# Velammal Institute of Technology, Panchetti
## Department of Mechanical Engineering

## ME8351- ENGINEERING THERMODYNAMICS
Focused question

## *UNIT- III*
## *PROPERTIES OF PURE SUBSTANCE & STEAM POWER CYCLE*

***PART –A (2 marks)***

**1. Define latent heat of ice?**

Total amount of heat added during conversion of ice 0° C into water of 0°C.

**2. What is pure substance?**

Pure substance is a substance which has a fixed chemical composition throughout its mass

.Example: Water, Nitrogen, Carbon dioxide, and helium. A pure substance does not have to be of a single chemical element or compound .A mixture of various chemical element or components is also called as pure substance as long as the mixture is homogeneous.

**3. What is saturation temperature and saturation pressure?**

At a given pressure, the temperature at which a liquid boils is called saturation temperature. At the given temperature, the pressure at which the liquid boils is called saturation pressure it is also called as vapour pressure.

**4. Define latent heat of vaporizations.**

The amount of heat added during heating of water from boiling point to dry saturated stage is called as latent heat of vaporization or enthalpy of vaporization of latent heat of steam.

**5. Define the terms 'Boiling point 'and 'Melting point' .**

Boiling point:

It is the temperature at which the liquid starts to change its state from liquid to vapour. Melting point:

It is the temperature at which the solid starts to change its state from solid to liquid.

**7. Define the sensible heat of water.**

The amount of heat required to raise the temperature of unit mass of water from 0°C to the saturation temperature under a constant pressure. it is denoted by hf .

**8. Define the term super heat enthalpy.**

The heat supplied to the dry steam at saturation temperature, to convert it into superheated steam at the temperature Tsup is called super heat enthalpy.

**9. What is wet and dry steam?**

The heat which partially evaporated and having water particles suspension is Called wet stream.

The steam which fully evaporated state and is not having any water particles is Called dry steam.

**10. State phase rule of pure substances.**

The number of independent variable associated with a multicomponents, multiphase system is given by the phase rule. It is also called as Gibbs phase rule .It is expressed by the equation as

$n = C - \Psi + 2$

Where,

n = the number of independent variable.
C = the number of components,

$\Psi$ = the number of phase present in equilibrium.

**11. Define dryness fraction of steam OR What is quality of steam?**

It is defined as the ratio of the mass of the total steam actually present to the mass of the totalsteam.

$$\text{Dryness fraction} = \frac{\text{Mass of dry steam}}{\text{Mass of total mixture}}$$

**12. Explain the term: Degree of super heat, Degree of sub cooling.**

**Degree of super heat:**

It is the difference between superheated temperature and saturated temperature at the same pressure.

**Degree of sub cooling.**

It is the amount by which the water is cooled beyond the saturated temperature at the same pressure.

**13. Define triple point and critical point for pure substance. Triple point:**

Triple point is the state at where all the three phases ie solid, liquid and vapour to exist in equilibrium.

**Critical point:**

It represents the highest pressure and temperature at which the liquid and vapour phases coexist in equilibrium. At the critical point the liquid and the vapour phases are distinguishable ie Liquid directly converted into vapour.

**14.When saturation pressure increases, what happens to saturation temperature** and freezing point? When saturation pressure increases, then the saturation temperature is increasing and the freezing point decreasing.

**15 Explain the process of steam generation and show the various stages on T-S diagram.**

In the T-S diagram, the region left of the water line, the water exists as liquid. In the right of the dry steam line, the water exists as a superheated steam. In between water and dry steam line, the water exists as a wet steam. Therefore, the dryness fraction lines are represented in these regions. The value of various quantities can be read from the diagram .It can be noted from the figure that thewater line and steam line are converging with the increase in temperature. At a particular point , the water directly converted into dry steam without formation of wet steam. The point is called „Critical Point"

