19.9 DALTON'S LAW OF PARTIAL PRESSURES

"Dalton's law of partial pressures states that the total pressure exerted by a mixture of gases or a mixture of gas and vapour is equal to the sum of individual partial pressures of the constituents of the mixture. The partial pressure of a constituent is the pressure exerted by it if it occupies the total volume at the same temperature of the mixture."

This is explained by taking the following example :

The total pressure in the condenser is the sum of the partial pressures of steam and air.

According to Dalton's law of partial pressure

$$p_t = p_s + p_a \quad \text{...(19.4)}$$

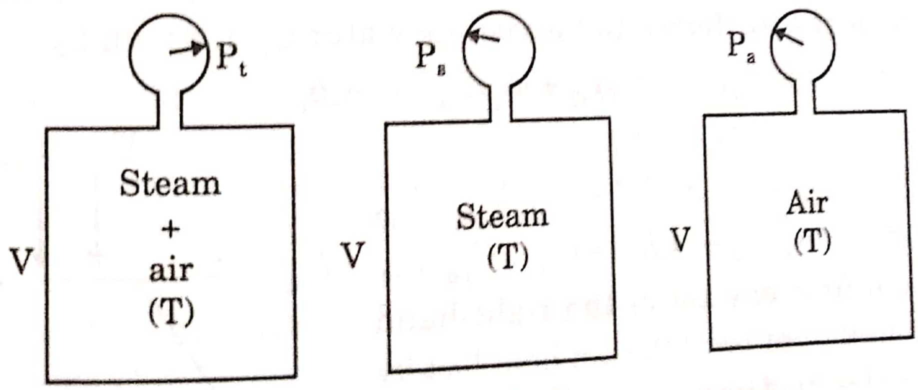

Fig. 19.8.

20.1. Introduction

A steam condenser is a closed vessel into which the steam is exhausted, and condensed after doing work in an engine cylinder or turbine. A steam condenser has the following two objects:

1. The primary object is to maintain a low pressure (below atmospheric pressure) so as to obtain the maximum possible energy from steam and thus to secure a high efficiency.
2. The secondary object is to supply pure feed water to the hot well, from where it is pumped back to the boiler.

Note : The low pressure is accompanied by low temperature and thus all condensers maintain a vacuum under normal conditions. The condensed steam is called condensate. The temperature of condensate is higher on leaving the condenser than that of circulating water at inlet. It is thus obvious, that the condensate will have a considerable liquid heat.

20.2. Advantages of a Condenser in a Steam Power Plant

Following are the main advantages of incorporating a condenser in a steam power plant:

1. It increases expansion ratio of steam, and thus increases efficiency of the plant.
2. It reduces back pressure of the steam, and thus more work can be obtained.
3. It reduces temperature of the exhaust steam, and thus more work can be obtained.
4. The reuse of condensate (*i.e.* condensed steam) as feed water for boilers reduces the cost of power generation.
5. The temperature of condensate is higher than that of fresh water. Therefore the amount of heat supplied per kg of steam is reduced.

20.3. Requirements of a Steam Condensing Plant

The principle requirements of a condensing plant, as shown in Fig. 20.1, are as follows:

1. *Condenser.* It is a closed vessel is which steam is condensed. The steam gives up heat energy to coolant (which is water) during the process of condensation.

2. *Condensate pump.* It is a pump, which removes condensate (*i.e.* condensed steam) 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.

