19.5 ADVANTAGES OF SURFACE CONDENSERS

The advantages of surface condensers are listed below :

(1) A high vacuum can be attained in the surface condenser (as much as 73.5 cm of Hg), providing a high thermal efficiency.

(2) The condensate can be directly used as boiler feed water. This is very important in any large power plant. A 400 MW capacity plant requires 2000 tons of steam flow per hour.

(3) Any kind of cooling water can be used in the condenser as it does not directly come in contact with steam.

The limitations of this type are :

(1) The surface condenser is bulky and therefore requires more space.

(2) Its capital, running and maintenance costs are considerably greater than that of jet condensers.

19.6 VACUUM IN CONDENSER AND ITS MEASUREMENT

The vacuum in the condenser is usually measured in cm of mercury. The vacuum in the condenser is the difference between the barometric pressure and the absolute pressure in the condenser.

The difference between the barometer reading and vacuum gauge reading as shown in Fig. 19.7 gives the absolute pressure in the condenser.

The vacuum in the condenser is equivalent to H_v cm of mercury as shown in figure which is generally measured by vacuum gauge. The burometric pressure is equivalent to H_b cm of mercury. Therefore the actual pressure in the condenser is equivalent to $(H_b - H_v)$ cm of mercury.

$\therefore$ Absolute pressure = $(H_b - H_v)$ cm of mercury.

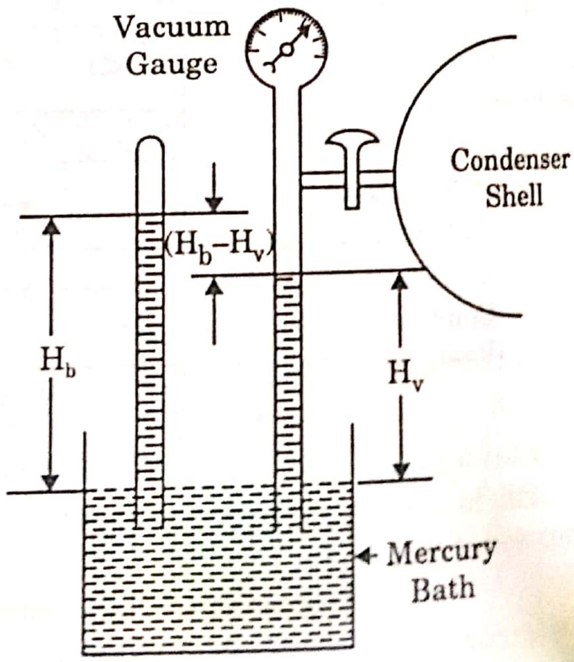

Fig. 19.7.

The barometric head H_b varies according to atmospheric conditions, and therefore the absolute pressure in the condenser is a function of the barometric pressure also.

If the standard barometric pressure is taken as 76 cm of mercury at sea-level, then the corrected vacuum in condenser (referred to 76 cm of mercury height) is given by

Corrected vacuum in cm of mercury = 76 – absolute pressure in condenser in cm of mercury

$$= 76 - (H_b - H_v) \quad ...(19.1)$$

19.7 AIR LEAKAGE, ITS EFFECTS ON THE PERFORMANCE OF CONDENSER AND METHODS OF ITS REMOVAL FROM CONDENSERS

The sources of air leakage into the condenser are listed below :

1. Air leaks through the joints, packings and glands into condenser as the pressure inside is below the atmospheric pressure. The quantity of air leakage through these sources depends upon the quality of workmanship.

2. The feed water contains air in dissolved condition. The dissolved air gets liberated when steam is formed and it is carried with the steam into the condenser.

3. The dissolved air in the water is also carried with the cooling water in jet condensers. This dissolved air gets liberated in condenser at low pressure.

Normally the quantity of air leakage in surface condensers is about 0.5% of the steam condensed when steam turbine is used as prime-mover and 0.15% of the steam condensed when steam engine is used as prime-mover. The quantity of air carried with cooling water in jet type condenser is about 0.005% of the cooling water.

The effects of air leakage in a condenser are listed below :

1. It increases the pressure in the condenser or back pressure of the prime-mover and reduces the work done per kg of steam.

2. The presence of air lowers the partial pressure of steam and its corresponding temperature.

The latent heat of steam increases at lower pressure. Therefore more quantity of water is required to condense one kg of steam as the quantity of latent heat removed is more. There is greater possibility of under-cooling the condensate with the reduction in partial pressure of steam due to the presence of air. This phenomenon reduces the overall efficiency of the power plant.

3. The heat transfer rates are greatly reduced due to the presence of air because air offers high resistance to heat flow. This further necessitates the use of increased quantity of cooling water to maintain the heat transfer rates. Otherwise, it reduces the condensation rate and further increases the back pressure on the prime-mover.

It is obvious from the above discussion that preventive measures should be taken to remove the air from the condenser.

The types of air-pumps which are commonly used are listed below :

1. Reciprocating Type (dry or wet).
2. Rotary type (Generally dry)
3. Steam Ejectors (Generally dry).

19.8 VACUUM EFFICIENCY

The lowest pressure (or highest vacuum) which can exist in a condenser is the saturation pressure of steam corresponding to the temperature of the water entering the condenser. But the actual pressure in the condenser is always greater than the ideal pressure by an amount equal to the partial pressure of air present in the condenser.

Assume : p_s = Saturation pressure of steam in bar corresponding to the temperature of water entering the condenser.

p_t = Total pressure of air and steam in the condenser $(p_a + p_s)$.

p_b = Atmospheric or Barometric pressure.

Ideal vacuum possible without air leakage = $(p_b - p_s)$

Actual vacuum existing in condenser due to air leakage

$= p_b - p_t = p_b - (p_a + p_s)$ where p_t is the actual pressure in the condenser.

The "vacuum efficiency" is defined as the ratio of actual vacuum to ideal vacuum.

$$\therefore \quad \text{Vacuum efficiency} = \frac{p_b - (p_a + p_s)}{p_b - p_s} = \frac{p_b - p_t}{p_b - p_s} \quad \text{...(19.2)}$$

If there is no air leakage into condenser, then $p_a = 0$ and therefore the vacuum efficiency becomes 100%. The factors affecting the vacuum efficiency are listed below :

(1) If air leakage increases, the vacuum efficiency decreases due to the increase in p_a.

(2) The vacuum efficiency decreases with the increase in barometric pressure with the same ideal exhaust pressure and same actual pressure in the condenser. This is illustrated with the following example :

Say p_a = 5 cm of Hg.

p_s = 5 cm of Hg.

and p_b is decreased from 76 cm of Hg to 75 cm of Hg.

Vacuum efficiency when p_b is 76 cm of Hg.

$$= \frac{76 - (5+5)}{76 - 5} = \frac{66}{71}$$

Vacuum efficiency when p_b is 75 cm of Hg

$$= \frac{75 - (5+5)}{75 - 5} = \frac{65}{70}$$

$$\frac{65}{70} < \frac{66}{71}$$

(3) If the cooling water is not sufficient then the pressure in the condenser increases and subsequently reduces the vacuum efficiency of the condenser.

Condenser Efficiency. There is no standard method for specifying the efficiency of a condenser. A method suggested by Parson and Co., well-known makers of steam turbines, has been widely used. The efficiency of a condenser is defined by a ratio as given below :

$$\text{Condenser efficiency} = \frac{T_{w0} - T_{wi}}{T_s - T_{wi}} \quad \text{...(19.3)}$$

where T_{wi} = Temperature of cooling water at inlet

and T_{w0} = Temperature of cooling water at outlet.

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