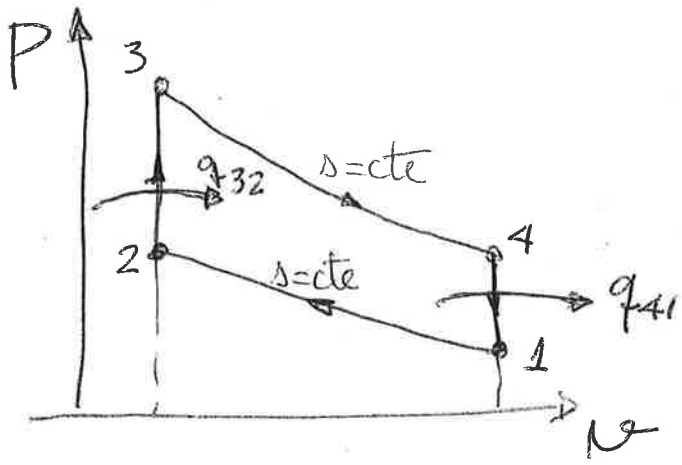
EXERCÍCIOS - CICLOS MOTORES A GÁS

1



a)

$T_1 = 290\ K \longrightarrow u_1 = 206,91\ kJ/kg$

$v_{r1} = 676,1$

$1 \to 2 : s = cte$

$$\rightarrow \begin{cases} \dfrac{v_{r2}}{v_{r1}} = \dfrac{v_2}{v_1} = \dfrac{1}{\lambda} \longrightarrow v_{r2} = 84,51 \longrightarrow T_2 = 652, \\ u_2 = 475,11 \end{cases}$$

$$\frac{p_2 v_2}{T_2} = \frac{p_1 v_1}{T_1} \longrightarrow p_2 = p_1 \left(\frac{T_2}{T_1}\right)\left(\frac{v_1}{v_2}\right)$$

$$p_2 = 1799,7\ kPa$$

$2 \to 3 : v = cte$

$$q_{23} - \cancel{w_{23}}^{0} = u_3 - u_2 \Longrightarrow u_3 = 1275,11\ kJ/$$

$$T_3 = 1575,1\ K$$

$$v_{r3} = 6,108$$

$$\frac{P_3 v_3}{T_3} = \frac{P_2 v_2}{T_2} \Rightarrow \underline{P_3 = 4,3471 MPa}$$

b) $3 \rightarrow 4$ ($s = cte$)

$$\frac{v_{r4}}{v_{r3}} = \frac{v_4}{v_3} = r$$

$$v_{r4} = 48,864 \Longrightarrow \underline{T_4 = 795,6 K}$$

$$\underline{u_4 = 588,74 kJ/}$$

$4 \rightarrow 1$ ($v = cte$)

$$q_{41} - \cancel{w_{41}}^{0} = u_1 - u_4$$

$$\underline{q_{41} = -381,83 kJ/kg}.$$

Assim: $W_{liquido} = q_{32} - |q_{41}| = 418,17 kJ/kg$

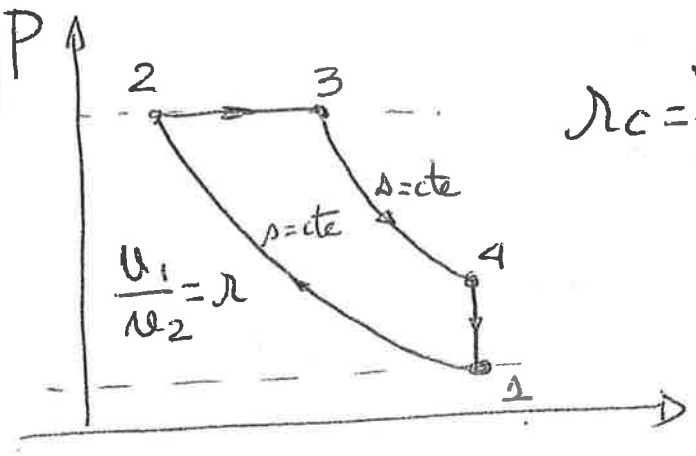
c) $\underline{\eta} = \frac{W_{liquido}}{q_{32}} = \frac{418,17 kJ/kg}{800 kJ/kg} = \underline{0,523}$

