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A Study on Experimental Investigation on Cooling Tower Performance Analysis with Dew Point Cooling

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ABSTRACT

Cooled water is necessary for air conditioners, manufacturing processes, power generation and many other purposes. Cooling tower is equipment used to reduce the temperature of water by extracting heat from water and emitting it to the atmosphere. Cooling towers are able to lower the water temperatures more than other devices that use only air to reject heat, like the radiator in a car and are therefore more cost-effective and energy efficient. In the past most of the processes requiring cooling used piped town water through the equipment. After cooling the equipment the water was drained to the gutter. So, the water was totally wasted after using it once. Cooling towers were introduced so that the wastage of water can be reduced by recycling the water. Cooling towers make use of evaporation. Some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. The evaporation process only takes place on the surface of a liquid and needs latent heat of vaporization to happen. Sensible heat is drawn from the body of the water to the surface to supply the energy needed for the latent heat. It can be seen that for a little evaporation a lot of sensible heat will be needed therefore the main body of the circulating water is cooled for very little loss of water. The main purpose of this study is to work on developing mathematical model for cooling tower and examine methodically the performance of a model of closed loop 10 RT counter flow induced draft bottle type cooling tower which has been developed only for this project purpose.

INTRODUCTION

Overheating of machine elements is common problem in industry. It is caused due to continuous operation of machine and atmospheric conditions of the surroundings. Operation cannot be stopped or in other words the machine cannot be given time to be cooled down and therefore there has to be provision for cooling. Water is the best cooling medium as it is cheap and available in abundance. However, it has to be noted that continuous flow of fresh water to the machine is not advisable as it creates great waste.

Cooling tower is used to fulfill the purpose of cooling with minimum usage of fresh water. It circulates fresh water for cooling to the machine and uses least make up water that is lost due to evaporation. Apart from industry cooled water is needed for, for example, air conditioners, or power generation. A cooling tower is the equipment used to reduce the temperature of a water stream by extracting heat from water and emitting it to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly as shown in the figure. Cooling towers are able to lower the water temperatures more than devices that use only air to reject heat, like the radiator in a car, and are therefore more cost-effective and energy efficient. Cooling towers are designed and manufactured in several types, with numerous sizes available in each type. Not all types are suitable for application to every heat load configuration. There are Page atmospheric towers which utilize no mechanical device to create airflow through the tower. There are also mechanical draft towers which use either single or multiple fans to provide flow of known volume of air through the tower. Mechanical draft towers are categorized as either forced draft on which the fan is located in the ambient air stream entering the tower and the air is blown through or induced draft where a fan is located in the exiting air stream that draws air through the tower. In a counter-flow cooling tower air travels upward through the fill or tube bundles, opposite to the downward motion of the water. In case of cross-flow cooling tower air moves horizontally through the fill as the water moves downward. If cooled water is returned from the cooling tower to be reused, some water must be added to replace, or make-up, the portion of the flow that evaporates. Because evaporation consists of pure water, the concentration of dissolved minerals and other solids in circulating water will tend to increase unless some means of dissolved-solids control, such as blow-down, is provided. Some water is also lost by droplets being carried out with the exhaust air (drift), but this is typically reduced to a very small amount by installing baffle-like devices, called drift eliminators, to collect the droplets. The make-up amount must equal the total of the evaporation, blow-down, drift, and other water losses such as wind blowout and leakage, to maintain a steady water level. Evaporation of the circulating water cools the majority of water in cooling tower. A cooling tower takes the heat transfer law 'the greater the exposed surface area, the greater will be the rate of heat transfer. The evaporation process only takes place on the surface of a liquid and needs latent heat of vaporization to happen (2256 kJ/kg).

Sensible heat (4.19 kJ/kg K), is drawn from the body of the water to the surface to supply the energy needed for the latent heat. It can be seen that for a little evaporation a lot of sensible heat will be needed therefore the main body of the circulating water is cooled for very little loss of water. Warm to hot water from the cooling process is pumped to the top of the cooling tower and into the sprays where the water is broken up into droplets and distributed over the Fill. The water droplet spreads out as it slides down the Fill creating the surface area necessary for evaporation. The evaporation rate of the water is restricted by the amount of moisture already in the air around it. To maintain evaporation the moistened air must be replaced with dry air, usually by fans blowing air through the tower.

