Lecture 7

Properties of Steam

Properties of Steam

- Formation of steam and related terms, thermodynamics properties of steam, steamtables, internal latent heat, internal energy of stream, entropy of water, entropy of steam, T- S diagrams), Hyperbolic, reversible adiabatic and throttling processes Quality of steam (dryness fraction), finding dryness fraction using separating and throttling calorimeter, Rankine cycle

PROPERTIES OF STEAM

- Steam is the vapour or gaseous phase of water.
- It is produced by heating of water and carries large quantities of heat within itself.
- Hence, it could be used as a working substance for heat engines and steam turbines.
- It does not obey ideal gas laws but in superheated state it behaves like an ideal gas.

- Steam exists in following states or types or conditions.
- (i) Wet steam (mixture of dry steam and some water particles) – evaporation of water into steam is not complete.
- (ii) Dry steam (dry saturated steam) – all water is completely converted into dry saturated steam.
- (iii) Superheated steam – obtained by further heating of dry saturated steam with increase in dry steam temperature.

FORMATION OF STEAM

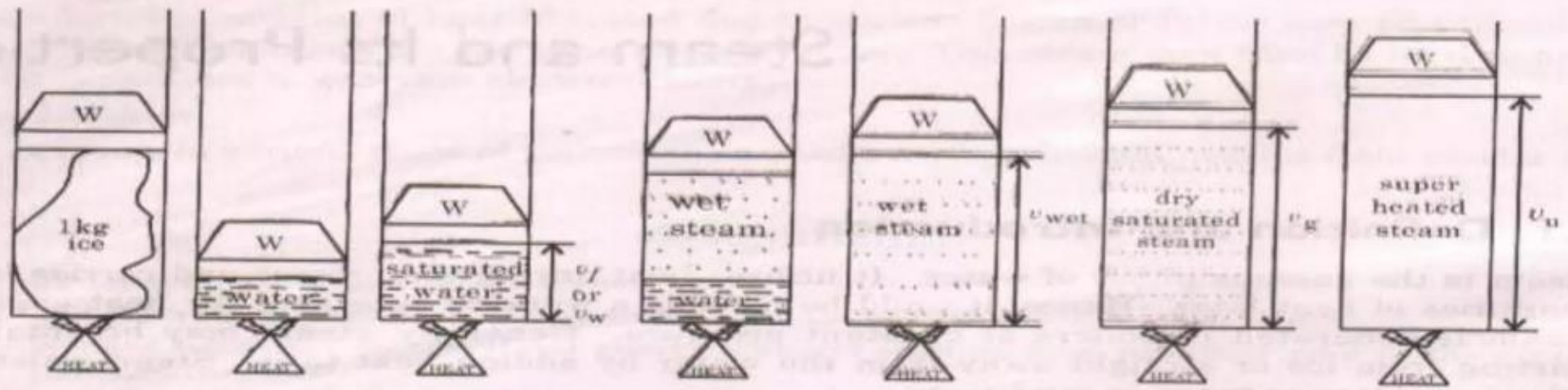


Fig 2.1 *Formation of Steam at Constant Pressure*

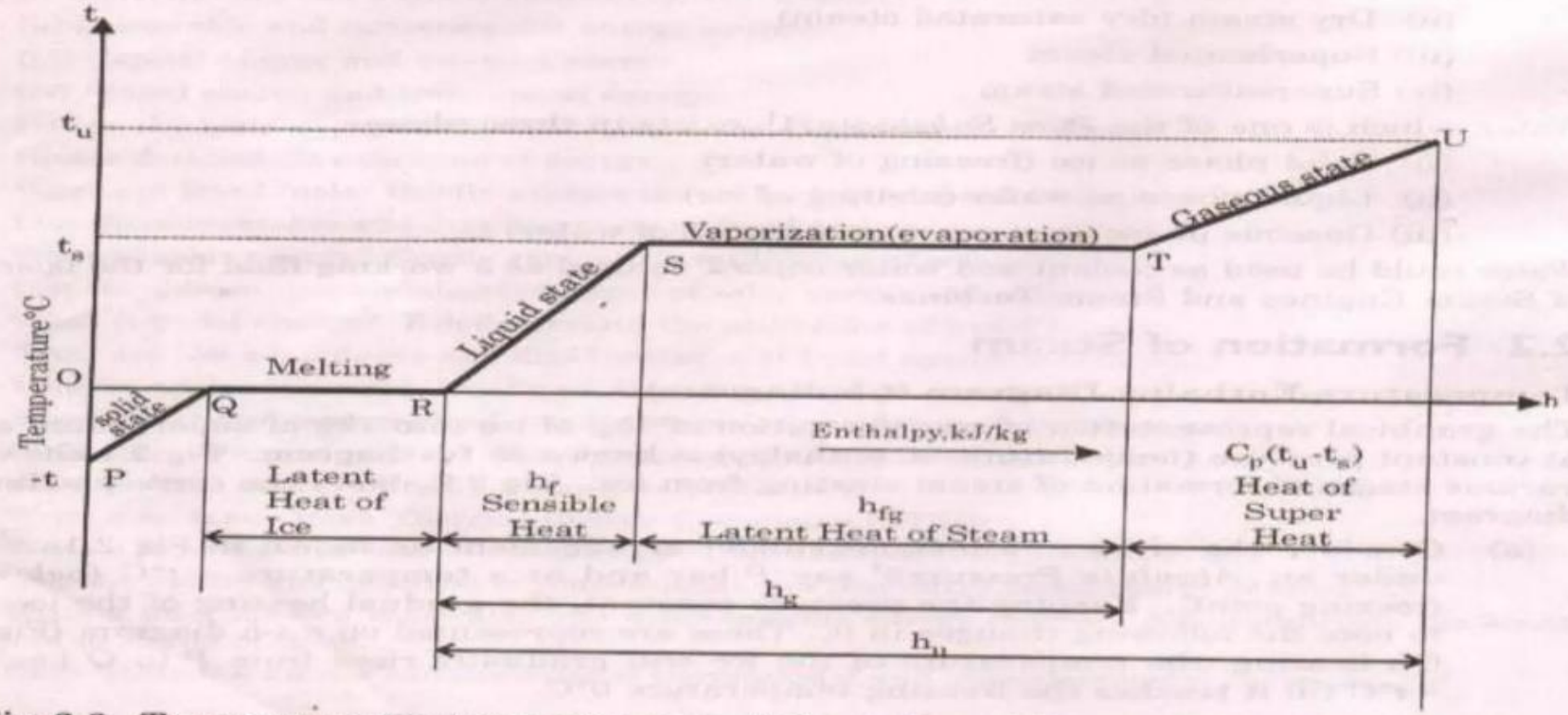


Fig 2.2 *Temperature-Enthalpy Diagram of Formation of Steam at Constant Pressure*

- ENTHALPY OF STEAM
- Enthalpy of liquid or Sensible heat (hf)

  It is the amount of heat required to raise the temperature of one kg of water from 0°C to its saturation temperature (boiling point) at constant pressure. (Line R-S)

  hf = cpw (tsat – 0) kJ/kg

  cpw = 4.187 kJ/kgK = specific heat of water
- Enthalpy of Evaporation or Latent heat (hfg)
- It is the amount of heat required to change the phase of one kg of water from saturated liquid state to saturated vapour state at constant saturation temperature and pressure. (Line S-T)
- Enthalpy of dry saturated steam (hg)
- It is the total amount of heat required to generate one kg of dry saturated steam from water at
- 0°C. (Line R-S-T)
- hg = hf + hfg

▣ Enthalpy of wet steam (h)

It is the total amount of heat required to generate one kg of wet steam having dryness fraction x from water at 0°C. It is the sum of sensible heat and latent heat taken by the dry part (x) of the wet steam.