**16. Write the formula for calculating entropy change from saturated water to super heated steam conditions.**

Entropy of super heated steam S sup = Sg + Cps log{Tsup / Ts}

***PART –B***

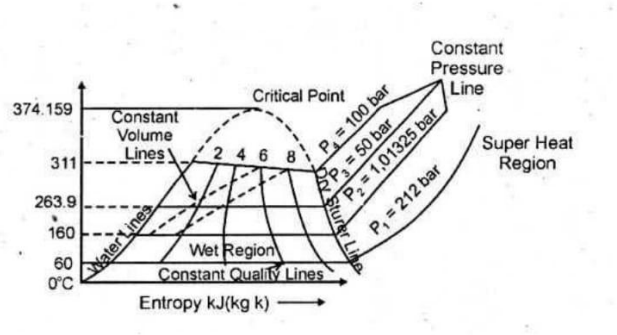
**1. Briefly explain the process of super-heated steam forming with the help of T-s diagram.**

**Formation of super-heated steam**

T-S is the plot of the saturation temperature of water and steam corresponding to the various absolute pressures against the entropies at those saturation temperature. It's show in figure. It is. very much useful to solve the numerical problems on steam as it considerably reduces time and labour m making calculations.

In the T-S diagram (for water), the region left of the water line, the water exist as liquid. In the right of the dry steam line, the water exists as a superheated steam. In between water and dry steam line, the water

exists as a wet steam. Therefore the dryness fraction lines are represented in these regions as shown in Figure. The value of various quantities can be directly read from the diagram.




It can be noted from the figure that the water line and steam line are covering with the increase in temperature. At a particular point, the water is directly converted into dry steam without formation of wet steam. This point is called critical point.

An isothermal process is represented by a horizontal line and a reversible adiabatic or isentropic process is represented by a vertical line. In the diagram, constant volume increase plotted in the wet region and constant pressure lines are plotted in the superheated region.

**Quality of steam**

Dryness fraction is defined as the ratio of the mass of the dry steam actually present to the mass of the total steam. It is denoted by V.mg - mass of dry steam in kg mg - mass of water vapour in suspension

Dryness fraction, $x = \frac{mg}{mf + mg}$.

mg – mass of dry steam in kg

mf – mass of water vapour in suspension.

This term presents only for wet stream.

For dry steam *mf* = 0.

The dryness fraction when expressed in percentage, (i.e., 100 x) is called the quality of steam.

**Wetness Fraction**

It is define as the ratio of the mass water vapour in suspension to the total steam

wetness fraction = $m_f/m_f+m_g$

**Phase Rule**

**The number of independent variables associated with multicomponent system is given by the phase rule, It is also called as Gibbs phase rule. It is represented by the equation as**

**$n = C - \psi + 2$**

**Saturation state**

The amount of heat added during heating of water from boiling point to dry saturated stage is called as latent heat of vaporization or enthalpy of vaporization or latent heat of system.

**Carnot cycle is not practicable for a steam power plant:**

The main difficulty to attain the cycle in practice is that isothermal condensation is stopped before it reaches to saturated liquid condition. Therefore the compressor has to deal with a non-homogeneous mixture of water and steam. Because of the large specific volume of liquid vapour mixture before compression, the compression size and work input have to be large. The higher power requirement reduces the plant efficiency as well as work ratio.

**Critical temperature and critical volume:**

The temperature, pressure and volume at the critical point is known as critical temperature, critical pressure and critical volume.

**Critical temp**: 374.15°C; Critical pressure: 221-2 bar

**Critical volume:** 0.00317 $m^3$/Kg

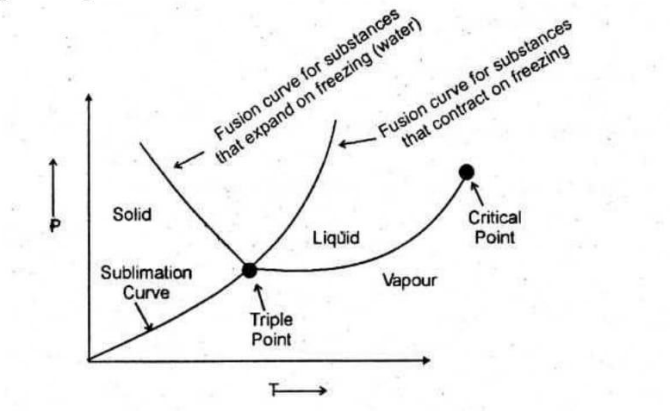
**Dryness Fraction:**

It is defined as the ratio of the mass of the dry steam actually present to the mass of the total steam. It is denoted by *x*.

