* Property of steam

Assignment No: 1

Q① Explain the formation of steam with the help of temperature - specific volume or heat added diagram also indicate sub-cooled, wet and super heated zones

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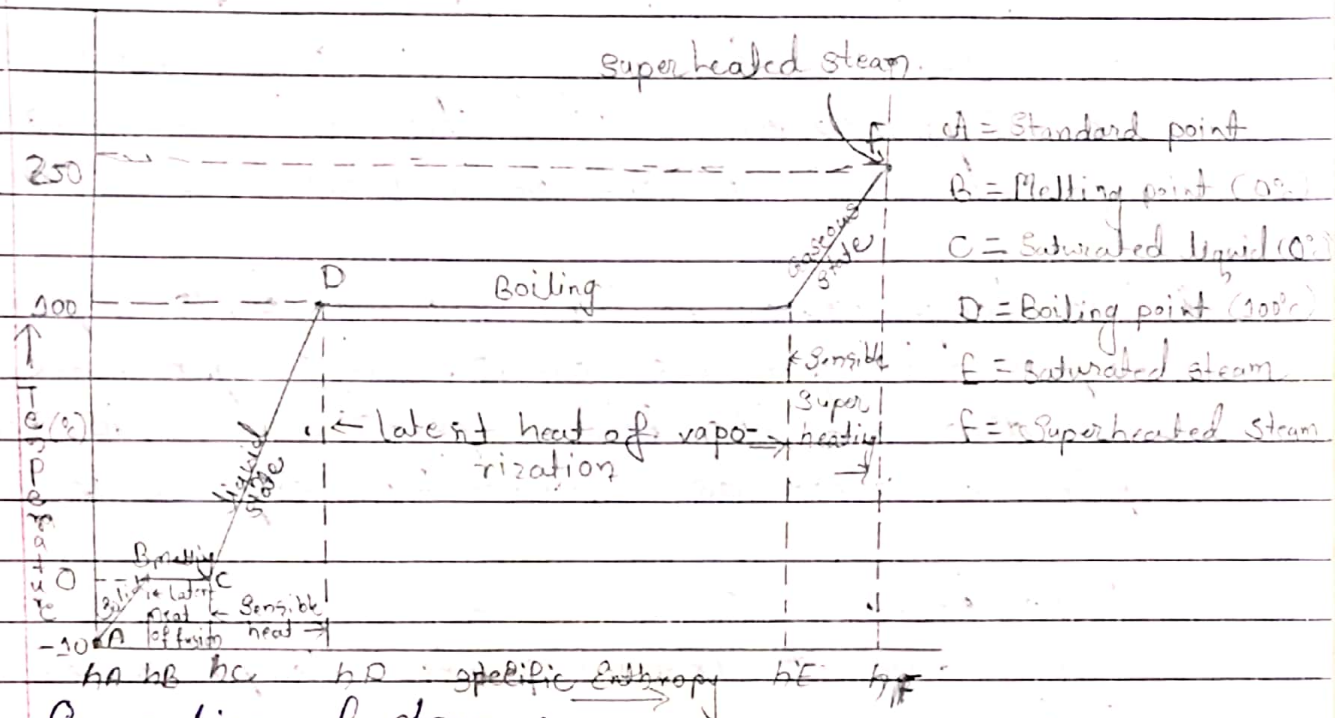

formation of steam:

① In general, steam can be formed by boiling water in a vessel. Steam formed at a higher pressure has higher temperature and can be made to flow easily through insulated pipes. from steam generator to point of use by this diagram

② Consider, a cylinder fitted with frictionless piston which may be loaded to any desired pressure 'P' bar. There is 1 kg of water 'initially at temperature 0°c' and constant pressure 'P' bar in cylinder under piston.

(3) The area of piston be one squre meter and volume of water be Vw m^3. Length of cylinder occupied by water is Vw m.

(4) let, heat be supplied to water and temperature of water will be rise when sensible enthalpy be supplied and until the boiling point is reached and it will be remain constant.

(4) The temperature at which water boils depends upon the pressure on it. Given pressure there is one definite boiling point and this boiling point is called as saturation temperature (t_s).

(5) Water boils at 99.63°c when the pressure on it is 1 bar and at 184.09°c when the pressure on it is 11 bars.

(6) Water will expand slightly during rising temperature and increasing volume of water due to move up of piston.

(7) In here is only small portion of heat added to water during rising temperature and this may be neglected in general.

(8). there is no further increasing temperature and pressure maintained constant but steam begins to form. this is actual production of steam.

⑨ Piston commences to rise in cylinder and rising higher and more higher as formed steam. The heat is absorbed is now converting water into steam is called evaporation enthalpy.

⑩ The steam formed will not be pure (dry) steam. and some water mixed with it, the part of water is evaporated and mixture of water and steam are put in cylinder. this mixture of steam is called wet steam.

⑪ Then heating of wet steam and as soon as last particle of water and produce steam is called dry saturated steam.

⑫ And heat is added in dry steam with constant 'p', rising temperature and volume is increasing is ~~called~~ this type of steam is called superheated steam.

