COOLING TOWER PERFORMANCE

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Abstract: Cooling towers are one of the most important industrial utilities used to dissipate the unwanted process heat to the atmosphere through the cooling water in the heat exchangers across the plant site. Cooling tower is one of the most expensive utility in terms of power consumption and water circulation. Maintaining water quality in the circulation loops is one of the major challenges in process optimization for most efficient performance. To identify the key performance parameters with respect to perspective of the operations' team, the water chemistry is the most crucial level and demands proper understanding to maintain complete control over the variations. Latest technological developments have made the water conservation more efficient and use of chemicals more limited by introducing "Recycling / reusing water practices" and "Chemical free platforms". With limited options available to the designed and operating cooling tower, these areas could be explored for better and cost effective performance and environment friendly impact.
Keyword: water circulation, water quality, water practices, Chemical free platforms.

I. INTRODUCTION

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.

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

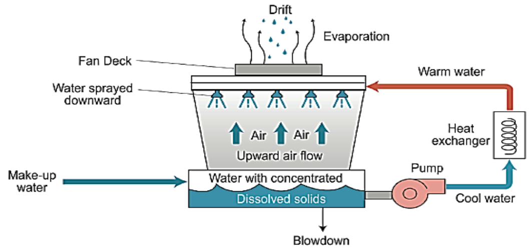

Figure 1 Schematic of an Induced Draft Cooling Tower

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: Water falls over successive layers of horizontal splash bars, continuously breaking into smaller droplets, while also wetting the fill surface. Plastic splash fill 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.

c) 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 fills. 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.

d) Drift eliminators: These capture water droplets entrapped in the air stream that otherwise would be lost to the atmosphere.

e) 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).

f) 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.

g) 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

h) 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.

1.2 Materials

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.

1.3 Types

1.3.1 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 heightof 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

1.3.2 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.

1.3.3 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.

1.3.4 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.

II. FACTORS AFFECTING PERFORMANCE

2.1 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. For example, a cooling tower sized to cool 4540 m3/hr through a 13.9°C range might be larger than a cooling tower to cool 4540 m3/hr through 19.5°C range.

2.2 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.

Equation 7 CT Range Def. 2

$$Range\ {}^{\circ}C = \frac{Heat\ Load\ (kCal/hr)}{Water\ Circulation\ Rate\ (LPH)}$$

Thus, Range is a function of the heat load and the flow circulated through the system. Cooling towers are usually specified to cool a certain flow rate from one temperature to another temperature at a certain wet bulb temperature. For example, the cooling tower might be specified to cool 48000 m3/hr from 44°C to 34°C at 26.7°C wet bulb temperature. As a generalization, the closer the approach to the wet bulb, the more expensive the cooling tower due to increased size. Usually a 2.8°C approach to the design wet bulb is the coldest water temperature that cooling tower manufacturers will guarantee. If flow rate, range, approach and wet bulb had to be ranked in the order of their importance in sizing a tower, approach would be first with flow rate closely following the range and wet bulb would be of lesser importance.

$$CT\ Approach\ (5^{\circ}C) = CW\ outlet\ temp\ (34^{\circ}C) - Wet\ bulb\ temp\ (29^{\circ}C)$$

2.3 Heat Load
The heat load imposed on a cooling tower is determined by the process being served. The degree of cooling required is controlled 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. The size and cost of the cooling tower is proportional to the heat load. If heat load calculations are low undersized equipment will be purchased. If the calculated load is high, oversize and more costly, equipment will result. Process heat loads may vary considerably depending upon the process involved. Determination of accurate process heat loads can become very complex but proper consideration can produce satisfactory results. On the other hand, air conditioning and refrigeration heat loads can be determined with greater accuracy.

