UNIT-IV Steam Condenser

6.1. Steam Condenser.

It can be defined as device used for condensation of steam at constant pressure, generally pressure is less than atmospheric pressure. Condenser is thus a closed vessel which is generally maintained at vacuum and cold fluid is circulated to remove heat from steam to cause its condensation. Function of the condenser is to remove heat from the wet steam exhausted from the steam turbine and condensed it to water that is pumped to boiler.

6.2. Advantages of the condenser.

1. Reduce the turbine exhaust pressure so as to increase the specific output of the turbine figure (6.1). If the circulating cooling water temperature in a condenser is low enough, it creates a low back pressure (vacuum) for the turbine, see figure (6.2).
2. Supply pure feed water, so that is pumped to the boiler.
3. Removal of air and non-condensable dissolved gases from feed water.
4. Re-use of condensate as feed water for the boiler to reduce the cost of power generation.

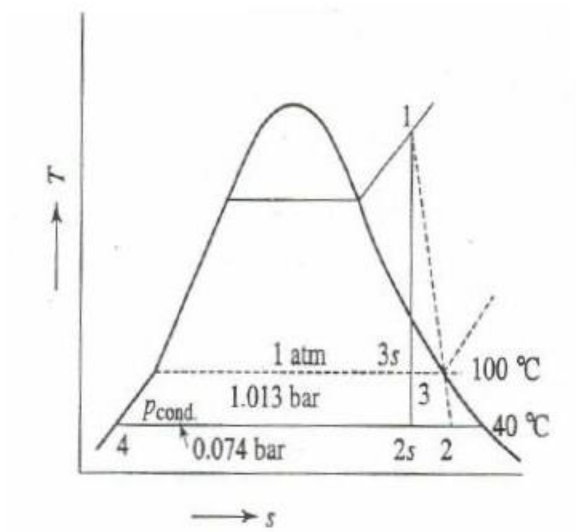
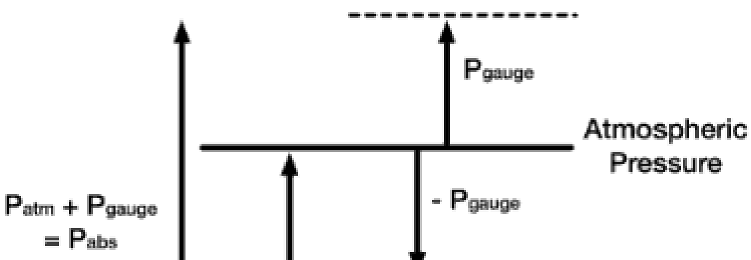


Figure (6.1): The use of condenser increases the specific work output of turbine from (h_1-h_3) to (h_1-h_2)



6.3. Main Types of Condensers

1. **Direct contact condensers**, where the condensate and cooling water directly mix and come out as a single stream.
2. **Surface condensers**, which are shell-and-tube heat exchangers where the two fluids do not come in direct contact and the heat released by the condensation of steam is transferred through the walls of the tubes into the cooling water continuously circulating inside them.

6.3.1. Direct contact condensers

There are three types:

1. **Spray condenser**: cooling water is sprayed into the steam, where steam mixing directly with cold water gets condensed. The exhaust steam from the turbine mixes with cooling water to produce saturated water, which is pumped, see figure (6.3).
2. **Barometric condenser:** the cooling water is pumped to fall in a series of baffles to expose large surface area for the steam fed from below to come in direct contact. The steam condenses and the mixture falls in a tail pipe to the hot well below, as shown in figure (6.4.a).
3. **Jet condenser**: the height of the tail pipe is reduced by replacing it with a diffuser. The diffuser helps raising the pressure in a short distance than a tail pipe, see figure (6.4.b).

