[redacted]

Aufgabe 1: Reaktor

a) aus der Energiebilanz.

$$\frac{dE}{dt} = \sum_i \dot{m}_i(t)\,[h_i(t) + he_i(t) + pe_i(t)] + \sum_j \dot{Q}(t) - \sum_n \dot{w}_n(t) \approx 0.$$

$$\dot{m}(h_{ein} - h_{aus}) + \dot{Q}_R + \dot{Q}_{aus} = 0$$

$$\dot{Q}_{aus} = -(-\dot{Q}_R + \dot{m}(h_{aus} - h_{ein}))$$

aus der TAB A-3.

$h_{ein} = 1267\ kJ/kg = h_f(70°C)$

$h_{aus} = h_f(100°C) = 1407.6\ kJ/kg$.

$$\dot{Q}_{aus} = -(-100\,kW) + 0.3\,kg/s \cdot (1267\,kJ/kg - 1407.6\,kJ/kg)$$

$$= 57.82\,kW$$

b) aus der Entropiebilanz.

$$0 = \dot{m}(s_e - s_a) + \sum_j \frac{\dot{Q}_j}{T_j} + \dot{s}_{erz}.$$

aus der Exergiebilanz.

$$0 = \dot{m}[h_e - h_a] + \left(1 - \frac{T_0}{T_j}\right) = 0.$$

$$\bar{T} = \frac{\dot{m}(h_e - h_a)}{\dot{m}(h_e s_e - s_a)} = \frac{c_v(T_{ein} - T_{aus})}{c_v \ln\left(\frac{T_{ein}}{T_{aus}}\right)}$$

$$= \frac{(288.15 - 298.15)\,K}{\ln\left(\frac{288.15\,K}{298.15\,K}\right)} = 293.12\,K$$

c) $\dot{Q}_{ans} = 65\,kW$, $\bar{T}_{kF} = 295\,K$

aus der Entropiebilanz.

$$0 = \dot{m}[s_e - s_a] + \sum_j \frac{\dot{Q}_j}{T_j} + \dot{S}_{erz}.$$

$$\dot{S}_{erz} = \dot{m}[s_e - s_a] - \frac{\dot{Q}_j}{295\,K}.$$

aus der TAB A-2.

$s_e = s_f(15°C) = 62.99\ kJ/kg$.

$s_a = s_f(25°C) = 104.88\ kJ/kg$.

$$\dot{S}_{erz} = 0.3\,kg/s \cdot (62.99 - 104.88)\,kJ/kg - \frac{65\,kW}{295\,K}$$

$$= -12.79\ kW/kg \cdot K$$

d) aus der Energiebilanz

$$\Delta m_{12}(h_{ein} - h_{aus}) + Q - W = 0.$$

$$\Delta m_{12} = \frac{Q_{aus,12}}{h_a - h_e} = \frac{Q_{aus}}{c_p(T_2 - T_1)}.$$

