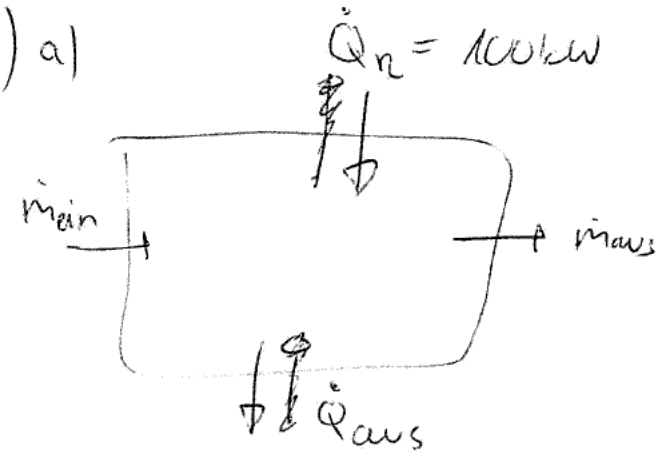
A1) a)



1. HS: $\dot{m}\left(h_1 - h_2 + \cancel{ke} + \cancel{pe}\right) + \sum\dot{Q} - \dot{W} = 0$ (stationär)

$0 < x_D < 1 \Rightarrow$ ND-Gebiet

Z_1: $70°C$ $x_D = 0.005$

$h_1 = h_f(70) + x_D\left(h_g(70) - h_f(70)\right)$ $\quad h_f = 292.98$, $h_g = 2626.8$ | A2

$h_1 = 304.65 \frac{kJ}{kg}$

$h_2 = h_f(100) + x_D\left(h_g(100) - h_f(100)\right)$ $\quad h_f = 419.04$, $h_g = 2676.1$ | A2

$h_2 = 430.33 \frac{kJ}{kg}$

$\dot{m}\left(h_1 - h_2\right) + 100kW - \dot{Q}_{aus} = 0$

$\underline{\dot{Q}_{aus} = 62.3\,kW}$

b) $\bar{T} = \frac{h_a - h_e}{s_a - s_e}$ $\rightarrow$ ideal fluid

$\bar{T} = \frac{\int_{T_1}^{T_2} c\,dT + v\cancel{(p_2 - p_1)}}{\int_{T_1}^{T_2} \frac{c}{T}\,dT}$ keine Druckänderung

$c = const$

A1b) $c = \text{const.}$

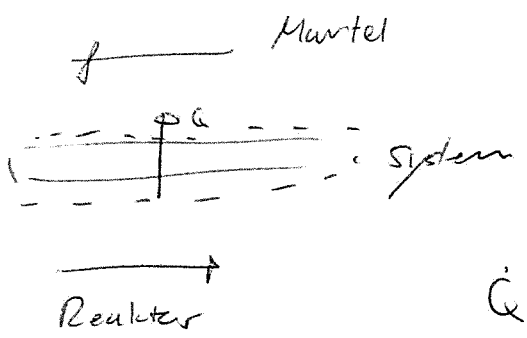
$$\Rightarrow \bar{T} = \frac{\cancel{c}\,(T_2 - T_1)}{\cancel{c}\,\ln\left(\frac{T_2}{T_1}\right)}$$

$T_2 = 298.15$

$T_1 = 288.1\text{I}$

$$\bar{T} = 293.12\ \text{K}$$

c) $\rightarrow \dot{Q}_{aus}$ betrachten



$$\frac{\cancel{dS}^{\,0,\text{stat.}}}{\cancel{dt}} = \frac{\dot{Q}}{\bar{T}} + \dot{S}_{erz}$$

$\dot{Q} = -62.3\ \text{kW}$

$\bar{T} = 293.12\ \text{K}$

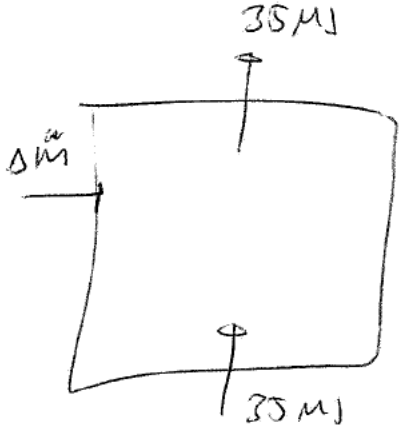
$$\dot{S}_{erz} = 0.213\ \frac{\text{kW}}{\text{K}}$$

