UNIT-3

Properties Of Steam

STEAM AND ITS PROPERTIES

- Steam is the gaseous phase of water. It utilizes heat during the process and carries large quantities of heat later. Hence, it could be used as a working substance for heat engines.
- Steam is generated in boilers at constant pressure. Generally, steam may be obtained starting from ice or straight away from the water by adding heat to it.

FORMATION OF STEAM

- temperature-Enthalpy Diagram t-h diagram)
  - The graphical representation of transformation of 1 kg of ice into 1 kg of superheated steam at constant pressure (temperature vs. enthalpy) is known as t-h diagram. shows the various stages of formation of steam starting from ice shows the corresponding t-h diagram.

FORMATION OF STEAM

- Consider 1 kg of ice in a pistion -cylinder arrangement as shown. it is under an Absolute Pressure say P bar and at temperature –t 0 C (below the freezing point). Keeping the pressure constant, the gradual heating of the ice leads to note the following changes in it, These are represented on a t-h diagram on heating, the temperature of the ice will gradually rises from p to Q i.e. from –t C till reaches the freezing temperature 0.

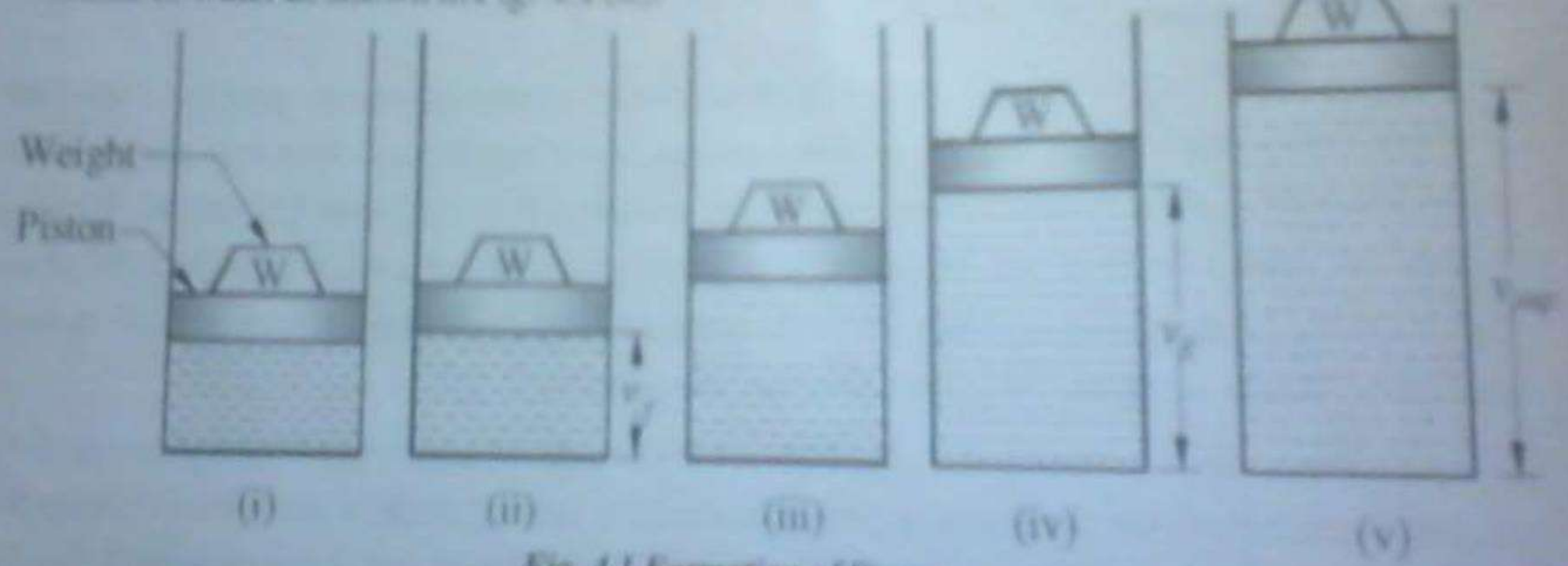


Fig. 4.1 Formation of Steam.