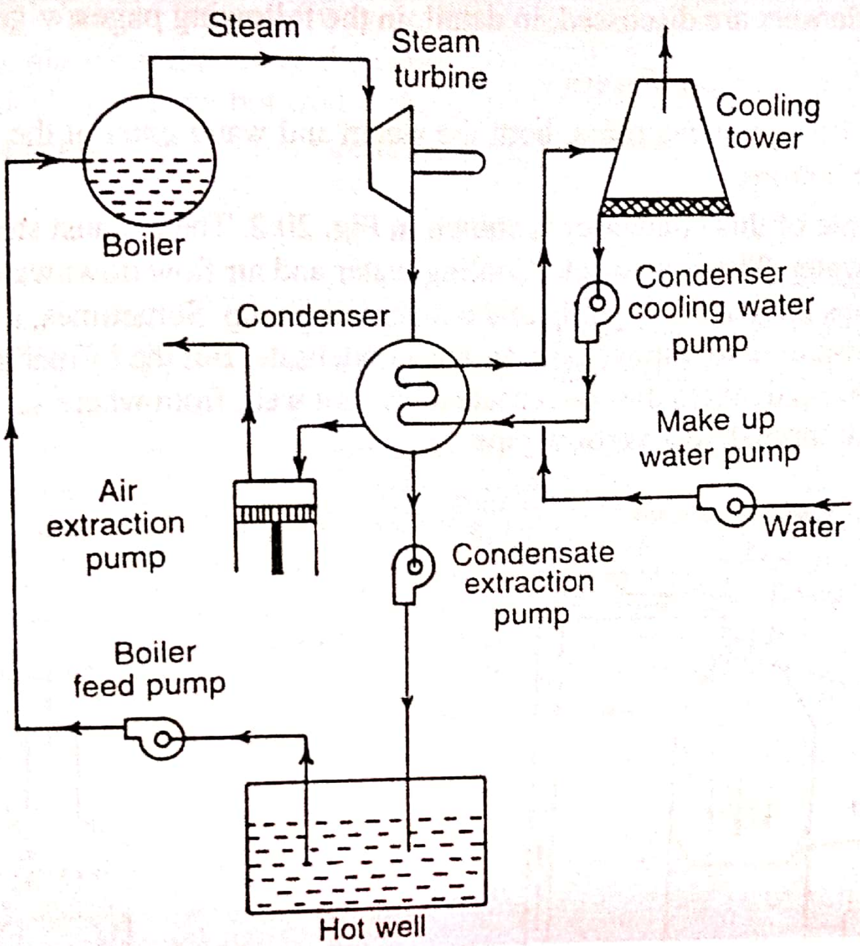

Fig. 20.1. Steam condensing plant.

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 (*i.e.* removes) 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.

20.4. Classification of Condensers

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

1. Jet condensers or mixing type condensers, and
2. Surface condensers or non-mixing type condensers.

condenser but they are not described here as they ...

(B) Non-mixing Type or Surface Condensers. In this type of condenser, the cooling water and exhaust steam do not come in direct contact with each other as in the case of jet condensers. This type is generally used where large quantities of inferior water is available and where better quality of feed water to the boiler must be used.

The arrangement of the surface condenser is shown in Fig. 19.5(*a*). It consists of an air-tight cylindrical shell closed at each end as shown in figure. A number of water tubes are fixed in the tube plates which are located between each cover head and shell.

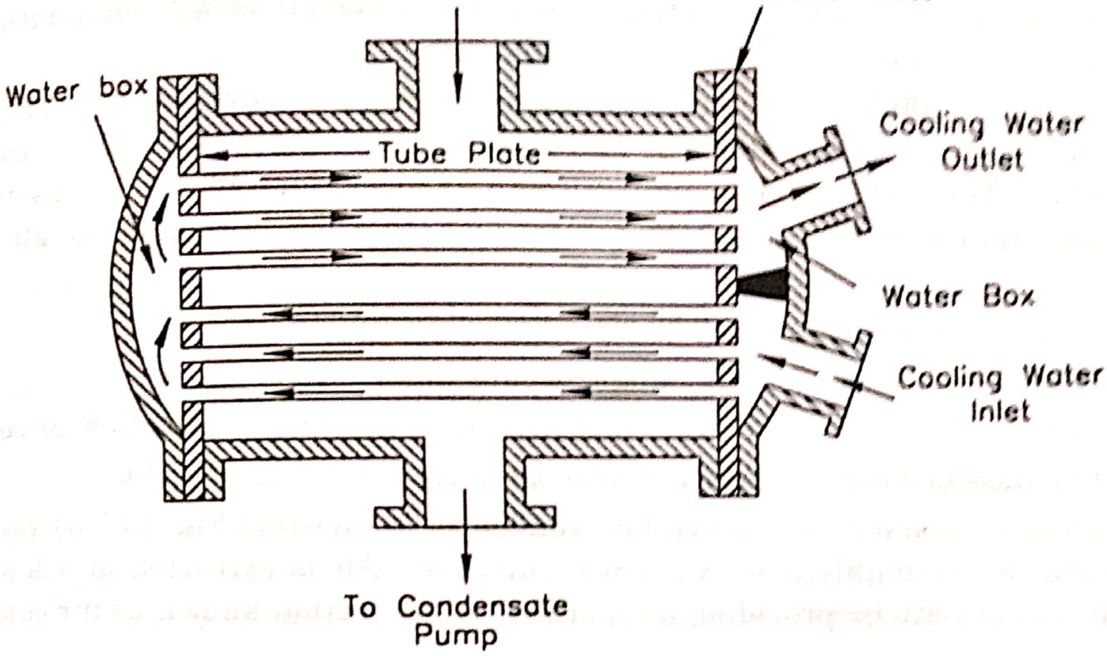

Fig. 19.5(*a*). Surface condenser.

The exhaust steam from the prime-mover enters at the top of the condenser and surrounds the condenser tubes through which cooling water is circulated under force. The steam gets condensed as it comes in contact with cold surface of the tubes. The cooling water flows in one direction through the first set of the tubes situated in the lower half of condenser and returns in the opposite direction through the second set of the tubes situated in the upper half of the condenser as shown in figure. The warm cooling water coming out from the condenser is discharged into the cooling tower, river or cooling pond. The condensate is taken out from the condenser by a separate extraction pump and air is removed by an air pump.

