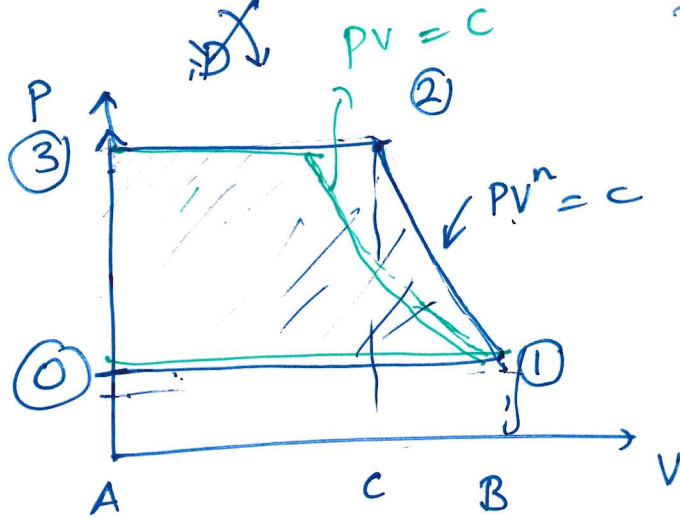
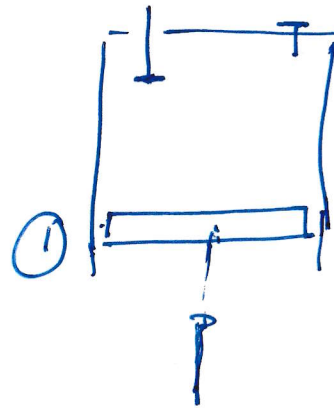
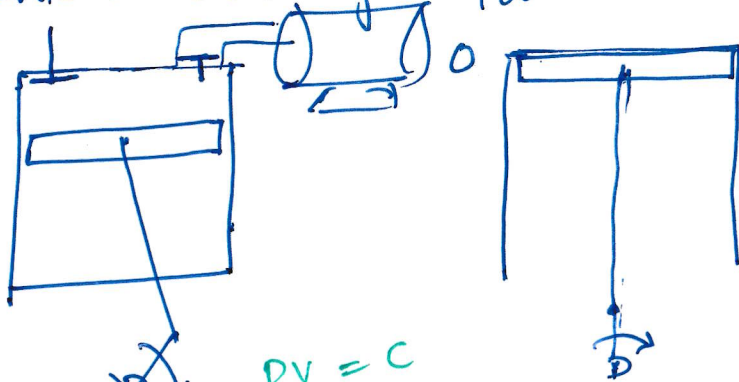


# Reciprocating compressor

①

Intake Delivery Tank



$$W = \text{Area } 32CA + \text{Area } 21BC - \text{Area } 01BA$$

$$= p_2 v_2 + \frac{p_2 v_2 - p_1 v_1}{n-1} - p_1 v_1$$

$$= (p_2 v_2 - p_1 v_1) \left[ 1 + \frac{1}{n-1} \right]$$

$$= \frac{n}{n-1} (p_2 v_2 - p_1 v_1)$$

$$= \frac{n}{n-1} m R (T_2 - T_1)$$

$$= \frac{n}{n-1} m R T_1 \left[ \frac{T_2}{T_1} - 1 \right]$$

$$= \frac{n}{n-1} m R T_1 \left[ \left( \frac{p_2}{p_1} \right)^{\frac{n-1}{n}} - 1 \right] \quad \left[ m = \frac{p v}{R T} \right]$$

Define  $r_p \triangleq \frac{p_2}{p_1}$  (pressure ratio)

$$= \frac{n}{n-1} m R T_1 \left[ r_p^{\frac{n-1}{n}} - 1 \right]$$

If compression is isothermal.

$$W = P_2 V_2 + P_1 V_1 \ln \frac{V_2}{V_1} - P_1 V_1$$

$$P_2 V_2 + P_1 V_1 \ln \frac{V_1}{V_2} - P_1 V_1$$

Since  $P_1 V_1 = P_2 V_2$  (isothermal)

