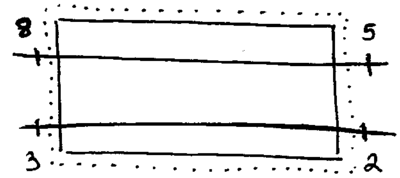
Nov.20/18

From example (different textbook)

H.E. :



$\dot{m}_A h_5 + \dot{m}_B h_3 = \dot{m}_A h_8 + \dot{m}_B h_2$

$\dot{m}_A (h_5 - h_8) = \dot{m}_B (h_2 - h_3)$

$(0.05)(251.88 - 95.47) = \dot{m}_B (235.93 - 55.16)$ } using h values with a different table.

$\boxed{\dot{m}_B = 0.039 \text{ kg/s}}$

$\dot{Q}_L = \dot{m}_B (h_1 - h_4) = (0.039)(239.16 - 55.16) = \boxed{7.18 \text{ kW} = \dot{Q}_L}$

$\dot{W}_c = \dot{m}_A \omega_A + \dot{m}_B \omega_B = \dot{m}_A (h_6 - h_5) + \dot{m}_B (h_2 - h_1)$

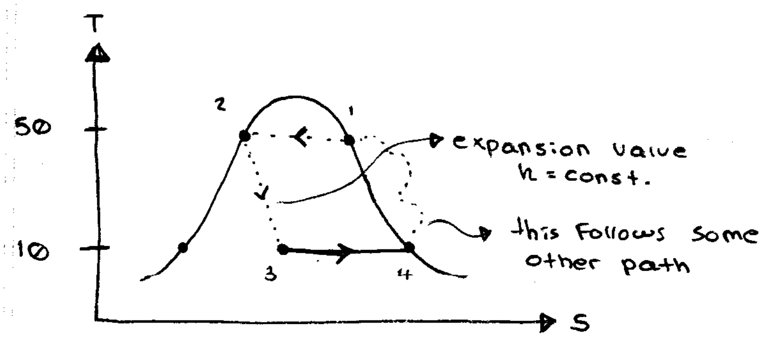
$= (0.05)(270.92 - 251.88) + (0.039)(255.93 - 239.16)$

$\boxed{\dot{W}_c = 1.61 \text{ kW}}$

$COP = \frac{\dot{Q}_L}{\dot{W}_c} = \frac{(7.18)}{(1.61)} = 4.46$

(9.114)

Example



$q_H = q_{gen} = 3000$ kJ/kg of ammonia

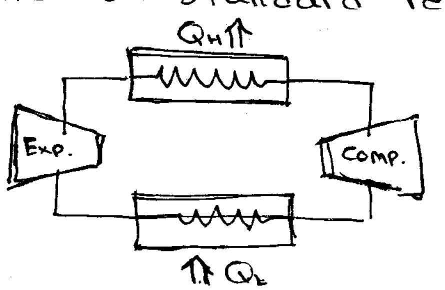
$q_L = h_4 - h_3 = h_g@10°C - h_f@50°C$

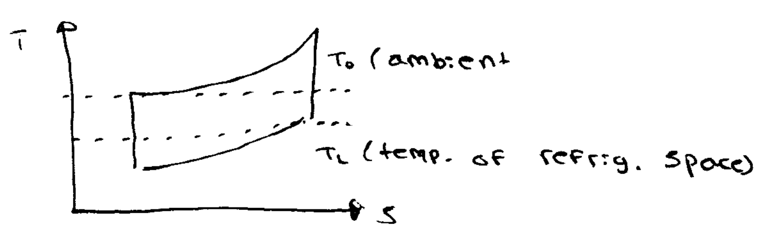
$q_L = 1452.2 - 421.6$

$q_L = 1030.6$ kJ/kg

$COP = q_L/q_H = \frac{1030.6}{3000} = \boxed{0.34}$ assume $\eta_{HP} = 1$

The air standard refrigeration cycle:





$$\beta = \frac{q_L}{w_{net}} = \frac{q_L}{w_c - w_E} = \frac{h_1 - h_4}{h_2 - h_1 - (h_3 - h_4)}$$

