Experimental Study on the Design of a Cooling tower for a Central Air-conditioning Plant

P.Balashanmugam, G.Balasubramanian

***Abstract*— The aim of our research is to undertake a case study of large cooling tower and reconditioning a small cooling tower of an air conditioning plant. The cooling towers are considered as an essential component of air conditioning plant. Cooling towers are equipment,devices commonly used to dissipate heat from power generation units, water-cooled refrigeration, air conditioning and industrial processes. In this paper, we use a natural draft counter flow cooling tower in investigating the performance of cooling towers. The humidity is defined as water particles present in the air. The humidity is the major factor in the atmosphere, it depends upon ambient temperature. Humidity is high in winter season and low in summer season. The performance of the natural draft cooling tower is dominated by wind speed, ambient air temperatures and humidity in the atmospheric conditions. When the humidity is high in the atmosphere, large quantity of water is required for cooling condensate. When humidity is low in atmosphere, small quantity of water is required for cooling condensate. The Cooling tower is one of the most important utilities in industrial and residential facilities. This paper estimates the energy efficiency, economic and environmental benefits of cooling tower.The investigations have been carried out at a test rig erected in the medical hospital. In this paper, the results of an experimental study on heat and mass transfer coefficients in packing of wet cooling towers are presented.**

***Index Terms*— cooling tower, tower height, DBT, HVAC, losses, Relative humidity, WBT, Cooling tower Efficiency.**

I. Introduction

Cooling tower is heat rejection equipment. Its main function is to extract waste heat from warm water to the atmosphere. Heat rejection in a cooling tower is specified as convection between the fine droplets of water and the surrounding air, and also as evaporation which allows a small portion of water to evaporate into moving air, the process involves both heat and mass transfer. Cooling towers are widely used in the power generation units, refrigeration and air conditioning industries [1]. Cooling towers can be classified by the movement of water and air as counter-flow and cross-flow types. Moreover, they can also be classified by means of air flow into mechanical draft and natural draft types. A cooling tower is a semi closed device for evaporative cooling of water by contact with air. The main function of cooling tower is to remove waste heat into the atmosphere from condenser. Cooling towers are an integral part of much industrial processes such as oil refineries, thermal power plants, petrochemical and chemical plants and HVAC system for cooling buildings. The cool water absorbs heat from the condenser becomes warmer. The warm water then returns to the cooling tower. In cooling tower the warm water sprayed downward, and air is blown upward. As the warm water droplets contact the air, some of the water droplets evaporate, and the air absorbs the heat released to the atmosphere, thereby lowering the temperature of the remaining water. In dry cooling tower the air is passed through the finned tubes forming a heat exchanger so only sensible heat is transferred to the air. In wet cooling towers the water is sprayed directly into the air. When evaporation occurs, both latent heat and sensible heat is exchanged. In cooling tower the ambient air is used to cool warm water coming from the condenser. They are many cooling tower designs or configurations. In natural draft towers are used very large thermal power plant and chemical plants. Due to large size of towers, they are generally used for water flow rates above 45000 m^3/ hr. Mechanical draft cooling towers utilize large fan to force or suck air through circulated water. Mechanical draft towers, tend to be relatively small structures where the air flow is driven by fan. The density difference between the warm air inside the tower and the cool dense ambient air outside the tower. A further classification is between counter flow and cross flow cooling towers. In cross flow cooling tower, the air flows at some angle to water flow direction and counter flow cooling tower, the air flows in the opposite direction to water flow direction. Cooling towers are commonly used devices for heat rejection into ambient air in many industrial applications such as condensers of refrigeration machines, power generation plants and the textile industry.

Common applications for cooling towers are providing cooled water for air-conditioning, manufacturing and electric power generation. The smallest cooling towers are designed to handle water streams of only a few gallons of water per minute supplied in small pipes like those might see in a residence, while the largest cool hundreds of thousands of gallons per minute supplied in pipes as much as 15 feet (about 5 meters) in diameter on a large power plant.

The generic term "**cooling tower**" is used to describe both direct (open circuit) and indirect (closed circuit) heat rejection equipment. While most think of a "cooling tower" as an open direct contact heat rejection device, the indirect cooling tower, sometimes referred to as a "closed circuit cooling tower" is nonetheless also a cooling tower.

An indirect or closed circuit cooling tower involves no direct contact of the air and the fluid, usually water or a glycol mixture, being cooled. Unlike the open cooling tower, the indirect cooling tower has two separate fluid circuits. One is an external circuit in which water is recirculated on the

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outside of the second circuit, which is tube bundles (closed coils) which are connected to the process for the hot fluid being cooled and returned in a closed circuit. Air is drawn through the recirculating water cascading over the outside of the hot tubes, providing evaporative cooling similar to an open cooling tower. In operation the heat flows from the internal fluid circuit, through the tube walls of the coils, to the external circuit and then by heating of the air and evaporation of some of the water, to the atmosphere. Operation of the indirect cooling towers is therefore very similar to the open cooling tower with one exception. The process fluid being cooled is contained in a "closed" circuit and is not directly exposed to the atmosphere or the recirculated external water.

In a counter-flow cooling tower air travels upward through the fill or tube bundles, opposite to the downward motion of the water. In cross-flow cooling tower air moves horizontally through the fill as the water moves downward. Nowadays energy issue is one of the most sensitive and complicated issues in the world. Fossil fuels which are the main source of energy are depleting and rising anxiety around the world about their negative effect on the atmosphere and the environment (Gan and Li, 2008). Energy is the key input in the development and economic growth.

Cooling towers are a very important part of many mechanical and chemical plants. The primary task of a cooling tower is to reject heat into the atmosphere. They represent a relatively inexpensive and dependable means of removing low-grade heat from cooling water. The make-up water source is used to replenish water lost to evaporation. Hot water from heat exchangers is sent to the cooling tower. The water exits the cooling tower and is sent back to the exchangers or to other units for further cooling Common applications for cooling towers are providing cooled water for air-conditioning, manufacturing and electric power generation. The smallest cooling towers are designed to handle water streams of only a few gallons of water per minute supplied in small pipes like those might see in a residence, while the largest cool hundreds of thousands of gallons per minute supplied in pipes as much as 15 feet (about 5 meters) in diameter on a large power plant.

