COOLING TOWERS

1. INTRODUCTION

This section briefly describes the main features of cooling towers.

1.1 What is a cooling tower?

Cooled water is needed for, for example, air conditioners, manufacturing processes or power generation. A cooling tower is an 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 (Figure 1). 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.

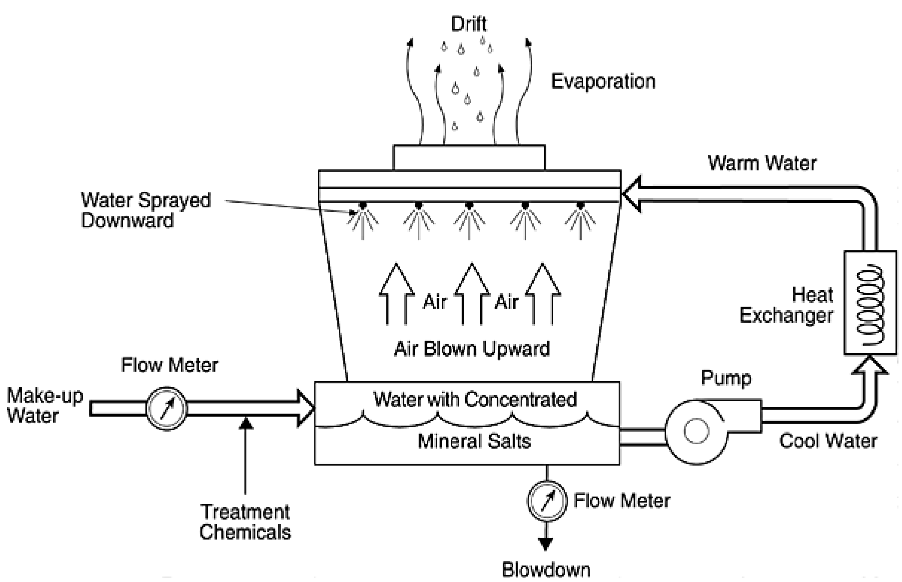

Figure 1. Schematic diagram of a cooling water system
(Pacific Northwest National Laboratory, 2001)

1.2 Components of a cooling tower

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.[1]

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. 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 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.

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 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 the tower (counter-flow design).

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 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.

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

[1] Section 1.2 is taken in its entirety from *Cooling Towers.* In: Energy Efficiency in Electrical Utilities. Chapter 7, pg 135 - 151. 2004, with the permission from Bureau of Energy Efficiency, Ministry of Power, India

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.

1.3 Tower 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 fiber, and concrete are widely used in tower construction, as well as aluminum and plastics for some components.[2]

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 fiber, the inlet air louvers of glass fiber, 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 fiber 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.

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.

Nozzles. Plastics are also widely used for nozzles. Many nozzles are made of PVC, ABS, polypropylene, and glass-filled nylon.

Fans. Aluminum, glass fiber 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, aluminum, or molded glass fiber reinforced plastic.

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[2] Section 1.3 is taken from *Cooling Towers.* In: Energy Efficiency in Electrical Utilities. Chapter 7, pg 135 - 151. 2004, with the permission from Bureau of Energy Efficiency, Ministry of Power, India

2. TYPES OF COOLING TOWERS

This section describes the two main types of cooling towers: the natural draft and mechanical draft cooling towers.

2.1 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 height of up to 200 m. These cooling towers are mostly only for large heat duties because large concrete structures are expensive.