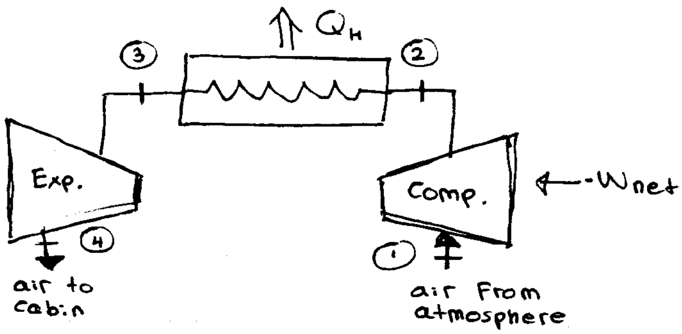
$$\approx \frac{C_p(T_1 - T_4)}{C_p(T_2 - T_1) - C_p(T_3 - T_4)}$$

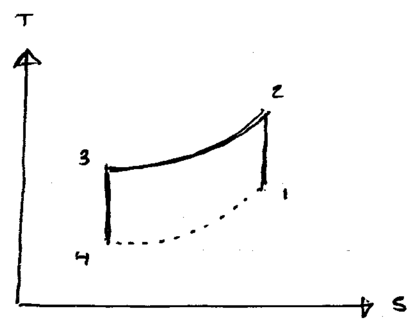
$$P_2/P_1 = (T_2/T_1)^{k/(k-1)} = P_3/P_4 = (T_3/T_4)^{\frac{k}{k-1}}$$

$$\beta = \frac{T_1 - T_4}{T_2 - T_1 - T_3 + T_4} = \frac{1}{(T_2/T_1)\left(\frac{1 - T_3/T_2}{1 - T_4/T_1}\right) - 1}$$

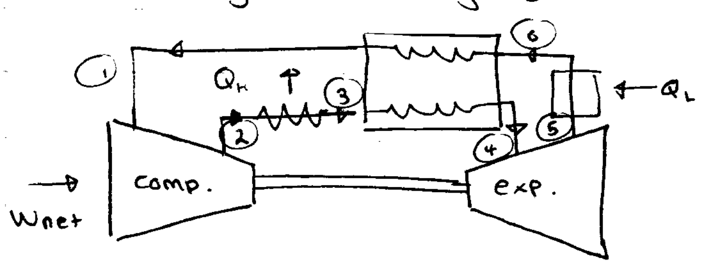
$$\beta = \frac{1}{(T_2/T_1) - 1} = \frac{1}{r_p^{(k-1)/k} - 1}$$

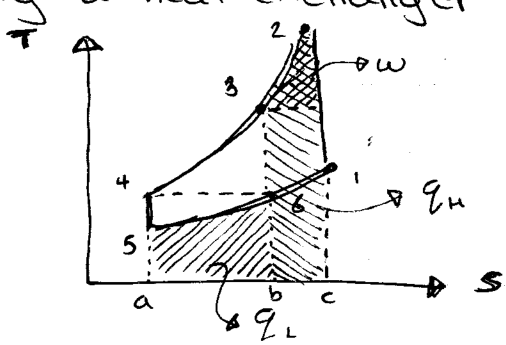
An air refrigeration cycle that might be used for aircraft cooling.