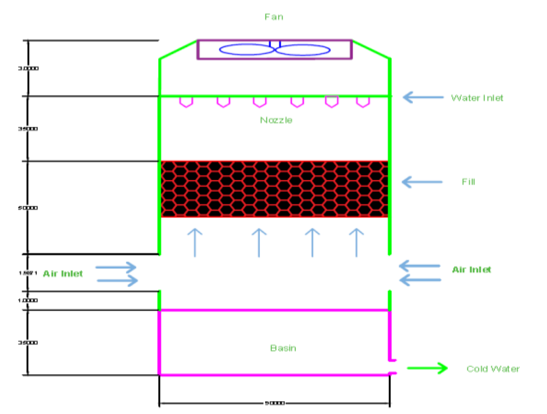

Figure 1 Auto CAD Design of Cooling Tower

LITERATURE SURVEY

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.

Cooling towers are able to lower the water temperatures more than devices that use only air to reject heat, like the radiator in a car, and are therefore more cost-effective and energy efficient.

Components

The basic components of a cooling tower include the frame and casing, fill, cold-water basin, drift eliminators, air inlet, louvers, nozzles and fans. These are described below.

a. **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 fibre units, the casing may essentially be the frame.
b. **Fill:** Most towers employ fills (made of plastic or wood) to facilitate heat transfer by maximizing water and air contact.

There are two types of fill:

- **Splash fill:** Waterfalls over successive layers of horizontal splash bars, continuously breaking into smaller droplets, while also wetting the fill surface. Plastic splash fills promote better heat transfer than wood splash fills.

- **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.

a. **Cold-water basin:** The cold-water basin is located at or near the bottom of the tower, and it 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 coldwater basin is beneath the entire fill. In some forced draft counter flow design, however, the water at the bottom of the fill is channelled to a perimeter trough that functions as the coldwater 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.
b. **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 the tower (counter-flow design).
c. **Drift eliminators:** These capture water droplets entrapped in the air stream that otherwise would be lost to the atmosphere.
d. **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.
e. **Nozzles:** These spray water 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 and spray in a round or square patterns, or they can be part of a rotating assembly as found in some circular cross-section towers.
f. **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, the type of propeller fans used is either fixed or variable pitch. A fan with non-automatic adjustable pitch blades can be used over a wide kW range because the fan can be 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.

TYPES

Natural draft cooling tower

The natural draft or hyperbolic cooling tower makes use of the difference in temperature between the ambient air and the hotter air inside the tower. As hot air moves upwards through the tower (because hot air rises), fresh cool air is drawn into the tower through an air inlet at the bottom. Due to the layout of the tower, no fan is required and there is almost no circulation of hot air that could affect the performance. Concrete is used for the tower shell with a height of up to 200 m. These cooling towers are mostly only for large heat duties because large concrete structures are expensive. There are two main types of natural draft towers:

- **Cross flow tower:** air is drawn across the falling water and the fill is located outside the tower.
- **Counter flow tower:** air is drawn up through the falling water and the fill is therefore located inside the tower, although design depends on specific site conditions.

Mechanical Draft Cooling Tower

Mechanical draft towers have large fans to force or draw air through circulated water. The water falls downwards 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 various parameters such as fan diameter and speed of operation, fills for system resistance etc.

Open vs. Closed-Circuit Towers

One of the primary differentiations between cooling towers is whether it is an open or closed-circuit tower. In open towers, the cooling water is pumped through the equipment where it picks up thermal energy and then flows directly to the cooling tower where it is dispersed through spray nozzles over the fill, where heat transfer occurs. Then, this same water is collected in the tower sump and is sent back to the equipment to begin the process again. In an open tower any contaminants in the water are circulated through the equipment being cooled.