Cooling towers are one of the most widely equipment units used in cooling systems, which also consist of a network of heat exchangers in closed circuit that consume water only to make up for the inherent losses in the process. The thermal performance of cooling towers has vital importance in the operation of a process. Because of their relevance in the processing industry, there are many works in the literature that address cooling water systems, Moreover, specific aspects are studied, namely design of cooling towers, control and operation of towers; modeling and simulation of the thermal performance and mass transfer on the height of the tower. The highly integrated features of cooling water systems (a single tower usually supplies multiple users) produce strong interactions among the hydraulic and thermal and mass process variables. For instance, the overall point of the pump, which results from its characteristics and on the entire cooling system. In addition, the recycle water flow rate depends on the operating distribution of rates in the parallel branches is also a function of their resistance to flow that is determined from pipe diameters, equivalent lengths and adjustment of the valves in each of the pipeline segments (Soylemez, 2004; Kloppers and Kroger, 2005).The operation of the system is even more complex at the thermal and mass levels. In each heat exchanger, a given heat load must be removed from process requirements. Furthermore, the inlet and outlet temperatures of the cooling water in the process heat exchangers must be within ranges that are compatible with the capacity of the cooling tower, as the total thermal load that is removed from the process units (through the heat exchangers) must be removed from the system in the cooling tower (Thomas and Houston, 1959a; Lowe and Christie, 1962; Thomas and Houston, 1959b).On the other hand, the transferred mass of the water in the cooling tower to air changes the outlet temperatures and flow rates of air. The outlet water temperature at the cooling tower is determined by its performance including air velocity, rate, and temperature and transferred water mass from hot water to the air affecting the height of the cooling tower (Lebrun and Silva, 2002; Pannkoke, 1996; Badran, 2003).

A. Theory and Principles

The Basic Water Cooling Tower behaves in a similar manner and has similar components to a full size
cooling tower.

- Basic principles

Consider the surface of a warm water droplet or film in contact with an air stream (see Fig. 1).

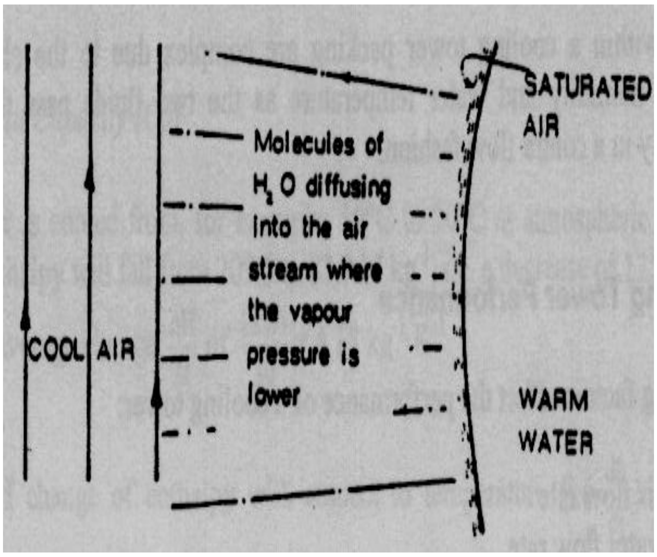

Figure 1. Basic principles of heat and mass transfer of water cooling tower.

Assuming that the water is hotter than the air, it will be cooled:

i) *By radiation* – This effect is likely to be very small under normal condition, and may be neglected.

ii) *By conduction and convection* – This will depend on the temperature difference, the surface area, air velocity, etc.

iii) *By evaporation* – This is by far the most important effect. Cooling takes place as molecules of H2O diffuse from the surface into the surrounding air. These molecules are then replaced by others from the liquid (evaporation) and the energy required for this is taken from the remaining liquid.

- Evaporation from a wet surface

The rate of evaporation from a wet surface into the surrounding air is determined by the difference between the vapour pressure at the liquid surface, i.e. the saturation pressure corresponding with the surface temperature, and the vapour pressure in the surrounding air. The latter is determined by the total pressure of the air and its absolute humidity. In an enclosed space, evaporation can continue until two vapor pressure are equal, i.e. until the air is saturated and at the same temperature as the surface. However, if unsaturated air is constantly circulated, the wet surface will reach an equilibrium temperature at which the cooling effect due to the evaporation is equal to the heat transfer to the liquid by conduction and convection from the air, which
under these conditions will be at a higher temperature. The equilibrium temperature reached by the surface under adiabatic conditions (i.e. in the absence of external heat gains or losses), is the “wet bulb temperature”.

In a cooling tower of infinite size and with an adequate air flow, the water leaving will be at the wet bulb temperature of the incoming air. For this reason, the difference between the temperature of the water leaving a cooling tower and the local wet bulb temperature is an indication of the effectiveness of the cooling tower. The “Approach to Wet Bulb” is one of the important parameters in the testing, specification, design and selection of the cooling tower.

B. *Purpose of a Cooling Tower*

A Cooling Tower is used with industrial applications that produce waste heat as a by-product of their operations. It provides an energy efficient and environmentally-friendly means of rejecting waste heat, saving our natural bodies of water from receiving vast quantities of warm water that would threaten marine life and ecology. They allow wind and air circulation to diffuse heat from the factories or manufacturing plants.

At the refrigeration plant, the heat is dissipated in the refrigerant condenser. The condenser may be air-cooled or water cooled. The heat transfer between two gases is more difficult and the total heat transfer surface requirement is more than between a liquid and gas**.** The water-cooled condenser and cooling tower is used because:

1. Because of larger heat transfer surface requirement, air cooled condenser may cost two or three times more than that of water cooled unit
2. The air-cooled condenser is economical to cool the refrigerant within 5 or 6˚C of DBT of air
3. The air-cooled condenser with cooling tower can operate at least 3˚ C below these conditions
4. Additional reduction of 3 C can save up to 105 in refrigerant compressor power.
5. Air cooled condensers are large and aesthetically they are undesirable.
6. The cooling capacity of ponds, lakes, river etc.cannot be predicted accurately. Unless water surface area is large enough, there is a certain amount of risk involved in using them.

- Refrigerant and cooling water

Water-cooled condenser requires separate equipments for handling cooling water. Where there is inadequate supply of cooling water, it is recirculated by cooling. This requires cooling tower and pumps for the circulation of cooling water. Cooling water circulated in the condenser absorbs the heat from the high pressure, high temperature refrigerant condenses. Then the water is cooled in the cooling tower. The water is then pumped to the condenser.

In this central air-conditioned plant there are three cooling towers and one of it is a standby. The working principle of cooling water layout is shown in fig.2.

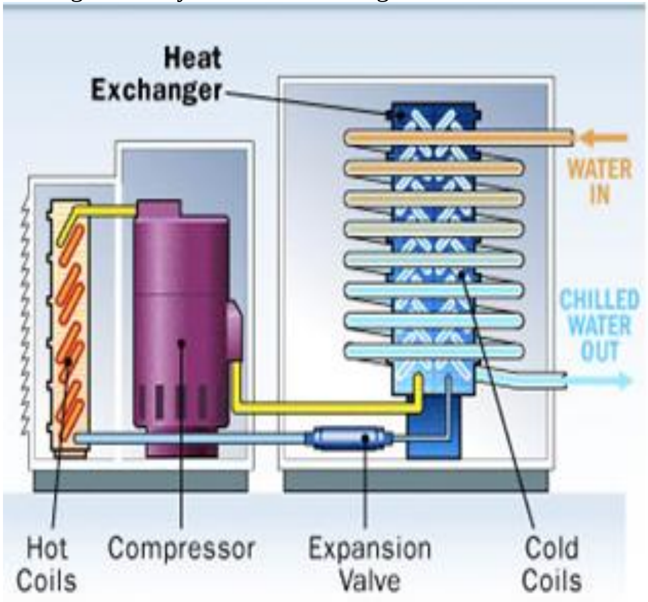

Figure 2. Working principle of cooling water layout.

