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Study the factors on which efficiency of cooling tower can be critically acclaimed (A case Study)

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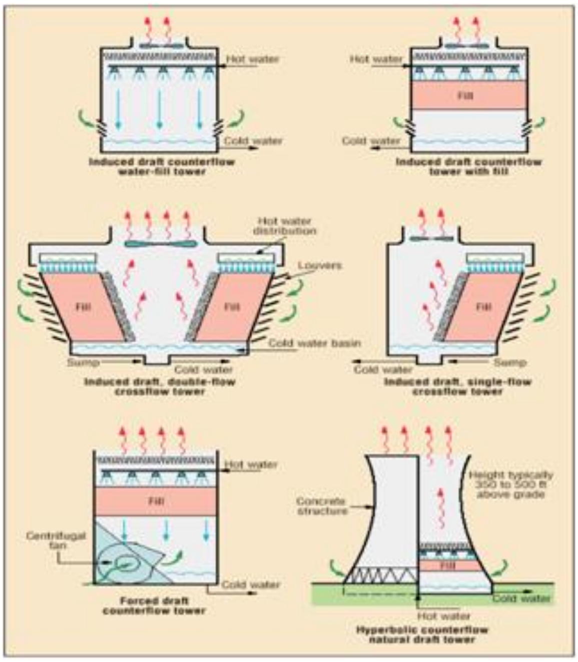
Abstract
Water cooling is widely used in many industrial processes to control heat removal from a hot material surface. In order to control the temperature distributions, a deeper understanding more accurate estimation of spray heat transfer rates is needed. In a new technique combining experiment and computational modeling developed **for water cooling**. It is better to understand the heat transfer mechanisms from the combustion gases to the cooling water and then from the cooling water to the environment. To meet this need a logic tree is developed to provide guidance on how to balance and identify problems within cooling system and schedule appropriate maintenance. Fluid dynamics, Thermodynamics and Heat transfer are involved in developing a cooling system model and the operation is familiar to the general operating companies. There will be the comparison and parametric investigation of the cooling system model in the logic tree and the results are summarized as **tables and charts.** The objective is to identify the several ways of improving efficiency of cooling tower. In this study we are doing the comparison of**some calculations** regarding the cooling tower.
Keywords: Cooling tower, efficiency, comparison, table & chart

I. Introduction

Cooling towers are a very important part of Power 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 Condenser is sent to the cooling tower. The water exits the cooling tower and is sent back to the boiler or toother units for further process. Cooling towers are a very important part of many power plants. The primary task of a cooling tower is to reject heat into the atmosphere. They represent a relatively inexpensive anddependable means of removing low-grade heat from cooling water. The make-up water sourceis used to replenish water lost to evaporation. Hot water from heat exchangers is sent to thecooling tower. The water exits the cooling tower and is sent back to the exchangers or to otherunits for further cooling. (Fig Description)



Data Collection 0f Types of cooling tower
1. Counter flows induced draft.
2. Counter flow forced draft.
3. Cross flow induced draft.

Counter flow induced draft: hot water enters at the top, while the air is introduced at the bottom and exits at the top. Both forced and induced draft fans are used. In cross flow induced draft towers, the water enters at the top and passes over the fill. 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. 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 m3/hr flow to several thousand tons and m3/hr. 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., an 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.

II. 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 maximising water and air contact. Fill can either be splash or film type. With 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 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 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 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. Afan 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.