In a closed-circuit tower, sometimes referred to as a fluid cooler, the cooling water flows through the equipment as in the open tower. The difference is when the water is pumped to the cooling tower, it is pumped through a closed loop heat exchanger that is internal to the cooling tower, then returned to the equipment. In this application, water in the closed loop is not in direct contact with the evaporative water in the tower, which means contaminants are not circulated through the equipment. In a closed-circuit tower, a small pump, known as a “spray pump” circulates a separate body of evaporative water from the tower sump, through the spray nozzles and over the internal heat exchanger piping. This "open" evaporative body of water is contained within the tower and needs to be regularly made up to replenish evaporative and other losses.

However, once water treatment in the closed cooling loop is stabilized, the only time it needs to be made up or adjusted is if there is a leak.

Hybrid Towers

Hybrid towers are closed towers which can operate either in the sensible heat transfer mode only (without evaporation) or a combination of sensible and latent heat transfer (with evaporation). During periods of low load and/or low ambient temperature, the spray of water is stopped and heat is sensibly transferred to the flow of air across the fins of the coils containing the cooling fluid. During periods when this is not enough, a latent heat transfer system is activated by switching on an evaporative cooler or water is sprayed across the dry coils to allow for increased heat transfer through evaporation. These processes offer substantial savings in water.

METHODOLOGY

These are to carried out in particular sequence to order it would still better, if the method of performing each operation may also be established. It may be kept in mind that for carrying out each. Actually there is always an expenditure of resources may be in terms of coast, time etc. For the purpose of carrying out the activities, the resources meet are in term of manpower, material, machines, money & time. The competitions of any activity or for that matter the future project cannot be said to be over values required resources are made available at the appropriate time. In other word man has to be prepared co-ordination these resources?

The activities are carries out under specified conditions of restrictions which we have a direct bearing on the competition of the involving the factor. Working Principle of Cooling Tower Cooling tower is essentially a heat and mass transfer device.

It removes heat from the water and loses a fraction of water during heat transfer to the air. When air is blown from downwards it came in contact with upcoming water the enthalpy of which is higher and at the time of contact this air causes evaporation of water droplet. It is known that in order to get evaporated water requires to gain certain amount of latent heat. It does so from nearby droplet and evaporates into vapor form. Due to removal of sensible heat, remaining water droplets loses temperature and cools down. Due to higher surface area in packing heat transfer rate increases and water is further cooled to the require temperature. Air moving upward takes away certain amount of water content in (vapor form) with it which is not desirable. In order to recover lost water drift eliminators are provided. Upcoming air loses their velocity and causes certain amount of vapor to be converted into water. The water falls downward and collected in the basin.

Design Calculation

➢ **Cooling Tower Approach (Cta)**

CTA = T2 – WBT = 35 – 31 = 4 0C

➢ **Cooling Tower Range (Ctr)**

CTR = T1 – T2 = 41 – 35 = 6 0C

➢ **Mass of Water Circulated in Cooling Tower**

Mw1 = Volume of circulating water x Mass density of water
Mw1 = 3.8 x 1000
Mw1 = 3800 Kg / hr

➢ **Heat loss by water (HL)**

HL = Mw1 x Cpw x (T1 – T2)
HL = 3800 x 4.186 x (41 - 35)
HL = 95440.8 KJ / hr

➢ **Volume of Air Required (G)**

G = (HL x Gs1) / [(Ha2 – Ha1) - (W2 – W1) x Cpw x T2]
G = (95440.8 x 0.842) / [(73 - 50) – (0.018 – 0.0118) x 4.186 x 35]
G = 3492.234 m3 / hr

➢ **Mass of Air Required (Ma)**
Ma = Volume of air required / Specific volume of air at inlet temperature
Ma = G / Gs1
Ma = 4485 Kg / hr

Based on above data power calculation can be calculated as follows,
Fan power = Air Volume (in ACFM) X Total Pressure in inch / 6356
=2223X0.6434/6356 =0.25
HP =0.25 X 746 watts =186.5 watt

MATERIAL AND EQUIPMENTS

Originally, cooling towers were constructed primarily with wood, including the frame, casing, louvers, fill and cold-water basin. Sometimes the cold-water basin was made of concrete. Today, manufacturers use a variety of materials to construct cooling towers.