d) $pme = \frac{W_{líquido}}{v_1 - v_2} = \frac{W_{líquido}}{v_1(1 - 1/r)}$

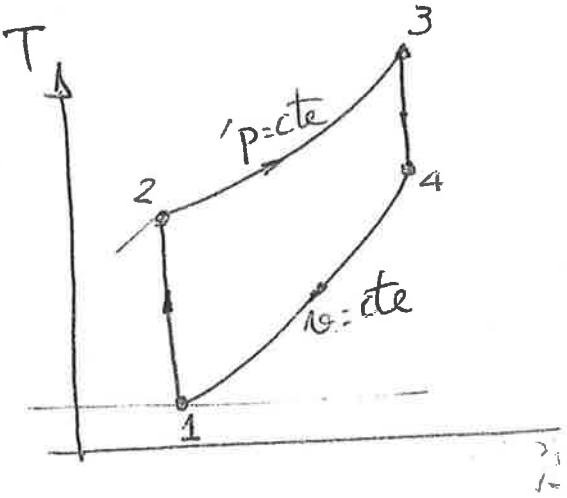
$$v_1 = \frac{RT_1}{P_1} = \frac{0{,}287 \frac{kPa \cdot m^3}{kg \cdot K} \cdot 290K}{100\,kPa} = 0{,}832 \frac{m^3}{}$$

$pme = 574{,}4\ kPa.$

(3)



$r_c = \frac{V_3}{V_2}$



$\frac{v_1}{v_2} = r$

a) $T_1 = 300K \Longrightarrow u_1 = 214{,}07\ kJ/kg$

$v_{r1} = 621{,}2$

$$v_{r2} = \frac{V_2}{V_1} v_{r1} = \frac{v_{r1}}{r} = \frac{621{,}2}{18} = 34{,}51$$

$T_2 = 898{,}3\ K$ e $h_2 = 939{,}98\ kJ/kg$

$$P_2 = P_1 \frac{T_2}{T_1} \frac{V_1}{V_2} = 5{,}39\ MPa$$

ou $P_2 = P_1 (P_{r2}/P_{r1})$

Como o processo $2 \to 3$ é isobárico:

