Performance Evaluation of Cooling Tower in Thermal Power Plant - A Case Study of RTPS, Karnataka

Pushpa B. S, Vasant Vaze, P. T. Nimbalkar

Abstract: An evaporative cooling tower is a heat exchanger where transformation of heat takes place from circulating water to the atmosphere. The warm water from the condenser is taken as an inlet water to the cooling tower and it is allowed to flow through the nozzles. As it falls down across baffles or louvers, the water is broken into small droplets. Simultaneously air is drawn in through the air inlet louvers provided at the base of the tower and then this air travels upward through the tower in the opposite direction of water flow. In this process a small portion of water gets evaporated which removes the heat from the remaining water causing it to cool down. This water is collected in a basin and is reused in the cooling water system process. Because of evaporation, some quantity of water is lost and thus to make up the loss, the fresh water is constantly added to the cooling water basin. In a Natural Draft Cooling Tower, warm water is cooled by evaporation process. Here, water gets cooled when a boundary layer is formed between saturated water and saturated air. If the mass flow rate is ideal, then the performance of cooling tower as well as the power plant will be improved. In this study, it is showed that by minimizing the size of water droplet, the performance of Natural Draft Cooling Tower can be enhanced. Study of Sensitivity Analysis is done which shows the dependency of parameters like air temperature, water temperature, relative humidity and rate of heat loss. Further, efficiency is also checked by using power generation data.

Keywords: Cooling Tower, Rate of Heat loss, Sensitivity Analysis, Efficiency.

I. INTRODUCTION

On this planet, next to air, water is the most important requirement for life. Because of depletion of fresh water resources and increasing population pressure, water sources have become precious. The first priority of fresh water is for human consumption and agriculture. Secondary priority of water is for industries like power plant. For the power plant large quantity of water is required for cooling the condensers. There are two cooling water systems, one is once through and the other is close-loop.

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The water requirement for the close-loop system is hardly 10% as compared to once-through cooling water system. Cooling towers are considered to be effective while adopting the close-loop system. The merit of cooling tower is that it reuses the cooling water in the system and makes the system economical as well as environmental friendly. Close loop system with cooling tower is used when the water resource is limited. If the condenser cooling system is performing well, then it adds to the overall efficiency of power plant. In a cooling tower, the condensate coming out from the condenser is cooled by evaporation. Therefore, an evaporative cooling tower is a heat rejection device which extracts waste heat to the atmosphere by cooling a stream of hot water. Here, the atmospheric air gains heat from the warm water in the tower. This air being lighter moves up and finally gets discharged to the atmosphere. The principle of cooling the water in cooling tower is similar to the evaporative condenser or spray pond. Therefore cooling towers are desired when positive control on the temperature of water is required. Cooling towers has been basically classified into two types:

1. Mechanical Draft Cooling Tower
2. Natural Draft Cooling Tower

In a Mechanical draft cooling towers, mechanical equipments such as fans are used for cooling the warm water. The warm water from the condenser falls over the fill surface. Because of the provision of fills, the water will be exposed to air for more time. This increases the rate of heat transfer between the water and air and the water gets cooled.

In a Natural draft cooling towers, cooling of water is done by using atmospheric air. The fresh cool air is drawn from the bottom of the tower and this air is used for heat transfer process. Due to the shape of the tower, fans are not required, hence it is economical.

The natural draft towers are further divided into three types:

1. Natural draft spray filled towers
2. Natural draft packed type tower
3. Hyperbolic cooling tower

II. LITERATURE REVIEW

Many investigators have done research on the performance of Cooling Tower. If there are any wastage of energy in the tower, then those areas were identified by performing investigations. Different methods are used by different researchers to investigate the problems and many ideas are suggested to increase the cooling tower efficiency. Performance was enhanced by examining the effects of variations of liquid/gas ratio using non uniform water distribution. Some studies showed, what impact the water

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temperature does on the plant performance. Then studies were done in the rain zone of cooling tower and it was seen that by using non uniform water droplet size, the performance can be increased. In the present study, performance of cooling tower is checked by determining the rate of heat loss for different surface area of water droplet and also sensitivity analysis is done to determine the dependency of meteorological parameters like air temperature, water temperature, relative humidity and wind speed on rate of heat loss.