In a chilled-water system, the entire air conditioner is installed on the roof or behind the building. It cools the water to between 40 and 45 degrees Fahrenheit (4.4 and 7.2 degrees Celsius). The chilled water is then piped throughout the building and connected to air handlers. This can be a versatile system where the water pipes work like the evaporator coils in a standard air conditioner. If it's well-insulated, there's no practical distance limitation to the length of a chilled-water pipe. Fig .3 shows the components of water cooled condenser.

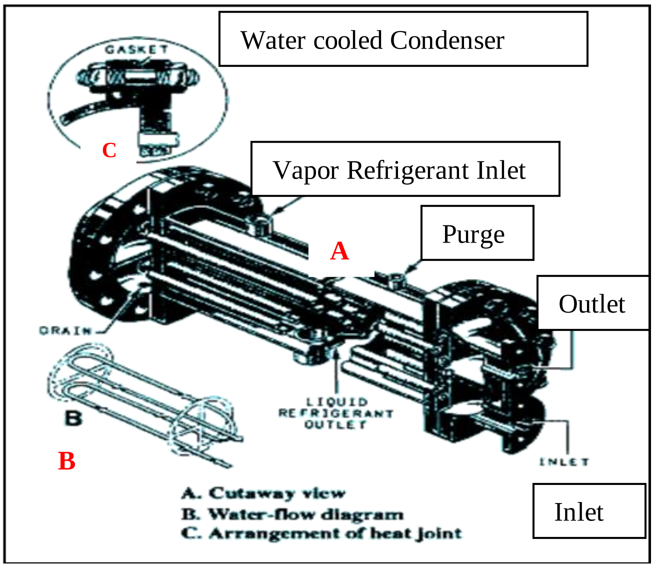

Figure 3. Components of Water cooled condenser.

C. Types of cooling tower

Cooling towers fall into two main categories:

• Natural draft

• Mechanical draft.

Natural draft towers use very large concrete chimneys to introduce air through the media. Due to the large size of these towers, they are generally used for water flow rates above 45,000m3/hr. These types of towers are used only by utility power stations. Mechanical 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 Mechanical draft towers depend upon their fan diameter and speed of operation.

- Mechanical draft towers

Mechanical draft towers are available in the following airflow arrangements:

1. Counter flows induced draft.
2. Counter flow forced draft.
3. Cross flow induced draft.

In the counter flow induced draft design, hot water enters at the top, while the air is introduced at the bottom and exits at the top. Both forced and induced draft fans are used. In cross flow induced draft towers, the water enters at the top and passes over the fill. An induced draft fan draws the air across the wetted fill and expels it through the top of the structure.

Cooling towers can be classified based on different aspects:

1. Material used
2. Water flow or capacity
3. Quality of the water to cool down

The basic cooling tower classification tends to be based on the following criteria:

1. Natural or mechanical draft
2. Induced or forced draft
3. Open, closed or hybrid cooling circuit

The cooling circuit type determines the exact heat exchange process.

D. Natural or mechanical draft

Natural draft cooling towers make use of the chimney operation of the cooling tower. The air flow is caused by the temperature difference between the air inside and outside the cooling tower.

The fans used in mechanical draft cooling towers cause the air flow. All cooling towers distributed by Almeco have mechanical draft. For natural draft cooling towers Almeco only carries out the maintenance. We also supply spare parts for this cooling tower type.

1) Natural Draft Cooling Tower

As the name indicates, the air is circulated inside the cooling tower by natural convection. The natural draft cooling towers are further classified as:

1. Natural draft cooling towers spray type, and
2. Natural draft cooling towers splash deck type.

2) Mechanical Draft Cooling Towers

The mechanical draft cooling towers are very much similar to that of the natural draft cooling towers. As the name indicates, air is circulated inside the tower mechanically instead of natural circulation. Propeller fans or centrifugal fans may be used.

Advantages of mechanical draft cooling towers over natural draft cooling towers:

- For the same capacity used, the mechanical draft cooling towers are much smaller than the natural draft cooling towers. This is because of the increase in cooling capacity due to increase in volume of the air being forced out by fan.
- Capacity control is possible in mechanical draft cooling tower. By controlling the speed of the fan, the volume of air can be controlled, which in turn controls the capacity.
- The natural draft cooling towers can be located only in open space. As they do not depend upon the atmospheric air, the mechanical draft cooling towers shall be located even inside the building.

Disadvantages of using mechanical draft cooling towers:

1. More power is required to run the system,
2. Increased running cost due to increase in maintenance of the fans, motors and its associated controls,

According to the location of the fan, they are further classified as:

1. Forced draft cooling towers, and
2. Induced draft cooling towers.

- Forced Draft Cooling Towers

In this system, fan is located near the bottom and on the side. This fan forces the air from bottom to top. An eliminator is used to prevent loss of water droplets along with the forced air.

- Induced Draft Cooling Towers

In this system, a centrally located fan at the top, takes suction from the tower and discharges it to the atmosphere. The only between the induced draft cooling tower and forced draft cooling tower is that the fan is located at the top in the induced draft cooling tower.

E. Induced or forced draft

Induced draft implies an inlet fan placed on top of the cooling tower and the creation of low pressure. Axial fans are always used for this type of draft. Forced draft means an exhaust fan placed at the base of the cooling tower which then causes overpressure. Both axial and centrifugal fans can be used.

II. COMPONENTS OF COOLING TOWER

The basic components of an evaporative tower are:

- **Frame and casing:** Most towers have structural frames that support the exterior enclosures (casings), motors, fans, and other components. With some smaller designs, such as some glass fiber units, the casing may essentially be the frame.
- **Fill:** Most towers employ fills (made of plastic or wood) to facilitate heat transfer by maximizing water and air contact. Fill can either be splash or film type.
- **Cold water basin:** The cold water basin located at or near the bottom of the tower, receives the cooled water that flows down through the tower and fill. The basin usually has a sump or low point for the cold water discharge connection. In many tower designs, the cold water basin is beneath the entire fill.
- **Drift eliminators:** These capture water droplets entrapped in the air stream that otherwise would be lost to the atmosphere.
- **Air inlet:** This is the point of entry for the air entering a tower. The inlet may take up an entire side of a tower

(cross flow 17 design) or be located low on the side or the bottom of counter flow designs.

