K \times ds = G \times (h_w - h_a) \times dha \times ds$$

$$K \times ds = Cw / (h_w - h_a) \times dtw$$

By integration $S = a \times v = av$ so by putting

$$KS / L = Kav / \ L = \frac{G}{L} f_{ha1}^{ha2} \, dh / \ h_w - h_a$$

$$\frac{Ks}{L} = \frac{Kav}{L} = Cw \times f_{tw1}^{tw2} \frac{dtw}{h_w - h_a}$$

NTU=Number of Transfer unit

$$NTU = Range \times \frac{Averageof}{h_w - h_a}$$

$$NTU = Range \times \left[sum \times (\frac{1}{hw - ha}) \ /4 \right]$$

$= f_a^b ydx = \frac{(b-a) \times (Y1 + Y2 + Y3 + Y4)}{4}$ Where

$$y1 = a + 0.1(b - a) = Cwt + 0.1 \times Range$$

$$y2 = Cwt + 0.4 \times Range$$

$$y3 = Cwt + 0.6 \times Range$$

$$y4 = Cwt + 0.9 \times Range$$

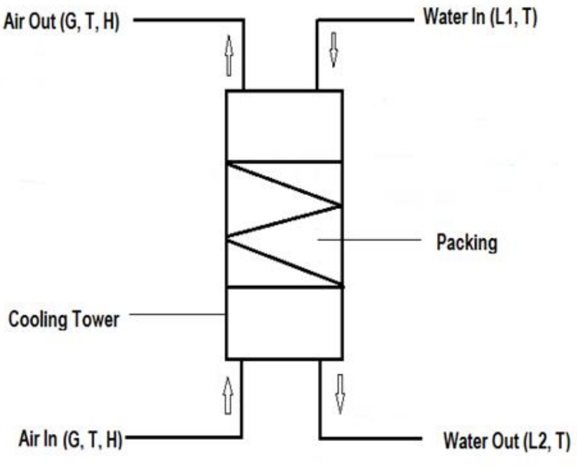

Figure 2: Heat and Mass Balance

For

$$\frac{Kav}{L} = Cw \times f_{tw1}^{tw2} \frac{dtw}{h_w - h_a} =$$

$$(tw2 - tw1) \times \left[\frac{\left(\frac{1}{dh1} + \frac{1}{dh2} + \frac{1}{dh3} + \frac{1}{dh4}\right)}{4} \right]$$

$$dh1 = value \times of \times (h_w - h_a) = Cwt + 0.1 \times Range$$

$$dh2 = Cwt + 0.4 \times Range$$

$$dh3 = Cwt + 0.6 \times Range$$

$$dh4 = Cwt + 0.9 \times Range$$

$$Heat \times In = Heat \times Out$$

$G =$ Mass Flow Rate of dry air

$L =$ Mass Flow Rate of Water

$G =$ Air Enthalpy of air

Water Heat In + Air Heat In = Water Heat Out + Air Heat Out

$$Cw \times L2 \times W_2 + G \times h_{a1}$$
$$= Cw \times L1 \times t_{w1} + G \times h_{a2} ....1$$

The difference between L2 [entering H_2O Flow rate] and L1 [leaving H_2O Flow rate] is a loss of water due to evaporation in the direct contact of H_2O and Air This evaporation loss is a result of difference in the H2O Vapor Content b/w air inlet and air exit of cooling tower evaporation loss is

$G \times (W_2 - W_1)$ Equal to $L2 - L1$ Therefore

$$L1 = L2 - G \times (W_2 - W_1) ....2$$

So by Putting the Value of Equation 2 to Equation 1

$$Cw \times L2 \times tw_2 + Gha_1$$
$$= Cw[L2 - G \times (W_2 - W_1) \times tw_1 + Gha_2]$$

Is so simplifying

$$Cw \times L2 \times (tw_2 - tw_1)$$
$$= G \times (ha_2 - ha_1) - Cw \times tw_1 \times G \times (W_2 - W_1)$$

Finally so $G \times (W2 - W1) = 0$ assumption

$Cw \times L2 \times (tw_2 - tw_1) = G \times (ha_2 - ha_1)$ Or

$Cw \times L \times (tw_2 - tw_1) = G \times (ha_2 - ha_1)$ So Enthalpy of exit air is