III. CASE STUDY AND DATA'S COLLECTED

The site selected for this project is Raichur Thermal Power Station (RTPS), at Shakthinagar, in Raichur district of Karnataka in India. This project is run by the Karnataka Power Corporation Limited (KPCL). It is a coal-fired power station and contributes about 40% of the total electricity generated in Karnataka. It has Eight units, out of which the installed capacity of first seven units is 210 MW whereas capacity of Eighth unit is 250 MW. The evaluation of performance in this report is for Unit Seven. So, data required for assessment of performance is taken from Unit 7 of the Power Station. Data on air temperature, inlet/outlet water temperature, relative humidity, wind velocity and power generation were collected from project for calculation of rate of heat loss, sensitivity analysis and efficiency.

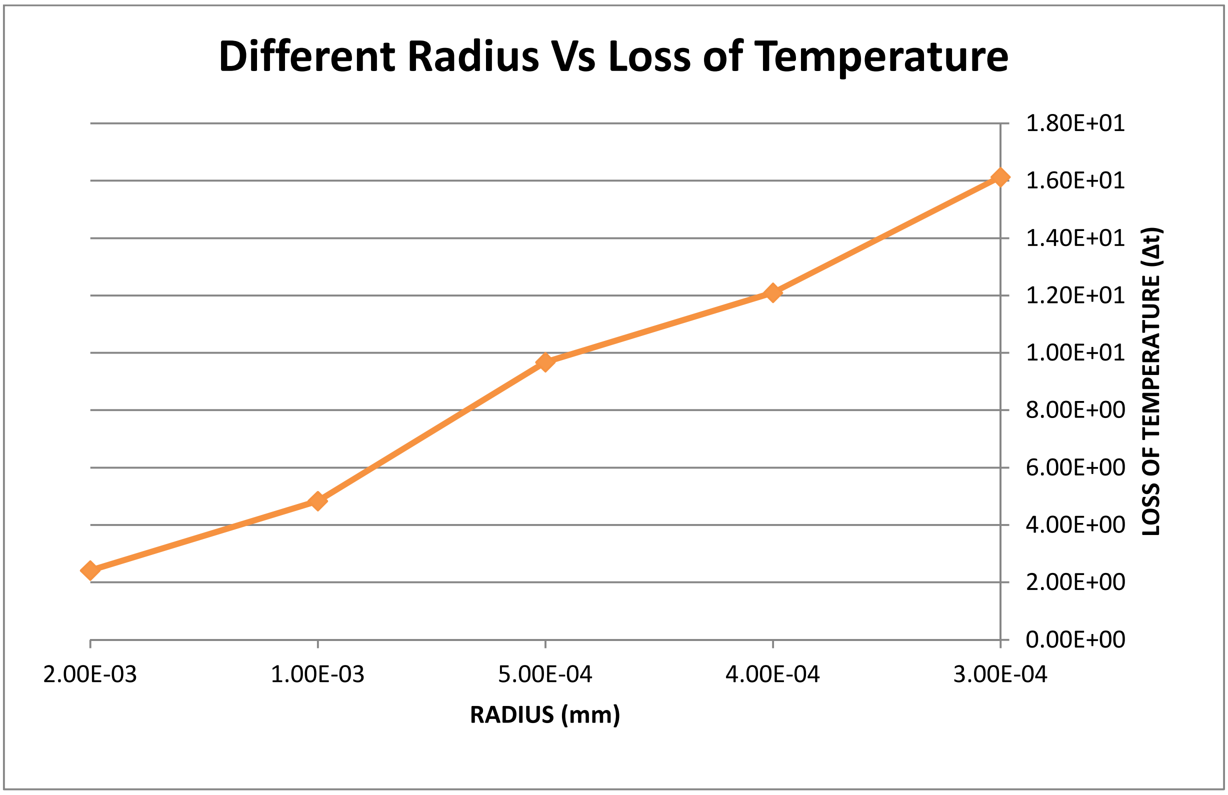
IV. METHODOLOGY FOR ASSESMENT

By doing performance evaluation of cooling tower, its efficiency can be improved by identifying the areas of energy wastage and by suggesting improvements. Using following procedure assessment is done.

- Calculation of Rate of Heat loss using Rohwer's Formula and Kohler's Formula.
- Calculation of fall velocity and time required for the water droplet to fall from nozzle to the water basin.
- Calculation of Temperature loss for different droplet size.
- Sensitivity Analysis of air temperature, water temperature, relative humidity and wind velocity with rate of heat loss.
- Determination of efficiency by plotting a graph of power generation versus loss of water temperature.

V. FINDINGS

- Calculations of rate of heat loss for different sizes of water droplet shows that, exposure of surface area play an important role in evaporation process.



Results from graph:
For Radius= 2mm; Rate of heat loss= 2.24°C
For Radius= 1mm; Rate of heat loss= 4.84°C
For Radius= 0.5mm; Rate of heat loss= 9.68°C
For Radius= 0.4mm; Rate of heat loss=12.1°C
For Radius=0.3mm; Rate of heat loss= 16.1°C
From these values it is seen that, as the size of water droplet is reduced, the rate of heat loss is increasing, i.e. cooling of water process is more effective as the water droplets are smaller in size. But as the design rate of heat loss is 10°C in the system, it has to be ensured that the size of water droplet is around 0.5mm radius and not more.

- By using actual power generation data, graph is plotted for power generation versus Loss of temperature. From this, Efficiency of the system can be determined.

