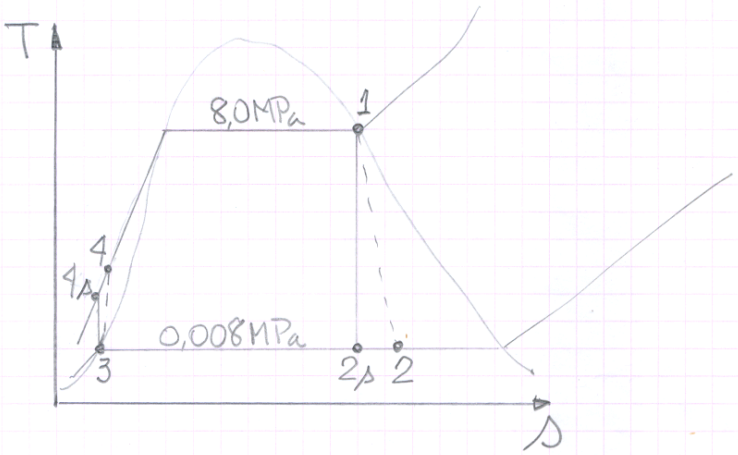
EXERCÍCIOS

CICLO VAPOR

(1) Propriedades Termodinâmicas

Seção	T(°C)	p(MPa)	h(kJ/kg)
1	295,1	8,0	2758,0
2	41,5	0,008	1939,3
3	41,5	0,008	173,9
4	42,1	8,0	183,4



Ex.1 Caracterização dos Estados:

* $h_1 = 2758\ kJ.kg^{-1}$; $s_1 = 5,7432\ kJ.kg^{-1}K^{-1}$

$$\eta_t = \frac{h_1 - h_2}{h_1 - h_{2s}} \rightarrow h_2 = h_1 - \eta_t(h_1 - h_{2s})$$

$$h_2 = 2758 - 0,85(2758 - 1794,8)$$

* $h_2 = 1939,3\ kJ.kg^{-1}$

* $h_3 = 173,9\ kJ.kg^{-1}$

* $h_4 = h_3 + \dot{W}_B/\dot{m}$ com $\eta_B = \frac{(\dot{W}_B/\dot{m})_s}{(\dot{W}_B/\dot{m})}$

$$(\dot{W}_B)_s = \dot{m}\,[v_3(p_4 - p_3)]$$

$$\left(\dot{W}_B/\dot{m}\right)_s = 8,06\ kJ.kg^{-1} \rightarrow \left(\dot{W}_B/\dot{m}\right) = \frac{8,06}{\eta_B} = 9,48\ kJ/kg$$

$\therefore h_4 = 183,36\ kJ.kg^{-1}$

a) $\dot{W}_{útil} = \dot{W}_t - \dot{W}_B = \dot{m}[(h_1 - h_2) - (h_4 - h_3)]$

$$\eta = \frac{(h_1 - h_2) - (h_4 - h_3)}{h_1 - h_4} = 0,314\ (31,4\%)$$

b) $\dot{m}_v = \frac{\dot{W}_{ciclo}}{(h_1 - h_2) - (h_4 - h_3)} = 4{,}449 \cdot 10^5 \text{ kg/h}$

c) $\dot{Q}_{cald} = \dot{m}_v (h_1 - h_4) = 318{,}2 \text{ MW}$

d) $\dot{Q}_{cond} = \dot{m}_v (h_2 - h_3) = 218{,}2 \text{ MW}$

e) $\dot{m}_{água} = \frac{\dot{Q}_{cond}}{(h_{as} - h_{ae})} = 9{,}39 \cdot 10^6 \text{ kg/h}$

com $h_{as} = 146{,}68 \text{ kJ/kg}$
$h_{ae} = 62{,}99 \text{ kJ/kg}$

Ciclo Ideal

$\eta = 0{,}371$
$\dot{m}_v = 3{,}77 \cdot 10^5 \text{ kg/h}$
$\dot{Q}_{cald} = 269{,}8 \text{ MW}$
$\dot{Q}_{cond} = 169{,}8 \text{ MW}$
$\dot{m}_{água} = 7{,}3 \cdot 10^6 \text{ kg/h}$

Exercícios

② Determinação dos Estados Termodinâmicos

①
$$h_1 = 3348{,}4 \text{ kJ.kg}^{-1}$$
$$s_1 = 6{,}6586 \text{ kJ.kg}^{-1}\text{K}^{-1}$$