Q ②. Define /explain the following :

① Saturation Pressure : The boiling temperature of water at a particular pressure is known as 'Saturation temperature' and corresponding pressure is known as 'Saturation pressure'.

② Saturation temperature : The boiling temperature of water at a particular pressure is known as 'Saturation temperature'.

③ Saturated liquid :
At 1 atm pressure and 100°C water exists as a liquid which is ready to vaporise is known as 'Saturated liquid'

④ Saturated vapour :
At 1 atm pressure, the temperature remains constant at 100°C until the last drop of liquid is vaporised is called as 'Satured Vapour'

⑤ Critical point :
The point where the change of volume falls to zero is known as 'Critical point'.

⑥ Dryness fraction of steam :
The ratio of mass of dry vapour (steam) to the total mass of mixture of water and steam.

$$x = \frac{mg}{mf + mg}$$

Q③. What is steam table ? Explain it's need and use briefly.

→ Steam table : The properties of steam such as pressure, temperature, specific volume, enthalpy and entropy are available in a tabular form and they are known as the thermodynamics steam table.

* ① Steam tables given values of 1 kg of water and 1 kg of steam.
* ② The steam table gives values of properties from the triple point of water to the critical point of steam.
* ③ If pressure is known use the table on pressure basis.
* ④ If temperature is known use the table on temperature basis.
* ⑤ Steam table is used because hand-calculating all the properties of may not be possible at times.
* ⑥ Ex: Specific heats for a fluid are weakly non linear function of temperature.

  In general, This function is not analytically known and values are found experimentally or with some interactive analytical approch. To maintain consensus among all, there need to be standard tables.

* ⑦ These properties are required in thermodynamics calculations where steam is used as working medium. It is quite comberstone to calculate each time, the value and relation between various properties. So, these are experimentally determined and presented in the form of tables showing value of each property w.r.t. either saturation temp^n or saturation pressure. These are called steam tables. If any given pressure falls in between two values given in table then value of concerned property on this pressure may be calculated by interpolation.

Q (4). Which are the different properties of the steam? Derive the relations to compute these properties from the steam table for subcooled liquid, wet steam and superheated steam.

⟹ The different properties of the steam are.

1. Specific enthalpy of water (h_w).
2. Specific enthalpy of saturated water (h_f).
3. latent heat of evaporation (h_{fg})
4. Specific enthalpy of dry saturated steam (h_g).
5. Specific enthalpy of super heated steam (h_{sup}).
6. ~~wet~~ Internal energy (u)
7. Entropy

proof: Take (1) wet steam:

(i) Dryness fraction $\boxed{(x) = \frac{m_g}{m_f + m_g}}$

Where,

m_g = mass of dry steam (kg);
m_f = mass of liquid water in mix (kg).

and (ii) Enthalpy of evaporation:

$\boxed{H_{fg} = x \cdot H_{fg}}$ .. KJ/kg ... (1 kg of wet steam).

(iii) Total heat: $\boxed{H_g = H_f + H_{fg}}$
(dry saturated steam)

(iv) Specific volume: $V_A = V_f + V_{fg} \cdot x$; $V_g = V_f + V_{fg}$.

$$\boxed{V_{sup} = \frac{V_g}{T_s} \times T_{sup}}$$

Where, V_{sup} = Specific volume of superheated steam.
V_g = Specific volume of dry saturated steam.
T_S = Temperature of dry saturated steam.

2) Superheated steam:

(i) $\boxed{H_{sup} = H_g + C_p(T_{sup} - T_{sat})}$

(ii) Internal Energy : $\Delta u = [H_{sup_2} - H_1] - [P_2 V_{sup_2} - P_1 V_1]$

(iii). Entropy (S): $S_{sup} = S_g + C_p \cdot \ln\left(\frac{T_{sup}}{T_{sat}}\right)$ kJ/kgK.

∴ Internal Energy for wet steam :

$$\Delta u = [(H_{f2} + X_2 \cdot H_{fg2}) - (H_{f1} + X_1 \cdot H_{fg1})] - (P_2 X_2 V_{g2} - P_1 X_1 \cdot V_{g1}).$$

∴ Entropy (S) for wet steam :

$$\boxed{S = S_f + S_g.}$$

Numericals :

Q ①. Calculate the specific volume and specific enthalpy of steam at 35% quality and pressure of 20 k·Pa.

→ Given, $x = 0.35 = \frac{35}{100} = 35\%$.

$p = 20$ kpa.
$v_g = ?$, $h_g = ?$

by steam table, we get,
$v_f = 0.001$ m^3/kg.
$v_g = 7.648$ m^3/kg
$H_f = 251.42$ kJ/kg.
$H_{fg} = 2357.5$ kJ/kg
$H_g = H_f + x \cdot H_{fg}$.

