Chapter – 7
Condensers and Cooling Towers

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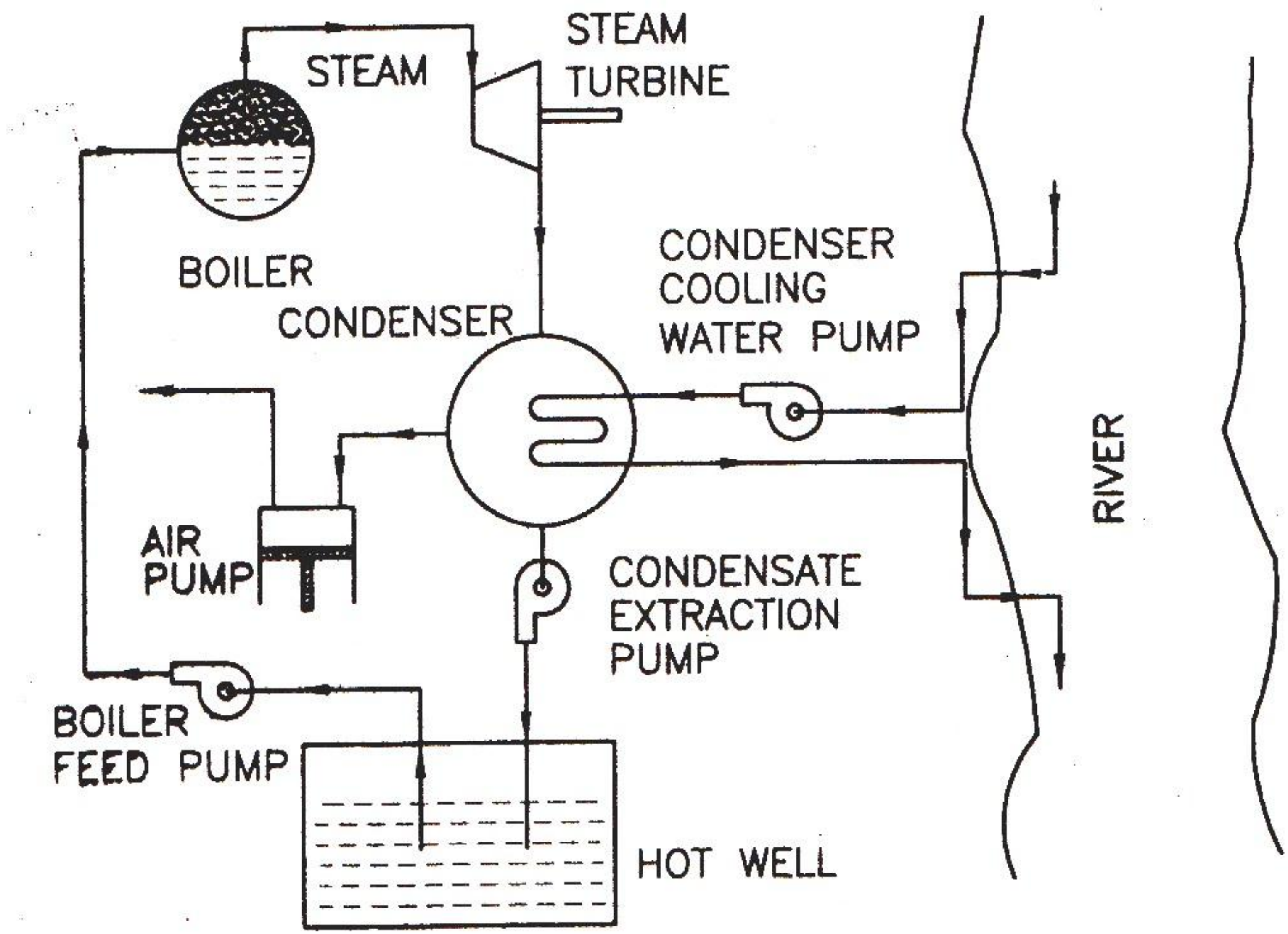
Introduction

- It is a device which condenses working fluid with the help of cooling media (another circulating fluid)
- If cooling media is air ⇨ Air cooled condenser, mostly used in refrigeration or mobile equipment.
- If cooling media is water ⇨ Water cooled condenser, mostly used in stationary plants.

