

UNI-T-4

~~Steam~~ Steam Condensers

Introduction :-

A Steam Condenser is a closed vessel into which the steam is exhausted, and condensed and doing work in an engine cylinder or turbine.

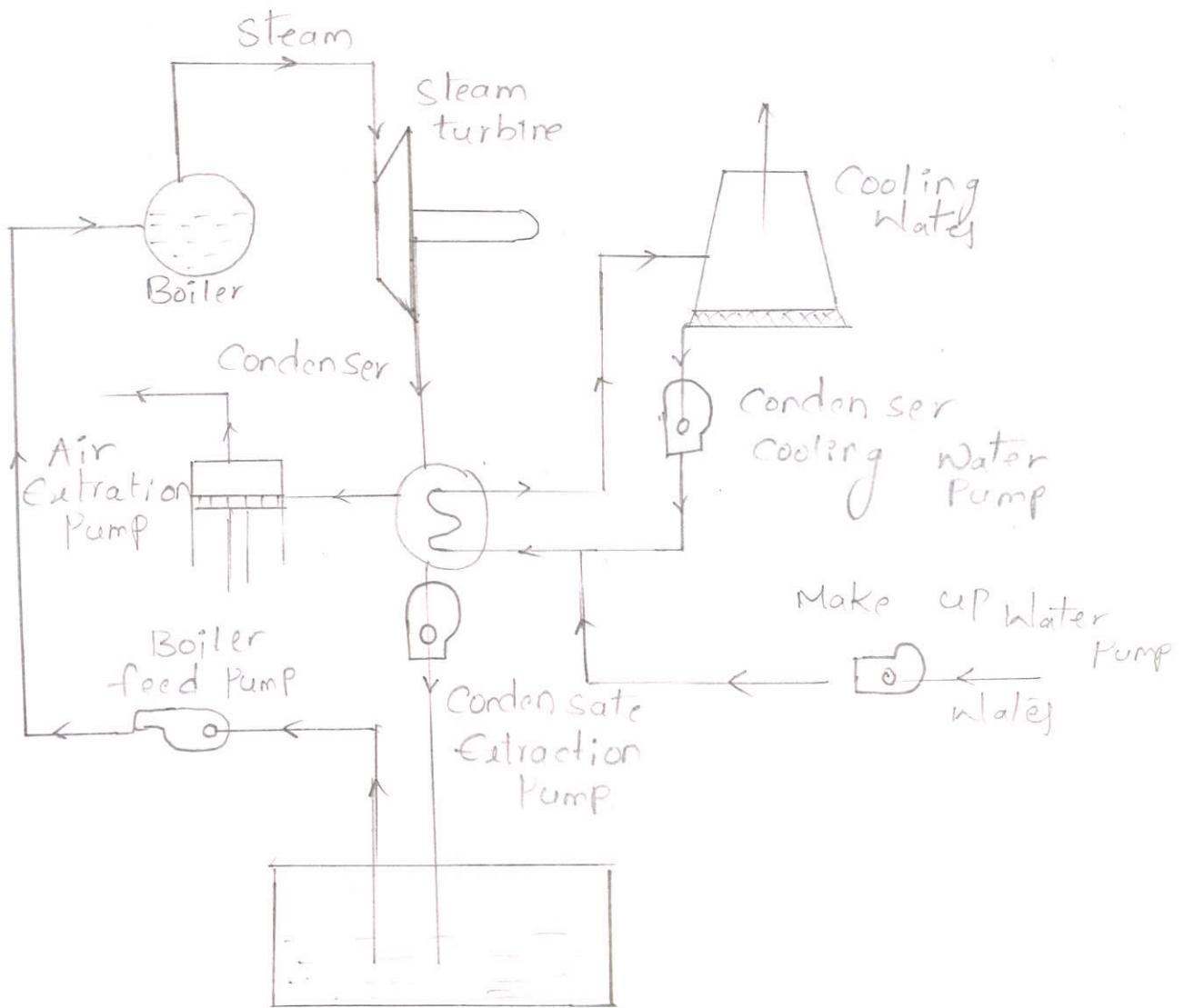
A steam condenser has the following two objects.

1. The primary object to maintain a low pressure so as to obtain the maximum possible energy from steam and thus to secure a high efficiency.

2. To secondary object to supply pure feed water to the hot well, from where it is pumped back to the boiler.

Requirements of a Steam Condensing Plant:-

The principle requirements of a condensing plant.



1. Condenser:

It is a closed vessel in which steam is considered. The steam gives up heat energy to coolant during the process of condensation.

2. Condensate Pump:

It is a pump which removes condensate from the condenser to the hot well.

3. Hot Well:

It is a sump between the condenser and boiler which receives condensate pumped by the condensate pump.

4. Boiler Feed Pump:

It is a pump which pumps the condensate from the hot well to the boiler. This is done by increasing the pressure of condensate above the boiler pressure.

