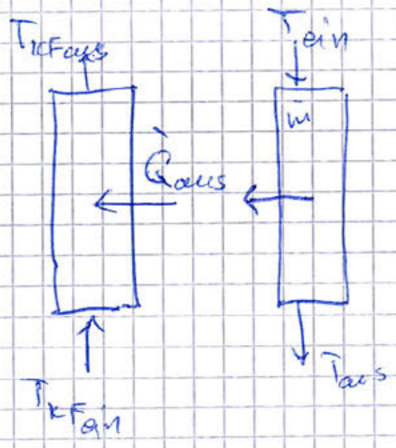
1

[redacted]

a) Ges: $\dot{Q}_{aus}$ über Reaktorwand an Kühlflüssigkeit



$\dot{m}_{ein} = \dot{m}_{aus}$

stationärer FP mit 1 Massenstrom

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

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

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

$$h_{ein} \xrightarrow[\boxed{A2}]{Tab} h(70°C, \text{liquid}) = \cancel{2333.8 \, kJ/kg}$$

$$\cancel{h_{ein} = h_{ein\,f} + x(h(100°C, \text{liquid}))} = \cancel{2257.0 \frac{kJ}{kg}}$$

$\boxed{A2}$ $\cancel{\rightarrow \dot{Q}_{aus} = 0.3 \frac{kg}{s} \cdot (2333.8 \frac{kJ}{kg})}$

$$h_{ein} \overset{\text{liquid}}{=} h(70°C) = 292.98 \, kJ/kg$$

$$h_{aus} = h(100°C) = 419.04 \, kJ/kg$$

$$\rightarrow \dot{Q}_{aus} = 0.3 \frac{kg}{s} \cdot \left(292.98 \frac{kJ}{kg} - 419.04 \frac{kJ}{kg}\right) + 100 \, kW$$

$$\dot{Q}_{aus} = 62.182 \, kW$$

b) Ges: $\bar{T}_{KF}$

$$\text{St. FP}: \quad 0 = \dot{m}(s_e - s_a) + \sum \frac{\dot{Q}}{\bar{T}} + \dot{S}_{erz}, \quad \bar{T} = \frac{h_2 - h_1}{s_2 - s_1}$$

IF:

$$\bar{T} = \frac{T_2 - T_1}{\ln\left(\frac{T_2}{T_1}\right)} = \frac{298.15K - 288.15K}{\ln\left(\frac{298.15K}{288.15K}\right)} = 293.12 K$$

c) Ges: $\dot{S}_{erz}$

STFP: $0 = \dot{m}(s_e - s_a) + \frac{\dot{Q}}{T} + \dot{S}_{erz}$

$\dot{S}_{erz} = \dot{m}(s_a - s_e) - \frac{\dot{Q}_{aus}}{T}$ ~~|| Ideale Flüssigkeit mit konst. c~~

$\dot{m} = 0.3 \frac{kg}{s}$

$\dot{Q}_{aus} = 65 kW$ Abgeführt → neg. einsetzen

$T = 100\,°C$

$s_a = s_{af} + x \cdot (s_{ag} - s_{af})$ @ 100°C

Tab $\boxed{A2}$ $= 1.3069 + 0.005 \cdot (7.3549 - 1.3069) \frac{kJ}{kgK} = 1.33714 \frac{kJ}{kgK}$

$s_e = s_{ef} + x(s_{eg} - s_{ef})$ @ 70°C

Tab $\boxed{A2}$ $= 0.9549 + 0.005 \cdot (7.7553 - 0.9549) \frac{kJ}{kgK} = 0.9889 \frac{kJ}{kgK}$

$\Rightarrow \dot{S}_{erz} = 0.3 \frac{kg}{s} \cdot (1.33714 - 0.9889) - \frac{-65 kW}{373.15 K}$

