Condensers and cooling towers

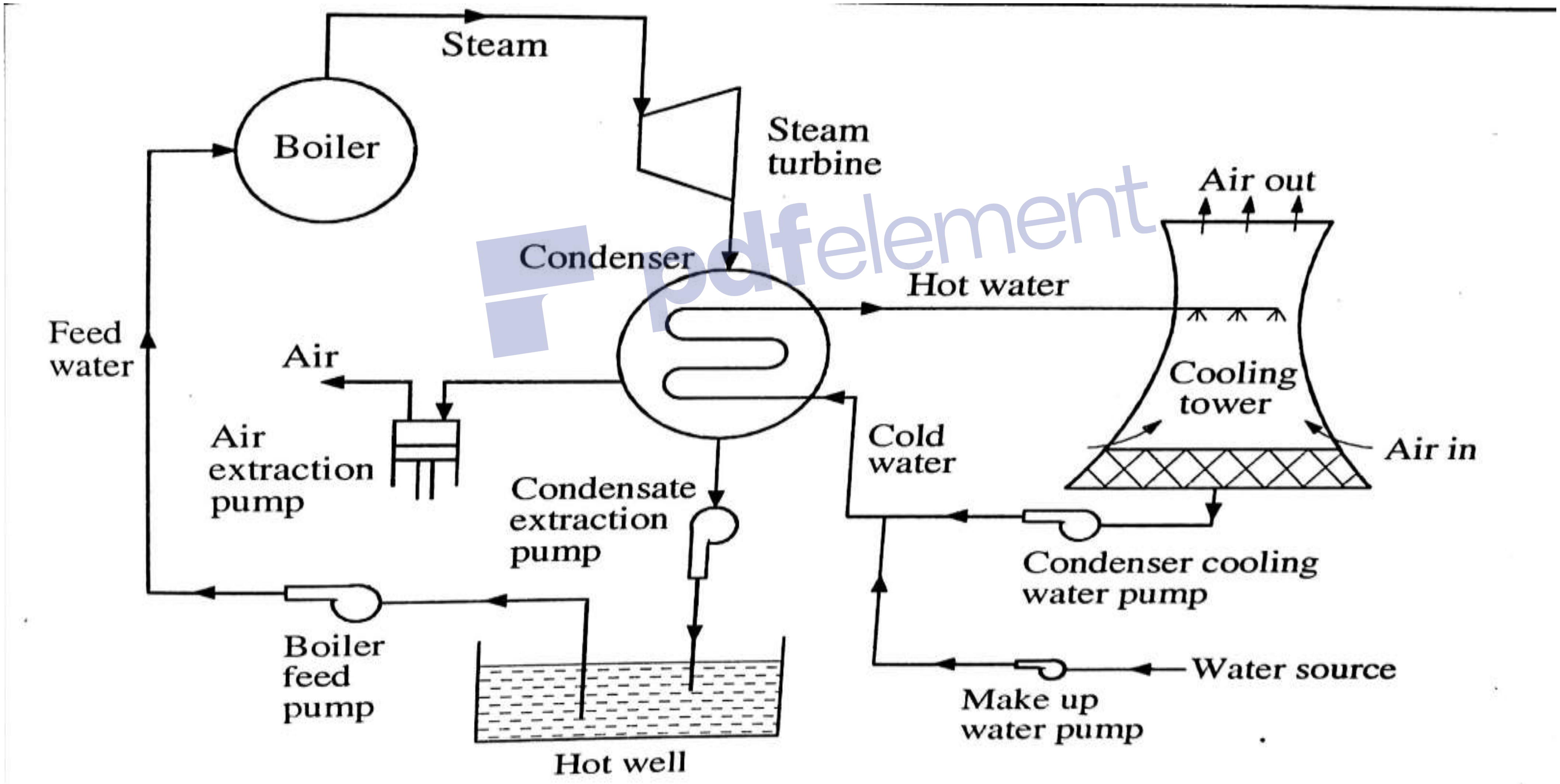
Condenser

Objects

1. The main object is to creates a low back (vacuum) for the turbine exhaust so as to obtain the maximum possible energy from steam and thus to secure a high efficiency.

2. Condense the exhaust steam from turbine.

Steam condensing plant



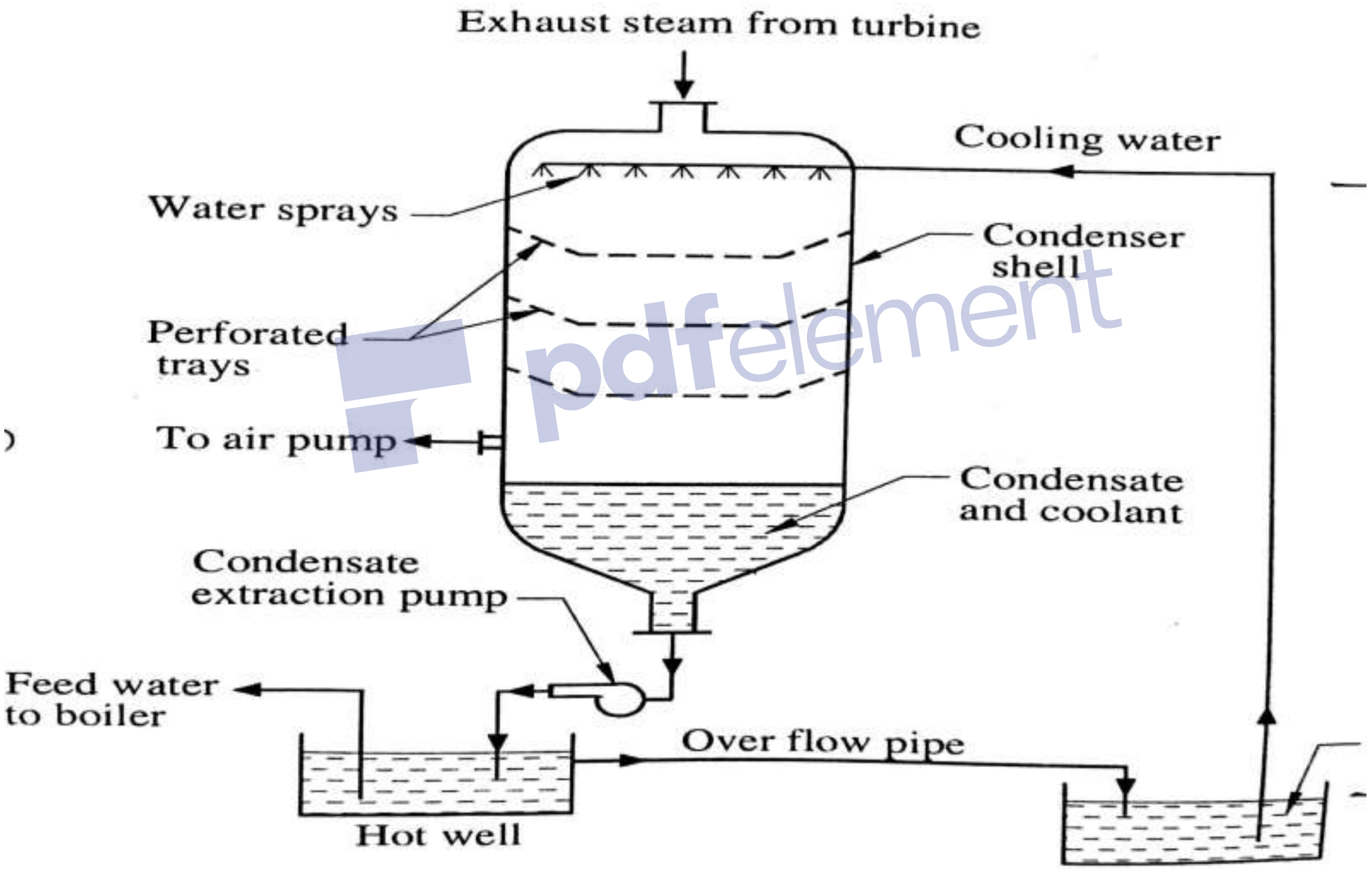
Types of condensers

1. Jet condenser

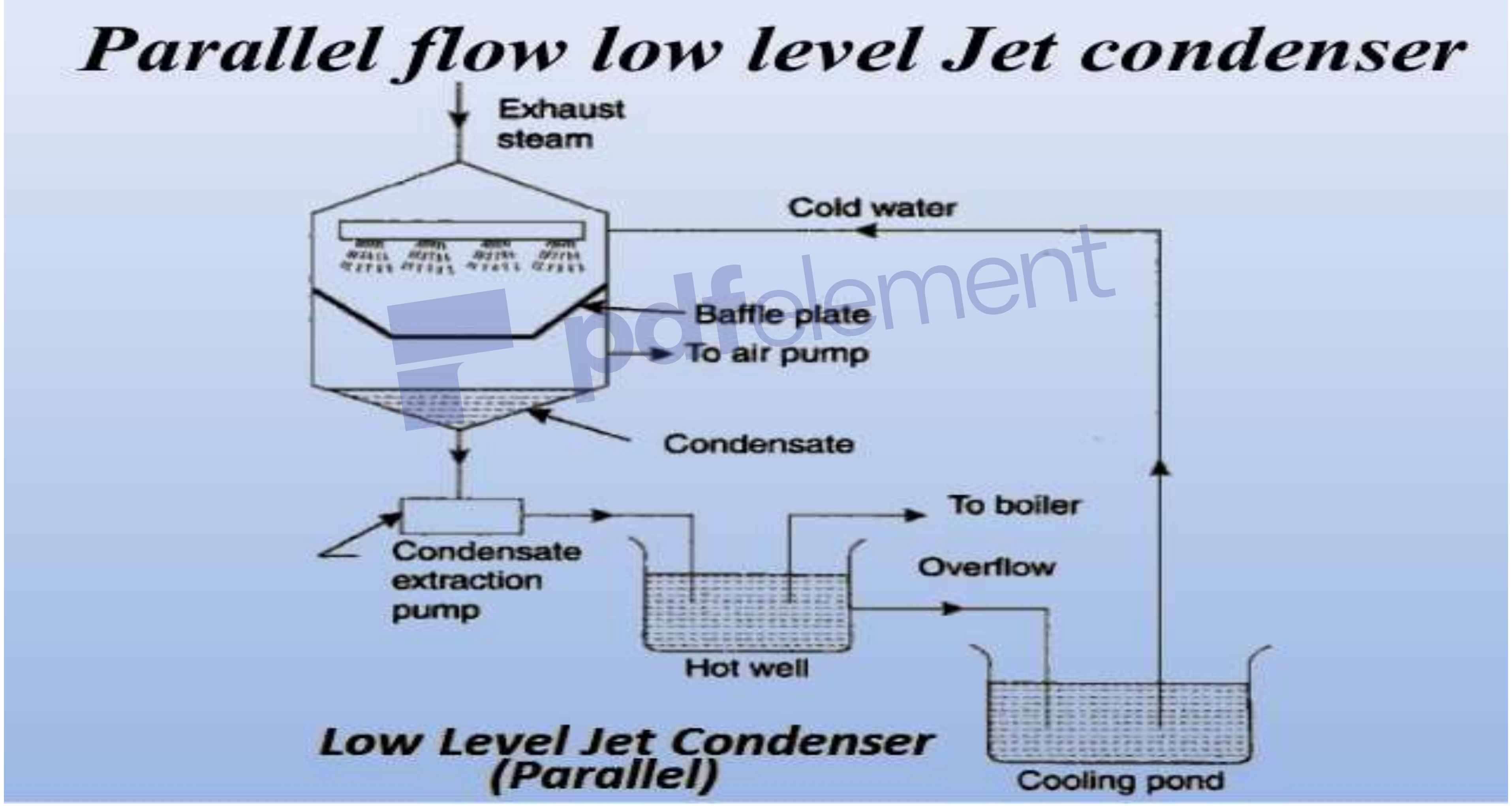
- Low level jet condenser
    - Parallel flow type
    - Counter flow type
- High level jet condenser
- Ejector jet condenser

