International Journal For Technological Research In Engineering
Volume 1, Issue 8, April-2014 *ISSN (Online): 2347 - 4718*

INVESTIGATION OF PERFORMANCE OF FOUR CELL INDUCED DRAFT CROSS FLOW COOLING TOWER

Moni Kuntal Bora[1], S. Nakkeeran[2]
[1]M.Tech in Thermal Engineering, [2]Department of Mechanical Engineering
Bharath University, Deemed University
Chennai, Tamil Nadu, India.

Abstract: In many refrigeration, chemical, combustion and power generation systems, excess heat need to be rejected to the environment. The most efficient way to do this is to use available water from lakes, rivers and the sea to remove the process heat via a heat exchanger and then to return the water back to its source at a higher temperature. Due to environmental and conservation laws and the shortage of such natural water resources, the alternative is to reject waste heat to the atmosphere. In areas where there is sustainable water supply at reasonable cost, evaporative or wet cooling towers are generally used. This paper describes about performance of induced draft cross flow cooling tower consist of four cells. Here, a comparison is done with the design values and the influencing factors of cooling tower performance are also mentioned. Reducing energy outflows for cooling tower may be as simple as regular maintenance. Proper maintenance will optimize heat transfer and help to upgrade cooling tower performance. Energy efficiency measure is to increase the efficiency of the existing cooling tower by improving the maintenance procedures and by implementing new proven technology in the current energy system.
Keywords: Range; Approach; effectiveness; heatload; evaporation loss; wet bulb temperature.

I. INTRODUCTION

In steam power plants, steam is generated from a heat source such as coal, gas, nuclear or geothermal. The steam is used to drive a turbine connected to an electricity generator. The steam enters the turbine at high pressure and leaves at a lower pressure. To maximize cycle efficiency the low pressure outlet is maintained at a vacuum state. The vacuum is created by cooling the steam back into liquid form in a condenser. A common way to provide the cooling is by pumping water from a nearby river lake or sea through the condenser. These cooling sources provide a vast amount of cooling liquid with a low temperature variation. The water is pumped to the power plant, which requires the plant to be as close to the source as possible. Large quantities of cooling water are required which makes distance and elevation from the water source to the plant influence its efficiency. When large quantities of water are extracted from the environment, heated up and returned, the impact on the ecosystem can be significant. Therefore, the increase in temperature is generally restricted by law. Furthermore, power plants often require being close to the heat source which eliminates direct cooling as an option. When water is used as the heat transfer medium, wet, or evaporative, cooling towers may be used. Wet cooling towers rely on the latent heat of water evaporation to exchange heat between the process and the air passing through the cooling tower. The cooling water may be an integral part of the process or may provide cooling via heat exchangers. Although cooling towers can be classified several ways, the primary classification is into dry towers or wet towers, and some hybrid wet-dry combinations exist. Sub classifications can include the draft type and/or the location of the draft relative to the heat transfer medium, the type of heat transfer medium, the relative direction of air movement, and the type of water distribution system. Here the subject of interest is an induced draft cross flow cooling tower consists of four cells. Induced draft towers utilize large fans to force or suck air through circulated water. The water falls downward 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 induced draft towers depend upon their fan diameter and speed of operation. In cross flow induced draft towers, the water enters at the top and passes over the fill. The air, however, is introduced at opposite sides. An induced draft fan draws the air across the wetted fill and expels it through the top of the structure. Many towers are constructed so that they can be grouped together to achieve the desired capacity. Individual cooling towers are called "cells."