$ha_2 = ha_1 + Cw \times \frac{L}{G} \times (tw_2 - tw_1)$ Is obtained so value of specific heat of water is tw_2 Entering Water Temperature- tw_1 (leaving water temperature) is called cooling range

Simply

$$ha_2 = ha_1 + \frac{L}{G} \times Range ....3$$

4. Tower Demand and Characteristics Curve)

First we can calculate the water to air ratio at water flow rate of $30{,}000 m^3 / hr$ [GPM (500/60)] lb/mint

Water at 60F (C) to 8.34538pounds and 500 obtained from 8.34523x60=

Air flow rate=Acfm/specific volume=1600,000/14.3309=111,646.76 lb/mint (specific volume@87.8F, RH 80% =14.3309ft/lb

$$Ratio = \frac{L}{G} = \frac{H2O \times Flow \times Rate}{Air \times Flow \times Rate} = \frac{166{,}666.67}{111{,}646.76} = 1.4928$$

The Ratio of L/G Is called slop

We know $y = a + b \times x$ where

$b = \frac{L}{G}$ and $a = ha_1$ and $x = Range$

So from Graph

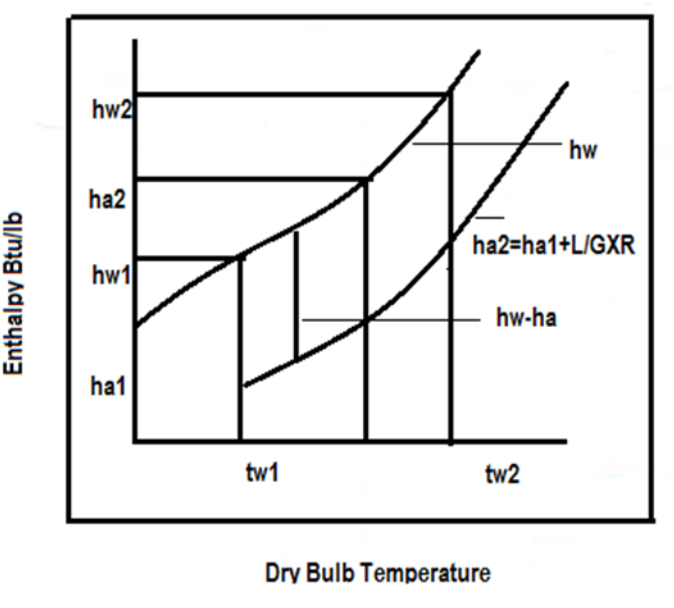

Figure 3

Enthalpy differences (HW-HA) Vz Temperature differences of exit Air (tw2-tw1)

We can calculate the enthalpy of air at given data RH=80% ambient WBT=82.4F, L/G=1.4928 tw2=107.6, tw1=89.6F, ha1 at 82.4F WBT=46.3624Btu/lb dry air

$Range = tw2 - tw1 = 107.6 - 89.6 = 18F$ So

$ha_2 = ha_1 + \frac{L}{G} Range$ So putting value at equation

$$= 46.36 + 1.4928 \times (18) = 73.2328 \frac{Btu}{lb \times dryair}$$

So at 73.2328 temperatures is 100.8F

By comparing number transfer unit (NTU) to water side and Air side the enthalpy difference will be calculated and the sum of all the total demand (NTU) will be calculated.

Table 1

WATER SIDE			**AIR SIDE**		
Description	**tw-F**	**hw-Btu/lb**	**Description**	**ha-Btu/lb**	**Enthalpy Diff**
tw1+0.1xR	90.50	56.64	ha1+0.1xR	47.25	0.1065
tw1+0.4xR	95.00	63.34	ha1+0.4xR	54.68	0.1154
tw1+0.6xR	98.00	68.2591	ha1+0.6xR	59.62	0.1159
tw1+0.9xR	102.50	76.4013	ha1+0.9xR	67.04	0.1069
Sum of enthalpy difference is (hw-ha)					0.4447

