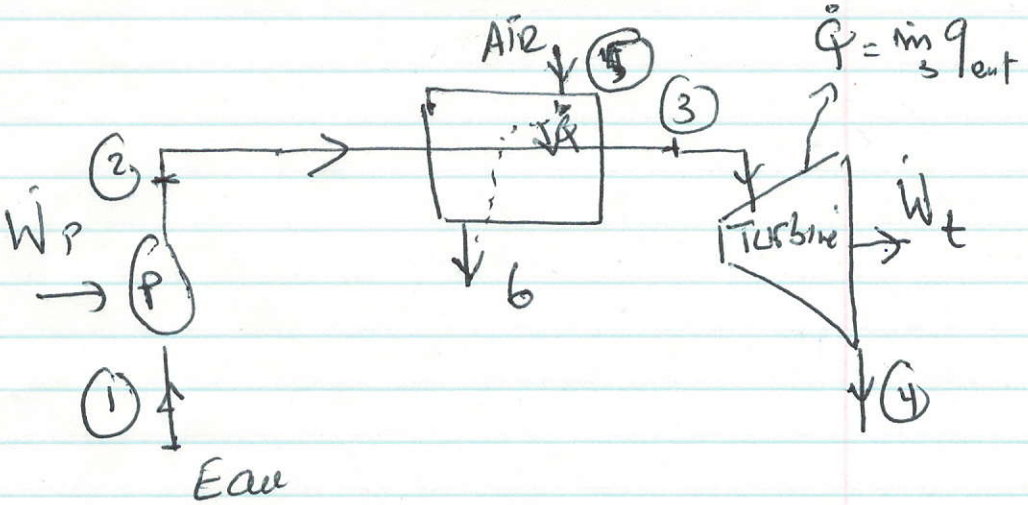
MEC1210, TD3 (Solutionnaire)



Hypothèses:

$\Delta \bar{E}_p, \Delta \bar{E}_c = 0$ (Air et eau)

Pas de pertes de pression $P_2 = P_3$, $P_5 = P_6$

échangeur de chaleur.

① $\begin{cases} P_1 = 800 kPa \\ T_1 = 165°C \\ \dot{V}_1 = 0{,}013296 \frac{m^3}{s} \end{cases}$

② $\begin{cases} P_2 = 4 MPa \\ T_2 = T_1 + 2°C = 167°C \end{cases}$

③ $\begin{cases} P_3 = P_2 = 4 MPa \end{cases}$

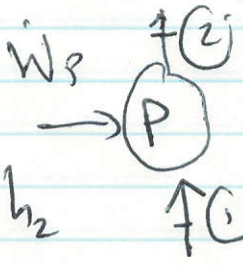
④ $\begin{cases} P_4 = 25 kPa \\ x_4 = 0{,}92 \end{cases}$

⑤ Air $\begin{cases} P_5 = 150 kPa \\ T_5 = 727 \\ \dot{V}_5 = 125.2277 \frac{m^3}{s} \end{cases}$

⑥ $\begin{cases} P_6 = P_5 \\ T_6 = 327°C \end{cases}$

a) $\dot{W}_p = ?$

Système Pompe



$$\begin{cases} \dot{W}_{in} + \cancel{\dot{Q}_{in}} + \dot{m}_1 h_1 = \cancel{\dot{W}_{out}} + \cancel{\dot{Q}_{out}} + \dot{m}_2 h_2 \\ \dot{m}_1 = \dot{m}_2 \end{cases}$$

$$\Rightarrow \boxed{\dot{W}_p = \dot{W}_{in} = \dot{m}_1 (h_2 - h_1)}$$

$P_1 = 800\ kPa$
$T_1 = 165°C$ $\xrightarrow[800\ kPa]{A5}$ $T_{sat} = 170,41°C$

$T_1 < T_{sat}$ => liquide Comprimé

$$h_1 = h_{f@165°C} = 697.24\ \frac{kJ}{kg}$$

$$v_1 = v_{f@165°C} = 0,001108\ m^3/kg$$

$$\dot{m}_1 = \frac{\dot{V}_1}{v_1} \qquad \dot{m}_1 = \frac{0,013296}{0,001108} = 12\ kg/s$$

$P_2 = 4\ MPa$
$T_2 = 167°C$ $\xrightarrow[4\ MPa]{A5}$ $T_{sat} = 250,35°C$.