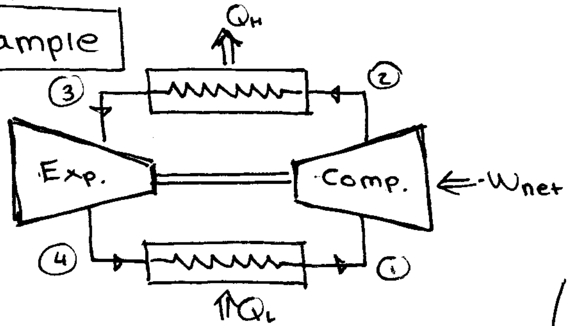
Air refrigeration cycle utilizing a heat exchanger





10.6

Example



$COP = \frac{q_L}{w_{net}}$ outlet

$q_L = h_1 - h_4$ inlet

$= C_p(T_1 - T_4)$

$= (1.004)((-20+273.2)-181.2) = 71.6$ kJ/kg

$$\left(\frac{P_3}{P_4}\right)^{\frac{k-1}{k}} = \frac{T_3}{T_4}$$

$$T_4 = \frac{15+273}{(5)^{0.4/1.4}} = 181.9 \text{ K}$$

$w_{net} = w_c - w_e$

$= (h_2 - h_1) - (h_3 - h_4)$

$= C_p(T_2 - T_1) - C_p(T_3 - T_4)$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} \rightarrow T_2 = (-20+273)(5)^{\left(\frac{0.4}{1.4}\right)} = 400 \text{ K}$$

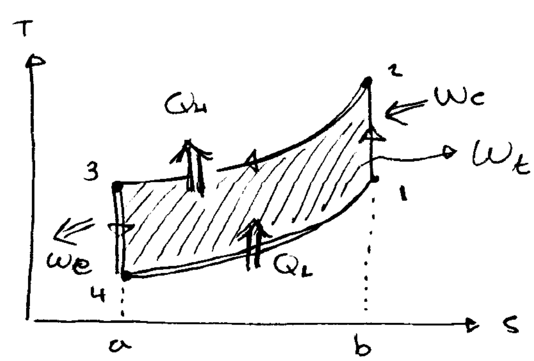
$\Rightarrow (1.004)[(400-273.2) - 288.2 + 181.9]$

$w_{net} = 40.7$ kJ/kg

$$COP = \frac{q_L}{w_{net}} = \left(\frac{71.6}{40.7}\right) = \boxed{1.76}$$

$q_L = 71.6$ kJ/kg

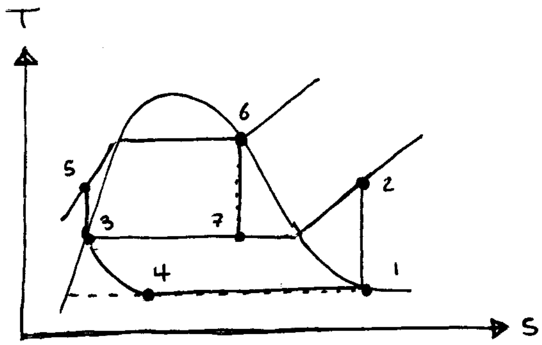
$$\dot{m} = \dot{Q}_L / q_L = 1 \text{ kW} / 71.6 \text{ kJ/kg} = \boxed{0.014 \text{ kg/s}}$$



$A_{a32b} = q_H$

$A_{a41b} = q_L$

Nov. 21/18



$T_1 = 150°C$ Sat. vapor

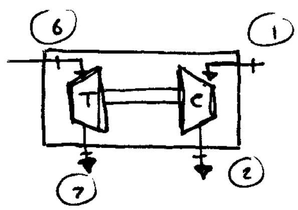
$T_2 = 90°C$ sat. vapor

$T_3 = 45°C$ sat. vapor

$$s_7 = s_6 = 1.6671 = s_f@_{1.1602\,MPa} + x_f\, s_{fg}@_{1.1602\,MPa}$$

$$x_f = 0.9121$$

$$h_7 = 264.11 + (0.9121)(157.95) = 408.08 \text{ kJ/kg}$$



$$\dot m_6 h_6 + \dot m_1 h_1 = \dot m_7 h_7 + \dot m_2 h_2$$

$$\begin{cases} \dot m_6 = \dot m_7 \\ \dot m_1 = \dot m_2 \end{cases} \Rightarrow \dot m_6 (h_6 - h_7) = \dot m_1 (h_2 - h_1)$$