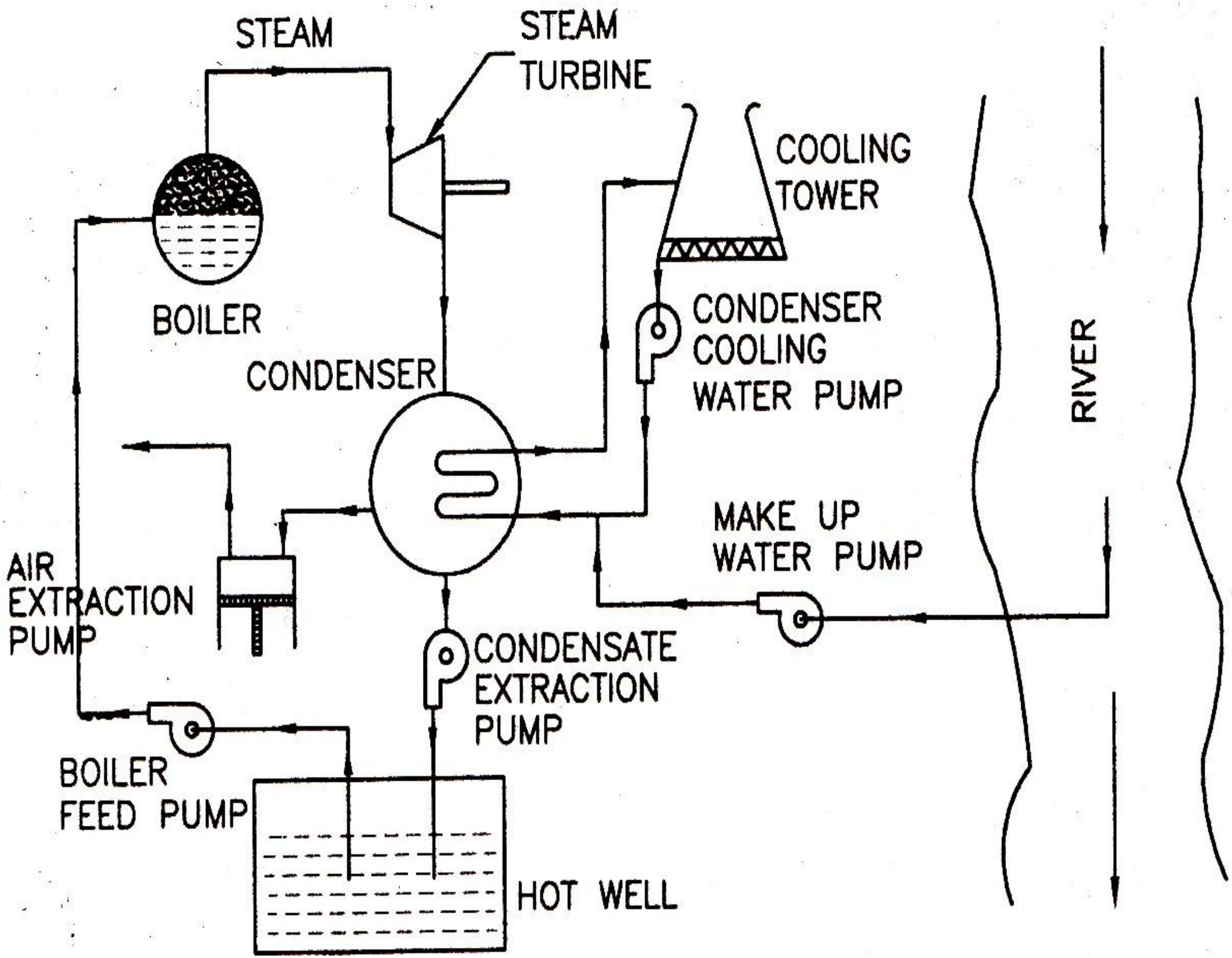
Introduction

- **Steam condenser:**
- It is condenser which is used to condense steam.
- Steam condensers are mostly water cooled i.e. in steam condenser,
- working fluid ⇨ steam
- cooling media ⇨ water
- **Functions:**
- Maintain condensing pressure below atmospheric for improving efficiency.
- To supply hot and pure water to cycle again