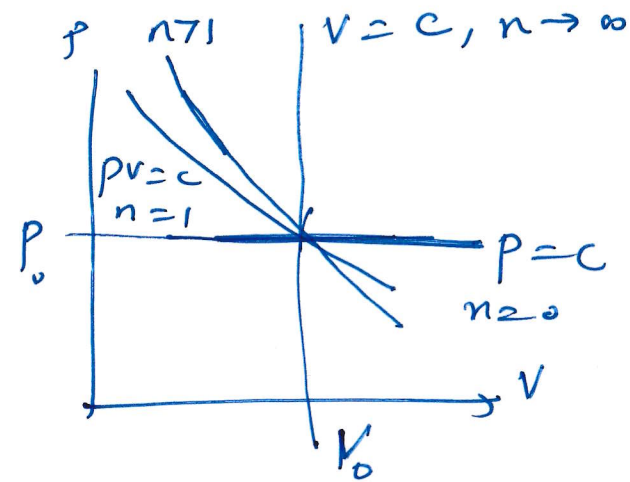
$$W = P_1 V_1 \ln \frac{V_2}{V_1} \quad P_1 V_1 \ln \frac{V_1}{V_2}$$

$$W = nRT \ln \frac{P_2}{P_1}$$

$$W_{iso} < W_{polytropic}$$

$$\eta_{isothermal} = \frac{W_{iso}}{W_{polytropic}}$$

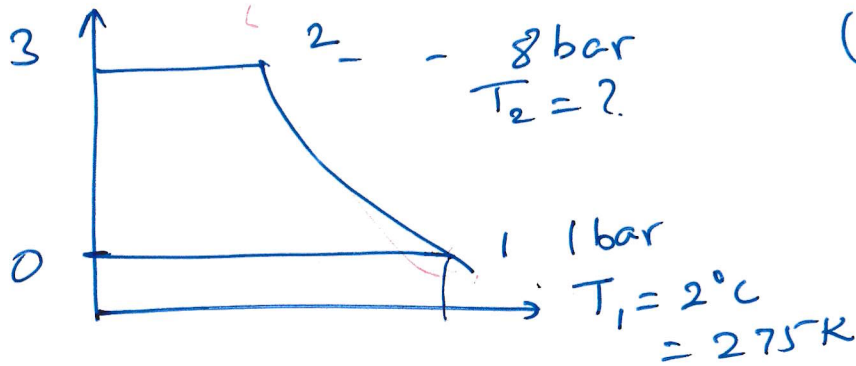
(isothermal efficiency)



(3)

A single acting reciprocating compressor is required to compress  $1.5 \text{ m}^3/\text{min}$  of R-134 refrigerant ( $\gamma = 1.31$ ,  $MW = 102$ ) with initial temperature  $2^\circ\text{C}$  from 1 bar to 8 bar. Assume compression is polytropic  $n = 1.12$ . Determine:

- 1) Temperature at the end of the compression
- 2) Power required to operate the compressor
- 3) Heat transferred during compression
- 4) Isothermal efficiency
- 5) Mass of the refrigerant compressed per minute



$$(1) \quad \frac{T_2}{T_1} = \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} \Rightarrow \frac{T_2}{275} = \left( \frac{8}{1} \right)^{\frac{0.12}{1.12}}$$

$$= 343.6 \text{ K} = 70.6^\circ\text{C}$$

$$(2) \quad W = \frac{n}{n-1} \underbrace{m R T_1}_{(P_1 v_1)} \left[ 2^{\frac{n-1}{n}} - 1 \right]$$

$$= \left( \frac{0.12}{0.12} \right) (100) \left( \frac{1.5}{60} \right) \left[ 8^{\frac{0.12}{1.12}} - 1 \right]$$

$$= 5.82 \text{ kW}$$

$$(3) \quad Q = \Delta u + W = m C_v \Delta T + W$$

$$m = \frac{P v}{R T}$$

$$R = \frac{8.314}{102} = 0.0815 \text{ kJ/kg K}; \quad C_v = \frac{R}{\gamma - 1} = \frac{0.0815}{1.31 - 1} = 0.263 \text{ kJ/kg K}$$

$$m = \frac{(100)(1.5/60)}{(0.0815)(275)} = 0.11 \text{ kg/s}$$

$$Q = (0.11)(0.263)(70.6 - 2) - \cancel{5.82} = -3.84 \text{ kW} \quad -3.14 \text{ kW}$$