$$T_3 = \frac{V_3}{V_2} T_2 = r_c T_2 = 1796{,}6\ K$$

$\therefore h_3 = 1999{,}1\ kJ/kg$ e $v_{r3} = 3{,}97$

Para a expansão isentrópica: $3 \rightarrow 4$

$$v_{r4} = \frac{V_4}{V_3} v_{r3} = \frac{V_4}{V_2} \frac{V_2}{V_3} v_{r3}$$

Como $V_4 = V_1$

$$v_{r4} = \frac{r}{r_c} v_{r3} = 35,73$$

Assim: $u_4 = 664,3 \text{ kJ/kg}$

$$T_4 = 887,7 \text{ K}$$

$$p_4 = p_1 \frac{T_4}{T_1} = 0,3 \text{ MPa}$$

b) $$\eta = 1 - \frac{q_{41}}{q_{23}} = 1 - \frac{(u_4 - u_1)}{(h_3 - h_2)}$$

$$\eta = 0,578$$

c) $$pme = \frac{w_{ciclo}}{v_1 - v_2} = \frac{w_{ciclo}}{v_1 (1 - 1/r)}$$

$$w_{ciclo} = q_{23} - q_{41} = (h_3 - h_2) - (u_4 - u_1)$$

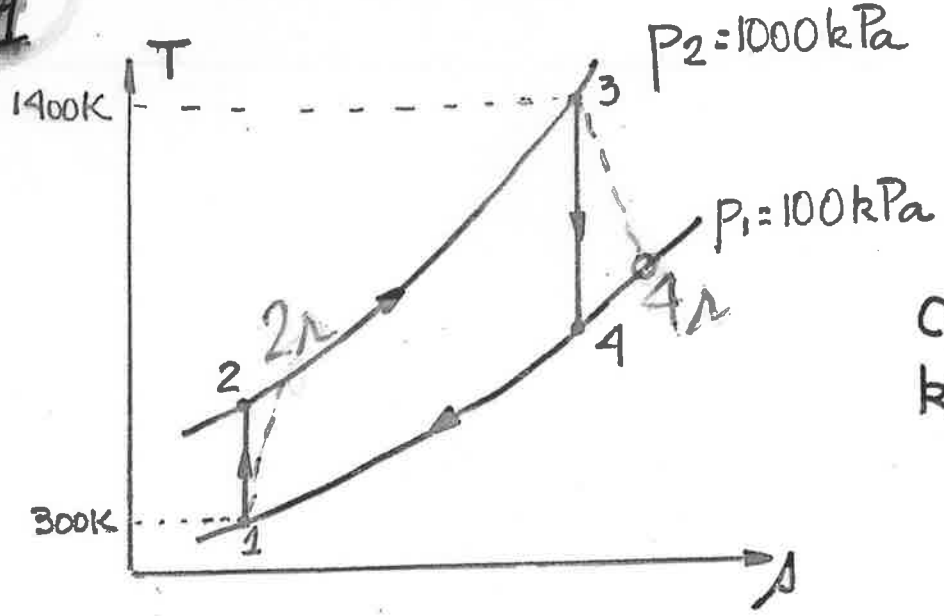
$$w_{ciclo} = 617,9 \text{ kJ/kg}$$

$$v_1 = \frac{(\bar{R}/M)T_1}{p_1} = 0{,}801\ м^3/кг$$

Ответ:

$$p_{ис} = 0{,}76\ МПа$$

Ex. 1



$c_p = 1{,}089\ kJ.k$
$k = 1{,}362$

Determinação dos Estados Termodinâmicos

(1) $T_1 = 300K$ e $P_1 = 100\,kPa$

(2) $P_2 = 10^3\,kPa$ e $\Delta_1 = \Delta_2$

$$T_2 = T_1 \left(P_2 / P_1 \right)^{\frac{k-1}{k}}$$

$$T_2 = 553{,}2K$$

(3) $T_3 = 1400K$ e $P_3 = 10^3\,kPa$

(4) $P_4 = 100\,kPa$ e $\Delta_4 = \Delta_3$

$$T_4 = T_3 \left(P_4 / P_3 \right)^{\frac{k-1}{k}}$$

$$T_4 = 759{,}2K$$

a) $$\eta = \frac{(\dot{W}_t/\dot{m}) - (\dot{W}_c/\dot{m})}{\dot{Q}/\dot{m}} = \frac{(h_3 - h_4) - (h_2 - h_1)}{(h_3 - h_2)}$$

$$\eta = \frac{(T_3 - T_4) - (T_2 - T_1)}{(T_3 - T_2)} = \underline{0,458\ (45,8\%)}$$

b) $$r_w = \frac{\dot{W}_t/\dot{m}}{\dot{W}_c/\dot{m}} = \frac{h_3 - h_4}{h_2 - h_1} = \frac{T_3 - T_4}{T_2 - T_1} = 2,53$$

$$\underline{\dot{W}_c = 0,395\ \dot{W}_t}$$

c) $$\dot{W}_t = \dot{m}_{ar}(h_3 - h_4) = \rho_1 \dot{V}_1 c_p (T_3 - T_4)$$

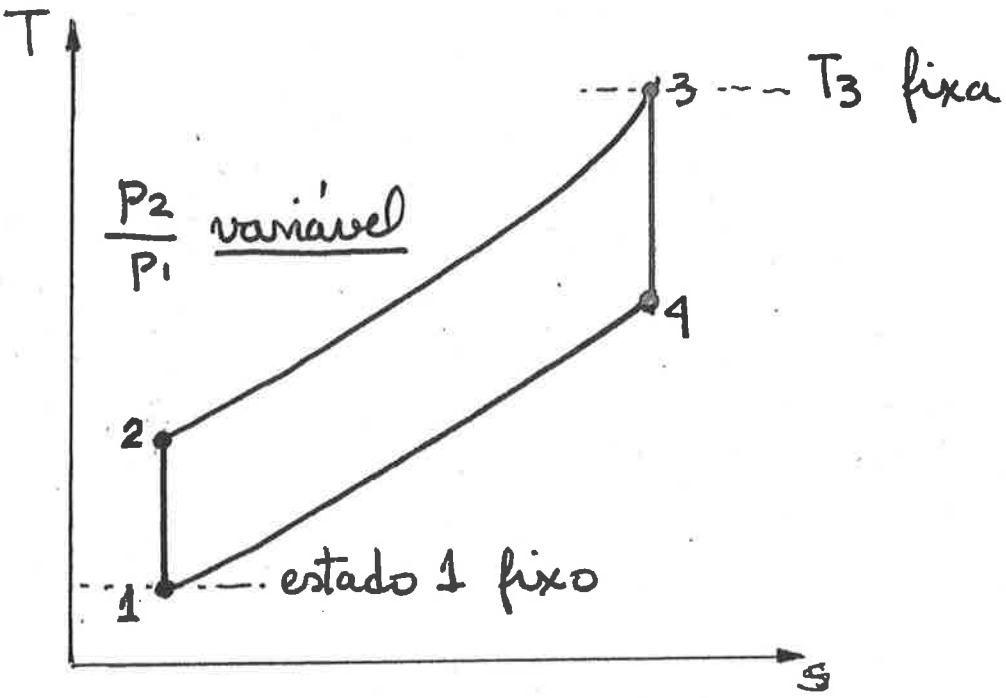
$$\rho_1 = \frac{P_1}{R_{ar} T_1} = \frac{100 * 10^3\ N.m^2}{\left(\frac{8314}{28,97}\ \frac{N.m}{kg.K}\right)(300\ K)} = \underline{1,16\ \frac{kg}{m^3}}$$