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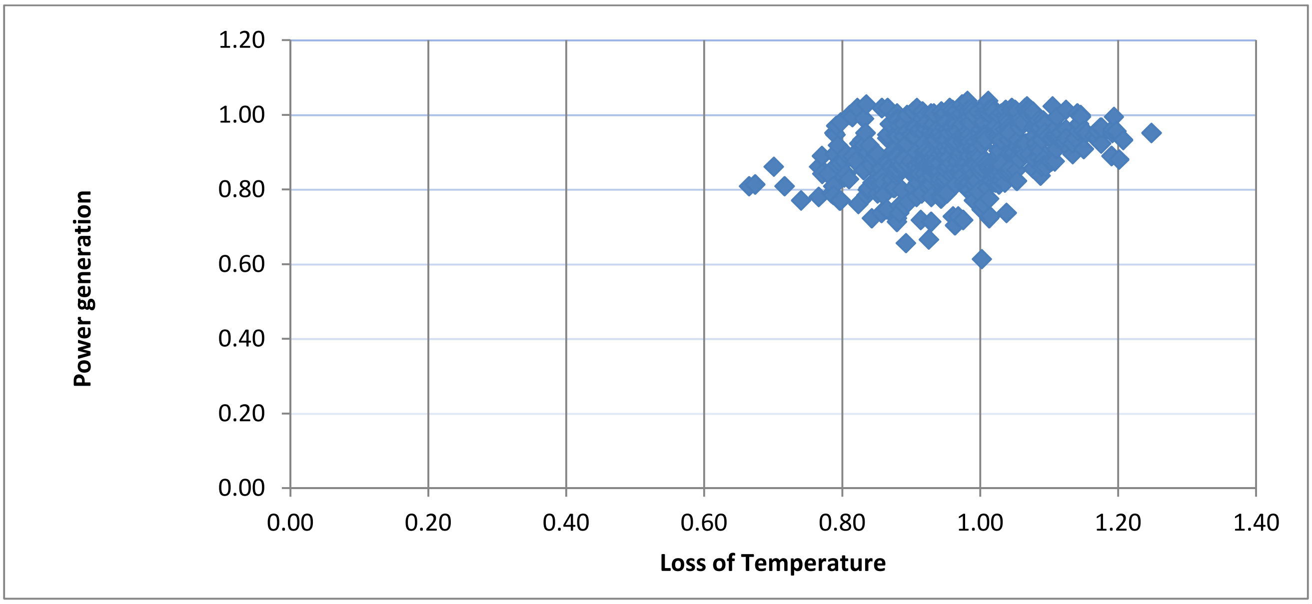
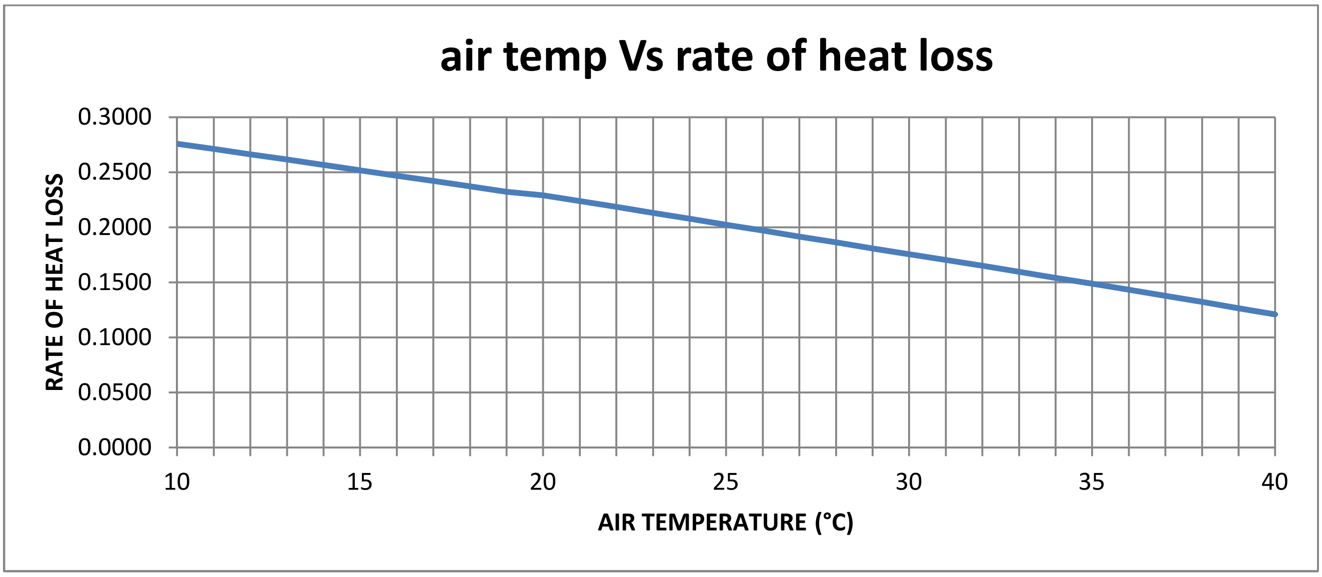


In this the power generation as well as cooling effected is presented in non-dimensional form. i.e the actual power generation is divided by the design power generation while, the actual loss in temperature achieved is divided by design loss in temperature. If the efficiency is good, allowing for the practical variations, all the values should be within 80 to 100% domain. If the values show large scatter, it means the efficiency is not good. In this report, the percentage of power generated more than 100 is 35% and the percentage of rate of heat loss more than 100 is 11% at the power project.

- Sensitivity Analysis is a technique used to determine how change in the values of different parameters influence the rate of heat loss. This technique is used within specific boundaries that will depend on one or more input variables.

