

Chapter three

Working fluids

(A) Ideal gas (Perfect gas):

An ideal gas is a gas which obeys the Boyle's law and Charles's law.

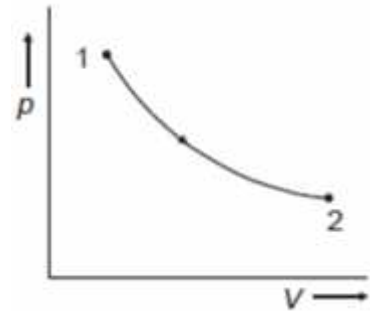
Boyle's law:- If a fixed mass of a gas is kept at constant temperature its volume varies inversely to its pressure.

$$V \propto \frac{1}{p}, \quad (T=\text{constant})$$

$$V = \frac{C}{p}, \quad pV = C$$

$$p_1 V_1 = p_2 V_2$$

$$\frac{p_1}{p_2} = \frac{V_1}{V_2}$$



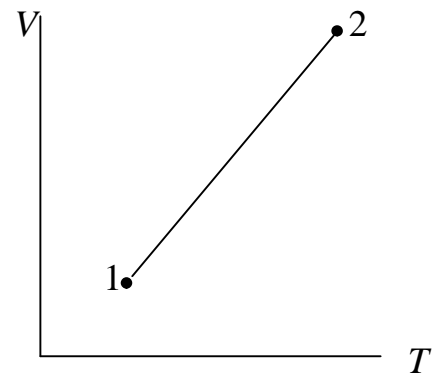
Charles's law:-

Statement No.(1):- If a fixed mass of a gas receives or reject heat at constant pressure, the volume of the gas directly proportional to its absolute temperature.

$$V \propto T, \quad (p=\text{constant})$$

$$V = CT, \quad \frac{V}{T} = C, \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

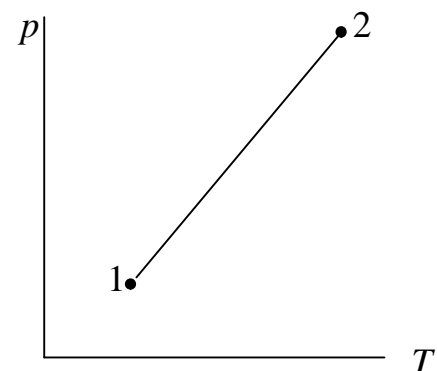


Statement No.(2):- If a fixed mass of gas receives or rejects heat at a constant volume, the pressure of the gas is directly proportional to its absolute temperature.

$$p \propto T$$

$$p = CT, \quad \frac{p}{T} = C, \quad \frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$



Equation of state for ideal gases:

Let 1kg of ideal gas follows Boyle's law from state 1 to state i and then change to state 2 at constant volume.

(a) According to Boyle's law (process 1 \rightarrow i)

$$pV = C$$

$$p_1 V_1 = p_i V_i \dots \dots \dots (1) \quad T_1 = T_i$$

(b) According to Charles's law (process $i \rightarrow$ 2)

$$\frac{p}{T} = C$$

$$\frac{p_i}{T_i} = \frac{p_2}{T_2} \dots \dots \dots (2) \quad V_i = V_2$$

$$\text{From eq.(1) } p_i = \frac{p_1 V_1}{V_i} = \frac{p_1 V_1}{V_2}$$

$$\text{Substituting } p_i \text{ in eq.(2): } \frac{p_1 V_1}{V_2 T_i} = \frac{p_2}{T_2}$$

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

$$\frac{p}{T} = \text{const} = R$$

$$p = RT, \quad pV = mRT$$

R : the gas constant

Another form of the characteristic equation can be derived using the kilogram-mole as a unit.

The kilogram- mole:- Is defined as a quantity of a gas equivalent to M kg of the gas, where M is the molecular weight of the gas.

Example : (the molecular weight of oxygen is 32, then 1kg mole of oxygen is equivalent to 32kg of oxygen)

$$m = nM$$

Where;

n :is the number of mole

M : is the molecular weight of the gas. (kg/mole)

$$pV = nMRT$$

Example (3.1):

Calculate R for air if the air at atmosphere pressure 1.01325 bar and 0°C has the density 1.293 kg/m³.