$H_g = 251.42 + 0.35 \times 2357.5$
$= \boxed{1076.54 \text{ kJ/kg}}$

and $v_g = v_f + x \cdot v_{fg}$ ... $(v_g - v_f)$
$= 0.001 + 0.35 \times (7.648 - 0.001)$.
$= \boxed{2.67 \text{ kJ/kg}}$

Q ②. Steam at 550 kPa and quality 92% occupies a rigid vessel of $0.4 m^3$. Calculate the mass, internal energy and enthalpy.

→ Given, $x = 0.92$, $p = 0.55$ MPa
$m = ?$, $u = ?$, $H = ?$

$\therefore v = x \times v_g = 0.92 \times 0.348 = 0.32$ m^3/kg

$\therefore m \cdot v = 0.4$
$\therefore m = 0.4/0.32 = \underline{1.25 \text{ kg}}$

$U = m(H - PV)$

$= m(H_f + X \cdot H_{fg} - PV)$

$= 1.25(655.72 + 0.92 \times 2096.6 - 550 \times 0.32)$

$\boxed{U = 3070.74 \text{ kJ.}}$

$H = m \times (H_f + x \cdot H_{fg})$

$= 1.25 \times 2584.59$

$\boxed{H = 3230.74 \text{ kJ.}}$

Q ③. A closed rigid vessel contains 125 g of liquid and 7.5 g of water vapours in equilibrium at 0.5 MPa. Determine the volume of the mixture.

→ Given, $P = 0.5$ MPa, $m_{steam} = M_L + M_V = 125 + 7.5$
$V = ?$ $= 132.5$ g.

$x = \frac{m_g}{m_f + m_g} = \frac{7.5}{132.5} = 0.05$

$v_g = v_f + x \cdot v_{fg} = 0.001 + 0.05 \times (0.374 - 0.001)$

$\boxed{v_g = 0.0196 \ m^3/kg}$

Volume of mix. steam $= m \times v_g = 132.5 \times 10^{-3} \times 0.0196$
$= 2.60 \times 10^{-3} \ m^3$.

$\therefore$ Volume of mix. Steam $= 2.60 \ lit^3$.

Q ④. A rigid tank of volume of 1 m^3 contains saturated steam of 100 kPa. If you cool the water to $T = 90°C$. Calculate the quality of the new mixture.

⟹ Given,

V_L = Vol. of liquid = 125 × 0.0010 = 0.0001 m^3.

V_v = Vol. of vapour = 0.0075 × 0.3740 = 0.0028 m^3

∴ Total volume = $V_L + V_v$ = 0.0029 m^3

∴ $\boxed{\text{Total volume} = 2.9 \text{ litres}}$.

Q ⑤. Calculate the mass of 15 m^3 of water (mixed phase liquid - vapour) at 500 kPa and quality of 50%.

⟹ Given, V_{steam} = 15 m^3.

P = 500 kPa

x = 0.5

$$v_g = 0.001 + 0.5 \times (0.374 - 0.001)$$
$$= 0.1875 \ m^3/kg$$

$$V_{steam} = m \times v_g$$
$$15 = m \times 0.1875$$
$$\boxed{m = 80 \ kg}$$

Q6. A closed rigid vessel contains 50g of liquid water and 50g of water vapour in equilibrium at 0.1 MPa

→ Given, $p = 0.1$ MPa, $x = 0.5$, $m = 50g + 50g = 0.1$

$$v_g = v_f + v_{fg} = 0.847 \ m^3/kg$$
$$v_{fg} = 0.5 \times 1.692 = 0.846 \ m^3/kg$$

$$H_g = H_f + H_{fg} = 1546.2 \ kJ/kg$$
$$H_{fg} = 0.5 \times 2257.4 = 1128.7 \ kJ/kg$$

$$S_g = S_f + S_{fg} = 4.325 \ kJ/kgK$$
$$S_f = 1.3 \ kJ/kgK$$
$$S_{fg} = 0.5 \times 6.05 = 3.02 \ kJ/kgK$$

$$\text{Internal energy} = m (H_g - PV)$$
$$= 0.1 (1546.2 - 0.1 \times 10^3 \times 0.847)$$

$$\boxed{U = 146.15 \ kJ}$$

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Q.(6). A closed rigid vessel contains 50g of liquid water and 50g of water vapour in equilibrium at 0.1 MPa.

→. Given, $p = 0.1$ MPa, $x = 0.5$, $m = 50g + 50g = 0.1kg$

$V_g = V_f + V_{fg} = \underline{0.847}$ m^3/kg

$V_{fg} = 0.5 \times 1.692 = \underline{0.846}$ m^3/kg.

$H_g = H_f + H_{fg} = \underline{1546.2}$ kJ/kg.

$H_{fg} = 0.5 \times 2257.4 = \underline{1128.7}$ kJ/kg.

$S_g = S_f + S_{fg} = \underline{4.325}$ kJ/kgK

$S_f = \underline{1.3}$ kJ/kgk.

$S_{fg} = 0.5 \times 6.05 = \underline{3.02}$ kJ/kgk.

Internal energy $= m(H_g - PV)$

$= 0.1(1546.2 - 0.1 \times 10^3 \times 0.847)$

$$\boxed{U = 146.15 \text{ kJ}}$$