2. Surface condenser

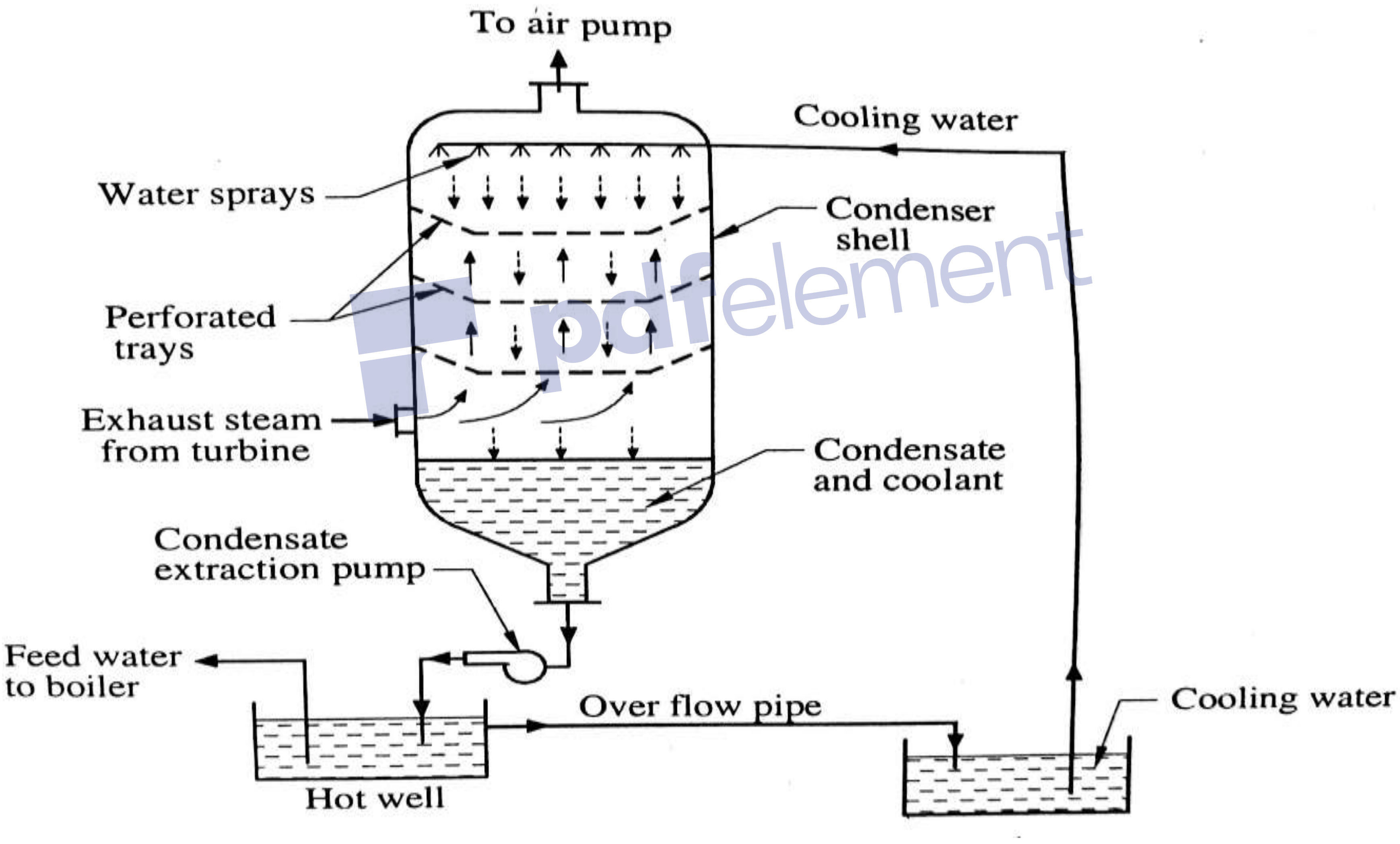
low level parallel flow jet condenser



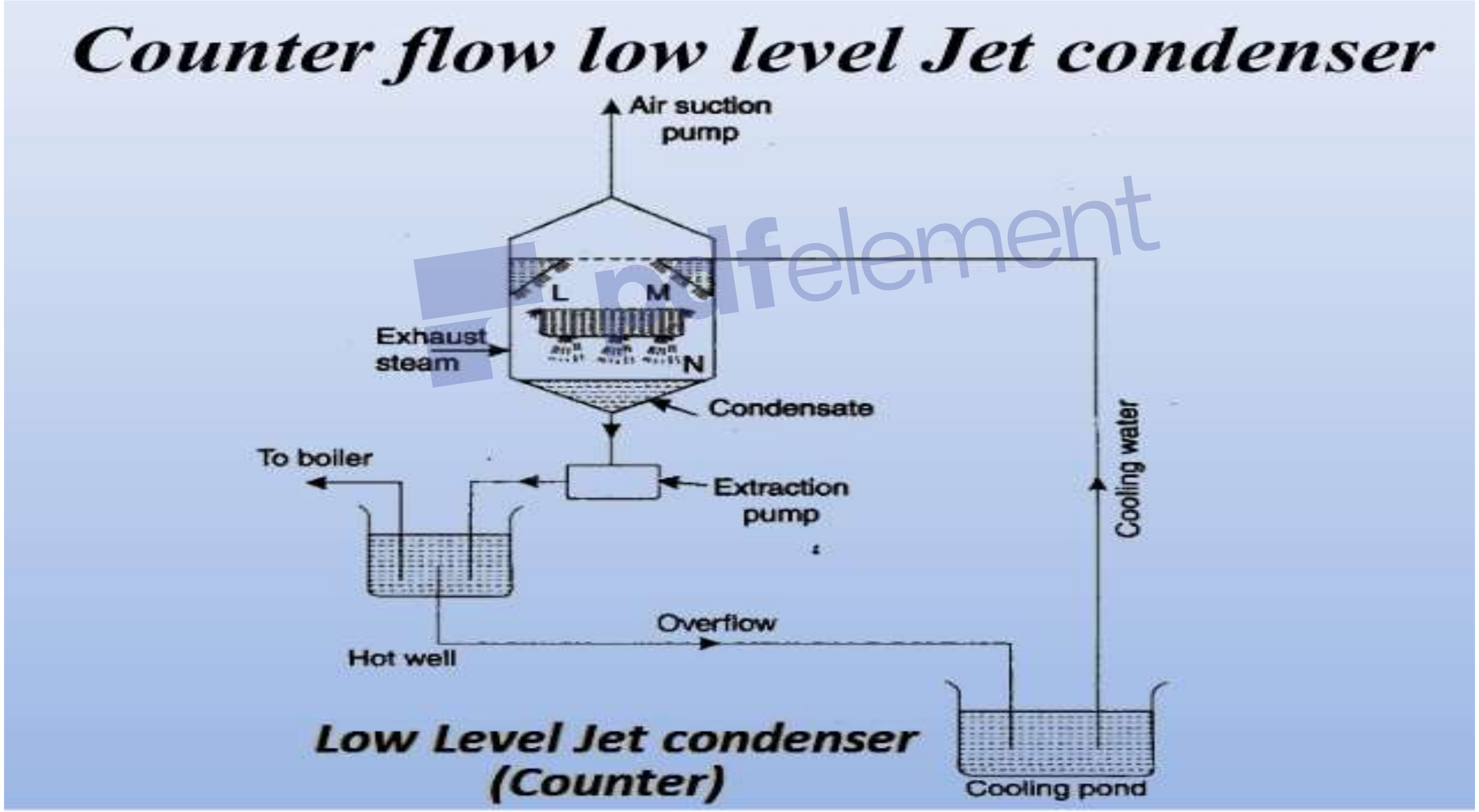
low level parallel flow jet condenser



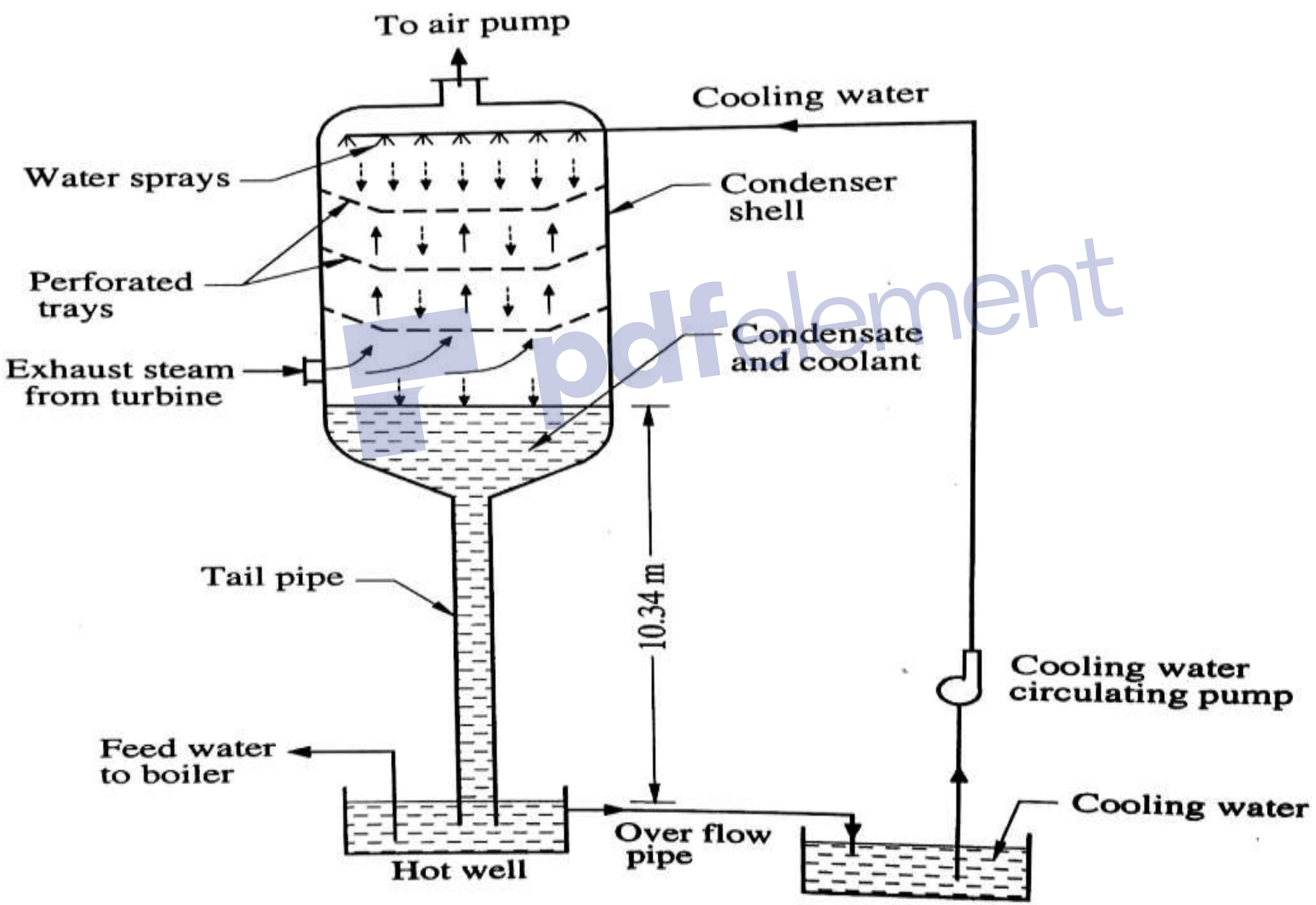
Low level counter flow jet condenser



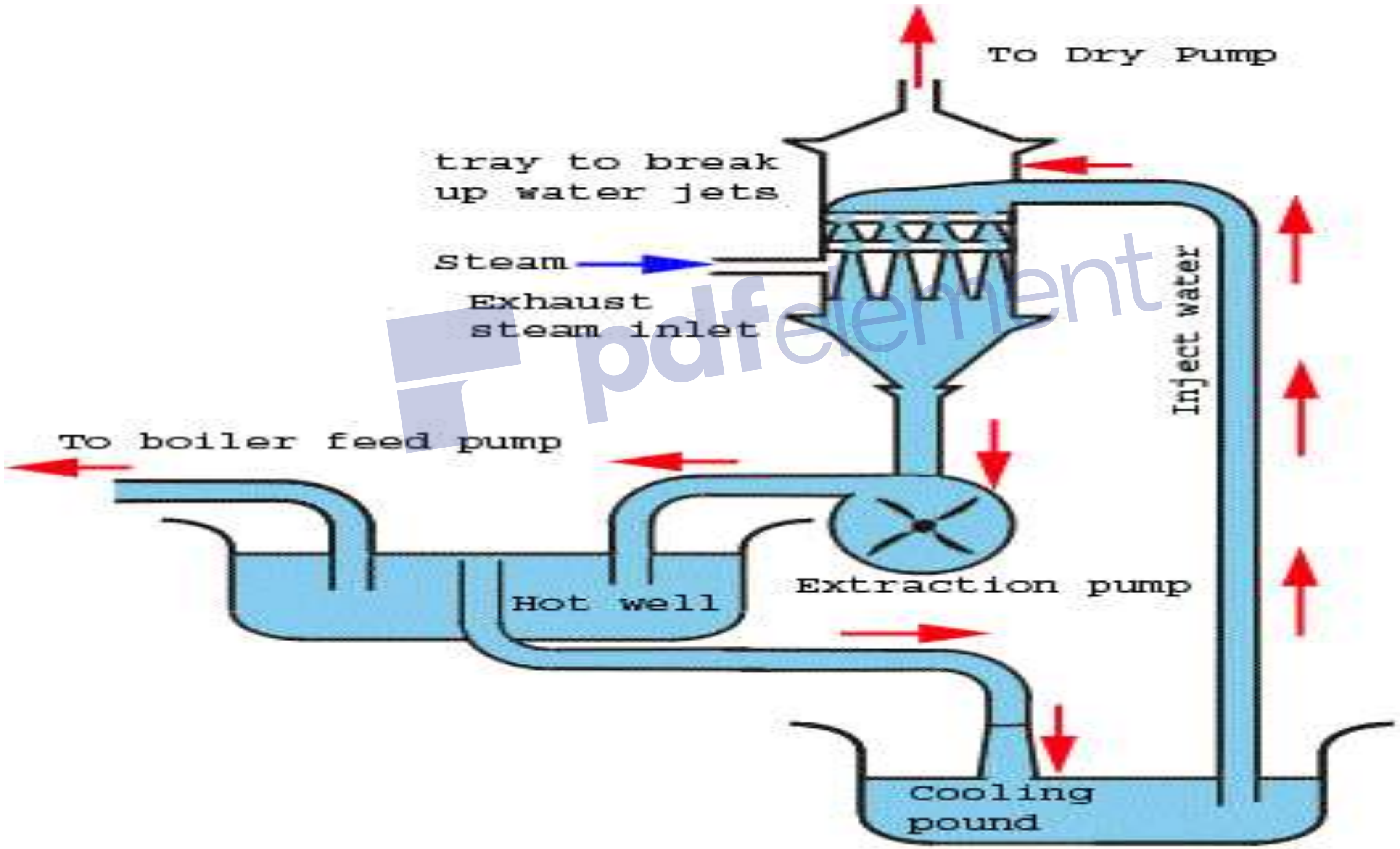
Low level counter flow jet condenser



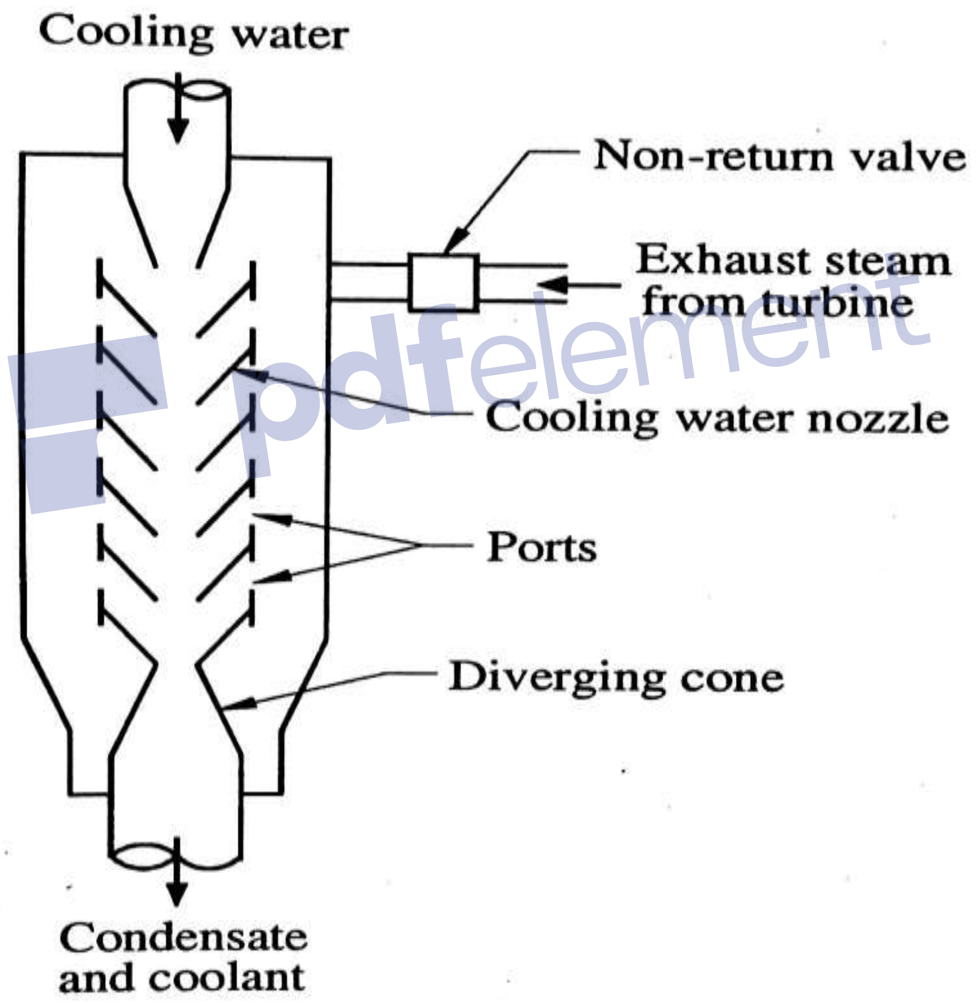