$T_2 > T_{sat}$ => liquide Comprimé

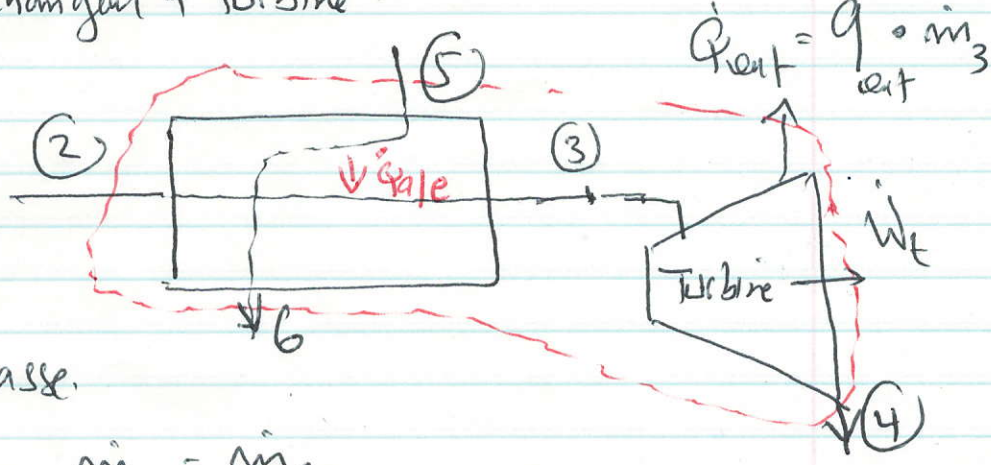
$h_2 = h_{f@167°C}$ $\xrightarrow[\text{interpolation}]{A4}$ $h_2 = 705.976\ \frac{kJ}{kg}$

D'où $\dot{W}_p = 12\,(705,976 - 697,24) = 104,83\ kW$

$$\dot{W}_p = 104,83\ kW$$

b) $\dot{W}_t = ?$

Système échangeur + Turbine



Bilan de masse.

$\dot{m}_2 = \dot{m}_4$, $\dot{m}_5 = \dot{m}_6$

Bilan d'énergie

$$\dot{m}_2 h_2 + \dot{m}_5 h_5 = \dot{m}_4 h_4 + \dot{m}_6 h_6 + \dot{W}_t + \dot{Q}_{out}$$

$$\dot{W}_t = \dot{m}_2 (h_2 - h_4) + \dot{m}_5 (h_5 - h_6) - \dot{Q}_{out}$$

$$= \dot{m}_2 (h_2 - h_4) + \dot{m}_5 C_p (T_5 - T_6) - \dot{Q}_{out}$$

$C_p = C_v + R = 0,718 + 0,287 = 1,005 \text{ kJ/kg.K}$

④ $\begin{cases} P_4 = 25 \text{ kPa} \\ x_4 = 0,92 \end{cases}$ mélange $\xrightarrow[25 \text{ kPa}]{A5}$ $h_4 = h_f + x_4 h_{fg}$

$= 271,96 + 0,92 \cdot 2345,5$

$\boxed{h_4 = 2429,82 \text{ kJ/kg}}$

$P_5 \dot{V}_5 = \dot{m}_5 R T_5$ (gaz parfait)