2.4 Wet Bulb Temperature
Wet bulb temperature is an important factor in performance of evaporative water cooling equipment. It is a controlling factor from the aspect of minimum cold water temperature to which water can be cooled by the evaporative method. Thus, the wet bulb temperature of the air entering the cooling tower determines operating temperature levels throughout the plant, process, or system. Theoretically, a cooling tower will cool water to the entering wet bulb temperature, when operating without a heat load. However, a thermal potential is required to reject heat, so it is not possible to cool water to the entering air wet bulb temperature, when a heat load is applied. The approach obtained is a function of thermal conditions and tower capability. Initial selection of towers with respect to design wet bulb temperature must be made on the basis of conditions existing at the tower site. The temperature selected is generally close to the average maximum wet bulb for the summer months. An important aspect of wet bulb selection is whether it is specified as ambient or inlet. The ambient wet bulb is the temperature, which exists generally in the cooling tower area, whereas inlet wet bulb is the wet bulb temperature of the air entering the tower. The later can be, and often is, affected by discharge vapours being re-circulated into the tower. Recirculation raises the effective wet bulb temperature of the air entering the tower with corresponding increase in the cold water temperature. Since there is no initial knowledge or control over the recirculation factor, the ambient wet bulb should be specified. The cooling tower supplier is required to furnish a tower of sufficient capability to absorb the effects of the increased wet bulb temperature peculiar to his own equipment. It is very important to have the cold water temperature low enough to exchange heat or to condense vapours at the optimum temperature level. By evaluating the cost and size of heat exchangers versus the cost and size of the cooling tower, the quantity and temperature of the cooling tower water can be selected to get the maximum economy for the particular process.

2.5 Tower Size
If heat load, range, approach and wet-bulb temperature are held constant, changing the fourth will affect the tower size as follows:

a) Tower size varies inversely with approach. A longer approach requires a smaller tower. Conversely, a smaller approach requires an increasingly larger tower and, at 5°F approach, the effect upon tower size begins to become asymptotic. For that reason, it is not customary in the cooling tower industry to guarantee any approach of less than 5°F.

III. WATER DISTRIBUTIONS

3.1 Optimize cooling water treatment
Cooling water treatment (e.g. to control suspended solids, algae growth) is mandatory for any cooling tower independent of what fill media is used. With increasing costs of water, efforts to increase Cycles of Concentration (COC), by cooling water treatment would help to reduce make up water requirements significantly. In large industries and power plants improving the COC is often considered a key area for water conservation.

3.2 Install drift eliminators
It is very difficult to ignore drift problems in cooling towers. Nowadays most of the end user specifications assume a 0.02% drift loss. But thanks to technological developments and the production of PVC, manufacturers have improved drift eliminator designs. As a result drift losses can now be as low as 0.003 –0.001%.

IV. FANS

The purpose of a cooling tower fan is to move a specified quantity of air through the system. The fan has to overcome the system resistance, which is defined as the pressure loss, to move the air. The fan output or work done by the fan is the product of air flow and the pressure loss. The fan output and kW input determines the fan efficiency. The fan efficiency in turn is greatly dependent on the profile of the blade. Blades include:

a) Metallic blades, which are manufactured by extrusion or casting processes and therefore it is difficult to produce ideal aerodynamic profiles

b) Fibre reinforced plastic (FRP) blades, are normally hand moulded which makes it easier to produce an optimum aerodynamic profile tailored to specific duty conditions. Because FRP fans are light, they need a low starting torque requiring a lower HP motor, the lives of the gear box, motor and bearing is increased, and maintenance is easier. A 85-92% efficiency can be achieved with blades with an aerodynamic profile, optimum twist, taper and a high coefficient of lift to coefficient of drop ratio. However, this efficiency is drastically affected by factors such as tip clearance, obstacles to airflow and inlet shape, etc. Cases reported where metallic or glass fibber reinforced plastic fan blades have been replaced by efficient hollow FRP blades. The resulting fan energy savings were in the order of 20-30%and with simple payback period of 6 to 7 months (NPC).

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