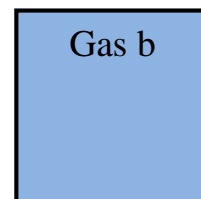
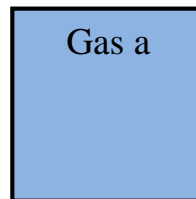
$$\hat{p} = RT$$

$$R = \frac{\hat{p}}{T} = \frac{p}{\rho T} = \frac{1.01325 \times 10^5}{1.293 \times 273} = 287 \text{ J / kg.K} = 0.287 \text{ kJ / kg.K}$$

Avogadro's hypothesis:- State that "equal volumes of different gases at the same pressure and temperature, contain equal number of molecules".

For gas (a):

$$p_a V_a = m_a R_a T_a = n_a M_a R_a T_a$$



For gas (b):

$$p_b V_b = m_b R_b T_b = n_b M_b R_b T_b$$

$$p_a V_a = p_b V_b$$

$$n_a M_a R_a T_a = n_b M_b R_b T_b$$

$$M_a R_a = M_b R_b$$

$$MR = \text{constant} = R_o$$

$$R = \frac{R_o}{M}$$

Where;

R_o :the universal gas constant

$$MR = R_o$$

$$pV=nR_oT$$

****:** Experiment has shown that the volume of 1 mole of any perfect gas at 1 bar and 0°C is approximately 22.71 m³. Therefore;

$$R_o = \frac{pV}{nT} = \frac{10^5 * 22.71}{1 * 273} = 8314 J / mole.K$$

Example (3.2):

A vessel of volume 0.2 m³ contains nitrogen at 1.013 bar and 15°C. If 0.2 kg of nitrogen is now pumped into the vessel, calculate the new pressure when the vessel has returned to its initial temperature. The molecular weight of nitrogen is 28, and it may be assumed to be a perfect gas.

Solution:

$$V=0.2 m^3, p_1=1.013 \text{ bar}, T_1=15^\circ\text{C}, p_2=?, T_2=T_1, M=28$$

$$p_1V_1 = m_1RT_1$$

$$R = \frac{R_o}{M} = \frac{8314}{28} = 296.9 J / kg.K$$

$$m_1 = \frac{p_1V_1}{RT_1} = \frac{1.013 * 10^5 * 0.2}{296.9 * 288} = 0.237 kg$$

$$p_2V_2 = m_2RT_2$$

$$m_2 = m_1 + 0.2$$

$$p_2 = \frac{m_2RT_2}{V_2} = \frac{0.437 * 296.9 * 288}{0.2} = 1.87 bar$$

Example (3.3):

A certain perfect gas of mass 0.01 kg occupies a volume of 0.003 m³ at a pressure of 7 bar and a temperature of 131 °C. The gas is allowed to expand until the pressure is 1 bar and the final volume is 0.02 m³. Calculate:

(i) the molar mass of the gas;

(ii) the final temperature.

Solution:

$$m=0.01kg, V_1=0.003 m^3, p_1=7 \text{ bar}, T_1=131^\circ\text{C}, p_2=1bar, V_2=0.02 m^3, M=?, T_2=?$$

$$p_1V_1 = mRT_1$$

$$R = \frac{p_1V_1}{mT_1} = \frac{7 * 10^5 * 0.003}{0.01 * 404} = 519.8 J / kg.K$$

$$R = \frac{R_o}{M} \Rightarrow M = \frac{R_o}{R} = \frac{8314}{519.8} = 16 \text{ kg / mole}$$

$$p_2 V_2 = m R T_2$$

$$T_2 = \frac{p_2 V_2}{m R} = \frac{1 \times 10^5 \times 0.02}{0.01 \times 519.8} = 384.8 \text{ K} = 111.8^\circ \text{ C}$$

Specific heats:-

The specific heat of a solid or liquid is usually defined as the heat required to raise unit mass through one degree temperature rise.

In symbols for small quantities: $dQ = mc dT$

Where;

m : is the mass. (kg)

dT : is the increase in temperature. (K)

c : is the specific heat. (J/kg.K)

****:** Two specific heats for gases are defined, the specific heat at constant volume (c_v), and the specific heat at constant pressure, (c_p).

$$c_p = \frac{1}{m} \frac{dQ}{dT}$$

$$c_v = \frac{1}{m} \frac{dQ}{dT}$$

$Q = mc_p dT$ (For a reversible non-flow process at constant pressure)

$dQ = mc_v dT$ (For a reversible non-flow process at constant volume)

Note:- For a perfect gas the values of c_p and c_v are constant for any one gas at all pressure and temperature while for real gases, c_p and c_v vary with temperature.

