

LECTURE 7

GRAPHICAL REPRESENTATION OF DATA

- 1. Pressure versus temperature (P-T)**
- 2. Pressure vs. volume (P-v)**
- 3. Temperature vs. volume (T-v)**
- 4. Temperature vs. entropy (T-s)**
- 5. Enthalpy vs. entropy (h-s)**
- 6. Pressure vs. enthalpy (P-h)**

The term saturation temperature designates the temperature at which vaporization takes place.

For water at 99.6 C the saturation pressure is 0.1 M Pa, and for water at 0.1 Mpa, the saturation temperature is 99.6 C.

If a substance exists as liquid at the saturation temperature and pressure it is called saturated liquid.

If the temperature of the liquid is lower than saturation temperature at the existing pressure it is called sub-cooled liquid or compressed liquid.

1. When a substance exists as part liquid and part vapor at the saturation temperature, its quality is defined as the ratio of the mass of vapor to the total mass.
2. If a substance exists as vapor at the saturation temperature, it is called a saturated vapor.
3. When the vapor is at a temperature greater than the saturation temperature, it is said to exist as superheated vapor.
4. At the critical point, the saturated liquid and saturated vapor state are identical.
5. At supercritical pressures, the substance is simply termed fluid rather than liquid or vapor.

6. If the initial pressure at -20°C is 0.260 kPa, heat transfer results in increase of temperature to -10°C . Ice passes directly from the solid phase to vapor phase.
7. At the triple point (0.6113 kPa) and a temperature of -20°C , let heat transfer increase the temperature until it reaches 0.01°C . At this point, further heat transfer may cause some ice to become vapor and some to become liquid. The three phases may be present simultaneously in equilibrium.

Tables of Thermodynamic Properties

Tables of thermodynamic properties of many substances are available, and in general, all these have same form.

Steam tables are selected because steam is used extensively in power plants and industrial processes.

The steam tables provide the data of useful thermodynamic properties like T , P , v , u , h and s for saturated liquid, saturated vapor and superheated vapor.

Since the properties like internal energy, enthalpy and entropy of a system cannot be directly measured; they are related to change in the energy of the system.

Hence one can determine Δu , Δh , Δs , but not the absolute values of these properties. Therefore it is necessary to choose a reference state to which these properties are arbitrarily assigned some numerical values.

For water, the triple point ($T = 0.01^\circ \text{C}$ and $P = 0.6113 \text{ kPa}$) is selected as the reference state, where the internal energy and entropy of saturated liquid are assigned a zero value.

In the saturated steam tables, the properties of saturated liquid that is in equilibrium with saturated vapor are presented.

During phase transition, the pressure and temperature are not independent of each other. If

the temperature is specified, the pressure at which both phases coexist in equilibrium is equal to the saturation pressure.

Hence, it is possible to choose either temperature or pressure as the independent variable, to specify the state of two-phase system.

Depending on whether the temperature or pressure is used as the independent variable, the tables are called temperature or pressure tables.

The two phases- liquid and vapor can coexist in a state of equilibrium only up to the critical point.

Therefore the listing of the thermodynamic properties of steam in the saturated steam tables ends at the critical point (374.15° C and 212.2 bar).

If the steam exists in only one phase (superheated steam), it is necessary to specify two independent variables, pressure and temperature, for the complete specification of the state. In the superheated steam tables, the properties- v , u , h , and s - are tabulated from the saturation temperature to some temperature for a given pressure.

The thermodynamic properties of a liquid and vapor mixture can be evaluated in terms of its quality. In particular, the specific volume, specific internal energy, specific enthalpy and specific entropy of a mixture of quality X are given by

$$v = (1-X)v_f + Xv_g, \quad u = (1-X)u_f + Xu_g, \quad h = (1-X)h_f + Xh_g = h_f + Xh_{fg}, \quad s = (1-X)s_f + Xs_g$$

where $h_{fg} = h_g - h_f =$ latent heat of vaporization.

Temperature-volume diagram

The locus of all the saturated states gives the saturated liquid curve AC and the locus of all the saturated vapor states gives the saturated vapor curve BC.

The point C represents the critical point. The difference between v_g and v_f reduces as the pressure is increased, and at the critical point $v_g = v_f$.

At the critical point, the two phases-liquid and vapor- are indistinguishable.

Pressure-volume diagram

The pressure-volume (P-V) diagram for a pure substance is shown in Figure. The curves AC and BC represent the saturated liquid curve and saturated vapor curve, respectively, and C is critical point.

The area under the curve represents the two-phase region. Any point M in this region is a mixture of saturated liquid (shown as f) and saturated vapor (g).

Mollier (h-s) Diagram

The h-s diagram was introduced by Richard Mollier and was named after him. It consists of a family of constant pressure lines, constant temperature lines and constant volume lines plotted on enthalpy versus entropy coordinates. In the two-phase region, the constant pressure and constant temperature lines coincide.