②
$$p_2 = 0{,}7 \text{ MPa} \quad \text{e} \quad s_2 = s_1$$

$$x_2 = \frac{s_2 - s_e}{s_g - s_e} = \frac{6{,}6586 - 1{,}9922}{6{,}708 - 1{,}9922} = 0{,}9895$$

$$h_2 = h_e + x_2(h_v - h_e) = 697{,}22 + 0{,}9895 * 2066{,}3$$
$$h_2 = 2741{,}8 \text{ kJ.kg}^{-1}$$

③
$$p_3 = 0{,}7 \text{ MPa} \quad \text{e} \quad T_3 = 440°\text{C}$$
$$h_3 = 3353{,}3 \text{ kJ.kg}^{-1}$$
$$s_3 = 7{,}7571 \text{ kJ.kg}^{-1}\text{K}^{-1}$$

④
$$p_4 = 0{,}008 \text{ MPa} \quad \text{e} \quad s_4 = s_3$$

$$x_4 = \frac{s_4 - s_e}{s_v - s_e} = \frac{7{,}7571 - 0{,}5926}{8{,}2287 - 0{,}5926} = 0{,}9382$$

$$h_4 = h_e + x_4(h_v - h_e) = 2428{,}5 \text{ kJ.kg}^{-1}$$

(5) $h_5 = 173{,}88\ kJ.kg^{-1}$ (liquido saturado)

(6) $h_6 = h_5 + v_5 (p_6 - p_5)$

$h_6 = 181{,}94\ kJ.kg^{-1}$

→ a) $W_{liq} = W_{12} + W_{34} - W_{65}$

$$\eta = \frac{(h_1 - h_2) + (h_3 - h_4) - (h_6 - h_5)}{(h_1 - h_6) + (h_3 - h_2)} = 0{,}403$$

→ b) $$\dot{m} = \frac{W_{liq}}{(h_1 - h_2) + (h_3 - h_4) - (h_6 - h_5)} = 65{,}64\ kg/s$$

2,363.04 kg/h

→ c) $\dot{Q}_{cd} = \dot{m}(h_4 - h_5) = 148\ MW$

Exercício 3

a) Determinação das propriedades

$h_1 = 3348{,}4\ kJ/kg$

$h_2 = 2832{,}8\ kJ/kg$; $s_2 = 6{,}8606\ kJ/kg \cdot K$

$h_4 = 173{,}9\ kJ/kg$

$h_3 = h_2 - \eta_t (h_2 - h_{3s})$ com $s_{3s} = s_2$

$h_{3s} = 2146{,}3\ kJ/kg \Rightarrow h_3 = 2249{,}3\ kJ/kg$

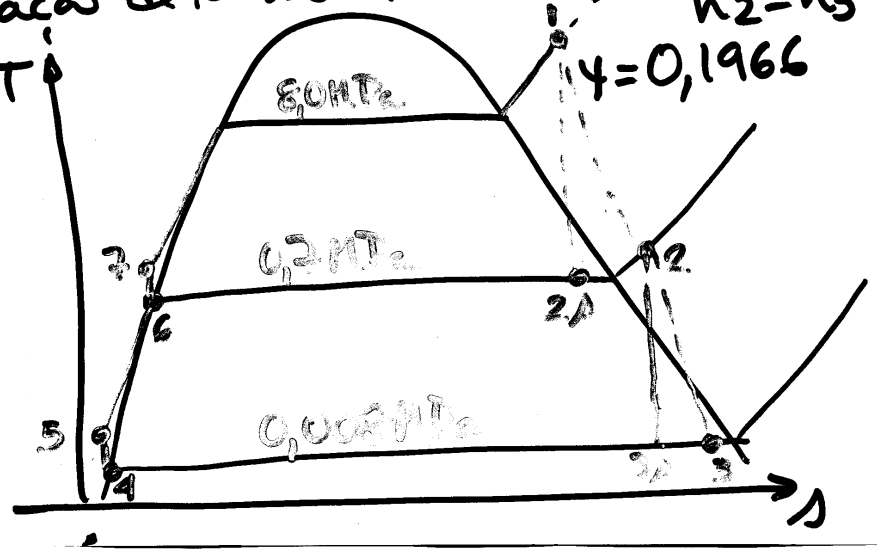
$h_6 = 697{,}2\ kJ/kg$

$h_5 = h_4 + v_4 (p_5 - p_4) = 179{,}6\ kJ/kg$

$h_7 = h_6 + v_6 (p_7 - p_6) = 705{,}3\ kJ/kg$

* fração de vapor extraída $y = \dfrac{h_6 - h_5}{h_2 - h_5}$

$y = 0{,}1966$



b) $\frac{\dot{W}_t}{\dot{m}_1} = (h_1 - h_2) + (1-y)(h_2 - h_3) =$

$= 984,4 \text{ kJ/kg}$

$\frac{\dot{W}_b}{\dot{m}_1} = (h_7 - h_6) + (1-y)(h_5 - h_4) =$

$= 8,7 \text{ kJ/kg}$ ← "valor ensinado"