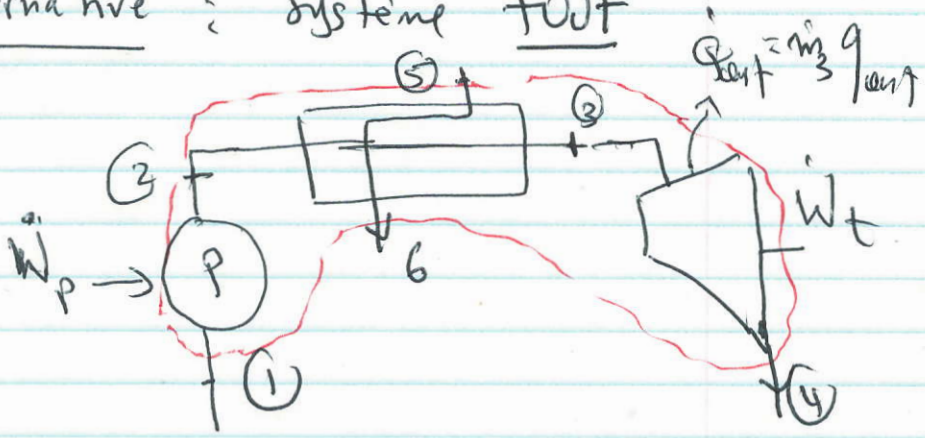
$\Rightarrow \boxed{\dot{m}_5 = \dfrac{P_5 \dot{V}_5}{R T_5}}$ $\dot{m}_5 = \dfrac{150 \cdot 125,22}{0,28 \cdot (727 + 273)} = 65,45 \text{ kg/s}$

$$\dot{m}_5 = \dot{m}_6 = 65{,}45 \text{ kg/s}$$

$$\dot{W}_t = 12\left(705{,}976 - 2429{,}82\right) + 65{,}45 \cdot 1{,}005\left(727 - 327\right) - 12 \cdot 35$$

$$\dot{W}_t = 5204{,}8 \text{ kW}$$

Solution alternative : Système tout



Bilan de masse

$$\dot{m}_1 = \dot{m}_4$$

$$\dot{m}_5 = \dot{m}_6$$

Bilan d'énergie

$$\dot{m}_1 h_1 + \dot{W}_p + \dot{m}_5 h_5 = \dot{m}_4 h_4 + \dot{W}_t + \dot{Q}_{out} + \dot{m}_6 h_6$$

$$\dot{W}_t = \dot{m}_1 (h_1 - h_4) + \dot{W}_p + \dot{m}_5 (h_5 - h_6) - \dot{Q}_{out}$$

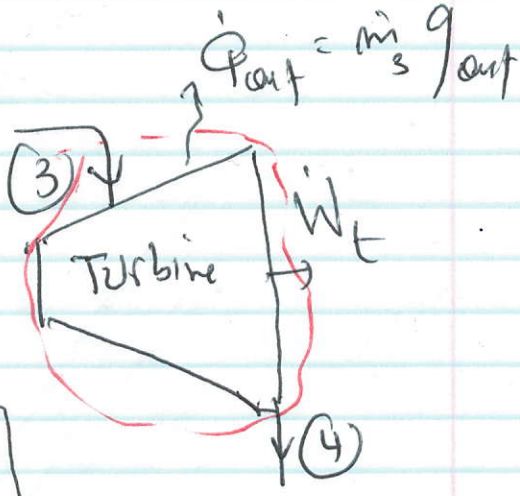
$$\dot{W}_t = \dot{m}_1 (h_1 - h_4) + \dot{W}_p + \dot{m}_5 c_p (T_5 - T_6) - \dot{Q}_{out}$$

$$\dot{W}_t = 12\left(697{,}24 - 2429{,}82\right) + 104{,}83 + 65{,}45 \cdot 1{,}005\left(727 - 327\right) - 12 \cdot 35$$