$\dot{S}_{erz} = 0.279 \frac{kW}{K}$

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1

d) $\frac{dE}{dt} = \dot{m}_{ein} \cdot \left(h_{ein} - h_{aus} \right) + \Delta m_{12} \, h_{reaktor} + \dot{Q}$

e) $\Delta S_{12} = \dot{m}_{ein} \cdot \left(s_2 - s_1 \right)$

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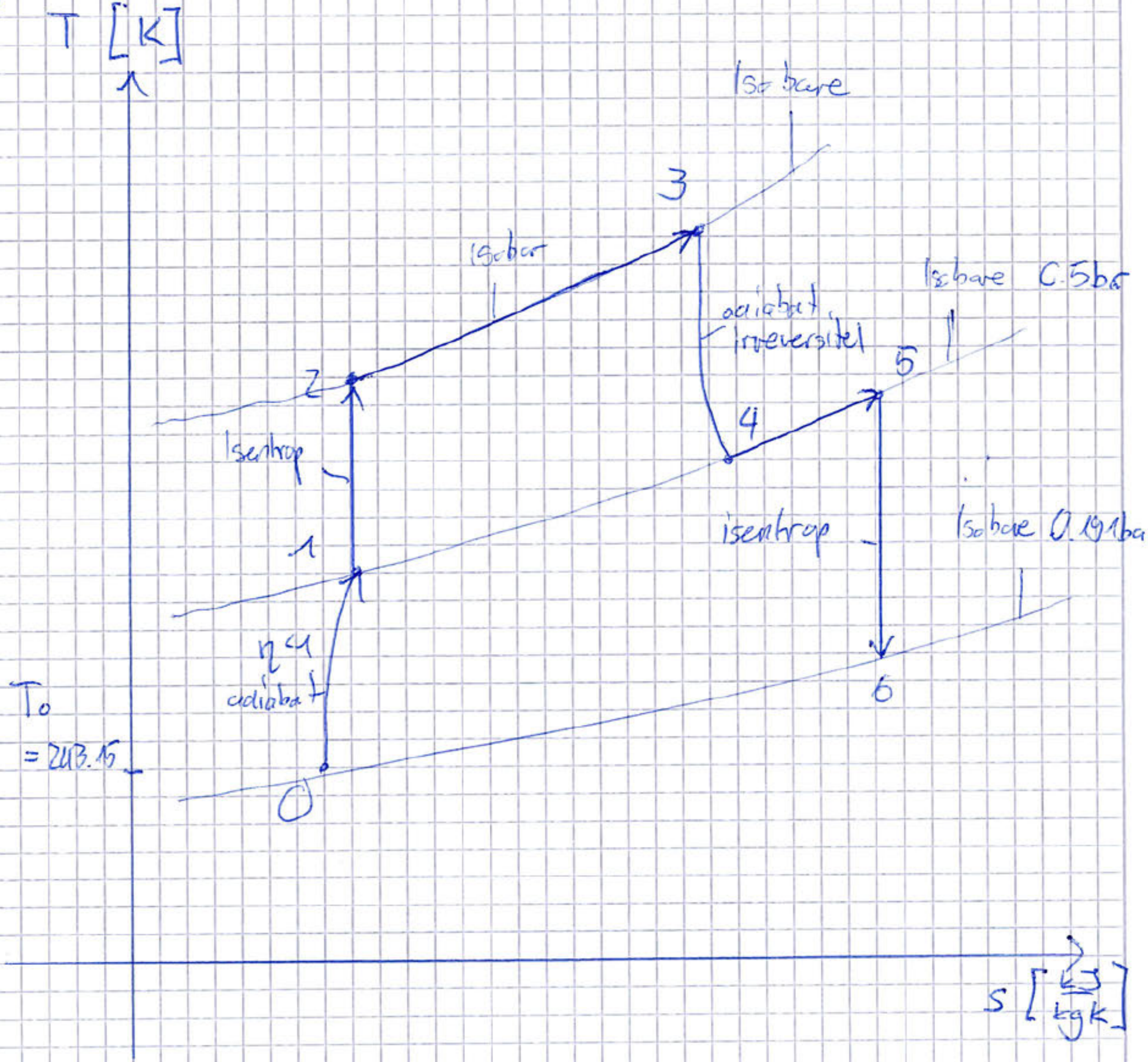
2