1d)

Z_1: $m_1 = 5755\,kg$

$T_1 = 100°C$

$x_1 = 0.005$



Z_2: $m = m_1 + \Delta m$

$T_2 = 70°C$

$x_2 = 0.005$

1. HS halboffen:

$$m_2 u_2 - m_1 u_1 + \cancel{\Delta KE} + \cancel{\Delta PE} = \Delta m h_{\Delta m} + \cancel{\sum Q} - \cancel{W}$$

($Q_{ein} = Q_{aus}$, $V = konst.$)

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

u_1: A-2 100°C $x = 0.005$

$u_1 = u_f + 0.005\,(u_g - u_f)$ $\quad u_f = 418.94$ | A2

$u_1 = 428.38\ \frac{kJ}{kg}$ $\quad u_g = 2506.5$

$u_2 = u_f(70) + 0.005\,(u_g(70) - u_f(70))$ $\quad u_f(70) = 292.95$

$u_2 = 303.8\ \frac{kJ}{kg}$ $\quad u_g(70) = 2469.6$ | A2

$h_{\Delta m}$: 20°C $x = 0.005$

$= h_f(20) + x\,(h_g(20) - h_f(20))$ $\quad h_c(20) = 83.96$

$h_g(20) = 2538.1$ | A2

$h_{\Delta m} = 96.23\ \frac{kJ}{kg}$

A1d)

$$\Delta m_{12} = \frac{(m_1 + \Delta m_{12})u_2 - m_1 u_1}{h_{sm}}$$

$$\Delta m h_{sm} = m_1 u_2 + \Delta m u_2 - m_1 u_1$$

$$\Delta m (h_{sm} - u_2) = m_1 u_2 - m_1 u_1$$

$$\Delta m = \frac{m_1 (u_2 - u_1)}{h_{sm} - u_2}$$

$$\underline{\Delta m_{12} = 3482 \text{ kg}}$$

A1e)

$$\Delta S = m_{12} s_2 - m_1 s_1$$

s_1: 100°C $x = 0.005$

→ A2 $\quad s_1 = s_f(100) + x(s_g(100) - s_f(100))$ $\quad s_f(100) = 1.3069$, $s_g(100) = 7.3549$

