Study of Cooling Towers and Comparision of Conventional Cooling Tower and Spray Cooling Pond

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***Abstract*— The cooling tower cools the hot water with cool air by cross current flow of two fluids that is air and water past each other in a tower filled with packing. This involves both mass and heat transfer. The water surface which exists on the tower packing is covered with an air film assumed to be saturated at water temperature. The heat is transferred between this film and the main body of air by diffusion and convection. The packing or fill is arranged to prevent a droplet of water from falling the full height of the tower. As it falls in hits a packing member, spaces forms a film, drops off and falls to hits a packing member. The cross – current air stream of air sweeps across these drops and films to effectively cool the water and humidity the air. As the water flow down through the tower its temperature may drop below the dry bulb temperature, it can only approach one of the controlling feature in tower design and performance is how close the inlet air wet bulb temperature and outlet water are expected to operate. Common apply large hyperboloid structures that can be up to 200 meters tall and 100 meters in diameter, or rectangular structures that can be over 40 ,meters tall and 80 meters long. Smaller towers are normally factory-built, while larger ones are constructed on site. Cooling towers are a very important part of many 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. Spray cooling ponds are avored as far as the cooling of condenser water. Modern designed cooling towers reputed to be much more efficient but are more expensive. There are times however, when spray cooling bonds have to be built and hoped that the experience gained in building such an old fashioned contraption will serve a useful purpose if a similar situation should arise at other industries. Thus we compared the efficiency of cooling tower and spray cooling pond. As the spray cooling pond efficiency is more than the cooling tower, so we recommended the spray cooling pond usage instead of cooling tower in the industries.**

INTRODUCTION

COOLING TOWER

The cooling tower cools the hot water with cool air by cross current flow of two fluids that is air and water past each other in a tower filled with packing. This involves both mass and heat transfer. The water surface which exists on the tower packing is covered with an air film assumed to be saturated at water temperature. The heat is transferred between this film and the main body of air by diffusion and convection. The packing or fill is arranged to prevent a droplet of water from falling the full height of the tower. As it falls in hits a packing member, spaces forms a film, drops off and falls to hits a packing member. The cross – current air stream of air sweeps across these drops and films to effectively cool the water and humidity the air. As the water flow down through the tower its temperature may drop below the dry bulb temperature, it can only approach one of the controlling feature in tower design and performance is how close the inlet air wet bulb temperature and outlet water are expected to operate. Common apply large hyperboloid structures that can be up to 200 meters tall and 100 meters in diameter, or rectangular structures that can be over 40 ,meters tall and 80 meters long. Smaller towers are normally factory-built, while larger ones are constructed on site. Cooling towers are a very important part of many 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. Typical closed loop cooling tower system is shown in Figure 1.

SPRAY COOLING POND

Spray cooling ponds are favoured as far as the cooling of condenser water. Modern designed cooling towers reputed to be much more efficient but are more expensive. There are times however, when spray cooling bonds have to be built and hoped that the experience gained in building such an old fashioned contraption will serve a useful purpose if a similar situation should arise at other industries.

PRINCIPLE OF HEAT TRANSFER

CONDUCTION

Conduction is the transfer of heat by direct contact of particles as matter. The transfer of energy could be primarily by elastic impact as in fluids or by free electron diffusions predominant in metals or phonon vibration as predominant in insulators. In other words, heat is transferred by conduction when adjacent atoms vibrate against one another or as electrons move from atom to atom. Conduction is greater in solids, where atoms are in constant, in liquids and gases, the molecules are usually further apart, giving a lower change of molecules colliding and passing on thermal energy.

CONVECTION

Convection is transfer of heat by movement of a heated fluid. Unlike the case of pure conduction, now currents in fluids are additionally involved in convection. This movement occurs into a fluid or within a fluid, and cannot happen in solids. In solids, molecules keep their relative position to such an extent that bulk movement or flow is prohibited, and therefore convection does not occur.

NATURAL CONVECTION

In nature convection a fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process continues, forming convection current. The driving force for natural convection is buoyancy, a result of differences in fluid density when gravity or any type of acceleration is present in the system.