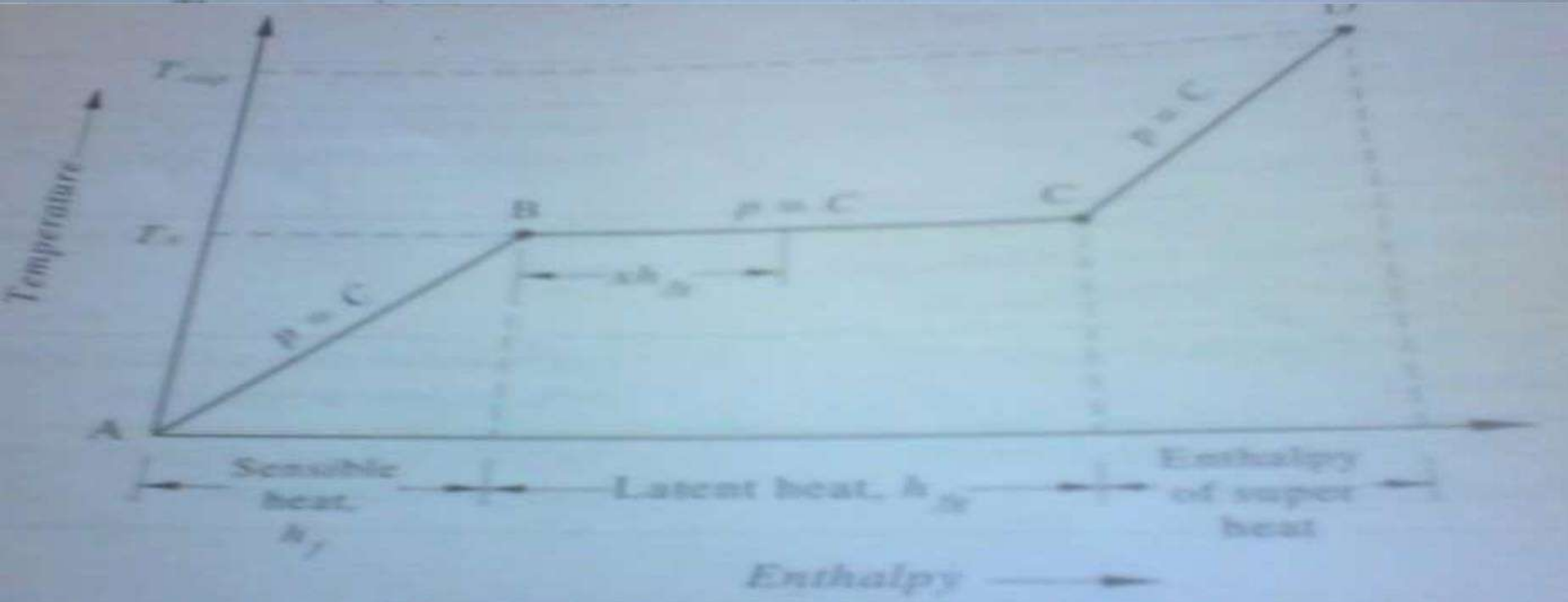


Fig. 4.2 Temperature - Enthalpy diagram

FORMATION OF STEAM

- Adding more heat, the ice starts melting without changing in the temperature till the entire ice is converted into water from Q to R. The amount of heat during this period from Q to R is called Latent heat of fusion of ice or simply Latent heat of ice.
- Continuous heating raises the temperature to its boiling point t C known as Saturation Temperature. The corresponding pressure is called saturation pressure. it is the stage of vaporization at 1.01325 bar atmospheric pressure (760mm . As pressure increases, the value of saturation temperature also increases. The amount of heat added during R to S is called Sensible Heat or Enthalpy of Saturated Water or Total Heat of Water (h, or h ''').

FORMATION OF STEAM

- During the process, a slight increase in volume of water (saturated water) may be noted. The resulting volume is known as Specific volume of Saturated Water (Vf or vW).
- (d) On further heating beyond S, the water will gradually starts evaporate and starts convert it to steam, but the temperature remains constant. As long as the steam is in contact with water, it is called Wet Steam or saturated steam

FORMATION OF STEAM

- On further heating the temperature remains constant, but the entire water converts to steam. But still it will be wet steam. The total heat supplied from OOC is called Enthalpy of Wet Steam (h wet). The resulting volume is known as Specific Volume of Wet Steam (v wet)
- On further heating the wet steam, the water particles, which are in suspension, will start evaporating gradually and at a particular moment the final particles just evaporates. The steam at that moment corresponding to point T is called Dry Steam or Dry Saturated Steam. The resulting volume is known as Specific Volume of Dry Steam (vg). This steam not obeys the gas laws. The amount of heat added during S to T is called Latent Heat of Vaporization of Steam or Latent Heat of Steam (hfg). During the process, the saturation temperature remains constant. The total heat supplied from O'C is called Enthalpy of Dry Steam (hg).