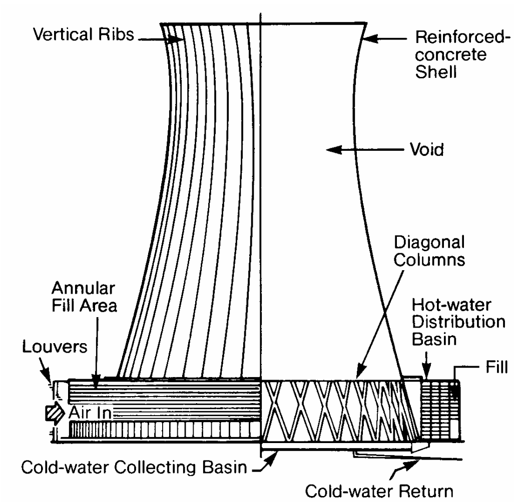

Figure 2. Cross flow natural draft cooling tower

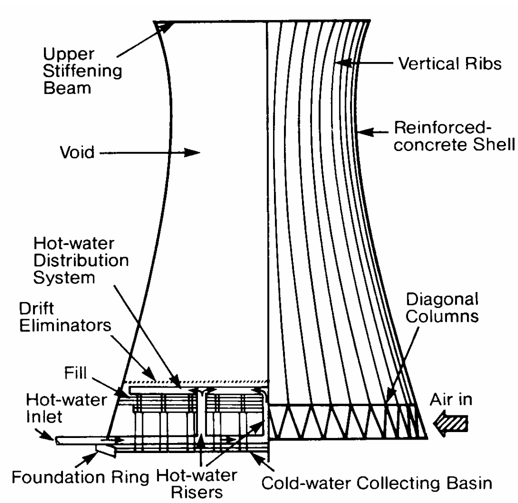

Figure 3. Counter flow natural draft cooling tower

(Gulf Coast Chemical Commercial Inc, 1995)

There are two main types of natural draft towers:

- Cross flow tower (Figure 2): air is drawn across the falling water and the fill is located outside the tower
- Counter flow tower (Figure 3): air is drawn up through the falling water and the fill is therefore located inside the tower, although design depends on specific site conditions

2.2 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.

Mechanical draft towers are available in a large range of capacities. Towers can be either 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.

The three types of mechanical draft towers are summarized in Table 1.

Table 1. Main features of different types of draft cooling towers (based on AIRAH)

Type of cooling tower	**Advantages**	**Disadvantages**
Forced draft cooling tower (Figure 4): air is blown through the tower by a fan located in the air inlet	▪ Suited for high air resistance due to centrifugal blower fans ▪ Fans are relatively quiet	▪ Recirculation due to high air-entry and low air-exit velocities, which can be solved by locating towers in plant rooms combined with discharge ducts
Induced draft cross flow cooling tower (Figure 5): ▪ water enters at top and passes over fill ▪ air enters on one side (single-flow tower) or opposite sides (double-flow tower) ▪ an induced draft fan draws air across fill towards exit at top of tower	▪ Less recirculation than forced draft towers because the speed of exit air is 3-4 times higher than entering air	▪ Fans and the motor drive mechanism require weather-proofing against moisture and corrosion because they are in the path of humid exit air
Induced draft counter flow cooling tower (Figure 6): ▪ hot water enters at the top ▪ air enters bottom and exits at the top ▪ uses forced and induced draft fans		

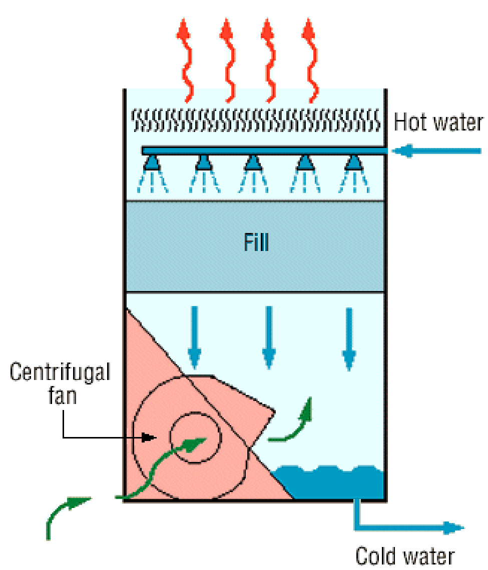

Figure 4. Forced Draft Cooling Tower ((GEO4VA))