III. Tower Materials

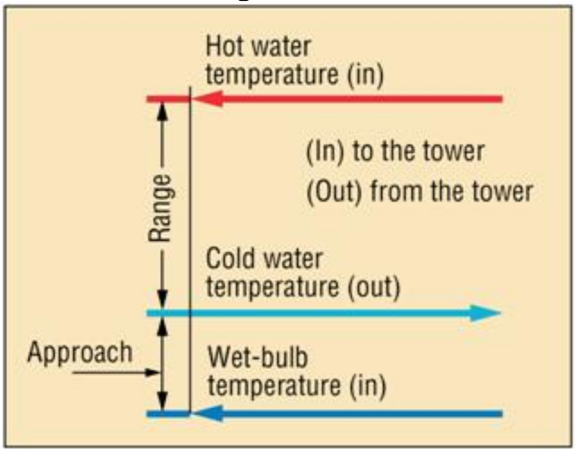
In the early days of cooling tower manufacture, towers were constructed primarily of wood. Wooden components included the frame, casing, louvers, fill, and often the cold water basin. If the basin was not of wood, it likely was of concrete. Today, tower manufacturers fabricate towers and tower components 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 fibre, and concrete are widely used in tower construction as well as aluminium and various types of plastics for some components. Wood towers are still available, but they have glass fibre rather than wood panels (casing) over the wood framework. The inlet air louvers may be glass fibre, 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 fibre is also widely used for cooling tower casings and basins, giving long life and protection from the harmful effects ofmany 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.

Plastics also find wide use as nozzle materials. Many nozzles are being made of PVC, ABS, polypropylene, and glass-filled nylon. Aluminum, glass fiber, and hot-dipped galvanized steel are commonly used fan materials. Centrifugal fans are often fabricated from galvanized steel. Propeller fans are fabricated from galvanized, aluminium, or moulded glass fibre reinforced plastic.

IV. Cooling Tower Performance



Range and Approach

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

i) "Range" is the difference between the cooling tower water inlet and outlet temperature
ii) "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.
iii) Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach).
iv) 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.
v) Evaporation loss is the water quantity evaporated for cooling duty and, theoretically, for every 10,00,000kCal 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) T1-T2 = Temp. differencebetween inlet and outlet water. Source: Perry’s Chemical Engineers Handbook
vi) Cycles of concentration (C.O.C) is the ratio of dissolved solids in circulating water to the dissolved solids in make up water.
vii) Blow down losses depend upon cycles of concentration and the evaporation losses and is given by relation:

Blow Down = Evaporation Loss / (C.O.C. – 1)

viii) Liquid/Gas (L/G) ratio, of a cooling tower is the ratio between the water and the air mass flow rates. Against design values, seasonal variations require adjustment and tuning of water and air flow rates to get the best cooling tower effectiveness through measures like water box loading changes, blade angle adjustments. Thermodynamics also dictate that the heat removed from the water must be equal to the heat absorbed by the surrounding air:

where:
L/G = liquid to gas mass flow ratio (kg/kg)
T1 = hot water temperature (°C)
T2 = cold water temperature (°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 (sameunits as above)

Factors Affecting Cooling Tower Performance

1) **Capacity**
2) **Range**
3) **Heat Load**
4) **Air Compresser**

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. 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.

Range °C = Heat Load in kcals/hour / Water Circulation Rate in LPH

Thus, Range is a function of the heat load and the flow circulated through the system.

$L(T1 - T2) = G(h2 - h1)$ $L = h2 - h1$ G T1

Cooling towers are usually specified to cool a certain flow rate from one temperatureto another temperature at a certain wet bulb temperature. For example, the cooling tower might be specified to cool 4540 m3/hr from 48.9°C to 32.2°C at 26.7°C wet bulb

Cold Water Temperature 32.2°C – Wet Bulb Temperature (26.7°C) = Approach (5.5°C)

As a generalization, the closer the approach to the wet bulb, the more expensive the cooling tower due to increasedsize. Usually a 2.8°C approach to the design wet bulb isthe coldest water temperature that cooling tower manufacturerswill guarantee. If flow rate, range, approach and wetbulb had to be ranked in the order of their importance insizing a tower, approach would be first with flow rate closelyfollowing the range and wet bulb would be of lesserimportance.

3.Heat Load

The heat load imposed on a cooling tower is determined by the process being served. The degree ocooling required is controlled by the desired operating temperature level of the process. In most cases, 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 thecooling tower is proportional to the heat load. If heat load calculations are low undersizedequipment 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.