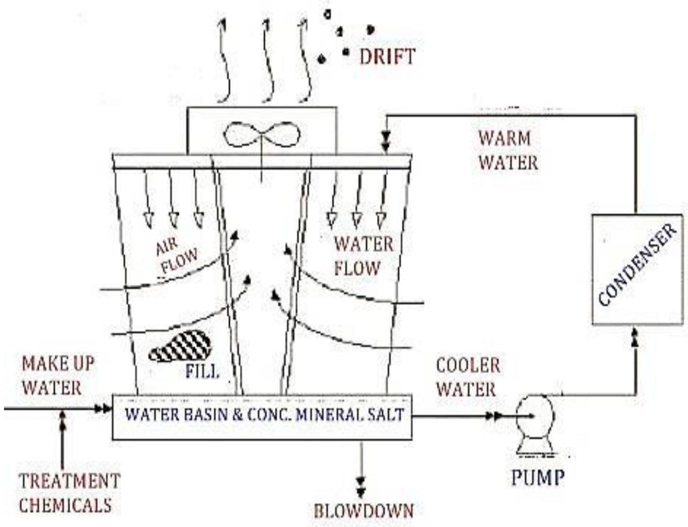


Fig. 1. Induced Draft Cross Flow Cooling Tower

In cross flow towers the air enters horizontally into the tower and goes directly into the fill as the water falls downwards and there is no rain zone. The air leaves the fill on the other side of the fill and does not need to flow through the water distribution system. Water distribution systems in cross flow towers are therefore, not as restricted in terms of design, which can often allow for a more uniform water distribution over the fill.

II. ELEMENTS OF COOLING TOWER

The basic components of an evaporative tower are: Frame and casing, fill, cold water basin, drift eliminators, air inlet, louvers, nozzles and fans. Cooling towers are the primary component used to exhaust heat in open recirculating cooling systems. They are designed to maximize air and water contact to provide as much evaporation as possible. This is accomplished by maximizing the surface area of the water as it flows over and down through the tower structure.

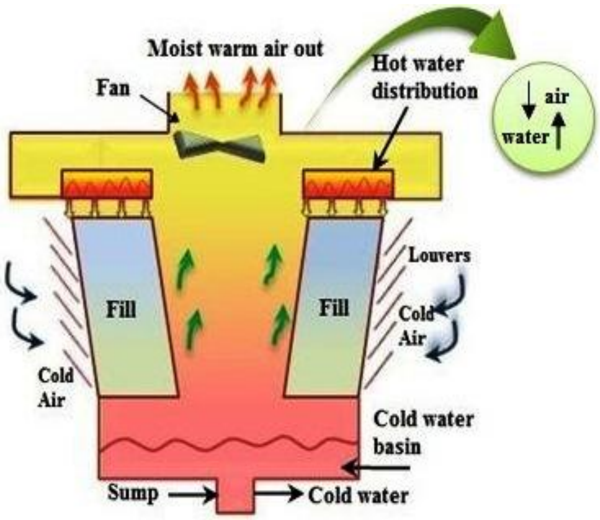
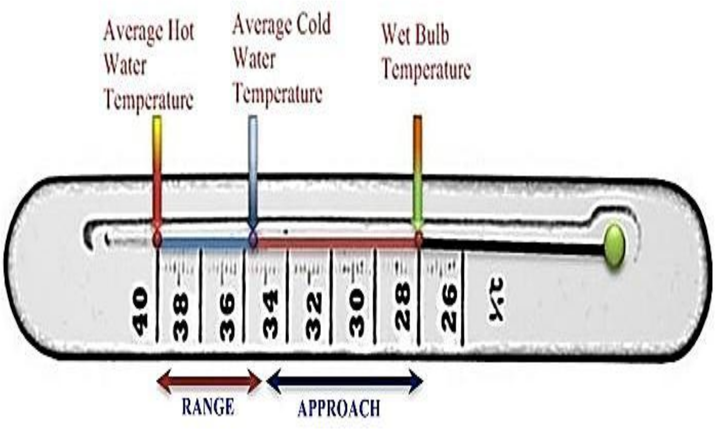


