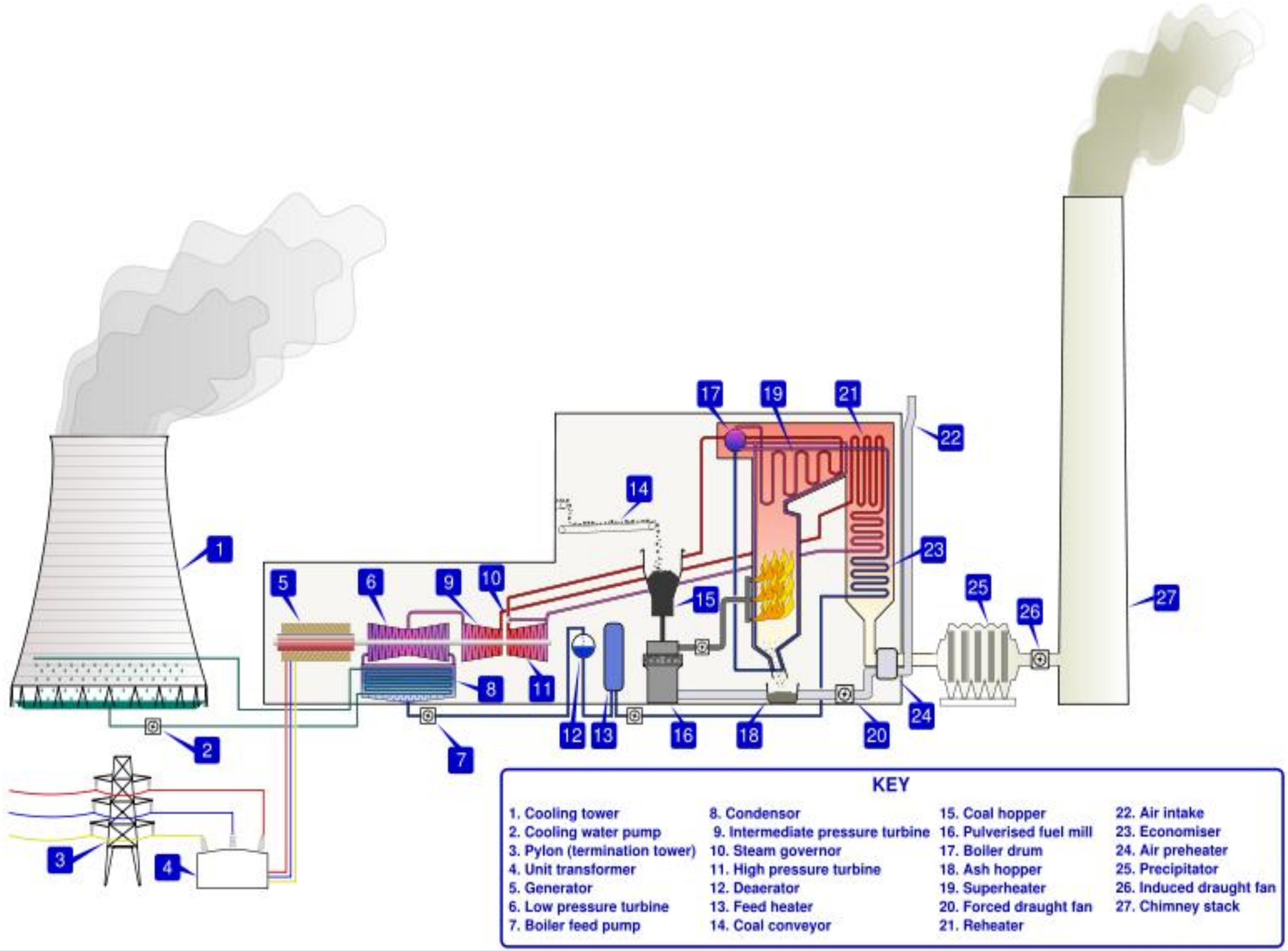
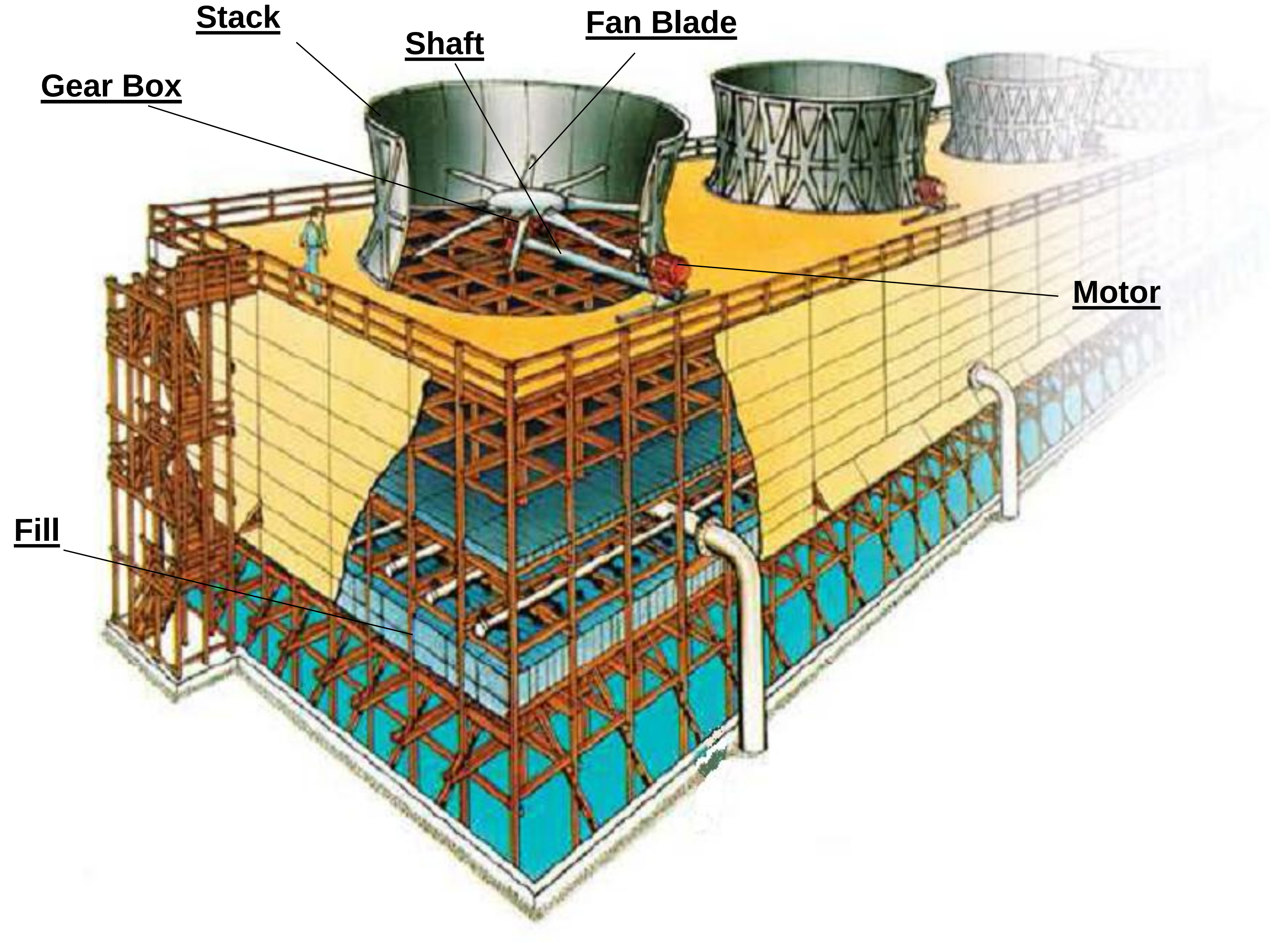
What is Cooling Tower