$$\underline{s_1 = 1.33714 \frac{kJ}{kgK}}$$

s_2 70°C $x = 0.005$ → A2

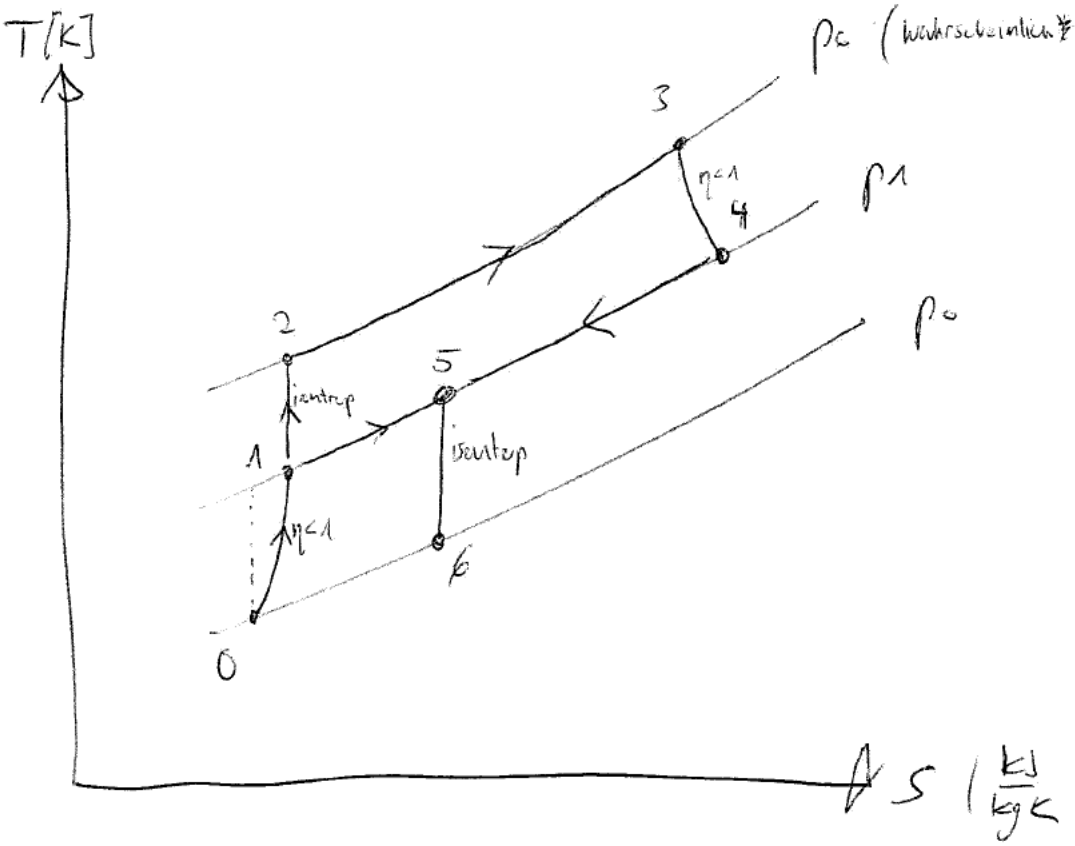
$s_2 = s_f(70) + x(s_g(70) - s_f(70))$ $\quad s_f(70) = .9549$, $s_g(70) = 7.7553$

$$s_2 = 0.9889 \frac{kJ}{kgK}$$

$$\Delta S = (m + \Delta m) s_2 - m_1 s_1 = \underline{1439.2 \text{ kJ/K} = \Delta S}$$

A2)

a)



z_0 : 0.191 bar −30°C

z_1 : p_1 (~~is~~ adiabat ~~$\eta=1$~~ $\eta<1$)

z_2 : isentrop ; p_2

z_3 : isobar

$p_1 = p_4 = p_5$

A2) b)

$p_5 = 0.5$ bar

$T_5 = 431.9$ K

$w_5 = 220$ m/s

T_6 mit Polytropenverhältnis: $n = \gamma_L = 1.4$

$$T_6 = T_5 \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} \qquad p_6 = 0.431 \text{ bar}$$

$$\underline{\underline{T_6 = 328.1 \text{ K}}}$$

→ 1. HS stationär

$$0 = \dot{m}\left(h_e - h_a + \frac{1}{2}\left(w_e^2 - w_a^2\right)\right) + \cancel{\dot{q}} - \cancel{\dot{w}}$$

(adiabat; $V = C.$)

$$2(h_6 - h_5) = w_5^2 - w_6^2$$

$$2(h_6 - h_5) - w_5^2 = -w_6^2$$

$$\sqrt{w_5^2 + 2(h_5 - h_6)} = w_6 \qquad , \quad h_5 - h_6 = c_p(T_5 - T_6)$$

$$c_p = 1.006$$

$$\underline{\underline{w_6 = 507.2 \text{ m/s}}}$$

A2) c)

$$e_{x,str_6} - e_{x,str_0} = h_6 - h_0 - T_u s_6 + T_u s_0 + ke_6 - ke_0$$

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

$$s_0 - s_6 = c_p \ln\left(\frac{T_0}{T_6}\right) - R \ln\left(\frac{p_6}{p_6}\right)^0$$

$$ke_6 - ke_0 = \frac{1}{2}\left(w_6^2 - w_0^2\right)$$

$$\Delta e = c_p (T_6 - T_0) + T_u \left\{ c_p \ln\left(\frac{T_0}{T_6}\right) + \frac{1}{2}\left(w_6^2 - w_0^2\right) \right.$$