Fig.2 Operation of Induced Draft Cross Flow Cooling Tower

First, the water is distributed evenly across the top of the cooling tower structure. Tower distributions decks can be a series of spray nozzles oriented up or down (like a landscaping sprinkler system) to uniformly distribute the water over the tower structure. In some cases, the distribution deck may just be a series of holes through which the water falls onto the tower structure. Regardless the distribution deck must uniformly apportion the recirculating water across the tower structure. Broken nozzles or plugged orifices will impede uniform distribution across the tower structure, negatively impacting the overall heat exchange capacity of the system. As the water falls from the distribution deck, the surface area is further expanded in the fill section. Older tower systems may feature splash bars made of plastic, fiberglass, or wood that serve to break the falling water into tiny droplets. In recent years, many different forms of labyrinth-like packing or film fill have been incorporated. The closely packed nature of film fill causes the water to travel through this portion of the tower in thin streams, improving thermal efficiency and the evaporation rate, thereby increasing heat rejection. There are several variations of film fill geometries commercially available, and though they do greatly increase the heat rejection rate over splash-type fills, they are also much more susceptible to fouling, scaling, and microbiological growth (these are discussed in greater detail in the System Concerns section). Development of any of these problems greatly reduces the cooling efficiency and in severe cases can collapse portions of the tower fill or tower structure. To avoid this, film fill should be inspected routinely to ensure it is clean and free of debris, scale, and biological activity. To minimize losses due to drift and help direct airflow into the tower, louvers and drift eliminators are commonly used. Louvers are most often seen along the sides of the tower structure, while drift eliminators reside in the top section of the tower to capture entrained water droplets that may otherwise leave through the stack. Damaged or incorrectly oriented louvers along with damaged drift eliminators will lead to excessive losses due to drift from the tower structure. Therefore, louvers and drift eliminator sections should be routinely inspected and repaired to ensure optimal water usage. After the water passes through the fill it cascades down to a collection basin at the base of the tower structure. From the basin the cold water can be pumped back into the system to extract process or comfort cooling needs and begin the cycle all over again. By design, cooling towers consume large volumes of water through the evaporation process to maintain comfort cooling or process cooling needs, although they use significantly less water than similar capacity once-through cooling systems. Because the evaporative loss is water containing little to no dissolved solids, the water remaining in the cooling tower becomes concentrated with dissolved solids, which can lead to scaling and corrosive conditions. To combat these problems, water with high total dissolved solid content must be drained from the system via “blowdown”. The associated losses caused by blowdown, evaporation, drift, and system leaks must be accounted for by system make-up requirements.

III. COOLING TOWER PERFORMANCE ESTIMATION



The significant factors responsible the performance of cooling towers, are:

Capacity of cooling tower	:	C	in	TR
Average Cold Water Temperature	:	t_2	in	^0C
Average Hot Water Temperature	:	t_1	in	^0C
Ambient wet bulb temperature	:	t_{wb}	in	^0C
Ambient Dry Bulb Temperature	:	t_{db}	in	^0C
Total Cooling Water Flow	:	W_{water}	in	m^3/hr

1. Range “R” = $t_1 - t_2$
2. Approach “A”= $t_2 - t_{wb}$
3. Cooling tower effectiveness,

$$\varepsilon = \frac{\text{Range}}{\text{Range} + \text{Approach}}\, x\ 100\%$$

4. Total Heat Load handled by Cooling Tower,
   THL = ($W_{water} x$ R x 10^3) /3025.9729503365 TR
5. Evaporation loss is the water quantity evaporated for cooling duty and, theoretically, for every 10, 00, 000 kCal heat rejected, evaporation quantity works out to 1.8 m^3. An empirical relation used often is:

Evaporation Loss (m^3/hr),

EL = 0.00085 x 1.8 $x W_{water} x$ R

6. %EL = (EL / W_{water})x 100.