KEY
1. Cooling tower
2. Cooling water pump
3. Pylon (termination tower)
4. Unit transformer
5. Generator
6. Low pressure turbine
7. Boiler feed pump
8. Condensor
9. Intermediate pressure turbine
10. Steam governor
11. High pressure turbine
12. Deaerator
13. Feed heater
14. Coal conveyor
15. Coal hopper
16. Pulverised fuel mill
17. Boiler drum
18. Ash hopper
19. Superheater
20. Forced draught fan
21. Reheater
22. Air intake
23. Economiser
24. Air preheater
25. Precipitator
26. Induced draught fan
27. Chimney stack

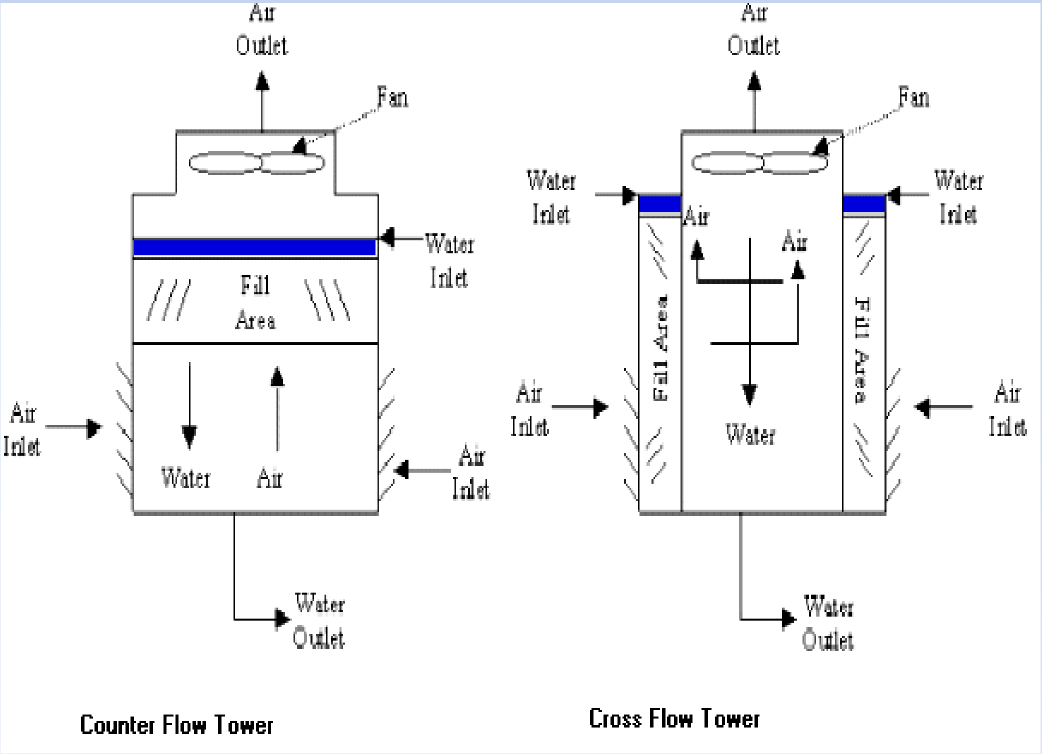

Stack
Shaft
Fan Blade
Gear Box
Motor
Fill

Theory of Cooling Towers

- Cooling towers fall into two main sub-divisions: natural draft and mechanical draft. Natural draft designs use very large concrete chimneys to introduce air through the media.

