

UNIT: II

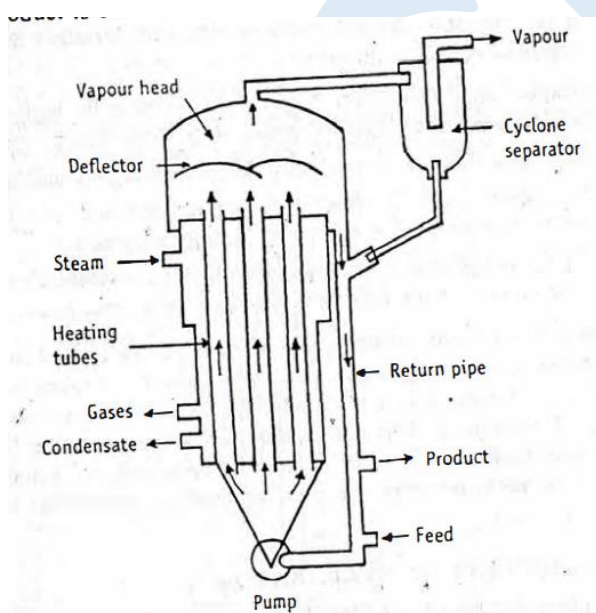
(EVAPORATION)

CLASS:17

**TOPIC: PRINCIPAL, CONSTRUCTION, WORKING, USES, MERITS AND DEMERITS
OF FORCED CIRCULATION EVAPORATOR, MULTIPLE EFFECT EVAPORATOR,
MULTIPLE EFFECT EVAPORATOR & ECONOMY OF MULTIPLE EFFECT
EVAPORATOR**

FORCED CIRCULATION EVAPORATOR

Principle: In forced circulation evaporator, liquid is circulated through the tubes at high pressures by means of a pump. Hence, boiling does not take place because boiling point is elevated. Forced circulation of the liquid also creates same form of agitation. When the liquid leaves the tubes and enters the vapour head, pressure falls suddenly. This leads to the flashing of super heated liquor. Thus evaporation is effected.

Construction :

Forced circulation evaporator.

The construction of a forced circulation evaporator is shown in Figure. The steam jacketed tubes are held between two tube sheets. The tube measures 0.1 metres inside diameter and 2.5 metres long. The part of the tubes projects into the vapour head (flash chamber), which consists of a deflector. The vapour head is connected to a return pipe, which runs downwards and enters into the inlet of a pump.

Working : Steam is introduced into calandria. Pump sends the liquid to the tubes with a positive velocity. As the liquid moves up through the tubes, it gets heated and begins to boil. As a result, the vapour and liquid mixture rushes out of the tubes at a high velocity. This mixture strikes the deflector, which throws the liquid downward. This results in an effective separation of liquid and vapour. The vapour enters the cyclone separator and leaves the equipment. The concentrated liquid returns to the pump for further evaporation. Finally the concentrated product is collected.

Uses: If evaporation is conducted under reduced pressure, forced circulation evaporator is suitable for thermolabile substances. This method is used for the concentration of insulin and liver extracts. It is well suited for crystallizing operations where crystals are to be suspended at all times.

Advantages: (1) In forced circulation evaporator, the heat transfer coefficient is high due to rapid liquid movement.

(2) Salting, scaling and fouling are not possible due to forced circulation.

(3) This evaporator is suitable for thermolabile substances because of rapid evaporation.

(4) It is suitable for high viscous preparations because pumping mechanism is used.

Disadvantages: In forced circulation evaporator, the hold-up of liquid is high. The equipment is expensive. because power (pump) is required for circulating the liquid.

MULTIPLE EFFECT EVAPORATOR

Vertical tube evaporator discussed earlier is a single effect evaporator (Figure). Such evaporators are connected in several ways so as to achieve large scale evaporation as well as greater economy. Although multiple effect evaporators are not used in the pharmaceutical industry, the principles are of interest and should be understood. This is illustrated using an example of triple effect evaporator with a parallel feed mechanism.

Advantages: (1) It is suitable for large scale and for continuous operation.

(2) It is highly economical when compared with single effect.

(3) About 5 evaporators can be attached.