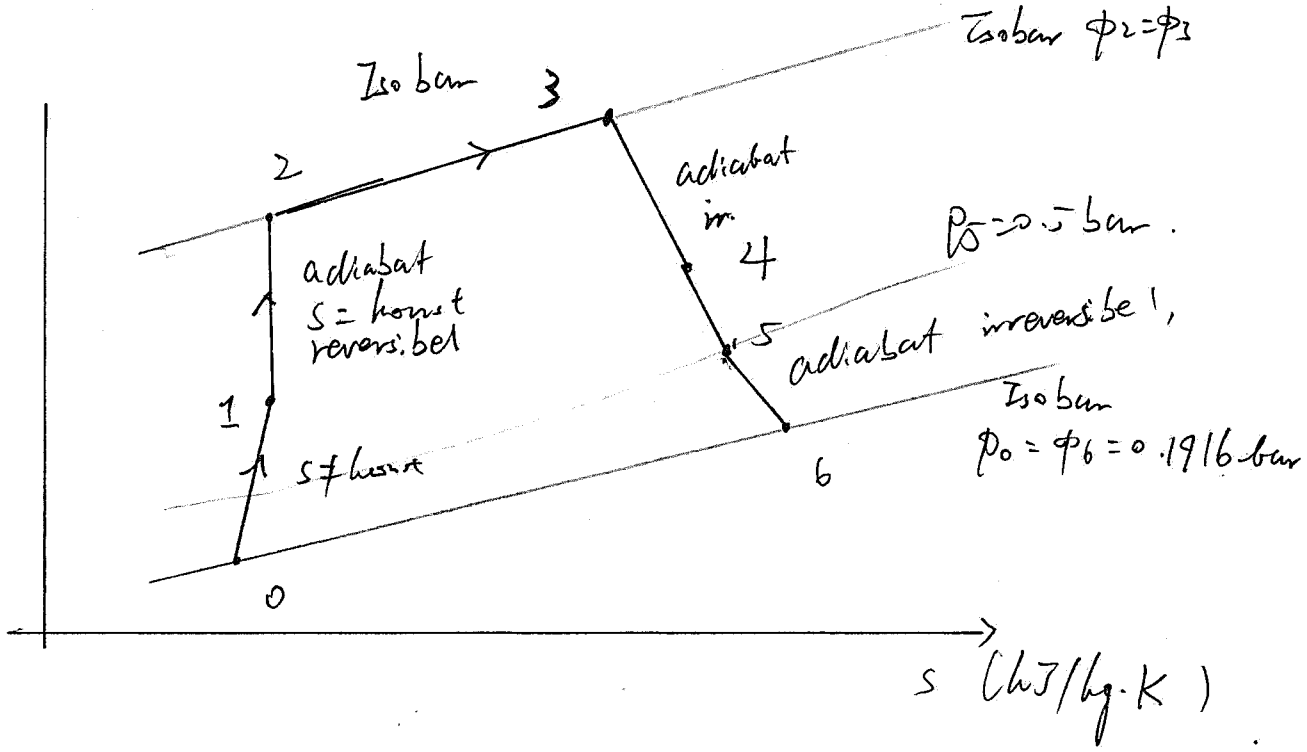
$c_p =$

Aufgabe 1: Reaktor

c) $\Delta m_{12} = 3600\ kg$.

Aufgabe 2: Exergie am Triebwerk

a) T (K)



b) aus der Energiebilanz

$$0 = \dot{m}\left[h_e - h_a + \frac{(w_e^2 - w_a^2)}{2}\right]1 + \sum_j \dot{Q}_j - \sum_n \dot{W}_{tn} = 0.$$

~~$\dot{Q}_j - \dot{W}_{tn} = 0$~~.

$\dot{W}_t = 0$ ~~$q = 1195$ kJ/kg~~. $w_e = w_{mft} = 200$ m/s.

$$\frac{(w_e^2 - w_a^2)}{2} = h_a - h_e = c_p(T_a - T_e)$$

$\Rightarrow$

$5 \to 6$ Isentrop $\longrightarrow$ $\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} = \left(\frac{p_0}{p_5}\right)^{\frac{0.4}{1.4}} = \left(\frac{0.191}{0.5}\right)^{\frac{0.4}{1.4}}$

$= 0.76$

$T_6 = T_5 \cdot 0.76 = 0.76 \cdot 431.9\,K = 328.07\,K$.

$$\left(\frac{W_5^2 - W_6^2}{2}\right) = c_p(T_6 - T_5)$$

$$= 1.006 \frac{kJ}{kg \cdot K}(328.07 - 431.9)K$$

$$= -104.45 \ kJ/kg.$$

$$W_6 = \sqrt{2 \cdot (104.45 \ kJ/kg) + W_5^2}$$

$$= 510 \ m/s.$$

c) $T_6 = 340K$, $W_6 = 510 \ m/s$

~~$e_{x,str,6} = h_6 = h_5 - T_6(s_6 - s_5) + \frac{W_5^2 - W_6^2}{2}$~~

~~$= c_p(T_6 - T_5)$~~

$$\Delta e_{x,str} = h_6 - h_0 - T_0(s - s_0) + \frac{W_L^2 - W_6^2}{2}$$

$$= c_p(T_6 - T_0) - T_0 c_p \ln\left(\frac{T_6}{T_0}\right) - R \ln\left(\frac{\phi_6}{\rho_0}\right) + \frac{W_L^2 - W_0^2}{2}$$

$$R = c_p - c_v = c_p - \frac{c_p}{\kappa} = 1.006 - \frac{1.006}{1.4} = 0.287.$$

$$T_0 = 273.15 - 30 = 243.15 \ K.$$

$$\Delta e_{x,str} = 1.006 \cdot (340 - 243.15) + 243.15 \cdot 1.006 \ln\left(\frac{340}{243.15}\right) - 0.287 \cdot \ln(1) + \frac{200^2 - 510^2}{2}$$

$$= -178 \ kJ/kg$$

$$\Delta e_{x,str} = 100 \ kJ/kg$$

d) $e_{x,ver} = T_0 S_{erz} = T_0 \left(m(s_2 - s_1) - \frac{Q_{12}}{T}\right)$

$$m = \frac{e_{x,ver}}{T_0(s_2 - s_1)} = \frac{e_{x,ver}}{T_0 \cdot c_p \ln\left(\frac{T_6}{T_0}\right)} = \frac{110 \ kJ/kg}{243.15 \cdot \ln\left(\frac{340}{243.15}\right) 1.006} = 1.27 \ kg$$

Aufgabe 3: Schmelzen von Eis durch perfektes Gas

a) $pV = mRT$.