Heat flow in a reversible constant pressure process, Q

$$Q = mc_p (T_2 - T_1)$$

Heat flow in a reversible constant volume process, Q

$$Q = mc_v (T_2 - T_1)$$

Joule's law:- state's that the internal energy of a perfect gas is a function of the absolute temperature only.

$$u = F(T)$$

Let 1kg of a perfect gas be heated at constant volume.

$$dQ = du + dW \text{ (non-flow energy equation)}$$

$$dQ = du + p dV \text{ (} dW=0 \text{ because volume remain constant)}$$

For a perfect gas, $dQ = c \, dT$

$$du = c \, dT,$$

$$c_v = \frac{du}{dT}$$

$$u = c_v T + K$$

where, (K) : constant

$$\text{when } T=0, u=0 \quad K=0$$

$$u = c_v T \text{ (for a perfect gas)}$$

$$\frac{U}{m} = c_v T \Rightarrow U = m c_v T$$

In any process for a perfect gas, between states 1 and 2;

Gain in internal energy;

$$U_2 - U_1 = m c_v (T_2 - T_1)$$

Relationship between the specific heats:-

Let a perfect gas be heated at constant pressure from T_1 to T_2 .

$$Q = (U_2 - U_1) + W \text{ (non-flow equation)}$$

$$\text{For a perfect gas; } U_2 - U_1 = m c_v (T_2 - T_1)$$

$$Q = m c_v (T_2 - T_1) + W$$

$$W = p(V_2 - V_1) \text{ (constant pressure process)}$$

$$pV_1 = mRT_1 \Rightarrow V_1 = \frac{mRT_1}{p}$$

$$pV_2 = mRT_2 \Rightarrow V_2 = \frac{mRT_2}{p}$$

$$W = p \left[\frac{mRT_2}{p} - \frac{mRT_1}{p} \right] = mR(T_2 - T_1)$$

$$Q = mc_v(T_2 - T_1) + mR(T_2 - T_1) = m(c_v + R)(T_2 - T_1)$$

But for constant pressure process; $Q = mc_p(T_2 - T_1)$

$$c_p = c_v + R$$

$$R = c_p - c_v$$

Enthalpy of a perfect gas:-

$$h = u + p$$

for perfect gas; $p = RT$

from Joule's law; $u = c_v T$

$$h = c_v T + RT = (c_v + R)T$$

$$h = c_p T \quad (\text{for perfect gas})$$

$$H = mc_p T$$

The ratio of specific heats:-

The ratio of specific heat at constant pressure to the specific heat at constant volume called the sensible heat ratio (γ).

$$\gamma = \frac{c_p}{c_v}$$

$$R = c_p - c_v$$

$$\frac{c_p}{c_v} - 1 = \frac{R}{c_v} \Rightarrow \gamma - 1 = \frac{R}{c_v}$$

$$c_v = \frac{R}{\gamma - 1}$$

$$c_p = \gamma c_v$$

$$c_p = \frac{\gamma R}{(\gamma - 1)}$$

Example (3.4):

A certain perfect gas has a specific heat capacities as follows: $c_p = 0.846$ kJ/kg K and $c_v = 0.657$ kJ/kg K. Calculate the gas constant and the molar mass of the gas.

$$R = c_p - c_v$$

$$= 0.846 - 0.657 = 0.189 \text{ kJ/kg.K}$$

$$R = \frac{R_o}{M} \Rightarrow M = \frac{R_o}{R} = \frac{8314}{189} = 44 \text{ kg / mole}$$

Example (3.5):

A perfect gas has a molar mass of 26 kg/kmol and a value of $\gamma = 1.26$. Calculate the heat rejected:

(i) when the gas is contained in a rigid vessel at 3 bar and 315°C, and is then cooled until the pressure falls to 1.5 bar.

(ii) when the gas enters a pipeline at 280°C, and flows steadily to the end of the pipe where the temperature is 20°C. Neglect changes in velocity of the gas in the pipeline.