$c_p = 1.006$

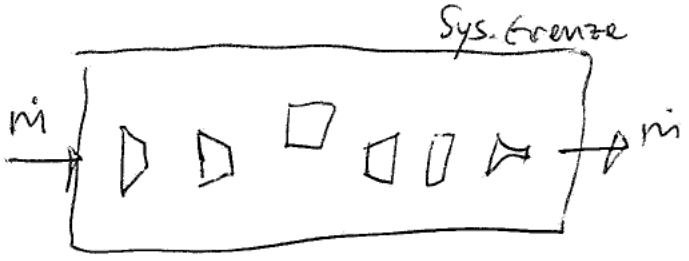
$T_6 = 328.1 \quad T_0 = 243.15 = T_u$

$w_6 = 507.2$

$w_0 = 200$

$$\Delta e_{x,str} = 120.8 \frac{kJ}{kg}$$

d)



$\dot{Q} = 0$

$\dot{W} = 0$ (W_{tot} geht für Kompression drauf)

$\frac{dE_x}{dt}$ (0, stationär) $= \sum \dot{E}_{x,str} - E_{x,verl}$ — stimmt nicht, $\dot{Q} \neq 0$

$= \dot{e}_{x,0} - e_{x,6}$ [illegible] $- e_{x,verl}$

Aufg 2 d)

$$0 = e_{x,0} - e_{x,6} +$$

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

$$0 = s_e - s_a + \frac{\dot{q}}{T} + \dot{S}_{0z}$$

$\dot{S}_{0z} = \frac{e_{x,vol}}{T_0}$

$$0 = s_0 - s_6 + \frac{\dot{q}}{T} + \frac{e_{x,vol}}{T_0}$$

$$c \ln\left(\frac{T_0}{T_6}\right) + \frac{\dot{q}}{T} + \frac{e_{x,vol}}{T_0} = 0$$

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

$T = 1289\,K$

$$e_{x,vol} = \left(-c \ln\left(\frac{T_0}{T_6}\right) + \frac{\dot{q}}{T}\right) \cdot T_0$$

$$\underline{\underline{e_{x,vol} = -152.1\ kJ/kg}}$$

A3) a) p_{g1}, m_g, $c_V = 0.633$

$M_g = 50$

IGL: $p_{g1} V_{g1} = m_g R_g T_{g1}$

für p_{g1}: Druck im EW und Gas muss gleich sein (GGW)

Druck von aussen = 1bar + p_K

$F_K = m_K \cdot g$ $\quad p = \frac{F}{A} = \frac{m_K g}{A}$, $A = \left(\frac{D}{2}\right)^2 \pi$

$p_K = \frac{82 \cdot 9.81}{0.00785} = 0.3396$ bar

$m_{EW} = 0.1$ kg vergessen.

$p_A = 1.3996$ bar $= p_{g1} = 1.4$ bar $\quad p_{EW} = \frac{m_{EW} g}{A} = 125$ Pa

$m_g = \frac{p_{g1} V_{g1}}{R_{g1} T_{g1}}$

$V_{g1} = 0.00314\ m^3$

$R_{g1} = \frac{R}{M} = 166.28$ J/kgK

$T_{g1} = 773.15$ K

$m_g = 3.42$ g

b) $p_{g2} = p_{g1}$ → der Kolben drückt immernoch von oben und es herrscht ein GGW.

($p_2 = 1.4$ bar)

Da $\dot{Q} = 0$ muss $T_{g2} = T_{EW2}$ gelten.