Than total NTU=Range x Sum (1/hw-ha) = 1.6677

So $\frac{Kav}{L} = C(\frac{L}{G})^{-m} ----4$

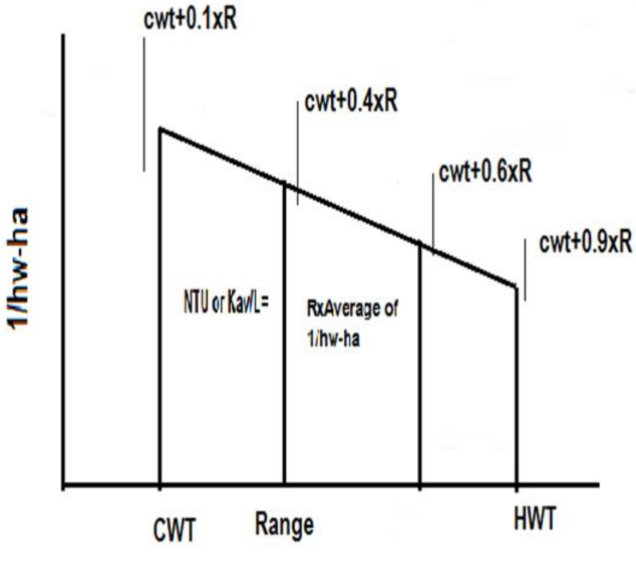

Figure 4

$$\frac{L}{G} = 1, \ldots\ldots C = Cons\tan t,$$
$$\ldots\ldots.m = \exp onent(-0.5to - 0.8)$$

Or $\frac{L}{G} = \frac{dha}{Cw \times (tw_2 - tw_1)}$

For the calculation of exponent at given value of water and air m= - 0.8

$$R = H_{WT} - C_{WT} = 104 - 89 = 15F$$

5. Cooling Tower Performance Variables

$$L1 = 16000 \times \frac{500}{60} = 133{,}333.3 lb/ \ \min$$

Heat Load $= L1 \times R1 = 133{,}333.3 \times 15 = 2000{,}000 \frac{Btu}{\min}$

Air mass flow rate G1= 80,848 lb/min

$$\frac{L}{G1} = L1/G1 = 133{,}333.3/80848 = 1.6492$$

L2=20,000X500/60=166,666.7lb/mint

Heat load D2=D1=2000, 000 Btu/mint. Air mass flow rate G2=G1=80,848lb/mint

$$\frac{L2}{G2} = \frac{166{,}666.7}{80848} = 2.0615$$

$$R = \frac{D2}{L2} = \frac{2000{,}000}{16{,}666.7} = 12F \rangle OR(R1 \times \frac{L1}{L2})$$

So Equation 4 can be written as

$$\frac{Kav}{L} = C(\frac{L}{G})^{-m}$$

$$\frac{Kav}{L} \times (\frac{L}{G})^{m} = C = 1.4866 \times (1.6492)^{0.8} = 2.21825$$

SO Putting value of Constant

$$NTU = \frac{Kav}{L} = C(\frac{L2}{G2})^{-m} = 2.21825 \times (2.0615)^{-0.8} = 1.2436$$

New cold water temperature= WBT + New Approach=80+10.45=90.4F. New HWT=CWT + Range =90.45+12=102.45F

6. Evaporation

As per investigation of this model trial show that contact with cooling tower air and water some warmth evacuated by reasonable warmth of air in contact with water about 60% of warmth expelled by dissipation of dissemination water, mass exchange from water to air stream inverse way if entering water temperature is lower than the entering air wet bulb temperature, reasonable warmth move includes an expansion in dry bulb temperature of blend in flat holy messenger however vanishing heat move includes an adjustment in dampness proportion of the blend in vertical development. The below table data consider for Fertilizer plant Cooling Tower where water circulation is 30,000m3/h at the plants(ammonia, Urea, Utilities, NP/CAN) by Centripetal/turbo pumps.