$\frac{\dot{Q}}{\dot{m}_1} = h_1 - h_7 = 2643,1 \text{ kJ/kg}$

$\eta = \frac{\dot{W}_t/\dot{m}_1 - \dot{W}_b/\dot{m}_1}{\dot{Q}/\dot{m}_1} = 0,369$

c) $\dot{W}_e = \dot{W}_t - \dot{W}_b \Rightarrow \dot{m}_1 = 3,69 \cdot 10^5 \text{ kg/h}$

(4) Determinação de entalpias específicas

$h_4 = 3479\ kJ/kg$

$h_a = 2793\ kJ/kg$; $h_{a'} = 693,3\ kJ/kg$

$h_b = 2487\ kJ/kg$; $h_{b'} = 435,4\ kJ/kg$

$h_K = 2026\ kJ/kg$; $h_1 = 110,5\ kJ/kg$

a) Extrações de vapor

$$\alpha_1 = \frac{h_{a'} - h_{b'}}{h_a - h_{b'}} = 0,1093\ kg/kg_{vapor}$$

$$\alpha_2 = \frac{(1-\alpha_1)(h_{b'} - h_1)}{h_b - h_1} = 0,1220\ kg/kg_{vapor}$$

b) Trabalho específico da Turbina

$$w_T = (h_4 - h_a) + (1-\alpha_1)(h_a - h_b) + (1-\alpha_1-\alpha_2)(h_b - h_K)$$

ou

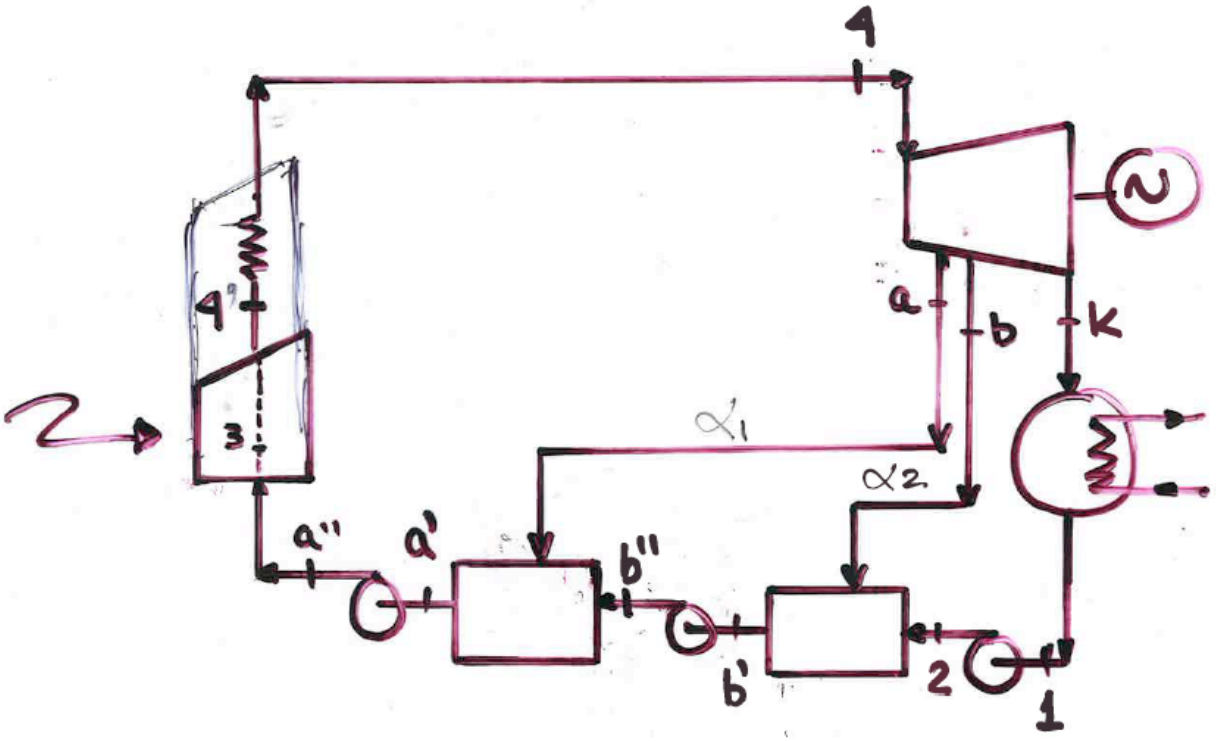
$$w_T = (h_4 - h_K) - \alpha_1 (h_a - h_K) - \alpha_2 (h_b - h_K)$$