- **Louvers:** Generally, cross-flow towers have inlet louvers. The purpose of louvers is to equalize air flow into the fill and retain the water within the tower. Many counter flow tower designs do not require louvers.
- **Nozzles:** These provide the water sprays to wet the fill. Uniform water distribution at the top of the fill is essential to achieve proper wetting of the entire fill surface. Nozzles can either be fixed in place and have either round or square spray patterns or can be part of a rotating assembly as found in some circular cross-section towers.
- **Fans:** Both axial (propeller type) and centrifugal fans are used in towers. Generally, propeller fans are used in induced draft towers and both propeller and centrifugal fans are found in forced draft towers.
- Components of Cooling Tower

1. Cold water basin
2. Basin Coating
3. Water distribution system
4. Classification by build
5. Anchor and Straps
6. Tower framework
7. Fan cylinder
8. Mechanical equipments
9. Bolding Hardware
10. Fans and Parts
11. Package Type
12. Fan decks
13. Casing & Louvers
14. Fire Production
15. Fill and drift eliminators
16.Nozzles

- Mechanical Components

1. Vibration Switches
2. Mechanical Davits
3. Gear Reducers
4. Drive shafts
5. Valves
6. Fans Speed reducers
7. Motors

A. Cooling tower performance

The important parameters, from the point of determining the performance of cooling towers, are:

- **"Range"** is the difference between the cooling tower water inlet and outlet temperature.
- **"Approach"** is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. Although, both range and approach should be monitored, the 'Approach' is a better indicator of cooling tower performance.19
- **Cooling tower effectiveness** (in percentage) is the ratio of range, to the ideal range,i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach).
- **Cooling capacity** is the heat rejected in kCal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.
- **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 m3
- **Cycles of concentration (C.O.C)** is the ratio of dissolved solids in circulating water to the dissolved solids in makeup water.
- **Blow down losses** depend upon cycles of concentration and the evaporation losses and is given by relation:

Some useful terms, commonly used in the cooling tower industry:

- **Drift -** Water droplets that are carried out of the cooling tower with the exhaust air. Drift droplets have the same concentration of impurities as the water entering the tower. The drift rate is typically reduced by employing baffle-like devices, called drift eliminators, through which the air must travel after leaving the fill and spray zones of the tower.
- **Blow-out -** Water droplets blown out of the cooling tower by wind, generally at the air inlet openings. Water may also be lost, in the absence of wind, through splashing or misting. Devices such as wind screens, louvers, splash deflectors and water diverters are used to limit these losses.Fig.4 shows the range and approach of cooling tower.

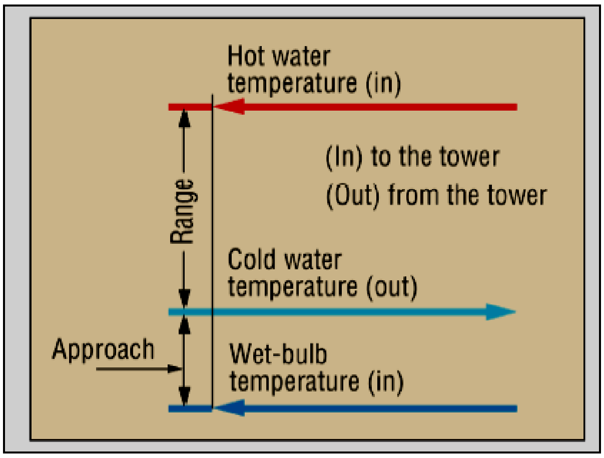

Figure 4. Range and Approach of cooling tower

- **Plume -** The stream of saturated exhaust air leaving the cooling tower. The plume is visible when water vapor it contains condenses in contact with cooler ambient air, like the saturated air in one's breath fogs on a cold day. Under certain conditions, a cooling tower plume may present fogging or icing hazards to its surroundings. Note that the water evaporated in the cooling process is "pure" water, in contrast to the very small percentage of drift droplets or water blown out of the air inlets.
- **Blow-down -** The portion of the circulating water flow that is removed in order to maintain the amount of dissolved solids and other impurities at an acceptable level.
- **Leaching -** The loss of wood preservative chemicals by the washing action of the water flowing through a wood structure cooling tower.
- **Noise -** Sound energy emitted by a cooling tower and heard (recorded) at a given distance and direction. The sound is generated by the impact of falling water, by the

movement of air by fans, the fan blades moving in the structure, and the motors, gearboxes or drive belts.

B. *Factors affecting cooling tower performance*

- **Capacity:** Heat dissipation (in kCal/hour) and circulated flow rate (m3/hr) are not sufficient to understand cooling tower performance. Other factors, which we will see, must be stated along with flow rate m3/hr.
- **Range:** Range is determined not by the cooling tower, but by the process it is serving. The range at the exchanger is determined entirely by the heat load and the water circulation rate through the exchanger and on to the cooling water.
- **Heat Load:** The heat load imposed on a cooling tower is determined by the process being served. The degree of cooling required is controlled 20 by the desired operating temperature level of the process. In most cases, a low operating temperature is desirable to increase process efficiency or to improve the quality or quantity of the product. In some applications (e.g. internal combustion engines), however, high operating temperatures are desirable.
- **Dry Bulb Temperature And Wet Bulb Temperature** The dry bulb temperature (DBT) is the temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture. The wet bulb is a measure of the quantity of moisture a particular sample of air can hold at that particular moment. Wet bulb temperature is an important factor in performance of evaporative water cooling equipment.
- **Humidity Of The Ambient Air** Humidity is defined as water particles presented in the air. The humidity is high in coastal areas and low in non coastal areas. Humidity is high in atmosphere, high quantity of water is required for cooling condensate.

III. PREVIOUS WORK

A lot of work has been done for modeling cooling towers in the past century. **Walker *et al.* (1923)** proposed a basic theory of cooling tower operation. **Merkel (1925)** developed the first practical theory including the differential equations of heat and mass transfer, which has been well received as the basis for most work on cooling tower modeling and analysis (**Khan *et al.*, 2003; Elsarrag, 2006; Qureshi and Zubair, 2006; ASHRAE, 2008; Lucas *et al.*, 2009**). In Merkel's model, in order to simplify the analysis, the water loss of evaporation is neglected, and the Lewis relation is assumed as unity. These assumptions may cause Merkel's model to underestimates the effective tower volume by 5-15% **(Sutherland, 1983).**

Jaber and Webb (1989) introduced the effectiveness-NTU (number of transfer units) design method for counter-flow cooling towers using Merkel's simplified theory.

Sutherland (1983) gave a more rigorous analysis of cooling tower including water loss by evaporation.

Braun (1988) and Braun *et al.* (1989) gave a detailed analysis and developed effectiveness models for cooling tower by assuming a linearized air saturation enthalpy and a modified definition of effectiveness using the constant saturation specific heat *Cs*. A modeling framework was developed for estimating the water loss and then validated over a wide range of operating conditions.

Bernier (1994,1995) presented a one-dimensional (1D) analysis of an idealized spray-type tower, which showed how the cooling tower performance is affected by the fill height, the water retention time, and the air and water mass flow rates.

Fisenko *et al.* (2004) developed a mathematical model of mechanical draft cooling tower, and took into account the radii distribution of the water droplets.