Open Cycle Condensing System

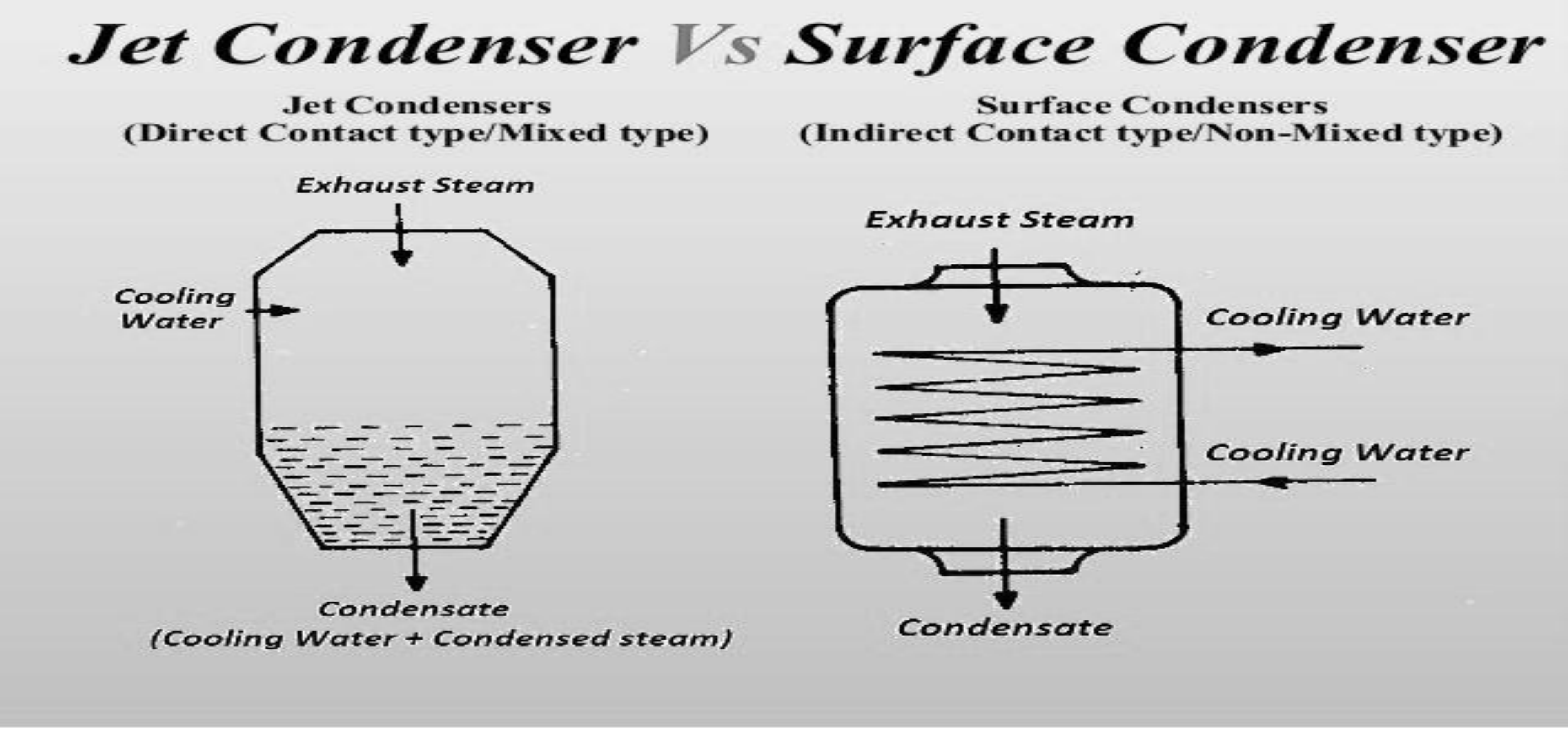


Closed Cycle Condensing System



Introduction

- Classification depending upon contact of working fluid and cooling media
- A. Jet condenser ➡ Direct Contact
- B. Surface Condenser ➡ Indirect contact



Introduction

- Classification depending upon contact of working fluid and cooling media
- A. Jet condenser → Direct Contact
- B. Surface Condenser → Indirect contact

JET CONDENSER	SURFACE CONDENSER
Direct contact	Indirect contact
Condensation due to mixing	Condensation due to heat transfer by conduction and convection
Maintenance cost is low	Maintenance cost is high.
Less Vacuum created	More Vacuum created
Small floor space required	Large floor space required
Condensate can not be directly used as feed water	Condensate can be directly used as feed water
Less power for pumping	More power for pumping
Less quantity of cooling water required	Large quantity of cooling water required
Suitable for low capacity plants	Suitable for large capacity plants

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Requirement of Modern Types of Condensers

- Helpful to avoid scale formation over the tubes.
- Dust deposition can be removed easily.
- Steam should be properly distributed over cooling surface with minimum pressure drop.
- There should be no air leakage.
- The quantity of cooling water circulated should be maintained, such that the temperature of cooling water leaving the condenser is equivalent to the saturation temperature of the steam corresponding to steam pressure in the condenser.

Sources of air leakage in Condensers

- Leakages takes place through joints, packaging, and glands as inside pressure is less than atmospheric pressure.
- The steam coming out off boiler contains dissolved air. This air goes to feed water. The dissolved air is separated when steam is formed and carried with the steam into the condenser.
- In jet condenser, a little quantity of air is dissolved with the injection water (0.5kg/10 tons of water).
- The air leakage in surface condenser is 0.05% of the steam condensed.