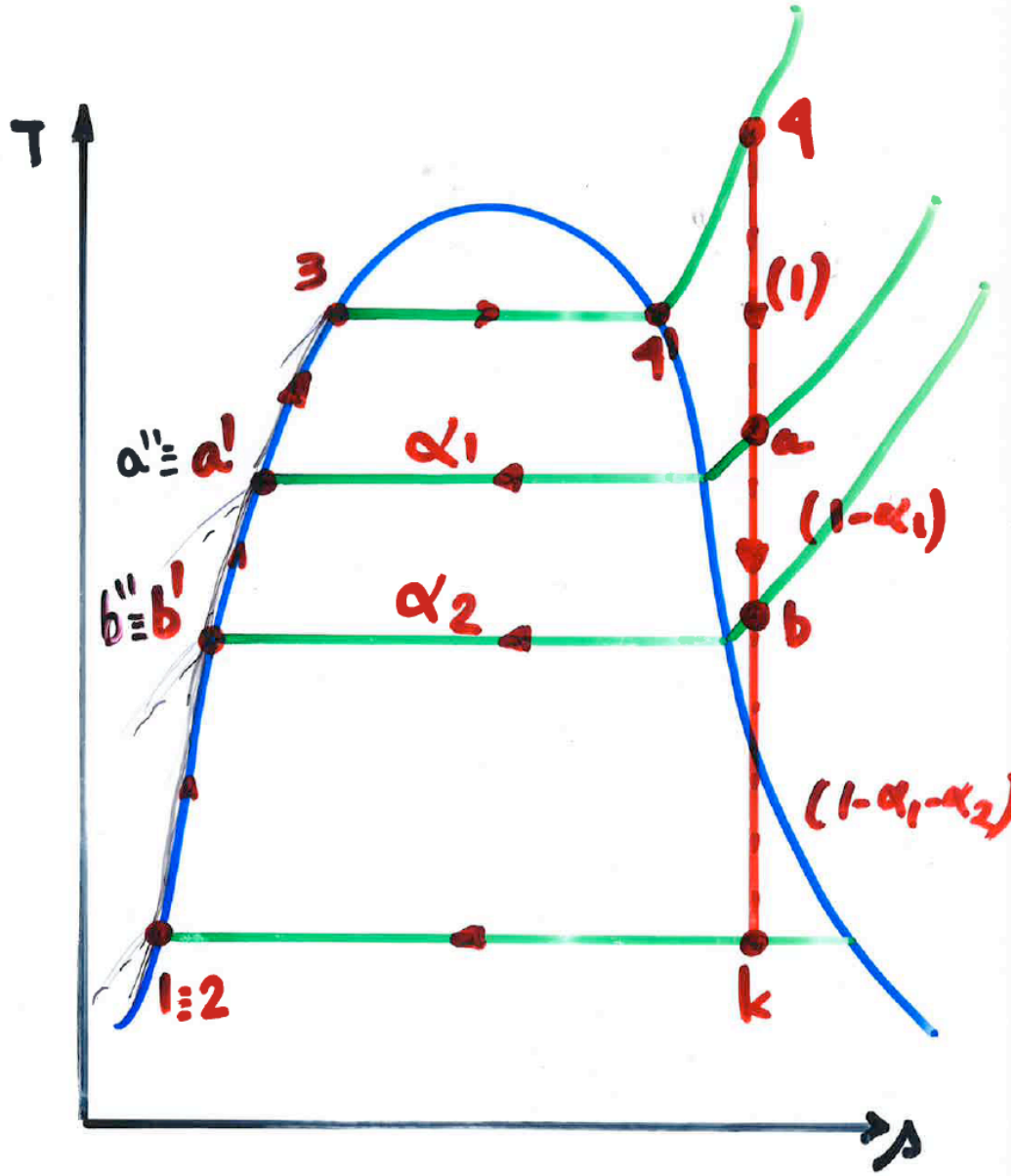
$$w_T = 1313\ kJ/kg_{vapor}$$

c) $\eta_{Reg} = \frac{w_T}{h_4 - h_{a'}} = 0,471$ (Desprezando bombas)

$$\eta = \frac{h_4 - h_K}{h_4 - h_1} = 0,432 \Longrightarrow \frac{\Delta\eta}{\eta} = 0,09$$

Ciclo com Regeneração




T
s
q
3
4
(1)
a'' ≡ a'
α1
a
(1-α1)
b'' ≡ b'
α2
b
(1-α1-α2)
1 ≡ 2
k