5. Air Extraction Pump:

It is a pump which extracts air from the condenser.

6. Cooling Tower:

It is a tower used for cooling the water which is discharged from the condenser.

7. Cooling Water Pump:

It is a pump which circulates the cooling water through the condenser.

Classification of Condensers:

The steam condensers may be broadly classified into following two types depending upon the way in which the steam is condensed

1. Jet Condensers or mixing type condensers
2. Surface Condensers or non-mixing type condensers.

Jet Condensers:

These days, the jet condensers are seldom used because there is some loss of condensers during the process of condensation and high power requirements for the pump used. Moreover, the condensate can not be.

as feed water to boiler as it not free from Salt.

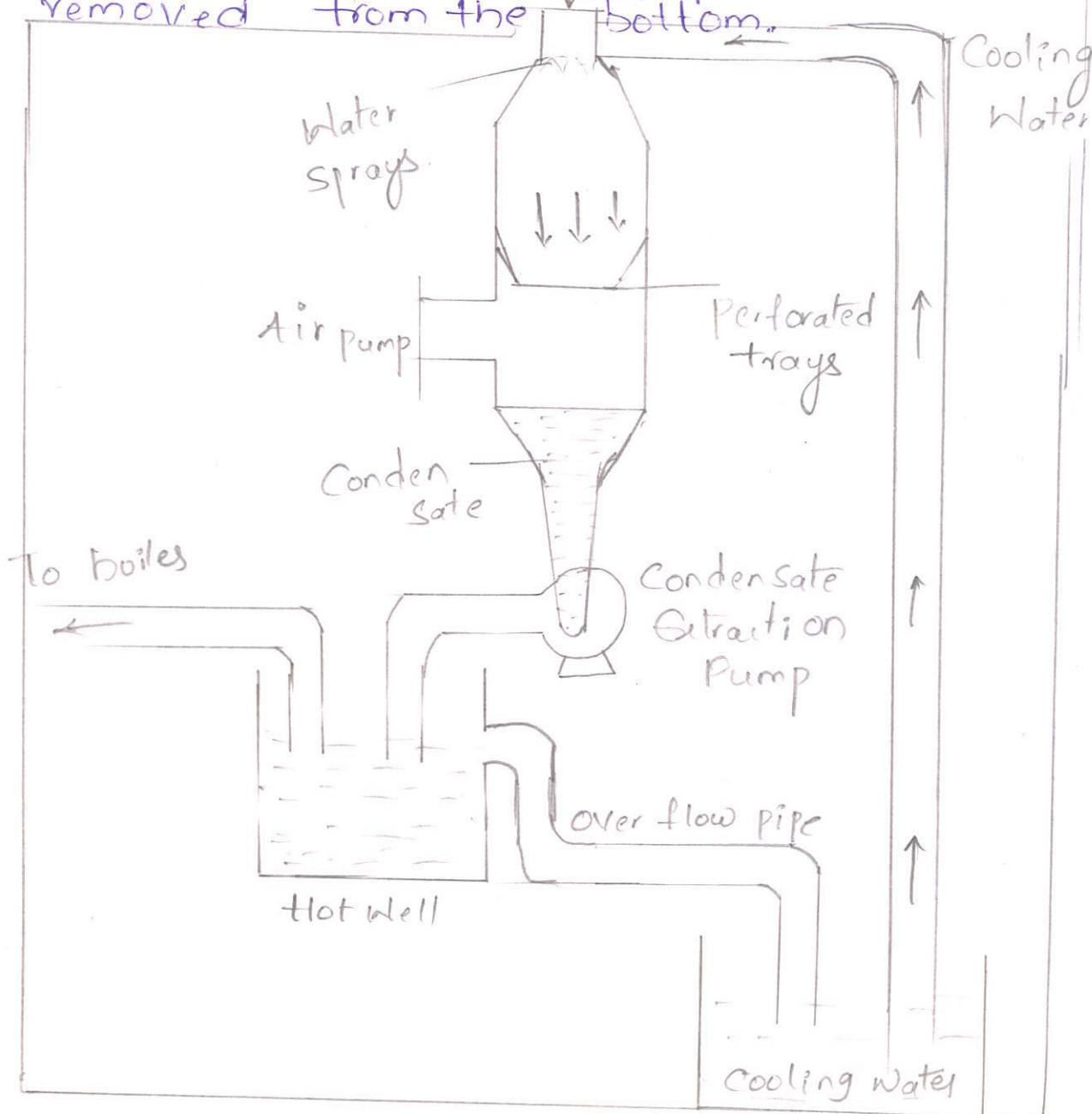
Types of jet Condensers:

The jet Condensers may be further classified on the basis of the direction of flow of the Condensate of the tubing system.

1. Parallel flow jet condenser.
2. Counter flow or low level jet condenser.
3. Barometric (or) high level jet condenser.
4. Ejector condenser.