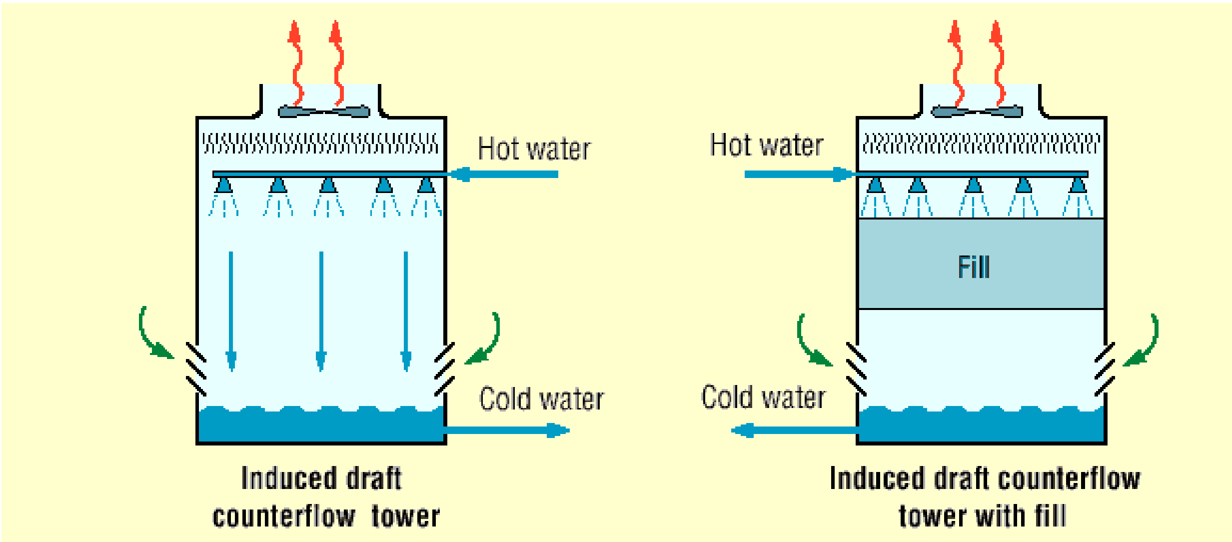

Figure 5. Induced draft counter flow cooling tower
(GEO4VA)

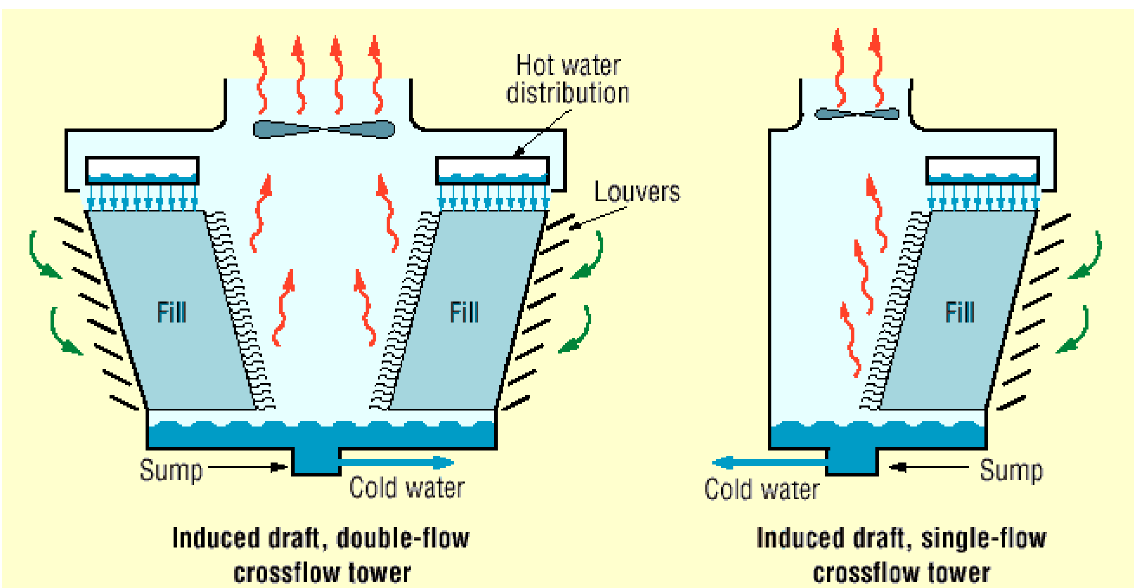

Figure 6. Induced draft cross flow cooling tower
(GEO4VA)

3. ASSESSMENT OF COOLING TOWERS

This section describes how the performance of cooling powers can be assessed.[3] The performance of cooling towers is evaluated to assess present levels of approach and range against their design values, identify areas of energy wastage and to suggest improvements.