- Mechanical draft cooling towers are much more widely used. These towers utilize large fans to force air through circulated water. The water falls downward over fill surfaces which help increase the contact time between the water and the air. This helps maximize heat transfer between the two.
- Heat is transferred from water drops to the surrounding air by the transfer of sensible and latent heat

Types of Mechanical Draft Towers



COOLING TOWER BASICS

- What are the Basic of Cooling Tower:-

Water flow rate.
Approach (difference between outlet water & wet bulb temperature)
Range (difference between inlet & outlet temperature).
Hot water temperature (HWT).
Cold water temperature (CWT).
Wet bulb temperature (WBT).
Liquid to air ratio (L/G).

- What factor affecting for CT performance:-

Inadequate or excess water flow.
Inadequate or excess air flow.
Type, quality & spacing of fills.
Type of drift eliminators.
Type & spacing of nozzles.
Motor rating, Fan & Gear box type.

Natural draft cooling tower

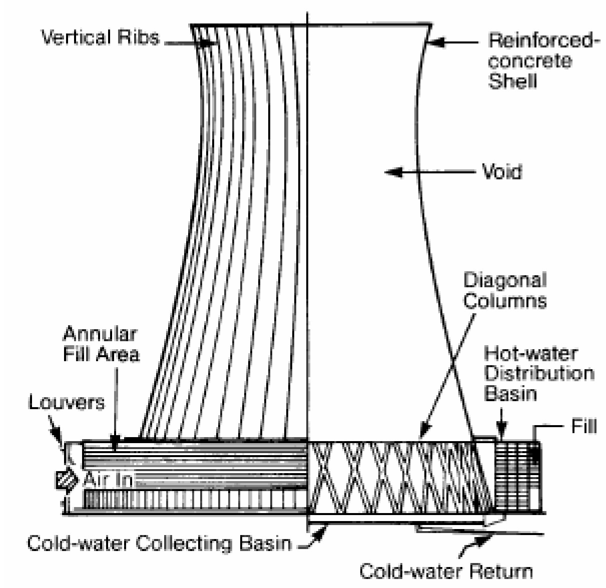


Figure 2. Cross flow natural draft cooling tower

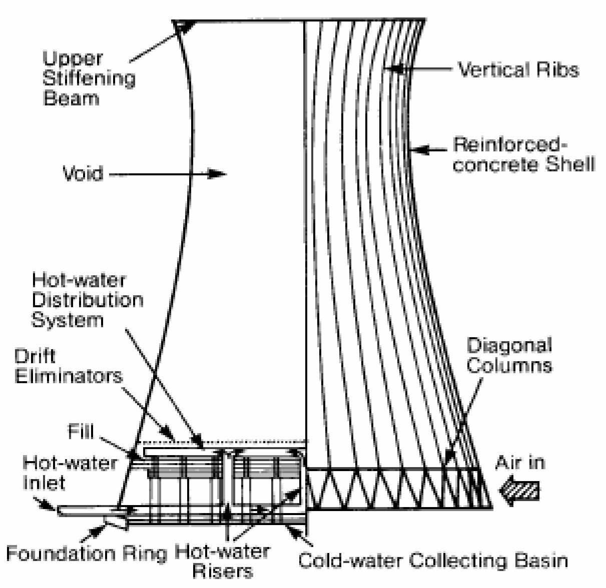


Figure 3. Counter flow natural draft cooling tower

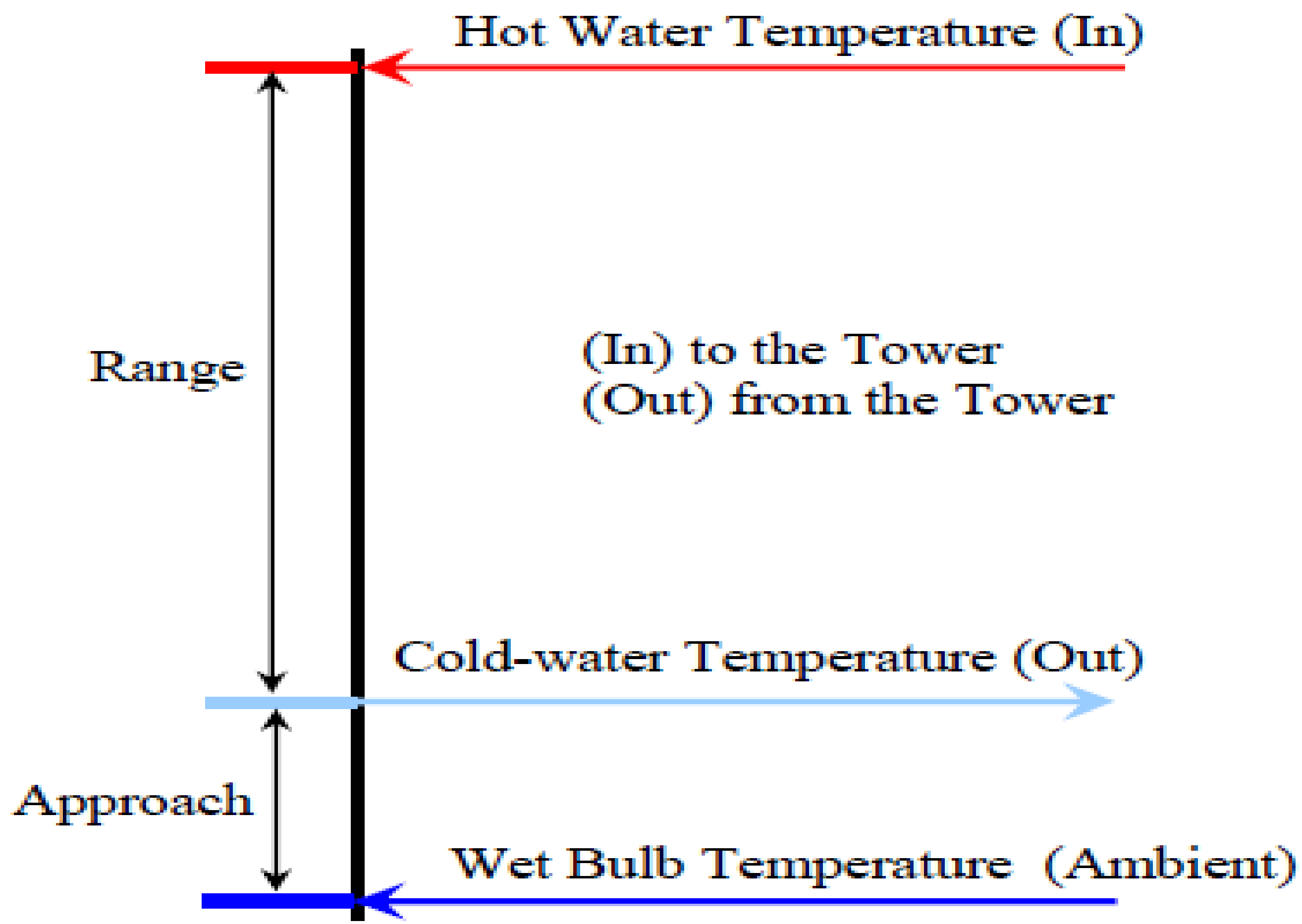


Figure 7. Range and approach of cooling towers

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)]