High level jet condenser



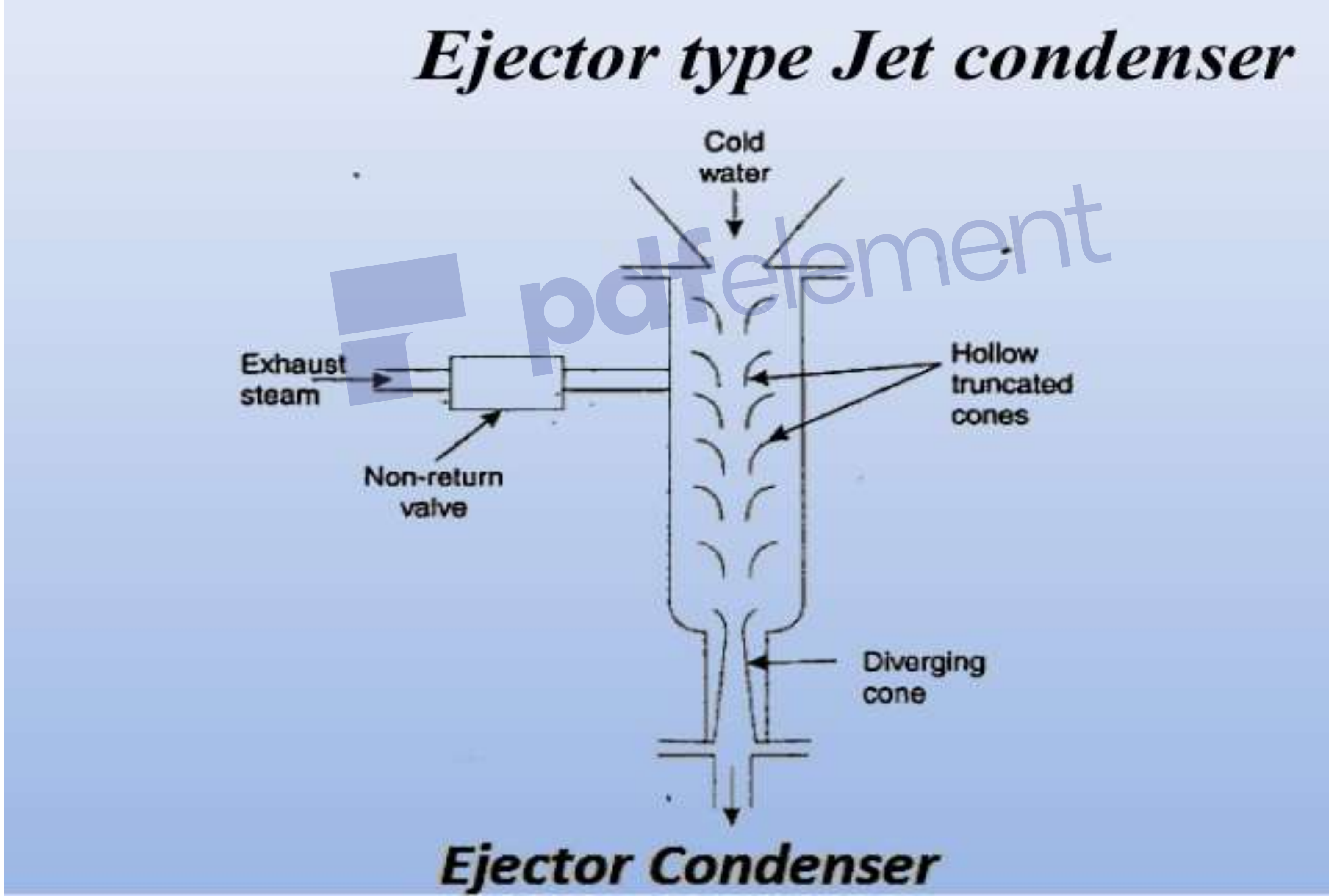
High level jet condenser



Ejector condenser



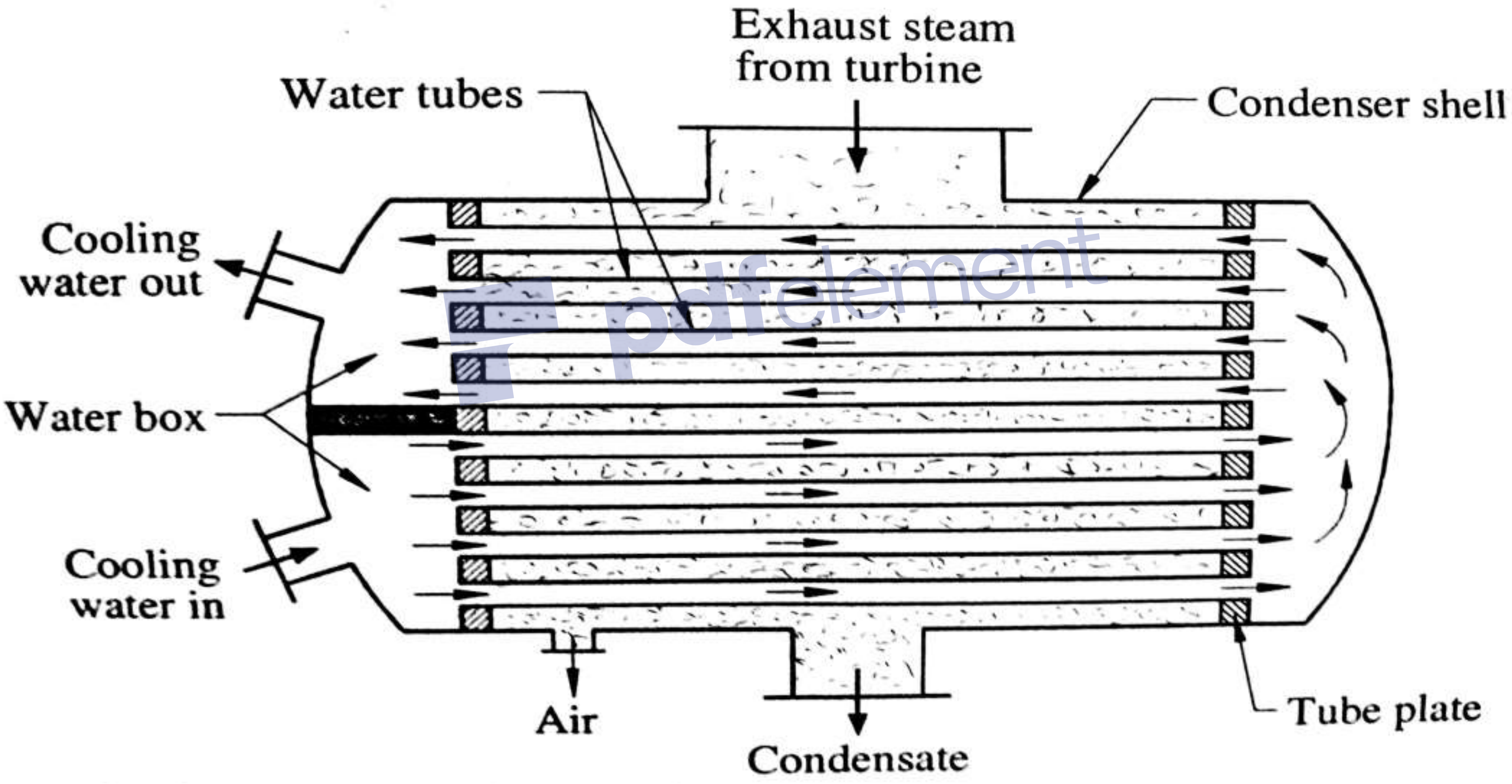
Ejector condenser



Advantages of jet condenser

- The quantity of cooling water required per kg of steam condensed is lower than that required for surface condenser.
- They are simple in design.
- They require less floor space.
- Lower maintenance cost.