During the performance evaluation, portable monitoring instruments are used to measure the following parameters:

- Wet bulb temperature of air
- Dry bulb temperature of air
- Cooling tower inlet water temperature
- Cooling tower outlet water temperature
- Exhaust air temperature
- Electrical readings of pump and fan motors
- Water flow rate
- Air flow rate

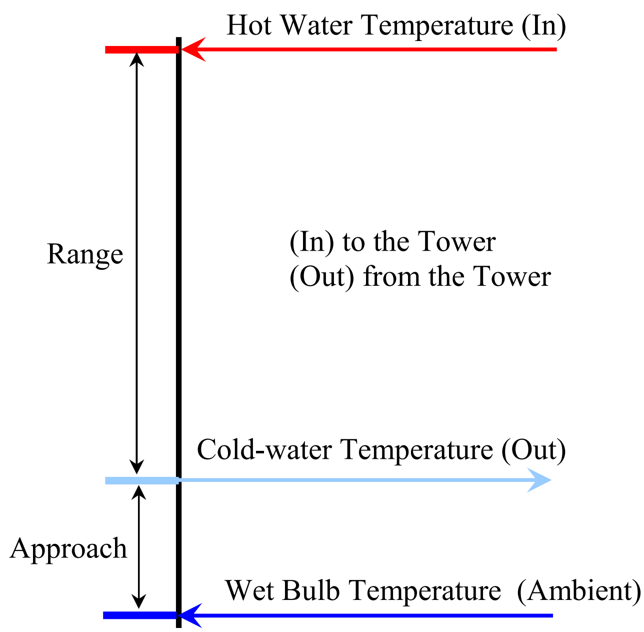

Figure 7. Range and approach of cooling towers

These measured parameters and then used to determine the cooling tower performance in several ways. (Note: CT = cooling tower; CW = cooling water). These are:

a) ***Range*** (see Figure 7). This is the difference between the cooling tower water inlet and outlet temperature. A high CT Range means that the cooling tower has been able to reduce the water temperature effectively, and is thus performing well. The formula is:

CT Range (°C) = [CW inlet temp (°C) – CW outlet temp (°C)]

[3] Section 1.2 is based on *Cooling Towers.* In: Energy Efficiency in Electrical Utilities. Chapter 7, pg 135 - 151. 2004, with the permission from Bureau of Energy Efficiency, Ministry of Power, India

b) ***Approach*** (see Figure 7). This is the difference between the cooling tower outlet cold-water temperature and ambient wet bulb temperature. The lower the approach the better the cooling tower performance. Although, both range and approach should be monitored, the `Approach' is a better indicator of cooling tower performance.

CT Approach (°C) = [CW outlet temp (°C) – Wet bulb temp (°C)]

c) ***Effectiveness***. This is the ratio between the range and the ideal range (in percentage), i.e. difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach). The higher this ratio, the higher the cooling tower effectiveness.

CT Effectiveness (%) = 100 x (CW temp – CW out temp) / (CW in temp – WB temp)

d) **Cooling capacity**. This is the heat rejected in kCal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.

e) ***Evaporation loss***. This is the water quantity evaporated for cooling duty. Theoretically the evaporation quantity works out to 1.8 m^3 for every 1,000,000 kCal heat rejected. The following formula can be used (Perry):

Evaporation loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x (T1-T2)
T1 - T2 = temperature difference between inlet and outlet water

f) ***Cycles of concentration*** (C.O.C). This is the ratio of dissolved solids in circulating water to the dissolved solids in make up water.

g) ***Blow down losses*** depend upon cycles of concentration and the evaporation losses and is given by formula:

Blow down = Evaporation loss / (C.O.C. – 1)

h) ***Liquid/Gas (L/G) ratio***. The L/G ratio of a cooling tower is the ratio between the water and the air mass flow rates. Cooling towers have certain design values, but seasonal variations require adjustment and tuning of water and air flow rates to get the best cooling tower effectiveness. Adjustments can be made by water box loading changes or blade angle adjustments. Thermodynamic rules also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air. Therefore the following formulae can be used:

L(T1 – T2) = G(h2 – h1)

L/G = (h2 – h1) / (T1 – T2)

Where:
L/G = liquid to gas mass flow ratio (kg/kg)
T1 = hot water temperature (^{0}C)
T2 = cold-water temperature (^{0}C)

h2 = enthalpy of air-water vapor mixture at exhaust wet-bulb temperature (same units as above)
h1 = enthalpy of air-water vapor mixture at inlet wet-bulb temperature (same units as above)

4. ENERGY EFFICIENCY OPPORTUNITIES

This section includes main areas for improving energy efficiency of cooling towers. The main areas for energy conservation include: [4]

- Selecting the right cooling tower (because the structural aspects of the cooling tower cannot be changed after it is installed)
- Fills
- Pumps and water distribution system
- Fans and motors

4.1 Selecting the right cooling towers

Once a cooling tower is in place it is very difficult to significantly improve its energy performance. A number of factors are of influence on the cooling tower's performance and should be considered when choosing a cooling tower: capacity, range, approach, heat load, wet bulb temperature, and the relationship between these factors. This is described below.

4.1.1 Capacity
Heat dissipation (in kCal/hour) and circulated flow rate (m^3/hr) are an indication of the capacity of cooling towers. However, these design parameters are not sufficient to understand the cooling tower performance. For example, a cooling tower sized to cool 4540 m^3/hr through a 13.9 ^{0}C range might be larger than a cooling tower to cool 4540 m^3/hr through 19.5 ^{0}C range. Therefore other design parameters are also needed.

4.1.2 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 going to the cooling water. The range is a function of the heat load and the flow circulated through the system:

Range ^{0}C = Heat load (in kCal/hour) / Water circulation rate (l/hour)

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 4540 m^3/hr from 48.9^{o}C to 32.2^{o}C at 26.7^{o}C wet bulb temperature.

4.1.3 Approach
As a general rule, the closer the approach to the wet bulb, the more expensive the cooling tower due to increased size. Usually a 2.8^{o}C approach to the design wet bulb is the coldest water temperature that cooling tower manufacturers will guarantee. When the size of the

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tower has to be chosen, then the approach is most important, closely followed by the flow rate, and the range and wet bulb would be of lesser importance.

Approach (5.5 ^{0}C) = Cold-water temperature 32.2 ^{0}C – Wet bulb temperature (26.7 ^{0}C)

4.1.4 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 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. However, in some applications (e.g. internal combustion engines) high operating temperatures are desirable. The size and cost of the cooling tower is increases with increasing heat load. Purchasing undersized equipment (if the calculated heat load is too low) and oversized equipment (if the calculated heat load is too high) is something to be aware of.

Process heat loads may vary considerably depending upon the process involved and are therefore difficult to determine accurately. On the other hand, air conditioning and refrigeration heat loads can be determined with greater accuracy.

Information is available for the heat rejection requirements of various types of power equipment. A sample list is as follows (BEE, 2004):

- Air Compressor
  - Single-stage - 129 kCal/kW/hr
  - Single-stage with after cooler - 862 kCal/kW/hr
  - Two-stage with intercooler - 518 kCal/kW/hr
  - Two-stage with intercooler and after cooler - 862 kCal/kW/hr
- Refrigeration, Compression - 63 kCal/min/TR
- Refrigeration, Absorption - 127 kCal/min/TR
- Steam Turbine Condenser - 555 kCal/kg of steam
- Diesel Engine, Four-Cycle, Supercharged - 880 kCal/kW/hr
- Natural Gas Engine, Four-cycle - 1523 kCal/kW/hr (= 18 kg/cm^2 compression)

4.1.5 Wet bulb temperature

Wet bulb temperature is an important factor in performance of evaporative water cooling equipment, because it is the lowest temperature to which water can be cooled. For this reason, the wet bulb temperature of the air entering the cooling tower determines the minimum operating temperature level throughout the plant, process, or system. The following should be considered when pre-selecting a cooling tower based on the wet bulb temperature:

- Theoretically, a cooling tower will cool water to the entering wet bulb temperature. In practice, however, water is cooled to a temperature higher than the wet bulb temperature because heat needs to be rejected from the cooling tower.
- A pre-selection of towers based on the design wet bulb temperature must consider conditions at the tower site. The design wet bulb temperature also should not be exceeded for more than 5 percent of the time. In general, the design temperature selected is close to the average maximum wet bulb temperature in summer.
- Confirm whether the wet bulb temperature is specified as ambient (the temperature in the cooling tower area) or inlet (the temperature of the air entering the tower, which is often affected by discharge vapors recirculated into the tower). As the impact of

recirculation cannot be known in advance, the ambient wet bulb temperature is preferred.

