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Aufgabe 1

a) Energiebilanz ~~und~~ um den Reaktor:

St.FP.

$$\underbrace{\frac{dE}{dt}}_{=0} = \sum \dot{m}(h + \cancel{ke + pe}^{\,=0}) + \sum \dot{Q} - \underbrace{\sum \dot{W}}_{=0}$$

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

$\dot{Q}_R = 100\,kW$

$$\dot{Q}_{aus} = \dot{Q}_R \cdot \dot{m}(h_{ein} - h_{aus}) = 62.182\,kW$$

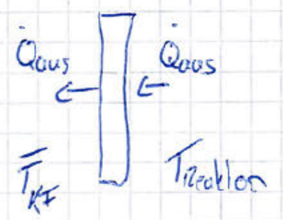
A2: $\begin{cases} h_{ein} = h_f(70°C) = 292.98\,\frac{kJ}{kg} \\ h_{aus} = h_f(100°C) = 419.04\,\frac{kJ}{kg} \end{cases}$

b) $\bar{T}_{KF} = \dfrac{\int_{ein}^{aus} T\,ds}{s_{aus} - s_{ein}}$ isobar $\rightarrow$ $\bar{T}_{KF} = \dfrac{h_{aus} - h_{ein}}{s_{aus} - s_{ein}}$

ideale Flüssigkeit: $\bar{T}_{KF} = \dfrac{\int_{T_1}^{T_2} c\,dT + \cancel{v(p_2 - p_1)}^{=0}}{\int_{T_1}^{T_2} \frac{c}{T}\,dT} = \dfrac{c(T_2 - T_1)}{c \ln\left(\frac{T_2}{T_1}\right)}$

$$\bar{T}_{KF} = \frac{T_2 - T_1}{\ln\left(\frac{T_2}{T_1}\right)} = 293.12\,K$$

c) Entropiebilanz um die Reaktorwand:



$$0 = \dot{m}(\cancel{s_e - s_a})^{=0} + \sum \frac{\dot{Q}}{\bar{T}} + \dot{S}_{erz}$$

$$\frac{\dot{Q}_{aus}}{T_{Reaktor}} - \frac{\dot{Q}_{aus}}{\bar{T}_{KF}} + \dot{S}_{erz} = 0$$

$$\dot{S}_{erz} = \dot{Q}_{aus} \cdot \left(\frac{1}{\bar{T}_{KF}} - \frac{1}{T_{Reaktor}}\right)$$

$\bar{T}_{KF} = 293.12\,K$

$T_{Reaktor} = 373.15\,K$

$$\dot{S}_{erz} = 0.0455\,\frac{kJ}{kgK}$$

$$= 45.5\,\frac{J}{kgK}$$

d) $m_1 = 5755\,kg$ $\quad x_1 = 0.005$ $\quad T_1 = 100°C$

A2: $h_1 = h_f(100°) + x_1 \cdot (h_g(100°) - h_f(100°)) = 430.3253\,\frac{kJ}{kg}$

$u_1 = u_f(100°) + x_1 (u_g(100°) - u_f(100°)) = 429.3778\,\frac{kJ}{kg}$

hinzu: $m_h = \Delta m_{12}$ $\quad T_{ein} = 20°C$ $\quad x_{ein} = 0$ $\quad u_{ein} = u_f(20°C) = 83.95\,\frac{kJ}{kg}$ A2

Energiebilanz:

$$\frac{dE}{dt} = \sum \dot{m} \cancel{(h + ke + pe)}^{=0} + \sum \dot{Q} - \cancel{\sum \dot{W}}^{=0}$$