$$\dot{m}_{ar} = \rho_1 \dot{V}_1 = 1,16\ kg/m^3 * 5\ m^3/s = 5,807\ \frac{kg}{s}$$

$$\dot{W}_t = 5,807\ kg/s * 1,089\ kJ/kg\,K * (1400 - 759,2) =$$

$$\left.\begin{aligned} \dot{W}_t &= 4052,6\ kW \\ \dot{W}_c &= 1601,2\ kW \end{aligned}\right\} \underline{\dot{W}_u = 2451,4\ kW}$$

Ex. 5



c_p , k são constantes

$$\frac{\dot{W}_{ciclo}}{\dot{m}} = (h_3 - h_4) - (h_2 - h_1)$$

$$\frac{\dot{W}_{ciclo}}{\dot{m}} = c_p (T_3 - T_4 - T_2 + T_1) =$$

$$= c_p T_1 \left(\frac{T_3}{T_1} - \frac{T_4}{T_3}\frac{T_3}{T_1} - \frac{T_2}{T_1} + 1 \right)$$

$$= c_p T_1 \left(\frac{T_3}{T_1} - \frac{T_3}{T_1}\left(\frac{P_1}{P_2}\right)^{\frac{(k-1)}{k}} - \left(\frac{P_2}{P_1}\right)^{\frac{(k-1)}{k}} + 1 \right)$$

$$\frac{\partial(\dot{W}_{ciclo}/\dot{m})}{\partial(P_2/P_1)} = \frac{\partial}{\partial(P_2/P_1)} \left\{ c_p T_1 \left(\frac{T_3}{T_1} - \frac{T_3}{T_1}\left(\frac{P_1}{P_2}\right)^{\frac{k-1}{k}} - \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} + 1 \right) \right\}$$

$$= c_p T_1 \left(\frac{k-1}{k}\right)\left\{\left(\frac{T_3}{T_1}\right)\left(\frac{p_1}{p_2}\right)^{-1/k}\left(\frac{p_1}{p_2}\right)^{2} - \left(\frac{p_2}{p_1}\right)^{-1/k}\right\}$$

$$= c_p T_1 \left(\frac{k-1}{k}\right)\left\{\left(\frac{T_3}{T_1}\right)\left(\frac{p_1}{p_2}\right)^{\frac{2k-1}{k}} - \left(\frac{p_2}{p_1}\right)^{-1/k}\right\}$$

Fazendo

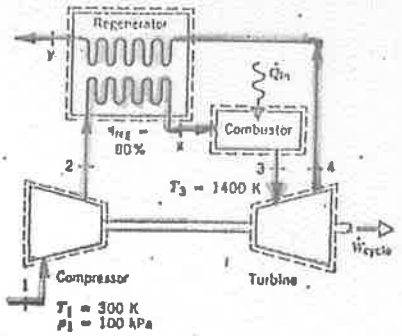
$$\frac{\partial(\dot{W}_{ciclo}/\dot{m})}{\partial(p_2/p_1)} = 0$$