Parallel flow jet Condenser:

In Parallel flow jet Condensers, both the steam and water enter the top, and the mixture removed from the bottom.

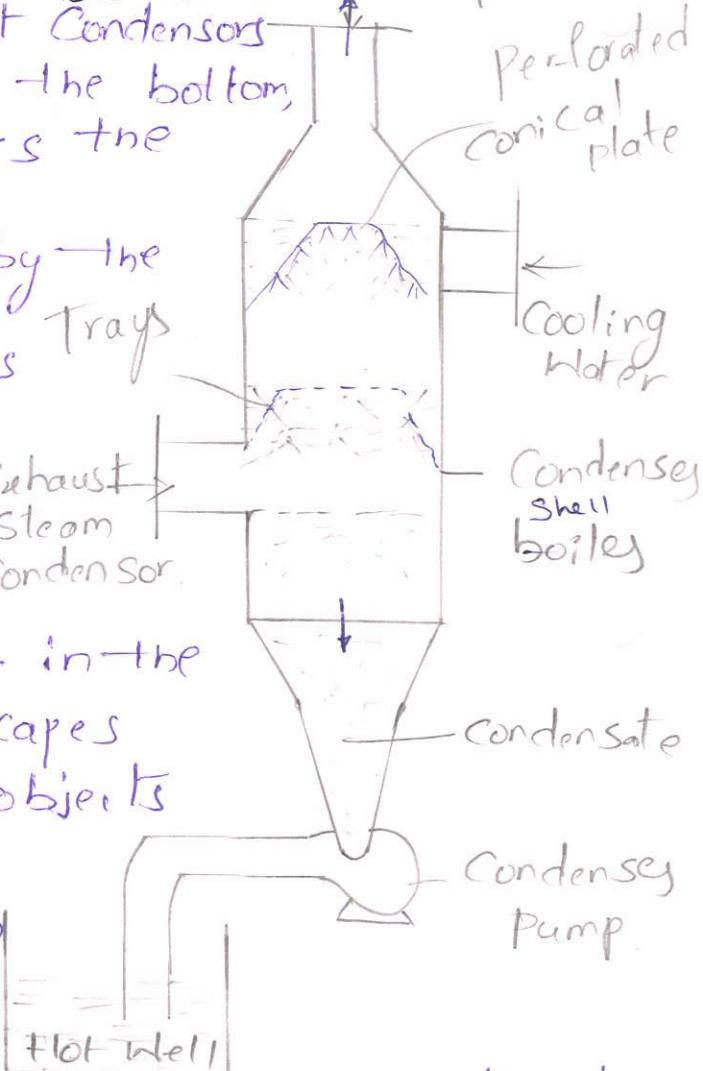


The principle of this condenser, the exhaust steam is consider in condensed when it mixes up with water. The condensate, cooling water and air flow down wards and are removed by two separate tanks (or) pumps known as air pump and condensate pump. Sometimes, a single pump known as inlet air pump is also used to remove both condensers. Pump. Both the former gives a greater vacuum. The condensate pump delivers the condensate to the hot well, from the surplus water flows to the cooling water tank through an overflow pipe.

Counterflow (or) low level jet condensers $\frac{\text{Air pump}}{\text{Perforated conical plate}}$

In Counter or Low level jet condensers the exhaust steam enters at the bottom, flows upwards and meets the down coming water.

The vacuum is created by the air pump placed at the top of the condenser shell. This draws the supply of cooling water, which falls in large number of jets, through the perforated conical plates as steam condenser. The falling water is caught in the trays, from which it escapes in a second series of objects and meets the exhaust steam entering at the bottom. The rapid condensation occurs, and the condensate and cooling water descends through a vertical pipe to the condensate pump which delivers it to the hot well.



Barometric or High Level Jet Condensers:

These Condensers are provided at a high level with a long vertical discharge pipe.

In high Level jet condenser

Exhaust steam enters at

the bottom, flows up

inwards, and meets the

down coming cooling water

in the cooling water in the

same way as that of low

level jet Condensers, the

Vacuum is created by the air pump, placed at the top of the Condenser shell.

The Condensate and cooling

water descends through a

vertical pipe to the hot well

without the aid any pump. The surplus

water from the hot well flows to the

Cooling water tank through an overflow pipe.

