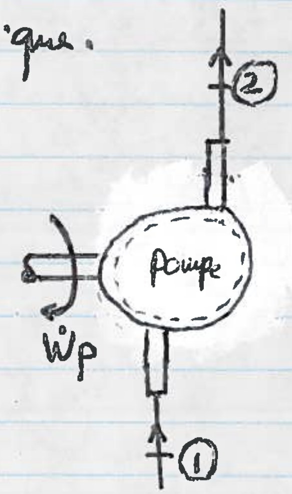
TD3_ MEC 1210 (H2017)

1 La puissance requise par la pompe (en kW) :

$1^{ère}$ loi appliquée à un système ouvert (Bilan d'énergie) :

hypothèses :

- Régime permanent
- Pas de perte de pression dans l'échangeur de chaleur et la chaudière.
- Gaz chaud : gaz parfait à C_p et C_v constantes.
- $(\Delta e_c, \Delta e_p)_{gaz\ chaud} \simeq 0$
- $(\Delta e_c, \Delta e_p)_{eau} \simeq 0$
- Pompe adiabatique.



Donc : $\dot{E}_{in} = \dot{E}_{out}$

$$\dot{W}_{in} + \cancel{\dot{Q}_{in}}^{0} + \sum_{in} \dot{m}\theta = \cancel{\dot{W}_{out}}^{0} + \cancel{\dot{Q}_{out}}^{0} + \sum_{out} \dot{m}\theta$$

$$\theta = h + \cancel{\frac{V^2}{2}}^{0} + \cancel{gz}^{0} = h.$$

Bilan de masse :

$\boxed{syst = pompe}$

$$\sum_{in} \dot{m} = \sum_{out} \dot{m} \longrightarrow \boxed{\dot{m}_1 = \dot{m}_2 = \dot{m}}$$

$$\dot{W}_{in} + \dot{m}_1 h_1 = \dot{m}_2 h_2 \longrightarrow \dot{W}_{in} = \dot{W}_p = \dot{m}(h_2 - h_1)$$

$$\boxed{\dot{W}_p = \dot{m}(h_2 - h_1)}$$

$$\text{État } 1 \begin{cases} P_1 = 900 \text{ kPa} \\ \text{liq. saturé} \end{cases} \xrightarrow{A5} \begin{cases} h_1 = h_{f@900kPa} = 742,56 \text{ kJ/kg.} \\ v_1 = v_{f@900kPa} = 0,001121 \text{ m}^3/\text{kg} \end{cases}$$

État 2 $\begin{cases} P_2 = 6\,MPa \xrightarrow{A5} T_{sat@6MPa} = 275{,}59\,°C \\ T_2 = 180\,°C \\ \qquad T_2 < T_{sat} \longrightarrow \text{liq. comprimé.} \end{cases}$

$\longrightarrow h_2 \simeq h_{f@180°C} = 763{,}05\ kJ/kg$ (table A4)

$\dot m$?

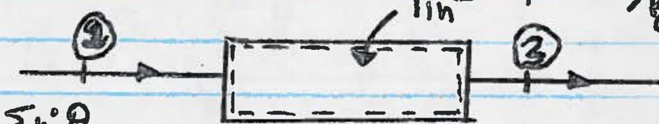
$$\dot m_1 = \frac{\dot V_1}{v_1} = \frac{(0{,}0138\ m^3/s)}{0{,}001121\ (m^3/kg)} = 12{,}31\ kg/s$$

$$\dot W_p = \dot m (h_2 - h_1) = \left(12{,}31\ \frac{kg}{s}\right)\left[(763{,}05 - 742{,}56)\ \frac{kJ}{kg}\right]$$

$$\boxed{\dot W_p = 252{,}23\ kW}$$

② La température de l'eau à l'entrée de la turbine (T_3) :

Bilan d'énergie :



$$\cancelto{0}{\dot W_{in}} + \dot Q_{in} + \Sigma \dot m \theta = \cancelto{0}{\dot W_{out}} + \cancelto{0}{\dot Q_{out}} + \Sigma \dot m \theta.$$

syst = chaudière

$$\theta = h + \cancelto{0}{\frac{V^2}{2}} + \cancelto{0}{gz}$$

$$\dot Q_{in} + \dot m_2 h_2 = \dot m_3 h_3$$ et $\dot m_2 = \dot m_3 = \dot m$ (Bilan de masse)