Wetter (2009) proposed a cooling tower model by using static mapping to the performance curve of a York cooling tower. Most existing models for cooling towers are steady-state or effectiveness models. Dynamic modeling of cooling tower is needed for control design and fault detection and diagnostics, and to the authors' best knowledge, no work has been reported on the dynamic model.

G. Al-Enezi *et al.* (2006) studied an experimental system includes a packed humidification column, a double pipe glass condenser, a constant temperature water circulation tank and a chiller for cooling water. They confirmed that the highest production rates are obtained at high hot water temperature, low cooling water temperature, high air flow rate and low hot water flow rate.

Milosavjevic *et al.* (2001) studied the thermal performance of a counter current cooling tower considering evaporation of a quantity of water and assuming that the heat and mass transfer are equivalent (Lewis number Le is equal to unity).

Halasz (1998) presented a general model describing all types of evaporative cooling processes. In his model, the author simplified the no dimensional equations by considering the air saturation curve as linear and the water mass flow rate as constant.

Jaber *et al.* (1989) shows how the theory of heat exchanger design may be applied to cooling towers. These authors demonstrated that the definitions of the effectiveness ε and NTU are in very good agreement with those used for heat exchanger design and are applicable to all cooling tower operating conditions. Several other mathematical models to correlate heat and mass transfer processes occurring in wet cooling towers exist; Such as those proposed and discussed by **Khan *et al.* (2004) and Kloppers *et al.* (2005).**

Cooling tower theory was first given by **Merkel, (1925)**. Effectiveness-NTU and logarithmic mean enthalpy methods were described by **Jaber and Webb, (1989).** They took the nonlinearity of the saturated air enthalpy versus temperature into consideration with a correction factor.

Kloppers and Kröger, (2005) analyzed the derivation of heat and mass transfer equations in counter flow wet cooling towers in detail. They described Merkel, NTU and Poppe methods and concluded that Poppe method yields higher Merkel numbers.

El- Dessouky et al. (1997) concluded that the effect of water evaporation on the cooling tower performance is not conservative but it can be as low as 1.3 % so that the assumption of constant water flow rate is justified. **Mohiuddin and Kant, (1996)** explained different numerical methods for the analysis of wet cooling towers. Khan et al. (2003) showed through numerical analysis that most of the heat transfer occurs by evaporation. The ratio of heat transfer by evaporation to total heat transfer was 90% at the top and

62.5% at the bottom of cooling tower packing. Assuming linear dependency of saturation enthalpy of air on temperature, **Halasz (1999)** showed that cooling tower efficiency depends on two dimensionless numbers. However, the results were corrected with a coefficient of linearization. It can be concluded from his results that his method is applicable only if the cooling range is less than 10°C. **Bedekar et al. (1998)** presented experimentally-obtained results on cooling tower performance for different inlet water temperatures and different water flow rates. They showed that tower characteristics and tower efficiencies are influenced by water inlet temperature. Experimental and numerical results for different filling materials in pilot-scale and industrial cooling towers were given by **Milosavljevic and Heikkilae (2001)**. Cooling towers were extensively described by **Berliner (1975) and Kröger (2004).**

IV. DESIGN OF COOLING TOWER

The cooling process in the cooling tower is very complex and the correct size of the cooling tower for any given condition is not easily determined as the controlling factors are many.

A. Design factor

The principle criteria on which design and manufacture of cooling tower are based are:

Achieving maximum contact between air and water in the tower by providing packing and good water distributing system. Assisting the flow of air in the tower by means of fan.

Minimizing the loss of water caused by water spray from the tower. This will also eliminate the risk of infection diseases transmitted to people by the hot humid air.

Relating the design of the tower to the quantity of water to be cooled with three temperatures, Wet of outside air water inlet temperature and temperature of cold water leaving the tower.

Problems arising from the quality of the water such as corrosion, fouling and the growth of bacteria are properly controlled.

Consider the space limitations at tower's location and the possibility of noise from the tower.

B. Performance of cooling tower and method to improve its performance

The cooling tower performance is always referred to WBT of the incoming air. This is the lowest temperature that the outgoing water can be cooled. The finite dimensions of a tower and the limited time in which water and air contact each other make it impossible to achieve this ideal cooling. The principle performance factor of a tower is its approach to the wet bulb temperature; this is the difference between the cooled water temperature leaving the tower and wet bulb temperature of the entering air. The smaller the approach, the more efficient the tower. Another important performance factor is the cooling range. This is the difference between the hot water temperature entering the tower and cold water temperature leaving the tower.

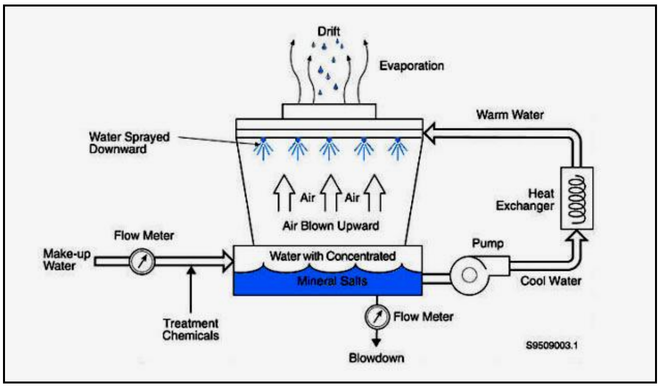

Figure 5.Working principle of Cooling Water System

The compressor discharges the high-pressure, superheated refrigerant vapor to the condenser, where it flows around the tubes through which water is being pumped. As the vapor gives up its superheat (sensible heat) to the seawater, the temperature of the vapor drops to the condensing point. The refrigerant, now in liquid form, is sub-cooled slightly below its condensing point. This is done at the existing pressure to ensure that it will not flash Circulating water is obtained through a branch connection from the fire main or by means of an individual pump taking suction from the sea. Sea water condensers have zinc anodes in the end covers to protect against corrosion.

Newer ships use a closed fresh water system, consisting of circulating pump, and keel-cooler. The purge connection (fig. left) is on the refrigerant side. It is used to remove air and other non-condensable gases that are lighter than the refrigerant vapor. Fig .5.shows that the working principle of cooling water system.

