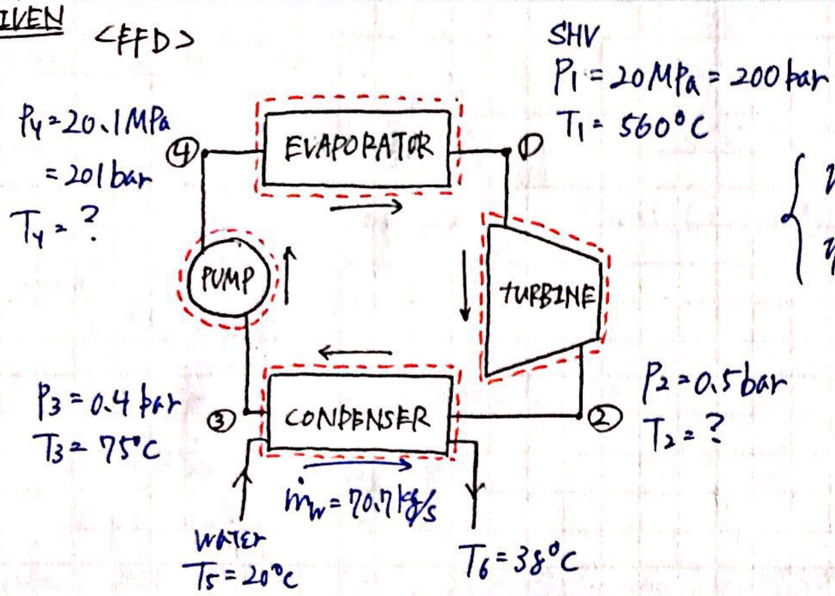
GIVEN <EFD>



$\begin{cases} \eta_T = 0.81 \\ \eta_p = 0.85 \end{cases}$

FIND (a) $\dot{m}$ of steam kg/s
(b) η_{TH}

ASSUMP SSSF, 1-DUF, open sys., $\Delta KE = \Delta PE = 0$, turbine & pump: $\dot{Q} = 0$
evaporator & condenser: $\dot{W} = 0$

EQN $\cancel{\frac{dm}{dt}\Big|_{sys}}^{0} = \sum_i \dot{m} - \sum_e \dot{m}$, $\cancel{\frac{dE}{dt}\Big|_{sys}}^{0} = \dot{Q} - \dot{W} + \sum_i \dot{m}(h + \cancel{pe}^0 + \cancel{ke}^0) - \sum_e \dot{m}(h + \cancel{pe}^0 + \cancel{ke}^0)$

$\cancel{\frac{ds}{dt}\Big|_{sys}}^{0} = \sum \frac{\dot{Q}}{T} + \sum_i \dot{m} s_i - \sum_e \dot{m} s_e + \dot{\sigma}_{gen}$

SOLN
from tables

$h_1 = 3425.4\ kJ/kg$, $s_1 = 6.374\ kJ/kg\text{-}K$

@ $T = 75°C$ $h_f = 314.03\ kJ/kg$, $h_g = 2634.6\ kJ/kg$, $s_f = 1.0158\ kJ/kg\text{-}K$, $s_g = 7.6812\ kJ/kg\text{-}K$

for the turbine, from <COE>

$0 = \cancel{\dot{Q}}^{0} - \dot{W} + \dot{m}(h_1 - h_2)$ $\quad (\because \dot{m}_1 = \dot{m}_2 = \dot{m}_3 = \dot{m}_4 = \dot{m})$