FORCED CONVECTION

Forced convection, by contract occurs when pumps, fans or other means are used to propel the fluid and create an artificially induced convection current. Forced heat convection is sometimes referred to as heat advection ,or sometimes simply advection for short .but advection is a more general process ,in heat advection ,the substance being “ advected ” in the fluid field is simply heat (rather than mass ,which is the other natural component in such situations ,as mass transfer and the heat transfer share generally the same equations).

RADIATION

Radiation is the transfer of heat energy through empty space .all the object with a temperature above absolute zero radiate energy at a rate equal to their emissivity multiplied by the rate at which energy would radiate from them if they were a black body. No medium is necessary for radiation to occur; radiation works even in and through a perfect vacuum. The energy from the sun travels through the vacuum of space before warming the earth. Also, the only way that energy can leave earth is being radiated to space. The two kinds of emission are simply different “colors” of electromagnetic radiation.

PRINCIPLE OF COOLING TOWER

The cooling tower is totally an orphan product, and as the word cooling is associated with it. ACR people have taken that word for granted water cannot be cooled with less than a 3c approach. Hence the cold water temperature achievable shall be 3c, i.e. more than the wet bulb temperature of air. The wet bulb temperature considered should be the actual wet bulb temperature of air entering into a cooling tower not atmospheric wet but actual wet bulb temperature entering a cooling tower is affected due to many factor .That is heat source near the cooling tower should not be hindered; recycling because of size of the tower; and orientation of the tower is respect to wind flow.

CLASSIFICATION OF COOLING TOWERS

1. Natural draft

2. Mechanical draft a. Forced draft b. Induced draft

i. Fan operated induced draft ii. Fan less induced draft

NATURAL DRAFT COOLING TOWER

In a natural draft cooling tower, hot water is allowed to fall from top of the cooling tower through a distribution system. As water gets downward flow, it broken up and redistributed by screen or fills. Atmospheric air, which enters the cooling tower horizontally, will come in contact with water and cooling process takes place. The quality of air entering the cooling tower will depend on atmospheric wind velocity, temperature conditions and hence performance of cooling tower various accordingly.

MECHANICAL DRAFT COOLING TOWER

Because of unreliable and uncontrollable performance of natural draft cooling tower, the system was devised to pass air at desired controlled rate. This is the air draft. If the air draft is created by mechanical means, they are called mechanical draft cooling tower.

FORCED DRAFT COOLING TOWER

This is counter flow type cooling tower. Hot water is sprayed at the top of cooling tower and air travels from bottom to top in opposite direction of water. In forced draft cooling tower, air is pushed inside the cooling tower from the bottom of the cooling tower.

Mechanical draft towers are available in the following airflow arrangements:

1. Counter Flow Induced Draft.

2. Counter Flow Forced Draft.

3. Cross Flow Induced Draft.

COUNTER FLOW

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.

CROSS FLOW

In cross flow induced draft towers, the water enters at the top and passes over the fill. The air, however, is introduced at the side either on one side (single-flow tower) or opposite sides (double-flow tower). An induced draft fan draws the air across the wetted fill and expels it through the top of the structure.

The Figure.3 illustrates various cooling tower types. Mechanical draft towers are available in a large range of capacities. Normal capacities range from approximately 10 tons, 2.5 m^3/hr flows to several thousand tons and m^3/hr. Towers can be factory built or field erected – for example concrete towers are only field erected.

Many towers are constructed so that they can be grouped together to achieve the desired capacity. Thus, many cooling towers are assemblies of two or more individual cooling towers or “cells.” The number of cells they have, e.g., a eight-cell tower, often refers to such towers. Multiple-cell towers can be lineal, square, or round depending upon the shape of the individual cells and whether the air inlets are located on the sides or bottoms of the cells.