C. Cooling Tower Efficiency

Cooling towers use the evaporative cooling principle to cool the circulated water, and

- they can achieve water temperatures below the dry bulb temperature - t_{db} - of the air cooling air

They are in general smaller and cheaper for the same cooling loads than other cooling systems. Cooling towers are rated in terms of approach and range**,** where

- the **approach** is the difference in temperature between the cooled-water temperature and the entering-air wet bulb - t_{wb} - temperature
- the **range** is the temperature difference between the water inlet and exit states

Since a cooling tower is based on evaporative cooling the maximum cooling tower **efficiency** is limited by the wet bulb temperature - t_{wb} - of the cooling air

- Cooling Tower Efficiency

The cooling tower efficiency can be expressed as

$\mu = (t_i - t_o)\, 100 / (t_i - t_{wb})$ (1)

where

μ = cooling tower efficiency - common range between 70 - 75%

t_i = inlet temperature of water to the tower (°C, °F)

t_o = outlet temperature of water from the tower (°C, °F)

t_{wb} = wet bulb temperature of air (°C, °F)

The temperature difference between inlet and outlet water *(t_i - t_o)* is normally in the range *10 - 15 °F.*

The water consumption - the **make up** water - of a cooling tower is about *0.2-0.*3 liter per minute and ton of refrigeration. Compared with the use and waste of city water the water consumption can be reduced with about *90 - 95%.*

D. Case study of cooling tower

First saw the air conditioned plant and cooling tower located near the hospital. Then knew about the different components such as compressor, evaporator, expansion device, cooling tower, condenser and capacity of central air conditioner plant and discussed about the type, the compounds or equipments involved in the cooling tower and function of the different components. Then collected the layout of central air-conditioner plant from technician and knows about the working principle of the plant and study the role of cooling tower at the Air –conditioner plant. Then collected the materials about cooling tower such as cooling tower types, terminologies, dimensions, foundation and life of cooling towers. The different dimension of the cooling tower is measured and studied the working of induced cross flow type in existing cooling tower. To determine the performance, efficiency and other parameters of cooling tower, some observations are needed. So they clean the area, the cooling towers suitable for taking readings. To take the reading on cooling tower, thermometer, anemometer, measuring vessel and stop watch were used to measure the Dry bulb temperature, Wet bulb temperature of air and water, velocity of air etc. Some of the arrangements can be done on the cooling tower to measure the flow rate of water at the inlet of cooling tower pumped from the condenser with the help of condenser pump. The fan fitted to the motor and the belts which connect the motor and fan are properly checked before take the readings because the loosening of belt and fan make cause severe damage to equipment and human beings. After making arrangement of instruments and other, we start to take the readings. First took the dry bulb temperature and wet bulb temperature of an entering air and leaving air with the help of sling pschrometer. Then measure the velocity of air before and after the induced fan with the help of anemometer. Measure the temperature of water at the inlet and outlet of the cooling tower and calculate the temperature drop at different timings. The mass flow of water is measured by making a by-pass arrangement to collect the water in a separating tank. The layout of Central air-conditioning plant is shown in fig. 6 and the working principle of Mechanical refrigeration cycle is also shown in fig.7.

- Specification
  Specification for 125TR of cooling tower
  Type of cooling tower : Induced draft –cross flow
  Cooling tower model : Square
Overall dimension (LXWXH):2mx2mx3.5m
  Number of cell : one
- Auxiliary Equipment
  Fan
  Type : Axial flow
  Number of fan : One set
  Number of fan blades : 6
  Diameter of fan : 1500 mm
  Fan speed : 960rpm
- Motor
  Number of motor : one
  Motor HP : 5H.P
  Motor speed : 960 rpm
- Distribution pipe
  Inlet/outlet pipe : 6

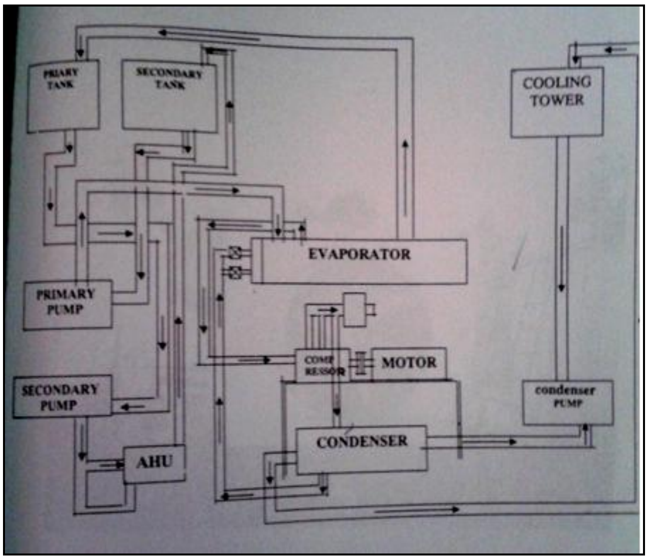

Figure 6.Layout of air-conditioned plant

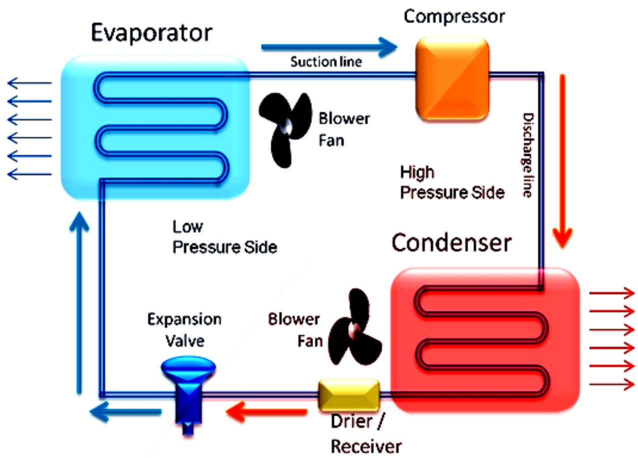

Figure 7. Working principle of mechanical refrigeration cycle

V. INSTALLATION AND MAINRENANCE OF COOLING TOWER

The installation and maintenance of cooling tower are as follows

A. Installation of cooling tower

The following general points are required to be taken into account for installation of cooling towers.
1. Cooling tower requires specific treatment for their installation.
2. This is very important part of the system.
3. The efficiency of the job that cooling tower does directly affect the operation of the plant.
4. Care must be taken in designing and installing the cooling tower as it directly affects the operation efficiency of the

system.

The cooling towers may be installed either inside or outside. We now see fundamental rules to be observed for indoor location as well as outdoor locations.

a) Inside installation of cooling tower

1. Properly level the tower and securely mount it. It should be placed on a steady surface such as concrete, wooden beams, steel deck etc.
2. Install the motor and drive equipment with the procedure outlined by the manufacture.
3. An ample supply of fresh air must always be available through intake duct, open windows or other available opening
4. Fresh air intake area of the duct must be as large as the air intake area of the tower.
5. The duct taking the hot air out of the tower must be as short as possible and it should take the hot air out properly.
6. Changes in cross-sectional area for the duct and bends in the duct discharging hot air must be kept minimum.
7. A door should be provided in the discharge duct for inspection and for cleaning purposes.

b) Outside installation of cooling tower

Fundamental rules to be observed for outdoor location of cooling towers are;
1. The cooling tower should be so located that the direction of the air discharge from the tower must be same as the direction of prevailing winds.
2. Adequate space around the tower be providing. The space is equal to the width of the tower at the inlet end. The space is needed for service and maintenance.
3. The tower should be leveled carefully. It should be firmly fixed on a steady surface such as concrete, wooden beams, steel decks etc.
4. The tower should not be placed close to windows, opening vent etc. In order to prevent transmission of noise to the room.
5. If the fan motor is not directly driven the V belt is used to drive the same. The motor and fans sheaves grooves be properly aligned over stretching of the belt on pulley be avoided as this will damage the belt.

