GIVEN

Disposal of hot industrial waste water (valve, flash chamber, turbine)

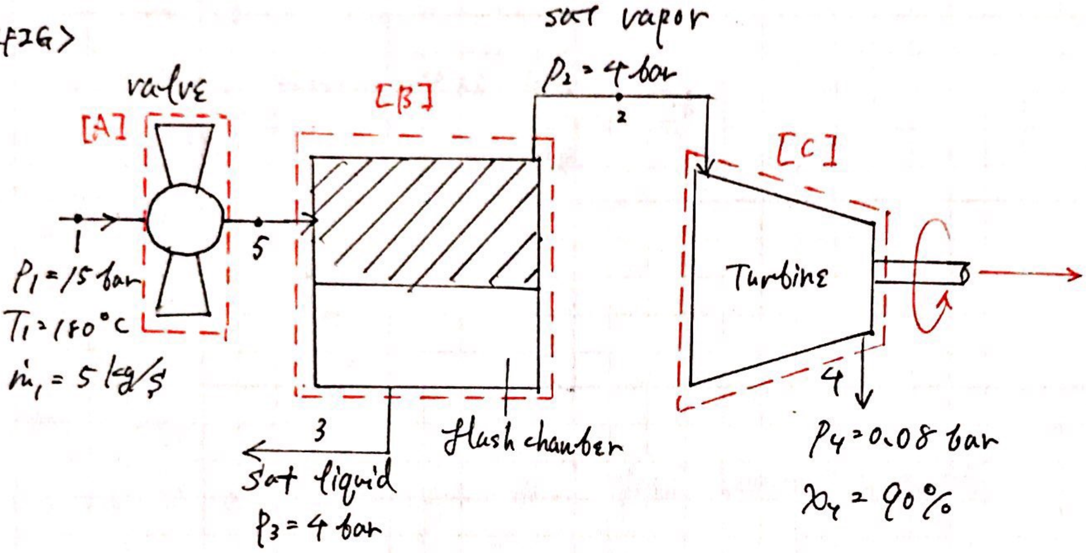
>> $p_1 = 15$ bar, $T_1 = 180°C$, $\dot{m}_1 = 5$ kg/s

$p_2 = 4$ bar

$p_3 = 4$ bar

$p_4 = 0.08$ bar $x_4 = 90\%$

EFD <FIG>



FIND Power developed by turbine $\dot{W}_{turbine}$, kW.

Assump SSSF, uniform flow, stray $\dot{Q} = \Delta PE = \Delta KE = 0$, open sys.

@ valve $\dot{W} = 0$ @ chamber $\dot{W} = 0$, no pressure change $\Delta p = 0$

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

SOLN

sys [A] $(1 \to 5)$

@ state 1 because @ T_1, $P_1 > P_{sat}$ CL and $\dot{m}_1 = \dot{m}_5$

$0 = \dot{m}_1(h_1 - h_5)$ $\therefore h_1 = h_5 = h_f(180) + v_f(P - P_{sat})$

$= (763.05 \frac{kJ}{kg}) + (0.0011274 \frac{m^3}{kg})(15 - 10.028) \times 10^2$ kPa

≈ 763.61 kJ/kg

sys [B] $(5 \to {}^{4}_{3})$

$\dot{m}_5 = \dot{m}_1 = \dot{m}_3 + \dot{m}_4$

@ state 3 sat liquid $h_3 = 604.65$ kJ/kg

@ state 2 sat vapor $h_2 = 2738.1$ kJ/kg

$$0 = \dot{m}_1 h_1 - \dot{m}_3 h_3 - \dot{m}_2 h_2$$

since $\dot{m}_3 = \dot{m}_1 - \dot{m}_2$

$$0 = \dot{m}_1 h_1 - (\dot{m}_1 - \dot{m}_2) h_3 - \dot{m}_2 h_2$$

$$0 = \dot{m}_1 (h_1 - h_3) + \dot{m}_2 (h_3 - h_2)$$

$$\dot{m}_2 = \frac{h_1 - h_3}{h_2 - h_3} \dot{m}_1$$

$$= \frac{(763.61\ kJ/kg) - (604.65\ kJ/kg)}{(2738.1\ kJ/kg) - (604.65\ kJ/kg)} \left(5\ \frac{kg}{s}\right)$$

$$\cong 0.3725\ \frac{kg}{s}$$

sys [C] $(2 \rightarrow 4)$

$$\dot{m}_2 = \dot{m}_4$$

if $x_4 = 0.90$ @ $p_4 = 0.08$ bar from saturation table

$$h_4 = h_f + (h_g - h_f) x_4$$

$$= (173.84\ kJ/kg) + [(2577.2\ kJ/kg) - (173.84\ kJ/kg)](0.90)$$

$$= 2335.964\ kJ/kg$$

$$0 = -\dot{W}_{turbine} + \dot{m}_2 h_2 - \dot{m}_4 h_4$$

$$\dot{W}_{turbine} = \dot{m}_2 (h_2 - h_4)$$

$$= (0.3725\ kg/s)[(2738.1\ kJ/kg) - (2335.964\ kJ/kg)]$$

$$\cong 149.8\ kW$$

$$\dot{W}_{turbine} = \boxed{150\ W}$$