Thus, Sensitivity analysis is very useful when attempting to determine the impact the actual outcome of a particular variable will have if it differs from what was previously assumed during the design process. By creating a given set of scenarios, how changes in one variable(s) will impact the target variable can be determined. Many things influence evaporation rate. Air temperature, water temperature, wind speed, and humidity all affect evaporation rate.

A. Air Temperature



The flow rate of air affects evaporation rate, because if fresh air is moving over the substance all the time, then the concentration in the air just above is less likely to go up with time, encouraging faster evaporation. If the air already has a high concentration of the substance evaporating, then the evaporation will be less. If the air is already saturated with other substances, almost none will evaporate.

The higher the air temperate the higher will be the evaporation rate. This can be seen in the graph, where air temperature is inversely proportional to rate of heat loss.

B. Relative Humidity

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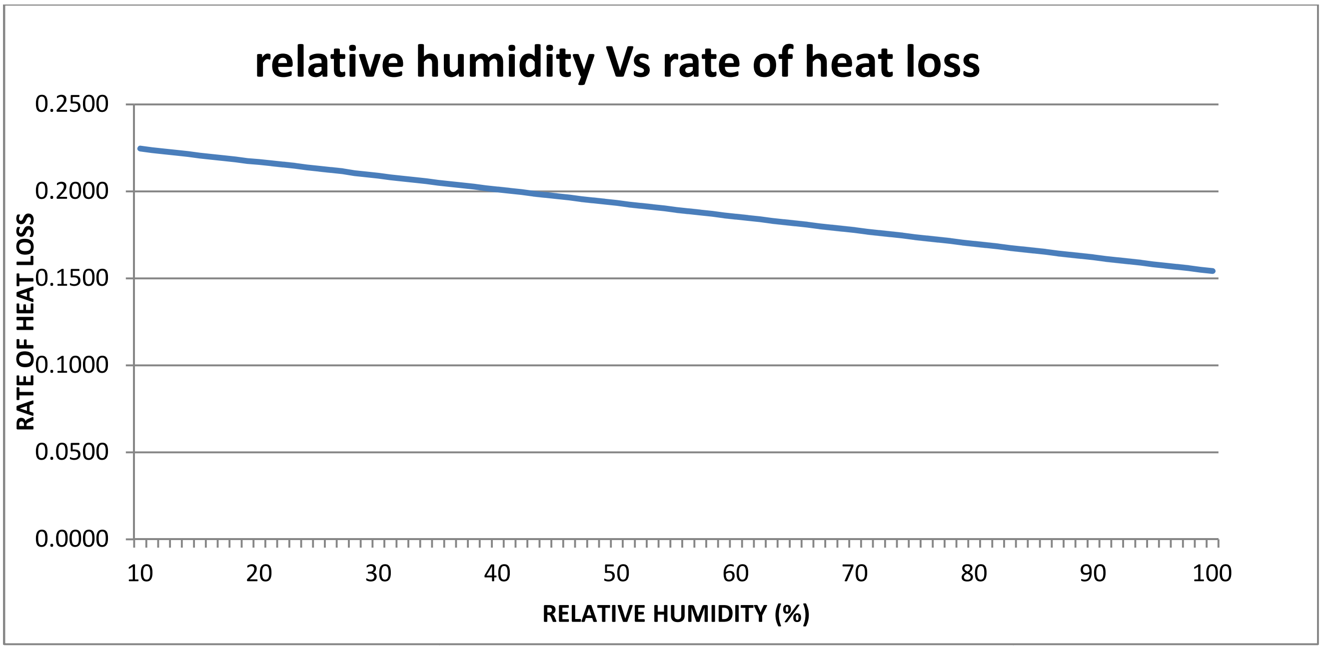