Construction: The construction of a multiple effect evaporator is shown in Figure using 3 evaporators i.e. triple effect evaporator. The other aspects of construction of vertical tube evaporator remain same as mentioned earlier. A perusal to Figure 12-8 indicates that the vapour from first evaporator serves as a heating medium for the 2nd evaporator. Similarly, vapour from 2nd evaporator serves as a heating medium for the 3rd evaporator. Last evaporator is connected to a vacuum pump.

Working: Parallel feed arrangement is used in this example.

Parallel feed : In this method, a hot saturated solution of the feed is directly fed to each of the three effects (evaporation) in parallel without transferring the material from one effect to the other, The parallel feed arrangement is commonly used in the concentration of salt solutions, where the solute crystallizes on concentration without increasing the viscosity.

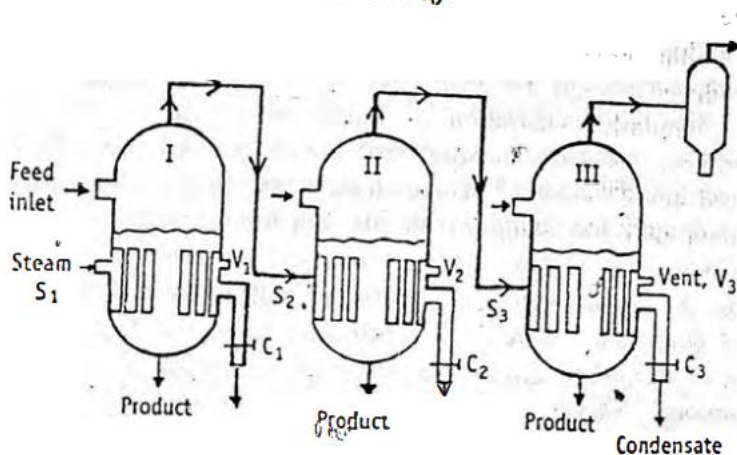
Operations: In the beginning, the equipment is at room temperature and atmospheric pressure. The liquid feed is introduced to all the three evaporators up to the level of the upper tube sheets. The following operations are attempted to achieve the effects as specified below

1. The vent valves V_1 , V_2 and V_3 are kept open and all other valves are closed (not shown in Figure).
2. Now a high vacuum is created in the liquid chambers of evaporators.
3. The steam valve S_1 and condensate valve C_1 are opened. Steam is supplied. Steam first replaces cold air in the steam space of 1st evaporator. When all the cold air is removed, the valve, V_1 is closed.
4. The supply of steam is continued until the desired pressure P_0 is created in the steam space of 1st evaporator. At this pressure, the temperature of the steam is t_0

5. Steam gives its temperature to the liquid feed in the 1st evaporator and gets condensed. Condensate is removed through the valve C_1 .

6. Due to heat transfer, the liquid temperature increases and reaches the boiling point. During this process, vapour will be generated from the liquid feed.

7. So formed vapour displaces air in the upper, part of 1st evaporator. Moreover, the vapour also displaces the air in the steam space of the 2nd evaporator



Triple effect evaporator with parallel feed arrangements.

8. After complete displacement of air by vapour in the steam compartment of 2nd evaporator, the valve V_2 is closed.

9. The vapour of 1st evaporator transmits its heat to the liquid of 2nd evaporator and gets condensed. Condensate is removed through the valve C_2 . These steps continue in the 3rd evaporator also.

As the liquid in the 1st evaporator gains temperature, the difference in temperatures between the liquid and steam decreases. hence, the rate of condensation decreases. As a result, the pressure in the vapour space of 1st evaporator gradually increases to P_1 by increasing temperature to t_1 . which is the boiling point of the liquid in 1st evaporator. and decreasing the temperature difference ($t_0 - t_1$).

A similar change takes place in the 2nd evaporator and the liquid reaches the boiling point. Similarly, the process will be repeated in 3rd evaporator. Finally three evaporators (or effects as they are called) come to a steady state with the liquid boiling in all the three bodies.

As boiling proceeds, liquid level in 1st evaporator comes down. Feed is introduced through the feed valve to maintain the liquid level constant. Similarly evaporation of liquid takes place in 2nd and 3rd evaporators. To maintain liquid levels constant, feed valves F_2 and F_3 are used for 2nd and 3rd evaporators. respectively. This process is continued until the liquid in all the evaporators reaches the desired viscosity.

