Determination of Dryness fraction :-

It is defined as the ratio of the mass of actual dry steam to the mass of same quanity of wet Steam.

$$X = \frac{m_g}{m_g + m_f}.$$

where

m_g = Mass of actual dry steam.

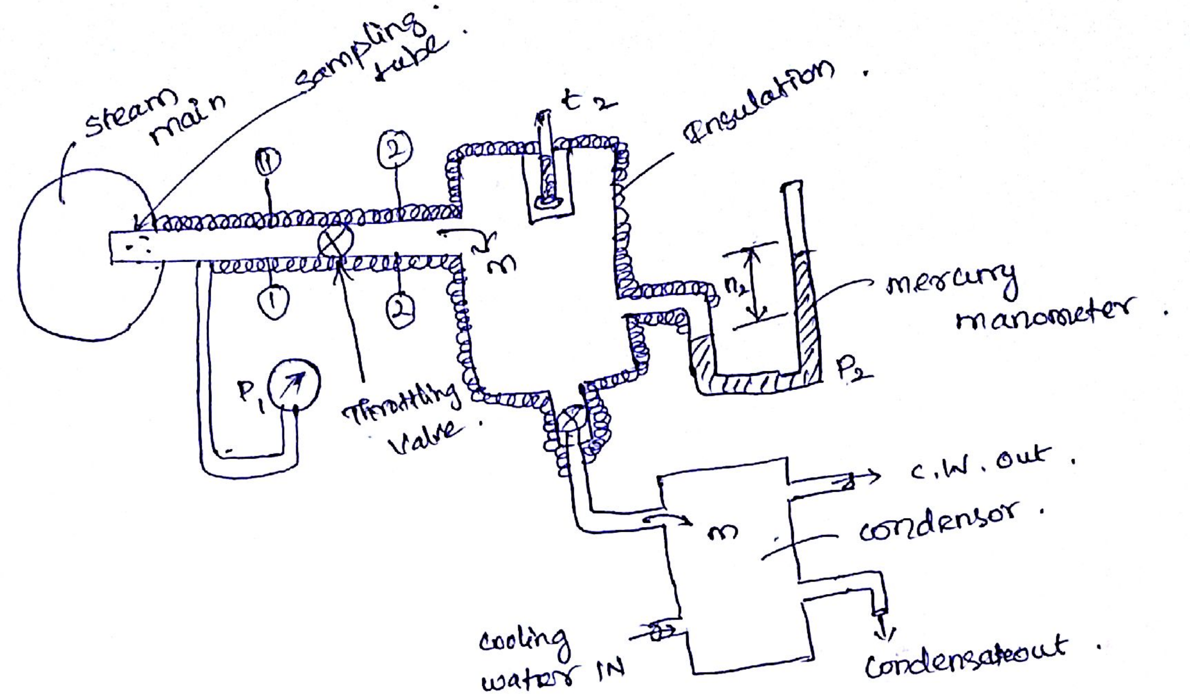
m_f = Mass of water is suspension

m = mass of wet Steam. $= m_g + m_f$.

latent heat of evaporization:-

The amount of heat added during heating of water from boiling point to dry saturated State is called latent heat of evapourization (or) enthalpy of vaporization.