B. Maintenance of cooling tower

Modern cooling tower fill, eliminators, advanced filter and separators and new water treatment chemicals have the efficiency of the tower and reduced the power consumption.

Routine cooling tower service includes visual inspection, mechanical maintenance and a physical cleaning programme which will maintain the system clean year-round.

The importance of cooling tower maintenance is well illustrated by its documented benefits. Power saving reflected in both electrical demand and consumption are significant.

In addition to this equipment life is increased through reduced corrosion of metal parts and erosion of system components including tubes and seals by abrasive particles. Chemicals requirements are reduced as clean system responds to water treatment better than fouled one. Calamities such as unexpected shutdown and severe freeze damage can be avoided along with their associated cost.

C. Environmental impact of cooling tower

The effect on the environment is considered in the design of cooling towers during the last decade. The cooling tower one of the external, readily visible structure, generally located on the top of the highest building in cities, as the cost of the land is very high

As the tower process water to remove heat, many considerations are imposed as listed below.
1. Chemical and mineral composition of discharge water.
2. Effects of discharge plume.
3. Quantity of water evaporated in the cooling tower
4. Temperature of discharge water.
5. Noise created by cooling tower operation
6. Conservation of electric power consumed by fans and pumps.
7. Aesthetics view of the tower

All the above mentioned consideration complicated the design of the cooling tower to fulfill the requirements of all parties involved.

VI. RECONDITIONING OF COOLING TOWER

In the reconditioning of cooling tower, the reconditioning process with the techno sins and tried to collect the details about the reconditioning. Then the cooling tower of domestic central air-conditioning plant which to be reconditioned and collected the data, such as capacity, efficiency and load etc. Then measured the dimensions of the different portions of the cooling tower and mark the measurement the model figure. To verify various portions and accessories of cooling tower and prepared two kinds of list, one list contains the portion are accessories which to be damaged and another contains the parts which to be repaired. The components of cooling tower such as supporting arm, baffles and spray nozzles are damaged due to corrosion and scaling of materials, rust formation, etc. Then bought new parts to replace the affected parts from hardware shops and made suitable according to the existing dimensions of cooling tower in the workshop. Finally rearranged the part of tower separately into a single unit and anti-corrosive painting is coated on the surface of cooling tower to prevent the corrosion and rust formation.

A. Material used for cooling tower

The following materials are used in manufacturing of the cooling tower

- Steel and concrete

1. Most important material due to its strength and ease of fabrication
2. It should be coated for protection against corrosion
3. Coating used are plastic bitumen and synthetic rubber
4. Concrete is used for big towers.

- Timber

1. Correctly prepared and applied timber is a costly effective material
2. Well-maintained timber can be expected to give good service up to 30 years
3. Algae and bacteria can be developed more easily on the surface, which is the main disadvantage.

- Asbestos

Though once popular not used now because of health hazards. Used only for eliminator and packing.

(d)Synthetic materials

1. UPVC (Unplasticized polyvinyl chloride) is very widely used material, as it does not support combustion.
2. They are subjected to attack by some organic solvents.
3. GRP (Glass reinforced plastic) is widely used for small packaged towers, suitable for service up to 80 to 100 ◦C
4. ABS (Acrylonitrile-butadience styrene) has high impact strength and suitable for temperature up to 60-70◦C.

B. *Material consideration*

As the water comes out of the cooling tower, the concentration of minerals and chemicals in the water increases as the cooling is effected by evaporating the 1 to 2 % of entering water. This concentration increases further with every pass of water. These materials of construction must be resistant enough to be corrosive effects of these minerals. To avoid this, a small amount of circulating water is blown out and chemically treated water is supplied. These considerations have caused changes in the construction materials used in cooling towers. Wood is rarely used as the water having higher mineral content leach out the wood. Fiberglass coated steel or concrete are commonly used.

C. *Water distribution systems in cooling tower*

The water distribution system in the cooling tower should distribute the water uniformly over the packing in the tower. The water droplets formed should be minimum in diameter that exposes the maximum surface area of a given water for cooling. But the dropping of waters should not be too small because otherwise there is excessive carryover. The water is distributed over packing either by gravity flow or under pressure through the nozzles provided.Fig.8 shows the water distribution system of cooling tower.

Figure 8.Water distribution system of cooling towers

VII. RESULTS AND DISCUSSIONS

Based on the trails conducted some of the points are found that have been influencing the cooling capacity of cooling tower. They are air velocity and temperatures drop across the fins. Both of them are directly proportional to each other. From trails it was found that the air flow velocity was poor in cooling, (as shown in fig 9-11) this is because obstruction in the air flow across the first due to algae formation in the fins. The heat exchange in the cooling tower fins was found ineffective due to scale formation in the inlet and outlet tables and tanks.

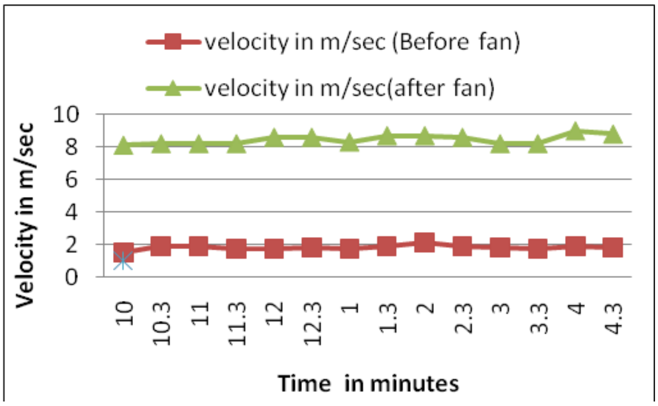

Figure 9.Velocity of air before and after fan against time during trail-1

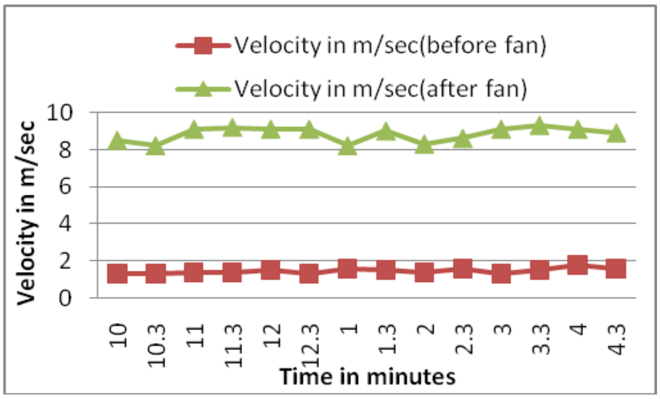

Figure 10. Velocity of air before and after fan against time during trail-2

The project was successfully completed by conducting trails on central air-conditioned plant cooling tower by observing different parameters like velocity, water .inlet temperature, water outlet temperature, temperature of air (DBT entering and leaving,WBT entering and leaving)Based on the set of observations on testing the cooling tower performance characteristics have been determined. Then the re-conditioned cooling tower was contains minerals salts which cause defects such as corrosion, scale formation etc.Finally we re-conditioned the cooling tower and found the solutions to rescues the problems or deflect and it is made to utilized for cooling purpose. Fig 12-15 shows that the water inlet and outlet temperature variations during the trails and the cooling tower efficiency also.