FORMATION OF STEAM

- On further heating beyond point T to U the temperature starts from ts to tu, the point of interest. This
- process is called Super heating. The steam so obtained is called Super Heated Steam. It obeys gas laws.

TYPES STEAM

The steam during the steam generation process can exist in three types:

1. Wet steam (saturated steam)
2. Dry steam (dry saturated steam)
3. Superheated steam

1. WET STEAM :

- Both the water molecules and steam coexist to form a two phase mixture, called wet steam.
- Which will be in thermal equilibrium because both of them will be at the same saturation temperature.

2. DRY SATURATED STEAM:

- A steam at the saturation temperature corresponding to a given pressure and having no water molecules in it is known as dry saturated steam or dry steam.

- Since the dry saturated steam does not contain any water molecules in it, its dryness fraction will be unity.

3. SUPERHEATED STEAM:

- When a dry saturated steam is heated further at the given constant pressure, its temperature rise beyond its saturation temperature. The steam in this state is said to be superheated.

ENTHALPY OF STEAM

- Enthalpy Of liquid:

  hf=Cpw(tf-0)

- Enthalpy of Dry saturated steam:

  hg=hf + hfg

- Enthalpy of Wet steam:

  h=hf + xhfg

- Enthalpy of Superheted steam:

  hsup= hg + Cps(Tsup –Tsat)

SPECIFIC VOLUME OF STEAM

- Specific volume of saturated water: vf
- Specific volume of dry saturated steam: vg
- Specific volume of wet steam:

$v = xvg + (1-x)vf$

- Specific volume of superheated steam:

$Vg/Ts = Vsup/Tsup$

INTERNAL ENERGY OF STEAM

- It is defined as the difference between the enthalpy of steam and external work of evaporation.

Internal energy of dry steam : $u_g = h_g - pv_g$ kJ/kg

Internal energy of wet steam : $u = h_f + xh_{fg} - pxv_g$ kJ/kg

Internal energy of superheated steam : $u_{sup} = h_{sup} - pv_{sup}$ kJ/kg

- Internal Latent heat:

  It is algebraic difference between the enthalpy of evaporation at given pressure and work of evaporation.

Internal Latent heat : $h_{fg} - pv$

THROTTLING PROCESS

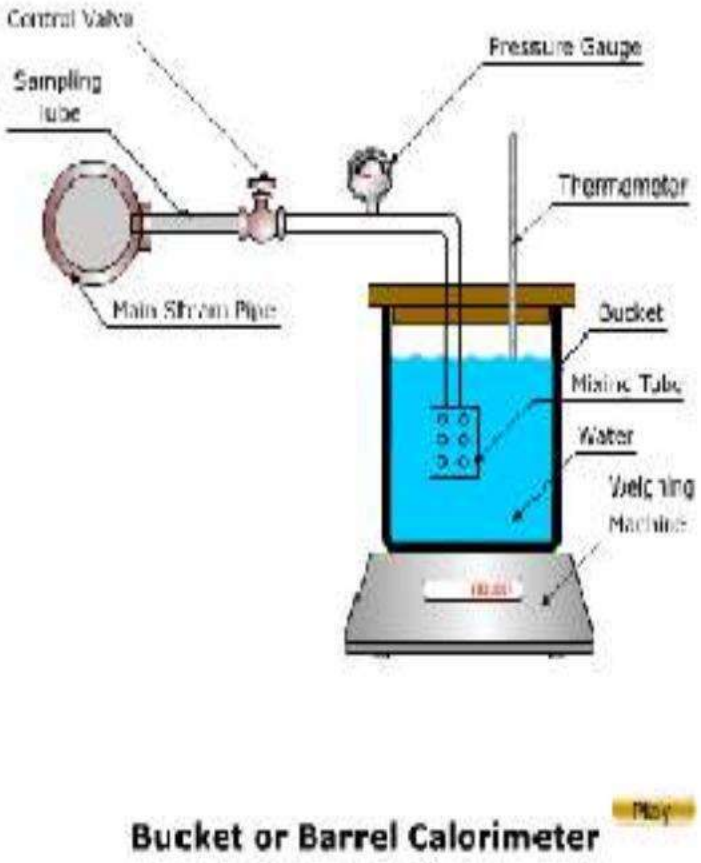
- The temperature change of a gas or liquid when it is forced through a valve or porous plug while kept insulated so that no heat is exchanged with the environment. This procedure is called a Throttling process.

MEASUREMENT OF DRYNESS FRACTION

- The dryness fraction of steam can be measured experimentally.
- Calorimeters are used for measurement of dryness fraction of steam.
- There are for methods of determining the dryness fraction of steam.