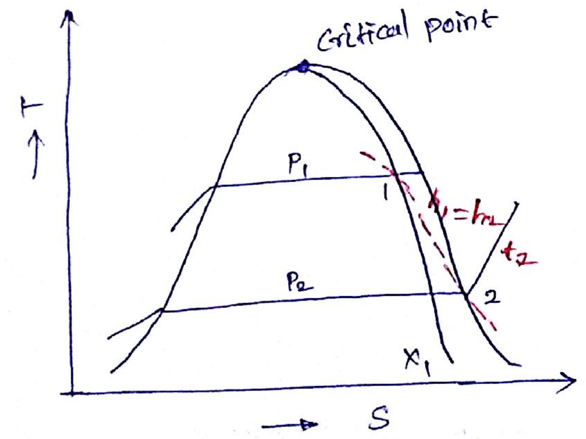
Throttling Calorimeter :-



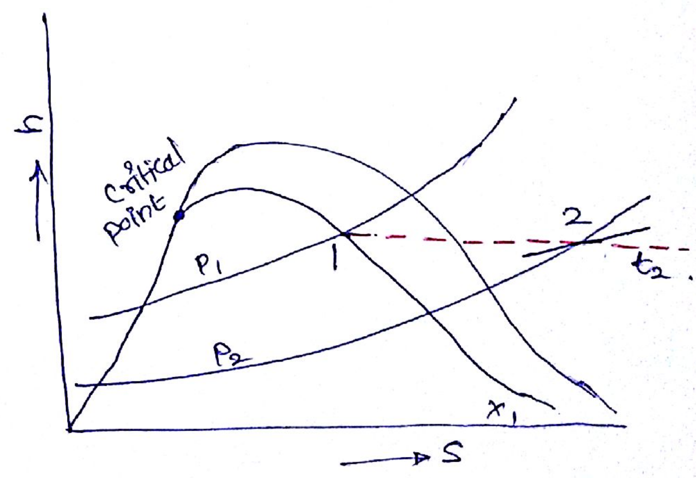
⇒ In the throttling calorimeter, a sample of wet steam of mass m and at pressure P_1 is taken from the steam mainly through a perforated sampling tube.

⇒ The wet steams are ~~flow~~ partially flowing the chamber and then P_2 pressure measured by mercury manometer, and temperature t_2. So that after throttling the steam is in the superheated region.

⇒ Steady flow energy equation gives the enthalpy after throttling as equal to enthalpy before throttling.



T-S diagram.



h-s diagram.

⇒ The initial and final equilibrium states 1 and 2 are joined by a dotted line since throttling is irreversible and the intermediate states are non-equilibrium state.

⇒ The initial states (wet) is given by P_1 and x_1 and the final state by P_2 and t_2 (superheated).

⇒ P_2 and t_2 are known values, h_2 can be found out from the superheated steam table.

⇒ The values of h_f and h_{fg} are taken from the saturated steam table corresponding to pressure P_1. Therefore, the quality of the wet steam x_1 can be calculated.

$$h_1 = h_2$$

$$h_2 = h_{fP1} + x_1 h_{fgP1}$$

$$\boxed{x_1 = \frac{h_2 - h_{fP_1}}{h_{fgP1}}}$$

Separating and Throttling Calorimeter :-

⇒ When the steam is very wet and the pressure after throttling is not low enough to take the steam to the superheated region then a combined separating and throttling calorimeter.

It is used for the measurement of quality.

⇒ In first, the steam is passed through a separator, where some part of the moisture separates out due to the sudden change in direction.