Solution:-

(i)/

Heat rejected per kg of gas; $Q = c_v (T_2 - T_1)$

$$R = \frac{R_o}{M} = \frac{8314}{26} = 319.8 \text{ J / kg.K}$$

$$c_v = \frac{R}{\gamma - 1} = \frac{319.8}{0.26} = 1.229 \text{ kJ / kg.K}$$

$$p_1 V_1 = mRT_1$$

$$p_2 V_2 = mRT_2 \Rightarrow V_1 = V_2 \Rightarrow \frac{p_1}{p_2} = \frac{T_1}{T_2}$$

$$T_2 = T_1 \left(\frac{p_2}{p_1} \right) = 588 \left(\frac{1.5}{3} \right) = 294 \text{ K}$$

$$Q = 1.229(294 - 588) = -361.3 \text{ kJ / kg}$$

(ii)/

$$h_1 + Q = h_2 + W \Rightarrow Q = h_2 - h_1$$

For perfect gas, $h = c_p T$

$$Q = mc_p (T_2 - T_1)$$

$$R = c_p - c_v \Rightarrow c_p = R + c_v = 0.3198 + 1.229 = 1.548 \text{ kJ/kg.K}$$

$$Q = 1.548(20 - 280) = -402.5 \text{ kJ/kg}$$

The working fluid:- Is the matter contained within the boundaries of a system. When two independent properties of the fluid are known then the thermodynamic state of the fluid is defined.

In thermodynamic systems the working fluid can be in the liquid, vapor or gaseous phase but the solid phase is not important in engineering thermodynamics.

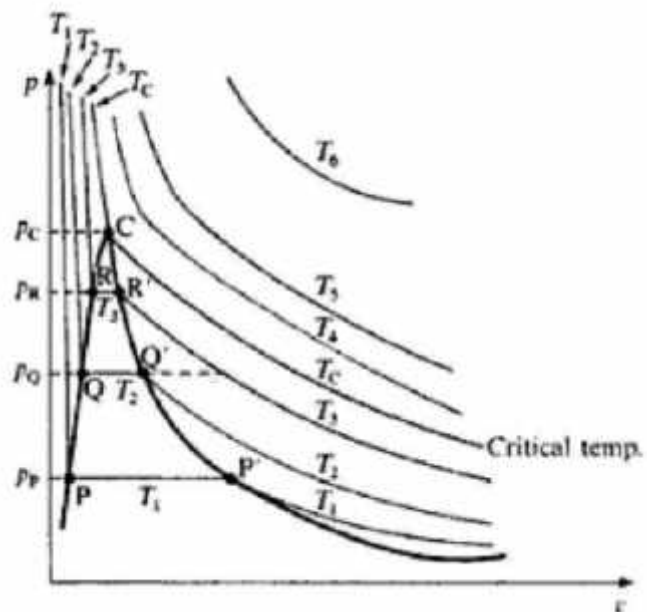
(Liquid, Vapour and gas):-

(P, Q, R): boiling points of a liquid.

P_C : critical pressure.

T_C : critical temperature.

C: critical point.



Saturation state:- Is defined as state at which a change of phase may occur without change of pressure or temperature.

The latent heat of vaporization:- Is the amount of heat required to change the phase of the substance from liquid to vapor, during this change of phase the pressure and temperature remain constant.

Critical pressure:- Is the pressure at which the turning point occurs between the saturated liquid line and the saturated vapor line.

Saturated liquid line:- Is a series of boiling points joined to form a line.

Saturated vapor line:- Is a series of point at which vaporization is complete joined to form line.

Isothermals line:- Is the line of constant temperature.

Note:- when a dry saturated vapor is heated at constant pressure its temperature rises and it becomes superheated.

Degree of superheated:- Is the difference between the actual temperature of the superheated vapor and the saturation temperature at the pressure of the vapor.

For example the vapor at point *S* is superheated at P_Q and T_3 and the degree of superheated is $(T_3 - T_1)$.

Region (1):-

Sub cool liquid (compressed liquid) :- A liquid at a pressure higher than the saturation pressure corresponding to its temperature. (or, a liquid at a temperature lower than the saturation temperature corresponding to its pressure).

$$T < T_{sat.}$$

Example:-

$P=1\text{bar}, \quad T=50^\circ\text{C}$

$P=1\text{bar}, \quad T=100^\circ\text{C}$

Region (2):-

Wet vapor:- Is a mixture of liquid and dry vapor

$$T = T_{sat.}, \quad p = p_{sat.}$$

Region (3):-

Superheated vapor:- It is a vapor at a temperature higher than the saturation temperature corresponding to its pressure.

$$T > T_{sat.}$$

Saturation state properties:-

p	t	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
(bar)	($^\circ\text{C}$)	(m^3/kg)	(kJ/kg)	(kJ/kg)	(kJ/kg)	(kJ/kg)	(kJ/kg)	($\text{kJ}/\text{kg K}$)	($\text{kJ}/\text{kg K}$)	($\text{kJ}/\text{kg K}$)
0.34	72	4.649	302	2472	302	2328	2630	0.980	6.745	7.725

Note:-

g : is used to denote the dry saturate state.

f : is used to denote the dry saturate liquid.

