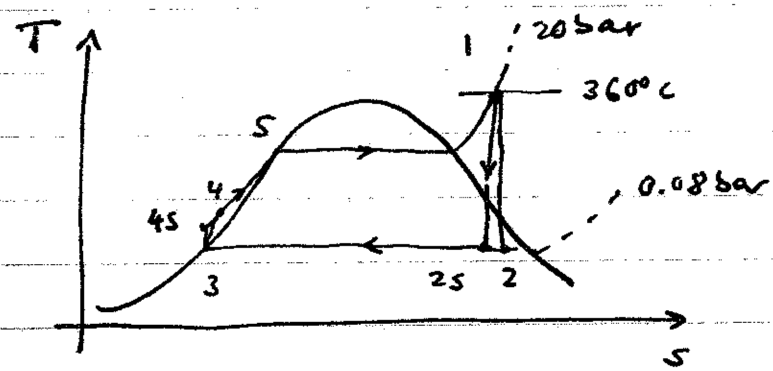
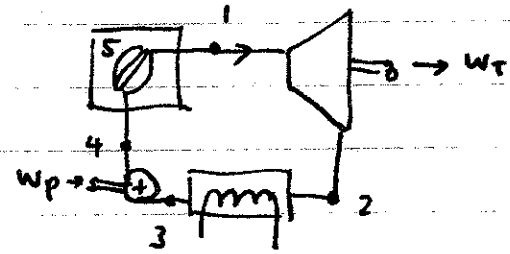
T12

16. Unified Sp09
ZS



Concepts:
- 2 phase-media
- ad. component efficiencies
- Rankine cycles



a) state 1: $h_1 = 3159.1$ kJ/kg
$s_1 = 6.9904$ kJ/kg-K

state 2s: $s_1 = s_{2s} = x_{2s} s_g + (1 - x_{2s}) s_f$

$\longrightarrow \quad x_{2s} = \frac{s_1 - s_f}{s_g - s_f} =$ $\quad s_g = 8.2312$ kJ/kg-K
$s_f = 0.5909$ kJ/kg-K

$x_{2s} = 0.837$ $\quad h_g = 2576.8$ kJ/kg, $h_f = 173.4$ kJ/kg

$\longrightarrow \quad h_{2s} = 2185$ kJ/kg $\quad V_3 = 0.001$ m³/kg

$w_T^s = h_1 - h_{2s} = 974$ kJ/kg ; $w_P^s = v_3 (P_1 - P_3) = 1.99$ kJ/kg

$q_R^s = h_{2s} - h_f = 2011.6$ kJ/kg ; $q_A^s = w_T^s - w_P^s + q_R = 2983.6$ kJ/kg

$w_{net}^s = w_T^s - w_P^s = 972$ kJ/kg ; $\eta_{th}^s = \frac{w_{net}^s}{q_A^s} = 0.326$

b) $\eta_P = \frac{h_{4s} - h_3}{h_4 - h_3} \rightarrow w_P = \frac{1}{\eta_P} w_P^s = 2.49$ kJ/kg

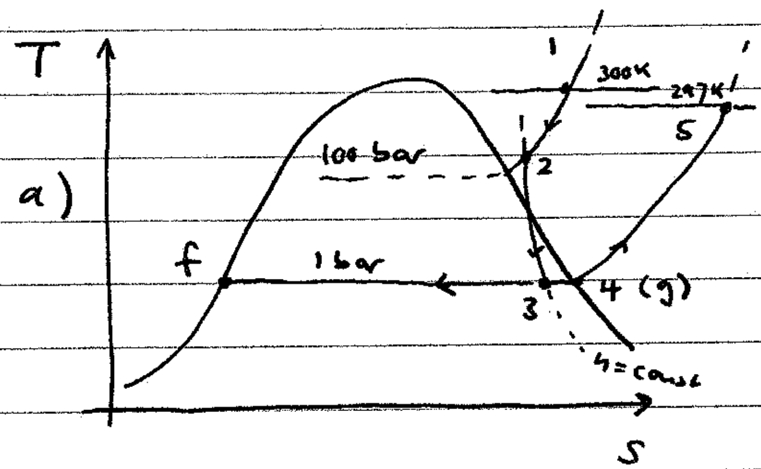
$\eta_T = \frac{h_1 - h_2}{h_1 - h_{2s}} \longrightarrow w_T = \eta_T w_T^s = 779.2$ kJ/kg