Table 2: Design Data (Cooling tower Fertilizer)

Item	Description	Cooling Tower Refinery	Cooling Tower Fertilizer	Cooling Tower Power plant
1	Water circulation rate (gpm)	12500 m3/hr	30,000m3/h	55000m3/h
2	Hot water temperature ©	38	40	40
3	Cold water temperature ©	32	35	32
4	Wet bulb temperature ©	30	29	30
5	Drift loss(%design circulation)(m3/hr)	20m3/h	60m3/h	110m3/h
6	No of fans	03	06	06
7	Evaporation loss (m3/hr)	220	528	968
8	Bleed(BD) (m3/hr)	200	528@2(1.76)	7968
9	Make up water (m3/hr)	440	1056	1936
10	Price/Loss m3/hr	3.6	3.8	3.9
11	Range	6	5	8
12	Approach	2	6	2

The below table shows that current situation of make-up, blow-down and evaporation losses against number of cycles.

Table 3: Make up water current quantity

Sr.No	**COC**	**Evaporation**	**Blow-down**	**Make-up**
		t/h	**t/h**	**t/h**
1	2	528	528	1064
2	3	528	264	792
3	4	528	176	704
4	5	528	132	660
5	6	528	105.6	633.6
6	7	528	88	616
7	8	528	75.42	603.42
8	9	528	66	594
9	10	528	58.67	586.67

Table 4: Make-up Water Proposed Quantity

SI.No	**COC**	**Evaporation**	**Blow-down**	**Make-up proposed**	**Make-up current**	**Make-up savings**
		t/h	**t/h**	**t/h**	**t/h**	**t/h**
1	2	518.70	518.70	1037	1064	27
2	3	518.70	259.35	778.05	792	13.95
3	4	518.70	172.9	691.60	704	12.4
4	5	518.70	129.67	648.37	660	11.63
5	6	518.70	103.74	622.44	633.6	11.16
6	7	518.70	86.46	605.15	616	10.85
7	8	518.70	74.10	592.80	603.42	10.62
8	9	518.70	64.84	583.53	594	10.47
9	10	518.70	57.64	576.04	586.67	10.63
Total savings						118.71

The below table shows the handsome water conservation by applying behaviour changes to ECO Design approach, here author save the total water conservation maximum at one unit of fertilizer i.e. 46244m3/h as compared to Refinery one unit.

Table 5: Make up water advance quantity

COC	**Evaporation**	**Blow-down**	**Blow-down savings**	**Make-up Advance**	**Make-up current**	**Make-up savings**
	t/h	**t/h**	**t/h**	**t/h**	**t/h**	**t/h**
2	259.35	259.35		518.70	1037	518.30
3	259.35	129.67	129.68	389.03	778.05	389.02
4	259.35	86.45	172.9	345.80	691.60	302.57
5	259.35	64.84	194.51	324.18	648.37	324.19
6	259.35	51.87	207.48	311.22	622.44	311.22
7	259.35	43.23	216.12	302.57	605.15	302.58
8	259.35	37.05	222.3	296.40	592.80	296.4
9	259.35	32.41	226.94	291.76	583.53	291.77
10	259.35	28.81	230.54	288.16	576.04	287.88
Total savings			1600.00		1600.47	3023.93

Table 6: Advanced make-up water savings

Sr.No	COC	Blow-down water savings	Make-up water savings
		m3/h	m3/h
1	2	X	518.30
2	3	129.68	389.02
3	4	172.90	302.57
4	5	194.51	324.19
5	6	207.48	311.22
6	7	216.12	302.58
7	8	222.3	296.4
8	9	226.94	291.77
9	10	230.54	287.88
Total savings		1600.47 m3/hr	3023.93 m3/h
Savings charges@3.6		1600.47 + 3023.93 = 46244 m3/hr x 24 x 365 = 40, 509, 744 m3/year 40 million m3/year	

7. Pressure Drop in Cooling Tower

The air pressure are always dropped in the area where the direction of air flow is changed or velocity of air flow is decreased suddenly in induced draft cross flow CT.

