(i)

GIVEN Piston-cylinder with refrigerant R-134a

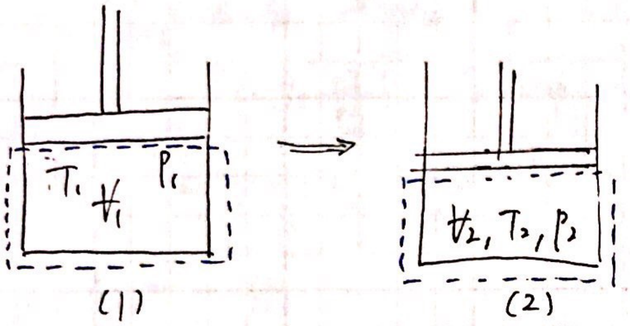
>> constant p process

* $p_1 = 4$ bar → p_2 , $T_1 \rightarrow T_2 = 30°C$

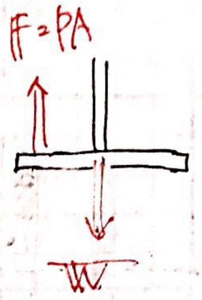
>> PE & KE negligible

FIND Show p-v diagram and find work, $\overline{W}$ and $\dot{Q}$

EFD



FBD



ASSUMP

- Closed sys.
- Quasi equilibrium
- PE = KE = 0
- isobar

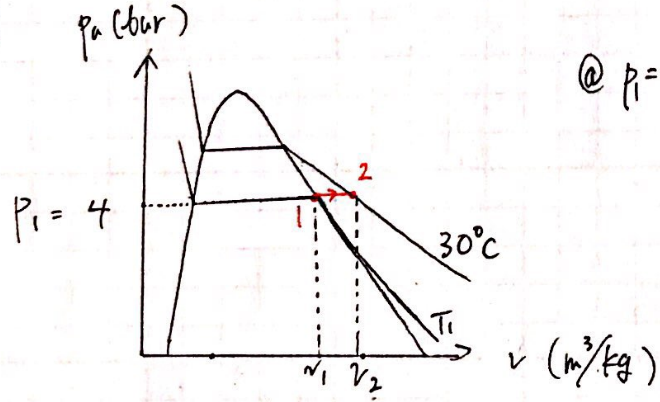
EQN

$$\cdot \ \cancel{\frac{dm}{dt}\Big|_{sys}}^{0} = \cancel{\dot{m}_{in}}^{0} - \cancel{\dot{m}_{out}}^{0}$$

$$\cancel{\Delta PE}^{0} + \cancel{\Delta KE}^{0} + \Delta U = Q - \overline{W}$$

$$\cdot \ \overline{W} = \int p \, d\forall$$

SOLN



@ $p_1 = 4.0$ bar $T_{sat} = 8.9306°C$

the is all gas, and from SHV @ $p_1 = 4$ bar and state 1 is ($T_1 = T_{sat}$)

$$v_{g1} = 0.051207 \frac{m^3}{kg}$$

and at state 2 using same table $v_{g2} = 0.05680$

thus,

$$w_{12} = \int_{v_{g1}}^{v_{g2}} p_1 dv = p_1 v_{g2} - p_1 v_{g1} = (4 \times 10^5 Pa)(0.05680 - 0.051207) \frac{m^3}{kg} \cong 2.237 \frac{kJ}{kg}$$

and from same table the internal energies are $\left(\frac{kJ}{kg}\right)$

$$u_1 = 235.09 \frac{kJ}{kg} \qquad u_2 = 252.4 \frac{kJ}{kg}$$

$$\Delta u_{12} = u_2 - u_1 = (252.4 - 235.09)\frac{kJ}{kg} = 17.31 \frac{kJ}{kg}$$

therefore

$$\begin{aligned} \Delta q_{12} &= \Delta u_{12} + \Delta w_{12} \\ &= \left(17.31 \frac{kJ}{kg}\right) + \left(2.24 \frac{kJ}{kg}\right) \\ &= 19.55 \frac{kJ}{kg} \end{aligned}$$

$$\boxed{\begin{aligned} w_{12} &= 2.24 \frac{kJ}{kg} \\ q_{12} &= 19.6 \frac{kJ}{kg} \end{aligned}}$$

(ii)

GIVEN sys. w/ 1 kg of H_2O

» Power cycle.