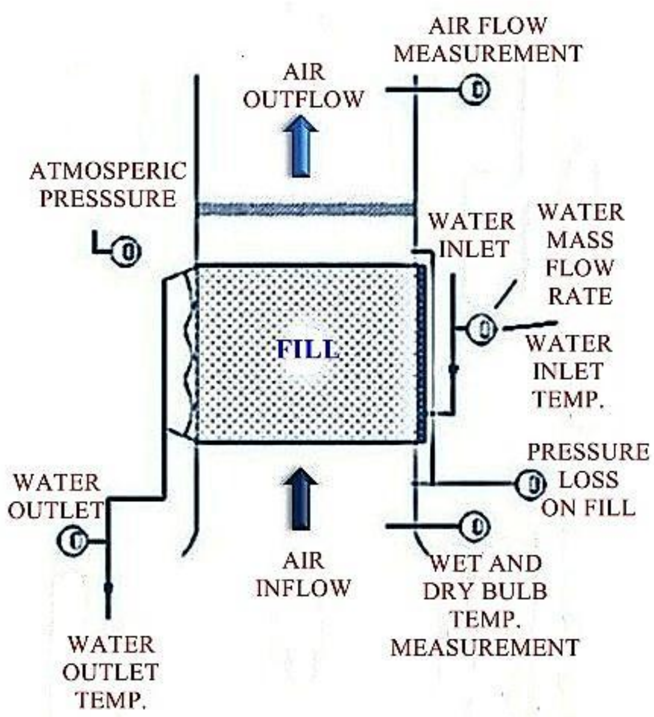


Fig. 3.Mmeasurement of different parameters

For measurement of different parameter different instrument are used. To measure t_{wb} and t_{db}sling psychomotor or whirling pyschrometer is used. For inlet and outlet water temperature i.e. t_1 and t_2 digital thermometer is used. For W_{water} pump head and flow characteristics are used.

Tabulation:

Particular	**Unit**	**Design Value**	**Actual value / Calculations**			
			Cell I	**Cell II**	**Cell III**	**Cell IV**
C	TR	-	10000	10000	10000	10000
t_2	^0C	38	35.0	35.0	35.0	35.0
t_1	^0C	45	40.1	39.7	39.7	39.8
t_{wb}	^0C	27	28.5	28.5	28.5	28.5
t_{db}	^0C	-	34.2	34.2	34.2	34.2
W_{water}	m^3/hr	8050	2012.5	2012.5	2012.5	2012.5
R	^0C	15	5.1	4.7	4.7	4.8
A	^0C	4	6.5	6.5	6.5	6.5
ε	%	-	43.97	41.96	41.96	42.48
THL	TR	40000	3391. 88	3125. 85	3125. 85	3192. 36
EL	m^3/hr	-	15.7	14.47	14.47	14.78
%EL	%	-	0. 78	0. 72	0. 72	0. 73

Now if we consider the range, total water flow, cold water temperature wet bulb temperature for each cell, and having same capacity then we can establish generalized performance characteristic curves. This curve gives an idea about the interrelation between all the above mentioned parameters.

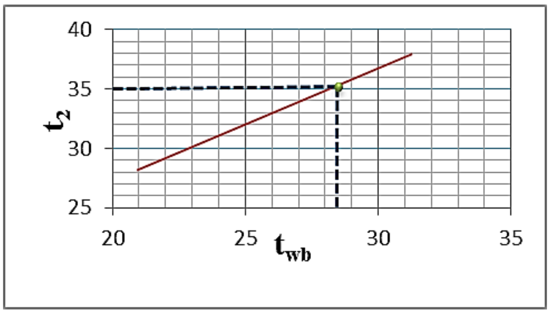


Fig. 4. Relation between t_2 andt_{wb} for each cell since they have same W_{water}.

IV. ELEMENTS INFLUENCES COOLING TOWER PERFORMANCE ESTIMATION

A. *Capacity utilization*

- Capacity, in terms of heat dissipation (in kCal/hour) and circulated flow rate (m3/hr) are an indication of the capacity of cooling towers.

B. *Range*

- Determined by the process it is serving.
- Determined by heat load and water circulation rate.
- Thus Range: *f* (Heat load & water circulation rate)
- Wet Bulb temperature: design range is specified at certain t_{wb} .
- The closer the approach to thet_{wb}, the more expensive the cooling tower due to increased size.