- Confirm with the supplier if the cooling tower is able to deal with the effects of increased wet bulb temperatures.
- The cold-water temperature must be low enough to exchange heat or to condense vapors at the optimum temperature level. The quantity and temperature of heat exchanged can be considered when choosing the right size cooling tower and heat exchangers at the lowest costs.

4.1.6 Relationship between range, flow and heat load

The range increases when the quantity of circulated water and heat load increase. This means that increasing the range as a result of added heat load requires a larger tower. There are two possible causes for the increased range:

- The inlet water temperature is increased (and the cold-water temperature at the exit remains the same). In this case it is economical to invest in removing the additional heat.
- The exit water temperature is decreased (and the hot water temperature at the inlet remains the same). In this case the tower size would have to be increased considerably because the approach is also reduced, and this is not always economical.

4.1.7 Relationship between approach and wet bulb temperature

The design wet bulb temperature is determined by the geographical location. For a certain approach value (and at a constant range and flow range), the higher the wet bulb temperature, the smaller the tower required. For example, a 4540 m^3/hr cooling tower selected for a 16.67^{o}C range and a 4.45^{o}C approach to 21.11^{o}C wet bulb would be larger than the same tower to a 26.67^{o}C wet bulb. The reason is that air at the higher wet bulb temperature is capable of picking up more heat. This is explained for the two different wet bulb temperatures:

- Each kg of air entering the tower at a wet bulb temperature of 21.1^{o}C contains 18.86 kCal. If the air leaves the tower at 32.2^{o}C wet bulb temperature, each kg of air contains 24.17 kCal. At an increase of 11.1^{o}C, the air picks up 12.1 kCal per kg of air.
- Each kg of air entering the tower at a wet bulb temperature of 26.67^{o}C contains 24.17 kCals. If the air leaves at 37.8^{o}C wet bulb temperature, each kg of air contains 39.67 kCal. At an increase of 11.1^{o}C, the air picks up 15.5 kCal per kg of air, which is much more than the first scenario.

4.2 Fill media effects

In a cooling tower, hot water is distributed above fill media and is cooled down through evaporation as it flows down the tower and gets in contact with air. The fill media impacts energy consumption in two ways:

- Electricity is used for pumping above the fill and for fans that create the air draft. An efficiently designed fill media with appropriate water distribution, drift eliminator, fan, gearbox and motor with therefore lead to lower electricity consumption.
- Heat exchange between air and water is influenced by surface area of heat exchange, duration of heat exchange (interaction) and turbulence in water effecting thoroughness of intermixing. The fill media determines all of these and therefore influences the heat exchange. The greater the heat exchange, the more effective the cooling tower becomes.

There are three types of fills:

- ***Splash fill media.*** Splash fill media generates the required heat exchange area by splashing water over the fill media into smaller water droplets. The surface area of the water droplets is the surface area for heat exchange with the air.
- ***Film fill media.*** In a film fill, water forms a thin film on either side of fill sheets. The surface area of the fill sheets is the area for heat exchange with the surrounding air. Film fill can result in significant electricity savings due to fewer air and pumping head requirements.
- ***Low-clog film fills.*** Low-clog film fills with higher flute sizes were recently developed to handle high turbid waters. Low clog film fills are considered as the best choice for sea water in terms of power savings and performance compared to conventional splash type fills.