Ejector Condenser:

In Ejector Condensers,

the steam and water

mix up while passing

through series of metal

cones. Water enters top

through a number of

guide cones. The exhaust

steam enters the Condenser

through non-return valve cone

arrangement. The steam and

air then passes through the

hollow truncated cones. After

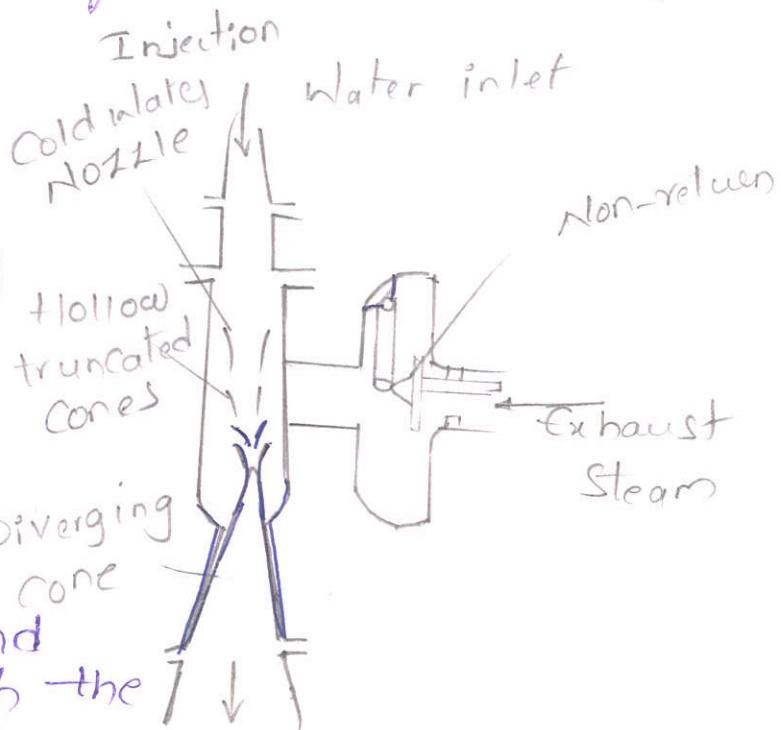
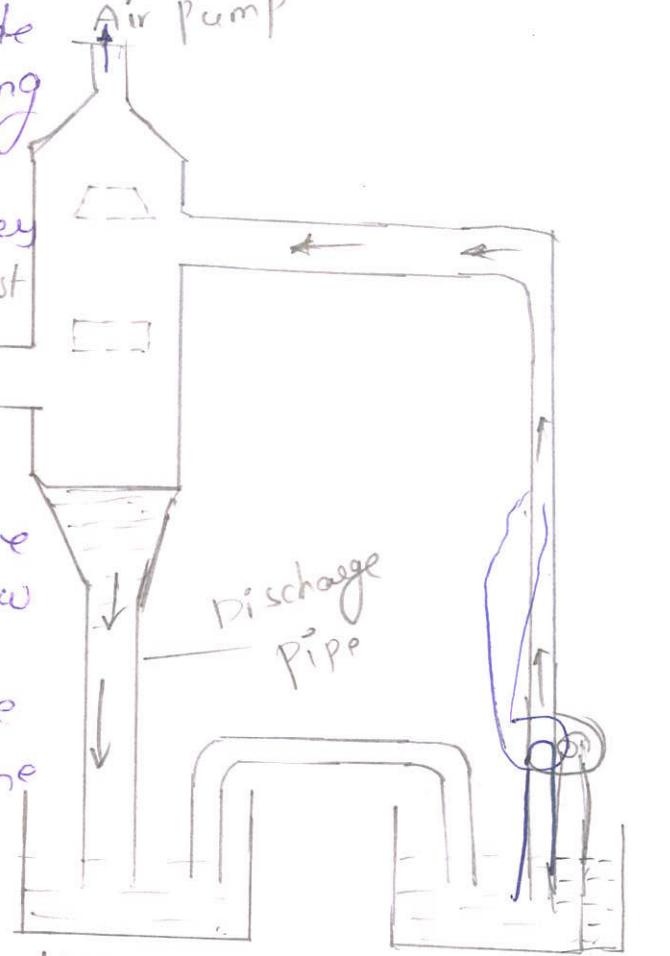
that it is dragged into the

diverging cones where its kinetic energy is partly

transformed to pressure energy. The Condensate

and cooling water is then discharged to the

hot well.