C. *Wet Bulb Temperature*

- t_{wb} of air entering the cooling tower determines operating temperature levels throughout the plant, process or system.
- Recirculation raises the effective t_{wb} of the air entering the tower with corresponding increase in cold water temperature.

D. *Approach and Flow*

- Approach is dependent on t_{wb} of air entering the cooling tower.
- The closer the approach to the wet bulb, the more expensive the cooling tower due to increased size.
- Water circulation rate is directly proportional to the heat load.

E. *Range, Flow and Heat Load*

- Range is a direct function of the quantity of water circulated and the heat load.
- Increasing the range as a result of added heat requires an increase in tower size.
- If the hot water temp is constant and the range is specified with a lower cold water temp, then the tower size required for such applications would increase considerably.

F. *Approach and Wet Bulb Temperature*

- Design t_{wb} is determined by the geographical location.
- Usually the t_{wb} selected should not exceed 5% of the time in that area.
- Higher t_{wb}, smaller the tower required to give a specified approach to the wet bulb at a constant range and flow rate.

G. *Fill Media Effects*

- Function: Heat exchange between air and water is influenced by surface area of heat exchange, time of heat exchange and turbulence in water effecting thoroughness of intermixing.
- Due to fewer requirements of air and pumping head, there is a tremendous saving in power with the intervention of film fill.
- Recently, low clog film fills with higher flute sizes have been developed to handle high turbid waters.

V. ROOTS OF LOW COOLING TOWER PERFORMANCE

Sinking energy outflows for cooling tower may be as simple as regular maintenance. Proper maintenance will optimize heat transfer and help to upgrade cooling tower performance.

Cooling towers expose the cooling water directly to the atmosphere. The warm cooling water is sprayed over a fill in the cooling tower to increase the contact area, and air is blown through the fill. The bulk of heat removed from the cooling water as a result of evaporation. The remaining cooled water drops into a collection basin and is recirculate to the chiller. An inadequately maintained cooling tower will produce warmer cooling water, causing in a condenser temperature 258.15 kelvin to 260.92 kelvin higher than a properly maintained cooling tower. This lessens the efficiency of the chiller, wastes energy, and escalations in charge. Furthermore, a poorly maintained cooling tower will have a shorter operating life, needs overpriced repairs, and undependable. The performance of a cooling tower reduces when the efficiency of the heat transfer process drops. Some of the common causes of this dreadful condition comprise:

A. Deposition of Scale:

When water evaporates from the cooling tower, it leaves scale deposits on the surface of the fill due to the minerals that were dissolved in the water. Raw water contains varying amounts of mineral salts such as calcium, magnesium, iron and silica. When these minerals exceed their solubility point due to increased cycles of concentration, the minerals precipitate out of solution and produce scale forming salts. Scale build-up turns as a barrier to heat transfer from the water to the air. Too much scale build-up is a signal of water treatment complications. It is essential to maintain a proper bleed-off schedule to prevent excessive over cycling.

B. Blocking of Spray Nozzles:

Due to water treatment complications Algae and sediment gather in the water basin in addition to excessive solids get into the cooling water and can block the spray nozzles. Results, irregular water distribution over the fill, resulting in irregular air flow through the fill and reduced heat transfer surface area. Air Flow complications Poor air flow through the tower reduces the amount of heat transfer from the water to the air. Poor air flow can be caused by debris at the inlets or outlets of the tower or in the fill. In addition to due to poor fan performance causing reduced air flow and ultimately leads to motor or fan failure.

C. Weak Pump Performance:
An indirect cooling tower uses a cooling tower pump. Appropriate water flow is significant to achieve optimum heat transfer. Loose connections, failing bearings, cavitation's, clogged strainers, excessive vibration, and non-design operating conditions give rise to reduced water flow, reduced efficiency, and early equipment failure.