Double pass surface condenser



Down flow surface condenser

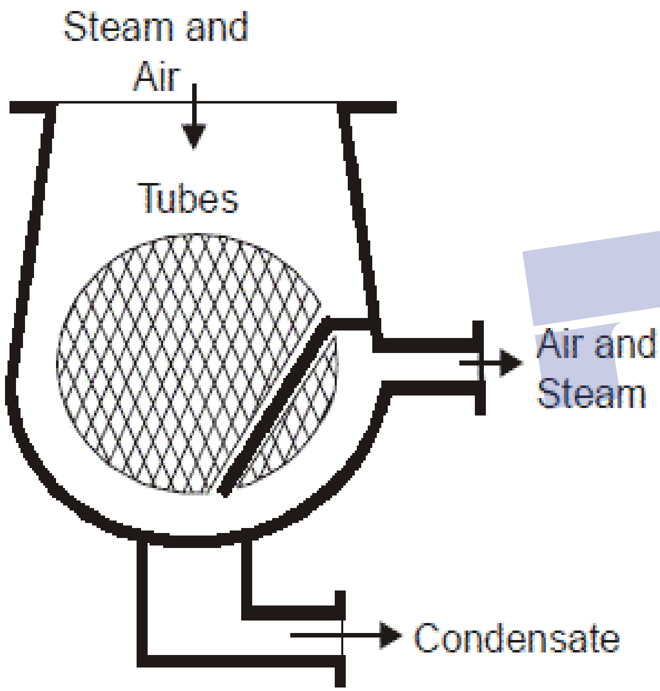


Fig. 1

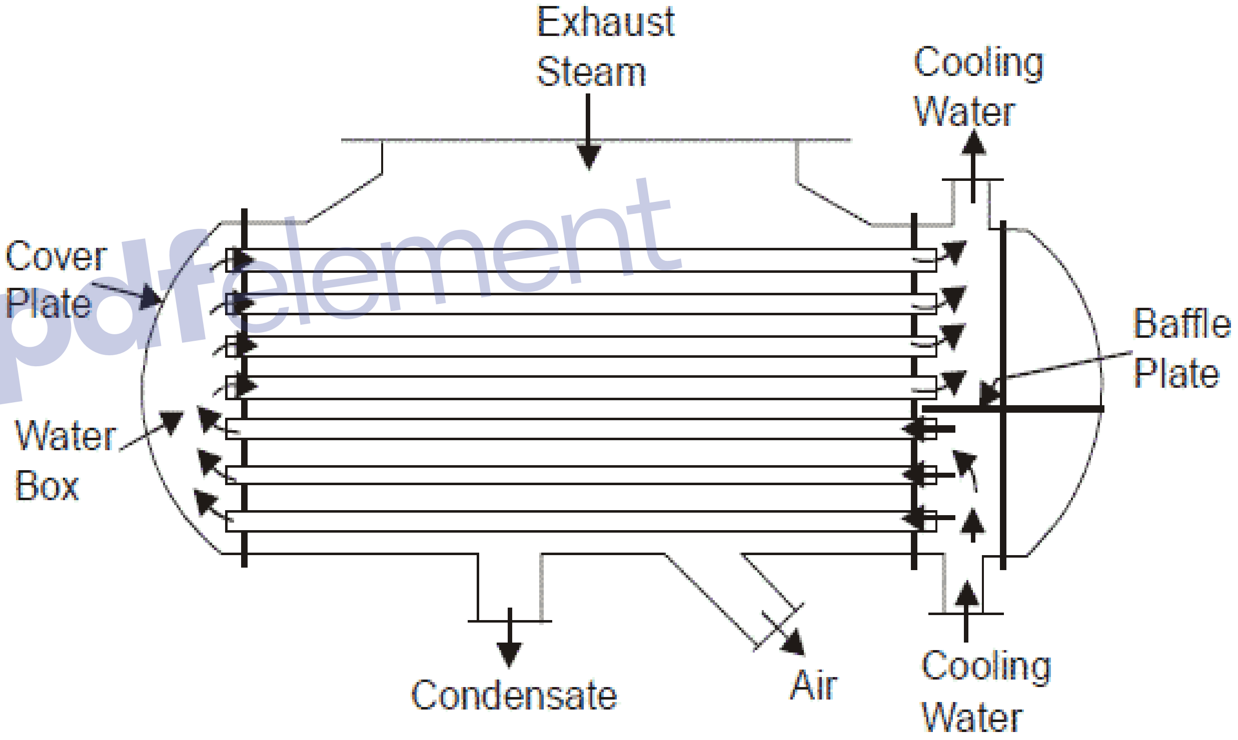
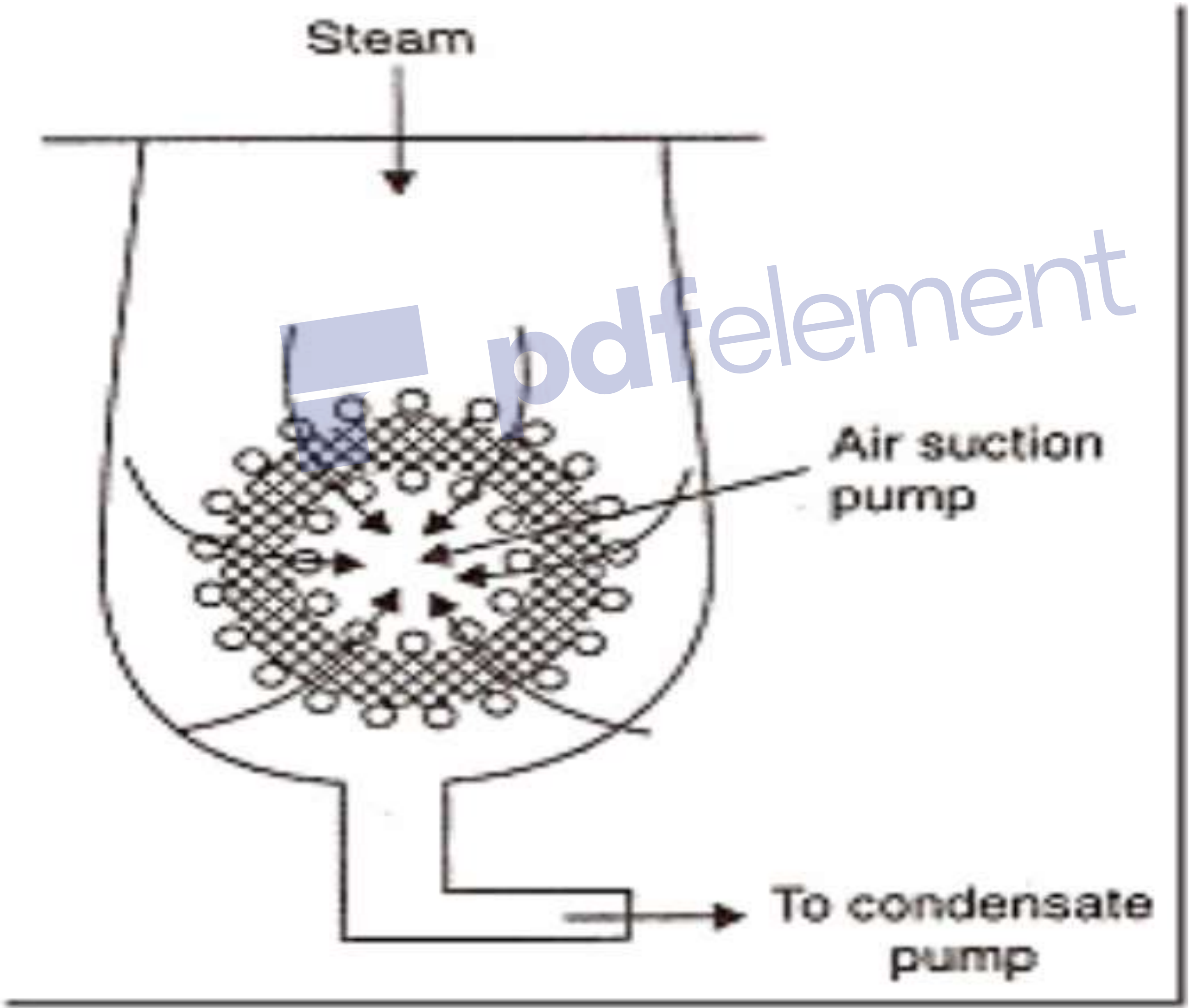
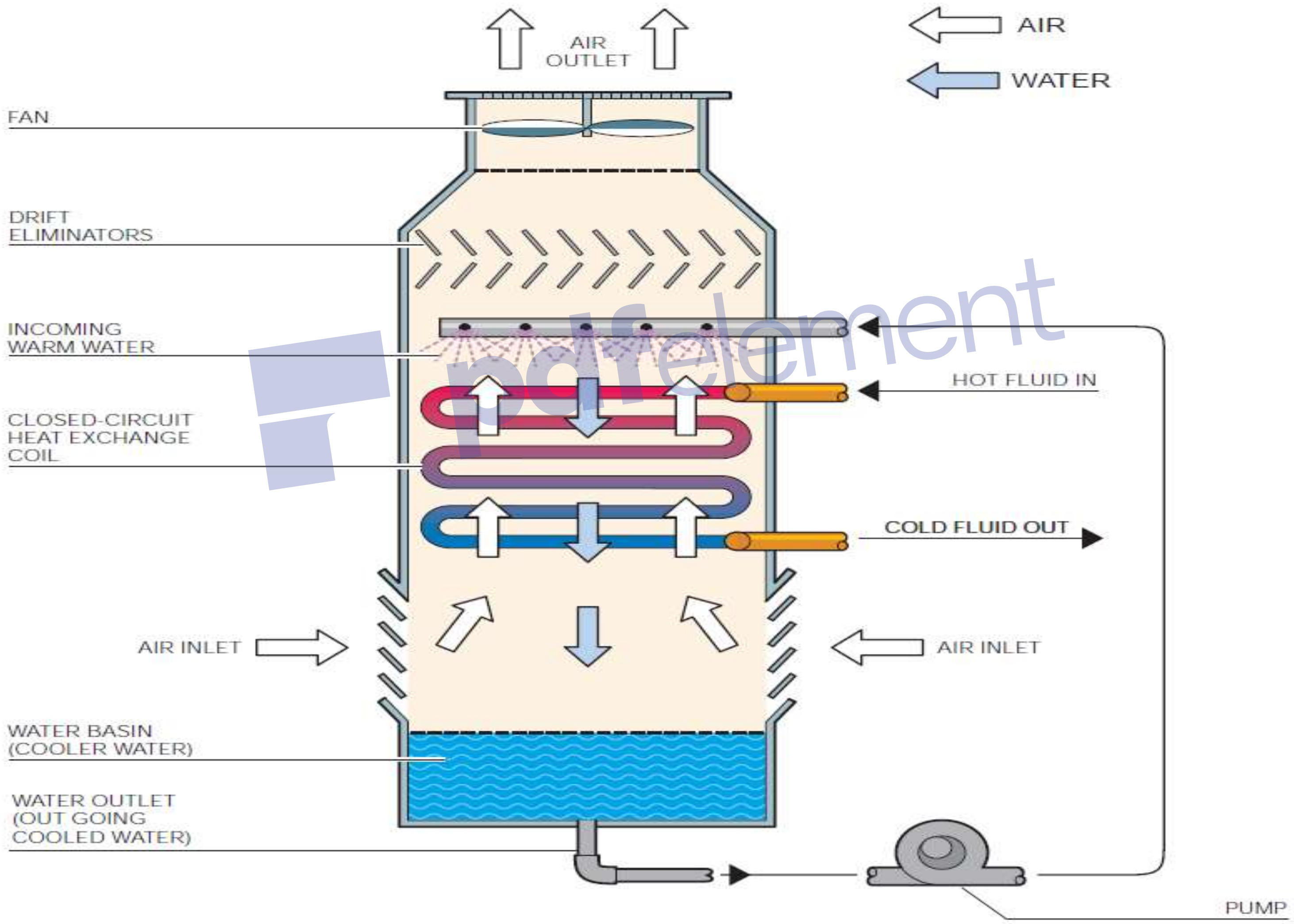


Fig. 2

Central flow surface condenser



Evaporative condenser



EVAPORATIVE CONDENSER

Advantages

- It is simple in design and cheap in first cost.
- It does not require large quantity of cooling water, so needs a small capacity cooling water pump.
- Its operating cost is less.

Jet condenser	Surface condenser
Cooling water and steam come in direct contact.	Cooling water and steam do not come in direct contact.
More suitable for low capacity plants.	More suitable for high capacity plants.
Vacuum created is upto 600 mm of Hg.	Vacuum crated is upto 760 mm of Hg.

Sources of air leakage in condenser

- The air leaks through the joints and packing and into condenser where the pressure is below the atmospheric pressure.

- The boiler feed water contains dissolved air. From the boiler it is carried off by steam and to the turbine and finally to the condenser.

- Normally the quantity of air leakage in surface condenser is 0.05% of steam condensed.

Effect of air leakage

- It is increases the back pressure on the turbine with the effect that there is less enthalpy drop and **low thermal efficiency of plant.**

- It reduces the rate of condensation of steam, because air having poor thermal conductivity **reduces the overall heat transfer from steam air mixture.**

- The presence of air in the condenser **increases the corrosive action.**

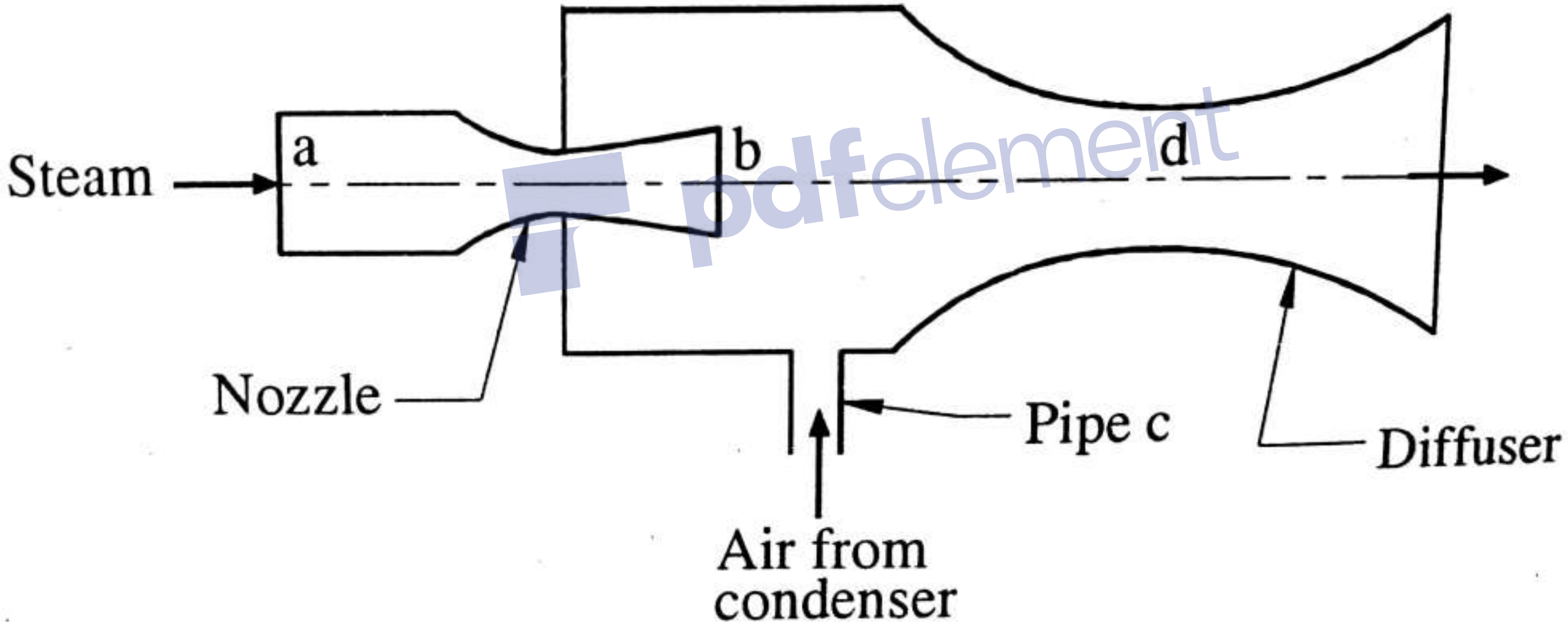
Methods of obtain maximum vacuum in condenser

1. **Air pump:**

it is used to extract air and other non-condensable gases from condenser.

- **Wet air pump**: it removes mixture of condensate and air with other non-condensable gases.
- **Dry air pump:** it removes the air and other non-condensable gases only.

- 2. Steam jet air ejector: to remove air from condenser.



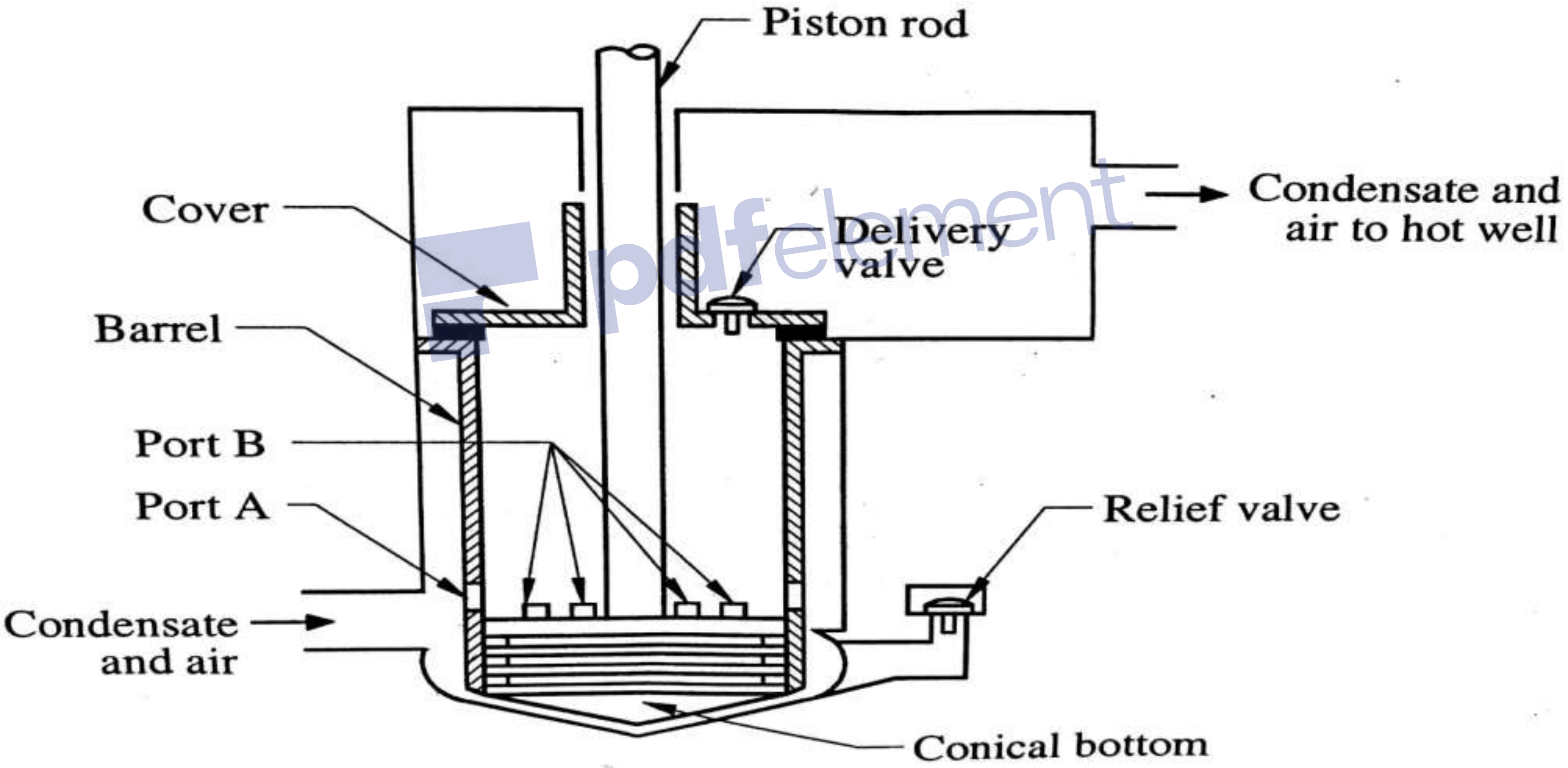
- **De-aerated feed water:**

it is process of removal of non condensable gases from water. It helps both in maintain better vacuum in condenser and controlling corrosion of steel shell and piping of power plant.