$$(4) \quad W_{iso} = P_1 v_1 \ln \frac{P_2}{P_1}$$

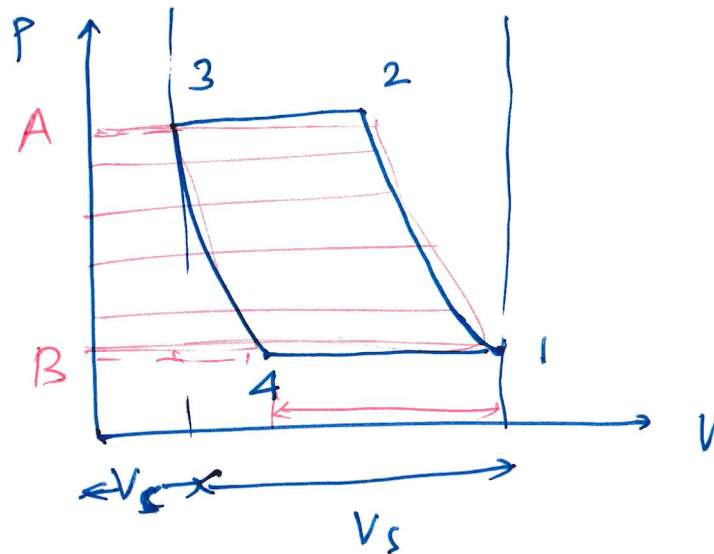
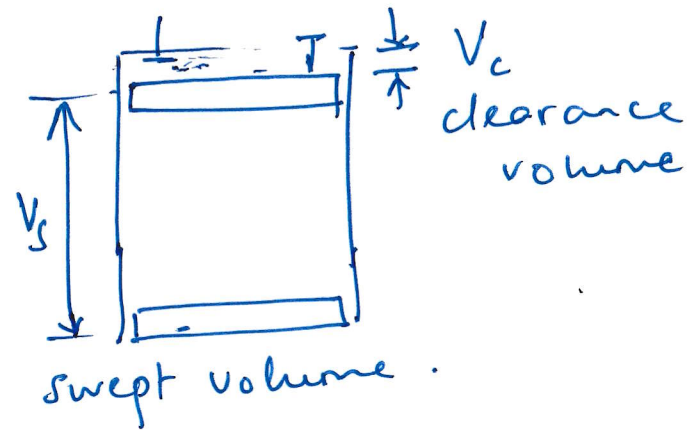
$$= (100) \left( \frac{1.5}{60} \right) \ln 8 = 5.2 \text{ kW}$$

$$\eta_{iso} = \frac{5.2}{5.82} = 89\%$$

$$W = \frac{mR(T_2 - T_1)}{n-1} = \frac{(0.11)(0.0815)(70.6 - 2)}{1.12 - 1} = 5.125 \text{ kW.}$$

(compression)

(4)

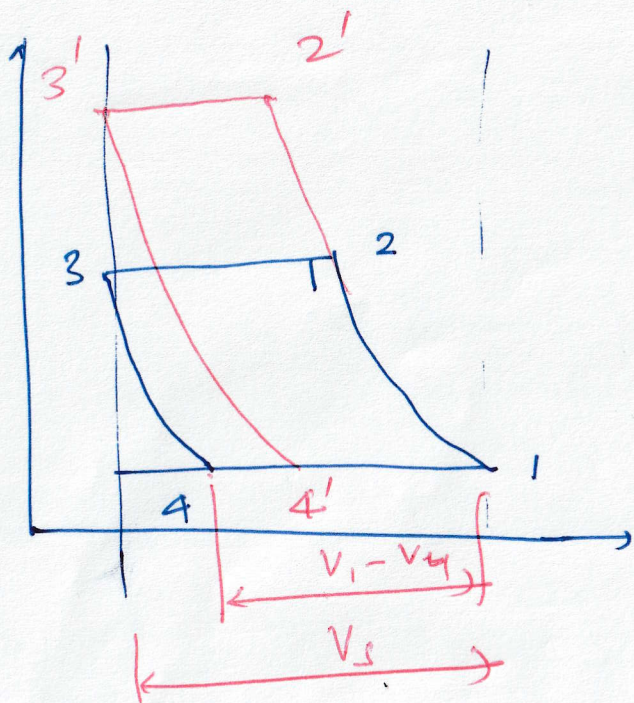


$$W = \text{Area AB12} - \text{Area AB34}$$

$$= \frac{n}{n-1} m_1 R T_1 \left[ r^{(n-1)/n} - 1 \right] - \frac{n}{n-1} m_4 R T_1 \left[ r^{(n-1)/n} - 1 \right]$$

$$= \frac{n}{n-1} (m_1 - m_4) R T_1 \left[ r^{(n-1)/n} - 1 \right]$$

(5)



$$\eta_{\text{rod}} \triangleq \frac{V_1 - V_4}{V_s}$$