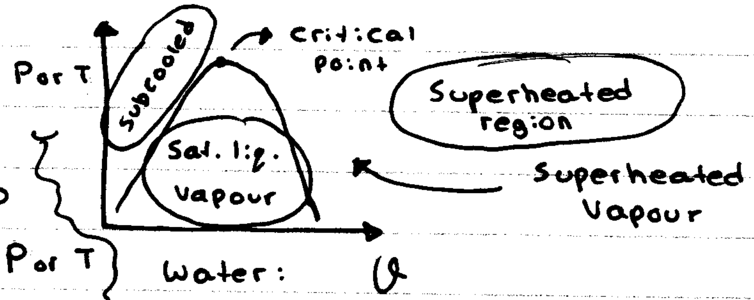
Sept. 28/17

Thermal

Thermo chapter 3 : Properties of Pure Substance

Superheated vapor



Properties (superheated)

1) $T > T_{sat}$ @ given P
2) $v > v_g$ @ given P or T
3) $u > u_g$ " "
4) $h > h_g$ " "
5) $P < P_{sat}$ @ given temp.

Water:

@ 1 atm

$T_{sat} = 100°c$

$120°c$

Properties (subcooled)

1) $T < T_{sat}$ @ given P
2) $v < v_f$ @ given P and T
3) $u < u_f$ " "
4) $h < h_f$ " "
5) $P > P_{sat}$ @ given temp.

v, u, h

T P

$120°c$ @ 1 atm (101 kPa)

→ P_{sat} (199 kPa)

($P_{sat} > P$)

Reference State and Reference Value : v, u, h, s

For water @ 0°c $u = 0$

$s = 0$

For refrigerant 134a → ref state $-40°c$ → $h = 0$, $s = 0$

Ideal gen. eq'n of State :

1. Boyle's Law → $v \propto 1/P$ [T = const]
2. Charles Law → $v \propto T$ [P = const]

$\boxed{P, v, T}$

$v \propto \frac{1}{P} \times T$ [P and T varied]

$v \propto T/P \rightarrow Pv \propto T$

K → depends on mass and type → $\boxed{Pv = KT}$

if mass = 1 kg → $Pv = RT$

$R_{air} = 287$ J/kg·K

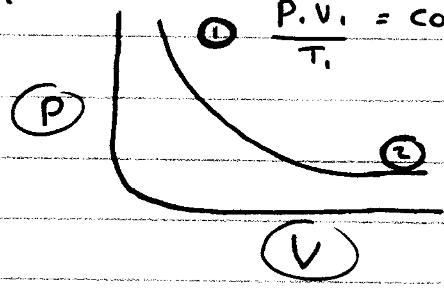
$= 0.287$ kJ/kg·K

$$\left[R = \frac{Pv}{T} = \frac{N}{m^2} \times \frac{m^3}{kg} \times \frac{1}{K} = J/kg \cdot K \right]$$

$Pv = RT$

$P\left(\frac{V}{m}\right) = RT$ → $\frac{PV}{T} = mR$ → constant (m: constant)

$\boxed{\therefore PV = mRT}$ (V: total volume)



$\frac{P_1 V_1}{T_1} = \text{const.}$

$\frac{P_2 V_2}{T_2} = \text{const.}$

$$\boxed{\begin{aligned} \frac{P_1 V_1}{T_1} &= \frac{P_2 V_2}{T_2} \\ Pv &= RT \\ PV &= mRT \end{aligned}}$$

Compressibility Factor : (Z)

$Z = \frac{Pv}{RT}$

$Pv = ZRT$

P_R or T_R — reduced pressure, reduced temp

$P_R = P/P_{cr}$

$T_R = T/T_{cr}$

$Z = 1$ (ideal gas)

$Z \neq 1$ (real gas)

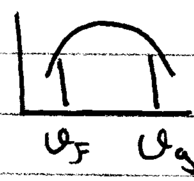
Example 3-5 : (From textbook)