Now the product valves are opened to collect the thick liquid. Thus in this evaporator, there is a continuous supply of feed. continuous supply of steam and continuous withdrawal of liquid from all the three evaporators. Hence, evaporator works continuously with all the temperatures and pressures in balance.

The evaporator can also be fed by forward feed method, backward feed method and mixed feed method. In the forward feed method, the mother liquor is introduced into 1st then transferred to 2nd

and then to 3rd. In the backward feed method, the mother liquor is introduced into the 3rd evaporator, then transferred to 2nd and then transferred to 1st. In mixed feed method. the mother liquor is introduced into 2nd evaporator then transferred to 3rd evaporator and then transferred to 1st evaporator.

Economy of Multiple Effect Evaporator

The economy of an evaporator is the quantity of vapour produced per unit steam admitted. It is calculated by considering the following assumptions.

Feed is admitted at its boiling point. Therefore, it does not require any more heat to raise its temperature. Hence, the supplied steam gets condensed to give heat of condensation. This heat will then be transferred completely to the liquid. The heat transferred now serves as latent heat of vaporisation. i.e., liquid undergoes vaporisation by receiving heat. Loss of heat by any means is negligible.

The economy of an evaporator may be expressed as:

$$\text{Economy of an evaporator} = \frac{\text{Total mass of vapour produced}}{\text{Total mass of steam supplied}}$$

In single effect evaporator, steam produces vapour only once. Hence

$$\text{Economy of a single effect evaporator} = \frac{N \text{ units of vapour produced}}{N \text{ units of steam supplied}} = 1$$

In multiple effect evaporator, one unit. of steam produces vapour many times. depending on the number of evaporators connected. Hence,

$$\text{Economy of multiple effect evaporator} = \frac{N \text{ units of vapour produced}}{1 \text{ unit of steam supplied}} = N$$

Therefore, economy of multiple effect evaporator is N times the economy of the single effect evaporator. However, such a great economy is approximately true as it depends on many factors such as temperature. of the feed, temperature range in the evaporator, ratio of weight of feed to the product and pressure difference.

MCQ Each carry 1 mark

1. **Evaporator which helps in growing of coarse crystals**
 - a. **Forced circulation evaporator**
 - b. Long tube vertical evaporator
 - c. Multiple effect evaporator
 - d. Short tube vertical evaporator
2. Select the preferable evaporator suitable for a corrosive liquid that gives a crystalline product
 - a. Climbing film evaporator
 - b. Falling film evaporator
 - c. **Forced circulation evaporator**
 - d. Vertical tube evaporator
3. What is the purpose of a deflector in a forced circulation evaporator?
 - a. Creates large surface area

- b. Facilitates pumping of liquid
 - c. Promotes separation of liquid and vapour**
 - d. Provides heat to the evaporator
- 4. Which of the following is TRUE about the Multiple effect evaporator?
 - a. It is suitable for batch operation
 - b. It is highly economical relative to a single effect**
 - c. It cannot attach more than two evaporators
 - d. It utilizes a horizontal tube evaporator
- 5. The quantity of vapour produced per unit of steam admitted is called
 - a. efficiency of the evaporator
 - b. capacity of the evaporator
 - c. productivity of evaporator
 - d. economy of the evaporator**
- 6. **Evaporator working on basis of Pump or pressure:**
 - A. Climbing Film Evaporator
 - B. Triple effect evaporator
 - C. Horizontal Tube Evaporator
 - D. Forced Circulation Evaporator**

Each carry 2 marks

1. Write the importance of forced circulation in forced circulation Evaporator.
2. How is multiple effect evaporator advantageous over single effect Evaporator?

Each carry 5 marks

1. Elaborate the concept of multiple effect evaporation. What specific advantages does it offer?
2. Explain the construction and working of a forced circulation evaporator.

Each carry 10 marks

1. Explain the term 'multiple effect evaporation' and 'evaporator Capacity. How can many effects go into a multiple effect evaporator?
2. What do you understand by multiple effect evaporator'? Describe one, Such evaporator. How do you feed such evaporator?
3. Classify evaporators. Describe principle and working of multiple effect Evaporator.