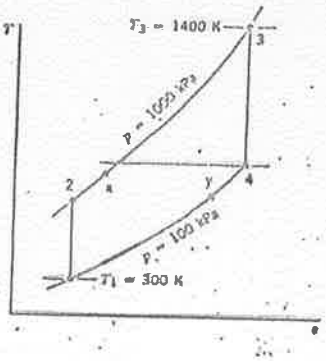
$$p_2/p_1 = \left(\frac{T_3}{T_1}\right)^{k/[2(k-1)]}$$

p/ $T_3 = 1400\,K$ e $T_1 = 300\,K$, $k = 1{,}362$

$$p_2/p_1 = 18{,}14$$

Ex. 6





$$\eta_{reg} = \frac{h_x - h_2}{h_4 - h_2}$$

Da Tabela de Propriedades do Ar

$h_1 = 300,19$ kJ/kg ; $h_2 = 579,9$ kJ/kg

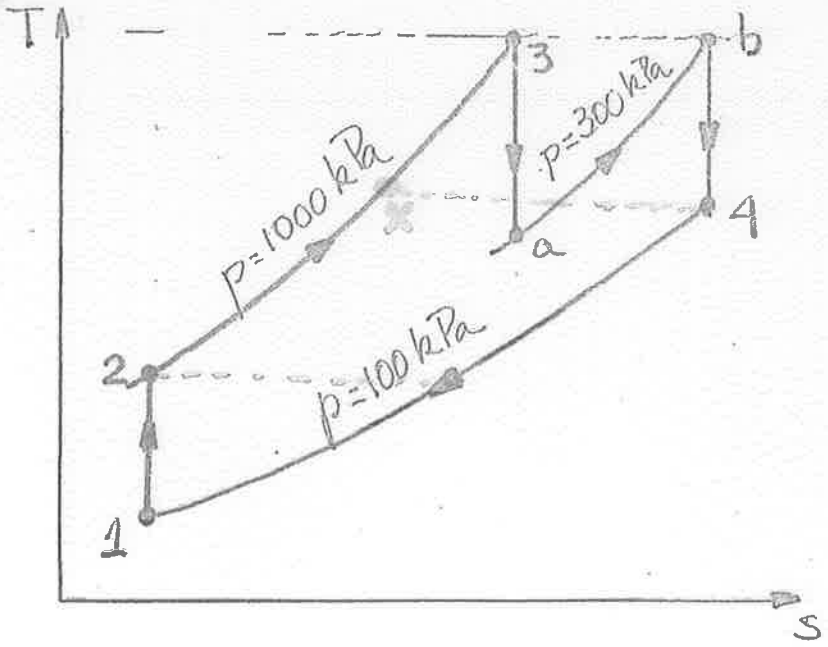
$h_3 = 1515,4$ kJ/kg ; $h_4 = 808,5$ kJ/kg

$$h_x = \eta_{reg}(h_4 - h_2) + h_2$$

$$h_x = 762,8 \text{ kJ/kg}$$

$$\therefore \eta = \frac{(h_3 - h_4) - (h_2 - h_1)}{(h_3 - h_x)} = 0,568 (56,8\%$$

Ex. 7



Obtenção das entalpias em a, b e 4

$s_3 = s_a \rightarrow p_{ra} = p_{r3}\frac{P_a}{P_3} = 450{,}5\,\frac{300}{1000} = 135{,}15$

$\rightarrow h_a = 1095{,}9\ kJ/kg$

$h_b = h_3$, pois $T_b = T_3$ (gás perfeito)

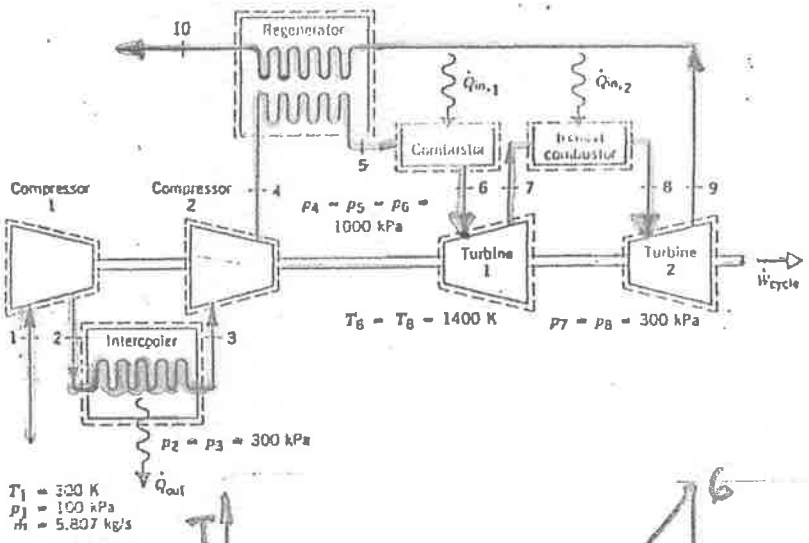
$s_b = s_4 \rightarrow p_{r4} = p_{rb}\frac{P_4}{P_b} = 450{,}5\,\frac{100}{300} = 150{,}17$