$$\frac{\dot m_6}{\dot m_1} = \frac{h_2 - h_1}{h_6 - h_7} = \frac{429.9 - 389.2}{425.7 - 408.08} = 2.31$$

$$\begin{aligned} \dot Q_L &= \dot m_1 (h_1 - h_4) \\ \dot Q_H &= \dot m_6 (h_6 - h_5) \end{aligned} \Rightarrow \beta = \frac{\dot Q_L}{\dot Q_H} = \frac{\dot m_1 (h_1 - h_4)}{\dot m_6 (h_6 - h_5)}$$

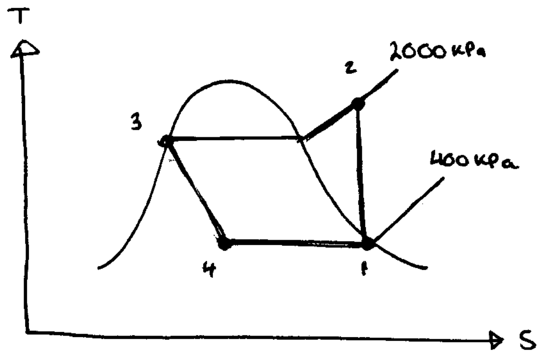
$$\left(\frac{\dot m_1}{\dot m_6}\right)\left(\frac{h_1 - h_4}{h_6 - h_5}\right)$$

$$w_p = v_3 (P_5 - P_3) = 0.00089 (3244.5 - 1160.2) = 1.855 \text{ kJ/kg}$$

$$h_5 = h_3 + w_p = 264.11 + 1.855 = 265.96 \text{ kJ/kg}$$

$$\beta = \left(\frac{1}{2.31}\right)\left(\frac{389.2 - 264.11}{425.7 - 265.96}\right) = \boxed{0.34}$$

HEAT PUMP



$$\beta = \frac{q_H}{w_c}$$

$$q_L = h_1 - h_4$$
$$q_H = h_2 - h_3$$

$$h_3 = h_f|_{2000\,kPa} = 110.21 \text{ kJ/kg}$$

$$\left.\begin{aligned} s_1 = s_2 &= 1.0779 \text{ kJ/kg} \\ P_2 &= 2000 \text{ kPa} \end{aligned}\right\} \Rightarrow h_2 = 317.43 \text{ kJ/kg}$$

$$q_H = 317.42 - 110.21 = 207.22 \text{ kJ/kg}$$

$$w_c = h_2 - h_1 = 317.43 - 271.9 = 45.53 \text{ kJ/kg}$$

$$\beta = q_H / w_c = \frac{207.22}{45.53} = \boxed{4.55}$$

where $\beta = \frac{\dot{Q}_H}{\dot{W}} \Rightarrow \dot{Q}_H = \beta \dot{W} = 4.55(2) = \boxed{9.1 \text{ kW}}$

$$\cancel{\dot{S}_{cv}}^{\,0} = \sum \cancel{\dot{m}_i s_i}^{\,0} - \sum \cancel{\dot{m}_e s_e}^{\,0} + \sum \frac{\dot{Q}_{cv}}{T} + \dot{S}_{gen}$$

or

$$\emptyset = \sum \frac{\dot{Q}_{cv}}{T} + \dot{S}_{gen}$$

$$\emptyset = \frac{\dot{Q}_L}{T_{amb}} - \frac{\dot{Q}_H}{T_{room}} + \dot{S}_{gen}$$