When saturated water is changed to dry saturated

Vapor,

$$Q = (u_2 - u_1) + W$$

W : represented by the area under the horizontal

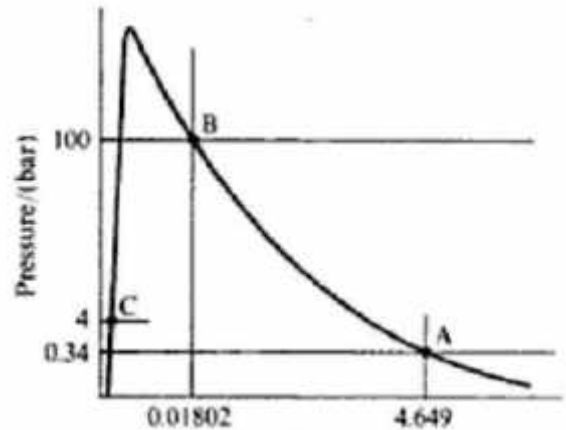
Line on the (p-) diagram.

$$W = (\hat{v}_g - \hat{v}_f) p$$

$$Q = (u_g - u_f) + p(\hat{v}_g - \hat{v}_f)$$

$$Q = (u_g + p\hat{v}_g) - (u_f + p\hat{v}_f)$$

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



Properties of wet vapor:-

The condition or quality of a wet vapor is most frequently defined by its dryness fraction, (x).

(mixture=saturated liquid+ saturated vapor)

Dryness fraction;(x):- is the mass of dry vapor in 1kg of the mixture.

$$x = \frac{\text{mas of dry saturated steam}}{\text{Total mass of wet steam}}$$

$$x = \frac{m_v}{m_t} = \frac{m_v}{m_l + m_v}$$

Where;

x : quality of vapor in the mixture.

m_v : mass of saturated steam.

m_l : mass of saturated liquid.

Wetness fraction=1-x

Wetness fraction:- is the mass of liquid in 1kg of the mixture.

****:** For a dry saturated vapor; $x=1 \Rightarrow x_2 = \frac{m_v}{0 + m_v} = 1$

****:** For a saturated liquid; $x=0 \Rightarrow x_1 = \frac{0}{m_l + 0} = 0$

Note:-

****:** The dryness fraction does not used in the superheated region.

****:** Variation of dryness fraction, $0 \leq x \leq 1$

The properties of wet vapor:

1- Specific volume (v):

$$v = \frac{\text{volume of liquid} + \text{volume of dry vapor}}{\text{total mass of wet vapor}}$$

$$\hat{v} = \hat{v}_f (1 - x) + \hat{v}_g x$$

****:** The volume of liquid is small compared to the volume of dry saturated vapor therefore is usually negligibly.

$$\hat{v} = \hat{v}_g x$$

2-The enthalpy:

Is given by the sum of the enthalpy of the liquid plus the enthalpy of the dry vapor.

$$h = (1 - x)h_f + xh_g$$

$$h = h_f + xh_{fg}$$

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

3-The internal energy:

Is given by the sum of the internal energy of the liquid plus the internal energy of the dry vapor.

$$u = (1 - x)u_f + xu_g$$

$$u = u_f + x(u_g - u_f)$$

Properties of superheated vapor:

For steam in the superheated region temperature and pressure are independent properties. When temperature and pressure are given for superheated steam then the state is defined and all the other properties can be found. For example; steam at 2bar and 300°C.

$$T > T_{sat.}$$

	Temperature/(°C)						
	250	300	350	400	450	500	600
$v/(m^3/kg)$	0.1115	0.1255	0.1386	0.1511	0.1634	0.1756	0.1995
$u/(kJ/kg)$	2681	2774	2861	2946	3030	3116	3291
$h/(kJ/kg)$	2904	3025	3138	3248	3357	3467	3690
$s/(kJ/kg K)$	6.547	6.768	6.957	7.126	7.283	7.431	7.701

****:** For pressure above 70 bar the internal energy can be found from $u = h - p\hat{v}$ because it is not tabulated in table.

