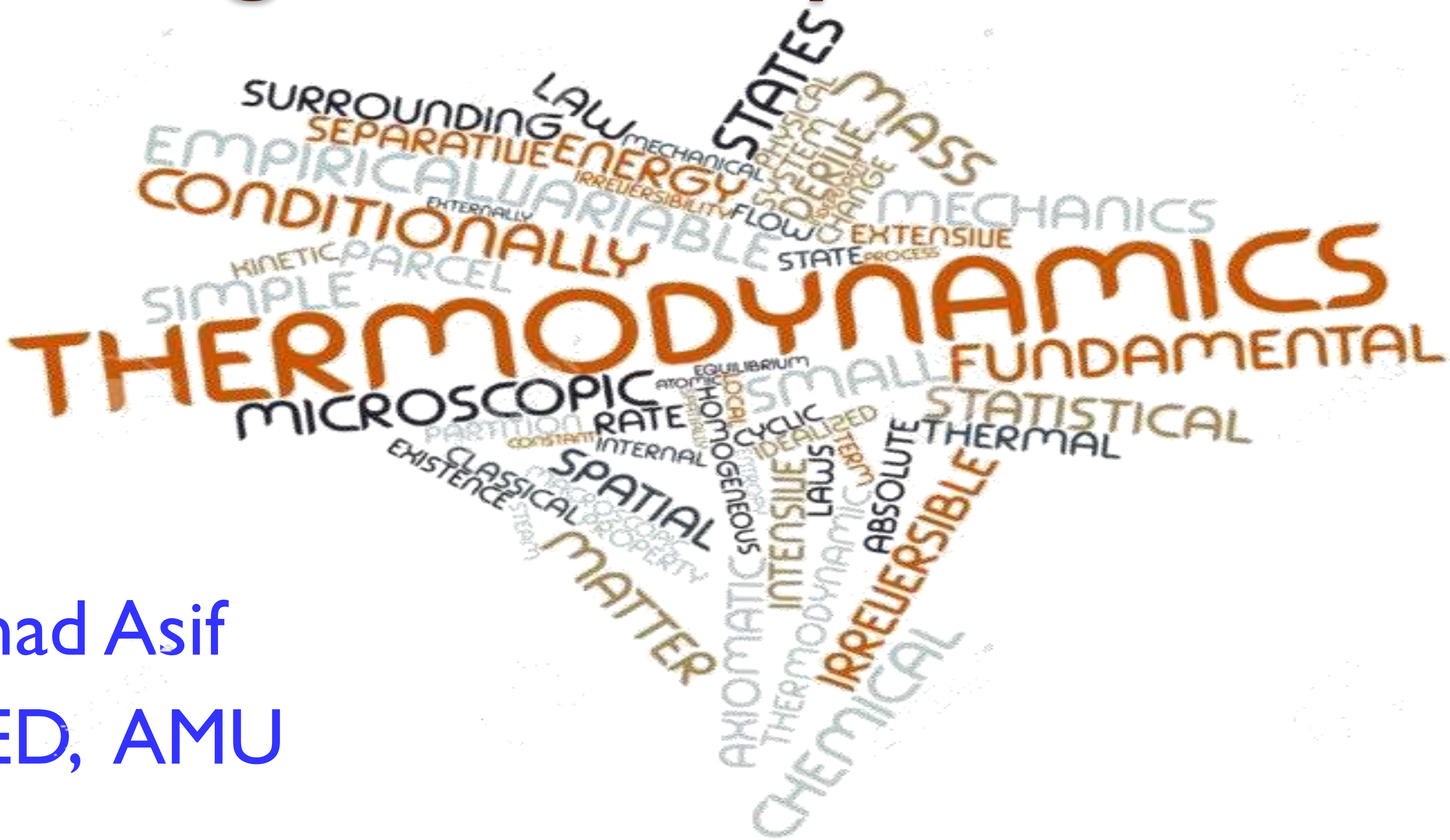
Engineering Thermodynamics

MEA1110



Dr. Mohammad Asif
MED, AMU

Unit-3

Pure Substance

Different Phases of Pure Substance, Two-Property Rule, Property Diagrams, Tables and Charts, T~ s, T~ P, P~ v, P~ h and Mollier (h~s) diagrams, Phase Boundaries, S-L-V region, CP and TP, Dryness Fraction and its Measurement, Separating and Throttling Calorimeters.