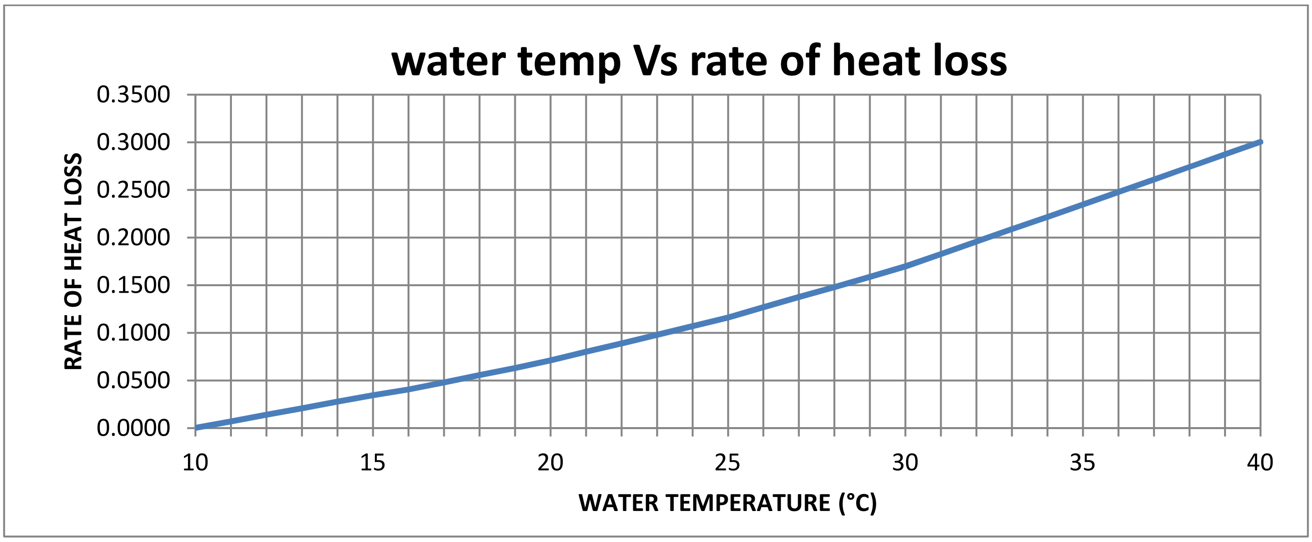
Humidity is the amount of water vapour in the air. The relative humidity (ϕ) of an air-water mixture is defined as the ratio of the partial pressure of water vapor (H2O) (e_w) in the mixture to the saturated vapor pressure of water (e^*_w) at a given temperature. Thus the relative humidity of air is a function of both water content and temperature.

Relative humidity is normally expressed as a percentage and is calculated by using the following equation.

$$\phi = \frac{e_w}{e^*_w} \times 100\%$$

The relative humidity is found by comparing the temperature of a dry thermometer with the temperature of a wet bulb thermometer. The wet bulb thermometer has water placed on its bulb, air is passed over it, the water evaporates, and the temperature is recorded. Most of the time the two thermometers will have different temperature readings, however, if the air is completely saturated with water the readings will be the same. When 100% relative humidity is reached the air can no longer accept water, the water on the bulb cannot evaporate, and the temperature will be the same as the dry bulb. So, the lower the wet bulb reading, the lower the humidity, the more moisture the air can accept, the more heat a cooling tower can be expected to reject. From the graph also it is clear that, as the relative humidity is increasing, the rate of heat loss is gradually reducing as the air is getting saturated.

C. Water Temperature



It is the water which is required to be cooled. If the water is at natural room temperature the rate of heat loss will be normal. However as the temperature of water is increased gradually, the rate of heat loss will gradually increase. This is depicted in the graph presented above. The temperature of the water also has an effect on the evaporation rate. Because hot water contains more energy than cold water, the rate at which molecules transition to the gaseous state increases proportionally with the temperature. Water evaporates quickly once the boiling point is reached. The temperature of the water says how energetic the water molecules are. The more energetic the molecules are, the more likely they are to break free from the liquid and get into the air. Therefore water temperature is directly proportional to rate of heat loss.

