[redacted] ThD I Prüfung 202x [redacted]

1. a) Energiebilanz um das Rohr: $\frac{dE}{dt} = \dot{m}(h_1 - h_2) + \dot{Q} - \dot{W}$ (0, stationär)

gesättigte Flüssigkeit 70°C

$h_1 = $ Tab A2 → $292.98 \frac{kJ}{kg}$

$\dot{Q} = \dot{m}(h_2 - h_1)$

$h_2 = $ Tab A2 $(100°)$ h_f = $419.04 \frac{kJ}{kg}$

$\dot{Q}_{ab} = 0.3 \frac{kg}{s}\left(419.04 \frac{kJ}{kg} - 292.98 \frac{kJ}{kg}\right) = 37.818\,kW$

eigentlich negativ

$\dot{Q}_{zu} = \dot{Q}_{R} + \dot{Q}_{ab}$ $\quad \dot{Q}_{ab} = \dot{Q}_R - \dot{Q}_{zu} = 100k - 37.818\,kW = 62.182\,kW$

$\dot{Q}_{zu} - \dot{Q}_R$

b) ?

c) stat. Fließprozess: $0 = \dot{m}(s_e - s_a) + \frac{\dot{Q}_{ab}}{T} + \dot{S}_{erz}$, $\quad \dot{S}_{erz} = \dot{m}(s_a - s_e) - \frac{\dot{Q}}{T}$

$s_e = $ Tab A2 → $0.9549 \frac{kJ}{kgK}$

$s_a = $ Tab A2 → $1.3069 \frac{kJ}{kgK}$

$= 0.3 \frac{kg}{s}\left(1.3069 \frac{kJ}{kgK} - 0.9549 \frac{kJ}{kgK}\right) + \frac{62.182}{295\,K} = 0.3163\,kW$

d) $\frac{dE}{dt} = \dot{m}(h_i) + \dot{Q} - \dot{W}$ (0)

integriert: $\Delta U = \Delta m\, h_{ein} + Q$

Tab A2 20°C 83.96 kJ/kg

$h_{ein} = $ ~~290.98 kJ/kg~~

$u_1 = T = 100°C$ → Tab A2 → $418.94 \frac{kJ}{kg}$

$u_2 = T = 70°C$ → Tab A2 → $292.95 \frac{kJ}{kg}$

$m_1 = 5755\,kg$

$m_2 = 5755\,kg + \Delta m$

$m_2 u_2 - m_1 u_1 = \Delta m \cdot h_{ein} + Q$

$\Delta m = \frac{m_2 u_2 - m_1 u_1 - Q}{h_{ein}}$

$(m_1 + \Delta m) u_2 - m_1 u_1 = \Delta m\, h_{ein} + Q$

$\Delta m (u_2 - h_{ein}) = m_1 u_1 + Q - m_1 u_2$

$\Delta m = \frac{m_1(u_1 - u_2) + Q}{u_2 - h_{ein}} = \frac{5755\,kg\left(418.94 \frac{kJ}{kg} - 292.95 \frac{kJ}{kg}\right) - 35 \cdot 10^3}{292.95 - 83.96 \frac{kJ}{kg}} = 3301.94\,kg$

e) ~~Entropiebilanz $\frac{dS}{dt} = \dot{m}(s_i) + \frac{\dot{Q}}{T} + \dot{S}_{erz}$~~

$\frac{dS}{dt}$ → integriert $m_2 s_2 - m_1 s_1$, $\quad m_2 = m_1 + \Delta m = 5755 + 3301.94 = 9056.94\,kg$

$s_1 = $ Tab A2 $1.3069 \frac{kJ}{kgK}$

$s_2 = $ Tab A2 0.9549

$= 9056.94\,kg \cdot 0.9549 \frac{kJ}{kgK} - 5755\,kg \cdot 1.3069 \frac{kJ}{kgK}$

$= 1127.26 \frac{kJ}{K}$

Thd I Autor Aufgabe 2:

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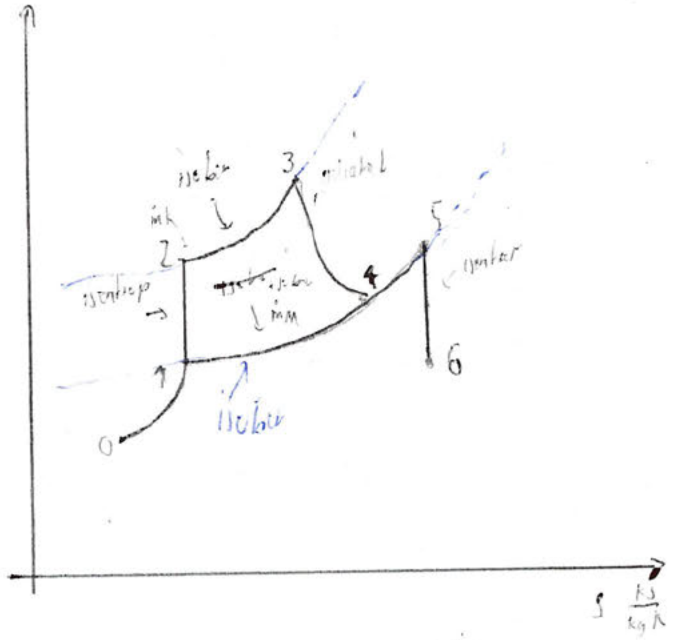
a)



b) w_6, T_6:

Prozess 56: Energiebilanz: $\frac{dE}{dt} = \dot m_{ges}\left(h_5 - h_6 + \frac{(w_5^2 - w_6^2)}{2}\right) + \dot Q - \dot W$ (stationär; adiabat)

reversibel adiabat = isentrop $\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{\kappa-1}{\kappa}}$ $T_6 = T_5 \cdot \left(\frac{p_6}{p_5}\right)^{\frac{\kappa-1}{\kappa}} = 431.9K \cdot \left(\frac{0{,}191 bar}{0{,}5 bar}\right)^{\frac{1{,}4-1}{1{,}4}} = \underline{\underline{328{,}075 K}} = T_6$

$0/\dot m = h_5 - h_6 + \frac{w_5^2}{2} - \frac{w_6^2}{2} - w = 0$

$w = \frac{R(T_6 - T_5)}{1-\kappa}$ $R = c_p - c_v = c_p - \frac{c_p}{\kappa}$ $= 1{,}006 - \frac{1{,}006 \frac{kJ}{kgK}}{1{,}4} = \underline{0{,}2874 \frac{kJ}{kgK}}$

$w_6 = \sqrt{2 \cdot (h_5 - h_6) + w_5^2 - 2w}$

$w = \frac{0{,}2874 \frac{kJ}{kgK} \cdot (328{,}075K - 431{,}9)}{1-1{,}4} = 74{,}6059 \frac{kJ}{kg}$

$= \sqrt{2 \cdot c_p(T_5 - T_6) + w_5^2 - 2w}$

$= \sqrt{2 \cdot 1006 \frac{J}{kgK} \cdot (431{,}9 - 328{,}075K) + (220 \frac{m}{s})^2 - 2 \cdot 74{,}6059 \cdot 10^3 \frac{J}{kg}}$

$= \underline{\underline{328{,}7629 \frac{m}{s}}} = w_6$

c) $h_6 - h_0 = T_0(s_6 - s_0) + \frac{w_6^2}{2} - \frac{w_0^2}{2} = c_p(T_6 - T_0) - T_0\left(c_p \ln\left(\frac{T_6}{T_0}\right) - R\ln\left(\frac{p_6}{p_0}\right)\right) + \frac{w_6^2}{2} - \frac{w_0^2}{2}$

$= 1006 \frac{J}{kgK} \cdot (328.075K - 273.15K) - 273.15K \cdot \left(1006 \frac{J}{kgK} \cdot \ln\left(\frac{328.075}{273.15}\right)\right) + \frac{(328.76 \frac{m}{s})^2}{2} - \frac{(200 \frac{m}{s})^2}{2}$

$= 96200 \frac{J}{kg}$ $\underline{\underline{96.200 \frac{kJ}{kg}}}$

d) Entropiebilanz $\frac{dS}{dt} = \dot{m}(s_0 - s_6) + \frac{\dot{Q}}{T} + \dot{S}_{erz}$ $\quad | : \dot{m}$ $\rightarrow$ $s_{erz} = s_6 - s_0 = c_p \ln\left(\frac{T_6}{T_0}\right) - R\ln\left(\frac{p_6}{p_0}\right)$

$= 1.006 \frac{kJ}{kgK} \cdot \ln\left(\frac{328.075}{273.15}\right)$

$= 0.3071 \frac{kJ}{kgK}$

$e_{x,verl} = T_0 \cdot s_{erz} = 273.15K \cdot 0.3071 \frac{kJ}{kgK} = \underline{\underline{73.276 \frac{kJ}{kg}}}$