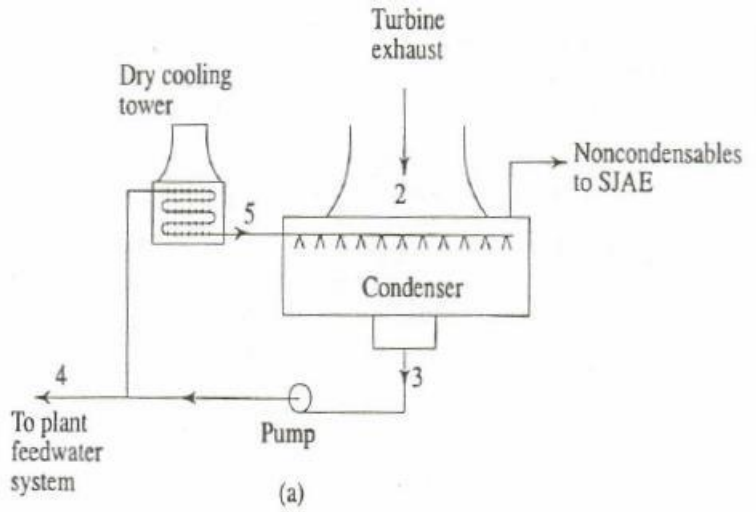


Figure (6.3): Spry condenser.

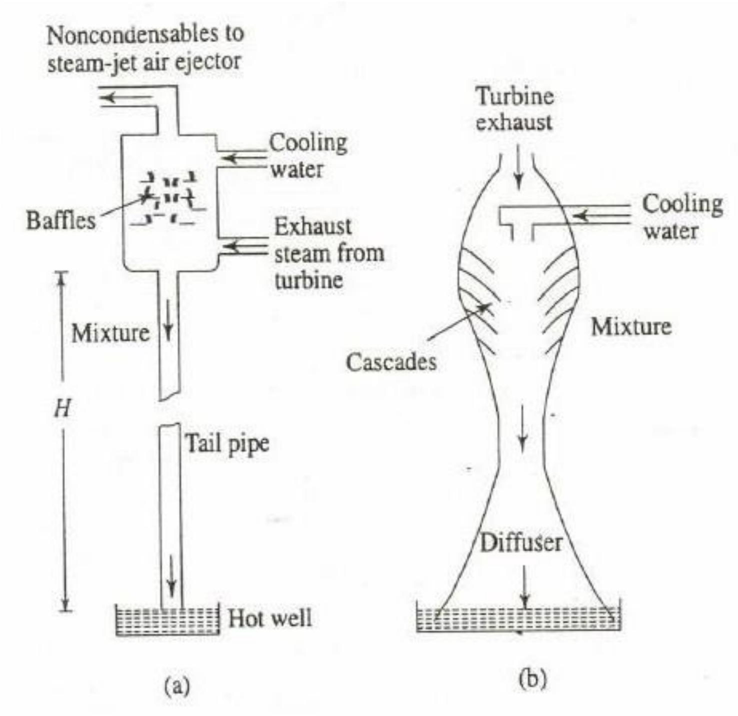


Figure (6.4): a- barometric condenser
b- Jet condenser.

6.3.2. Surface Condensers

Surface condensers are the most common types of condenser and offer great advantage in terms of no contamination of feed water. In these condensers the steam to be condensed and cooling fluid (water) do not come in contact with one another, instead the heat transfer occurs between two fluids through surface in between. Generally, cooling water flows through the pipes/tubes and steam surrounds them. These condensers are preferred in the locations where large quantity of poor-quality cooling fluid (impure water) is available and condensate is to be recirculated.

Surface condensers can be classified based on number of passes of condenser i.e. single Pass as explained in figure (6.5), or multi-pass. Where pass is the number of times the cooling water crosses any transverse section. Typical surface condenser having two passes as shown in figure (6.6)