$$\dot{S}_{gen} = \frac{\dot{Q}_H}{T_{room}} - \frac{\dot{Q}_L}{T_{amb}}$$

$$\dot{Q}_H - \dot{Q}_L = \dot{W} \Rightarrow \dot{Q}_L = \dot{Q}_H - \dot{W}$$

$$\dot{Q}_L = (9.1) - (2) \rightarrow \dot{Q}_L = 7.1 \text{ kW}$$

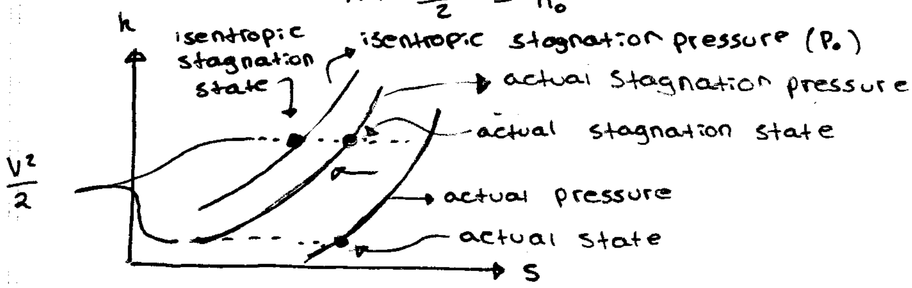
$$\dot{S}_{gen} = \left(\frac{9.1}{293.15}\right) - \left(\frac{7.1}{268.15}\right) \Rightarrow \boxed{0.00456 \text{ kW/K}}$$

Nov. 22/18

The isentropic stagnation state is the state a flowing fluid would attain if it underwent a reversible adiabetic deceleration to zero velocity.

↳ designated with subscript o

$$h + \frac{V^2}{2} = h_o$$



→ 15.1

$\boxed{\text{Example}}$ $h + \frac{V^2}{2} = h_o \Rightarrow \frac{V^2}{2} = h_o - h = C_{p_o}(T_o - T)$

$$V^2/2 = C_{p_o}(T_o - T)$$

$$\frac{(200)^2}{2(1000)} = 1.000(T_o - 300) \Rightarrow T_o = 319.9 \text{ K}$$

$$\frac{T_o}{T} = \left(\frac{P_o}{P}\right)^{\frac{k-1}{k}} \Rightarrow P_o = P(T_o/T)^{k/k-1}$$

$$P_o = 150\left(\frac{319.9}{300}\right)^{\frac{1.4}{0.4}} = \boxed{187.8 \text{ kPa}}$$

A.7.2

$T = 300\text{K}$ $h = 300.47 \text{ kJ/kg}$ $P_r = 1.146$

$$h_o = h + V^2/2 = 300.47 + \frac{200^2}{2 \times 1000} = 320.47 \text{ kJ/kg}$$

→ From table, $T_o = 319.9 \text{ K}$ and $P_{ro} = 1.3956$

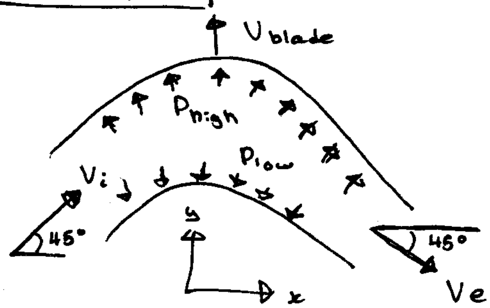
$$P_o/P = P_{ro}/P_r \Rightarrow P_o = P \times P_{ro}/P_r = 150\left(\frac{1.3956}{1.146}\right)$$

$$\boxed{P_o = 187.8 \text{ kPa}}$$

Momentum Eq'n For Flow Volume

$$\sum F_x = \sum \dot{m}_e (V_e)_x - \sum \dot{m}_i (V_i)_x$$
$$\sum F_y = \sum \dot{m}_e (V_e)_y - \sum \dot{m}_i (V_i)_y$$
$$\sum F_z = \sum \dot{m}_e (V_e)_z - \sum \dot{m}_i (V_i)_z$$