Lecture-4

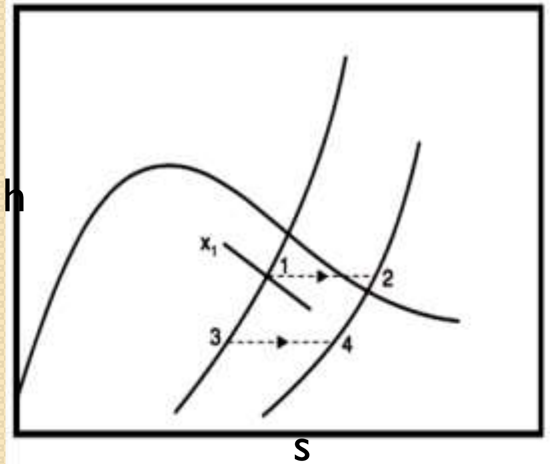
Measurement of dryness fraction

The quality of wet steam is defined by its dryness fraction

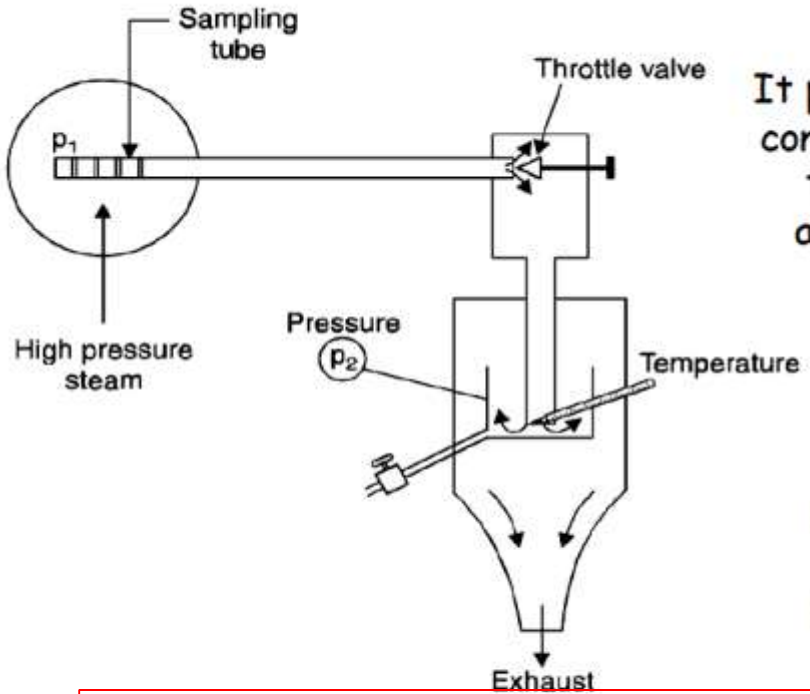
- When the dryness fraction, pressure and temperature of the steam are known, then the state of wet steam is fully defined.
- In a steam plant it is at times necessary to know the state of the steam.
- Many of the steam prime-movers are supplied with superheated steam
- The enthalpy (total heat) of such a steam is readily determined when its pressure and temperature are known.
- However, there are many cases in which saturated steam or wet steam is supplied
- The measurement of its temperature, when pressure is known, simply confirms the fact that the steam is saturated or wet.
- In no way it gives any information as to either the quality of steam or the enthalpy of steam
- To aid in the determination of the quality (dryness fraction) of wet steam, various types of steam calorimeters have been devised
- The types of colorimeters used for this purpose are :
  - ✓ -Throttling calorimeter - Steam that is nearly dry
  - ✓ Separating calorimeter - Steam is very wet
  - ✓ Combined Separating and Throttling calorimeter

Throttling Calorimeter

The steam to be sampled is taken from the pipe by means of suitable positioned and dimensioned sampling tube



The throttling process is shown on h-s diagram by the line 1-2



It passes into an insulated container and is throttled through an orifice to atmospheric pressure