a)



	p bar	T K			Notes
0	0.191	243.15			↓ adiabat, η < 1
1					↓ Adiabat reversibel → isentrop
2	↓ isobar	↓ T_3 = 1289			↓ isobar
3					↓ adiabat irreversibel
4					↓ isobar
5	0.5 bar	431.9 K			↓ adiabat, reversibel → isentrop
6	0.191 bar				

b) $w_5 = 220\ m/s$, $p_5 = 0.5\,bar$, $T_5 = 431.9K$

Schubdüse adiabat reversibel $\rightarrow s_5 = s_6$

ideales Gas: $\left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} = \frac{T_6}{T_5} \rightarrow T_6 = T_5 \cdot \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}}$

$\rightarrow T_6 = 431.9K \cdot \left(\frac{0.191\,bar}{0.5\,bar}\right)^{\frac{0.4}{1.4}} = 328.07K$

St FP: Um ganze Turbine

$0 = \dot{m}\left(h_e - h_a + \frac{w_e^2 - w_a^2}{2}\right) + \cancel{\dot{Q}}^{\,0}_{\text{adiabat}} - \cancel{\dot{W}_t}^{\,0}$

$0 = \dot{m}\left(h_e - h_a + \frac{w_e^2 - w_a^2}{2}\right)$

$\rightarrow$ Weiter auf anderem Blatt

c) $\Delta e_{x,str} = e_{x,str_6} - e_{x,str_0}$

$\rightarrow \Delta e_{x,str} = \left(h_6 - h_0 - T_0(s_6 - \underset{\text{Umgebung}}{s_0}) + ke_6 + pe\right) - \left(h_0 - h_0 - T_0(s_0 - s_0) + ke_0 + pe\right)$

$\rightarrow \Delta e_{x,str} = h_6 - h_0 - T_0 \cdot (s_6 - s_0) + ke_6 + pe - ke_0$

$= c_p \cdot (T_6 - T_0) - T_0 \cdot \left(c_p \ln\left(\frac{T_6}{T_0}\right) - \cancel{R \ln\left(\frac{p_0}{p_0}\right)}^{\,0}\right) + \frac{w_6^2}{2} - \frac{w_0^2}{2}$

$= 1.006 \frac{kJ}{kgK} \cdot (340K - 243.15K) - 243.15K \cdot \left(1.006 \frac{kJ}{kgK} \cdot \ln\left(\frac{340}{243.15}\right)\right) + \frac{510^2}{2} - \frac{200^2}{2}$

$\Delta e_{x,str} = 110.06 \frac{kJ}{kg}$

2

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b) weiter

$$\cancel{\dot{m}}(h_a - h_e) = \cancel{\dot{m}}\left(\frac{w_e^2 - w_a^2}{2}\right)$$

$$h_a - h_e = \frac{w_e^2 - w_a^2}{2} \qquad \| \; w_a = w_6 \;, \; w_e = w_{Luft}$$

$$w_{Luft}^2 - 2(h_6 - h_0) = w_6^2$$

perfektes Gas

$$\rightarrow w_6 = \sqrt{w_{Luft}^2 - 2(h_6 - h_0)} \qquad \| \; h_6 - h_0 = c_p(T_6 - T_0)$$

$$w_6 = \sqrt{w_{Luft}^2 - 2c_p(T_6 - T_0)}$$

$$w_6 = \sqrt{200^2 \frac{m^2}{s^2} - 2 \cdot 1.006 \frac{kJ}{kgK} \cdot (328.07K - 243.15)}$$

$$w_6 = 199.47 \; m/s$$

müsste höher sein

d) $\dot{e}_{x,verl} = \frac{T_0 \cdot \dot{S}_{erz}}{\dot{m}_{Ges}} \rightarrow e_{x,verl} = \frac{T_0 \cdot S_{erz}}{m_{Ges}}$

$$S_{erz} = m \cdot (s_2 - s_1) \;, \; T_0 = 243.15K$$

$$\rightarrow e_{x,verl} = \frac{T_0 \cdot m \cdot (s_2 - s_1)}{m_{Ges}} \qquad \| \; s_2 - s_1 =$$