COOLING TOWER SIZE (overall width is 21.65 meters; the overall height, 15.25 meters, and the pump head, 10.6 m approximately.)					
Hot Water °C	46.11	46.66	47.22	47.77	48.3
Cold Water °C	29.44	30	30.55	31.11	31.66
Overall Length Mts	43.9	34.15	32.93	29.27	25.61
No. of Fans	4	4	3	3	3
Fan Diameter Mts.	7.32	7.32	7.32	7.32	7.32
Total Fan kW	270	255	240	202.5	183.8
Efficiency	63.91	64.29	64.69	63.76	65.45

Information is available for the heat rejection requirements of various types of power equipment.

A sample list is as follows:

Air Compressor

various types	**heat rejection**
Single-stage	129 kCal/kW/hr
Single-stage with after cooler	862kCal/kW/hr
Two-stage with intercooler	518 kCal/kW/hr
Refrigeration, Compression	63 kCal/min/TR
* Refrigeration, Absorption -	127 kCal/min/TR
* Steam Turbine Condenser	127 kCal/min/TR
Steam Turbine Condenser	555 kCal/kgof steam
Diesel Engine, Four-Cycle, Supercharged	880 kCal/kW/hr
Natural Gas Engine, Four-cycle	1523 kCal/kW/hr (18 kg/cm2 compression)

V. Efficient System Operation

Cooling Water Treatment

Cooling water treatment is mandatory for any cooling tower whether with splash fill or with film type fill for controlling suspended solids, algae growth, etc. 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, power plants, COC improvement is often considered as a key area for water conservation.

Drift Loss in the Cooling Towers

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%.

Cooling Tower Fans

The purpose of a cooling tower fan is to move a specified quantity of air through the system, overcoming the system resistance which is defined as the pressure loss. The product of air flow and the pressure loss is air power developed/work done by the fan; this may be also termed as fan output and input kW depends on fan efficiency.

The fan efficiency in turn is greatly dependent on the profile of the blade. An aerodynamicprofile with optimum twist, taper and higher coefficient of lift to coefficient of drop ratio can provide the fan total efficiency as high as 85–92 %. However, this efficiency is drastically affected by the factors such as tip clearance, obstacles to airflow and inlet shape,etc.

As the metallic fans are manufactured by adopting either extrusion or casting process it is always difficult to generate the ideal aerodynamic profiles. The FRP blades are normally hand moulded which facilitates the generation of optimum aerodynamic profile to meet specific duty condition more efficiently. Cases reported where replacement of metallic or Glass fibre reinforced plastic fan blades have been replaced by efficient hollow FRP blades, with resultant fan energy savings of the order of 20–30% and with simple pay back period of 6 to 7 months. Also, due to lightweight, FRP fans need low starting torque resulting in use of lower HP motors. The lightweight of the fans also increases the life of the gear box, motor and bearing is and allows for easy handling and maintenance.

Performance Assessment of Cooling Towers

In operational performance assessment, the typical measurements and observations involved are:

- Cooling tower design data and curves to be referred to as the basis.
- Intake air WBT and DBT at each cell at ground level using a whirling pyschrometer.
- Exhaust air WBT and DBT at each cell using a whirling psychrometer.
- CW inlet temperature at risers or top of tower, using accurate mercury in glass or a digital thermometer.
- CW outlet temperature at full bottom, using accurate mercury in glass or a digital thermometer.
- Process data on heat exchangers, loads on line or power plant control room readings, as relevant.
- CW flow measurements, either direct or inferred from pump motor kW and pump head and flow characteristics.
- CT fan motor amps, volts, kW and blade angle settings
- TDS of cooling water.
- Rated cycles of concentration at the site conditions.
- Observations on nozzle flows, drift eliminators, condition of fills, splash bars, etc.