Materials are chosen to enhance corrosion resistance, reduce maintenance, and promote reliability and long service life. Galvanized steel, various grades of stainless steel, glass fibre, and concrete are widely used in tower construction, as well as aluminium and plastics for some components.

a. **Frame and casing:** Wooden towers are still available, but many components are made of different materials, such as the casing around the wooden framework of glass fibre, the inlet air louvers of glass fibre, the fill of plastic and the cold-water basin of steel. Many towers (casings and basins) are constructed of galvanized steel or, where a corrosive atmosphere is a problem, the tower and/or the basis are made of stainless steel. Larger towers sometimes are made of concrete. Glass fibre is also widely used for cooling tower casings and basins, because they extend the life of the cooling tower and provide protection against harmful chemicals.
b. **Fill:** Plastics are widely used for fill, including PVC, polypropylene, and other polymers. When water conditions require the use of splash fill, treated wood splash fill is still used in wooden towers, but plastic splash fill is also widely used. Because of greater heat transfer efficiency, film fill is chosen for applications where the circulating water is generally free of debris that could block the fill passageways.
c. **Nozzles:** Plastics are also widely used for nozzles. Many nozzles are made of PVC, ABS, polypropylene, and glass-filled nylon.
d. **Fans:** Aluminium, glass fibre and hot-dipped galvanized steel are commonly used fan materials. Centrifugal fans are often fabricated from galvanized steel. Propeller fans are made from galvanized steel, aluminium, or moulded glass fibre reinforced plastic.
e. **Gear reducer** The selection of gear reducer is based on fan speed and requirement of horsepower for the fan.
f. **Drive shafts:** The drive shafts are prepared from mild galvanized steel, or with stainless steel tubes or CFC materials. These shafts are dynamically balanced to lower operating vibrations.
g. **Piping:** Usually manufacturers provide side inlet piping. They also leverage on other economical method that requires only single riser for every hot water basins. You can avail all FRP, steel, or PVC pipes in customized formats.
h. **Water distributing system valves:** Reliable flow control valves offers uniform water distribution. Manufacturers are providing heavy duty valve intended with durable materials requiring minimum maintenance.
i. **Splash boxes:** Splash box is placed inside the hot water basin. The open, gravity flow design of the splash box promotes uniform water distribution to the fill. This distribution allows user to access quick, affordable maintenance and cleaning with an ease.
j. **Drift eliminators:** These are extremely efficient thermoformed PVC bonded components. Engineers require no extra structure to support the drift eliminators.
k. **Casing:** Casing of the tower is made with corrugated FRP sheets. FRP material is waterproof and antirust. It is able to withstand biological deterioration and need zero maintenance. Engineers attach the casing to structural components with stainless steel screw with washers. The trim pieces at corners are FRP.
l. **Louvers:** These are corrugated FRP(Fiber reinforced plastic) sheets used for preventing splash out from the cooling tower.

We must required different machines for different operations like:

a. Sheet cutting machine (Hand shearing machine)
b. Sheet banding machine
c. Welding machine

d. Drilling machine
e. Hand grinder

CONCLUSION

The thesis was about experimental investigation and performance analysis of counter flow induced draft cooling tower. The main purpose of this study was to work on developing mathematical model for cooling tower and examine methodically the performance of a model of closed loop 10 RT counter flow induced draft bottle type cooling tower. A model of closed loop circuit of cooling tower has been developed for the project. Parametric study of counter flow induced draft cooling tower is presented by a thermo-hydraulic-performance optimization analysis. Different (L/G) values were studied for the best thermo-hydraulic performance of counter flow induced draft cooling tower. The effect of difference between dry bulb and wet bulb temperature of inlet air on optimum performance of cooling tower was studied. The difference between wet bulb and dry bulb temperature of air has great influence on the NTU and effectiveness of cooling tower. For greater (L/G) values the effectiveness of cooling tower was increased. The increase in water temperature must be combined with increase of water mass flow rate for the same air flow rate. Cooled water temperature vs wet bulb temperature graphs were plotted to analysis the cooling performance of cooling tower. The designed setup can also be used as lab apparatus for investigating the performance of cooling tower.

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