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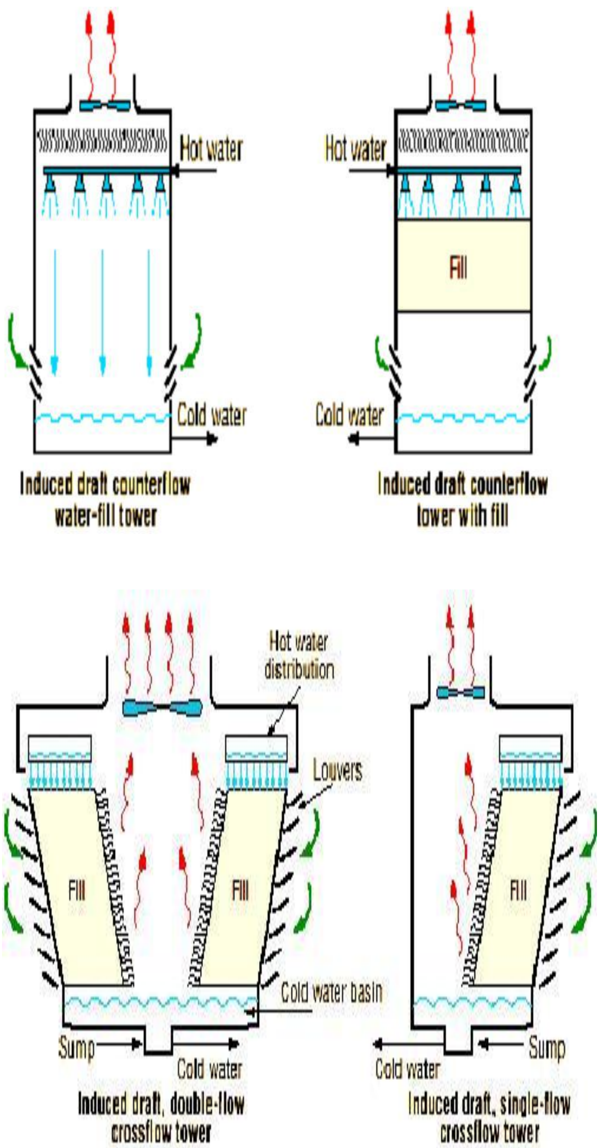

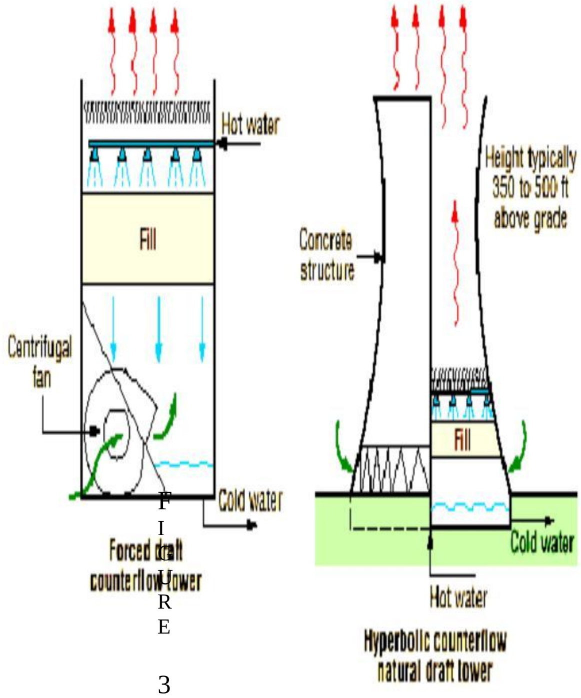

FIGURE 3

COMPONENTS 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.

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.

With splash fill, waterfalls over successive layers of horizontal splash bars, continuously breaking into smaller droplets, while also wetting the fill surface. Plastic splash fill promotes better heat transfer than the wood splash fill.

Film fill consists of thin, closely spaced plastic surfaces over which the water spreads, forming a thin film in contact with the air. These surfaces may be flat, corrugated, honeycombed, or other patterns. The film type of fill is the more efficient and provides same heat transfer in a smaller volume than the splash fill.

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 fills. 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.

In some forced draft counter flow design, however, the water at the bottom of the fill is channeled to a perimeter trough that functions as the cold water basin. Propeller fans are mounted beneath the fill to blow the air up through the tower. With this design, the tower is mounted on legs, providing easy access to the fans and their motors.

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 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. Depending upon their size, propeller fans can either be fixed or variable pitch.

A fan having non- automatic adjustable pitch blades permits the same fan to be used over a wide range of kW with the fan adjusted to deliver the desired air flow at the lowest power consumption. Automatic variable pitch blades can vary air flow in response to changing load conditions.