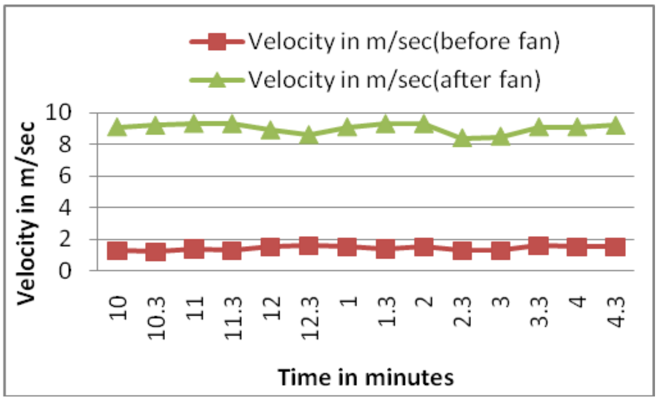

Figure 11. Velocity of air before and after fan against time during trail-3

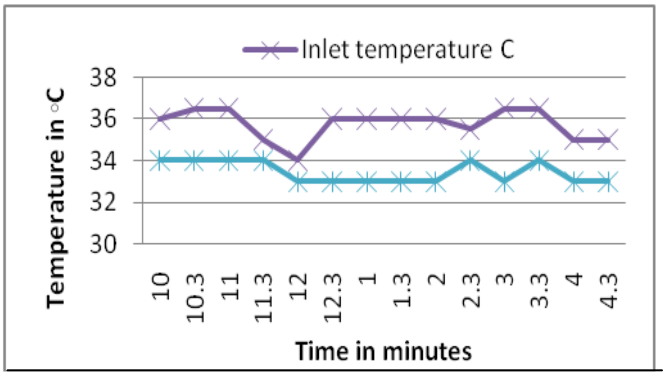

Figure 12. Water inlet and outlet temperature variations against time during the trail-1

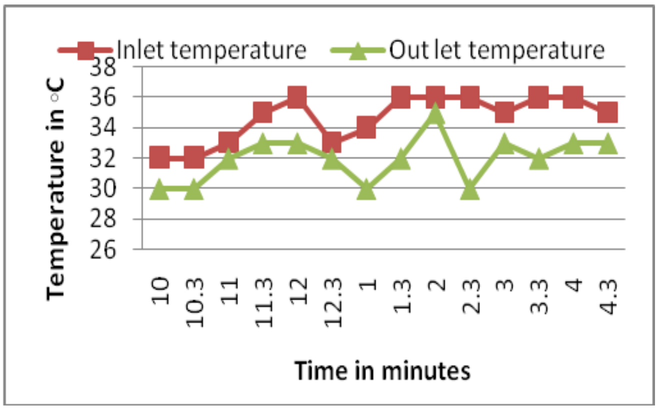

Figure 13. Water inlet and outlet temperature variations against time during the trail-2

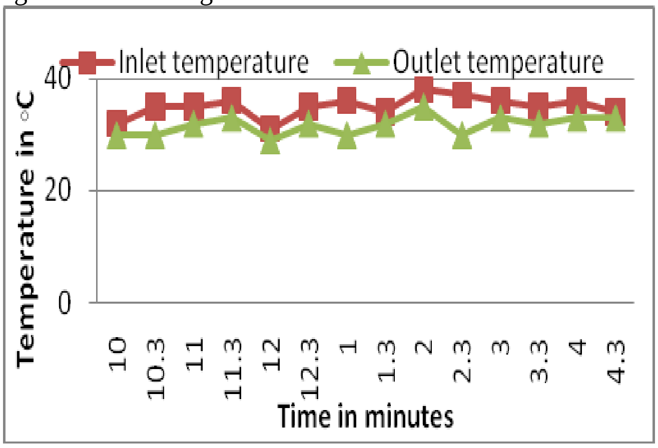

Figure 14 Water inlet and outlet temperature variations against time during the trail-3

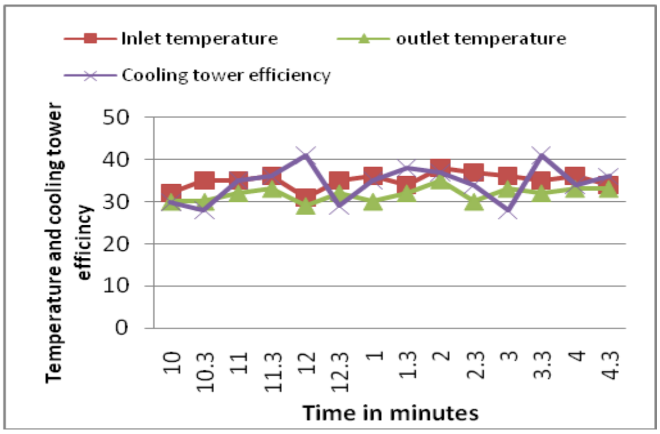

Figure 15. Water inlet and outlet temperature variations and cooling tower efficiency against time during the trail-3

VIII. CONCLUSION

The design of cooling tower is closely related to tower Characteristic and different types of losses generated in a cooling tower. Even though losses are generated in the cooling tower, the cooling is achieved due to transfer heat between air and water. In ideal condition, the heat loss of water must be equal to heat gain by air. But in actual practice it is not possible because of some type of losses. Cooling tower performance increases with an increase in air flow rate and characteristic decreases with increase in water to air mass ratio. The test result between wet and dry type cooling towers shows that for a given flow rate of water and inlet temperature, the cooling range of the wet type is more than the dry type. However, at higher inlet water temperatures the cooling range of the dry type approach the wet type. The reason for the higher cooling range in the wet type tower is that a fraction of the circulated water undergoes evaporative cooling apart from conduction and convection. We can conclude that by increasing the efficiency of the cooling tower is built in non coastal areas (Humidity is low) we can increase the cooling tower efficiency.In this paper the results of the experimental investigation on local intensities of heat and mass transfer the fill of wet cooling towers, have been presented. The experimental cooling tower has been constructed and installed in Medical college hospital. The experimental results have confirmed the assumption of the authors that due to unsteady flows of water and air, and depending on air number the rain droplets have been lifted from the lower edge of packing up to 1/2 of fill height. On the basis of analysis of many papers, the authors have concluded that the influence of the phase contact surface variation in the fill is no importance, and that contribution by phase contact changing is negligible in comparison to the total transferred heat and mass, so the averaged values of heat and mass transfer coefficients have been accepted across the fill volume. On making a brief study absent cooling problems a solution. Prevent the algae formation by using slime coating is suggested and to protect the cooling tower from scale formation by using scrapers, wire brush etc.

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