$h = hf + x(hfg)$

▣ Enthalpy of superheated steam (hsup)

It is the total amount of heat required to generate one kg of superheated steam at required superheat temperature from water at 0°C. Superheated steam behaves like an ideal gas and obeys gas laws. (Line R-S-T-U)

$hsup = hf + hfg + cps\ (Tsup - Tsat)$

$hsup = hg + cps\ (Tsup - Tsat)$

$cps = 2.1\ kJ/KgK$ = specific heat of superheated steam

▣ Heat of superheat

Amount of heat required to get superheated steam from dry saturated steam is called heat of superheat. (Line T-U)

Heat of superheat = $cps\ (Tsup - Tsat)\ kJ/Kg$

▣ Degree of superheat

It is the temperature difference between superheated steam and dry saturated steam.

Degree of superheat = (Tsup – Tsat)

▣ Dryness Fraction of Saturated Steam (x)

It is a measure of quality of wet steam. It is the ratio of the mass of dry steam (ms) to the mass of total wet steam (ms+mw), where mw is the mass of water particles in suspension.

x = ms/(ms+mw)

▣ Quality of Steam

It is the representation of dryness fraction in percentage: Quality of Steam = 100(x)

▣ Wetness Fraction

It is the ratio of the mass of water vapor (mw) to the mass of total wet steam (ms +mw)

Wetness fraction = mw/(ms+mw) = (1-x)

▣ Priming

It is the wetness fraction expressed in percentage.

Priming = (1 - x) 100

▣ SPECIFIC VOLUME OF STEAM

It is the volume occupied by steam per kg of its mass.

Specific volume of dry steam (vg) : Its value can be obtained directly from the steam tables

Specific volume of wet steam (v) : v = x (vg)

Specific volume of superheated steam (vsup): vsup = vg (Tsup/Tsat)

INTERNAL ENERGY OF STEAM:

h = u + Pv

u = h – Pv

P = Pressure of steam

v = Specific volume of steam

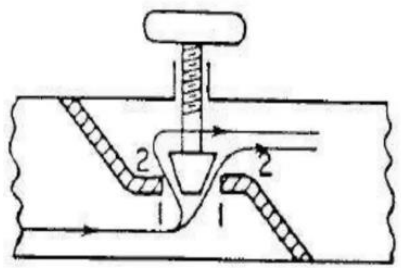
ug = hg – P(vg) for dry saturated steam

u = h – P (v) for wet steam

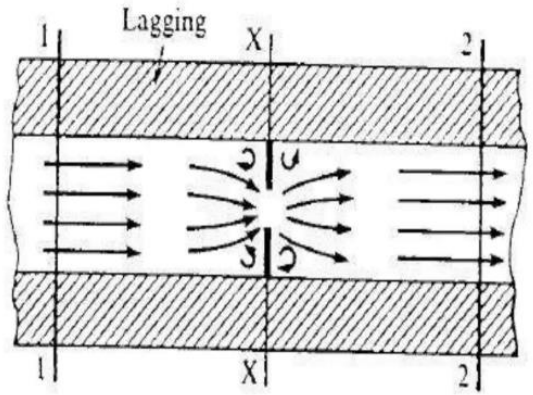
usup = hsup – P(vsup) for superheated steam

Throttling

- A throttling process is one in which the fluid is made to flow through a restriction,
- e.g. a partially opened valve or an orifice plate, causing a considerable loss in the pressure of the fluid.