TOWER MATERIALS

In the early days of cooling tower manufacture, towers were constructed primarily of wood. Wooden components included the frame, casing, louvers, fill, and often the cold water basin. If the basin was not of wood, it likely was of concrete.

Today, tower manufacturers fabricate towers and tower components from a variety of materials. Often several materials are used to enhance corrosion resistance, reduce maintenance, and promote reliability and long service life.

Galvanized steel, various grades of stainless steel, glass fiber, and concrete are widely used in tower construction as well as aluminum and various types of plastics for some components.

Wood towers are still available, but they have glass fiber rather than wood panels (casing) over the wood framework. The inlet air louvers may be glass fiber, the fill may be plastic, and the cold water basin may be steel.

Larger towers sometimes are made of concrete. Many towers—casings and basins—are constructed of galvanized steel or, where a corrosive atmosphere is a problem, stainless steel. Sometimes a galvanized tower has a stainless steel basin. Glass fiber is also widely used for cooling tower casings and basins, giving long life and protection from the harmful effects of many chemicals.

Plastics are widely used for fill, including PVC, polypropylene, and other polymers. Treated wood splash fill is still specified for wood towers, but plastic splash fill is also widely used when water conditions mandate the use of splash fill. Film fill, because it offers greater heat transfer efficiency, is the fill of choice for applications where the circulating water is generally free of debris that could plug the fill passageways.

SPECIAL TYPE OF COOLING TOWER
FILLESS FANLESS COOLING TOWER

Cooling tower without fans and fills
No power requirement

Comparable performance with that of normal cooling tower
Zero maintenance

No major break down

WORKING PRINCIPLE OF A FILLESS

FANLESS COOLING TOWER

It is an equipment to cooling water with the help of atmospheric air

Atmospheric air is not saturated with water and has affinity to absorb additional moisture till it becomes saturated. This principle of moisture absorption is used to cool water.

The energy required to cool the evaporate water is taken by falling temperature of the remaining water

For each kilogram of water evaporated, about 550 Kcal of heat energy is available for cooling the remaining water.

TERMINOLOGIES IN COOLING TOWER
WET BULB TEMPERATURE

The thermodynamic wet bulb temperature is the temperature a volume of air would have if cooled adiabatically to saturation at constant pressure by evaporation of water into it, all latent heat being supplied by the volume of air. The thermodynamic wet-bulb temperature is a thermodynamic property of a mixture of the air and water vapour. The value indicated by a simple wet-bulb thermometer often provides an adequate approximation of the thermodynamic wet-bulb temperature.

DRY-BULB TEMPERATURE

The dry-bulb temperature is the temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture. In construction, it is an important consideration when designing a building for a certain climate. Nall called it is one of the “the most important climate variables for human comfort and building energy efficiency.

HUMIDITY

Humidity is the amount of water vapour in the air. In daily language the term “humidity” is normally taken to mean relative humidity. Relative humidity is defined as the ratio of the partial pressure of water vapour in a parcel of air to the saturated vapour pressure of water vapour at a prescribed temperature. Humidity may also be expressed as absolute humidity and specific humidity. Humidity indicates the likelihood of precipitation, dew, or fog. High humidity makes people feel hotter outside in the summer because it reduces the effectiveness of sweating to cool the body by preventing the evaporation of perspiration from the skin. This effect is calculated in a heat index table.

RELATIVE HUMIDITY

Relative humidity is defined as the ratio of the partial pressure of water vapour in a gaseous mixture of air and water vapour to the saturated vapour pressure of water at a given temperature. Relative humidity is expressed as a percentage and is calculated in the following manner:

$$RH=P(H2O)/P^*(H2O)$$

Where

P(H2O) is the partial pressure of water vapour in the gas mixture;

P^*(H2O) is the saturation pressure of water at the temperature of the gas mixture; and

RH is the relative humidity of the gas mixture being considered.

Relative humidity is often mentioned in weather forecasted reports, as it is an indicator of the likelihood of precipitation, dew, or fog. In hot summer weather, it also increases the apparent temperature to humans by hindering the evaporation of perspiration from the skin as the relative humidity rises.