Example



$$\sum F_x = \frac{\cancel{d(mV_x)}}{\cancel{dt}}^{\,0} + \sum \dot{m}_e V_{ex} - \sum \dot{m}_e V_{ex}$$
$$= \dot{m}_e V_{ex} - \dot{m}_i V_{ix} = \dot{m}(V_{ex} - V_{ix})$$
$$= \dot{m}(V_e \cos 45° - V_i (\sin 45°))$$
$$\boxed{\sum F_x = 0}$$

$$\sum F_y = \frac{\cancel{d(mV_y)}}{\cancel{dt}}^{\,0} + \sum \dot{m}_e V_{ey} - \sum \dot{m}_i V_{iy}$$
$$= \dot{m}(V_e(-\sin 45°) - V_i(\sin 45°)) = -\dot{m} V_i \sqrt{2}$$
$$\boxed{\sum F_y = -\dot{m} V_i \sqrt{2}}$$

The continuity eq'n:

$$\dot{m}_e = \dot{m}_e = \rho A_i V_i = \rho A_e V_e \qquad \frac{A_i}{A_e} = \frac{V_i}{V_e}$$

Adiabetic, one-dimensional steady state flow of an incompressible fluid, through a nozzle

Energy: $$h_e - h_i + \frac{V_e^2 - V_i^2}{2} + (Z_e - Z_i)g = 0$$

Entropy: $$T ds = dh - v dP \xrightarrow{\text{isentropic}} h_e - h_i = \int_i^e v\,dP$$
$$h_e - h_i = v(P_e - P_i)$$

If we assume incompressible fluid:

$$\boxed{v(P_e - P_i) + \frac{V_e^2 - V_i^2}{2} + (Z_e - Z_i)g = 0}$$

Bernoulli's Eq'n

Example

$V_1 = 30$ m/s $\quad V_2 = 7$ m/s

$P_1 = 350$ kPa $\quad P_2 = 600$ kPa

$T_1 = 25$ °C $\quad T_2 = ?$

$$\rightarrow v(P_{es} - P_i) + \frac{V_e^2 - V_i^2}{2} + \cancel{(Z_e - Z_i)}g$$

(assuming $v = 0.001003$)

$$\rightarrow P_{es} - P_i = \left(\frac{V_i^2 - V_e^2}{2}\right)\frac{1}{v} \Rightarrow P_{es} - P_i = \frac{(30^2) - (7)^2}{(0.001003)(2)(1000)} = 424 \text{ kPa}$$

$$\rightarrow P_{es} = 774 \text{ kPa}$$

$$h_{es} - h_i = \frac{V_e^2 - V_i^2}{2} = 0$$

$$h_{es} - h_i = \frac{V_i^2 - V_e^2}{2} = \frac{30^2 - 7^2}{2(1000)} = 0.4255 \text{ kJ/kg}$$