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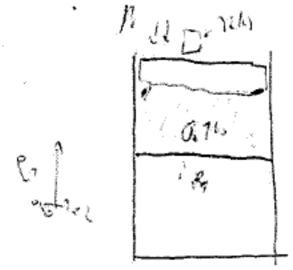
ThD I Frühj 2028

3. a) $R = \frac{\bar{R}}{M} = \frac{8.314 \frac{J}{mol\,K}}{50 \frac{g}{mol}} = 166.28 \frac{J}{kg\,K}$



Fläche $= A = (0.05\,m)^2 \pi = 0.00785\,m^2$

Kräftegleichgewicht: $p_1 \cdot A - p_0 \cdot A - (m_K + m_{Eis}) \cdot g = 0$

$p_1 = \frac{(m_K + m_{Eis}) \cdot g}{A} + p_0$

$= \frac{(32\,kg + 0.1\,kg)\,9.81 \frac{m}{s^2}}{0.00785\,m^2} + 10^5\,Pa$

$= 140\,098.2357\,Pa = \underline{\underline{1.401\,bar}}$

$pV = mRT,$

$T_1 = 773.15\,K$

$m = \frac{p_1 \cdot V_1}{R \cdot T_1}$

$= \frac{1.401 \cdot 10^5\,Pa \cdot 3.14 \cdot 10^{-3}\,m^3}{166.28 \frac{J}{kg\,K} \cdot 773.15\,K} = 0.003422\,kg$

$= \underline{\underline{3.4222\,g}}$

b) $T_{g,2} = T_{Eis,2}$ → da keine Wärme mehr fliesst. $T_{Eis,2} = T_{Eis,1}$ → hat noch Eis

$T_{g,2} = \underline{\underline{0°C}}$ (→ 273.15 K), Die Temperatur ist 0 grad, weil im oberen Behälter immer noch Eis vorhanden ist, das heisst, alle Wärme die das Gas abgegeben hat, hat nur Eis geschmolzen und nicht erwärmt.

$p_2 = p_1 =$ ~~1 bar~~ $\underline{\underline{1.401\,bar}}$ ← Der Druck ändert sich nicht, da das Kräftegleichgewicht immer noch gelten muss.

c) E.bilanz ges: $\frac{dE}{dt} = \dot{m}(h \ldots) + \dot{Q} - \dot{W}$ (ΔU gewählt)

Integriert:

$U_2 - U_1 = Q - W$

$W + m \cdot c_v (T_2 - T_1) = Q$

$W = \int_1^2 p\,dV = p_1 (V_2 - V_1) \quad V_2 = \frac{m R T_2}{p_2}$

$= \frac{0.003422\,kg \cdot 166.28 \cdot 273.15}{1.401 \cdot 10^5}$

$= 1.401 \cdot 10^5\,Pa\,(0.00096 - 0.00314\,m^3)$ $= 0.00096\,m^3$

$= \underline{-304.96\,J}$

$\frac{N}{m^2} \cdot m^3$

$Q = 0.003422\,kg \cdot 0.633 \frac{kJ}{kg\,K} (500 - 0)\,K - 304.96 \cdot 10^{-3}$

$= \underline{\underline{779.257\,J}}$

d) Energiebilanz Wasser: $\frac{dE}{dt} = \dot{m}(\ldots) + \dot{Q} - \dot{W}$

$m(u_2 - u_1) = Q$

~~$u_1 = u_{fl} + x$~~

Zuerst p_{EW} = Kräftebilanz: $p_{EW} = \frac{m_K g}{A} + p_0 = \frac{3\ldots 9.81}{0.007115 m^2} + 10^5 = 1.4006$ bar

$u_1 = u_{fest} + (1-x)(u_{fl} - u_{fest})$

$= -333.458 + (1-0.6)(-0.045 - (-333.458))$

$= -200.0924$

$u_2 = \frac{Q}{m} + u_1$

$= \frac{779.257 \cdot 10^{-3} kJ}{0.1 kg} + (-200.0924 \frac{kJ}{kg}) = \underline{-192.300 \frac{kJ}{kg}}$

$p_2 = p_1$ ← immer noch Kräftegleichgewicht

$X_{2,fl} = \frac{u_2 - u_{fest}}{u_{fl} - u_{fest}} = \frac{-192.300 - (-333.458)}{-0.045 - (-333.458)} = 0.42337$, $X_{Eis} = 1 - X_{fl}$