- * Process 1–2 : isovol $\dot{Q}_{in}$ $P_1 = 5\text{ bar}, T_1 = 160°C \rightarrow P_2 = 10\text{ bar}, T_2$
- * Process 2–3 : isobar $\dot{Q}_{out}$ $\rightarrow T_3 = T_{sat3}$
- * Process 3–4 : isovol $\dot{Q}_{out}$ $\rightarrow T_4 = 160°C$
- * Process 4–1 : isotherm expansion w/ $Q_{41} = 815.8$ kJ

FIND

(a) sketch T–v & P–v diagrams

(b) W & Q for each process.

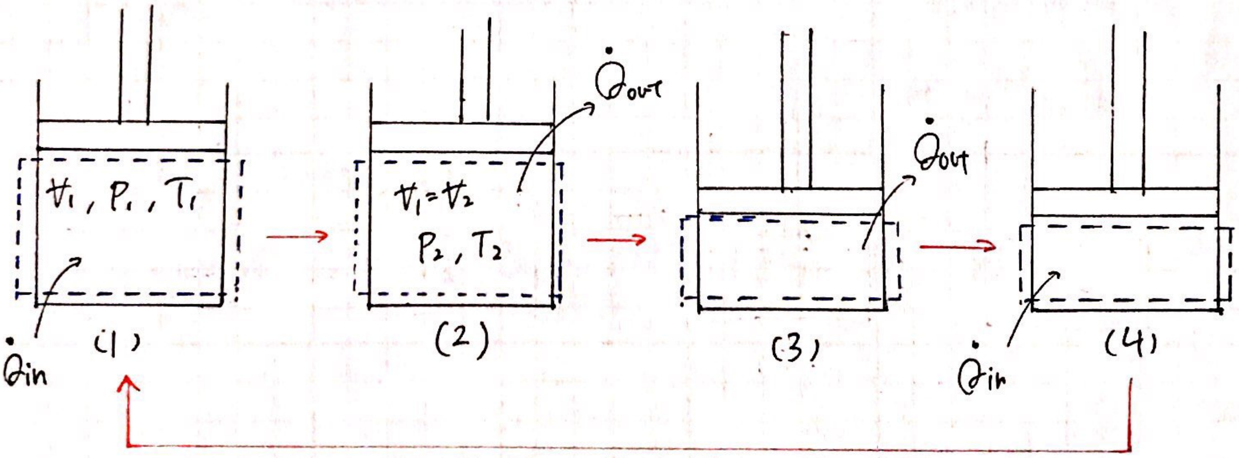
ASSUMP

- Quasiequilibrium
- closed sys.
- PE = KE = 0

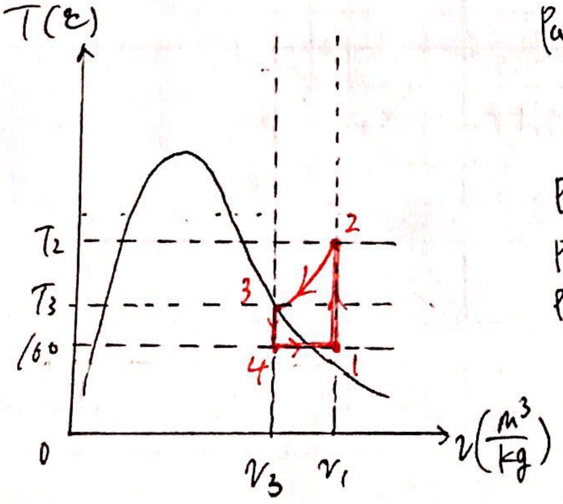
EQN

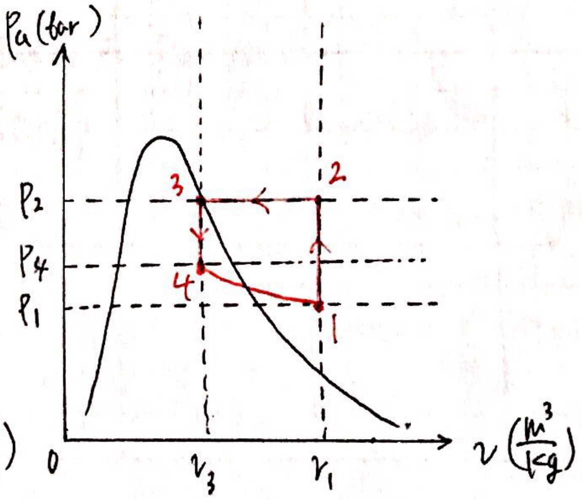
- $\left.\frac{dm}{dt}\right|_{sys} = \cancel{\dot{m}_{in}}^{0} - \cancel{\dot{m}_{out}}^{0}$, $\cancel{\frac{dm}{dt}}^{0}$
- $\Delta Q = \Delta U + \Delta W$
- $W = \int P d\forall$