D. Minimizing Corrosion:
Corrosion of cooling towers can be very costly in terms of service disruption, loss of production, increased maintenance and capital equipment replacement. Applying a properly designed chemical water treatment program is the simplest method of preventing these corrosion problems. Raw water quality must be taken into consideration when determining the most effective type of treatment program.

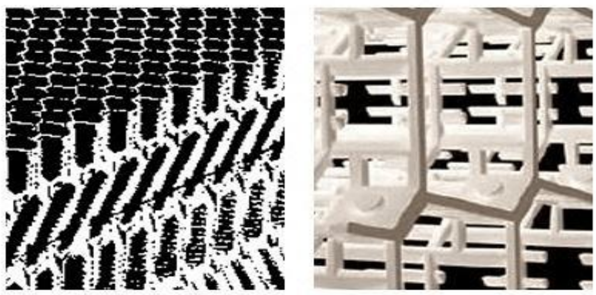
E. Avoidance of Fouling
Air contains particles of dust and dirt of various kinds causing recirculating water to become contaminated with a variety of materials. This creates fouling on the inside surfaces and leads to corrosion and loss of cooling transfer efficiency. Since towers contain warm water, are open to sunlight, trap a variety of life forms and nutrient sources, they are perfect breeding grounds for algae, fungi and bacteria. Implementing a properly designed treatment program of microorganism is most effective in controlling biological fouling.

VI. ENERGY EFFICIENT COOLING TOWER OPPORTUNITIES

As technology is changing daily, it will be very useful to estimate if it is possible to increase the heat capacity of the existing cooling system with or without some reasonable investment, which will ultimately affect energy consumption. Actually, the first energy efficiency measure is to increase the efficiency of the existing plant by improving the maintenance procedures and by implementing new proven technology in the current energy system.

Key energy efficient cooling tower opportunities are:

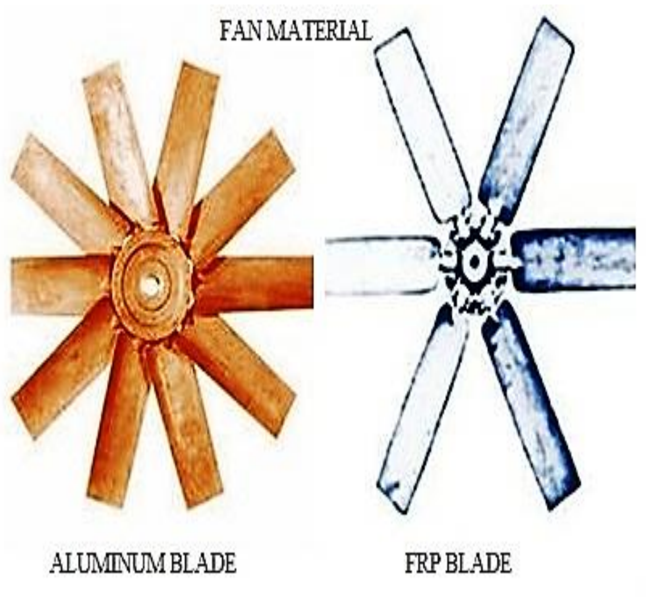
• Replace splash fills which are generally made wood or plastic (recently used) with self-extinguishing poly vinyl chloride (PVC) cellular film fill or hybrid fills which have less pressure drop, less fouling and easy to clean.



PVC AND HYBRID FILL

• Bleed-off or Blowdownis the continuous or intermittent wasting of a small fraction of circulating water in order to prevent concentration of chemicals in water. The purpose of blow-down in water cooling apparatus is to reduce soluble solids or hardness. This reduces the scale-forming tendencies of water. Optimize blow down rate as per Cycles of concentration limit. An excellent chemical water treatment regimen is your first step in reducing bleed-off. As water circulates through the cooling system and a portion is evaporated in the cooling tower, the concentration of solids – minerals, organics, contaminants and corrosives – increases until it reduces efficient performance and can damage your equipment .Water use can be minimizing by adopting zero blowdown technology (ZBT).

