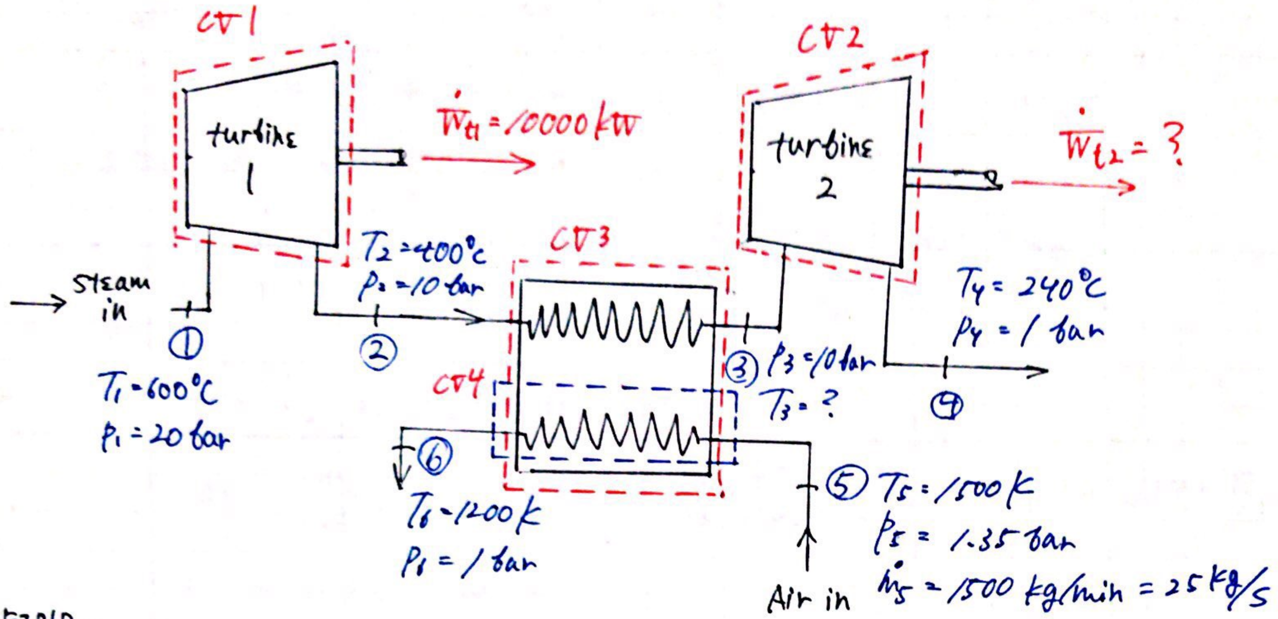
GIVEN Separate stream, air & steam, turbine & heat exchanger arrangement

+ <EFD>



FIND

(a) T_3 in K (b) $\dot{W}_{t2}$ in kW

ASSUMP

open sys, SSSF, uniform flow, air ideal gas, neglect $\dot{Q}$, ΔPE, & ΔKE

Heat exchanger neglect $\dot{W}$

EQN

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

$$pV = mRT \quad \left(R_{air} = 287.05\,\frac{J}{kg\cdot K}\right)$$

SOLN

(a) <CV1>

$$\dot{m}_1 - \dot{m}_2 = 0 \Leftrightarrow \dot{m}_1 = \dot{m}_2$$

state ①② are SHV, and from table $h_1 = 3690.7\,kJ/kg$

$h_2 = 3264.5\,kJ/kg$

therefore

$$0 = -\dot{W}_{t1} + \dot{m}_1 h_1 - \dot{m}_2 h_2$$

$$\dot{m}_1 = \dot{m}_2 = \frac{\dot{W}_{t1}}{h_1 - h_2} = \frac{10000\,kW}{(3690.7 - 3264.5)\,kJ/kg} \cong 23.46\,kg/s$$

<CV3> $\dot{m}_2 - \dot{m}_3 \Leftrightarrow \dot{m}_2 = \dot{m}_3 = 23.46$ kg/s

and

$$0 = \cancel{\dot{W}}^{0} + \dot{m}_2 h_2 - \dot{m}_3 h_3 + \dot{m}_5 h_5 - \dot{m}_6 h_6$$

also from <CV4>

$\dot{m}_5 = \dot{m}_6$ and from table $h_5 = 1636$ kJ/kg

$h_6 = 1278$ kJ/kg

now

$$0 = \dot{m}_2 (h_2 - h_3) + \dot{m}_5 (h_5 - h_6)$$

$$h_3 = \frac{\dot{m}_5}{\dot{m}_2}(h_5 - h_6) + h_2 = \frac{25 \text{ kg/s}}{23.46 \text{ kg/s}}(1636 \text{ kJ/kg} - 1278 \text{ kJ/kg}) + 3264.5 \text{ kJ/kg}$$

$$\cong 3646 \text{ kJ/kg}$$

then from table @ $P_3 = 1.0$ bar & $h_3 = 3646$ kJ/kg

state ③ is SHV

using interpolation

$$T_3 = (3646 \text{ kJ/kg} - 3566.2 \text{ kJ/kg}) \frac{600°C - 540°C}{3698.6 \text{ kJ/kg} - 3566.2 \text{ kJ/kg}} + 540°C$$

$$\cong 576.2$$

$$\boxed{T_3 = 576°C}$$

(b) <CV3> $\dot{m}_3 - \dot{m}_4 = 0 \Leftrightarrow \dot{m}_3 = \dot{m}_4 = 23.46$ kg/s

@ state ④ it is SHV, so from table $h_4 = 2954.6$ kJ/kg

then

$$0 = -\dot{W}_{t2} + \dot{m}_3 h_3 - \dot{m}_4 h_4$$

$$\dot{W}_{t2} = \dot{m}_3 (h_3 - h_4) = (23.46 \text{ kg/s})(3646 \text{ kJ/kg} - 2954.6 \text{ kJ/kg})$$

$$\cong 16220 \text{ kW}$$

$$\boxed{\dot{W}_{t2} = 1.62 \times 10^4 \text{ kW}}$$