On a : $P_3 = P_2 = 6\,MPa$

$$\longrightarrow \frac{\dot Q_{in} + \dot m h_2}{\dot m} = h_3$$

$$h_3 = \frac{\dot Q_{in}}{\dot m} + h_2 = q_{in} + h_2 \quad (\text{car : } \dot Q = \dot m q)$$

$$h_3 = 2415{,}25\,\frac{kJ}{kg} + 763{,}05 = 3178{,}30\ kJ/kg.$$

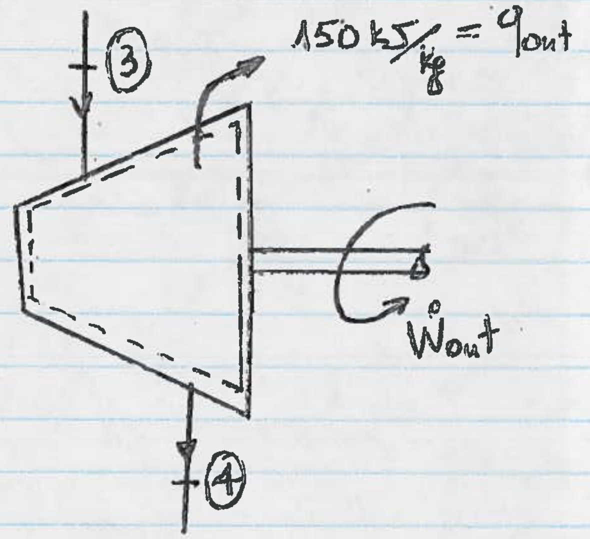
État 3 $\begin{cases} P_3 = 6\,MPa \\ h_3 = 3178{,}30\ kJ/kg \end{cases} \xrightarrow{A5} \begin{cases} h_f = h_{f@6MPa} = 1213{,}8 \\ h_g = h_{g@6MPa} = 2784{,}6 \end{cases} kJ/kg.$

$h_3 > h_g \longrightarrow$ Vapeur surchauffée.

$\xrightarrow{A6} \begin{cases} P_3 = 6\,MPa \\ h_3 = 3178{,}30\,\frac{kJ}{kg} \end{cases} \longrightarrow \boxed{T_3 = 400°C}$

3 La puissance développée par la turbine (en kW):

Bilan d'énergie:



$$\dot{W}_{in}^{\nearrow 0} + \dot{Q}_{in}^{\nearrow 0} + \sum_{in} \dot{m}\theta = \dot{W}_{out} + \dot{Q}_{out} + \sum_{out} \dot{m}\theta$$

$$\theta = h + \frac{V^2}{2}^{\nearrow 0} + gz^{\nearrow 0}$$

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

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

Bilan de masse: $\dot{m}_3 = \dot{m}_4 = \dot{m}$

$$\dot{W}_T = -\dot{Q}_{out} + \dot{m}(h_3 - h_4) = -\dot{m}q_{out} + \dot{m}(h_3 - h_4)$$

$$\dot{W}_T = \dot{m}(h_3 - h_4 - q_{out})$$

h_4?
$\begin{cases} P_4 = 300\,kPa \\ x_4 = 0{,}93 \end{cases}$ (Mélange saturé).

$h_4 = h_{f@300kPa} + x_4\, h_{fg@300kPa}$

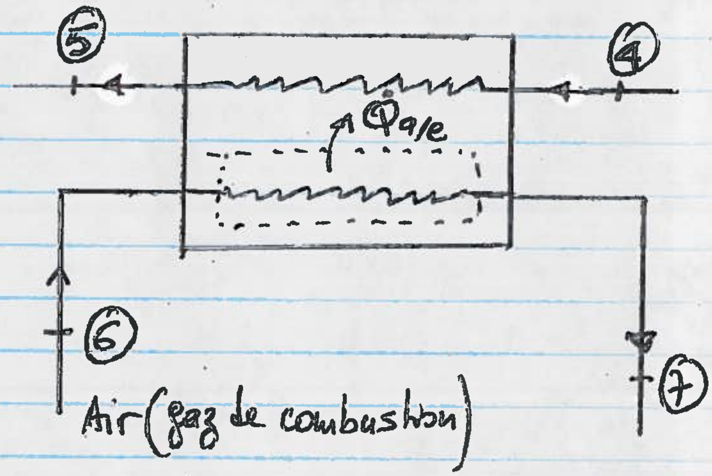
$\xrightarrow{A5}$ $h_4 = 561{,}43 + (0{,}93)(2163{,}5) = 2573{,}48$ kJ/kg.

