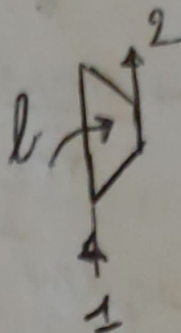


ESAME "SISTEMI ENERGETICI PER
INGEGNERIA FISICA" 20/02/2021

1) COMPRESSIONE 1 → 2

Aria → GAS PERFETTO

$$\gamma = \frac{C_p}{C_v} = \frac{C_p}{C_p - \frac{R}{M}} = 1,404$$



$$\theta_{\text{aria}} = \frac{\gamma - 1}{\gamma} = 0,288$$

$$V_1 = \frac{R^* T_1}{P_1} = 0,89 \frac{\text{m}^3}{\text{kg}}$$

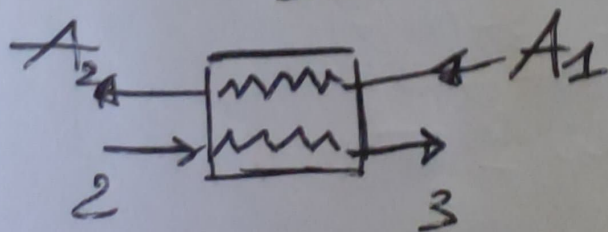
$$\dot{m}_1 = \dot{V}_1 / V_1 = 11,28 \text{ kg/s}$$

$$T_{2,15} = T_1 (P_{\text{comp}})^{\theta} = 629,83 \text{ K}$$

$$T_{2,\text{resc}} = T_2 + \frac{(T_{2,15} - T_1)}{\eta_{15, \text{comp}}} = 413,45^\circ \text{C}$$

$$S_2 = S_1 + C_p \ln \frac{T_2}{T_1} - R^* \ln P_{\text{comp}} = 86,29 \frac{\text{J}}{\text{kgK}}$$

RISCALDAMENTO ISOBARO 2 → 3



①

$$\dot{m}_{A1} c_{p_{Ania}} (T_{A1} - T_{A2}) = \dot{m}_2 c_{p_{Ania}} (T_3 - T_2)$$

$$\downarrow$$

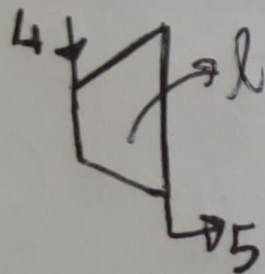
$$T_3 = T_2 + \frac{\dot{m}_{A1} (T_{A1} - T_{A2})}{\dot{m}_2} = 768,4^\circ\text{C}$$

$$S_3 = S_2 + c_p \ln \frac{T_3}{T_2} = 502,67 \frac{\text{J}}{\text{kgK}}$$

$$b) W_{\text{calen}} = \dot{m}_1 c_{p_A} (T_2 - T_1) = 4269,04 \text{ kW}$$

$$\dot{m}_4 = \dot{m}_3 + \dot{m}_{\text{GN}} = 11,38 \frac{\text{kg}}{\text{s}} \quad \underline{\text{Bil. massa}}$$

ESPANSIONE



$$W_{\text{EXP}} = \dot{m}_4 c_{p_{\text{GAS}}} (T_4 - T_5) = 8000 \text{ kW}$$

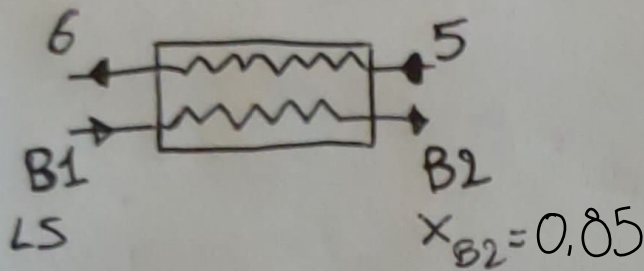
$$\phi_{\text{GAS}} = 0,265$$

$$T_{5,15} = T_4 (\beta_{\text{EXP}}) = 763,1 \text{ K}$$

$$T_5 = T_4 - (T_4 - T_{5,15}) \eta_{15, \text{EXP}} = 560,95 \text{ K}$$

$$W_{\text{NET}} = (W_{\text{calen}} - W_{\text{EXP}}) \eta_{\text{MECC, EL}} = 3618,9 \text{ kW}$$

c) Prodotto Vapore



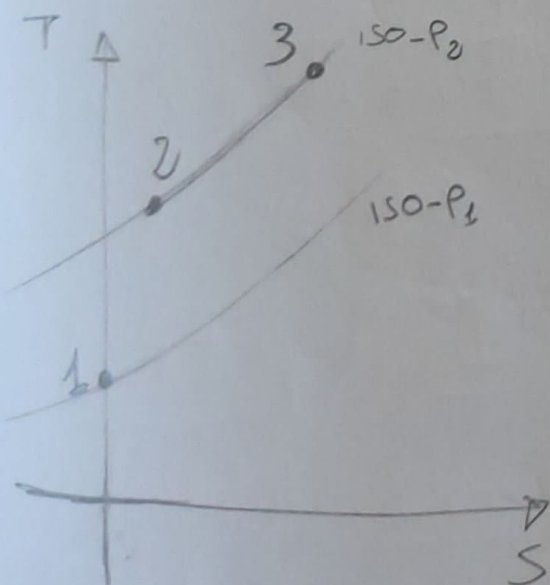
$$\dot{m}_s c_{p,s} (T_s - T_6) = \dot{m}_{B1} (h_{B2} - h_{B1})$$