Measurement of Vacuum in Condenser

- In case of condenser, vacuum means pressure below atmospheric pressure.
- It is expressed in mm of Hg.
- Corrected vacuum in mm of Hg = (760 – Absolute pressure in mm of Hg)
- Corrected vacuum in mm of Hg = [760 – (Actual barometric height – Actual vacuum)]
- 760 mm of Hg = 1.01325 bar,
- 1 mm of Hg = 1.01325/760 = 0.001333 bar.

Vacuum Efficiency in Condenser

- Vacuum efficiency is defined as the ratio of actual vacuum to the ideal vacuum.
- The actual pressure in the condenser is always greater than the ideal pressure because of the partial pressure of air present in the condenser.
- The lowest pressure in a condenser is the saturation pressure of steam corresponding to steam temperature entering in to the condenser.
- Let, P_s = Saturation pressure of steam in bar
- P_t = Total pressure of air and steam in condenser
- P_a = Pressure of air in the condenser
- P_b = Atmospheric or Barometric pressure
- Total Pressure, $P_t = P_a + P_s$ and ideal vacuum without air leakage = $(P_a - P_s)$

Vacuum Efficiency in Condenser

- Actual vacuum present in condenser due to air leakage = Pb – Pt

  = Pb – (Pa+Ps)

- Vacuum Efficiency = Actual Vacuum / Ideal Vacuum
- Vacuum Efficiency (η_v) = $P_b - P_t / P_b - P_s$
- If no air leakage in condenser Pa = 0, and vacuum efficiency will be 100%.

Condenser Efficiency

- Condenser Efficiency is defined as the ratio of difference between the outlet and inlet temperature of cooling water to the difference between temperature corresponding to the vacuum in the condenser and inlet temperature of cooling water.
- Let, Two = Cooling water temp. at outlet to condenser.
- Twi = Cooling water temp. at inlet to condenser.
- Ts = Temp. corresponding to vacuum in condenser.
- $\eta_c = Two – Twi / Ts – Twi$
- The quantity of cooling water calculated by:
- $m_w = m_s [\, x.\, h_{fg} + C_{pw} (t_s – t_{w2})] / C_{pw} (t_{w2} – t_{w1})$