- Air inlet
- Fill

- Fan inlet (0.1 to 0.3)

$K \times (airvelocity/4008.7)^2 \times DensityRatio$, K=1.6 TO 1.3= Pressure drop Coefficient

Density Ratio=air density/0.075lf/ft3@70F dry air condition. In cooling tower pressure losses is called “Static Pressure loss” or system resistance, the performance of cooling tower fan depends on the static pressure at CT

$$\Pr essureDrop = \frac{KPV^2}{2g}, g = 32.172 ft/\sec^2$$

$$= K \times 0.1922 \times (1/2) \times Air.density.ratio \times V^2,$$
$$0.1922 inchWG$$

$$= K \times V^2 \times Density.Ratio.......1\frac{lb}{ft^2} = 0.1922 inchWG$$

$$C \times 1.8 + 32 = F$$
$$F - 32 \times 0.5556 = C$$

Air Enthalpy at exit(97F)=66.5773Btu/lb, Air Enthalpy at inlet(80F)=43.6907Btu/lb. Therefore L/G=Air enthalpy exit-air enthalpy inlet/15.5063=66.5773-43.6907)/15.5063=1.4760. The air mass is calculated from equation G=L/(L/G), L=net water flow rate. L=design water flow rateGPM(500/60)X(1-%By pass/100)

G=12,500(500/60)X(1-3.26/100)/1.4760=68,27.5LB/MINT

1 Specific volume@ 85.24DBT & 80% RH=14.22ft3/lb

Air flow volume @air inlet=air mass flow x specific volume, Air inlet=68,271.5 x 14.2230=971,028ft3/mint

2 specific volume@14.1126ft3/lb WBT

Air flow volume 963,485ft3/mint/14.1126=68271.26

Air velocity inlet=air flow volume@air inlet/net area=971028/1134=856.29ft/mint, Air density@85.24DBT&80%RH=0.0718LB/FT3

Pressure Drop coefficient =2.5= $K \times (\frac{V}{4008.7})^2$ X Density Ratio

$$= 2.5 \times (\frac{856.29}{4008.7})^2 \times (\frac{0.0718}{0.0750}) = 0.1092 \text{ Inch Aq}$$

8. Velocity Recovery at Fan Stack

R/D=0.15 to 0.10

1 Fan inlet Zone R/D=0.15

Inlet height Zone=0.15xFan Dia=0.15x28ft=50.4inch

2 straight zones

Pitch angel+deflection+edge=5.73inch+14inch+6inch=25.73inch

3 velocity recovery zone

Total fan stach height-fan inlet zone height-straight zone height

=10x12-50.4-25.73=43.87inch

Diameter of fan stack top=fan dia+2xTan7xventuri height

Area of fan stack top=0.7854x (dia square-air square)

0.7854x[28=2xTan7x43.87/12)2-(88)2=613.6ft2

Air velocity @fan stack top=air volume/area=1019716.289/613.6=1661.86ft/mint

Velocity pressure $= (\frac{airvelocity}{4008.7})^2 \times (\frac{air.density}{0.075}$

$= (\frac{1661.86}{4008.7})^2 \times (\frac{0.0696}{0.0750}) = 0.1594$Inch of Aq

9. Air Water Distribution System Design

Pressure Ratio=static Pressure/velocity pressure at air inlet

Tables

(a). Mass flow rate of air kg/s → x – axis, Evaporation loss kg/s → y – axis

Table 7

0.015	0.025	0.03	0.035	0.04	0.045	0.05	0.05
0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8

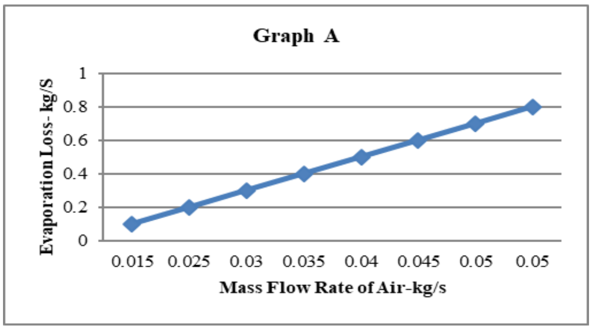

Figure 5

(b). Water inlet temperature (C^o) x – axis . Evaporation loss kg/s y – axis

Table 8

37	38	39	40	41	42	43	44	45	46	47
0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7