• Installing Fibre Reinforced Plastic blades in place of aluminum metallic blades for cooling fans. Fiber reinforced plastic (FRP) blades are normally hand molded which makes it easier to produce an optimum aerodynamic profile tailored to specific duty conditions. A significant efficiency can be achieved with blades with an aerodynamic profile, optimum twist, taper and a high coefficient of lift to coefficient of drop ratio. However, this efficiency is drastically affected by factors such as tip clearance, obstacles to airflow and inlet shape, etc.



• Incorporation of thermostatic controls for fan operation. Implementation of variable speed drives control systems for pumps and fans.
• By using electromagnetic valve proper cooling scheduling can be achieve.
• Install new nozzles having low back pressure and durable light hard anodized construction having ball valve for flow control to obtain a more uniform water pattern.

NOZZEL USED IN CROSS FLOW COOLING TOWER

• Consider Cycles of concentration improvement measures for water savings. Maximizing cooling tower cycles offers many benefits in that it reduces water consumption, minimizes waste generation, decreases chemical treatment requirements, and lowers overall operating costs.
• Efficiency estimation of Cooling Tower pumps per monthly basis.
• Installing and improving the design of drift eliminators the drift loss can be minimize.
• Proper measurement of the parameters will give a less errors in results. This helps in proper maintenance and controlling, as a result better performance.
• In the case of more than one cooling tower cell like four cell cooling tower, sequential control has to be used. It can be done manually or automatically.

VII. CONCLUSION

It is seen that the wet bulb temperature for each cell is 28.5 0C and cold water temperature is 35 0C. Approach for each cell is estimated 6.5 while design value is 4. Theoretically, a cooling tower will cool water to the entering wet bulb temperature, when operating without a heat load. However, a thermal potential is required to reject heat, so it is not possible to cool water to the entering air wet bulb temperature, when a heat load is applied. Always cold water temperature low enough to exchange heat, this affects cost and size of the cooling tower. For meeting the heat load, few modifications would be needed to increase the water flow through the tower. The use of cooling towers is a key strategy in reducing energy use in many cooling systems. But this energy efficiency is traded off for increased water use over sensibly cooled systems. With cooling towers being responsible for a sizeable percentage of water consumption, water conservation through its monitoring and maintenance is a smart choice. Monitoring plays the role of recording baseline information while also allowing building operators to monitor the physical components of the cooling tower and implement improvements to increase water and energy efficiency. Potential cost savings vary from plant to plant, depending on the cost for raw water, waste disposal costs, chemical treatment quantities, and energy.

REFERENCES

[1] Kreith Ed. Frank, *"The CRC Handbook of Thermal Engineering",* Boca Raton: CRC Press LLC, 2000.
[2] Nag P.K., "*Power Plant Engineering*", 3rd edition, TataMcGraw-Hill.
[3] Arora, C.P. (2000) *Refrigeration and Air Conditioning*, TataMcGraw-Hill.
[4] Kloppers, J C, Kröger, D G, 2004, A critical investigation into the heat and mass transfer analysis of cross flow wet-cooling towers, Numerical Heat Transfer, Vol. 46, pp. 785–806.
[5] Baker Donald (1984) "*Cooling Tower Performance"* Chemical Publishing Co, N.Y.
[6] A.I. Petruchik, A.D. Solodukhin, N.N. Stolovich, S.P. Fisenko, toward the analysis of experimental data onthermal efficiency of evaporative cooling tower, Appl.Energy: Russian J. Fuel Power Heat Sys. 37 (6) (2000) 142–149.
[7] Zivi, S M and Brand, B B, 1956, An analysis of the Crossflow Cooling Tower, Refrig. Eng., Vol. 64, pp. 31–34, 90–92.
[8] Donald R. Baker, Howard A. Shryock "A Comprehensive Approach to the Analysis of Cooling Tower Performance".
[9] Fisenko S.P, Solodukhin A.D. "Evaporative cooling of water in a natural draft cooling tower", International Journal of Heat and Mass Transfer (2002).