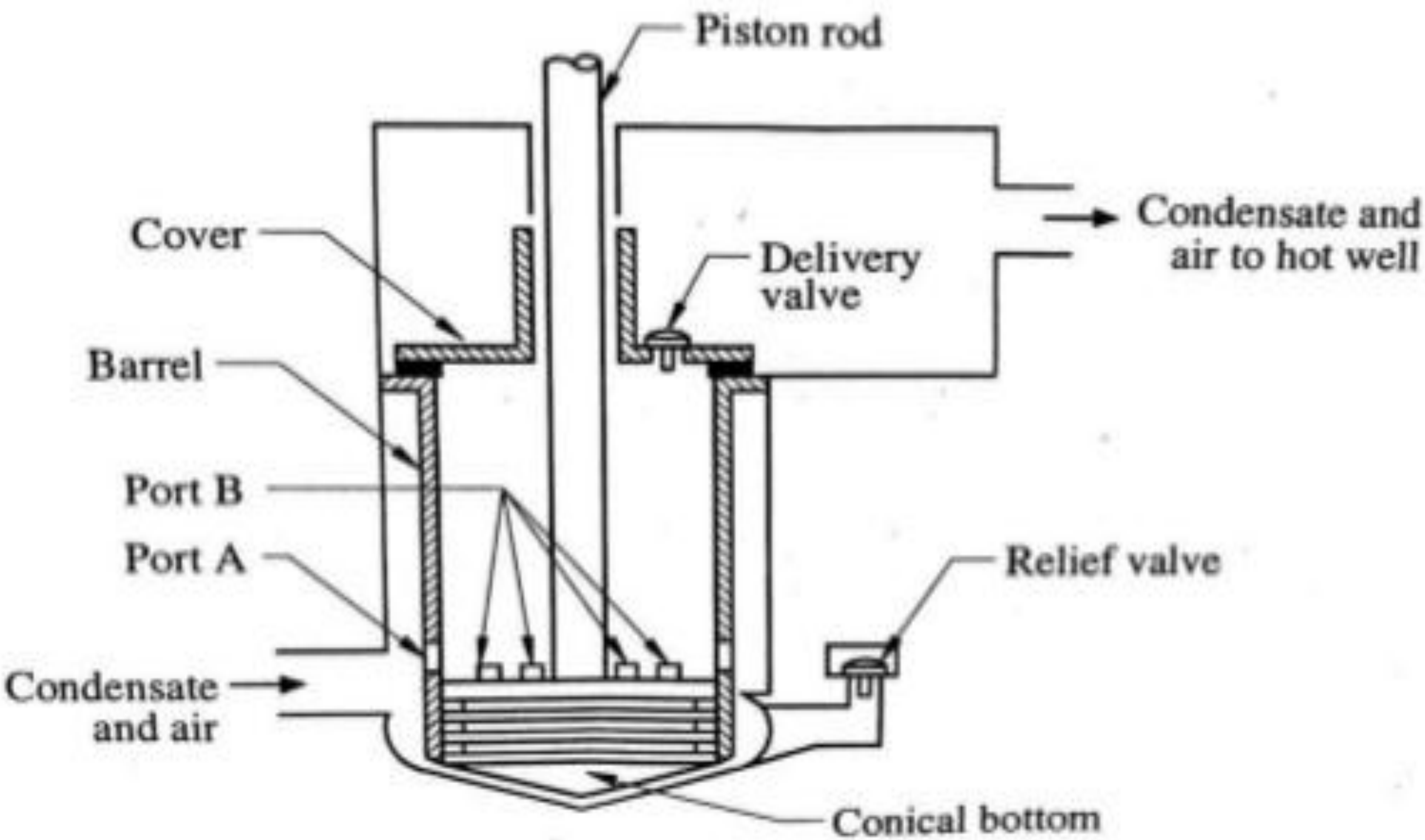
Air Pump

- Two types of air pumps:

1. Wet Air Pump – used to remove the air and condensate.
2. Dry Air Pump – used to remove moist air.

Edward's Air Pump

Edward air pump



Edward's Air Pump

- It consist of cylindrical body in which a pump barrel is fitted.
- The piston is reciprocating in pump barrel, the piston is conical at the bottom and has ports on the flat top surface.
- When the piston moves in upward direction, the condensate and air from the condenser is taken below the conical portion of the piston.
- When piston moves in downward direction vacuum is created on the top side.
- So the condensate and air pushed into the barrel through the ports.
- During this travel of piston the delivery valves are closed.

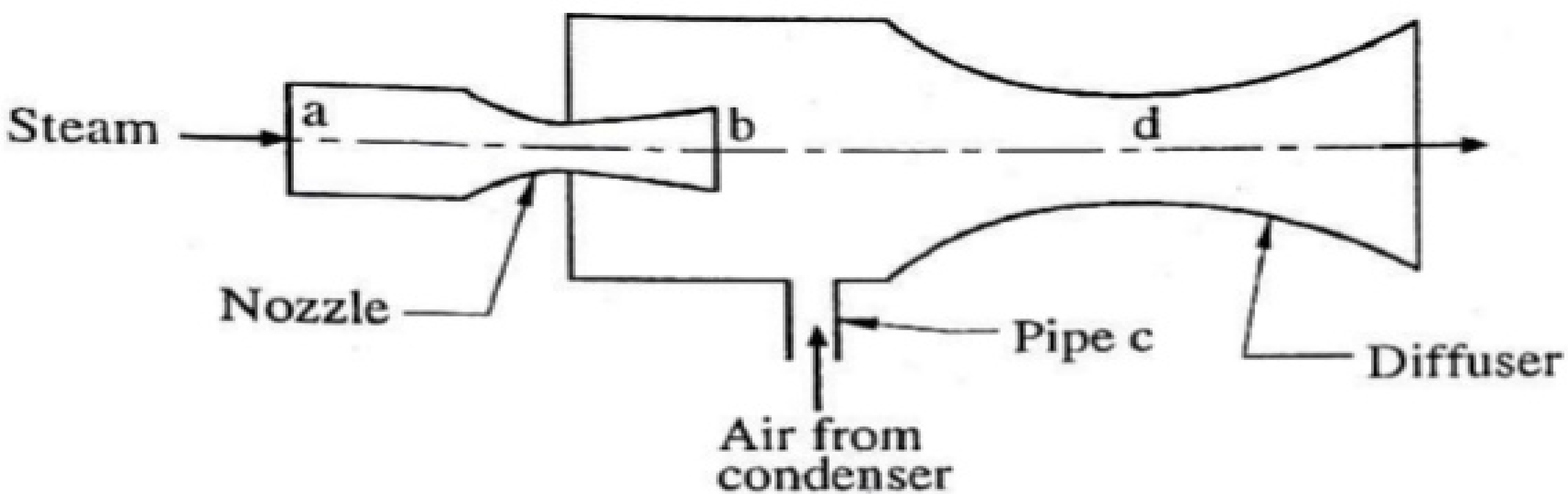
Edward's Air Pump

- When the piston moves again in upward direction, the condensate and air is compressed and delivery valve opens.
- The mixture is then sent to the hot well.
- Some amount of water is held above the delivery valves to ensure any air leakage into the condenser.
- The air and condensate is again supplied below the conical portion of the piston and working is repeated.
- If pressure inside the condenser is increased above atmospheric pressure the relief valve releases excess pressure.