$\dot{W}_T = (12{,}31\ \text{kg/s})\left[3178{,}30 - 2573{,}48 - 150\right] = 5598{,}83$ kW

$\boxed{\dot{W}_T = 5{,}6\ \text{MW}}$

4) La chaleur échangée au niveau de l'échangeur de chaleur :

<u>Bilan d'énergie</u> :



$\dot{W}_{in}^{\,\nearrow 0} + \dot{Q}_{in}^{\,\nearrow 0} + \sum_{in} \dot{m}\theta = \dot{W}_{out}^{\,\nearrow 0} + \dot{Q}_{out} + \sum_{out} \dot{m}\theta$

$\theta = h + \frac{V^2}{2}^{\nearrow 0} + gz^{\nearrow 0}$

$\dot{m}_6 h_6 = \dot{Q}_{out} + \dot{m}_7 h_7$

Bilan de masse :

$\dot{m}_6 = \dot{m}_7 = \dot{m}_{air}$.

$\rightarrow$ $\dot{Q}_{out} = \dot{m}_{air}(h_6 - h_7) = \dot{m}_{air}\, c_p (T_6 - T_7)$

$\dot{Q}_{a/e} = \dot{m}_{air}\,(C_v + R)(T_6 - T_7)$

$\dot{m}_{air}$?

$P_6 \dot{V}_6 = \dot{m}_6 R T_6 \longrightarrow \dot{m}_6 = \dot{m}_{air} = \dfrac{P_6 \dot{V}_6}{R T_6}$

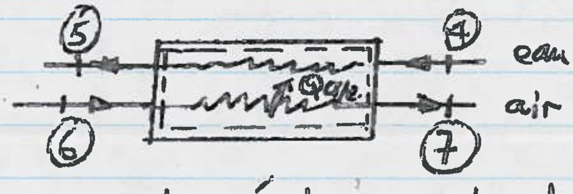
$\dot{m}_{air} = \dfrac{(100\ \text{kPa})(49{,}94\ \frac{m^3}{s})}{(0{,}287\ \text{kPa}\cdot m^3/\text{kg}\cdot K)(600+273)\,K} = 19{,}93$ kg/s

$$\dot{Q}_{a/e} = (19{,}93\ \text{kg/s})(0{,}718+0{,}287)\left[600-420\ °\text{C}\right]$$

$$\boxed{\dot{Q}_{a/e} = 3605{,}33\ \text{kW}}$$

5 Diagramme T-v aux points (2, 3, 4 et 5):

T_5 ? Bilan d'énergie:



$$\overset{0}{\dot{W}_{in}} + \overset{0}{\dot{Q}_{in}} + \sum_{in} \dot{m}\,\theta = \overset{0}{\dot{W}_{out}} + \overset{0}{\dot{Q}_{out}} + \sum_{out} \dot{m}\,\theta$$

syst = Échangeur de chaleur.

$$\theta = h + \frac{V^2}{2} + gz$$

$$\dot{m}_{eau} h_4 + \dot{m}_{air} h_6 = \dot{m}_{eau} h_5 + \dot{m}_{air} h_7$$

$$\dot{m}_{eau} h_5 = \dot{m}_{eau} h_4 + \dot{m}_{air}(h_6 + h_7)$$

$$h_5 = h_4 + \frac{\dot{m}_{air}}{\dot{m}_{eau}}(h_6 + h_7) = 2573{,}48 + \frac{19{,}93}{12{,}31}\left((C_v - R)(T_6 - T_7)\right)$$