$V = 80L$, $m = 4\,kg$

$v = V/m = 80/4 \times 1000 = 0.02\ m^3/kg$

Table A-12

@160 kPa : v_f



$v_f = 0.0007435\ m^3/kg$

$v_g = 0.12355\ m^3/kg$

$v_f < v < v_g$

∴ refrigerant 134a is in Sat. liquid vapor region

$T = T_{sat\ @160kPa} = -15.60\ °C$

b) Quality $= v - v_f + x\, v_{fg}$

$\therefore x = \frac{v - v_f}{v_{fg}} = \frac{v - v_f}{v_g - v_f}$

$x = 0.157$

c) Enthalpy

c) Enthalpy

$h = h_f + x h_{fg}$

$= 31.18 \text{ kJ/kg} + 0.157 \times 209.96 \text{ kJ/kg}$

$\therefore h = 64.1 \text{ kJ/kg}$

d) Vapor Vol.

$x = \dfrac{m_g}{m_t} \qquad \therefore m_g = x m_t$

$= 0.157 \times 4 \text{ kg}$

$= 0.628 \text{ kg}$

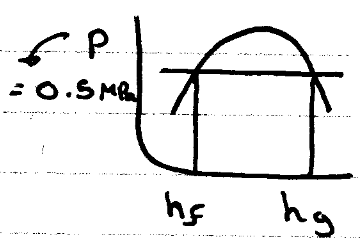
$v_g = \dfrac{V_g}{m_g} \qquad \therefore V_g = v_g \times m_g = 0.6 \times 0.12335$

$= 0.0776 \text{ m}^3$

$= 77.62 \text{ vapor}$

Example 3-7:

From table A-5



Sept. 28/17

Thermal Sci.

Chapter 4: Energy Analysis of Closed Systems

obj:
1) Moving boundary work
2) Energy balance for closed system
3) Specific heats
4) Int. energy, enthalpy + s.p. heats of ideal gas, solid, liquid.

Work = Force × distance

$\delta W = F \times ds$

$= PA\, ds$

$\boxed{= P\, dv}$ → vol

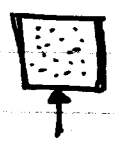
Press. $P = F/A$

$\therefore F = PA$

$\therefore$ Total work for process 1-2:

$$W_b = \int_1^2 P\, dv$$

1) V = const.

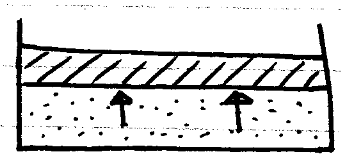


$P\cancel{dV}^{0}$

$\therefore \delta w = 0$

$w_b = 0$

2) P = const.



$W_b = \int_1^2 P\, dv$

$= P\int_1^2 dv$

$W_b \Rightarrow P(v_2 - v_1)$

$\Rightarrow W_b = P(m\upsilon_2 - m\upsilon_1)$

υ → sp. vol

$\upsilon = V/m$

$V = m\upsilon$

$W_b = P(\upsilon_2 - \upsilon_1)$

3) Isothermal process (ideal gas)

T = const.

Boyle's Law : $T = C$; $V \propto \frac{1}{P}$

$V = \text{const.} = C$

$\therefore \boxed{P = C/V}$ → ①

$PV = C = P_1 V_1 = P_2 V_2$ → ②

$PV = mRT$ → ③

$$W_b = \int_1^2 P\, dv = \int_1^2 \frac{C}{V}\, dv = C\int_1^2 \frac{dv}{V} = C\left[\ln V_2 - \ln V_1\right]$$

$$= C \ln \frac{V_2}{V_1}$$

$$W_b = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$$

Polytropic Process:

$PV^n = C \quad n \neq 1$

$\hookrightarrow P = CV^{-n} \quad \Big| \quad W_b = \int_1^2 P\,dv = \int_1^2 CV^{-n}\,dv$

$= C\int_1^2 V^{-n}\,dv$

$\Rightarrow C\left[\dfrac{V_2^{-n+1} - V_1^{-n+1}}{-n+1}\right]$

$C = P_1V_1^n = P_2V_2^n$

$$\boxed{W_b = \frac{P_2V_2 - P_1V_1}{1-n}}$$

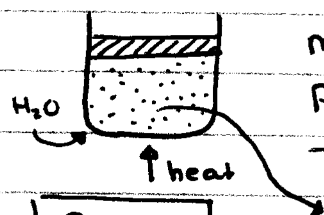
$PV = mRT$

$$\boxed{W_b = \frac{mR(T_2 - T_1)}{1-n}}$$

$v_1 = @60 \text{ psia}, 320°F$

$v_2 = @80 \text{ psia}, 400°F$

Example 4-2:



$\boxed{P = C}$

$m = 10 \text{ lbm}$

$P_1 = 60 \text{ psia}$

$T_1 = 320°F$

$T_2 = 400°F$

TABLE A6E

$W_b = mP(v_2 - v_1)$

$= 10 \times 60\ (8.3548 - 7.4863)$

$= (\text{lbm})(\text{lbf/in}^2)(\text{ft}^3/\text{lbm})$

$= 75038\ (\text{ft}\cdot\text{lbf})$

Example 4-3:

$W_b = P_1V_1 \ln V_2/V_1$

$= 100 \text{ kPa} \times 0.4\text{ m}^3 \times \ln \dfrac{0.1\text{ m}^3}{0.4\text{ m}^3}$

$= -55.5 \text{ kJ}$

$= \text{kPa} \times \text{m}^3$

$= \dfrac{\text{kN}}{\cancel{\text{m}^2}} \times \cancel{\text{m}^2}(\text{m})$

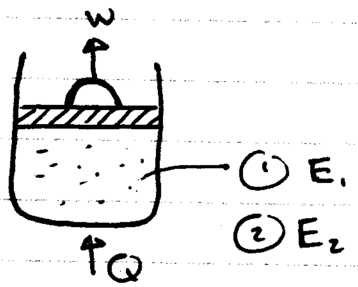
$= \text{kJ}$

Energy balance For Closed Systems

$E_{in} - E_{out} = \Delta E_{system}$ $\qquad \dot{Q} = Q \times \Delta t$

$\dot{E}_{in} - \dot{E}_{out} = d/dt\, E_{sys}$ $\qquad \dot{W} = W/\Delta t$

$dE/dt = \Delta E/\Delta t$



$$E_1 + Q = E_2 + W$$

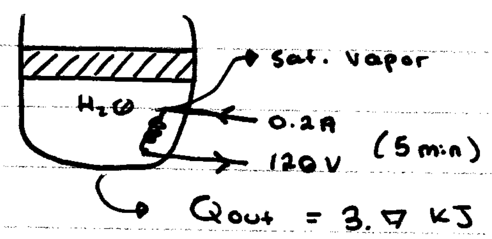
$$\boxed{\therefore\ Q - W = \Delta E}$$

↳ general form of 1st law of thermodynamics

$$Q_{net,in} - W_{net,out} = \Delta E$$

↳ $Q - W = \Delta U$

Example 4-5:



$P_1 = P_2 = 300$ kPa

$m = 25$ g

$$Q - W = \Delta E = \Delta U + \boxed{\cancel{\Delta KE + \Delta PE}} \to 0$$

$$Q - W = \Delta U$$

$$Q - (W_b + W_{other}) = U_2 - U_1$$

$$Q - P(V_2 - V_1) - W_{other} = U_2 - U_1$$

$$Q - W_{other} = (U_2 + P_2V_2) - (U_1 + P_1V_1)$$

$H = U + PV$ $\qquad \therefore\ Q - W_{other} = H_2 - H_1 = \Delta H$

$-3.7\text{ kJ} - 7.2\text{ kJ} =$

TABLE A-5

$P_1 = 300$ kPa

↳ $h_1 = h_g @ 300$ kPa $= 2724.9$ kJ/kg

$P = VI$

$W_e = VI\Delta t = 120\text{ V} \times 0.2\text{ A} \times 5 \times 60 = 7.2\text{ kJ}$

$$-3.7 + 7.2 = (0.025)(h_2 - 2724.9)$$

$h_2 = 2864.9$ kJ/kg $\quad|\quad P_2 = 300$ MPa

$T_2 = 200\ ^\circ C$ (Example 4-6) $\quad|\quad h_2 = 2864.9$ kJ/kg