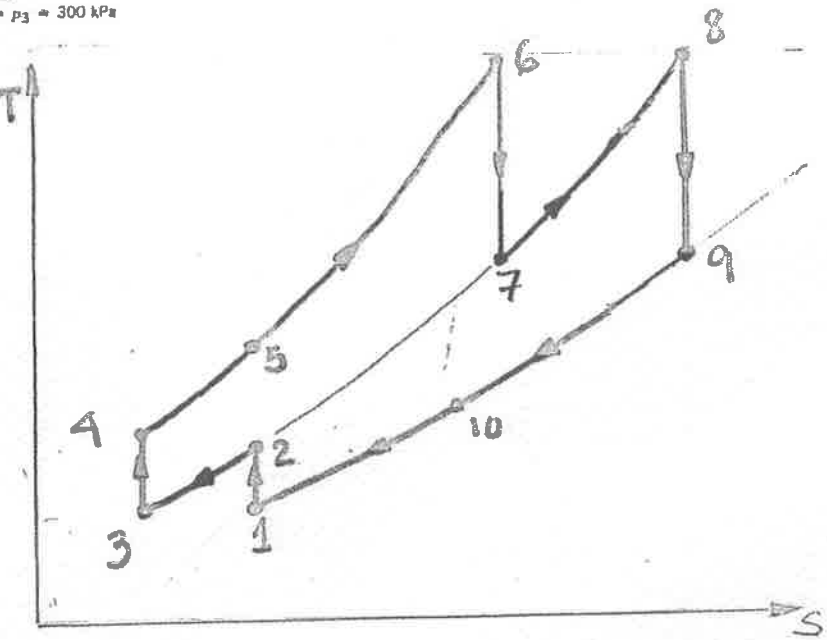
$\rightarrow h_4 = 1127{,}6\ kJ/kg$

Como $\eta_{reg} = 100\% \Rightarrow h_x = h_4$

$\therefore \eta = \frac{(h_3 - h_a) + (h_b - h_4) - (h_2 - h_1)}{(h_3 - h_x) + (h_b - h_a)} = \underline{0{,}654\ (65{,}4\%)}$

Ex. 8





Definição dos valores das entalpias:

$h_1 = h_3$ $(T_1 = T_3)$ $h_1 = 300,19\ kJ\ h5^{-1}$

$h_2 = 411,3\ kJ.h5^{-1}$ $(p_1 = p_2)$

$h_4 = 423,8\ kJ.h5^{-1}$ $(p4 = p3)$

$h_6 = h_8$ $(T_6 = T_8)$ $h_6 = 1515,4\ kJ.h5^{-1}$

$h_7 = 1095,9\ kJ.h5^{-1}$ $(p7 = p6)$

$h_9 = 1127,6\ kJ.kg^{-1}$ $(s_8 = s_9)$

Para o estado 5:

$$\eta_{reg} = \frac{h_5 - h_4}{h_9 - h_4}$$

$$h_5 = h_4 + \eta_{reg}(h_9 - h_4) = 986,8\ kJ/kg$$

a) Rendimento Térmico

$$\dot{W}_T/\dot{m} = (h_6 - h_7) + (h_5 - h_9) = 807,3\ kJ/kg$$

$$\dot{W}_C/\dot{m} = (h_4 - h_3) + (h_2 - h_1) = 247\ kJ/kg$$

$$\dot{Q}/\dot{m} = (h_6 - h_5) + (h_8 - h_7) = 948,1\ kJ/kg$$

$$\eta = \frac{\dot{W}_t - \dot{W}_c}{\dot{Q}} = 0,604$$

b) $$r_W = \frac{\dot{W}_T}{\dot{W}_C} = 3,44$$

c) $$\dot{W}_{ciclo} = \dot{m}(\dot{W}_T - \dot{W}_C) = 3325\ kW$$