- **Air tight joints:**

the air leaks through the joints, packing and glands into the condenser. This can be reduced by proper workmanship while the joints and maintained as such by proper inspection from time to time.

Edward air pump



Dalton’s law of partial pressure

- It states “the pressure of the mixture of air and steam is equal to the sum of the pressure which each constituent would expert, if it occupied the same space by itself”

- $P_c = P_a + P_s$
- Where, P_c= pressure in condenser.

  P_a= partial pressure of air,

  P_s= partial pressure of steam.

Vacuum and condenser efficiency

- **Vacuum efficiency:** It is the ratio of the actual vacuum at the steam inlet to the maximum obtainable vacuum in a perfect condensing plant, i.e., it is the ratio of actual vacuum to ideal vacuum.

- If, Ps= saturation pressure of steam corrosponding to the steam temperature entering into condenser.

  Pc= total pressure of air and steam in the condenser (Pa+Ps).

  Pb= atm. Or barometric pressure.

- Ideal vacuum possible without air leakage = (Pb-Ps)
- Actual vacuum existing in condenser due to air leakage= Pb-Pc

  = pb – (Pa+Ps)

- Vacuum efficiency, **η_v= Pb- (Pa+Ps)/Pb-Ps**

= Pb-Pc/Pb-Ps

- The leakge of air and insufficient quality of cooling water decreases the vacuum efficirncy of the condenser.

Condenser efficiency

- It is ratio actual rise in the temperature of cooling water to the maximum possible rise in temperature of cooling water.

$$\eta_c = \frac{\text{Actual rise in the temperature of cooling water}}{\text{Inlet temperature of steam} - \text{Inlet temperature of cooling water}}$$

$$\therefore \eta_c = \frac{T_o - T_i}{T_s - T_i}$$

where T_o = Outlet temperature of cooling water,

T_i = Inlet temperature of cooling water,

T_s = Saturation temperature of steam corresponding to actual absolute pressure in the condenser.

Mass of cooling water required for condensation of steam

The mass of cooling water required for condenser to condense a given amount of steam is calculated as follows :

Let m_w = Mass of cooling water,

m_s = Mass of steam condensed (i.e. condensate),

h = Total heat of steam entering the condenser,

h_{f_1} = Total heat in condensate,

T_i = Inlet temperature of circulating water, and

T_o = Outlet temperature of circulating water.

We know that heat lost by steam

$$= m_s (h - h_{f_1})$$

Heat gained by cooling water

$$= m_w c_w (T_o - T_i)$$

From energy balance, heat gained by cooling water = Heat lost by steam

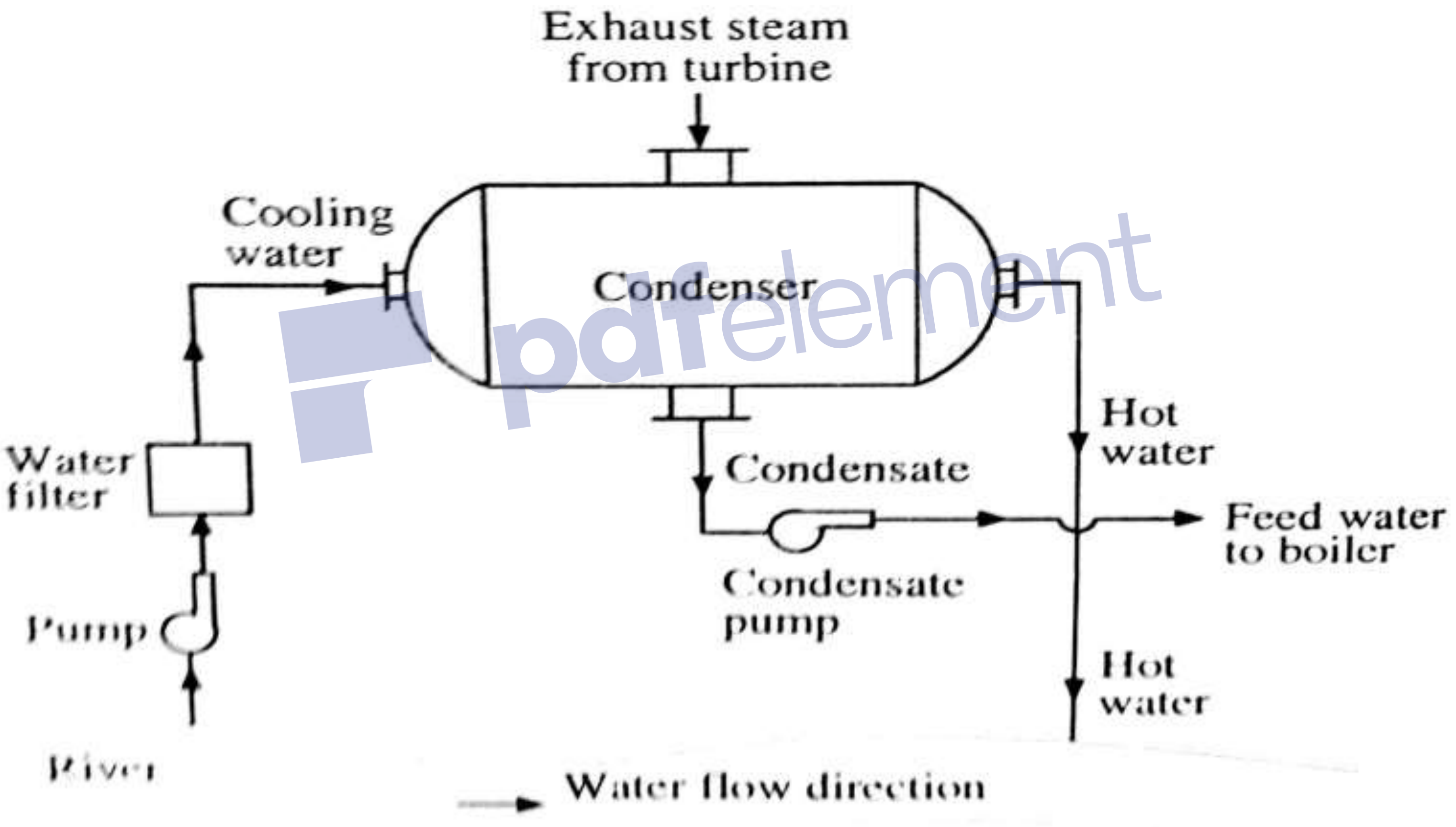
$$\therefore m_w c_w (T_o - T_i) = m_s (h - h_{f_1})$$