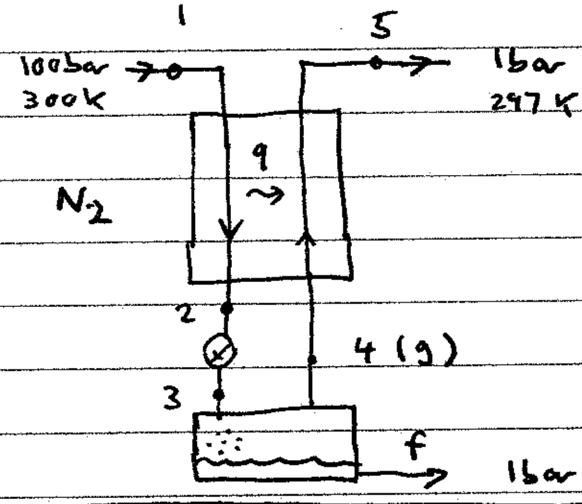
$w_{net} = w_T - w_P = 776.5$ kJ/kg ; $q_R = h_2 - h_f = 2206.5$ kJ/kg

$q_A = w_{net} + q_R = 2983$ kJ/kg

$\eta_{th} = \frac{w_{net}}{q_A} = 0.26$; $\frac{\Delta w_{net}}{w_{net}^s} = 20\%$; $\frac{\Delta \eta_{th}}{\eta_{th}^s} = 20\%$

a)





$\dot{V}_3 = 0.167 \, m^3/s \qquad \dot{m}_3 = \frac{1}{v_3}\dot{V}_3$

$\dot{m}_1 = \dot{m}_3$ cons. mass

from tables:
$h_1 = 291.9$ kJ/kg
$h_5 = 308$ kJ/kg
$h_g = h_4 = 76.7$ kJ/kg
$h_f = -122$ kJ/kg
$v_g = 0.21639$ m^3/kg
$v_f = 0.00124$ m^3/kg

$1 \to 2$: 1st law $\quad h_1 - h_2 = q$

$2 \to 3$: 1st law $\quad h_3 = h_2$ (note $T_2 \neq T_3$!)

(throttling: no heat, no work)

$4 \to 5$: 1st law $\quad \dot{m}_4 (h_5 - h_4) = \dot{m}_3 q$

quality: $\dot{m}_4 = \dot{m}_g \to \frac{\dot{m}_4}{\dot{m}_3} = x_3$, $h_3 = h_g x_3 + h_f (1 - x_3)$

combine $\quad h_1 - h_3 = q = x_3 (h_5 - h_g) \to x_3 = \frac{h_1 - h_f}{h_5 - h_f} \qquad \underline{x_3 = 0.962}$

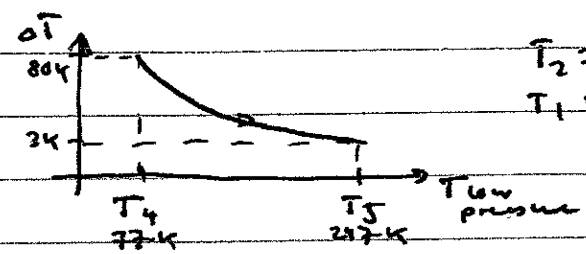
b) mass flow: $v_3 = x_3 v_g + (1 - x_3) v_f = 0.2082 \, m^3/kg \to \underline{\dot{m}_3 = 0.8 \, kg/s}$

c) heat transfer: $h_3 = x_3 h_g + (1 - x_3) h_f = 69.1$ kJ/kg $\to \dot{Q} = \dot{m}_3 (h_1 - h_3)$

$\underline{\dot{Q} = 178.2 \, kW}$

d) liquid N_2 rate: $\dot{m}_f = (1 - x_3) \dot{m}_3$, $\underline{\dot{m}_f = 0.03 \, kg/s}$

e) from T-s diagram



~~$T_2 \approx 157K \to \Delta T(T_4) = 80K$~~

$T_1 = 300K \to \Delta T(T_5) = 3K$

irreversible heat transfer due to finite temp. difference