Here the temperature is taken and the steam ideally should have about 5.5 K of superheat

- If steam initially wet is throttled through a sufficiently large pressure drop, then the steam at state 2 will become superheated
- State 2 can then be defined by the measured pressure and temperature.
- The enthalpy, h2 can then be found and hence

$$h_2 = h_1 = (h_{f1} + x_1 h_{fg1}) \text{ at } p_1$$

$$\text{Where, } h_2 = h_{f2} + h_{fg2} + c_{ps} (T_{sup2} - T_{s2})]$$

$$\therefore x_1 = h_2 - h_{f1} / h_{fg2}$$

Hence the dryness fraction is determined and state 1 is defined

Separating and Throttling Calorimeter

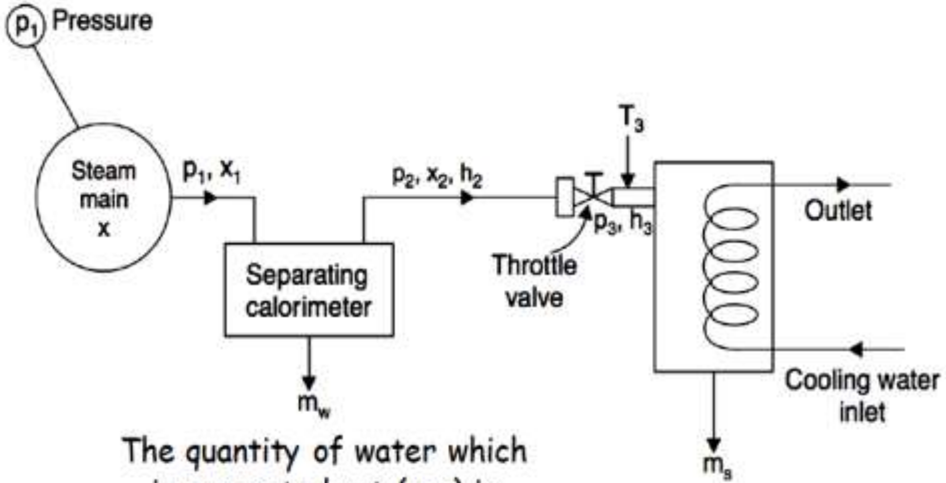
Since mechanical separation of suspended water particles from wet steam cannot be perfect, a separating calorimeter is not so accurate as a throttling calorimeter

- The operation of the throttling calorimeter depends on the steam being superheated after throttling and it will fail in its purpose, if the steam is so wet before throttling that it remains wet after throttling.
- Therefore, a very successful method of measuring the dryness fraction of very wet steam is by a combined separating and throttling calorimeter.
- If the steam whose dryness fraction is to be determined is very wet then throttling to atmospheric pressure may not be sufficient to ensure superheated steam at exit
- In this case it is necessary to dry the steam partially, before throttling, This is done by passing the steam sample from the main through a separating calorimeter

Separating and Throttling Calorimeter

The steam is made to change direction suddenly, and the water, being denser than the dry steam is separated out

the steam remaining, which now has a higher dryness fraction, is passed through the throttling calorimeter



The quantity of water which is separated out (*mw*) is measured at the separator

With the combined separating and throttling calorimeter it is *necessary* to condense the steam after throttling and measure the amount of condensate (*ms*)

Hence fraction in main, $x_1 = \dfrac{\text{Mass of dry vapour}}{\text{Total mass}} = \dfrac{x_2 m_s}{m_w + m_s}$.

The dryness fraction, x_2, can be determined as follows :

$$^{*}h_3 = h_2 = h_{f_2} + x_2 h_{fg_2} \text{ at } p_2 \quad [^{*}h_3 = h_{f_3} + h_{fg_3} + c_{ps}(T_{sup_3} - T_{s_3}) \text{ at pressure } p_3]$$

$$x_2 = \frac{h_3 - h_{f_2}}{h_{fg_2}}$$

The values of h_{f_2} and h_{fg_2} are read from steam tables at pressure p_2. The pressure in the separator is small so that p_1 is approximately equal to p_2.

If a throttling calorimeter only is sufficient, there is no need to measure condensate, the pressure and temperature measurements at exit being sufficient