$$\text{Dryness Fraction, } x = \frac{m_g}{m_f + m_g}.$$

## 2. Explain the following p-v, p-T, T-v, T-s, h-s diagrams.

**p-T diagram**

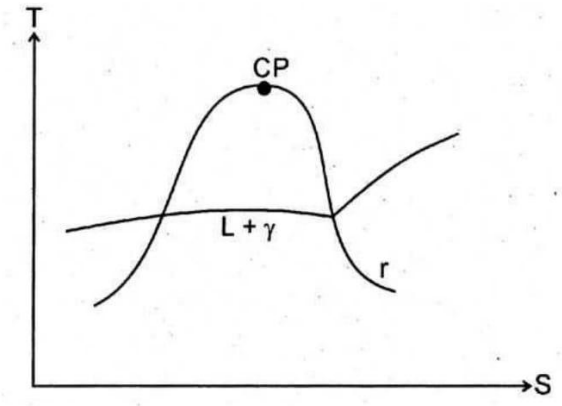


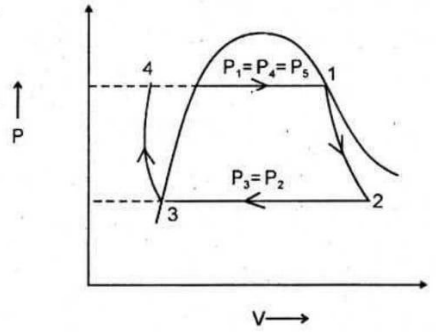

The state changes of a pure substance when heated slowly at different constant pressure are plotted on P − T co-ordinate as shown in Figure. This diagram is often called as phase diagram since all three phases are separated from each other by three lines. The sublimation curve separates the solid and vapour regions, the vaporization, curve separates the liquid and vapour regions, and the fusion or melting curve separates the solid and liquid regions. These three curves meet at the triple point where all three phases consist on equilibrium. The vaporisation curve ends at the critical point because above this point no distinction can be made between liquid and vapour phases.

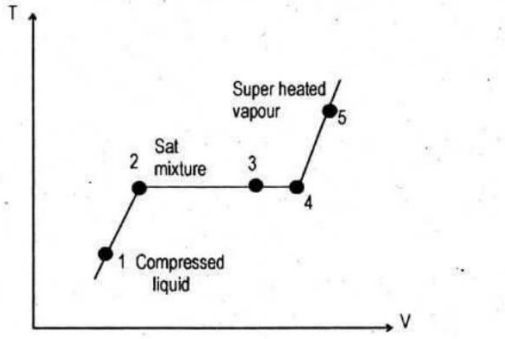
**T-S diagram:**

The Rankine Cycle is an ideal cycle for vapour power cycles.

**Processes:**
**p-V diagram:**
**1-2:** Isentropic expansion
**2-3:** Constant Pressure and heat Rejection
**3-4:** Water is pumped to boiler Pressure
**4-5:** Constant pressure head addition in boiler up to sat-temperature.
**5-1:** Constant pressure and temperature in boiler.

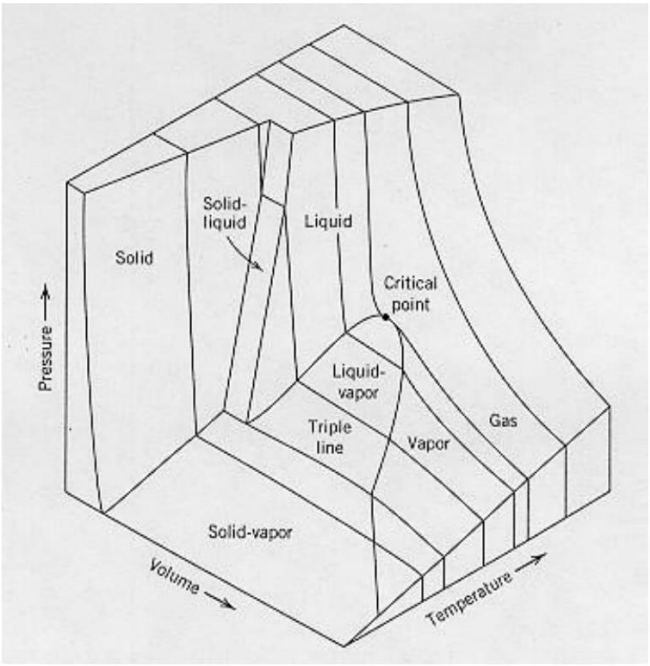



The substance 2 and 3-exists between liquid and vapour region. Involve both phases in a equilibrium are located under the done, called the **saturated liquid-vapour mixture** region (or) wet region.