$= \underline{\underline{0.57663}}$

ThD I Prüfung 2024

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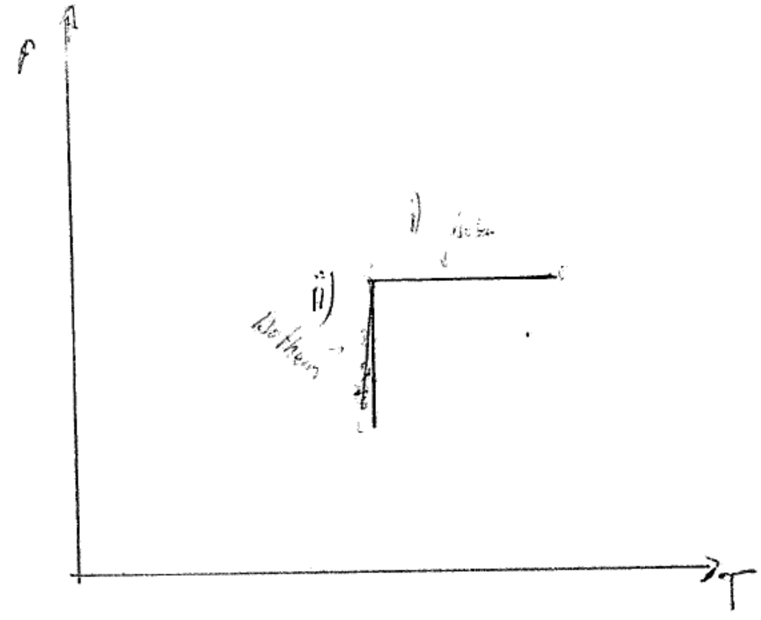
4. a)



b) $T_1 = -10°C$, $T_{Verdampfer} = -10°C - 6K = \underline{-16°C} = T_2$,

$h_2 =$ Tab A10, $-16°C \to h_g = 237,74 \frac{kJ}{kg}$

E bilanz Verdichter $\frac{dE}{dt} = \dot{m}(h_2-h_3) + \dot{Q} - \dot{W}_K$ (0, stat. ; adiabat)

h_3: $s_3 = s_2$, da adiabat reversibel, $\to$ s2 = Tab A10 $= \underline{0,9298} \frac{kJ}{kgK} = s_3$

h_3 interpolieren mit Tab A12 $\to$ 8 bar $\frac{273,66\frac{kJ}{kg} - 267,25\frac{kJ}{kg}}{0,9377\frac{kJ}{kgK} - 0,9066\frac{kJ}{kgK}}\left(0,9298\frac{kJ}{kgK} - 0,9066\frac{kJ}{kgK}\right) + 267,25\frac{kJ}{kg} = \underline{271,31\frac{kJ}{kg}}$

$$\dot{m} = \frac{\dot{W}_K}{h_2-h_3} = \frac{-28\frac{J}{s}\cdot 10^{-3}}{237,74\frac{kJ}{kg} - 271,31\frac{kJ}{kg}} = \underline{\underline{0,0008374\frac{kg}{s}}} = 0,83399\frac{g}{s}$$

c) ~~adiabat~~ adiabate Drosseln sind isenthalp, $h_1 = h_4$

$h_f =$ Tab A11 $\to$ 8 bar $h_f = \underline{93,42\frac{kJ}{kg}} = h_1$

$p_1 = p_2$, $p_2 =$ Tab A10 $\to T = -16°C$: $p_{sättigung} = \underline{1,5774\ bar}$

x_1 interpolieren mit Tab A11, $p = 1,5774$ bar

$$X_1 = \frac{h_1 - h_f}{h_g - h_f}$$

$$h_f = \frac{29,78\frac{kJ}{kg} - 25,77\frac{kJ}{kg}}{1,6-1,4}(1,5774-1,4) + 25,77 = \underline{29,32747}$$

$$h_g = \frac{237,97 - 236,04}{1,6-1,4}(1,5774-1,4) + 236,04 = 237,7326\frac{kJ}{kg}$$

$$X_1 = \frac{93,42 - 29,32747}{237,7326 - 29,2747} = \underline{\underline{0,3077}}$$

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

$\dot{Q}_{zu}$: $\frac{dE}{dt}^{0} = \dot{m}(h_1 - h_2) + \dot{Q} - \dot{W}^{0}$

$\dot{Q}_{zu} = \dot{m}(h_2 - h_1) = 0.000837 \frac{kg}{s} (237.74 - 93.72 \frac{kJ}{kg}) = 120.336 \, J/s$

$\varepsilon_K = \frac{120.336 \, J/s}{28 \, J/s} = \underline{\underline{4,30}}$

e) Friere nicht gut kalt