Steam Jet Air Ejector

Method of obtaining max vacuum :

- **Steam Jet Air Ejector :** remove air from condenser when a wet pump is employed. It consist of convergent – divergent nozzle and a diffuser.



Steam Jet Air Ejector

- It consist of convergent divergent nozzle and diffuser.
- The exhaust steam from boiler enters portion of the nozzle were kinetic energy increases and pressure reduces.
- The air from the condenser along with small amount of vapour mix with low pressure steam.
- The mixture of moist air and steam then moves to the diffuser portion where its velocity decreases and pressure increases.
- It helps to reduce the pressure in the condenser up to 0.08 bars if number of ejector are used.

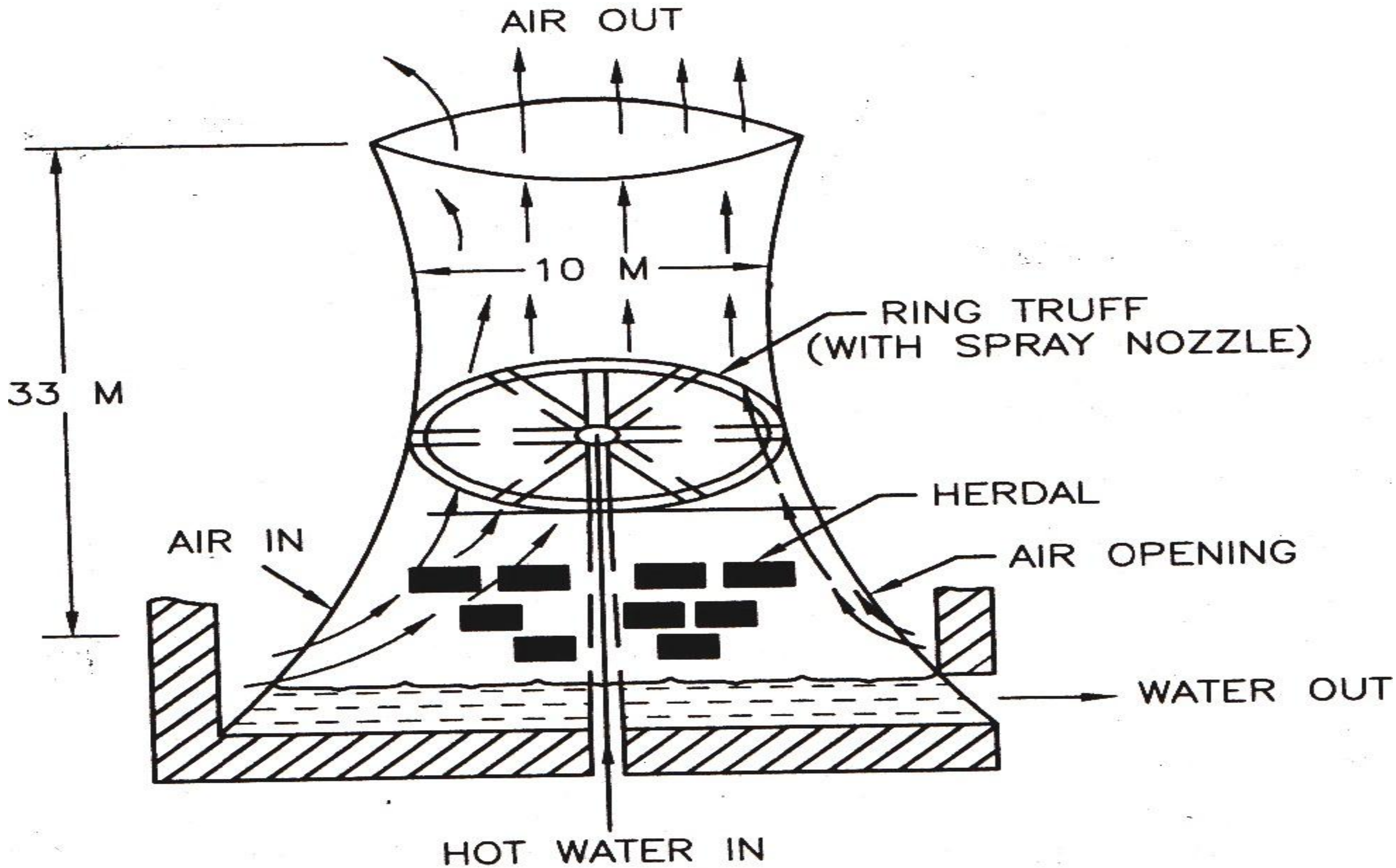
Cooling Towers

- It reject heat from condenser cooling water.
- The water cooled in cooling tower is being reused.
- There are two types of cooling tower:

1. Natural draft
2. Mechanical draft

   - Forced Draft
   - Induced Draft

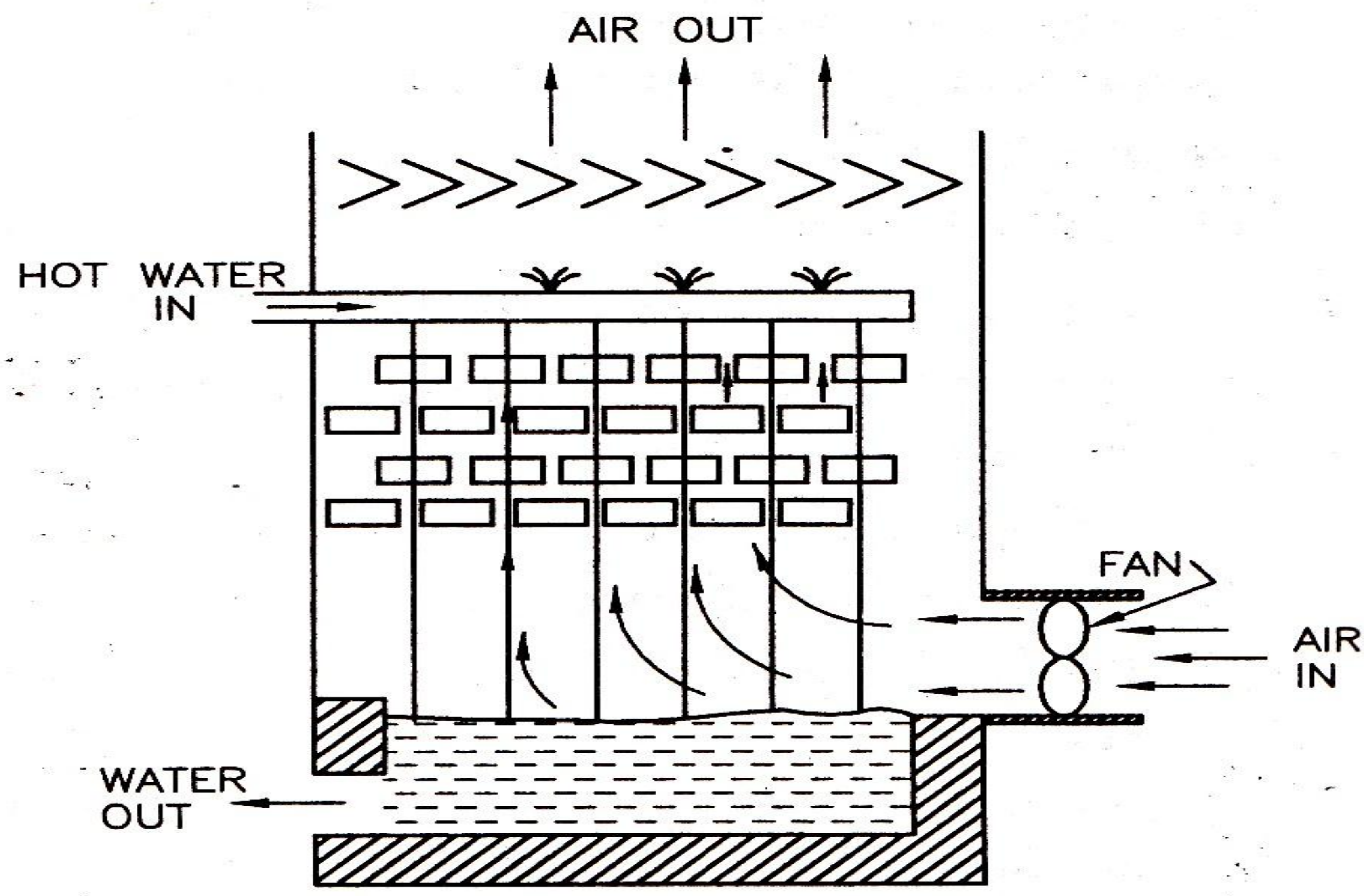
Natural Draft Cooling Tower (Hyperbolic Cooling Tower)



Natural Draft Cooling Tower (Hyperbolic Cooling Tower)

- **Advantages:**
- Operation is simple.
- No additional fan or blower required.
- Operation cost is low.
- Can sustain very high speed wind.
- Less floor area required.
- **Dis-Advantages:**
- Initial cost is high.
- Performance depends on psychometrics conditions.