The findings of one typical trial pertaining to the Cooling Towers of a Thermal Power Plant 3 x 200 MW is given below:

Observations

Unit Load 1 & 3 of the Station	398 MW
Mains Frequency	49.3
Inlet Cooling Water Temperature °C	44 (Rated 43°C)
Outlet Cooling Water Temperature °C	37.6 (Rated 33°C)
Air Wet Bulb Temperature near Cell °C	29.3(Rated 27.5°C)
Air Dry Bulb Temperature near Cell °C	40.8°C
Number of CT Cells on line with water flow	45 (Total 48)
Total Measured Cooling Water Flow m3/hr	70426.76
Measured CT Fan Flow m3/hr	989544

Analysis

CT Water Flow/Cell, m3/hr	1565 m3/hr (1565000 kg/hr) (Rated 1875 m3/hr)
CT Fan Air Flow, m3/hr (Avg.)	989544 m3/hr (Rated 997200 m3/hr)
CT Fan Air Flow kg/hr (Avg.)	1068708 kg/hr @ Density of 1.08 kg/m3
L/G Ratio of C.T. kg/kg	1.46 (Rated 1.74 kg/kg)
CT Range	(44 – 37.6) = 6.4°C
CT Approach	(37.6 – 29.3) = 8.3°C
% CT Effectiveness = Range (Range + Approach) x100 = 6.4 (6.4 + 8.3) = 43.53	
Rated % CT Effectiveness	100 * (43 – 33) / (43 – 27.5) = 64.5%
Cooling Duty Handled/Cell in kCal =	1565 6.4 103 (i.e., Flow Temperature Difference in 103 kCal/hr)
Evaporation Losses in m3/hr = 0.00085 x 1.8 x circulation rate (m3/hr) x (T1-T2) = 0.00085 x 1.8 x 1565 x (44- 37.6) = 15.32 m3/hr per cell	
Percentage Evaporation Loss [15.32/1565]*100	0.97%
Blow down requirement for site COC of 2.7 = Evaporation losses/COC-1 =	15.32/(2.7-1) per cell i.e., 9.01 m3/hr Make up water requirement/cell in m3/hr =
Evaporation Loss + Blow down Loss	15.32 + 9.01 = 24.33

Comments

- Cooling water flow per cell is much lower, almost by 16.5%, need to investigate CW pump and system performance for improvements. Increasing CW flow through cell was identified as a key result area for improving performance of cooling towers.
- Flow stratification in 3 cooling tower cells identified.
- Algae growth identified in 6 cooling tower cells.
- Cooling tower fans are of GRP type drawing 36.2 kW average. Replacement by efficient hollow FRP fan blades is recommended.

VI. Flow Control Strategies

Control of tower air flow can be done by varying methods: starting and stopping (On-off) of fans, use of two- or three-speed fan motors, use of automatically adjustable pitch fans, use of variable speed fans. On-off fan operation of single speed fans provides the least effective control. Two-speed fans provide better control with further improvement shown with three speed fans. Automatic adjustable pitch fans and variable-speed fans can provide even closer control of tower cold-x100water temperature. In multi-cell towers, fans in adjacent cells may be running at different speeds or some may be on and others off depending upon the tower load and required water temperature. Depending upon the method of air volume control selected, control strategies can be determined to minimise fan energy while achieving the desired control of the Cold water temperature.

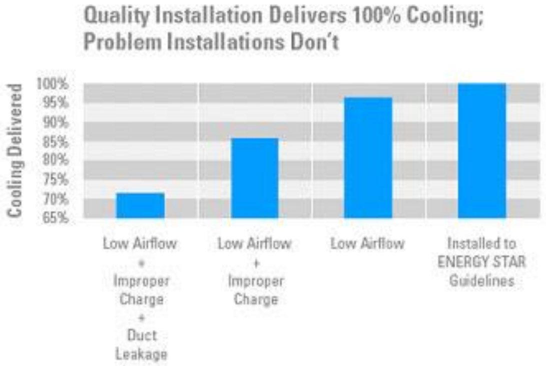
Energy Saving Opportunities in Cooling Towers