$$\dot{W}_t = 5204{,}8 \text{ kW}$$

Solution alternative: en deux fois

Système turbine



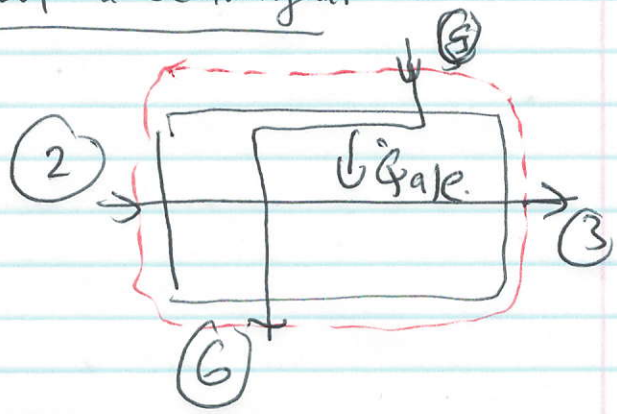
$\dot{m}_3 = \dot{m}_4$ (bilan masse)

Bilan d'énergie

$\dot{m}_3 h_3 = \dot{m}_4 h_4 + \dot{Q}_{out} + \dot{W}_t$

$$\boxed{\dot{W}_t = \dot{m}_3 (h_3 - h_4) - \dot{Q}_{out}}$$

$h_3 = ?$ Système tout l'échangeur



Bilan masse.

$\dot{m}_5 = \dot{m}_6$

$\dot{m}_2 = \dot{m}_3$

Bilan d'énergie

$\dot{m}_2 h_2 + \dot{m}_5 h_5 = \dot{m}_3 h_3 + \dot{m}_6 h_6$

$\dot{m}_3 (h_3 - h_2) = \dot{m}_5 (h_5 - h_6)$

$h_3 = h_2 + \frac{\dot{m}_5}{\dot{m}_3} (h_5 - h_6)$

$$\boxed{h_3 = h_2 + \frac{\dot{m}_5}{\dot{m}_3} c_p (T_5 - T_6)}$$

$$h_3 = 705.976 + \frac{65.45}{12} \cdot 1,005 \left(727 - 327\right) = 2898.55 \frac{kJ}{kg}$$

$$\boxed{h_3 = 2898,55 kJ/kg}$$

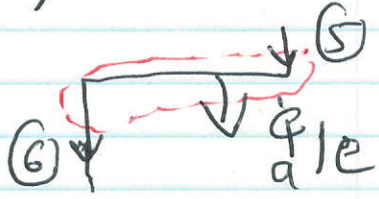
D'où $\dot{W}_t = 12(2898.55 - 2429,82) - 12 \cdot 35 = 5204,8 kW$

$$\boxed{\dot{W}_t = 5204,8 kW}$$

c) $\dot{Q}_{q/e}$? Système Air (5-6)

$\dot{m}_5 = \dot{m}_6$

$\dot{m}_5 h_5 = \dot{m}_6 h_6 + \dot{Q}_{q/e}$



$\dot{Q}_{q/e} = \dot{m}_5 (h_5 - h_6) = \dot{m}_5 C_p (T_5 - T_6)$

$$\boxed{\dot{Q}_{q/e} = \dot{m}_5 C_p (T_5 - T_6)}$$

$\dot{Q}_{q/e} = 65,45 \cdot 1,005 (727 - 327) = 26311 kW$

$$\boxed{\dot{Q}_{q/e} \simeq 26311 kW}$$

Solution alternative : Système eau 2 – 3

bilan de masse: $\dot{m}_2 = \dot{m}_3$

bilan d'énergie $\dot{m}_2 h_2 + \dot{Q}_{q/e} = \dot{m}_3 h_3$

$$\boxed{\dot{Q}_{q/e} = \dot{m}_3 (h_3 - h_2)}$$

$$\dot{Q}_{q/e} = 12 (2898,55 - 705.976) \approx 26311 \text{ kW}$$

$$\boxed{\dot{Q}_{q/e} = 26311 \text{ kW}}$$

d) T-v