$$R_i = \frac{R}{M_g} = \frac{8.314\,kJ/kmol \cdot K}{50\,kg/kmol}$$

$$= 0.16628\,kJ/K.$$

$$p_g = 1\,bar + \left(\frac{F}{A}\right) = 1\,bar + \frac{32\,kg \cdot 9.81\,m\,s^{-2}}{\pi \cdot \left(\frac{100}{2}\right)^2 cm}$$

$$= 0.1 + 0.396$$

$$= 1.46\,bar.$$

~~$p_{g,1} = 1.5\,bar$~~.

$$m_g = \frac{RT}{pV} = \frac{0.16628\,kJ/K \cdot 500\,°C}{1.46\,bar \cdot 3.14\,L}$$

$$= 2.92\,g.$$

f)

c) aus dem 1. HS $T_{g,2} = 0.003$.

$$Q_{12} = \cancel{n(h_2 - h_1)} mU = m(c_v(T_2 - T_1))$$

$$= m \cdot c_v (T_2 - T_1)$$

$$= 3.6\,g \cdot 0.663 \frac{J}{g \cdot K} \cdot (0.003\,°C - 500\,°C)$$

$$= -1193\,J$$

d) $u_2 = c_v(T_2 - T_1) = -331.49\ kJ/kg$.

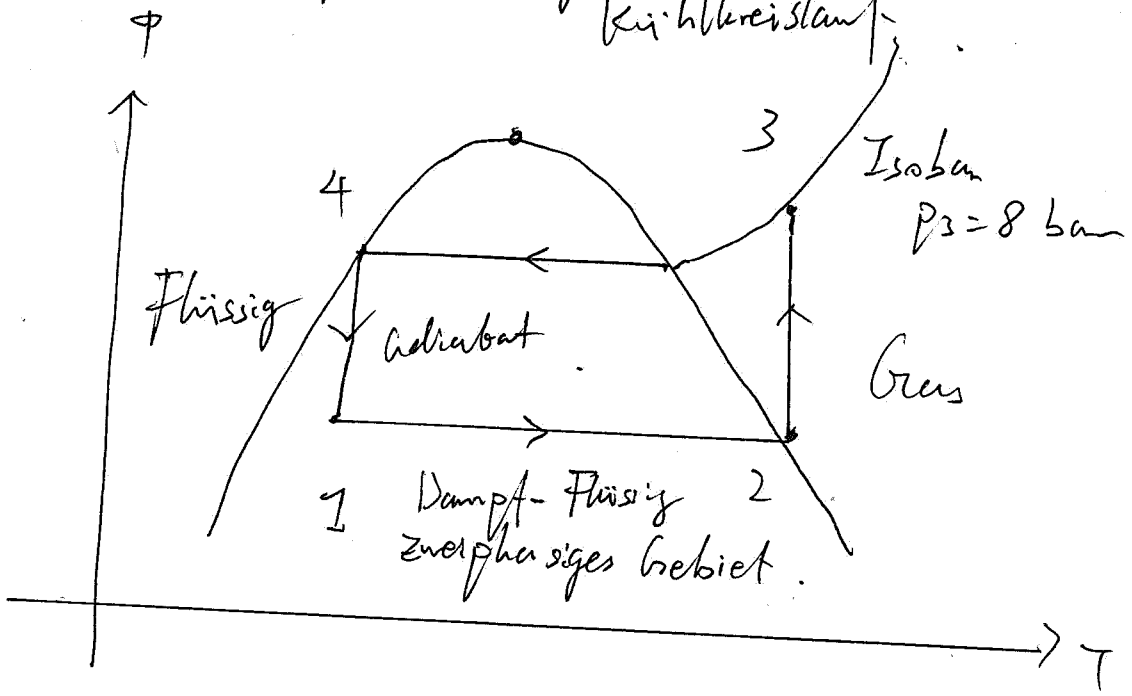
$$x_{Eis,2} = \frac{\cancel{-u_g}}{\cancel{u_f - u_g}} \frac{u_2 - u_f}{u_g - u_f}$$

$$= \frac{-331.49\ kJ/kg + 0.033}{-333.44\ kJ/kg + 0.033}$$

$$= 0.994$$

Aufgabe 4: Gefrierbrechung mit einem R134a.

a)



b) aus der TAB A-15 interpoliert

$$\dot{m}_{Kältemittel}(h_2 - h_3) + \dot{W}_K = 0$$

$$\dot{m}_K = \frac{28\,W}{h_3 - h_4} = \frac{28\,W}{\Delta h} = 4\,kg/h.$$

c) $$x_1 = \frac{u_1 - u_f}{u_g - u_f}$$

$u_1 = u_4$.

d) $\varepsilon_K = \frac{|\dot{Q}_{zu}|}{|\dot{W}_t|}$

$= \frac{\dot{Q}_{zu}}{|\dot{Q}_{ab}| - |\dot{Q}_{zu}|}$

$= \frac{\qquad}{28\,W}$

e) Wärmestrom $\dot{Q}_K$ garantiert