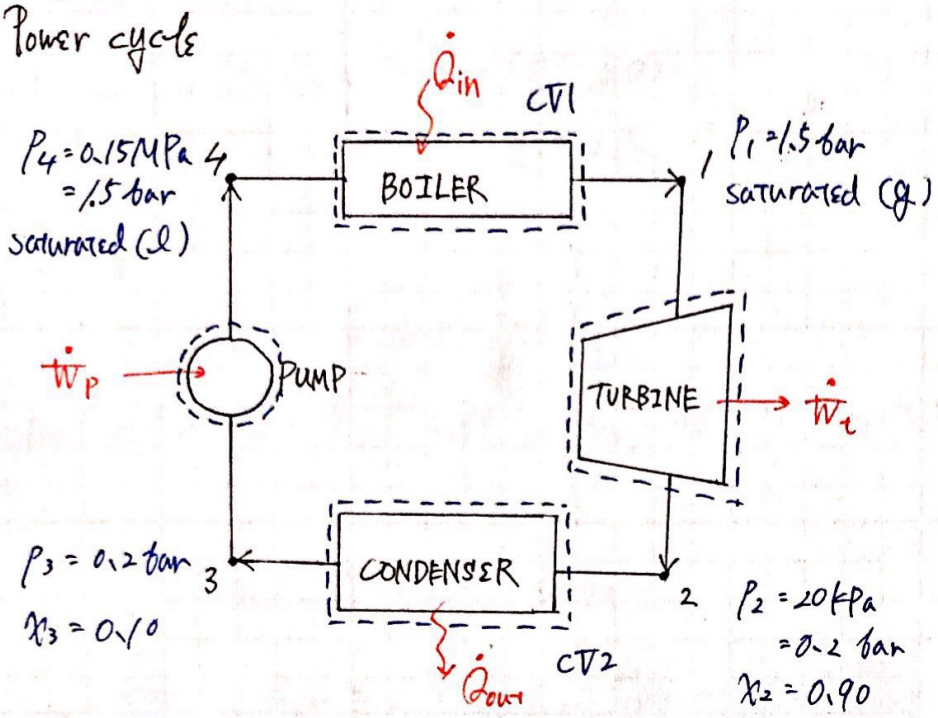
(1) GIVEN <EFD>

Power cycle




FIND

(a) thermal efficiency, $\eta$

(b) Carnot efficiency $\eta_{carnot}$

(c) Determine whether cycle is reversible, irreversible, or impossible.

ASSUMP

Open sys, SSSF, IDUF, Turbine & Pump: adiabatic

Boiler & Condenser: $\dot{W} = 0$, $\Delta PE = \Delta KE = 0$

EQN

$$\left.\frac{dm}{dt}\right|_{sys} = \sum_i \dot{m}_i - \sum_e \dot{m}_e \quad , \quad \left.\frac{dE}{dt}\right|_{sys} = \dot{Q} - \dot{W} + \sum_i \dot{m}_i (h + pe + ke) - \sum_e \dot{m}_e (h + pe + ke)$$

SOLN

for every component $\dot{m}_1 = \dot{m}_2 = \dot{m}_3 = \dot{m}_4 = \dot{m}$

Enthalpys

$h_4 = h_f|_{p=1.5} = 467.13$ kJ/kg $\quad h_f|_{p=0.2} = 251.42$ kJ/kg

$h_1 = h_g|_{p=1.5} = 2693.1$ kJ/kg $\quad h_g|_{p=0.2} = 2608.9$ kJ/kg

$$h_2 = h_f|_{p=0.2} + (h_g|_{p=0.2} - h_f|_{p=0.2})x_3$$

$$= 251.42 \text{ kJ/kg} + (2608.9 \text{ kJ/kg} - 251.42 \text{ kJ/kg})(0.90) \approx 2373.15 \text{ kJ/kg}$$

likewise

$$h_3 = h_f|_{p=0.2} + (h_g|_{p=0.2} - h_f|_{p=0.2})x_2 \approx 487.17 \text{ kJ/kg}$$

Temperatures

$T_1 = T_4 = 111.35\,°C = 384.50\,K$

$T_2 = T_3 = 60.06\,°C = 333.21\,K$

(a)

[CV1]

$0 = \dot{Q}_{in} - \cancel{\dot{W}}^{0} + \dot{m}h_4 - \dot{m}h_1$

$\therefore q_{in} = \frac{\dot{Q}_{in}}{\dot{m}} = h_1 - h_4 = 2693.1\ kJ/kg - 467.13\ kJ/kg = 2225.97\ kJ/kg$

[CV2]

$0 = \dot{Q}_{out} - \cancel{\dot{W}}^{0} + \dot{m}h_2 - \dot{m}h_3$

$\therefore q_{out} = \frac{\dot{Q}_{out}}{\dot{m}} = h_3 - h_2 = 487.17\ kJ/kg - 2373.15\ kJ/kg = -1885.98\ kJ/kg$

$\eta = \frac{\dot{q}_{in} - |\dot{q}_{out}|}{\dot{q}_{in}} \times 100 = \frac{2225.97 - 1885.98}{2225.97} \times 100 \cong 15.27$

$\boxed{\eta = 15.3\,\%}$

(b)

$\eta_{carnot} = \left(1 - \frac{T_2}{T_1}\right) \times 100 \cong 13.34$

$\boxed{\eta_{carnot} = 13.3\,\%}$

(c)

since $\eta > \eta_{carnot}$

this is $\boxed{\text{impossible}}$