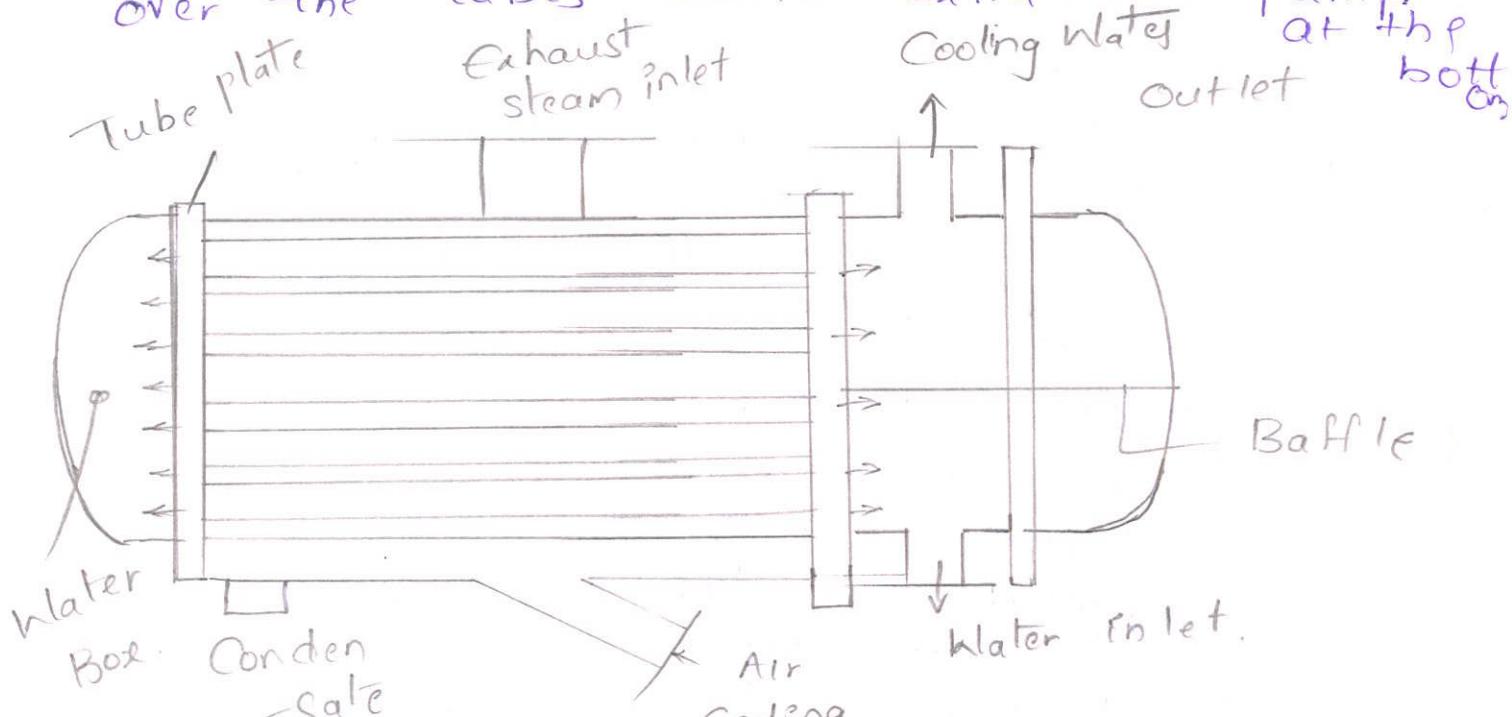


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Surface Condenser:

→ A Surface Condenser has a great advantage over the Jet Condensers, as the Condensate does not mix up the Cooling water. As a result of this, whole Condensate can be reused in the boiler. This type of Condenser is essential in ships which can carry only a limited quantity of fresh water for the boilers. It is also widely used in land installations, where inferior water is available or the better quality of water for feed is to be used economically. It is longitudinal sections.

The water tubes pass horizontally through main condensing space for the steam. The steam enters at the top to flow downward over the tubes suction extraction pump at the bottom.



Types of Surface Condensers:

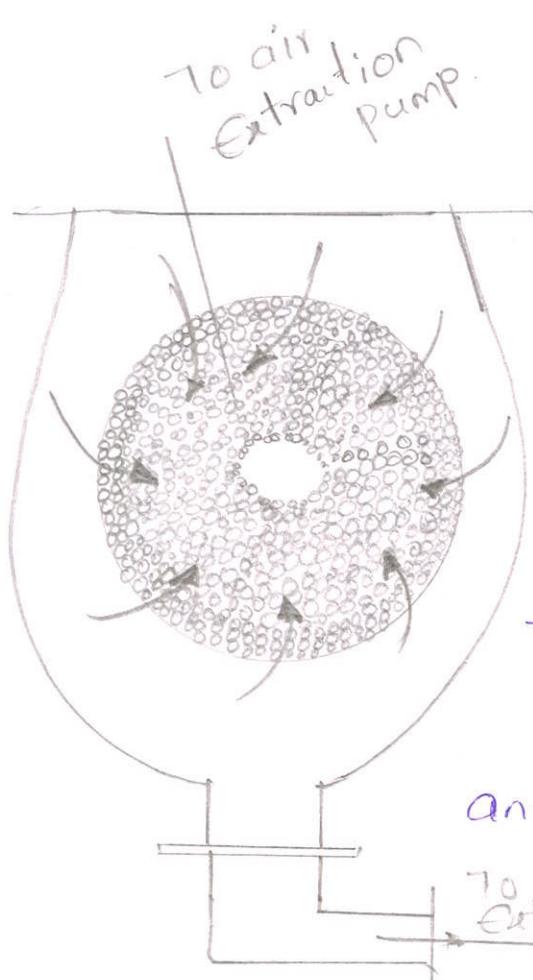
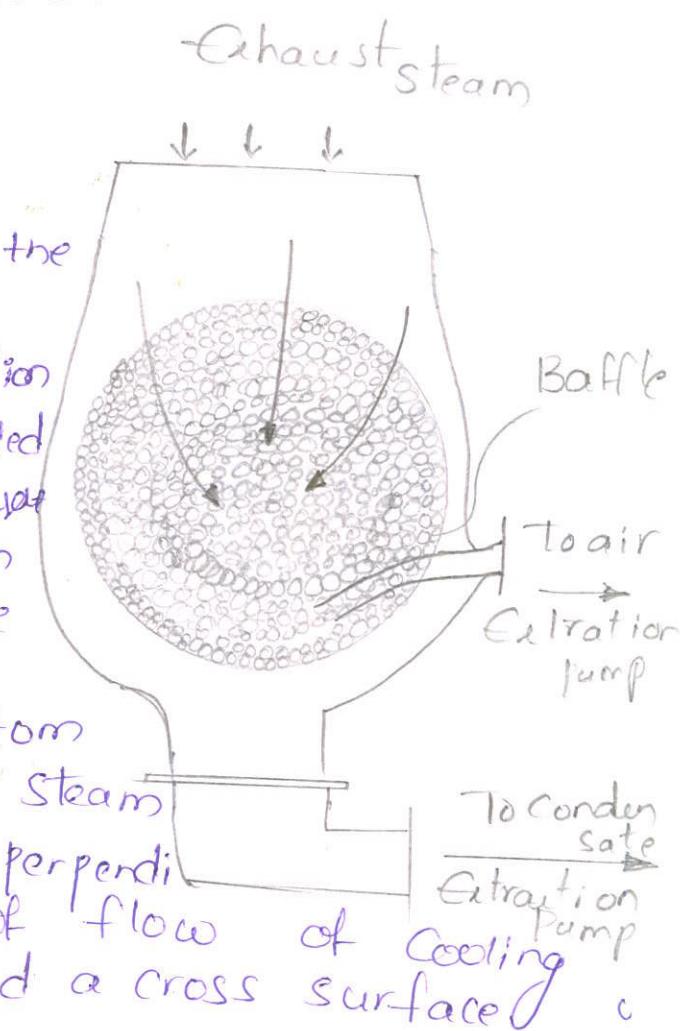
The Surface Condensers may be further classified on the basis of the direction of flow of the following four types.

1. Downflow Surface Condensers.
2. Central flow Surface Condensers.
3. Regenerative Surface Condensers.
4. Evaporative Condensers.

Down flow Surface Condensers:

In down flow surface condensers, the exhaust steam enters at the top flow downwards over the tubes due to force of gravity as well as suction of the extraction pump fitted at the bottom. The condensate is collected at the bottom and then pumped by the suction pipe, which is provided near the bottom is converted of condensed steam into air. As the steam flows perpendicular to the direction of flow of water this is also called a cross surface condensers.

Central flow Surface Condensers:



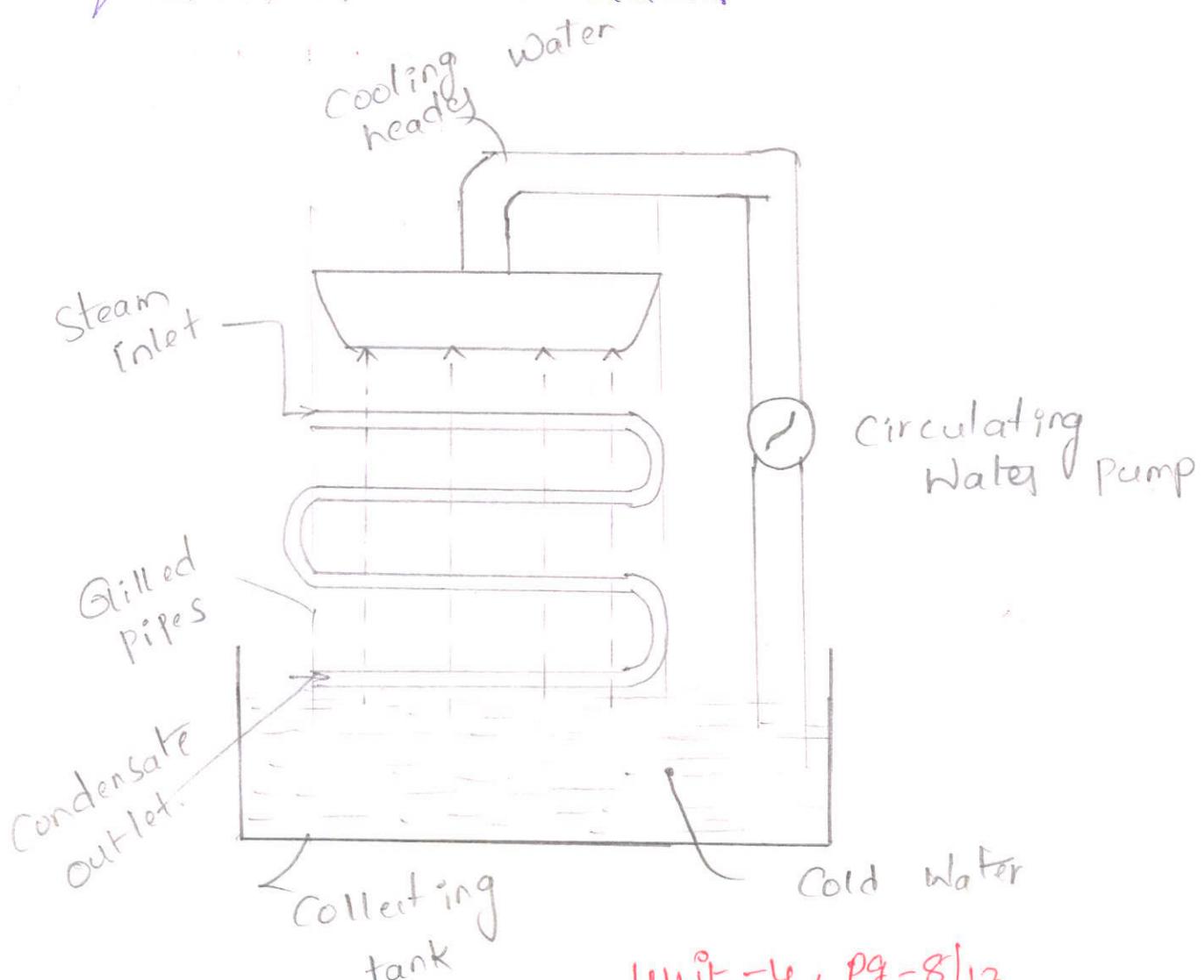
In central flow of surface condensers, the exhaust steam enters at the top and flow downwards. The suction pipe of the air extraction pump is placed in the centre of the tube nest. This causes the steam to flow radially inwards over the tubes towards the suction pipe. The condensate is collected at the bottom and then pumped the extraction.

Regenerative Surface Condensers:

In regenerative Surface Condensers, the Condensate is heated by a regenerative method. The Condensate after leaving the tubes is passed through the Exhaust steam from the Engine or turbine. It thus raises its temperature for use as feed water for the Boiler.

Evaporative Condenser:

The steam to be condensed enters at the top of pipes outside which a film of cold water is falling. At the same time, as a result of this, the steam circulating inside the pipe is condensed. The remaining cooling is collected at an increased temperature and is reused. Its original temperature is restored by the addition of the requisite of cold water.



The Evaporite Condensers are provided when the Circulating water is to be used again and again. These Condensers consist of sheets of gilled Piping, which is bent backwards and forward's and placed in a vertical plane.

Comparison of Jet and Surface Condensers

S.No.	Jet Condensers	Surface Condensers.
1.	Cooling water and steam are mixed up.	1. Cooling water and steam are not mixed up.
2.	Less Suitable for high Capacity plants	2. More suitable for high capacity plants.
3.	Condensate is wasted.	3. Condensate is reused.
4.	It requires less quantity of circulating water.	4. It requires a large quantity of circulating water.
5.	The Condensing plant is economical and simple	5. The condensing plant is costly and complicated.
6.	Its Maintenance Cost is low.	6. Its maintenance cost is high.
7.	More Power is required for air pump	7. Less power is required for air pump.
8.	high power is required for water pumping.	8. Less power required for water pumping.

Mixture of Air & Steam (Raleten's law of Partial Pressure):-

The pressure of the mixture of air and steam is equal to the sum of the pressures, which each constituent would exert, if it occupied the same space by itself.

$$\therefore P_c = P_a + P_s$$

P_a = Partial pressure of air

P_s = Partial pressure of steam

$$+ \text{ corrected vacuum} = 760 - (\text{Barometer reading} - \text{Vacuum gauge reading})$$

Vacuum Efficiency :-

$$\eta_v = \frac{\text{Actual Vacuum}}{\text{Ideal Vacuum}}$$

\therefore Actual Vacuum = Barometric pressure - Actual pressure

Ideal Vacuum = Barometric pressure - Ideal pressure

Condenser Efficiency :-

$$\eta_c = \frac{\text{Temperature rise of cooling water}}{\text{Vacuum temperature}} - \text{Inlet cooling water temperature}$$

$$= \frac{t_o - t_i}{t_v - t_i}$$

t_o - outlet temp of cooling water

t_i - inlet temp of cooling water

t_v - Vacuum temp. It is saturated temp to the condenser pressure.