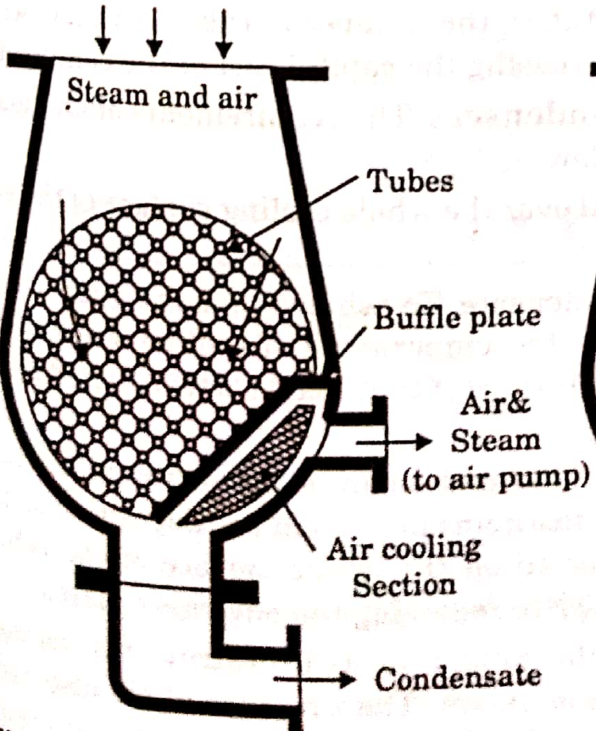

Fig. 19.5(*b*). Downflow condenser.

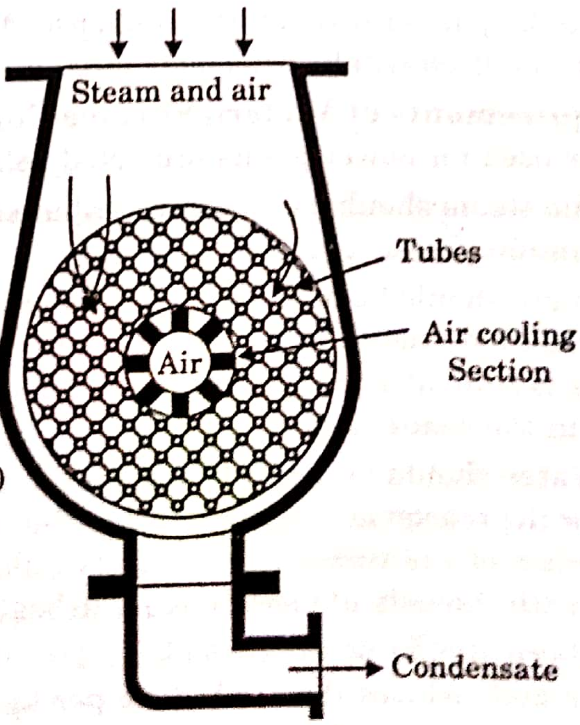

Fig. 19.5(*c*). Central flow condenser.

A section of tubes near the air pump suction is screened off by providing a baffle as shown in Figs. 19.5(*b*) and 19.5(*c*). The number of tubes used in this section per unit area are more compared with other parts of the condenser. The velocity of water through these tubes is also maintained higher. This is done to reduce the amount of steam going along with the air. The extensive cooling of air in this section increases the density of air going out and reduces the required capacity of air pump as much as 50%.

The surface condenser requires three pumps when it works on dry-vacuum system, one for circulating the cooling water, one for extracting the condensate and a third is required for removing air. The surface condenser requires only two pumps when it works as in wet vacuum system, one for circulating the cooling water and other for extracting the air and condensate together.

The surface condensers may be classified according to :

(*a*) Number of water passes : single or multipass

(*b*) Direction of condensate flow and tube arrangement as downflow or central flow.

A two pass down-flow surface condenser is shown in Fig. 19.5(*b*).

A cross-sectional view of down-flow condenser is shown in Fig. 19.5(*b*). Steam enters from the top and flows mainly downward over the tubes. Air is extracted at a lower temperature than the condensate by providing a separate cooling section known as air cooler as explained earlier.

A sectional view of central flow condenser is shown in Fig. 19.5(*c*). In this arrangement, the air cooling section is provided at the centre of the tube nest and air is extracted from this section. This arrangement causes the steam to flow radially inwards towards the centre and pass over the entire periphery of tubes. The condensate formed is extracted from the bottom as shown in Fig. 19.5(*c*). This arrangement is an improvement over downward flow type as it has an access to the whole periphery of the tubes.

In surface condensers, cooling water is passed through the tubes and steam surrounds the tubes. The space occupied by the tubes in the condenser shell is hardly 10% of the condenser shell volume. The specific volume of the steam at the condenser pressure is very large and if the steam is to be passed through the condenser tubes, the number of tubes (volume occupied by the tubes) required will be extremely large increasing the capital cost of the condenser.

... of an ideal surface