$$\therefore m_w = \frac{m_s (h - h_{f_1})}{c_w (T_o - T_i)}$$

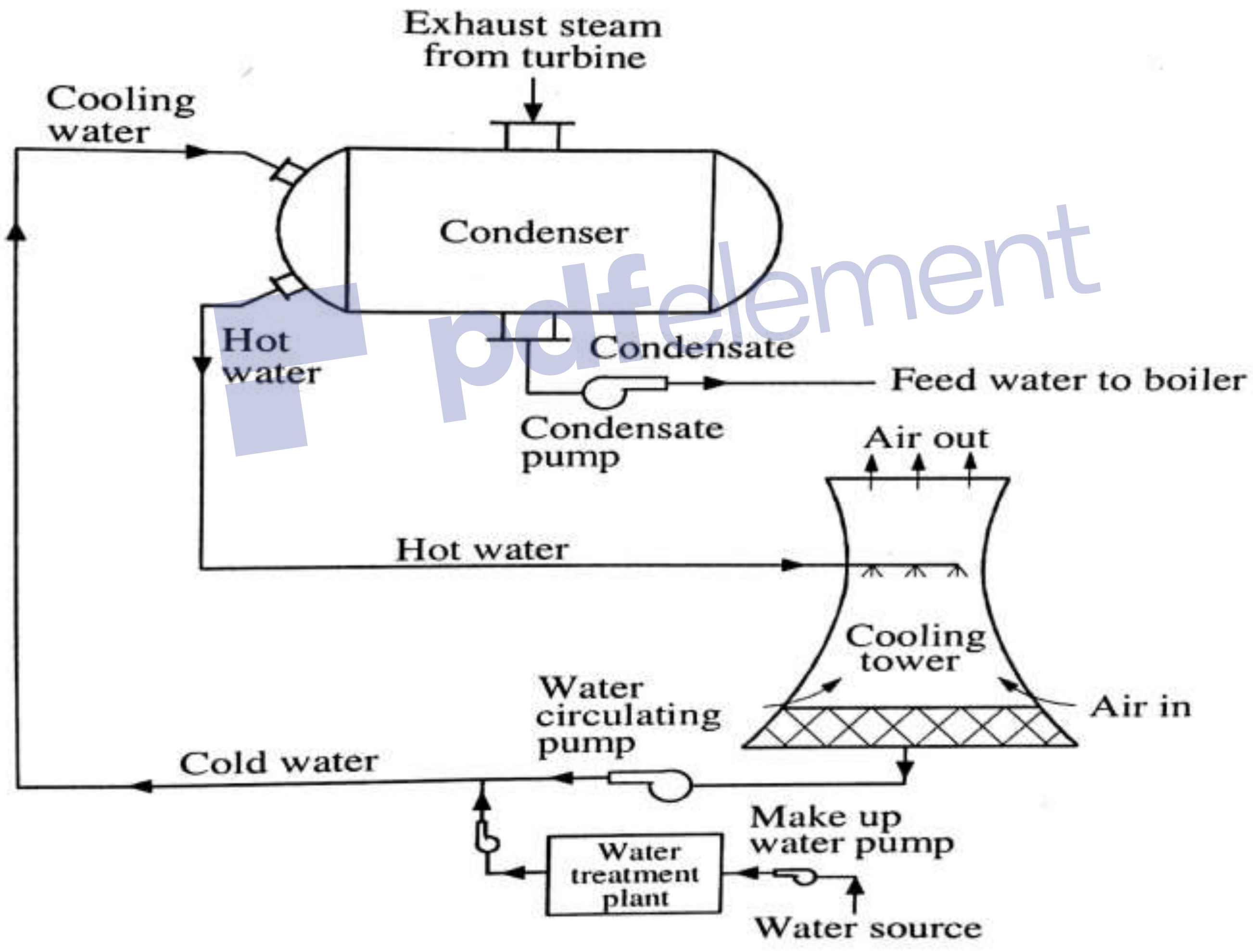
Condenser water cooling systems

1. Open or once through system
2. Closed cooling system
3. Mixed cooling system

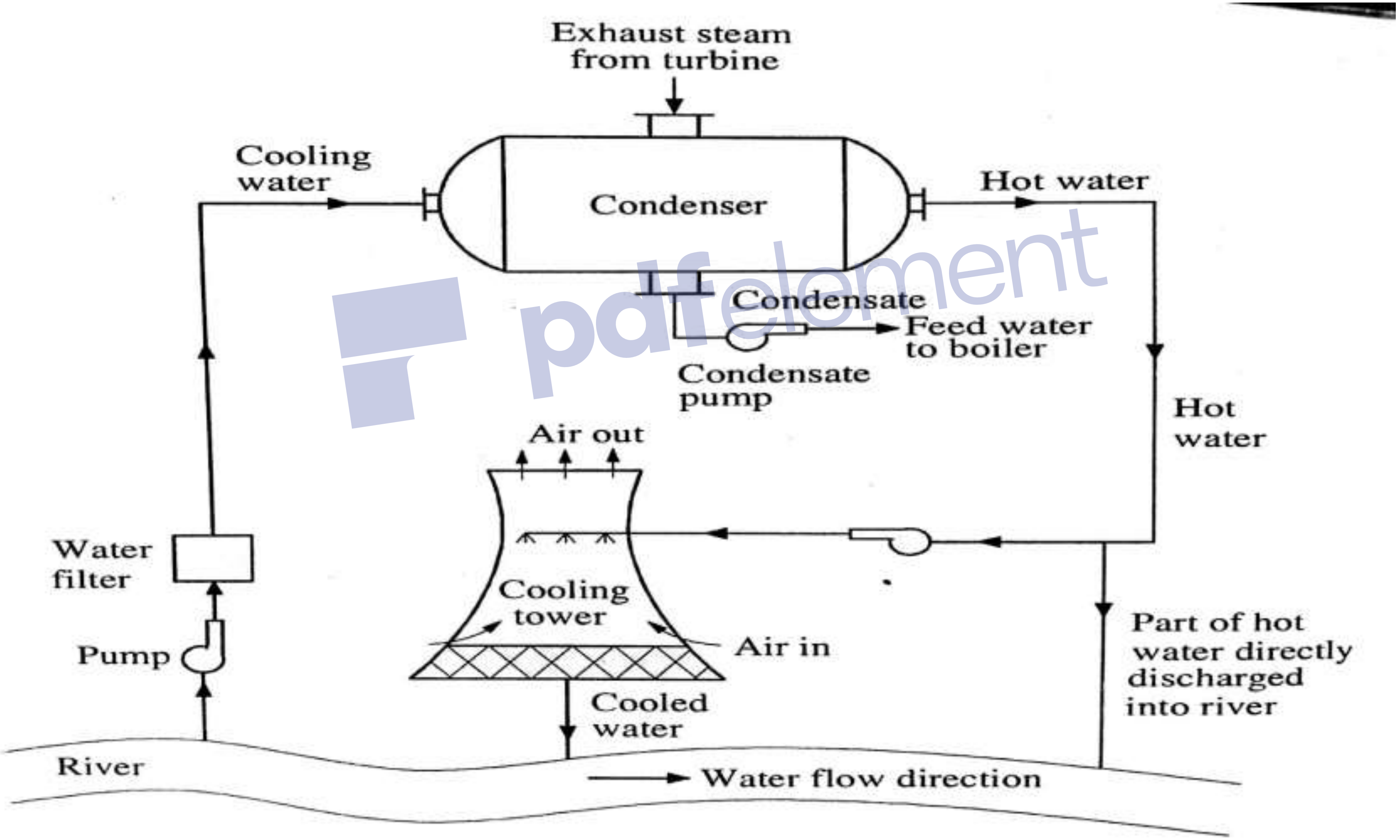
Open or once through system



Closed cooling system



Mixed cooling system



Cooling Tower

Types of cooling tower

1. Natural draught-cooling towers

2. Mechanical cooling towers

    1. Forced draught cooling towers

    2. Induced draught cooling towers

Natural draught-cooling towers

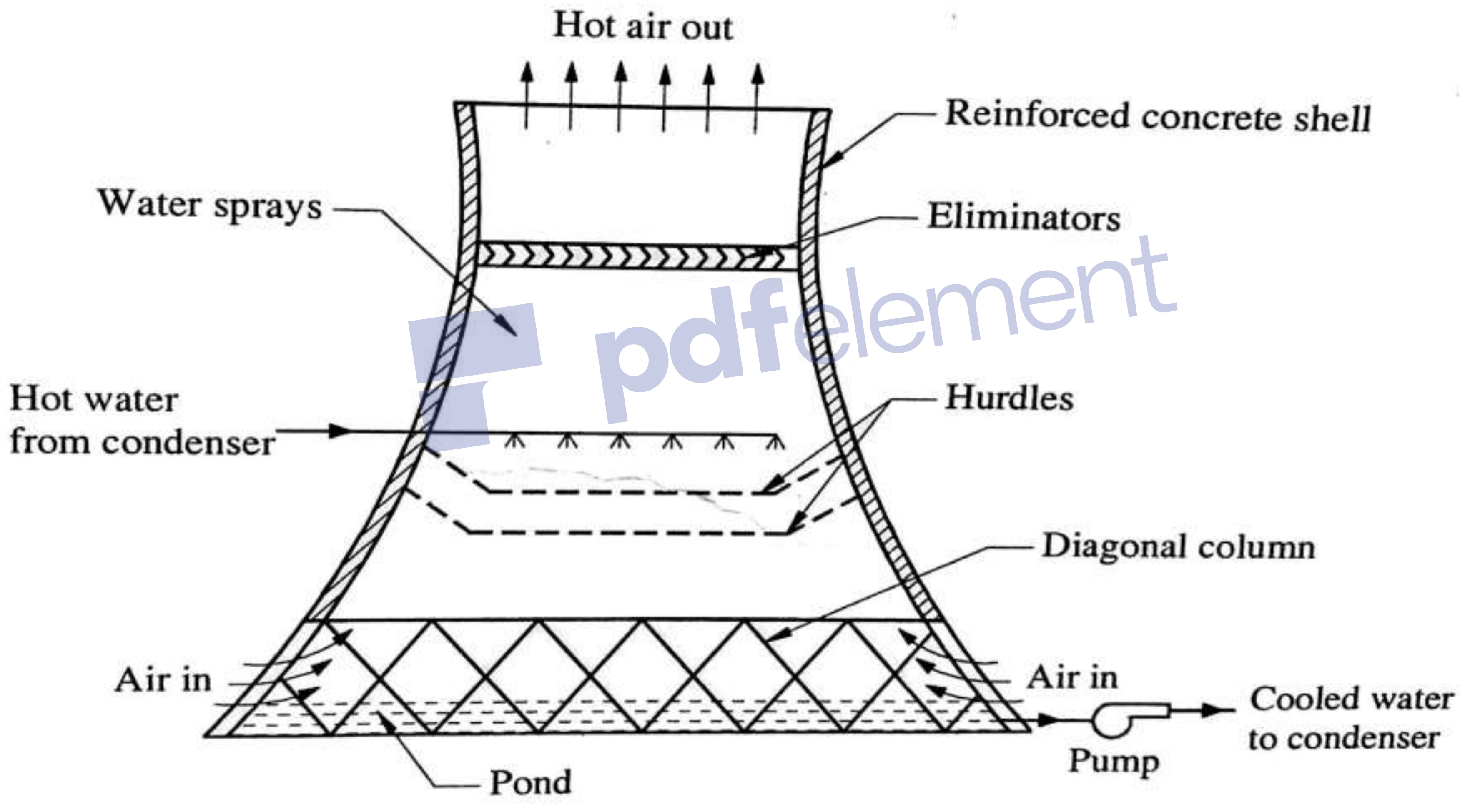
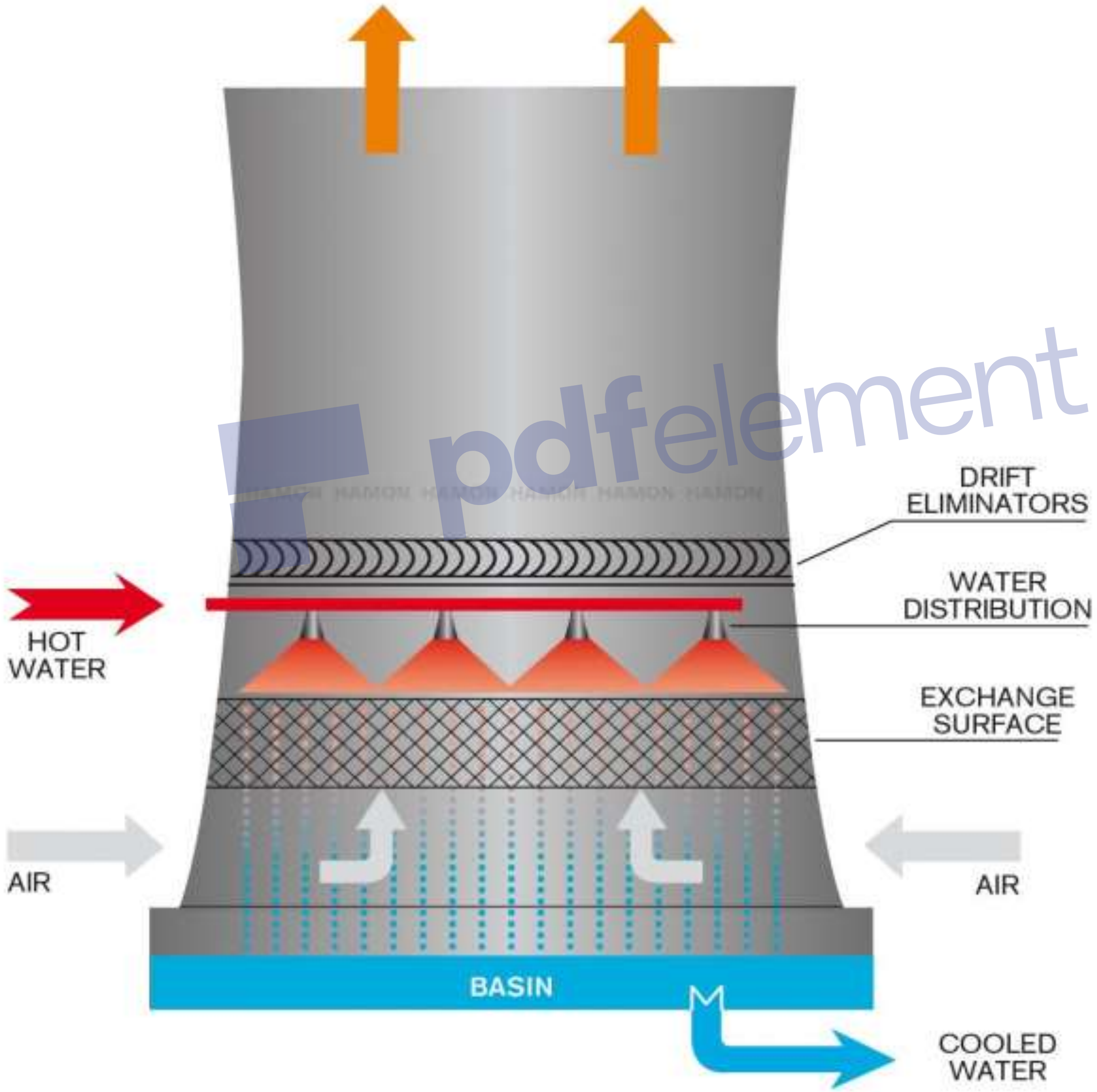