Table 1: Design Values of Different Types of Fill
(BEE India, 2004; Ramarao; and Shivaraman)

	Splash fill	**Film fill**	**Low clog film fill**
Possible L/G ratio	1.1 – 1.5	1.5 – 2.0	1.4 – 1.8
Effective heat exchange area	30 – 45 m^2/m^3	150 m^2/m^3	85 - 100 m^2/m^3
Fill height required	5 – 10 m	1.2 – 1.5 m	1.5 – 1.8 m
Pumping head required	9 – 12 m	5 – 8 m	6 – 9 m
Quantity of air required	High	Lowest	Low

4.3 Pumps and water distribution

4.3.1 Pumps
Areas for energy efficiency improvements are discussed in details in the *Pumps and Pumping Systems* chapter.

4.3.2 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.

4.3.3 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%.

4.4 Cooling tower 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:
- Metallic blades, which are manufactured by extrusion or casting processes and therefore it is difficult to produce ideal aerodynamic profiles
- Fiber reinforced plastic (FRP) blades are normally hand molded 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 fiber 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 pay back period of 6 to 7 months (NPC).

The chapter *Fans and Blowers* gives more information about fans.

5. OPTION CHECKLIST

This section lists the most important options to improve energy efficiency of cooling towers.

- Follow manufacturer's recommended clearances around cooling towers and relocate or modify structures that interfere with the air intake or exhaust
- Optimize cooling tower fan blade angle on a seasonal and/or load basis
- Correct excessive and/or uneven fan blade tip clearance and poor fan balance
- In old counter-flow cooling towers, replace old spray type nozzles with new square spray nozzles that do not clog
- Replace splash bars with self-extinguishing PVC cellular film fill
- Install nozzles that spray in a more uniform water pattern
- Clean plugged cooling tower distribution nozzles regularly
- Balance flow to cooling tower hot water basins
- Cover hot water basins to minimize algae growth that contributes to fouling
- Optimize the blow down flow rate, taking into account the cycles of concentration (COC) limit
- Replace slat type drift eliminators with low-pressure drop, self-extinguishing PVC cellular units
- Restrict flows through large loads to design values
- Keep the cooling water temperature to a minimum level by (a) segregating high heat loads like furnaces, air compressors, DG sets and (b) isolating cooling towers from sensitive applications like A/C plants, condensers of captive power plant etc. *Note: A 1^oC cooling water temperature increase may increase the A/C compressor electricity consumption by 2.7%. A 1^oC drop in cooling water temperature can give a heat rate saving of 5 kCal/kWh in a thermal power plant*
- Monitor approach, effectiveness and cooling capacity to continuously optimize the cooling tower performance, but consider seasonal variations and side variations
- Monitor liquid to gas ratio and cooling water flow rates and amend these depending on the design values and seasonal variations. For example: increase water loads during summer and times when approach is high and increase air flow during monsoon times and when approach is low.
- Consider COC improvement measures for water savings
- Consider energy efficient fibre reinforced plastic blade adoption for fan energy savings
- Control cooling tower fans based on exit water temperatures especially in small units
- Check cooling water pumps regularly to maximize their efficiency

6. WORKSHEETS

This section includes following worksheets:
1. Key Technical Specifications
2. Cooling Tower Performance

Worksheet 1 : KEY TECHNICAL SPECIFICATION

No.	Parameter	Units	Cooling tower reference	
			CT 1	CT 2
1.	Type of cooling tower			
2.	Number of tower			
3.	Number of cells per tower			
4.	Area per cell			
5.	Water flow	m^3/hr		
6.	Pumping power	kW		
7.	Pumping head	m		
8.	Fan power	kW		
9.	Design hot water temperature	^{0}C		
10.	Design cold-water temperature	^{0}C		
11.	Design wet bulb temperature	^{0}C		

Worksheet 2: COOLING TOWER PERFORMANCE

No.	Parameter reference	Units	Cooling tower (CT)	
			CT 1	**CT 2**
1.	Dry bulb temperature	°C		
2.	Wet bulb temperature	°C		
3.	CT inlet temperature	°C		
4.	CT outlet temperature	°C		
5.	Range	°C		
6.	Approach	°C		
7.	CT effectiveness	%		
8.	Average water flow	kg/hr		
9.	Average air quantity	kg/hr		
10.	Liquid/gas (L/G) ratio	kg water/kg air		
11.	Evaporation loss	m^3/hr		
12.	CT heat loading	kCal/hr		

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