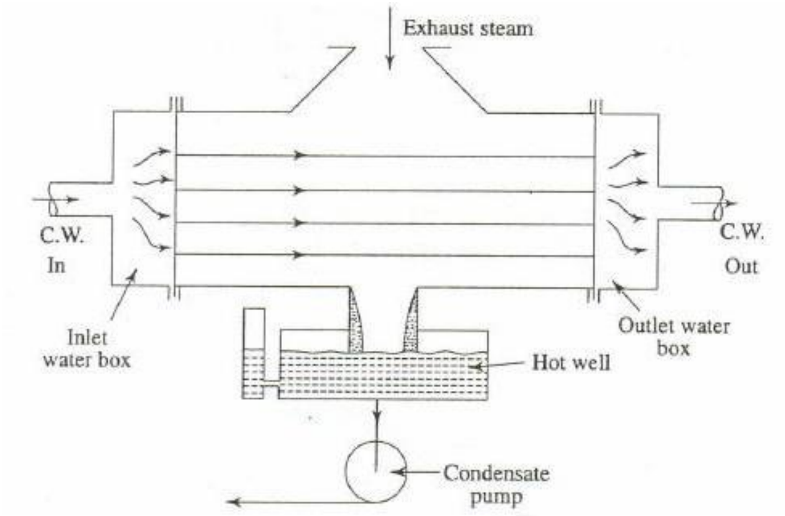


Figure (6.5): single pass surface condenser

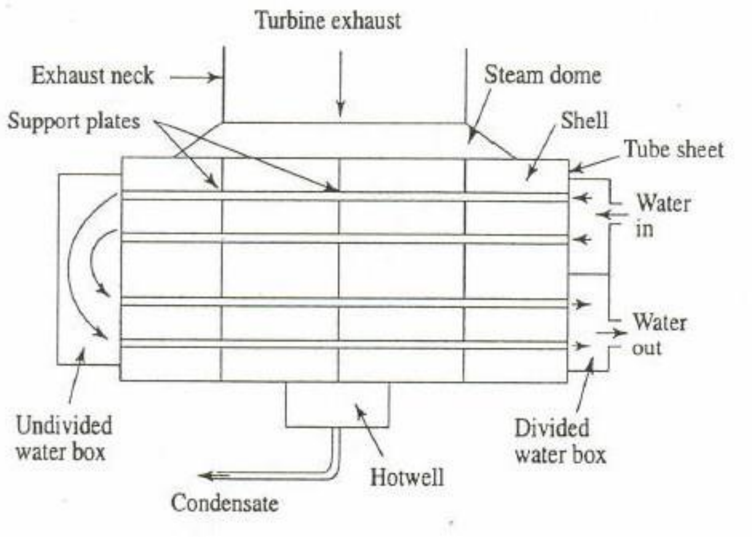


Figure (6.6): Two pass surface condenser

6.4. Comparison between Surface and Direct Contact Steam Condensers.

There are some differences between these types of condensers as follows;

	Surface Condenser	Direct Contact Condenser
1	Cooling water and steam flow separately.	Cooling water and steam are mixed.
2	Suitable for high capacity plant.	Used for low capacity plant.
3	Circulating water quantity is high.	Need less quantity of circulating water.
4	Condensing plant is costly and completed.	Condensing plant is economical and simple.
5	Less power required for water pumping.	High power required for water pumping.

6.5. Air Leakage in the Condenser

Air may be entered to the steam condenser through different ways like;

1. The dissolved air in the feed water enters into the boiler, which reaches to condenser from the exhaust steam from the turbine.
2. Air may be leaked from the joints of the pipes or shall of the steam condenser.
3. For the jet type steam condenser, air can leak into the condenser with the injection water as dissolved air.

The leaked air effect on the performance of the steam condenser, where is cause:

1. Reduce the vacuum pressure in the condenser.
2. Reduce the rate of heat transfer in the condenser, where air is a poor heat conductor.
3. Increase the power required to drive the pump.

6.6. Mixture of Steam and Dry Air in the Condenser.

Dalton’s law of partial pressures stated that "the absolute pressure inside condenser is the sum of partial pressures of steam and air inside it". The partial pressure of steam shall be equal to the saturation pressure corresponding to entering steam temperature. This partial pressure of steam could be predicted from steam table. Mathematically, absolute pressure in condenser (P_c), as per Dalton’s law;

$$Condenser\ pressure = Steam\ pressure + Air\ Leakage\ pressure$$

$$P_C = P_S + P_a$$

Where: P_C: is the condenser pressure.

P_S: partial pressure of steam.
P_a: partial pressure of air leakage in the condenser.

Moreover, the absolute pressure inside the condenser is:

$$Absolute\ pressure = Atmospheric(Barometric)\ presure + (gauge\ pressure)$$

i.e.,

$$P_{Condense(absolute)} = P_{Barometric} - P_{Vacuum}$$

Where for vacuum the gauge, pressure has a negative sign as illustrated in figure (6.2). It's useful to know the standard barometric head is 750 mmHg or 1.0 bar, to convert the pressure units.