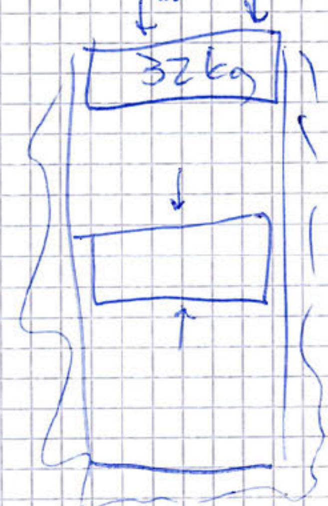
3

[redacted]

a) $T_{g1} = 500°C$ $\quad p_{g1} = ?$

$V_{g1} = 3.14 L$ $\quad m_g = ?$

$10^5 \frac{N}{m^2}$ $\quad 32 \cdot 9.81 \frac{kg\,m}{s^2} = = 313.92 N$



$A = \pi r^2, \; r = \frac{D}{2} = 0.05 m$

$A = 7.853 \cdot 10^{-3} m^2$

p durch Gewicht $= \frac{313.92 N}{7.853 \cdot 10^{-3} m^2} = 0.4$ bar

GGW, in EW Kammer 1.4 bar, so muss in Gaskammer auch 1.4 bar

$\rightarrow p_{G,1} = 1.4$ bar

$m_G = \frac{p_G V_G}{R_G T_G} \xrightarrow{R_G = \frac{\bar{R}}{M_G}} m_G = \frac{1.4 \cdot 10^5 \frac{N}{m^2} \cdot 3.14 \cdot 10^{-3} m^3}{\frac{8314 \frac{J}{kmol\,K}}{50 \frac{kg}{kmol}} \cdot 773.15 K}$

$m_G = 3.419 \cdot 10^{-3} kg = 3.419 g$

b) $T_{g2} = T_{EW2}$, $p_{1EW} = p_{2EW}$ da inkompressibel, $= 1.4$ bar

$\rightarrow$ damit immernoch ein Gleichgewicht herrscht, ist p_{2G} auch immernoch 1.4 bar.

c)

Geschl. System an Kolben:

$$\Delta U = \dot{Q}_{12} - \dot{W}_{12}$$

$$m(u_2 - u_1) = Q_{12} - \int_1^2 p\,dV$$

3

d)