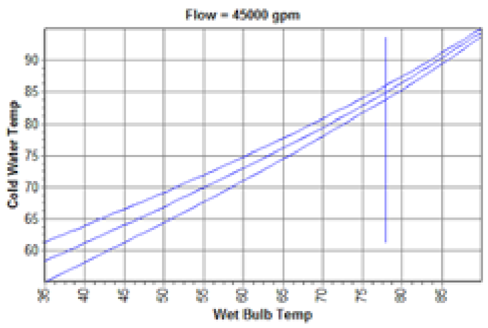
1) Follow manufacturer's recommended clearances around cooling towers and relocate or modify structures that interfere with the air intake or exhaust.
2) Optimise cooling tower fan blade angle on a seasonal and/or load basis.
3) Correct excessive and/or uneven fan blade tip clearance and poor fan balance.
4) On old counter-flow cooling towers, replace old spray type nozzles with new square spray ABS practically non-clogging nozzles.
5) Replace splash bars with self-extinguishing PVC cellular film fill.
6) Install new nozzles to obtain a more uniform water pattern
7) Periodically clean plugged cooling tower distribution nozzles.
8) Balance flow to cooling tower hot water basins.
9) Cover hot water basins to minimise algae growth that contributes to fouling.
10) Optimise blow down flow rate, as per COC limit.
11) Replace slat type drift eliminators with low pressure drop, self extinguishing, PVCcellular units.
12) Restrict flows through large loads to design values.
13) Segregate high heat loads like furnaces, air compressors, DG sets, and isolate cooling towers for sensitive applications like A/C plants, condensers of captive power plant etc. A 1°C cooling water temperature increase may increase A/C compressor kW by 2.7%. A 1°C drop in cooling water temperature can give a heat rate saving of 5 kCal/kWh in a thermal power plant.
14) Monitor L/G ratio, CW flow rates w.r.t. design as well as seasonal variations. It would help to increase water load during summer and times when approach is high and increase air flow during monsoon times and when approach is narrow.
15) Monitor approach, effectiveness and cooling capacity for continuous optimisation efforts, as per seasonal variations as well as load side variations.

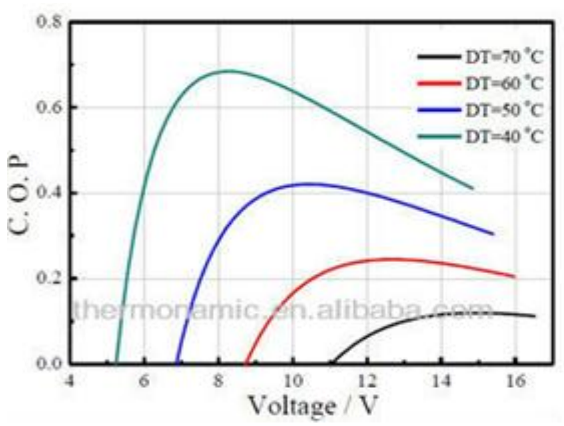
16) Consider COC improvement measures for water savings.
17) Consider energy efficient FRP blade adoption for fan energy savings.
18) Consider possible improvements on CW pumps w.r.t. efficiency improvement.
19) Control cooling tower fans based on leaving water temperatures especially in case of small units.
20) Optimise process CW flow requirements, to save on pumping energy, cooling load, evaporation losses (directly proportional to circulation rate) and blow down losses.

Some typical problems and their trouble shooting for cooling towers

Efficiency graph of cooling tower







Suggestion

1. Keep the height of cooling tower as long as possible.
2. Exhaust fan rpm should be high.
3. Maximum area should be given for air inlet.
4. Sprinklers should be located at high altitude to provide much altitude to water to cool.
5. Material of cooling tower must be selected according to condition.

VII. Summary

Special thanks to guide, collage, ME-dept., group members to help to develop this concept by spending our valuable time. The aim of this concept study factors on which efficiency of cooling tower can be critically acclaimed.

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