$\Delta U = Q$ $\qquad\qquad Q = 35\,MJ$

2: $T_2 = 70°C$ $\quad x_2 = 0$ $\quad$ A2: $u_2 = u_f(70°C) = 292.95\,\frac{kJ}{kg}$

$$(m_1 + \Delta m_{12}) \cdot u_2 - m_1 \cdot u_1 - \Delta m_{12} u_{ein} = Q$$

$$\Delta m_{12} u_2 - \Delta m_{12} u_{ein} = Q - m_1 u_2 + m_1 u_1$$

$$\Delta m_{12} = \frac{Q - m_1 u_2 + m_1 u_1}{u_2 - u_{ein}} = 3589.2\,kg$$

e) $\cancel{m_2 s_2 - m_1 s_1 = \Delta m_{12} s_{ein} + \frac{Q}{T} + S_{erz}}$

$$\Delta S_{12} = m_2 s_2 - m_1 s_1 - \Delta m_{12} s_{ein}$$

$m_2 = m_1 + \Delta m_{12} = 9344\,kg$

$m_1 = 5755\,kg$

A2: $s_2 = s_f(70°) = 0.9549\,\frac{kJ}{kgK}$

$s_1 = s_f(100°) + x_1 \cdot (s_g(100°) - s_f(100°)) = 1.33714\,\frac{kJ}{kgK}$

$s_{ein} = s_f(20°) = 0.2966\,\frac{kJ}{kgK}$

$$\Delta S_{12} = 162.8\,\frac{kJ}{K}$$

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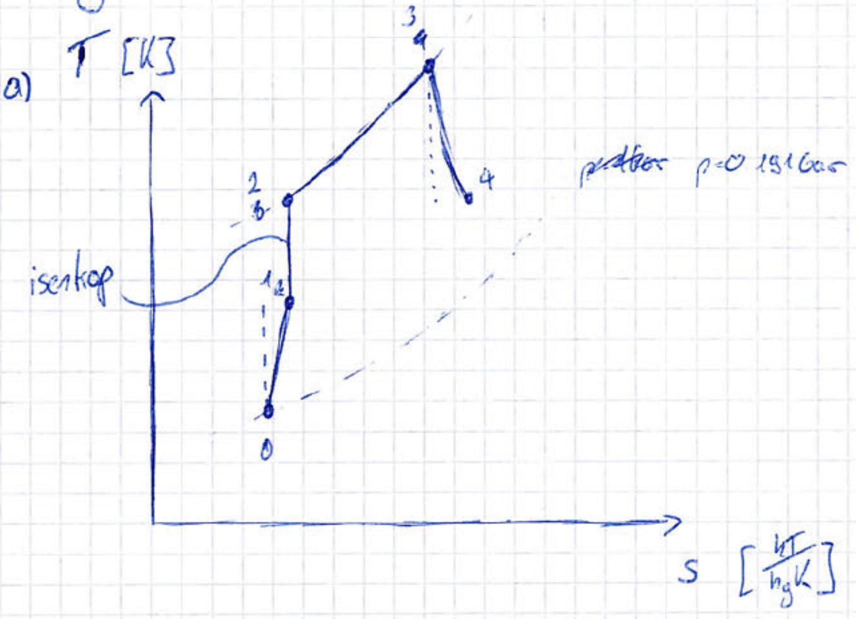
Aufgabe 2

isobare

a) T [K]



b) Energiebilanz um das ganze Triebwerk:

St.FP.

$$\underbrace{\frac{dE}{dt}}_{=0} = \sum \dot m (h + ke + \underbrace{pe}_{=0}) + \underbrace{\sum \dot Q}_{} - \underbrace{\sum \dot W}_{=0} \qquad \dot W_{net} = 0$$

$$\dot m \left(h_0 + \frac{\omega_0^2}{2}\right) - \dot m \left(h_6 + \frac{\omega_6^2}{2}\right) + \dot Q = 0$$

$$h_0 - h_6 + \frac{\omega_0^2}{2} - \frac{\omega_6^2}{2} + \dot q = 0$$

$$\frac{\omega_6^2}{2} = c_p (T_0 - T_6) + \frac{\omega_0^2}{2} + \dot q =$$

$$\omega_6 = \sqrt{2\left(c_p (T_0 - T_6) + \frac{\omega_0^2}{2} + \dot q\right)} = 1503 \ \frac{m}{s}$$