DEW POINT

The dew point is the temperature to which a given parcel of air must be cooled, at constant barometric pressure, for water vapour to condense into water. The condensed water is called dew. The dew point is a saturation point.

When the dew point temperature falls below freezing it is often called the frost point, as the water vapour no longer creates dew but instead creates frost or hoarfrost by deposition.

The dew point is associated with relative humidity. A high relative humidity indicates that the dew point is closer to the current air temperature. Relative humidity is equal to the current temperature (and the air maximally saturated with water). When the dew point stays constant and temperature increases, relative humidity will decrease.

At a given barometric pressure, independent of temperature, the dew point indicates the mole fraction of water vapour in the air, and therefore determines the specific humidity of the air.

The dew point is an important statistic for general aviation pilots, as it is used to calculate the likelihood of carburettor icing and fog, and estimate the height of the cloud base.

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. (See Figure 4).

"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. (See Figure 4).

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.

Cooling tower effectiveness = 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.
An empirical relation used often is:
Evaporation Loss (m3/hr) = 0.00085 x 1.8 x circulation rate (m3/hr) x (T1-T2)

Where

T1-T2 = Temp. Difference between inlet and outlet water.

THE PRESSURE LOSSES ARE:

1. Tower packing or fill (70-80% of loss)
2. Air inlet if induced draft
3. Mist eliminators at top
4. Air direction change losses and entrance to packing on forced draft units.

These losses are a function of air velocity, number and spacing of packing decks, liquid rate and relation between L'&Ga.

P'=NBGa (0.0675/pg)

Pressure drop values per individual deck P'/N range from 0.003-0.006 inch of water for low L' and Ga rates to 0.03-0.06 inch of water for high L' and Ga rates. Pressure losses through wooden mist eliminators based on 0.0675lb/cu.ft.air varies from 0.01 inch water at Ga 800 to 0.07 at Ga=2000 as almost a straight line function. These loses are based on the face area of the eliminators.

FAN HORSE POWER FOR MECHANICAL DRAFT TOWER

It can be calculated by using the equation:

BHP=Fps/(6356)*(0.50)

F=actual cfm at fan inlet
Ps=total static pressure of fan, inches of water

This relation includes a 50% static efficiency of the fan and gear losses assuming a gear drive. If belt driven the difference will not be great. The conditions for actual inlet conditions for an induced draft fan must be obtained from equation. Economical tower sizes usually require fan horse power between 1.05 and 0.08 horse power per square foot on the ground plan area and motors larger than 75HP are not often used due to inability to obtain the proper fans and gears in the space required.

Water distribution must give uniform water flow over the tower packing many towers use a gravity feed system discharging the water through throughs and ceramic, metal or plastic nozzles. Other systems use pressure nozzles discharging upward, before falling back over the packing head due to the pressure rates usually run from 1 to 3.5 gpm/ft^2 of ground plan area.

CYCLES OF CONCENTRATION

In a sense, this value is the inverse of the blow down. It is quite useful in calculating the treatment dosage. The higher its value, the more efficiency the water is being used.

ppm calcium in the circulating water COC = --

ppm calcium in makeup water.

MAKEUP WATER REQUIRED

This value is simply the sum of the water evaporated and water blow down.

AIR REQUIRED

Enough air must be drown or forced through the tower to evaporate the amount of water. Two additional measurements are needed: the wet bulb temperature and dry bulb temperature of the inlet air. Psychometric table or chart will show that the water content of such air. It has been that the temperature of the outlet air is very close to the average of the inlet and outlet water temperature. The difference between these two values will give the amount of water vapour. The dry air required to remove this quantity of water is evaporation rate divided by this value.

WATER EFFICIENCY

The lowest temperature to which water can be cooled by its own evaporation is the wet bulb temperature of the air with which is in contact. The water efficiency of a cooling tower would be the ratio of the actual cooling to the theoretical cooling.