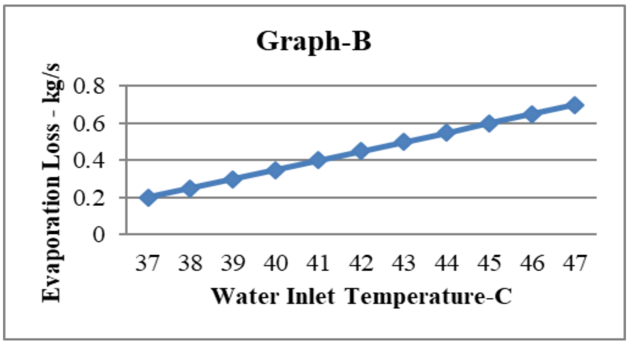

Figure 6

(c). Specific Humidity (Kg/ kg) x – axis, Evaporation loss kg/s y – axis

Table 9

0.011	0.0115	0.012	0.0125	0.013	0.0135
0.6	0.5	0.4	0.3	0.2	0.1

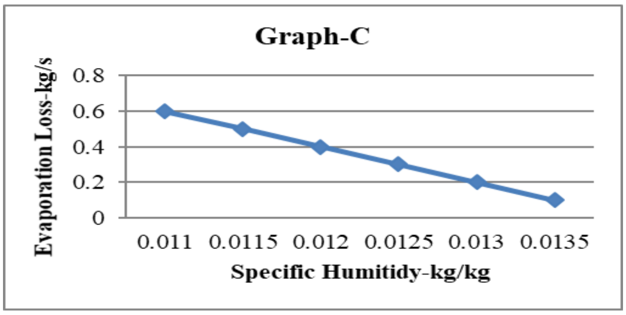

Figure 7

(d). Mass flow rate Kg / s of water x – axis, Evaporation loss kg/s y – axis

Table 10

0.015	0.017	0.019	0.021	0.023	0.025
0.2	0.3	0.4	0.5	0.6	0.7

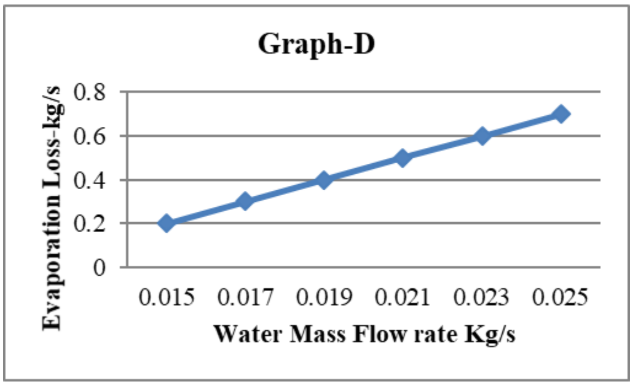

Figure 8

(e). Air inlet temperature °C x – axis , Evaporation loss kg/s y – axis

Table 11

22	23	24	25	26	27	28	29	30
0.5	0.35	0.38	0.42	0.45	0.47	0.52	0.55	0.65

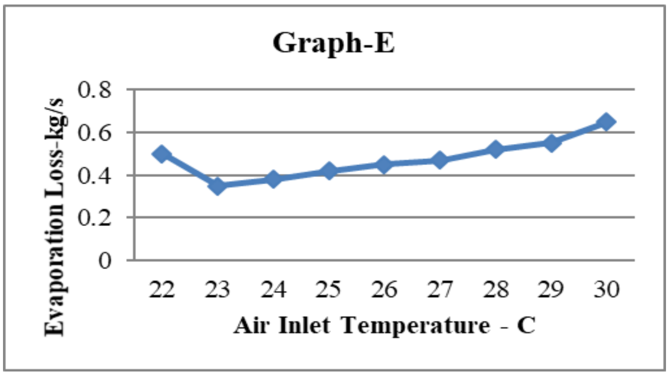

Figure 9

10. Conclusion

Operating values such as water inlet temperature, air specific humidity and air flow rate are found to have significant impact on the performance of the CT. However water flow rate and ambient air inlet temperature does not have effect on the performance of the CT. the model prediction show a good coordination with experimental data. Water conservation purposes can be achieved further by effective monitoring, audit and inspection checklist of plant SOP. The Author under thread to Environment Sustainability recommended

Enforcement and water charges under PEPA Act 1997, the purposed water Charges for this unit is based on water consumption i.e. 3.8m3/h.

11. Recommendation

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