$$h_{B2} = h_{LS}(50\text{ bar}) - x_{B2} \Delta h_{EV}(50\text{ bar}) = 2548 \frac{\text{kJ}}{\text{kg}}$$

$$\dot{m}_{B1} = 3 \text{ kg/s}$$

$$T_6 = T_s - \frac{\dot{m}_{B1} (h_{B2} - h_{B1})}{\dot{m}_s c_{p,s}} = 226,24^\circ\text{C}$$

Commento: $T_6 < T_{SAT}(50\text{ bar}) = 263,94^\circ\text{C}$
 IMPOSSIBILE Prodotto 3 kg/s



$$2) a) M_{cil} = \rho_{MET} (\pi D^2) L = 0,01276 \text{ kg}$$

$$M_{H_2O} = \rho_{H_2O} V_{H_2O} = 0,04975 \text{ kg}$$

$$M_{H_2O} c_{H_2O} (T_{in_{H_2O}} - T_{EQ}) = M_{MET} c_{MET} (T_{EQ} - T_{in_{MET}})$$



$$T_{EQ} = 63,56^\circ\text{C}$$

TEMPERATURA
di equilibrio
(REC. ADIABATICA)

$$b) E_{ceduta} = \int_{MET} V c_{MET} (T_{EQ} - T_{FIN}) = 222,4 \text{ J}$$

c) ASSUNTO VALORI L'APPROCCIO A PARAMETRI
CONCENTRATI (DA VERIFICARE) $\rightarrow Bi < 0,1$

$$\frac{\theta}{\theta_i} = e^{-Bi F_{ou}}$$

$$\theta_i = T_{EQ} - T_{AMB} = 48,56^\circ\text{C}$$

$$\theta = T_{FIN} - T_{AMB} = 5^\circ\text{C}$$

$$F_{ou} = \left(\frac{K}{\rho c} \right) t / (L_c^2) = 4430,77$$

$$L_c = \frac{V}{A_s} = 1,25 \cdot 10^{-3} \text{ m}$$

(4)

$$Bi = -\ln\left(\frac{\theta}{\theta_i}\right) / F_{av} = 5,13 \cdot 10^{-4} < 0,1$$

$$h_{anis} = \frac{Bi K}{L_c} = 41,05 \frac{W}{m^2 K}$$

• Convezione Forzata

$$h_{anis} = (0,51 Re^{0,5} Pr^{0,37}) \frac{K_{anis}}{D} = 41,05 \frac{W}{m^2 K}$$

$$Pr = \left(\frac{c_p \mu}{K}\right)_{anis} = 0,722$$

$$Re = \left(\frac{h_{anis} D}{K_{anis}} \cdot \frac{1}{0,51 Pr^{0,37}} \right)^2 = \frac{\rho N D}{\mu} = 329,65$$

↓

$$N = \frac{Re \mu}{\rho D} = 0,97 m/s$$

d) Convezione Naturale $\Delta T = 180^\circ$

$$Nu = \frac{hD}{K} = 0,53 Re^{0,25} = 0,53 Gr^{0,25} Pr^{0,25}$$

$$Gr = \frac{\rho \beta (T - T_{anis}) D^3}{\left(\frac{\mu}{\rho}\right)^2} \Rightarrow h = B (T - T_{anis})^{1/4}$$

$$B = \left(\frac{0,53 K Pr^{0,25}}{D} \right) \cdot \left(\frac{\rho \frac{1}{T_{anis}} D^3}{\nu^2} \right)^{0,25} = 5,148 \frac{W}{m^2 K^{5/4}}$$

(5)

Bilancio

$$\rho c V \frac{dT}{dt} = -h(T - T_{amb}) \cdot A_s$$

$$\rho c V \frac{dT}{dt} = -B(T - T_{amb})^{1/4} (T - T_{amb}) A_s$$

$$\frac{dT}{dt} = -\frac{BA}{\rho c V} (T - T_{amb})^{5/4}$$

$$\theta = T - T_{amb}$$
$$d\theta = dT$$

$$\frac{d\theta}{dt} = \phi \theta^{+5/4}$$

$$\phi = -\frac{BA}{\rho c V} =$$
$$-0,001584 \frac{K^{3/4}}{s}$$

$$\int_{\theta_{in}}^{\theta_{fin}} \frac{d\theta}{\theta^{+5/4}} = \phi \Delta t$$

$$-4\theta_F^{-1/4} - (-4\theta_i^{-1/4}) = \phi \Delta t$$

$$\theta_F = \left[\frac{(\phi \Delta t - 4\theta_i^{-1/4})}{-4} \right]^{-4} = 24,37 K$$

$$T_F = 39,37^\circ C$$

$$Bi_F = \frac{h_F L_c}{K} = 1,7 \cdot 10^{-4} Bi_i = \frac{h_i L_c}{K} = 1,43 \cdot 10^{-4}$$