$\rightarrow \dot{\omega}_t = 3425.4\ kJ/kg - h_2 \quad \cdots ①$

and if $\Delta S = 0$ $\quad s_1 = s_2$ this implies the state to be SLVM

quality $\equiv x_{2s} = \frac{s_1 - s_f}{s_g - s_f}\Big|_{p=0.5bar} = \frac{6.374 - 1.0912}{7.5930 - 1.0912} \cong 0.81251$

then

$h_{2s} = h_f + (h_g - h_f)x_{2s}\Big|_{p=0.5bar}$

$= 340.54\ kJ/kg + (2645.2\ kJ/kg - 340.54\ kJ/kg)(0.813) \cong 2214.2\ kJ/kg$

$\dot{w}_{t,s} = h_1 - h_{2s} = 3425.4\ kJ/kg - 2214.2\ kJ/kg = 1211.2\ kJ/kg \quad \cdots ②$

since η_t is given

$$\eta_t = 0.81 = \frac{3425.4\,kJ/kg - h_2}{1211.2\,kJ/kg} \qquad (\because ①, ②)$$

$$h_2 = 3425.4\,kJ/kg - (0.81)(1211.2\,kJ/kg) \cong 2444.3\,kJ/kg$$

thus,

$\longrightarrow T_2 = 81.32°C$

likewise for the pump, from <COE>

$$0 = -\dot{W}_P + \dot{m}(h_3 - h_4)$$

$$\dot{w}_P = h_3 - h_4 \quad \cdots ③$$

now since it is a CL $\quad s_3 \simeq s_f|_{T=75°C} = 1.0158\,kJ/kg\text{-}K$

$$h_{comp,liq}(0.4bar, 75°C) \approx h_f + v_f(P_1 - P_{sat})\Big|_{T=75°C}$$

$$= 314.03\,kJ/kg + (0.0010258\,m^3/kg)(0.4\times10^2\,kPa - 0.38595\times10^2\,kPa)$$

$$\cong 314.03\,kJ/kg$$

$\therefore h_3 = 314.03\,kJ/kg$

$\rightarrow ③ \quad \dot{w}_P = 314.03\,kJ/kg - h_4$

now if $\Delta S = 0$ where $s_3 = s_4$

$$\dot{w}_{P,s} = -\int_3^4 v\,dp = -v_f(p_4 - p_3) = -(0.0010258\,m^3/kg)(201\times10^2\,kPa - 0.4\times10^2\,kPa)$$

$$= -20.578\,kJ/kg \quad \cdots ④$$

since η_p is given

$$\eta_p = 0.85 = \frac{-20.578\,kJ/kg}{314.03\,kJ/kg - h_4} \qquad \because ③, ④$$

$$\therefore h_4 \cong 338.24\,kJ/kg$$

next for condenser <COE> for the cooling water

$$0 = \dot{Q} + \dot{m}_w(h_f|_{T=38°C} - h_f|_{T=20°C})$$

$$\dot{Q} = (70.7\,kg/s)(83.914\,kJ/kg - 159.17\,kJ/kg) \cong -5320.6\,kJ/kg$$

thus,

$$\dot{Q} = \dot{m}(h_3 - h_2)$$

$$\dot{m} = \frac{\dot{Q}}{h_3 - h_2} = \frac{-5320.6\,kJ/kg}{-2130.27\,kJ/kg} \cong 2.497 \cong \boxed{2.50\,kg/s} \text{ — (a)}$$

now, since

$$\dot{q}_C = h_3 - h_2 = -2130.27 \ \mathrm{kJ/kg} \ \text{(going out)}$$

and also for evaporator

$$\dot{q}_H = h_1 - h_4$$
$$= 3425.4 \ \mathrm{kJ/kg} - 338.24 \ \mathrm{kJ/kg}$$
$$\cong 3087.16 \ \mathrm{kJ/kg} \ \text{(going in)}$$

then

$$\eta_{TH} = \frac{\dot{q}_H - |\dot{q}_C|}{\dot{q}_H} = \frac{3087.16 \ \mathrm{kJ/kg} - 2130.27 \ \mathrm{kJ/kg}}{3087.16 \ \mathrm{kJ/kg}}$$

$$\cong 0.3099 \cong \boxed{0.310} \text{—(b)}$$