**p-v-T surface.**




**3. What do you understand by pure substance? Give some typical examples. Ideal and actual Rankine cycles**

Plot the standard Rankine cycle on T-s diagram and label the all the processes assuming the steam to be dry and saturated at the end of expansion.

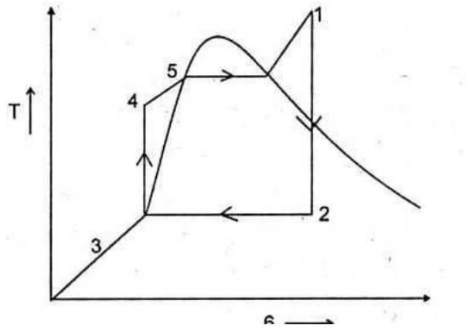
**Process:**

1- 2: Isentropic expansion
2- 3: Constant pressure and temperature heat rejection
3- 4: Water is pumped to boiler pressure
4- 5: Constant pressure heat addition in boiler up to
5- 1: Constant pressure and temperature is boiler

**Efficiency of Rankine Cycle**

The improvements that can be made to improve the efficiency of Rankine cycle are

1) Lowering the condenser pressure.
2) Super heated steam is supplied to the turbine.
3) Increasing the boiler pressure to certain limit.
4) Implementing reheat and regeneration in the cycle.




**4. Cycle Improvement Methods - Reheat and Regenerative cycles, Economizer, pre heater, Binary and Combined cycles.**

The methods for improving the performance of the Rankine cycle are

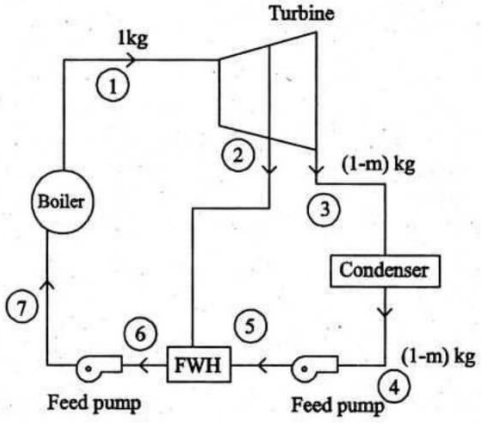
(1) Lowering the condenser pressure.

(2) Super heated steam is supplied to the turbine.

(3) Increasing the boiler pressure to certain limit.

(4) Implementing reheat and regeneration is the cycle.

**Regenerative Rankine cycle with an open feed water heater:**




Steam is bled from the turbine at the time of expansion to the feed water heater, where the feed water is preheated before entering in to the boiler

$$\eta_{reg} = \frac{W}{Q_S} = \frac{(h_1 - h_2) + (1 - m)(h_2 - h_3)}{h_1 - h_7}$$

This increases the efficiency.

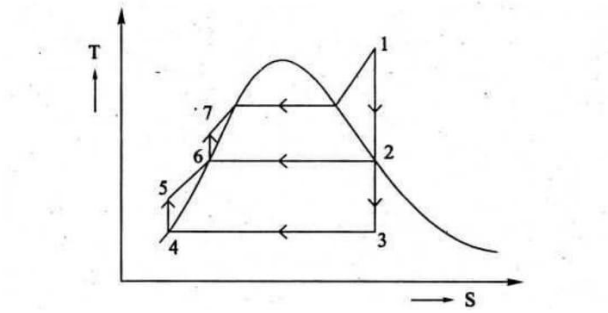
To find mass of steam bled,

According to energy balance in feed water heater

$$m\,h_2 + (1 - m)\,h_5 = h_6$$

$$m\,h_2 + h_5 - m\,h_5 = h_6$$

$$m = \frac{h_6 - h_5}{h_2 - h_5}$$




**Effect of regeneration of a steam power plant:**

The effects of regeneration of a steam power plant are

- ✓ Improving thermal efficiency.
- ✓ Effective utilization of heat.