Example (3.6):

Calculate the specific volume, specific enthalpy and specific internal energy of wet steam at 18 bar, dryness fraction 0.9.

Solution:

$$\hat{v} = \hat{v}_g x$$

At $p=18\text{bar}$, $\hat{v}_g=0.1104\text{m}^3/\text{kg}$, $h_f=885\text{kJ/kg}$, $h_{fg}=1912\text{kJ/kg}$, $u_f=883\text{kJ/kg}$, $u_g=2598\text{kJ/kg}$

$$\hat{v} = 0.9 * 0.1104 = 0.0994\text{m}^3 / \text{kg}$$

$$h = h_f + xh_{fg} = 885 + 0.9 * 1912 = 2605.8\text{kJ} / \text{kg}$$

$$u = u_f + x(u_g - u_f) = 883 + 0.9(2598 - 883) = 2426.5\text{kJ} / \text{kg}$$

Example (3.7):

Find the dryness fraction, specific volume and specific internal energy of steam at 7 bar and specific enthalpy 2600 kJ /kg.

Solution:

At $p=7\text{bar}$, $h_f=697\text{kJ/kg}$, $h_{fg}=2067\text{kJ/kg}$, $u_f=696\text{kJ/kg}$, $u_g=2573\text{kJ/kg}$, $\hat{v}_g=0.2728\text{m}^3/\text{kg}$

$$h = h_f + xh_{fg}$$

$$2600 = 697 + x(2067) \Rightarrow x = 0.921$$

$$\hat{v} = \hat{v}_g x = 0.921(0.2728) = 0.251 \text{ m}^3 / \text{kg}$$

$$u = u_f + x(u_g - u_f) = 696 + 0.921(2573 - 696) = 2424.7 \text{ kJ} / \text{kg}$$

Example (3.8):

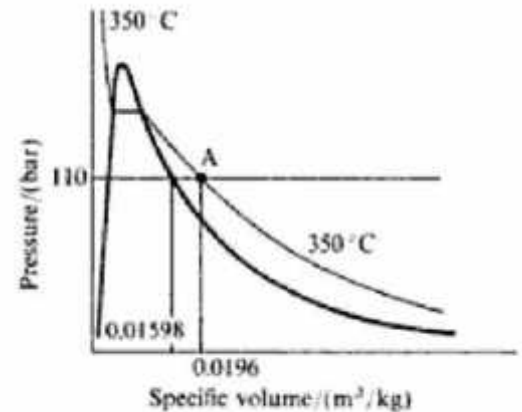
Steam at 110 bar has a specific volume of $0.0196 \text{ m}^3/\text{kg}$, calculate the temperature, the specific enthalpy, and the specific internal energy.

Solution:

At $p=110\text{bar}$, $\hat{v}_g=0.01598 \text{ m}^3/\text{kg}$

$$\hat{v} > \hat{v}_g$$

The steam is superheated



From superheated tables at 110 bar and specific volume is $0.0196 \text{ m}^3/\text{kg}$, the temperature; $T=350^\circ\text{C}$, and $h=2889 \text{ kJ/kg}$.

$$u = h - p\hat{v} = 2889 - 110 \times 10^2 \times 0.0196 = 2673.4 \text{ kJ} / \text{kg}$$

The degree of superheated $= T_{act.} - T_{sat.} = 350 - 318 = 32^\circ \text{C}$

Example (3.9):

Steam at 150 bar has a specific enthalpy of 3309 kJ/kg . Calculate the temperature, the specific volume and the specific internal energy.

Solution:

At $p=150 \text{ bar}$, $h_g=2611 \text{ kJ/kg}$ $h(3309)$ the steam is superheated

At $p=150 \text{ bar}$ and $h=3309 \text{ kJ/kg}$ $T=500^\circ\text{C}$
 $= 0.02078 \text{ m}^3/\text{kg}$

$$u = h - p\hat{v} = 3309 - \frac{150 \times 10^5 \times 0.02078}{10^3} = 2997.3 \text{ kJ} / \text{kg}$$

Interpolation:-

For properties which are not tabulated exactly in the tables it is necessary to interpolate between the values tabulated.