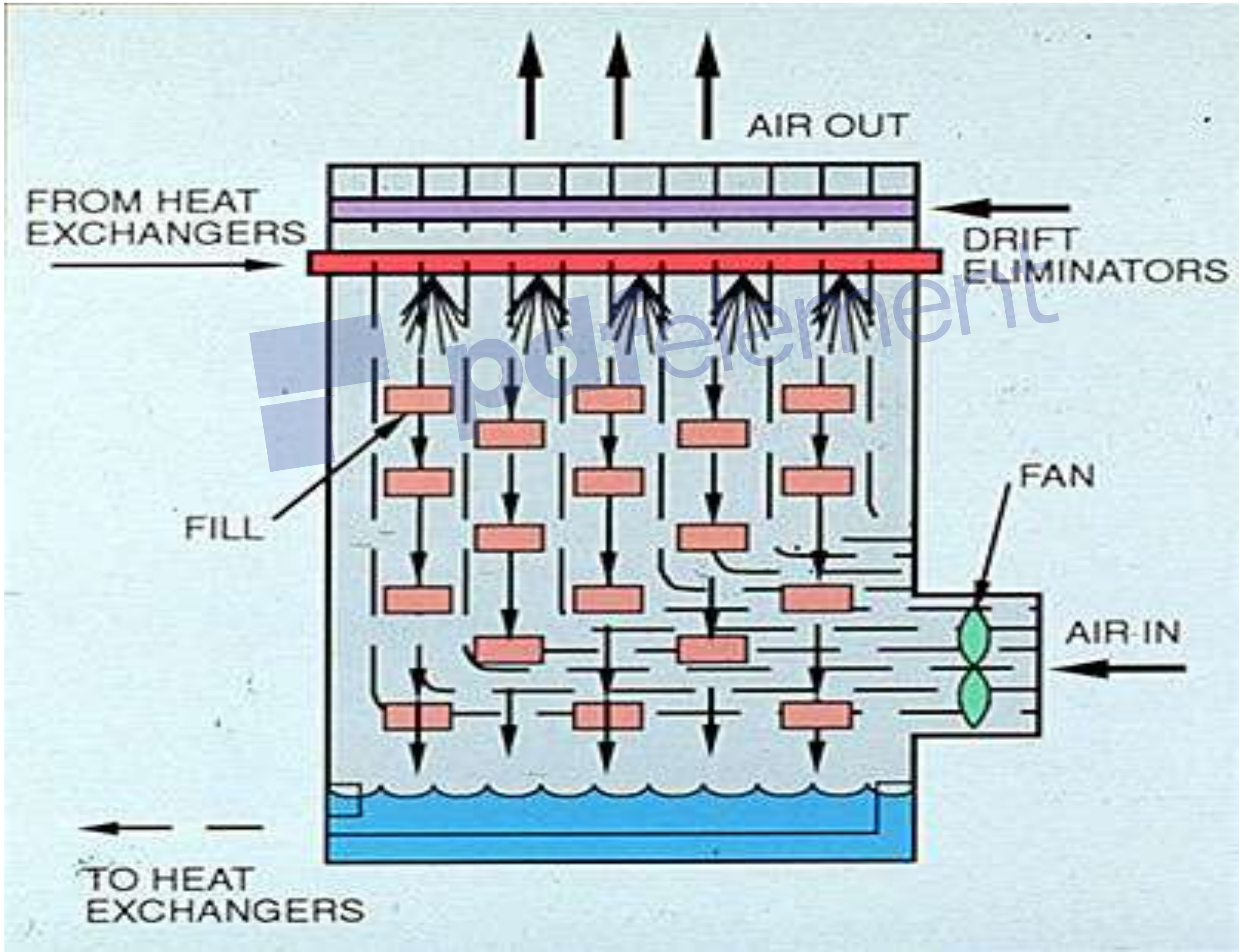
Fig. 5.17 Hyperbolic cooling tower

Natural draught-cooling towers

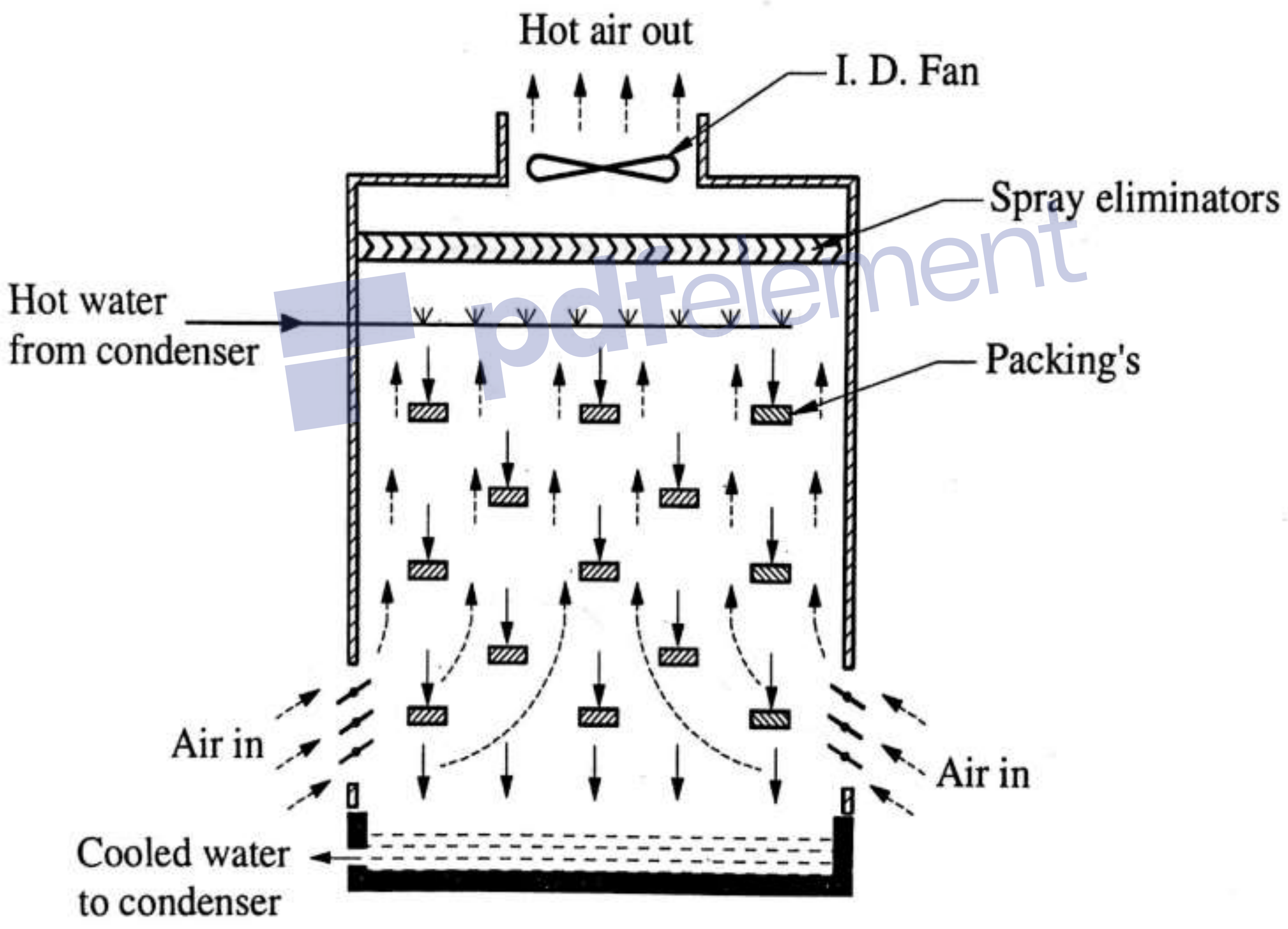


Natural draught-cooling towers

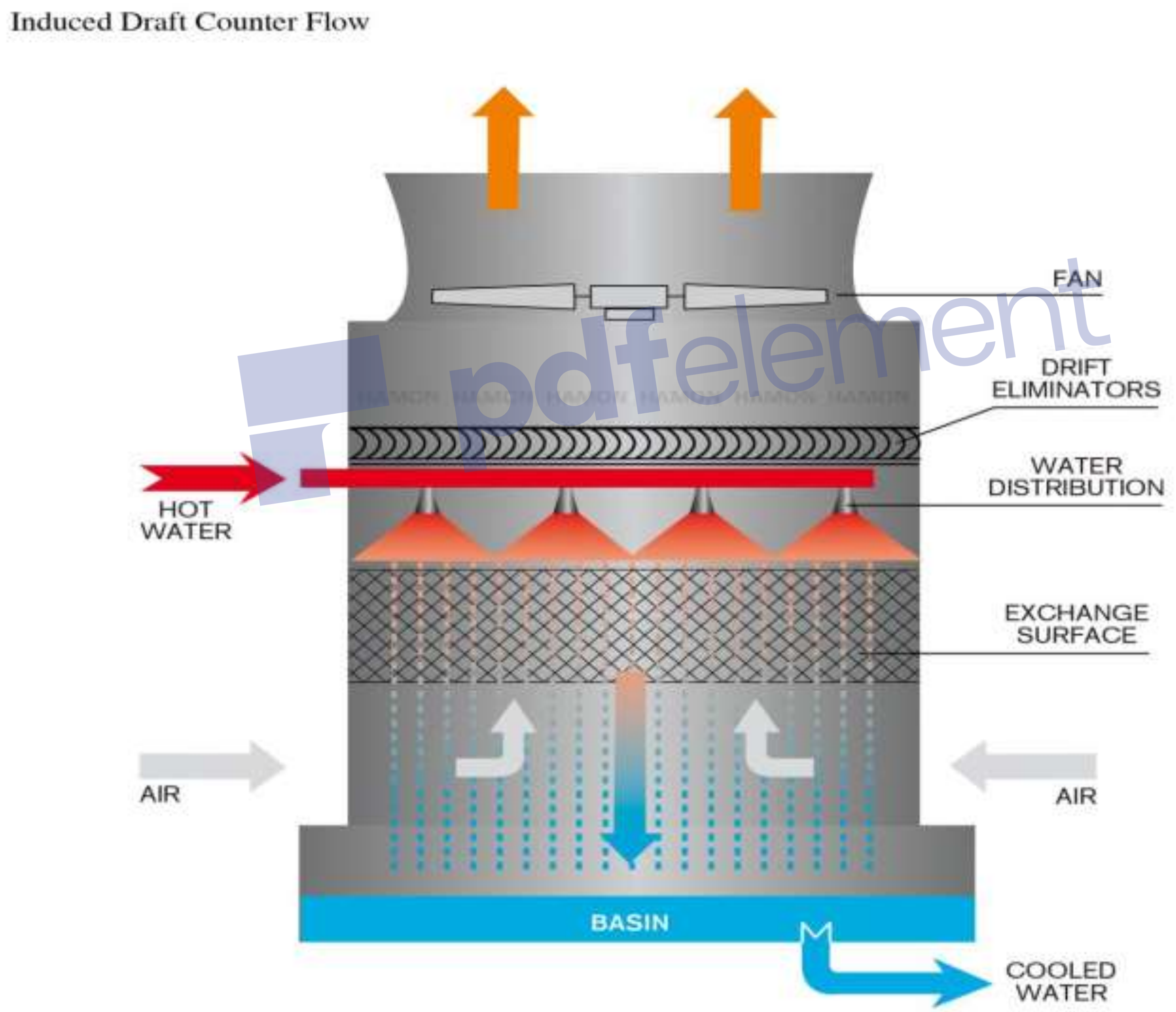
Forced draught cooling tower



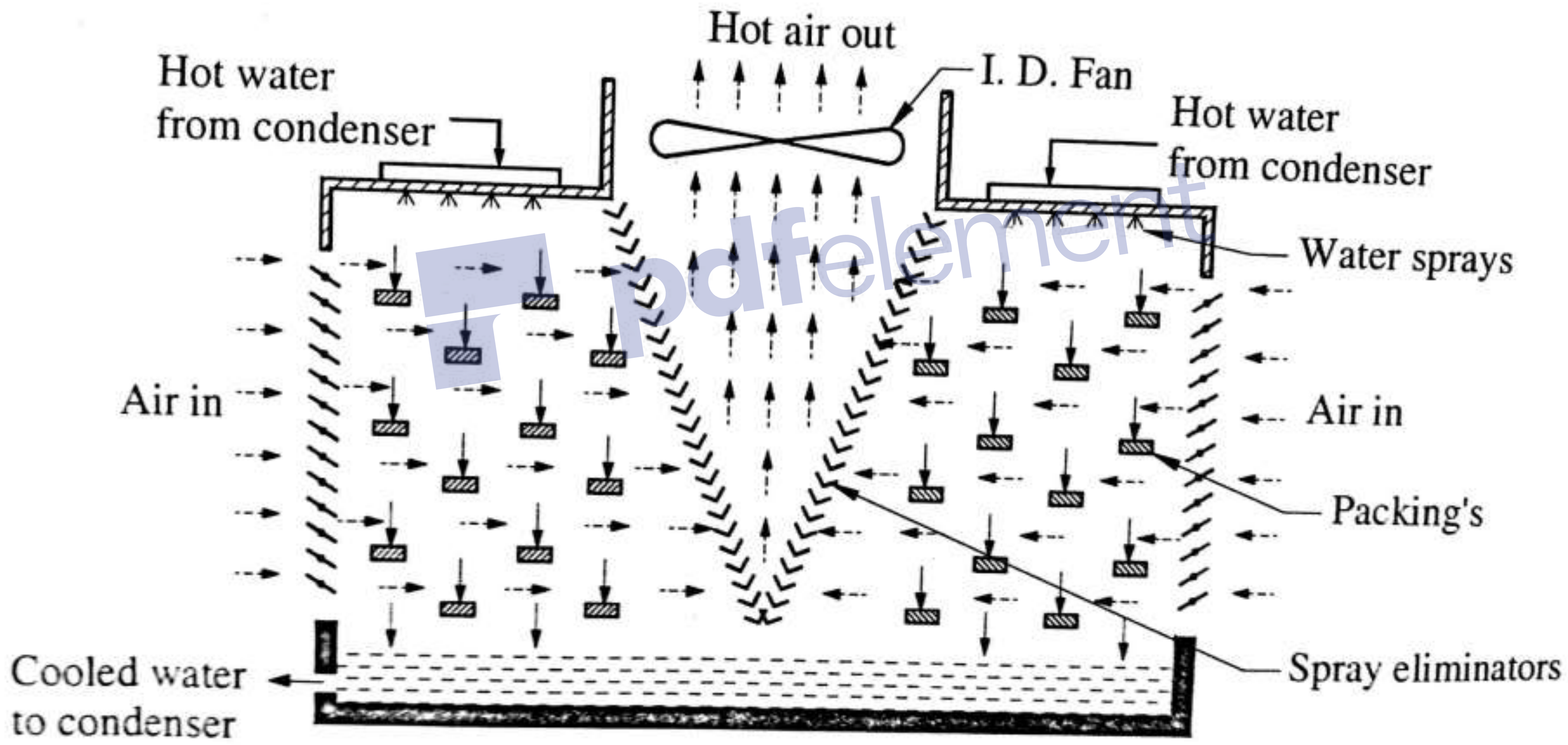
Induced draught (counter flow) cooling tower



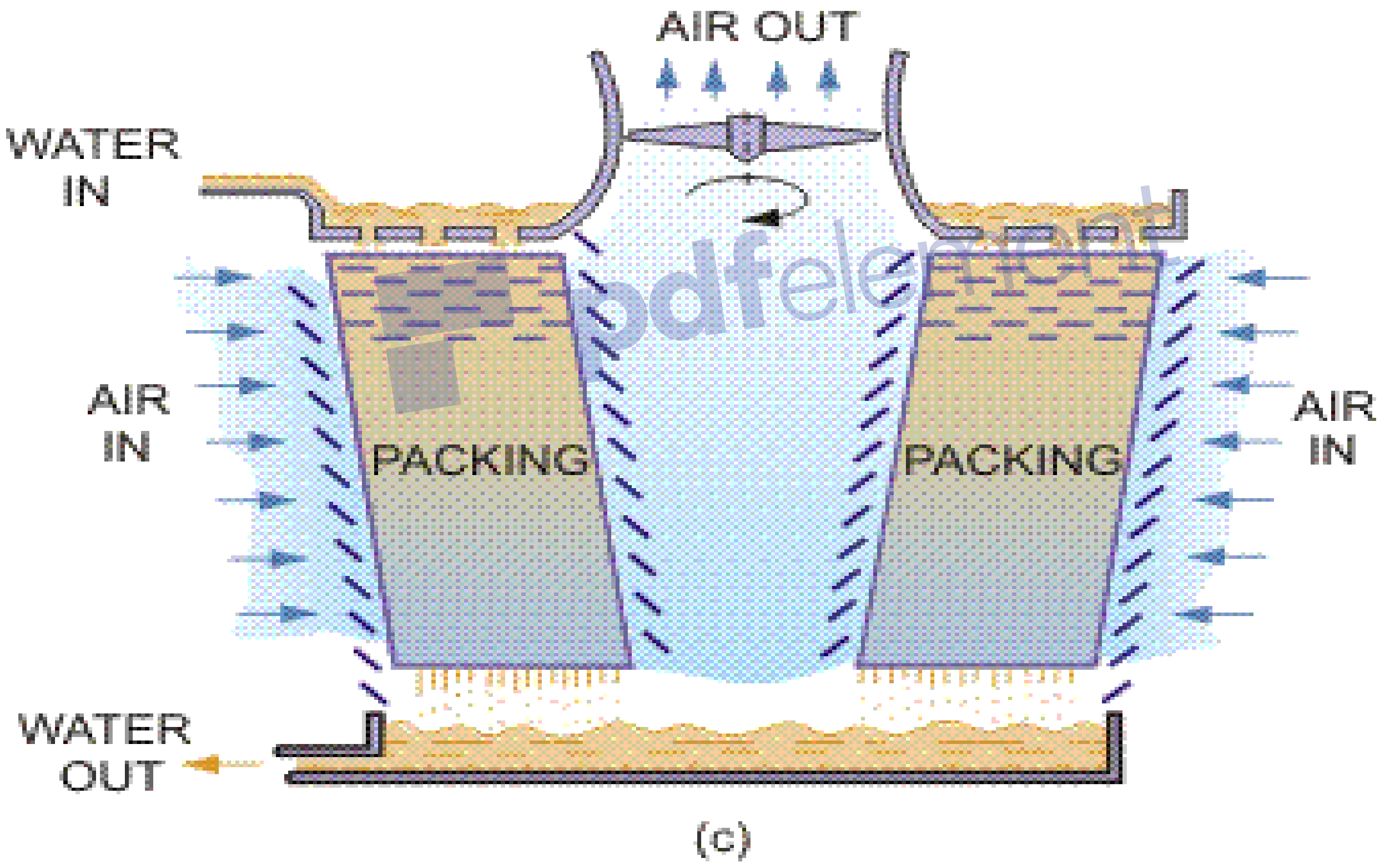
Induced draught (counter flow) cooling tower



Induced draught (cross-flow) cooling tower



Induced draught (cross-flow) cooling tower



Principle	Natural draught cooling tower	Forced draught cooling tower
Size and shape	It may be 125 m high and 100 m in diameter and has hyperbolic shape.	It may be 15 m high and thousands of meters in length and has long rectangle box shape.
Initial cost	high	Half of natural tower draught cooling tower.
Operating cost	less	High
Maintenance cost	low	High
Water loss	less	More
life	more	Less

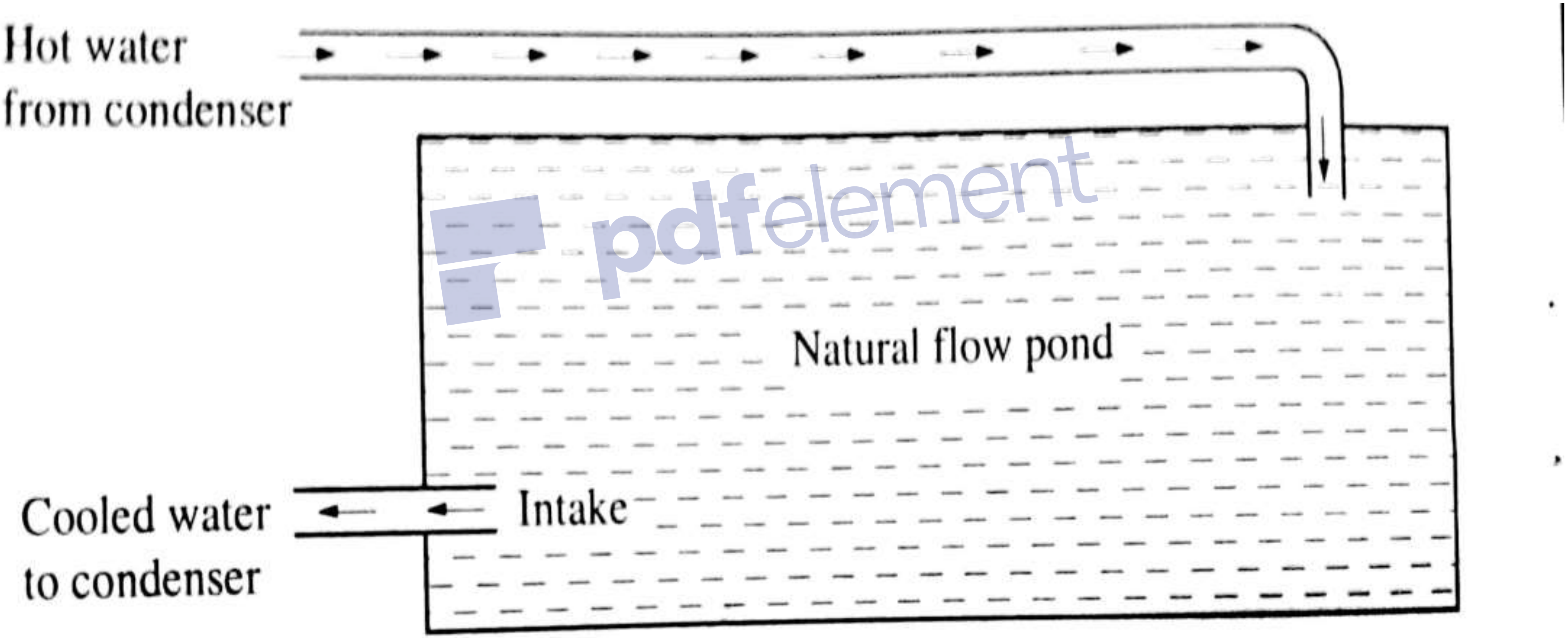
Cooling ponds

- The cooling pond is one of the simple method of cooling the condenser water.