5-6 adiabat reversibel

$\rightarrow$ isentrop $\Rightarrow n = \kappa$

$$\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{\kappa-1}{\kappa}}$$

$T_6 = 328.1 K$

$T_6 = 54.95 °C$

c)

$$\dot E_{x_{str_0}} = \dot m \left(h_0 - h_0 - T_0 (s - s_0) + \frac{\omega_0^2}{2}\right)$$

Wir rechnen mit 510 m/s!

$$\dot E_{x_{str_6}} = \dot m \left(h_6 - h_0 - T_0 (s_6 - s_0) + \frac{\omega_6^2}{2}\right)$$

$$\Delta e_{x_{str}} = \left(h_6 - h_0 - T_0 (s_6 - s_0) + \frac{\omega_6^2}{2} - \frac{\omega_0^2}{2}\right)$$

$h_6 - h_0 = c_p (T_6 - T_0)$

$$\Delta e_{x_{str}} = \left(c_p (T_6 - T_0) - T_0 \left(c_p \ln\left(\frac{T_6}{T_0}\right)\right) + \frac{\omega_6^2}{2} - \frac{\omega_0^2}{2}\right)$$

$s_6 - s_0 = \ln\left(\frac{T_6}{T_0}\right) c_p - R \underbrace{\ln\left(\frac{p_2}{p_1}\right)}_{=0}$

$\Delta e_{x_{str}} = $ ~~1124.607 kJ/kg~~ $122.2 \ \frac{kJ}{kg}$

d) Exergie für stationären FP:

$$0 = -\Delta \dot{E}x_{str} + \sum \left(1 - \frac{T_0}{T}\right)\dot{Q} - \underbrace{\cancel{\sum \dot{W}}}_{=0} - \dot{E}_{x,verl}$$

$$e_{x_{verl}} = -\Delta e_{x_{str}} + \left(1 - \frac{T_0}{T}\right) q =$$

$q = 1195 \frac{kJ}{kg}$

$T_0 = 293.15K$

$\bar{T}_B = 1289K$

$$e_{x_{verl}} = 847.38 \frac{kJ}{kg}$$

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Aufgabe 3

a) $M = 50 \frac{kg}{kmol}$ $c_v = 0.633 \frac{kJ}{kgK}$ $T_{G,1} = 500°C$ $V_{G,1} = 5.15 \cdot 10^{-3} m^3$

$pV = mRT$ $R = \frac{\bar{R}}{M} = 166.29 \frac{J}{kgK}$

$p_{1g} = p_{amb} + (m_K + m_{EW}) g \cdot \frac{1}{A}$ $A = \pi \frac{d^2}{4}$

$p_{1G} = 1.4 bar$

$m_{1G} = \frac{p_{1G} V_{1G}}{R T_{1G}} = 0.0056 kg = 5.6 g$

b) $T_{G,2} = 0°C$ $p_{G,2} = p_{G,1} = 1.4 bar$

Temperatur: Da $x > 0$ ist, ~~...~~ befindet sich das EW immer noch im EW Gebiet und die ganze zugeführte Wärme wurde zum schmelzen angewendet, nicht zur Temp erhöhung! und das Gas steht im thermischen GG → gleiche Temperatur!

Druck: Da der aussendruck und die Masse konstant ist, bleibt p automatisch auch konst!

c) $V_{2g} = \frac{m_G \cdot R T_{2,G}}{p_{2G}} = 1.817 L$

$\Delta U = Q - W$ $W = \int_1^2 p\, dV = p (V_2 - V_1) = -466.62 J$

$Q = \Delta U + W = -2239.02 J$ $\Delta U = m c_v (T_2 - T_1) = -1772.4 J$

$|Q_{12}| = 2239.02 J$

d) $x_1 = 0.6$ $\frac{dE}{dt} = \cancel{\dot{m}(h + ke + pe)} + \Sigma\dot{Q} - \cancel{\Sigma\dot{W}}$ $V_d = const$