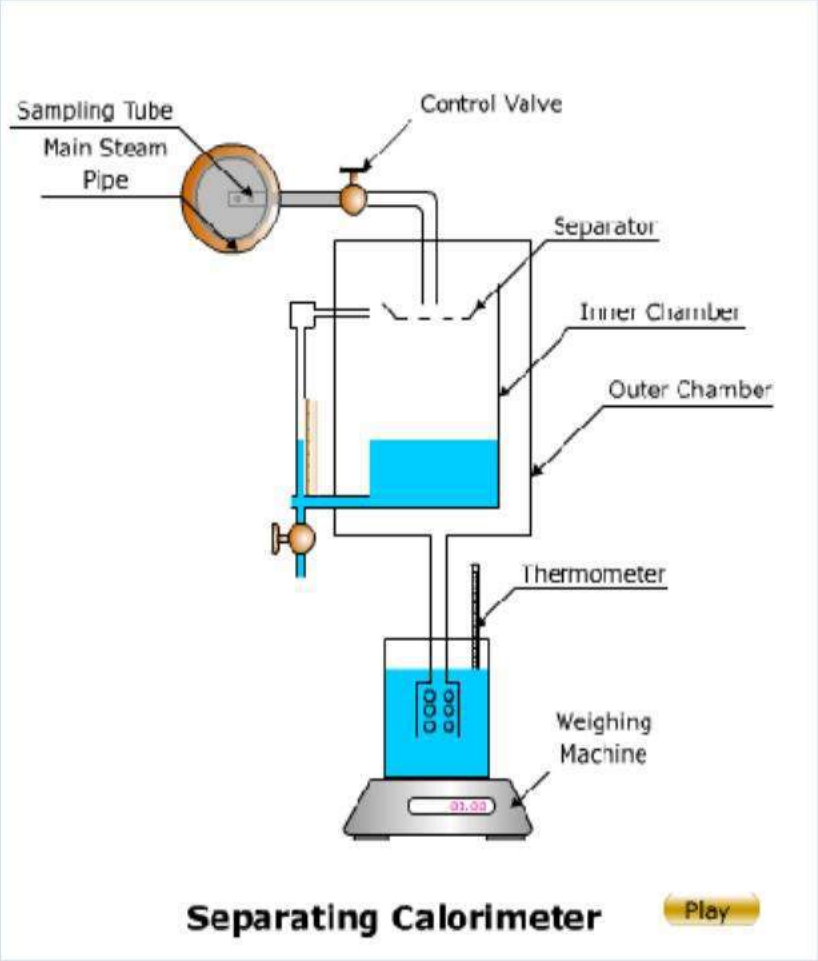
1. Bucket or barrel calorimeter
2. Throttling calorimeter
3. Separating calorimeter
4. Combined separating & throttling calorimeter

BUCKET OR BARREL CALORIMETER



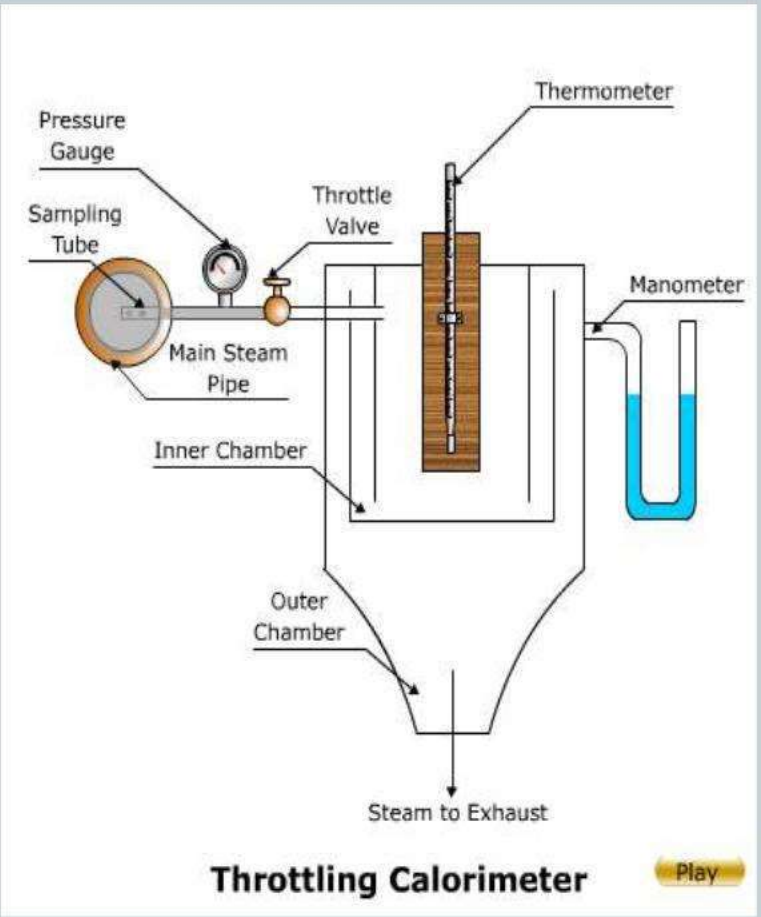
- In this calorimeter a known mass of water and then heat loss by steam is equated to heat gained by water. The steam is passed through a sample tube into bucket calorimeter contains known weight of water.
- The weight of calorimeter with water before mixing steam & after mixing the steam is measured by thermometer.