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)]

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)

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

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.

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

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)

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)

Dry-bulb temperature

• Dry bulb temperature is the temperature that is usually thought of as air temperature, and it is the true thermodynamic temperature. It is the temperature measured by a regular thermometer exposed to the airstream.

Wet-bulb temperature

• Wet bulb temperature is the lowest temperature that can be reached by the evaporation of water only. It is the temperature one feels when one's skin is wet and is exposed to moving air. Unlike dry bulb temperature, wet bulb temperature is an indication of the amount of moisture in the air. **Wet-bulb temperature** can have several technical meanings:

Types of Mechanical Draft Cooling towers

- Counter flow induced draft
- Counter flow forced draft
- Cross flow induced draft

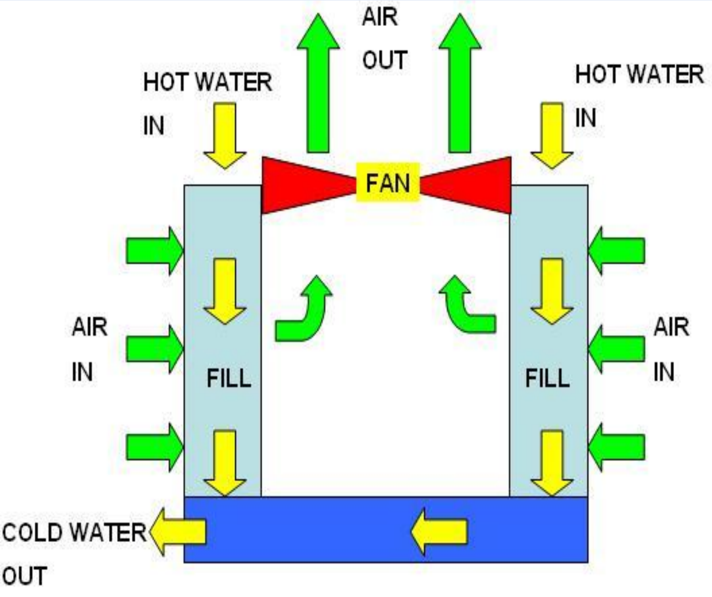
Cross flow induced draft towers

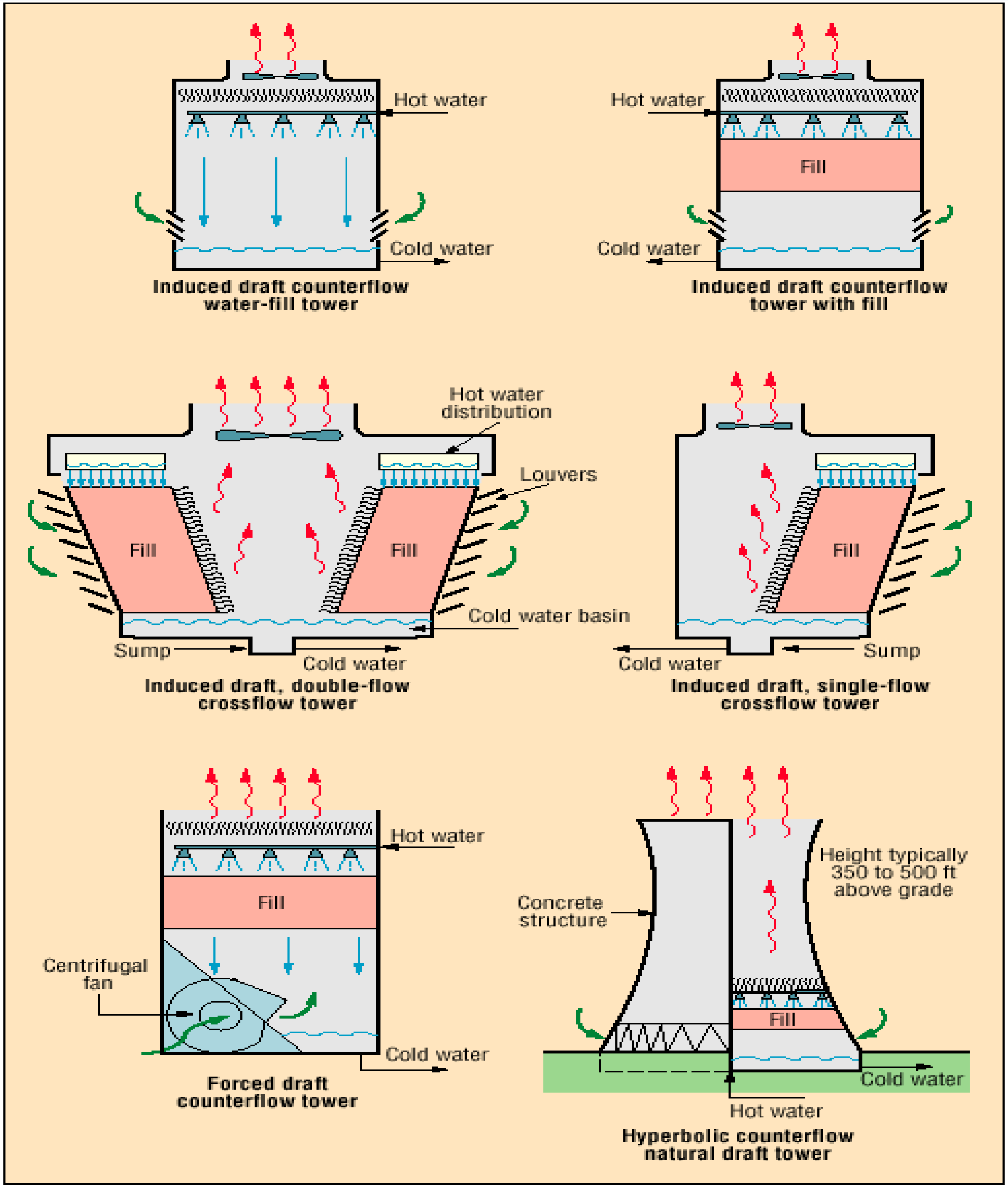
- Hot water enters at the top and passes over the fill.