Valve



Orifice Plate

Throttling Calorimeter

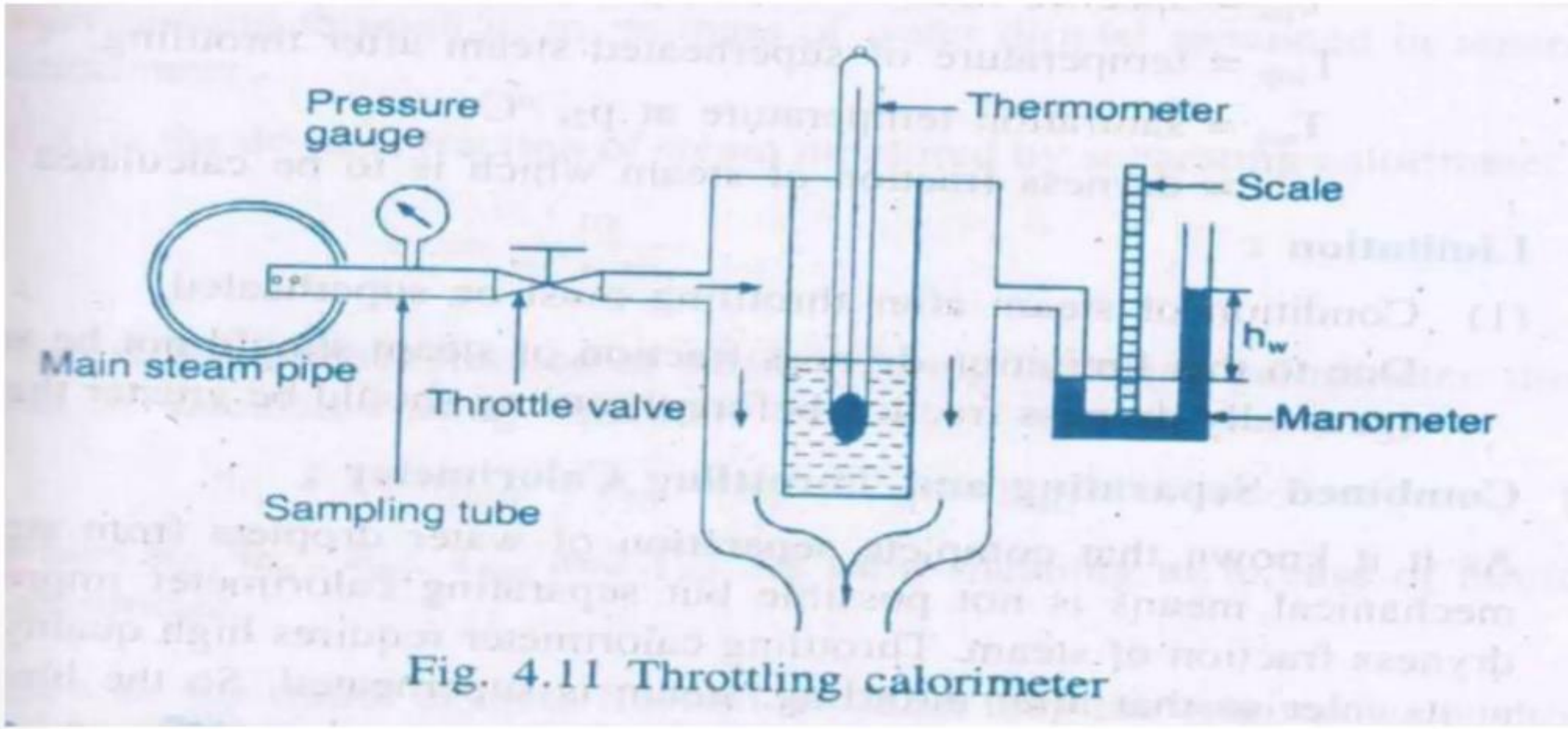


Fig. 4.11 Throttling calorimeter

•In this calorimeter a throttling valve is used to throttle the steam.

•The pressure of steam reduces after throttling. Pressure and temperature of steam before and after throttling is measured.

•Enthalpy of steam before and after throttling remains constant.

•To measure dryness fraction condition of steam after throttling must be superheated steam.

•Enthalpy of stem before throttling = Enthalpy of stem after throttling

$$hf1+xhfg1=hf2+hfg2+Cps(Tsup - T\ sat)$$

$$x= (hg2+Cps(Tsup - T\ sat) - hf1)/hfg1$$

Limitation: Steam must become superheated after throttling. That means it is not very useful for steam containing more amount of water particles.