$$h = u + Pv$$

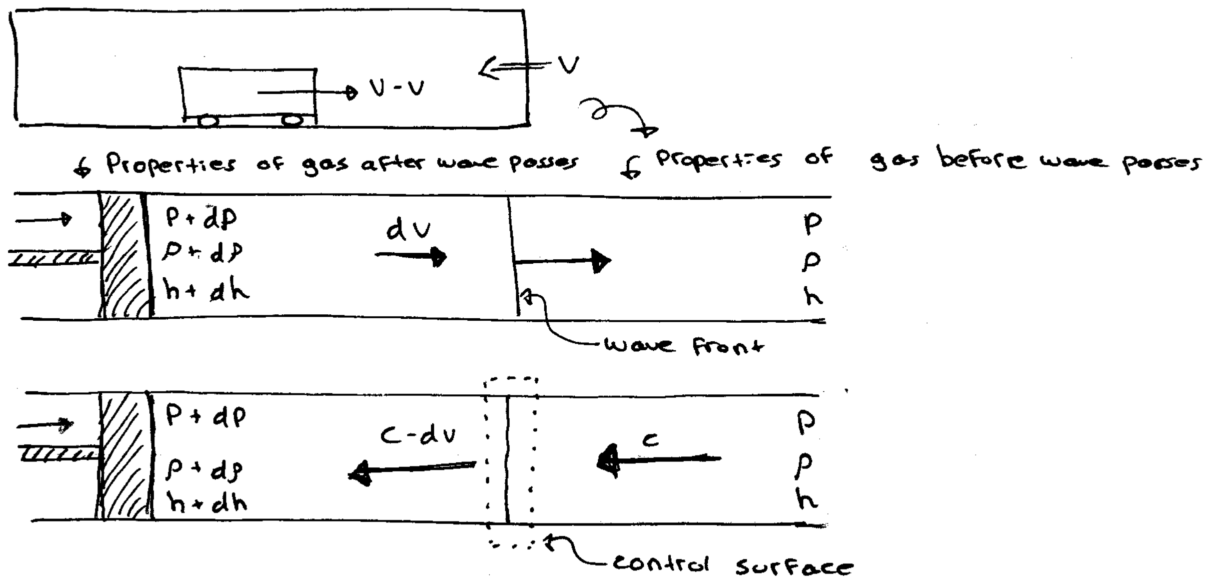
$$u_e - u_i = h_e - h_i - v(P_e - P_i)(600 - 350) = 0.1747 \text{ kJ/kg}$$

$$Tds = du + Pdv \qquad dv = 0 \text{ (incompressible)}$$

$$Tds = du$$

$$ds = du/\underset{\text{constant ??}}{\underline{\underline{T}}} \Rightarrow S_e - S_i = \frac{u_e - u_i}{T}$$

$$S_e - S_i = \frac{0.1747}{298.2} = 0.000586 \text{ kJ/kg}\cdot\text{K}$$



$$\dot{m}_i = \dot{m}_e \Rightarrow \rho A c = (\rho + d\rho)(A)(c - dv)$$

$$\cancel{\rho A c} = \cancel{\rho A c} - \rho A dv + cA d\rho - \cancel{A d\rho dv}^{\approx 0}$$

$$\boxed{c\, d\rho - \rho\, dv = 0} \quad (\text{II})$$

$$T ds = dh - v dP = dh - dP/\rho$$

For isentropic process $\rightarrow$ $dh - \frac{dP}{\rho} = 0$

From eq'n (I) $dh = c dv$ $\rightarrow$ $c dv - \frac{dP}{\rho} = 0$

$$\boxed{\frac{dP}{\rho} - c dv = 0} \quad (\text{III})$$

From (II) and (III) $\Rightarrow$ $\frac{dP}{d\rho} = c^2$ $\quad \boxed{\left(\frac{\partial P}{\partial \rho}\right)_s = c^2}$ (IV)

$$T ds = du + P dv = du - (P d\rho / \rho^2)$$

$$T ds = dh - v dP = dh - dP/\rho$$

For isentropic process : $du - \frac{P d\rho}{\rho^2} = 0$ (*)

$$dh - \frac{dP}{\rho} = 0 \quad (**)$$

If assume c_p and c_v are constant : $du = c_v dT$

$$dh = c_p dT$$

From (*) and (+)(+) $\quad C_v \, dT - \dfrac{P \, d\rho}{\rho^2} = 0$

$$C_p \, dT - dP/\rho = 0$$

$$K = \frac{C_p}{C_v}$$

$$\Rightarrow \boxed{\frac{dP}{P} - \frac{k \, d\rho}{\rho} = 0}$$

$$\left(\frac{dP}{d\rho}\right)_s = \frac{kP}{\rho} = c^2 \qquad \text{V}$$

$$\frac{P}{\rho} = RT \longrightarrow KRT = C^2$$

$$\boxed{C = \sqrt{KRT}} \qquad \text{VI}$$

$$\boxed{M = \frac{V}{C} = \frac{V}{\sqrt{KRT}}}$$