- Air is introduced at the side, either on one side (single flow tower) OR opposite sides (double flow tower)

Counter flow induced draft

- Hot water enters at the top, while the air is introduced at the bottom and exits at the top
- Here both forced and induced draft fans are used


AIR
OUT
HOT WATER
IN
HOT WATER
IN
FAN
AIR
IN
FILL
FILL
AIR
IN
COLD WATER
OUT


Hot water
Cold water
Induced draft counterflow water-fill tower
Hot water
Fill
Cold water
Induced draft counterflow tower with fill
Hot water distribution
Louvers
Fill
Fill
Cold water basin
Sump
Cold water
Induced draft, double-flow crossflow tower
Fill
Sump
Cold water
Induced draft, single-flow crossflow tower
Hot water
Fill
Centrifugal fan
Cold water
Forced draft counterflow tower
Height typically 350 to 500 ft above grade
Concrete structure
Fill
Cold water
Hot water
Hyperbolic counterflow natural draft tower

What does a Cooling tower consist of

- Frame and casing
- Fill
- Cold water basin
- Drift eliminators
- Air inlet
- Louvers
- Nozzles and Fans

Frame and casing

- Many towers have structured 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.

Fill

- Plastic or wood. Fills can be splash or film type.
- In splash type, 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 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.
- Film type—MORE EFFICIENT and provides same heat transfer in a smaller volume than the splash fill

Cold water basin

- Located at 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 cold water discharge connection

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 be at the ENTIRE side or CROSS FLOW DESIGN or be located low on the side or the bottom of counter flow designs

Louvers

- Equalize air flow into the fill and retain the water within the tower

Nozzles

- Provide water sprays to WET the FILL

Fans

- Both AXIAL (propeller type) and CENTRIFUGAL fans are used

- Axial fans are used in INDUCED draft towers

- Both AXIAL and CENTRIFUGAL fans are found in forced draft towers.