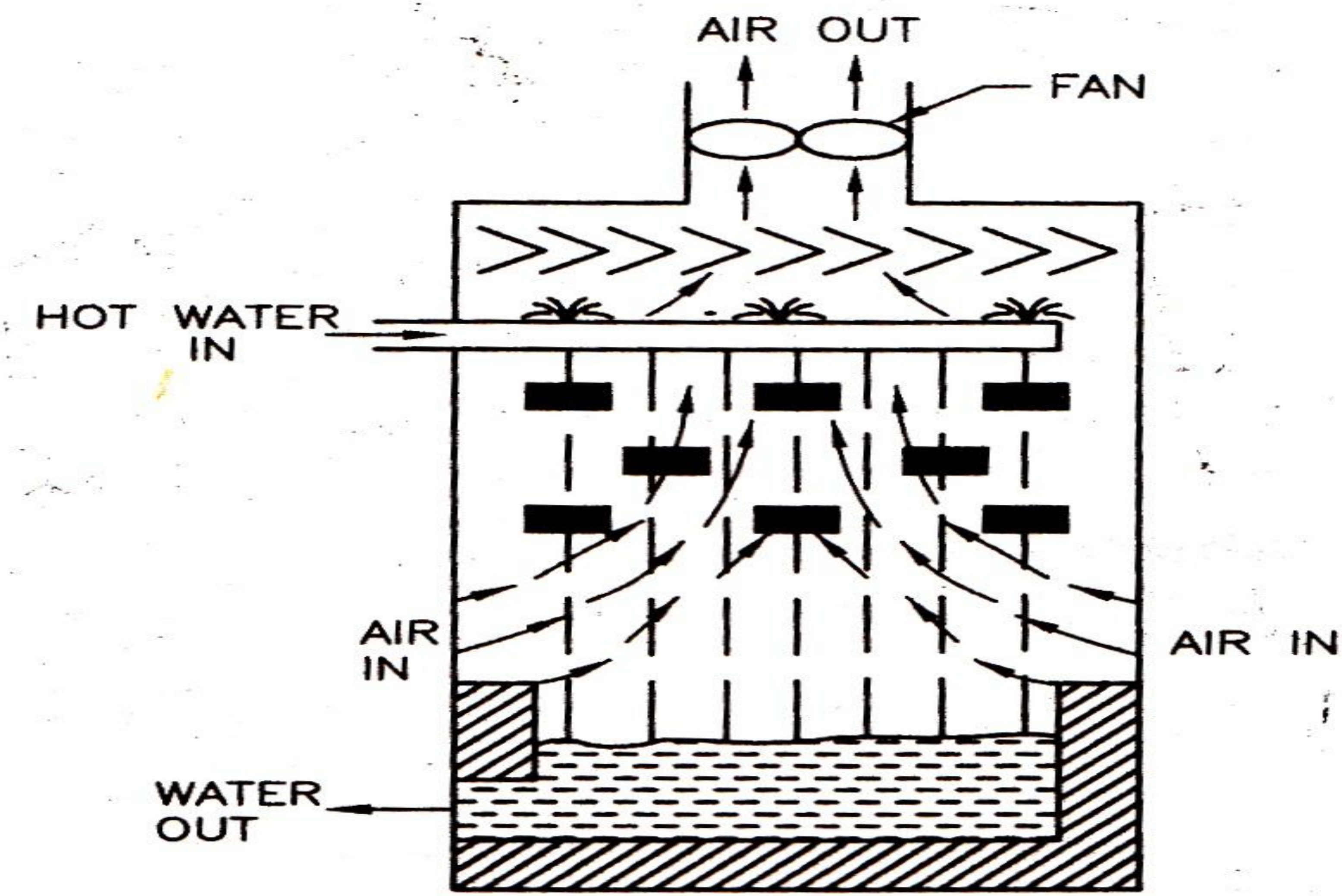
Mechanical Draft Cooling Tower (Forced Draft)



Mechanical Draft Cooling Tower (Forced Draft)

- **Advantages:**
- No corrosion on fan blades as it handles only dry air.
- More safe and efficient with less capital cost.
- Rate of evaporation is more.
- **Dis-Advantages:**
- Power requirement is high.
- Fan size is limited to 4 m only.
- High operating cost.

Mechanical Draft Cooling Tower (Induced Draft)



Mechanical Draft Cooling Tower (Induced Draft)

- **Advantages:**
- Initial cost is low.
- Less space required.
- Rate of cooling is more.
- **Dis-Advantages:**
- Rate of evaporation varies with air velocity.
- Higher power motor is required to drive the fan.

Maintenance Cooling Tower

- Greasing of motor bearings.
- Oiling of gear boxes.
- Inspection of fan, motor, pumps, etc.
- Noise and vibrations to be checked.
- Hardness testing of circulating water.
- Inspection of spray nozzles to avoid clogging.