Mass of cooling Water Required for condensation of Steam:-

$$\text{Heat lost by steam} = m_s(h - h_f)$$

$$\text{Heat gained by cooling water} = m_w c_w (t_o - t_i)$$

$$\therefore \text{Heat gained by cooling water} = \text{Heat lost by steam}$$

$$\therefore m_w c_w (t_o - t_i) = m_s (h - h_f)$$

$$\therefore m_w = \frac{m_s (h - h_f)}{c_w (t_o - t_i)}$$

m_w - Mass of cooling water
 m_s - Mass of steam condensed
 h - Total heat of steam entering the condenser

h_f - Total heat in condenser

t_i - Inlet temp of water

t_o - outlet temp of water

The following observations were recorded during a test on a steam condenser

Barometer reading = 765 mm of Hg

Condenser vacuum = 710 mm of Hg

Mean condenser temp = 35°C

Condensate temperature = 28°C

Condensate collected per hour = 2 tonne

Quantity of cooling water per hour = 60 tonne

Temp of cooling water at inlet $t_i = 10^\circ\text{C}$ ~~per hour~~ = ~~60 tonne~~

Temp of cooling water at outlet $t_o = 25^\circ\text{C}$

Find : 1. Vacuum collected to the standard barometer, 2. Vacuum

efficiency of the condenser, 3. Undeveloped of the condenser

4. Condenser efficiency, 5. Quality of the steam entering the condenser

6. Mass of air per m³ of condenser volume and 7. Mass of air per kg of uncondensed steam.

Soln: $T = 35^\circ\text{C} = 35 + 273 = 308\text{K}$; $t_c = 28^\circ\text{C}$; $m_s = 2\text{t/h} = 2000\text{kg/h}$
 $m_w = 60\text{t/h} = 60,000\text{kg/h}$, $t_i = 10^\circ\text{C}$; $t_o = 25^\circ\text{C}$

1. Vacuum collected to the standard barometer reading

\therefore Absolute pressure in the condenser

= Barometer reading - condenser vacuum

= 765 - 710 = 55 mm of Hg

Vacuum collected to the standard barometer reading
(Actual & Barometric)

= 760 - 55 = 705 mm of Hg

2. Vacuum efficiency of the condenser

From steam table, condenser temp of 35°C, $P_g = 0.0562 \text{ bar} = \frac{0.0562}{0.00133}$

$$P_g = 42.2 \text{ mm of Hg}$$

Ideal vacuum = Barometric pressure - Ideal pressure
 $= 765 - 42.2 = 722.8 \text{ mm of Hg}$

Vacuum efficiency, $n_v = \frac{\text{Actual Vacuum}}{\text{Ideal Vacuum}} = \frac{710}{722.8} = 0.982 \text{ or } 98.2\%$

3. Undercooling of the condensate :-

∴ Undercooling of the condensate = Mean condenser - condensate temp
 $= 35 - 28 = 7^\circ\text{C}$

4. Condenser efficiency :-

$\therefore P_c = 765 - 710 = 55 \text{ mm of Hg} = 55 \times 0.00133 = 0.073 \text{ bar}$

From steam table, pressure is 0.073 bar, vacuum b.p. $t_v = 39.83^\circ\text{C}$

∴ Condenser efficiency (n_c) = $\frac{t_v - t_i}{t_v - t_e} = \frac{39.83 - 10}{39.83 - 10} = 0.503 \text{ or } 50.3\%$

5. Quality of steam entering the condenser

Let x = Quality of steam entering the condenser

From steam table, $P = 0.073 \text{ bar}; h_f = 166.7 \text{ kJ/kg}; h_{fg} = 2407.4 \text{ kJ/kg}$
 at $t = 28^\circ\text{C}, h_{f1} = 119.3 \text{ kJ/kg}$

Total heat of entering steam

$$h = h_f + xh_{fg} = 166.7 + x \times 2407.4$$

∴ Mass of cooling water (m_w) = $\frac{m_s(h - h_{f1})}{c_w(t_o - t_i)}$

$$60000 = \frac{m_s(h - h_{f1})}{c_w(t_o - t_i)} = \frac{2000(166.7 + x \times 2407.4 - 119.3)}{4.2(25 - 10)}$$

$$x = 0.7611$$

6. Mass of air per m³ of condenser volume:-

∴ Absolute pressure of air (as per Dalton's law)

$$P_a = P_c - P_s = 0.073 - 0.0562 = 0.0168 \text{ bar}$$
$$= 0.0168 \times 10^5 = 1680 \text{ N/m}^2$$

∴ Mass of air per m³ of condenser volume

$$\therefore Pv = mRT \text{ & } V = 1 \text{ m}^3$$

$$\therefore m_a = \frac{P_a V}{R T} = \frac{1680 \times 1}{287 \times 308} = 0.0191 \text{ kg}$$

7. Mass of air per kg of uncondensed steam

From steam table, t = 35°C, V_g = 25.245 m³/kg

∴ Mass of air per kg of uncondensed steam

$$\therefore m_a = \frac{P_a V_g}{R T} = \frac{1680 \times 25.245}{287 \times 308} = 0.48 \text{ kg}$$