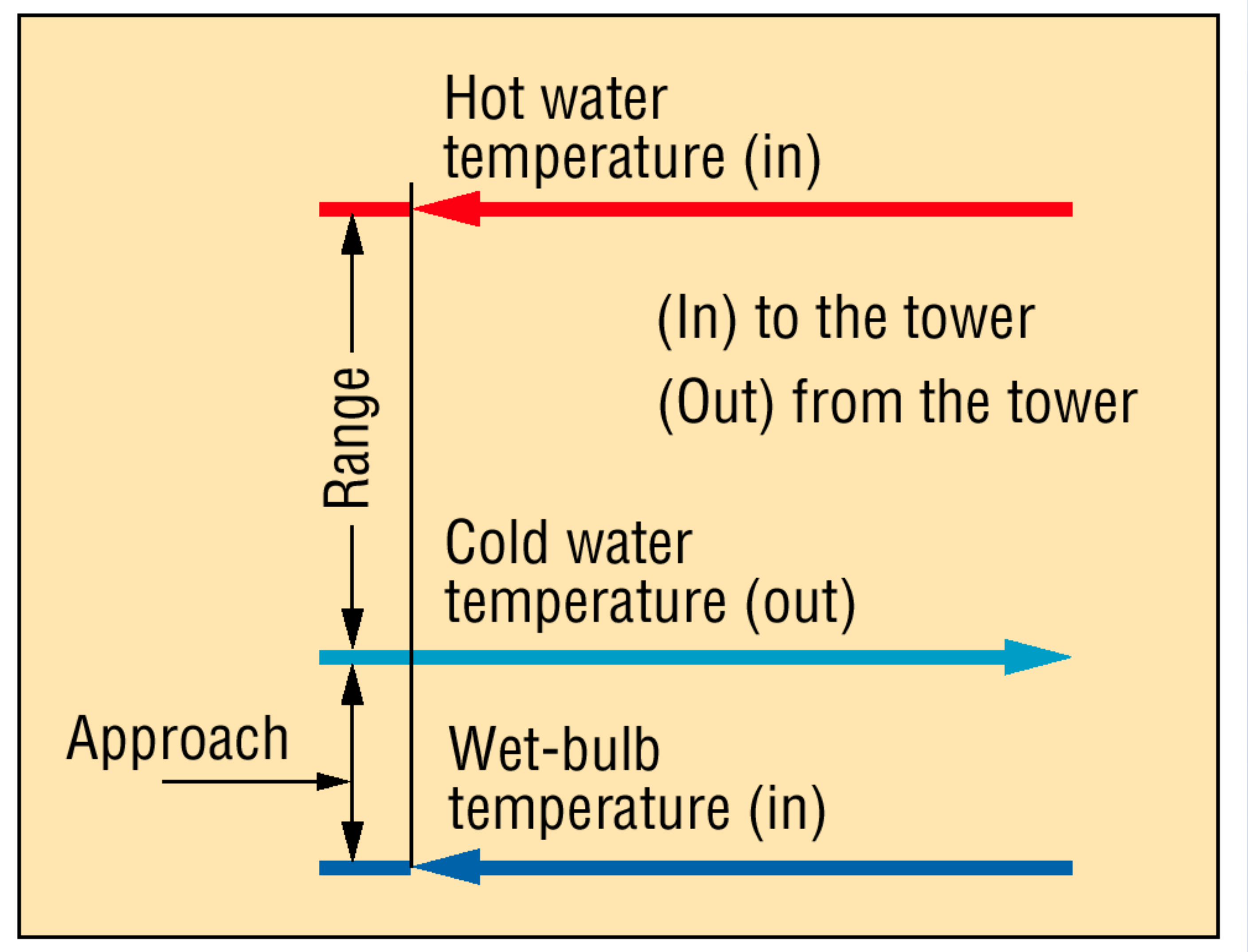
Cooling tower material

- Wood--- frame, casing, louvers, fill, and cold water basin (or concrete)

- Galvanised steel, various grades of stainless steel, glass fibre and concrete, aluminium and various types of plastics for some components

- Large towers are made of CONCRETE
- Plastics are widely used for FILL, including PVC, polypropylene and other polymers
- Plastics also find wide use in nozzle materials

Cooling tower Performance



Cooling tower performance

- Range : (water in – water out temperature)
- Approach : (water out – WBT)
- Effectiveness : Range/(Range + Approach)
- Cooling capacity: Heat rejected in kcal/h or TR = m x Cp x temp. difference

- Evaporation loss:

  = (Circulation rate x temp. difference)/675

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

- Blow down: depends on C.O.C and evaporation losses = Evap. Losses/(C.O.C. -1)

Factors affecting Cooling tower performance

Capacity utilization

- Amount of water circulated

Range

- Determined by the process it is serving
- Determined by heat load and water circulation rate
- Thus Range: f (Heat load & water circulation rate)

- Wet Bulb temperature: design range is specified at certain WBT

- The closer the approach to the WBT, the more expensive the cooling tower due to increased size.

Factors affecting Cooling tower performance

Wet Bulb Temperature

- WBT of air entering the cooling tower determines operating temperature levels throughout the plant, process or system.
- Recirculation raises the effective WBT of the air entering the tower with corresponding increase in cold water temperature.

Approach and Flow

- Approach is dependent on WBT of air entering the cooling tower.
- Water circulation rate is directly proportional to the heat load

Factors affecting Cooling tower performance

Range, Flow and Heat Load

- Range is a direct function of the quantity of water circulated and the heat load.
- Increasing the range as a result of added heat requires an increase in tower size.
- If the hot water temp is constant and the range is specified with a lower cold water temp, then the tower size required for such applications would increase considerably.

Approach and Wet Bulb Temperature

- Design WBT is determined by the geographical location.
- Usually the WBT selected should not exceed 5% of the time in that area.
- Higher WBT, smaller the tower required to give a specified approach to the wet bulb at a constant range and flow rate

Factors affecting Cooling tower performance

Fill Media Effects

- Function: Heat exchange between air and water is influenced by surface area of heat exchange, time of heat exchange and turbulence in water effecting thoroughness of intermixing.
- Due to fewer requirements of air and pumping head, there is a tremendous saving in power with the intervention of film fill.
- Recently, low clog film fills with higher flute sizes have been developed to handle high turbid waters. (sea water)

Efficient System Operation of a Cooling tower

Cooling Water Treatment

- For controlling suspended solids, algae growth, etc.

- Improving treatment methods, increases C.O.C, thereby reduces make up water requirements.

- For large Cooling towers (especially power plants), water treatment is the key area for energy conservation.

Drift loss

- Should be less than 0.02% of the circulation rate
- With technological development, incorporation of efficient designs of drift eliminators enables to specify to as low as 0.003 to 0.001%.

Efficient System Operation of a Cooling tower

Cooling Tower fans

Purpose: To move a specified quantity of air through the system, overcoming the system resistance, which is defined as the pressure loss.

Work done by the fan: air flow x pressure loss

Efficient System Operation of a Cooling tower

Cooling Tower fans

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Work done by the fan: air flow x pressure loss

Fan efficiency:

- Dependent on profile of the blade like tip clearance, obstacles to air flow and inlet shape etc.

- Metallic fans doesn’t have the ideal aerodynamic profile characteristics

- Hence FRP fans finds use for such application, where power consumption is as low as 80 to 85% compared to metallic ones.

Fan efficiency contd..