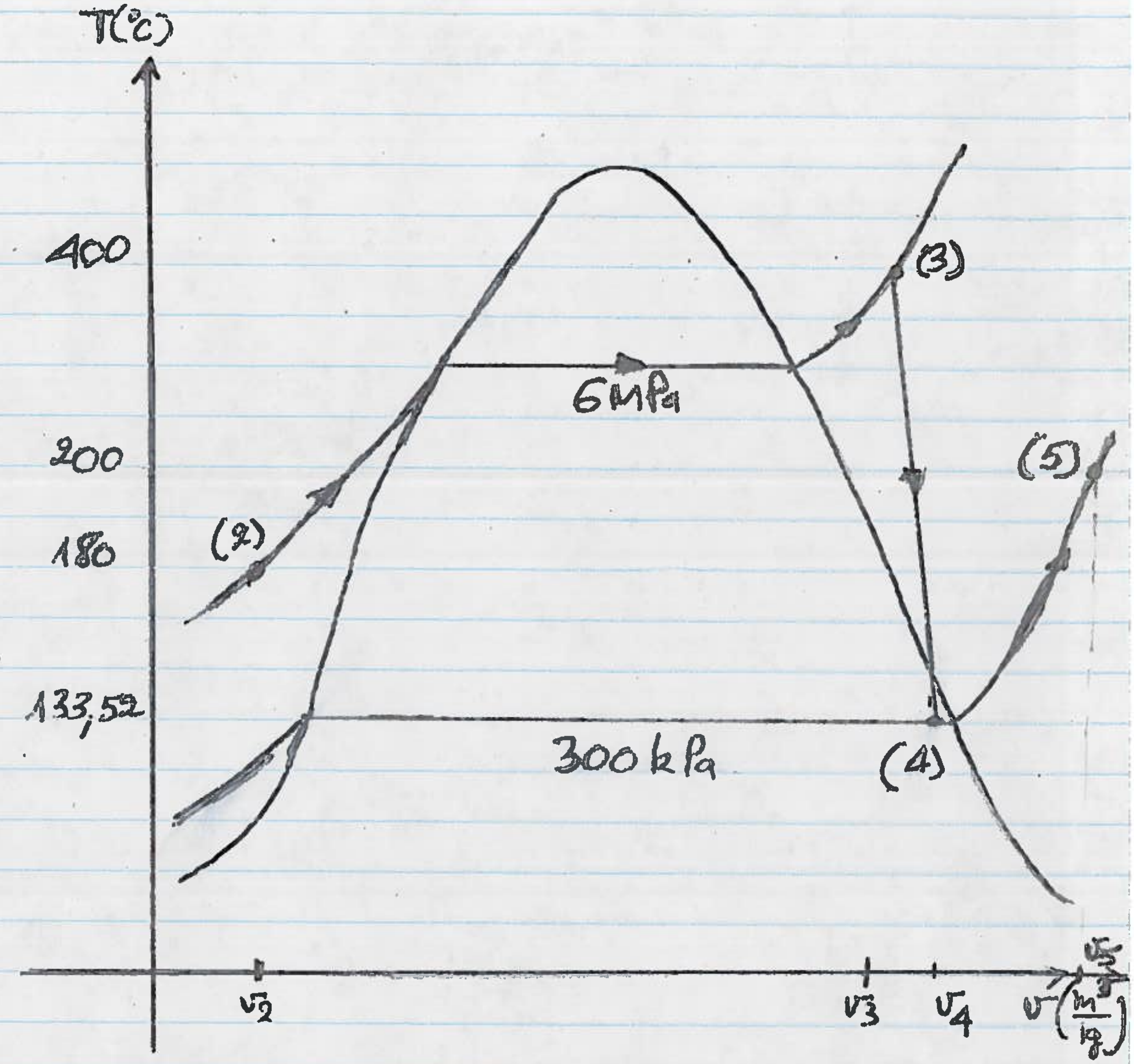
$$h_5 = 2573{,}48 + 1{,}619\left((0{,}718+0{,}287)(600-420)\right)$$

$$h_5 = 2866{,}35\ \text{kJ/kg}.$$

$$\begin{cases} P_5 = 300\ \text{kPa} \\ h_5 = 2866{,}35\ \text{kJ/kg} \end{cases} \xrightarrow{A5} \begin{cases} h_f = 561{,}43 \\ h_g = 2724{,}9 \end{cases} \text{kJ/kg}.$$

$h_5 > h_g \longrightarrow$ Vapeur surchauffée

$$\xrightarrow{A6} \begin{cases} P_5 = 0{,}3\ \text{MPa} \\ h_5 = 2866{,}35\ \text{kJ/kg} \end{cases} \longrightarrow T_5 \simeq 200\ °\text{C}.$$



$T_2 = 180°C$; $P_2 = 6\,MPa$; $v_2 = 0{,}001127\ m^3/kg$

$T_3 = 400°C$; $P_3 = 6\,MPa$; $v_3 = 0{,}04742\ m^3/kg$

$T_4 = 133{,}52°C$; $P_4 = 300\,kPa$; $v_4 = 0{,}56348\ m^3/kg$.

$T_5 = 200°C$; $P_5 = 300\,kPa$; $v_5 = 0{,}71643\ m^3/kg$.