(hot water – cold water)

Water efficiency= ---------------------------------x100

(hot water – wet bulb)

PERFORMANCE CALCULATION OF COOLING TOWER

DATA

Cooling water inlet temperature of the cooling tower =45°C=Tin

Cooling water outlet temperature of the cooling tower =33°C=Tout

Wet bulb temperature of the inlet air =29°C=Twet

Water volumetric flow rate =350m³/hr

Ground plan area of the tower =16*6m²

Number of decks =40

Type of deck used ='J'deck

Number of cells in tower =4

CALCULATION

Tin =45°c Tout =33°c Twet =29°c Density=1000kgm³/hr

Total volumetric flow rate in to the cooling tower=1400m³/hr

Range =Tin-Tout

=45-33Range =12°c

Approach =Tout-Twet

=33-29

Approach =4°c

EVAPORATION LOSS

Water flow rate is =1400m³/hr

Cooling water inlet temperature =45°c Cooling water outlet temperature=33°c

Evaporation loss= 0.00085*1.8*circulation rate*(T1-T2)

= 0.00085*1.8*1400*(45-33)

= 25.704m³/hr

CYCLE OF CONCENTRATION

Cycle of concentration= Xc/Xm

Xc - concentration of chloride in circulating water in ppm

Xm – concentration of chloride in makeup water in ppm

Coc = 150/50=3

WATER EFFICIENCY

(hot water -cold water)

Water efficiency= ---------------------------*(100)

(hot water-wet bulb)

Water efficiency = ((45-33)/(45-29)) *100

=75%

DRIFT LOSS IN COOLING TOWER

It is very difficult to ignore drift problem in cooling towers. Now-a-days most of the end user specification calls for 0.02% drift loss.

With technological development and processing of PVC, manufacturers have brought large change in the drift eliminator shapes and the possibility of making efficient designs of drift eliminators that enable end user to specify the drift loss requirement to as low as 0.003 – 0.001%.

PERFORMANCE CALCULATION OF SPRAY COOLING POND DATA

Cooling water inlet temperature of the cooling tower =45°C=Tin

Cooling water outlet temperature of the cooling tower=30°C=Tout

Wet bulb temperature of the inlet air =29°C=Twet

Total water flow rate =1400m³/hr

Ground plan area of the tower =16*6m²

Number of spray nozzles =710(3/4")

CALCULATION

Tin =45°c

Tout =30°c

Twet =29°c

Density =1000kgm³/hr

Range =Tin-Tout

=45-30=15°c

Approach=Tout-Twet

=30-29

=1°c

EVAPORATION LOSS

Water flow rate is=1400m³/hr Cooling water inlet temperature=45°c Cooling water outlet temperature=30°c

Evaporation loss= 0.00085*1.8*circulation rate*(T1-T2)

= 0.00085*1.8*1400*(45-30)

= 32.13m³/hr

CYCLE OF CONCENTRATIONCycle of concentration= Xc/Xm

Xc - concentration of chloride in circulating water in ppm

Xm – concentration of chloride in makeup water in ppm

Coc = 150/50=3

WATER EFFICIENCY

(hot water -cold water)

Water efficiency = ---------------------------*(100)

(hot water -wet bulb)

= ((45-30)/(45-29)) *100 Water efficiency = 93.75%

ADVANTAGES OF COOLING TOWER

1. The vibration and noise are minimum as mechanical equipments are set on a solid foundation.
2. As it handles dry air, problems of fan blade erosion are avoided.
3. It is more safe as it is located on the ground level.
4. The main advantage is that coldest water comes in contact with driest air and warmest water comes in contact with the most humid air.
5. The first cost is lower due to the reduction in pump capacity required and smaller length of water pipes.

ADVANTAGES OF SPRAY COOLING POND

1. It does not require additional parts when compared to the conventional cooling towers, hence power requirement is low.
2. Initial cost is low.
3. Cooling water effectiveness is high when compared to conventional cooling towers.

CONCLUSION

Extensive study of cooling tower is phosphoric plant has been carried out with the operating parameters.

As a outset, conventional cooling towers are provided in plants where there is space constraint and to meet the plant heat load requirements.

FLFL cooling tower are provided to meet the process requirement or to cool the process fluid which require additional water make-up in turn make the water contaminance free.

Spray pond cooling towers which requires more space have been located over the pump and more effective by direct contact with air.

Spray pond cooling towers is less expensive since it is consuming less power and minimum piping.

All the cooling towers have been provided in the plant based on the design and process requirements and heat loads very effectively and efficiently using the space and with minimum power.