$$\cancel{x_{eis,2} = \frac{m_2 - m_{liq}}{m_{eis} - m_{Liq}}}$$

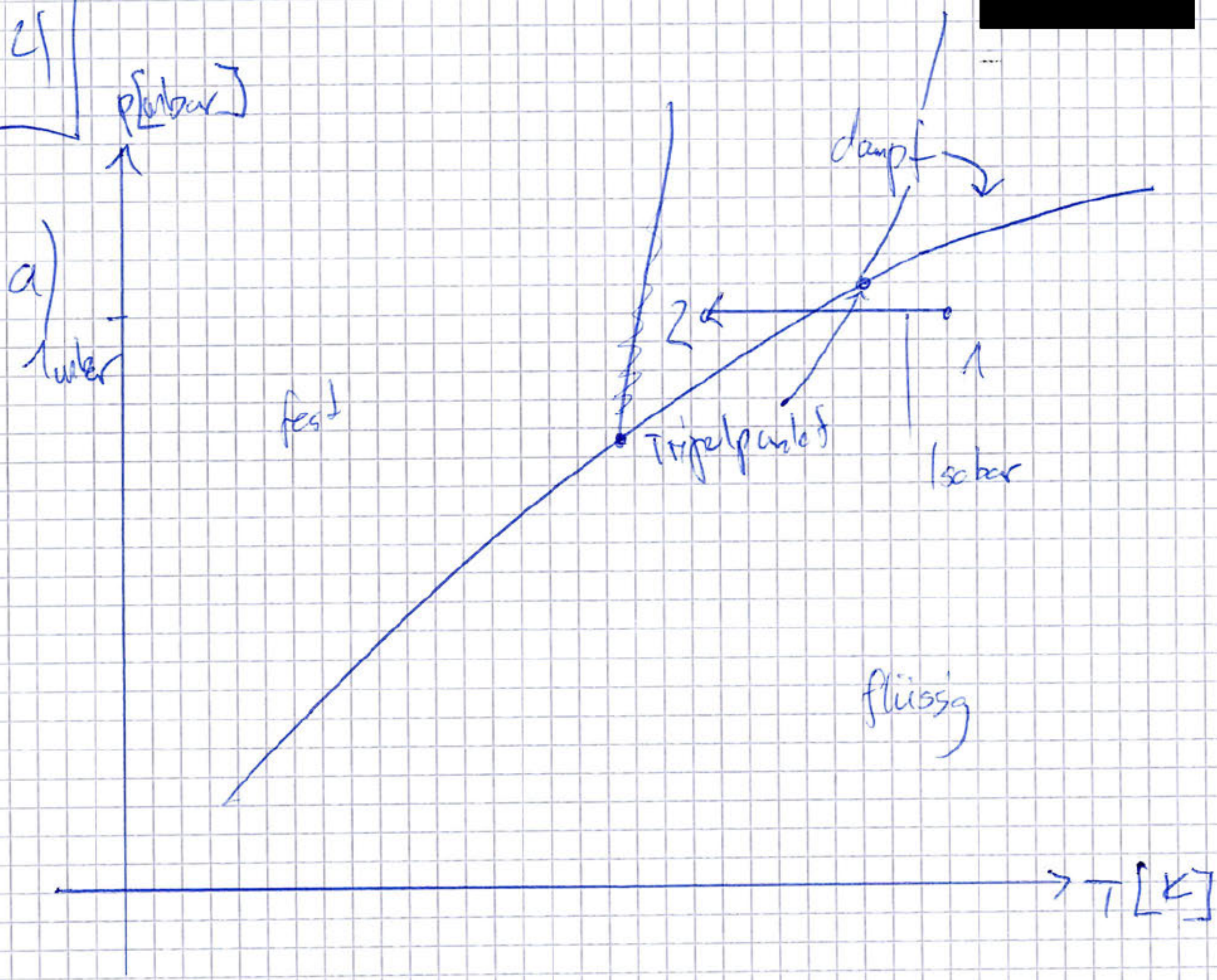
$$x_{eis_2} = \frac{m_{eis}}{m_{eis} + m_f} = \frac{m_{eis}}{0.1\,kg}$$

$$\cancel{m_{eis}} = \cancel{x_{eis}} = u_{EW} = u_{fest} + x \cdot (u_{flüss} - u_{fest})$$

$$\text{Tab 1} \rightarrow u_{EW} = -333.458\,\frac{kJ}{kg} + x \cdot (-0.045 + 333.458)$$

4)

a)



b) Energiebilanz am Verdichter:

Druck Inverval 1 mbar

$$0 = \dot{m}_{kühl} (h_{ein} - h_{aus}) - \dot{W}_K$$

$$\dot{W}_K = \dot{m}_{kühl} \cdot (h_2 - h_3)$$

$$\dot{m}_{kühl} = \frac{\dot{W}_K}{h_2 - h_3}$$

h_2 (sat. vap) A11

h_3 (8 bar, sat vap; da verdichtet) A11 $= 264.15 \frac{kJ}{kg}$

4)

[redacted]

c) $x_1 = \frac{h_1 - h_{1f}}{h_{1g} - h_{1f}}$

d) $\varepsilon_K^{rev} = \frac{1}{\frac{T_{warm}}{T_{kalt}} - 1}$

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

e) Es würde Noch kälter werden