- Due to light weight, FRP blades require low starting torque, resulting in low kW of the motors

- Light weight increases the life of the gear box, motor and bearings and allows for easy handling and maintenance

Performance Assessment of Cooling towers

Typical measurements and Observations

- **Inlet and outlet water temp.**
- **DBT and WBT**
- **Heat loads of process**
- **TDS of cooling tower**
- **Blowdown**
- **Make up water requirements**
- **C.O.C at site conditions**

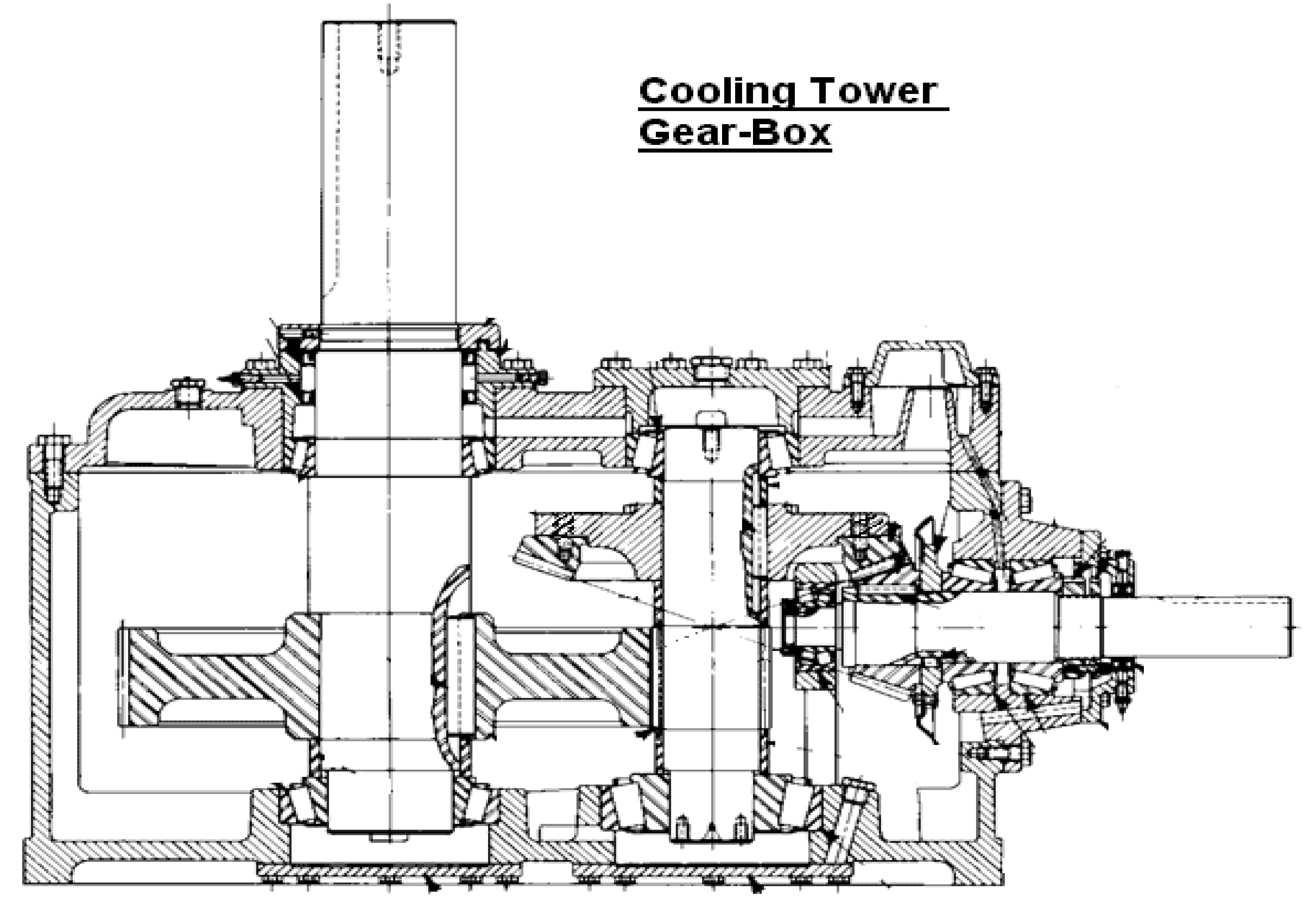
Energy saving opportunities

- **Replace splash bars with self extinguishing PVC cellular film fill**
- **Install new nozzles to obtain a more uniform water pattern**
- **Optimise blow down rate as per COC limit**

Energy saving opportunities contd..

- **Installing FRP blades in place of metallic blades**
- **Incorporation of thermostatic controls for fan operation**
- **Consider COC improvement measures for water savings**
- **Evaluate the efficiency of CT pumps on a periodic basis**