Wir rechnen mit $Q = 1500 J$:

$\Delta U = Q_{12}$ $Q = |Q_{12}|$

$m_w (u_2 - u_1) = Q_{12}$ für $p = 1.4$ $u_1 = u_{fl} + x (u_{fest} - u_{fl}) = -200.1 \frac{kJ}{kg}$

$u_2 = \frac{Q_{12}}{m_w} + u_1 = -185.1 \frac{kJ}{kg}$

→

$$x_2 = \frac{u_2 - u_{Flüssig}}{u_{FE} - u_{Flüssig}} = 0.555$$

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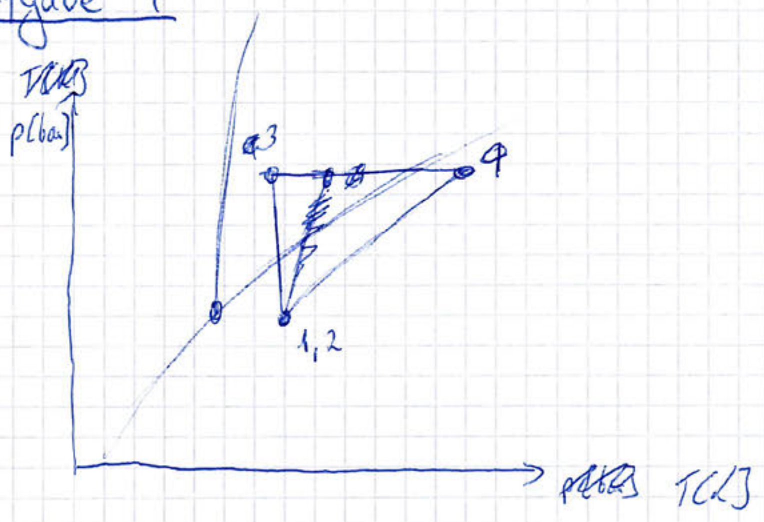
Aufgabe 9

a)



b) $T_1 = 283.15\,K$ $\quad T_{Sublimation} = 273.15\,K \rightarrow T_1$

$T_{Verdampfer} = 277.15\,K = 4°C$

$T_2 = 4°C \quad x_2 = 1 \quad$ A 10: $h_2 = 249.53\,\frac{kJ}{kg}$

$s_{2} = 0.9169\,\frac{kJ}{kg}$

A10: $s_3 = s_2 = 0.9169$

Wir interpolieren in A12 bei 8bar.

$$h_3 = h(sat) + \frac{h(40) - h(sat)}{s(40) - s(sat)} \cdot (s_3 - s(sat)) = 267.33\,\frac{kJ}{kg}$$

st. FP.

$$\underbrace{\frac{dE}{dt}}_{=0} = \Sigma \dot{m}\,(h + \cancel{ke} + \cancel{pe}) + \cancel{\Sigma \dot{Q}} - \Sigma \dot{W}$$

$$\dot{W} = \dot{m}\,(h_2 - h_3) \qquad \dot{m} = \frac{\dot{W}}{h_2 - h_3} = 1.57\,\frac{g}{s}$$

c) Drossel adiabat → isenthalp!

$h_4 = h_1 \quad$ isobar → $p_4 = p_3 = 8bar \quad$ A11: $h_4 = h_f(8bar) = 93.42\,\frac{kJ}{kg}$

$h_1 = 93.42\,\frac{kJ}{kg} \quad$ isobar → $p_1 = p_2 = 3.3765\,bar$

Wir nehmen A10 bei ~~40~~ 4°C & 3.3765bar.

$$x = \frac{h_1 - h_f}{h_g - h_f} = 0.196$$

d)

$$\epsilon_K = \frac{\dot{Q}_{zu}}{|\dot{W}_t|} \qquad \dot{Q}_{zu} = \dot{Q}_K = \dot{m} \cdot (h_2 - h_1) = 245\,J/s$$

$$\dot{W}_t = 28\,W$$

$$\epsilon_K = 8.75$$