SEPARATING CALORIMETER



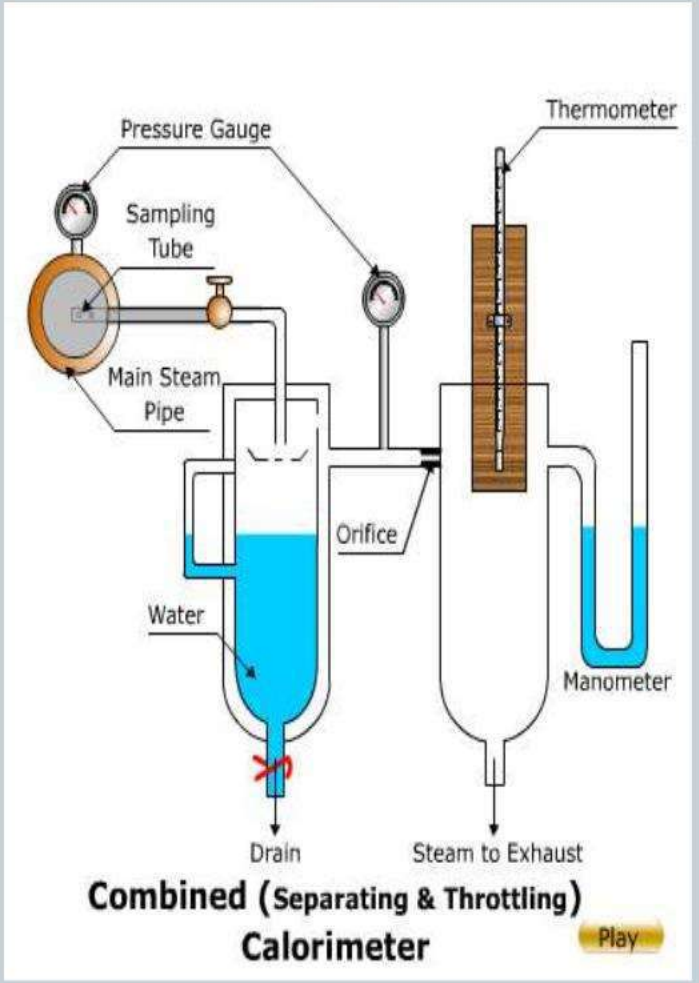
- This calorimeter is used to measure dryness fraction of very wet steam. The steam is passed through sampling tube. The moisture is separated mechanically from steam passing through the separator .
- The water partials are separated due to inertia of water partials as steam is passed through the perforated trays.
- The out going steams is then condensed in the bucket calorimeter.

THROTTLING CALORIMETER



- This types of calorimeter is used to measure dryness fraction of steam whose dryness fraction is considerably high.
- The steam sample is passed through a throttle valve & is allowed to throttle down to pressure unit until it comes out in dry saturated or super heated condition.
- The pressure & temperature of steam coming out of throttling calorimeter is measured with water manometer & thermometer respectively.

COMBINED SEPARATING & THROTTLING CALORIMETER



COMBINED SEPARATING & THROTTLING CALORIMETER

- The combined separating & throttling calorimeter gives the dryness fraction of wide quality steam very accurately.
  - In this calorimeter, the stream from sampling tube is first passed through the separating calorimeter where most of the moisture is removed & steam partly dried.
- This steam is further passed to throttling calorimeter where it comes out as dry saturated or in superheated form.
- The steam coming out from throttling calorimeter is condensed in condenser coming out of condenser is recorded.
  - The weight of water separated In separating calorimeter & the pressure & temperature of steam coming out from throttling valve are also recorded.