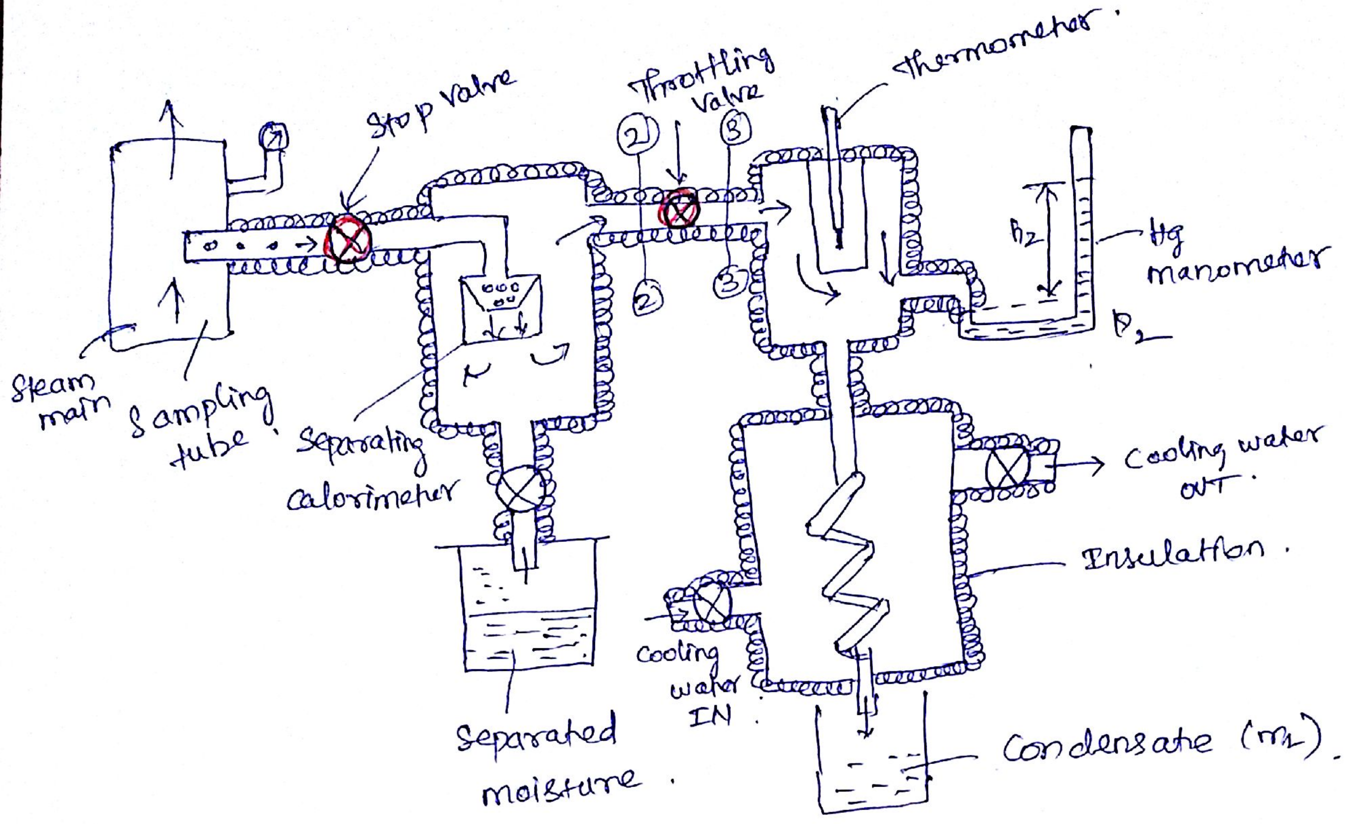
⇒ 1-2, the moisture separation from the wet sample of steam at constant pressure P_1

⇒ 2-3, throttling the pressure P_2.

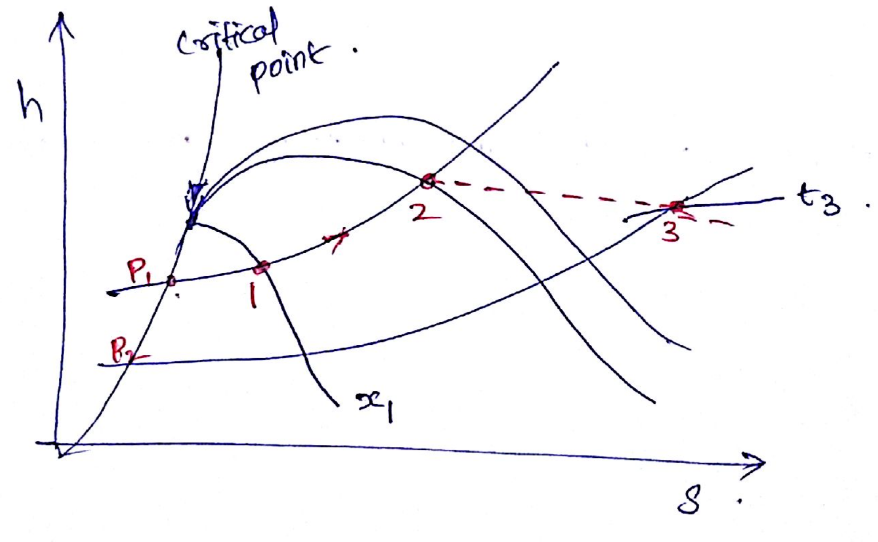
⇒ wet steam moisture is separate and then condensed & collected

⇒ partially dry steam is throttled to superheated vapour at lower pressure P_2. condensed and collected.