Gear box sectional view



DRIVE SHAFT

Fan Blades

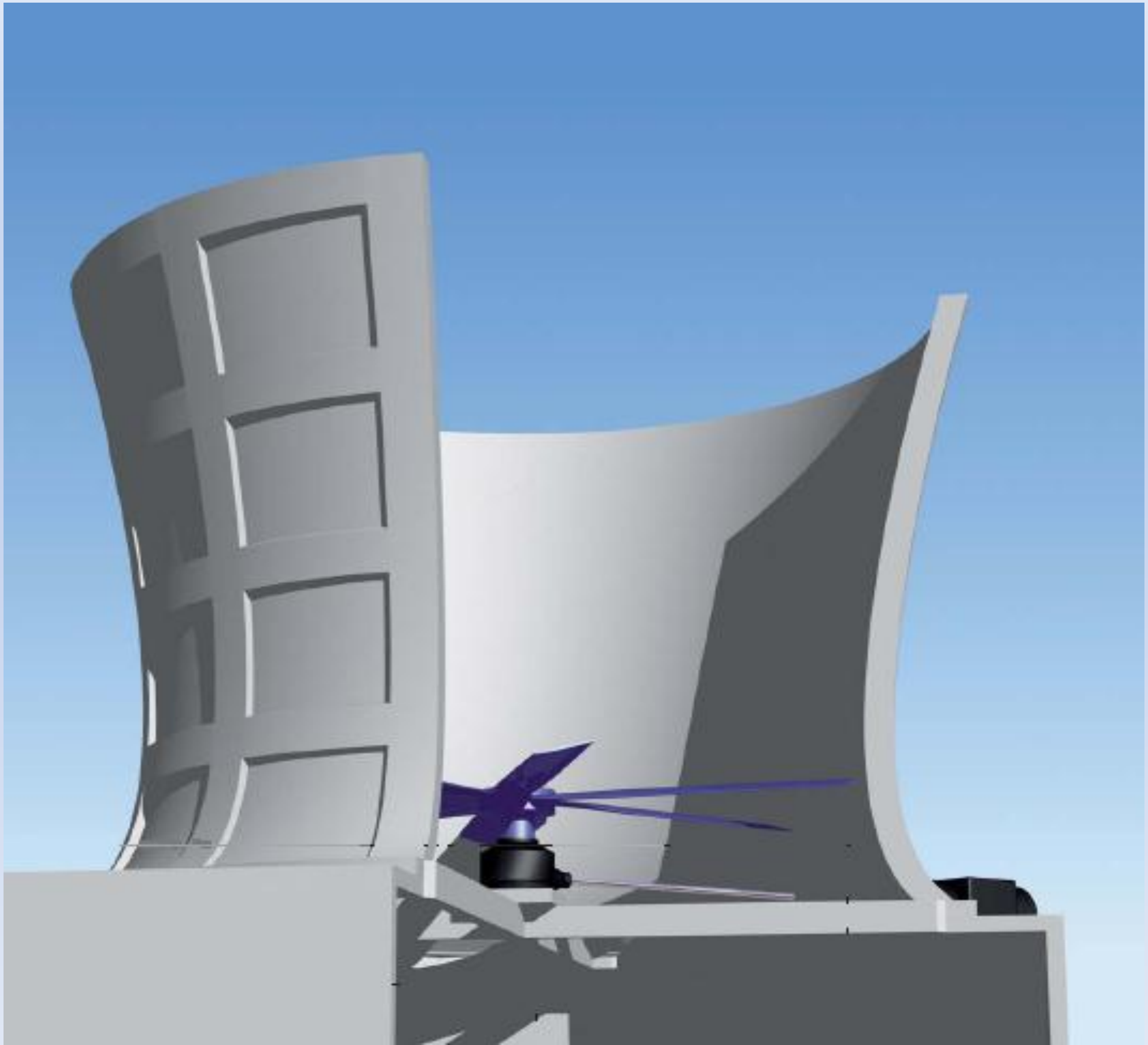
Let us see the Fan Blades

Type of Fan Blades present at BBGS

GAMON Blade

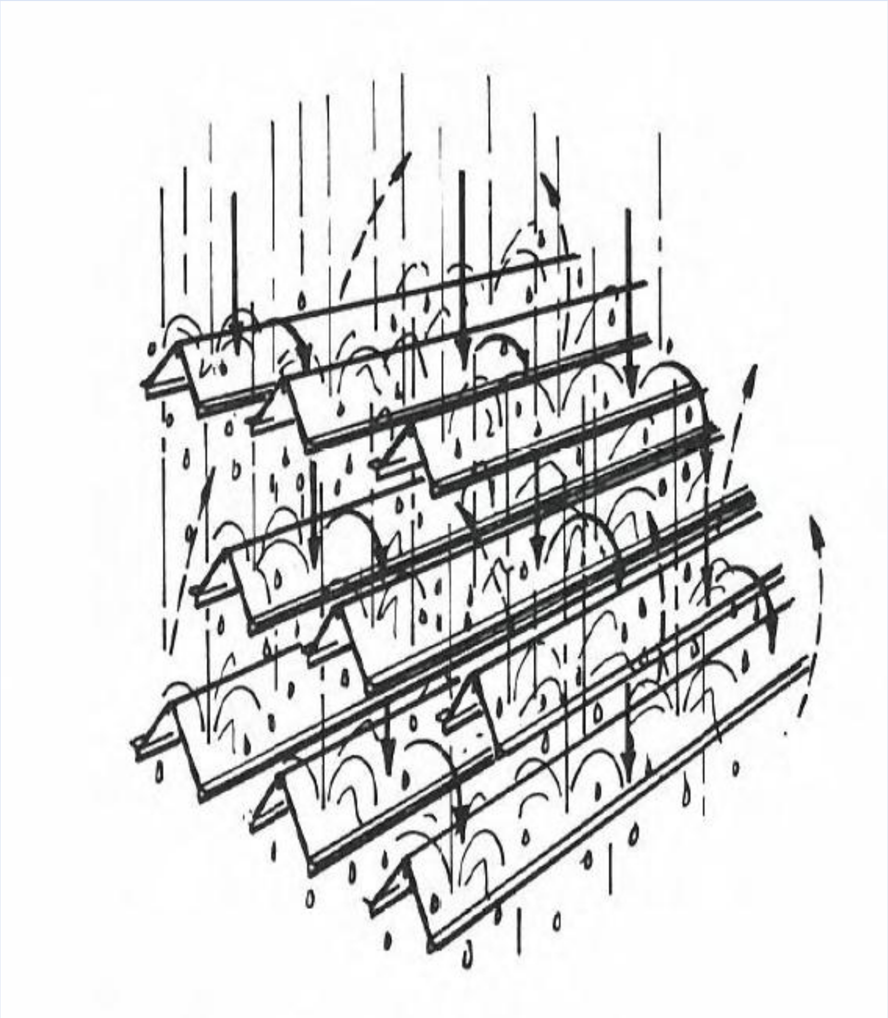
PARAG Fan Blade

STACK



Film Fills

Splash Type Fill



<u>The End</u>