EFD



SOLN





from $\overset{\text{saturation}}{\text{table}}$ T_{sat} @ $p_1 = 5$ bar is $T_{sat1} = 151.83°C$

T_{sat} @ (3) is $T_{sat3} = 179.88°C$

(I) Process 1→2 :

since isovol $W_{12} = 0$

and from $\overset{\text{SHV}}{\text{table}}$ internal energies can be calculated using interpolation

$$u_1 = [(160-151.83)°C] \cdot \frac{(2610.1-2560.8)\frac{kJ}{kg}}{(180-151.83)°C} + 2560.8\frac{kJ}{kg}$$

$$u_1 = 2575.1\frac{kJ}{kg}$$

$$\therefore U_1 = (1.0kg)u_1 = 2575.1\ kJ$$

also $\forall_1 = (1.0kg)v_1 = v_1 = \left\{[(160-151.83)°C] \cdot \frac{(0.40466-0.37484)\frac{m^3}{kg}}{(180-151.83)°C} + 0.37484\frac{m^3}{kg}\right\}(1.0kg)$

$$\cong 0.3835\ m^3$$

$\forall_2 = \forall_1 \Leftrightarrow v_2 = v_1$

so looking at SHV @ $p_2 = 10$ bar, v_2

$$U_2 = (1.0kg)u_2 = (1.0kg)\left\{\left[(0.3835-0.37295)\frac{m^3}{kg}\right] \cdot \frac{(3297.5-3193.3)\frac{kJ}{kg}}{(0.38347-0.37295)\frac{m^3}{kg}} \cdots + 3193.3\frac{kJ}{kg}\right\}$$

$$\therefore U_2 = 3297.5\ kJ$$

$$\therefore Q_{12} = \Delta U_{12} = U_2 - U_1 = 3297.5\ kJ - 2575.1\ kJ = 722.4\ kJ$$

$$\boxed{\begin{aligned} W_{12} &= 0 \\ \dot{Q}_{12} &= 722\ kJ \end{aligned}}$$

(II) process 2→3

first find v_3 (@ $T_3 = 179.88°C$ $p_3 = p_2 = 10$ bar)

from $\overset{\text{saturation}}{\text{table}} \longrightarrow v_3 = 0.19436\frac{m^3}{kg}$ $\therefore \forall_3 = 0.19436\ m^3$

then

$$W_{23} = \int_{\forall_2}^{\forall_3} p_2 d\forall = (10\times10^5\ Pa)(0.19436 - 0.3835)m^3 = -189.140\ kJ$$

and using $\overset{\text{saturation}}{\text{table}}$ $u_3 = 2582.7\frac{kJ}{kg} \Rightarrow U_3 = 2582.7\ kJ$

$$\therefore Q_{23} = \Delta U_{23} + W_{23} = (2582.7 - 3297.5)kJ - 189.140\ kJ$$

$$= -900.94\ kJ$$

$$\boxed{\begin{aligned} W_{23} &= -189\ kJ \\ Q_{23} &= -901\ kJ \end{aligned}}$$

(III) process 3→4

because isovol $W_{34} = 0$

and $v_4 = v_3$, $T_4 = 160°$ from this we use SLTM to find u_4

$$\text{quality } x = \frac{v_4 - v_{f4}}{v_{g4} - v_{f4}} = \frac{0.19436 - 0.001102}{0.30678 - 0.001102} \cong 0.63223$$

thus,

$$u_4 = (1-x)u_f + x u_g$$

$$= 0.36777 \times 674.79 \frac{kJ}{kg} + 0.63223 \times 2567.8 \frac{kJ}{kg}$$

$$\cong 1871.61 \frac{kJ}{kg}$$

$$\therefore U_4 = 1871.61 \text{ kJ}$$

$$\therefore Q_{34} = \Delta U_{34} = U_4 - U_3 = (1871.61 - 2582.7) \text{ kJ} \cong -711.1 \text{ kJ}$$

$$\boxed{\begin{array}{l} W_{34} = 0 \\ Q_{34} = -711 \text{ kJ} \end{array}}$$

(IV) Process 4→1

$$U_{41} = U_1 - U_4 = (2575.1 - 1871.61) \text{ kJ} \cong 703.5 \text{ kJ}$$

and because Q_{41} is given we know the work

$$Q_{41} = U_{41} + W_{41}$$

$$\therefore W_{41} = 815.8 - 703.5$$

$$\cong 112.3$$

$$\boxed{W_{41} = 112 \text{ kJ}}$$

a bit off from 108 kJ

but for all calculations I used scientific significant figure operations.