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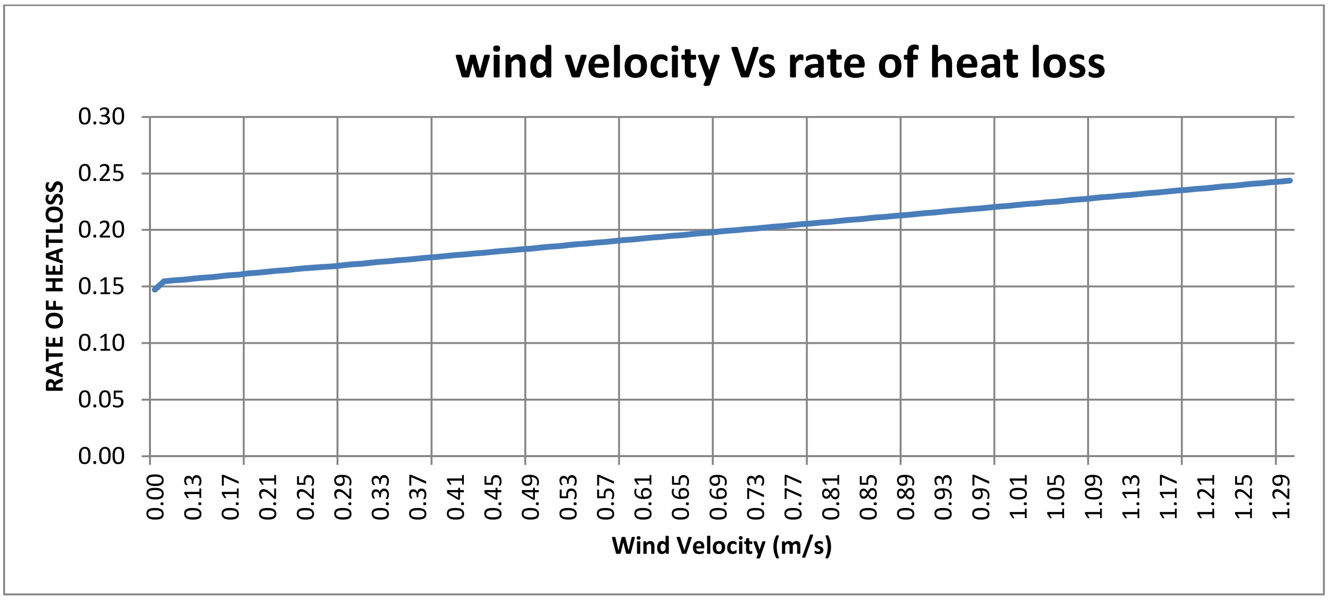
D. Wind Velocity



Increased wind speed will increase evaporation rate up to a point. The reason is that if the air was perfectly still, air near to the source of any moisture would become saturated, and unable to take up any more moisture. Because the air was not moving, then this would mean that no more moisture would be able to be absorbed. If the air is in motion, then the air next to the source of the moisture is replaced by less saturated air, which can take up more moisture and is then replaced. If there is enough motion to replace the saturated air with fresh less saturated air, then the evaporation rate will stay pretty much the same. Thus, the faster the wind speed, the faster is the evaporation rate. This can be experienced when we use a blow dryer or a hand dryer in bathrooms. In cooling tower the entire process is taking place in a close environment. It means the natural wind will not be taking part in the process of cooling. However as the water droplets are falling under the gravity and air particles move upward under density currents, the wind action is generated. As the air moves upward the outside ambient air is drawn in and effect cooling. It also becomes warm and moves up in the tower and the process continues.

VI. CONCLUSIONS

1. The cooling tower efficiency of Unit 7 is very good.
2. The rate of heat loss is affected by the atmospheric parameters such as air temperature, water temperature, relative humidity and rate of heat loss.
3. The supply of fresh air, the size of droplets and the temperature of warm water will be governing the efficiency of the natural draft cooling tower.

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