⇒ With P_2 and t_2 are measured, h_3 can be found out from the superheated steam table.



$$h_3 = h_2 = h_{fP_1} + x_2 h_{fgP_1}.$$



h-s diagram.

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Enthalpy of Steam :- (H)

Wet steam $h_{wet} = h_f + x h_{fg}$ (KJ/kg)

Dry steam $h_{dry} = h_g$ (kJ/kg)

Super heat steam $= h_g + C_{ps}(T_{sup} - T_{sat})$ KJ/kg.

$= h_f + h_{fg} + C_{ps}[T_{sup} - T_{sat}]$.

C_{ps} = Specific heat of super heated steam.

2.0 to 2.3 KJ/kg.K.

Entropy of Steam :- [S]

Wet $S_w = S_f + x S_{fg}$ KJ/kg.K.

Dry $S_d = S_f + S_{fg} = S_g$. KJ/kg.K.

Superheated $S_{sup} = S_f + S_{fg} + C_{ps}\left(\frac{T_{sup}}{T_{sat}}\right)$.

~~Sapecif~~ Specific Volume of Steam :- [v]

$V_w = V_f + x V_{fg}$

wet $V_w = x V_g$.

Dry $V_d = V_g$.

$V_{sup} = V_g \times \frac{T_{sup}}{T_{sat}}$ m³/kg.

Problems :-

(1) Find the saturation temperature, the changes in specific volume & entropy during evaporation and the latent heat of vapourisation of steam at 1 MPa.

1 Pa = 10^5 bar.

1 MPa = 10 bar.

From steam table at 10 bar.

$T_{sat} = 179.9°C$.

change in specific volume,

$V_f = 0.001127$

$V_g = 0.19430$.

$V_{fg} = V_g - V_f$.

$= 0.19430 - 0.001127$

$V_{fg} = 0.1931$ m³/kg.

change in Entropy,

$$S_{fg} = S_g - S_f.$$

$$= 6.583 - 2.138.$$

$$S_{fg} = 4.445 \text{ KJ/kg.k.}$$

change in Enthalpy.

$$h_{fg} = h_g - h_f.$$

$$= 2776.2 - 762.6.$$

$$= 2013.6 \text{ KJ/kg.}$$

(2) Saturated Steam has an entropy of 6.76 KJ/kg.k. what are its pressure, temperature, specific volume, enthalpy.

$$S = 6.76 \text{ KJ/kg.K.}$$

$$T_{sat} = 158°C.$$

pressure = 5.8 bar.

Specific Volume = 0.32572

Enthalpy = 2754 KJ/kg.k.

(3) Find the enthalpy and entropy of steam, when the pressure is 2 MPa and the specific volume is 0.09 m^3/kg.

Specific Volume $V = 0.09 \, m^3/kg$.

pressure $P = 2$ MPa $= 20$ bar.

Pressure Table

$$V = V_f + x V_g.$$

$$0.09 = 0.001177 + x(0.09955)$$

$$x = 0.895$$

$$\boxed{x = 89.5\%}$$

@ 20 bar.

$$h_W = (h_f + x h_{fg})$$

$$= 908.5 + 0.895(1888.7)$$

$$\boxed{h_W = 2598.88 \text{ KJ/kg}}$$

Specific Volume :-

$$S_g = S_f + x\,S_{fg}.$$

$$= 2.447\ kJ/kg. + 0.895\,(3.890)$$

$$S_g = 5.928\ kg/kJ/K.$$

(4) Determine the condition of steam at a temperature of 8 220°C. and the enthalpy of 2750 kg/kg.,

$T = 220°C$

$h = 2750\ kJ/kg.$

$h > h_g \Rightarrow$ Superheated steam

$h = h_g \Rightarrow$ Dry steam.

$h < h_f$ = wet steam

at 220°c $h_g = 2750$

$h < h_g.$

$2750 < 2799.9.$

So, the condition is wet.

$$h_w = h_f + x h_{fg}.$$

$$x = \frac{h_w - h_f}{h_{fg}} = \frac{2750 - 943.7}{1856.2}$$

$$\boxed{x = 97.3\ \%}$$