Example (3.10):

Find the temperature, specific volume, specific internal energy and specific enthalpy of dry saturated steam at 9.8 bar.

$$\frac{10 - 9}{179.9 - 175.4} = \frac{9.8 - 9}{T - 175.4}$$

$$(T - 175.4) = 0.8(179.9 - 175.4)$$

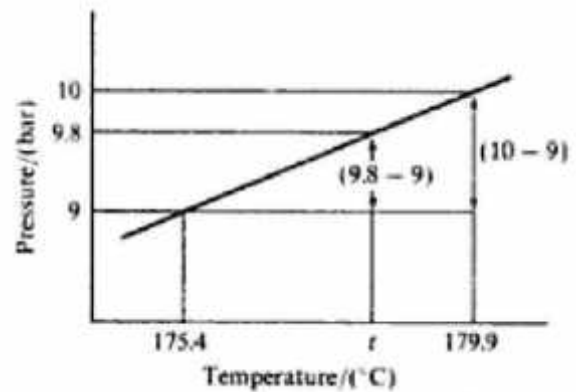
$$T = 175.4 + 0.8 * 4.5$$

$$T = 179 \text{ } ^\circ\text{C}$$

$$\frac{10 - 9}{2778 - 2774} = \frac{9.8 - 9}{h - 2774}$$

$$(h - 2774) = 4 * 0.8$$

$$h = 2774 + 4 * 0.8 = 2777.2 \text{ kJ / kg}$$



Example (3.11):

Steam at 5 bar and 320°C. Find the specific volume and enthalpy.

$$\frac{350 - 300}{0.5701 - 0.5226} = \frac{320 - 300}{\hat{v} - 0.5226}$$

$$50(\hat{v} - 0.5226) = 0.0475(20)$$

$$\hat{v} = \frac{0.0475 * 20}{50} + 0.5226 = 0.5416 \text{ m}^3 / \text{kg}$$

Note:- In some cases a double interpolation is necessary for example to find the enthalpy of superheated steam at 18.5 bar and 432°C.

$$\frac{450 - 400}{3364 - 3256} = \frac{432 - 400}{h - 3256}$$

$$\frac{450 - 400}{432 - 400} = \frac{3364 - 3256}{h - 3256}$$

$$h = \frac{432 - 400}{450 - 400} (3364 - 3256) + 3256 = 3325.1 \text{ kJ / kg}$$

$$h = 3248 + 0.64(3357 - 3248)$$

$$h = 3317.8 \text{ kJ / kg}$$

$$\frac{20 - 15}{3317.8 - 3325.1} = \frac{18.5 - 15}{h - 3325.1}$$

$$h = \left(\frac{18.5 - 15}{20 - 15} \right) (3317.8 - 3325.1) + 3325.1$$

$$h = 0.7(-7.3) + 3325.1 = 3320 \text{ kJ / kg}$$

Example (3.12):

Sketch a pressure-volume diagram for steam and mark on it the following points. Labeling clearly the pressure, specific volume and temperature of each point.

solution:

point(a):

at $p=20$ bar, $T_s=212.4^\circ\text{C} < T(250^\circ\text{C})$

superheated

$p=20$ bar, $v=0.1115\text{m}^3/\text{kg}$, $T=250^\circ\text{C}$

point(b):

at $T=212.4^\circ\text{C}$, $v_g=0.0995\text{m}^3/\text{kg}$

dry saturated

$p=20$ bar, $v_g=0.0995\text{m}^3/\text{kg}$, $T=212.4^\circ\text{C}$

point(c):

at $p=10$ bar, $h=2650\text{kJ/kg}$, $h_g=2778\text{kJ/kg}$

$h_g > h$ wet steam

$$h = h_f + xh_{fg}$$

$$2650 = 763 + x(2015) \Rightarrow x = 0.936$$

$$\hat{v} = x\hat{v}_g = 0.936 * 0.1944 = 0.182\text{m}^3/\text{kg}$$

$p=10$ bar, $v=0.182\text{m}^3/\text{kg}$, $T=T_s=179.9^\circ\text{C}$

point(d):

at $p=6$ bar, $h=3166\text{kJ/kg}$, $h_g=2757\text{kJ/kg}$

$h > h_g$ superheated

at $p=6$ bar and $h=3166\text{kJ/kg}$, $T=350^\circ\text{C}$ and $v=0.4743\text{m}^3/\text{kg}$