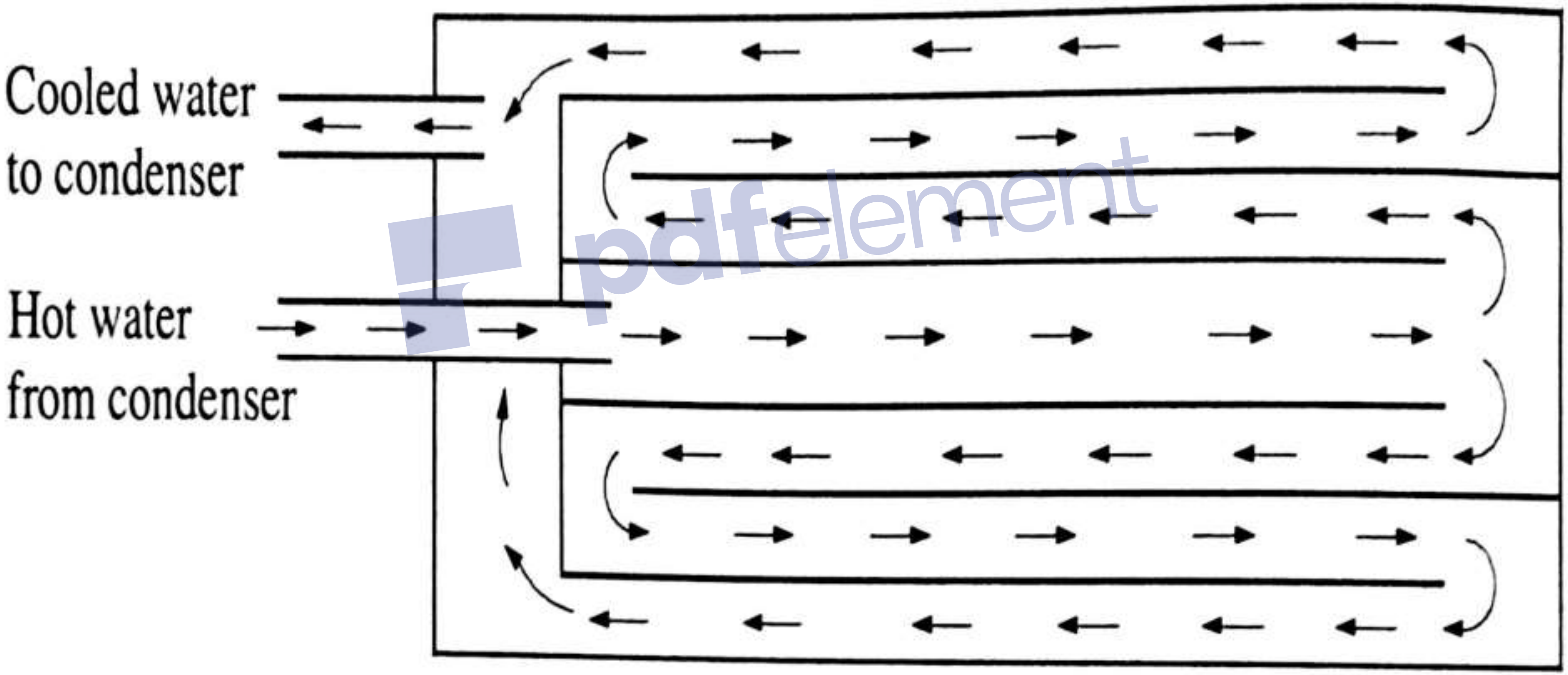
- This method is less efficient than cooling water.

1. Natural and directed flow cooling pond.
2. Single deck and double deck cooling pond.
3. Open and louver fence cooling pong.

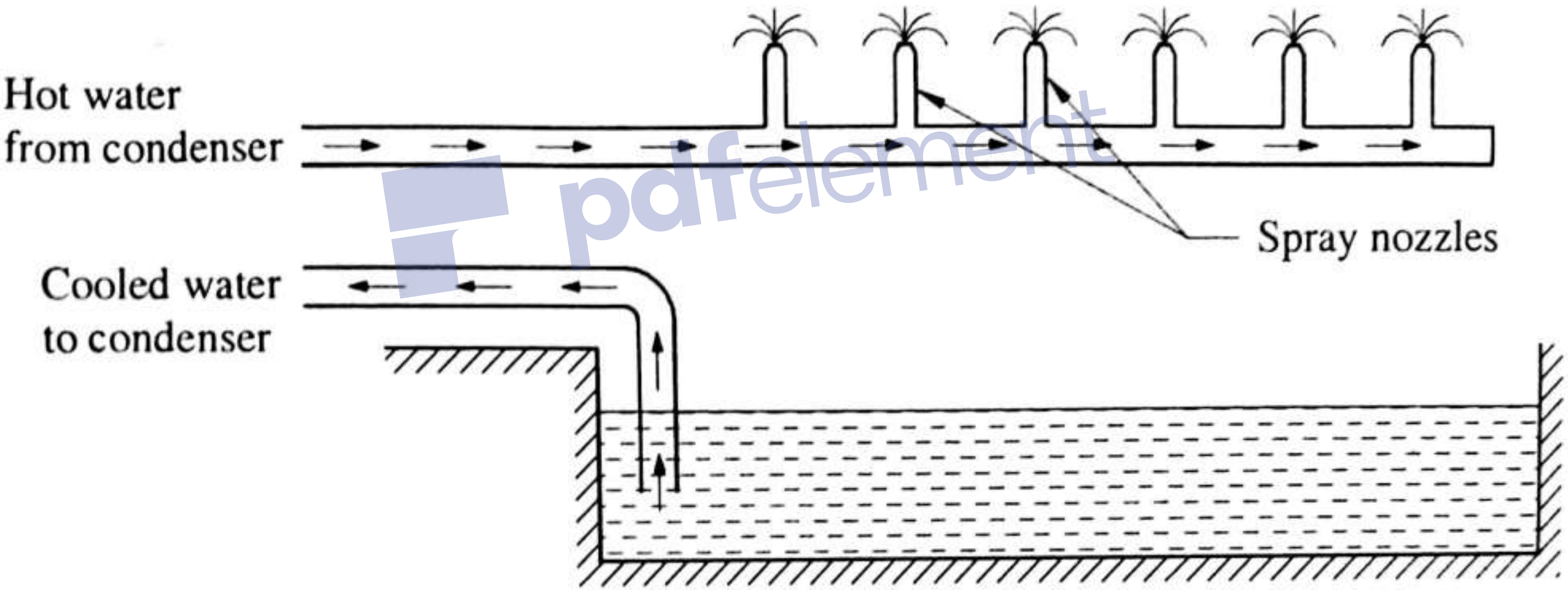
Natural flow cooling pond



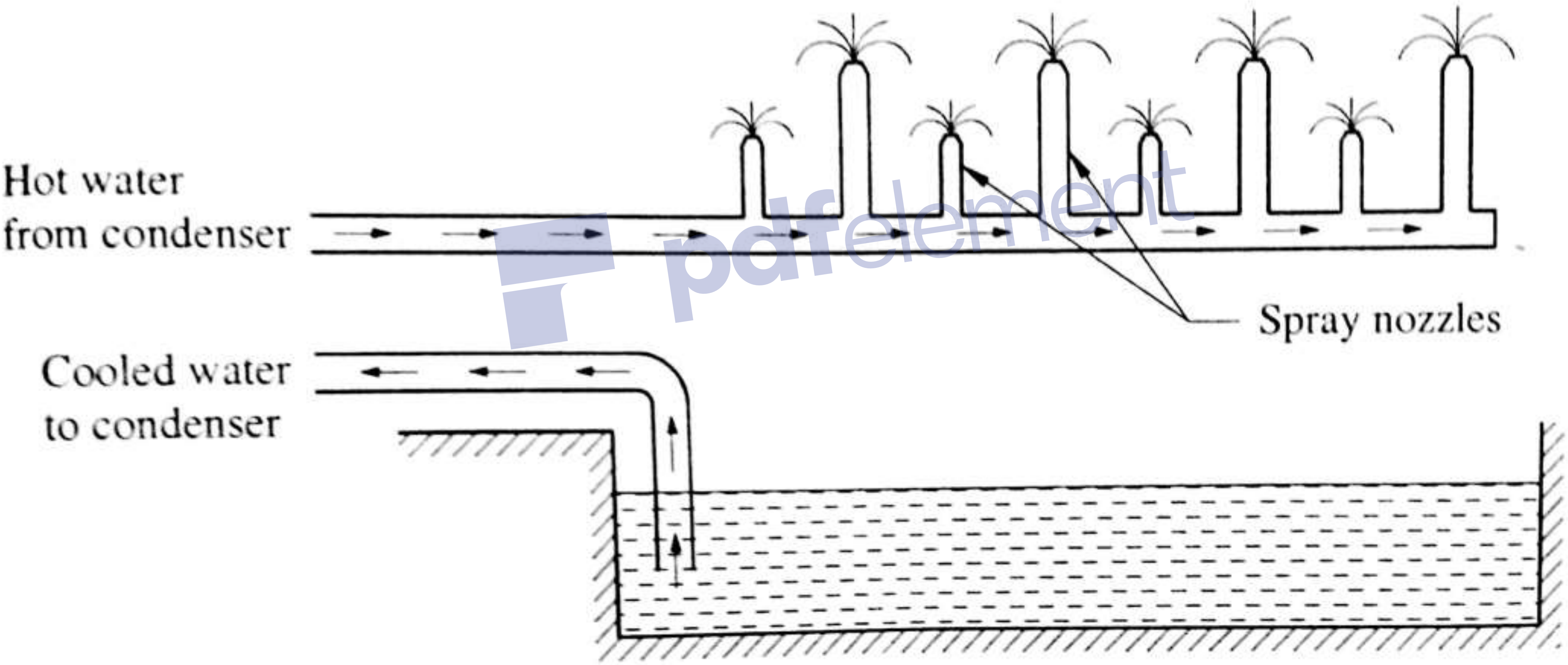
Directed flow cooling pond



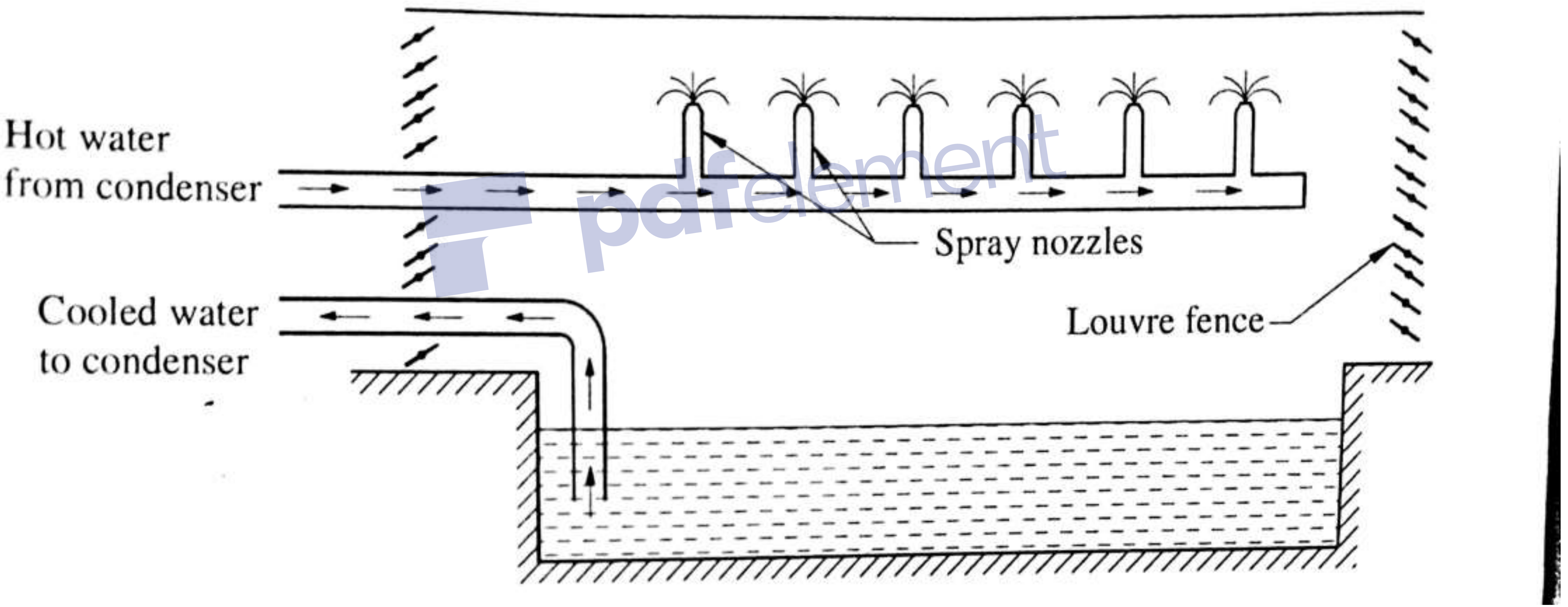
Single deck spray pond



Double deck spray pond



Spray pond with louver fence



Advantages of cooling ponds

- Its initial cost is less

- Simple in design and arrangement.

Disadvantages

- It requires large area for cooling
- More amount of loss of water due to evaporation.
- Low cooling efficiency.
- There is no control over the temperature of cooled water.

The End