Combined Separating and Throttling Calorimeter

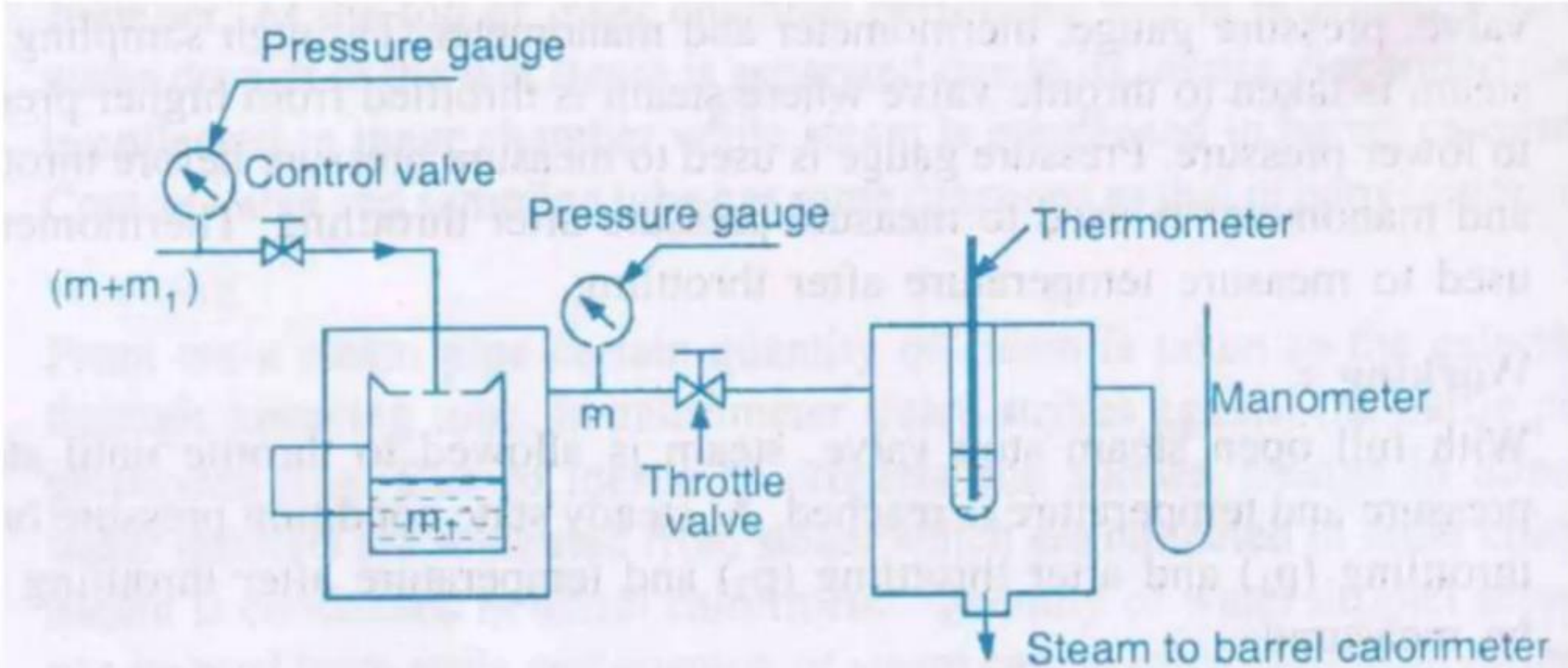


Fig. 4.12 Combined separating and throttling calorimeter

•The limitations of separating and throttling calorimeters can be overcome if they are
used in series as in this type of calorimeter.
•It gives accurate estimation of dryness fraction.

$$x = x1.\ x2$$

x1 = dryness fraction of steam measured from separating calorimeter.

x2 = dryness fraction of steam measured from throttling calorimeter.


THANK YOU
All the best in you end of semester exam's