Tab. 1 → $T_{sat}(p = 1.4) = 0.000°C = T_{2g}$

c) 1. HS: $\Delta E = Q - W$

$W = p_2 V_2 - p_1 V_1$

$W = p_2 V_2 - p_1 V_1$

V_2 via IGL: $p_2 V_2 = m_g R_G T_{G2}$

$V_2 = 0.0011\ m^3$

$p_2 = 1.7\ bar$
$m_g = m_{g1}$
$R_G = R_{g1}$
$T_{g2} = 0°C = 273.15\ K$

$W = p(V_2 - V_1)$

$W = -284.3\ J$

$\Delta E = m(u_2 - u_1)$

→ perf. Gas $u_2 - u_1 = c_v (T_2 - T_1)$

$m c_v (T_2 - T_1) = Q - W$

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

$c_v = 633\ J/kgK$ $T_2 = 0°C$ $T_1 = 500°C$

$Q = -1367\ J$

A3) d)

T_1: 0°C , $x_{Eis} = 0.6$ $m_{FW} = 0.1\,kg$

→ 1. HS Bilanz um FW

$\Delta U = u_2 - u_1 = Q - W$ (inkompressibel)

↳ 1367 J

$u_1 = u_f + x(u_g - u_f)$, $u_f = -333.458$, $u_g = -0.045$ (f = fest, g = flüssig)

$x = (1 - x_{Eis}) = 0.4$

Tab 1

$u_1 = -200.4\ \frac{kJ}{kg}$

~~$u_2 = Q + u_1 = 1367\,J + 0.1 \cdot (-200.4) \cdot 1000$~~

~~$u_2 = u_1$~~

$m(u_2 - u_1) = Q - W$

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

$u_2 = -186.73\ kJ/kg$

Tab 1: $p = 1.4$ bar

$u = u_{Fest} + x_{Fl}(u_{Fl} - u_{Fest})$

$x_{Fl} = \frac{u - u_{Fest}}{u_{Fl} - u_{Fest}}$

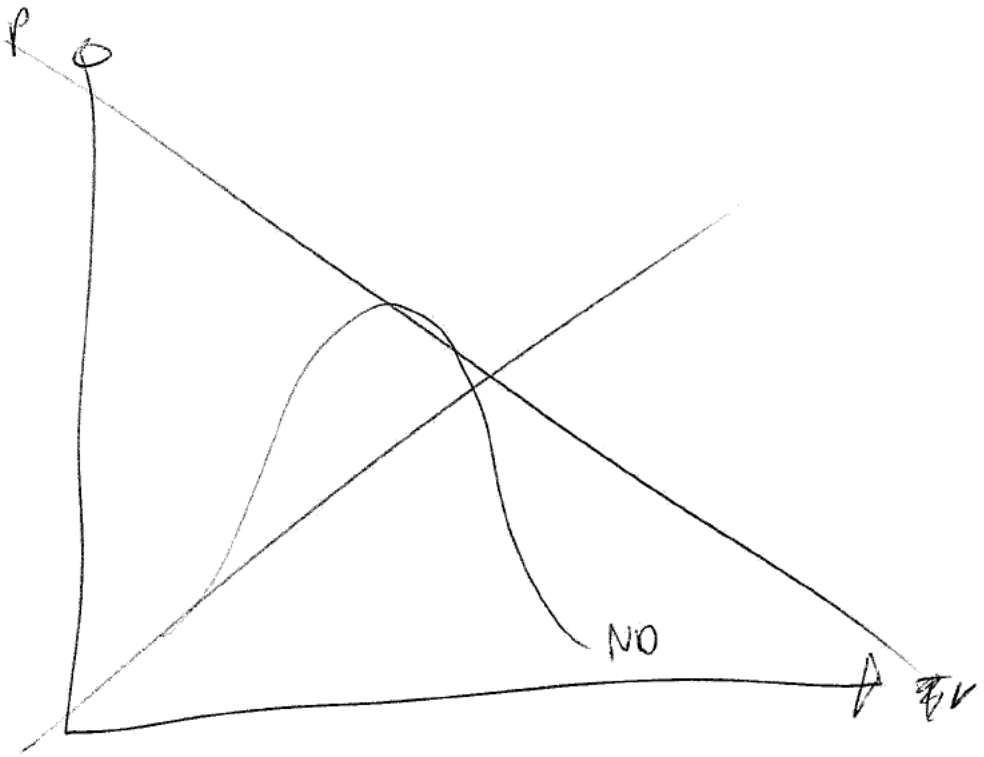
$u_{Fl} = -0.045$

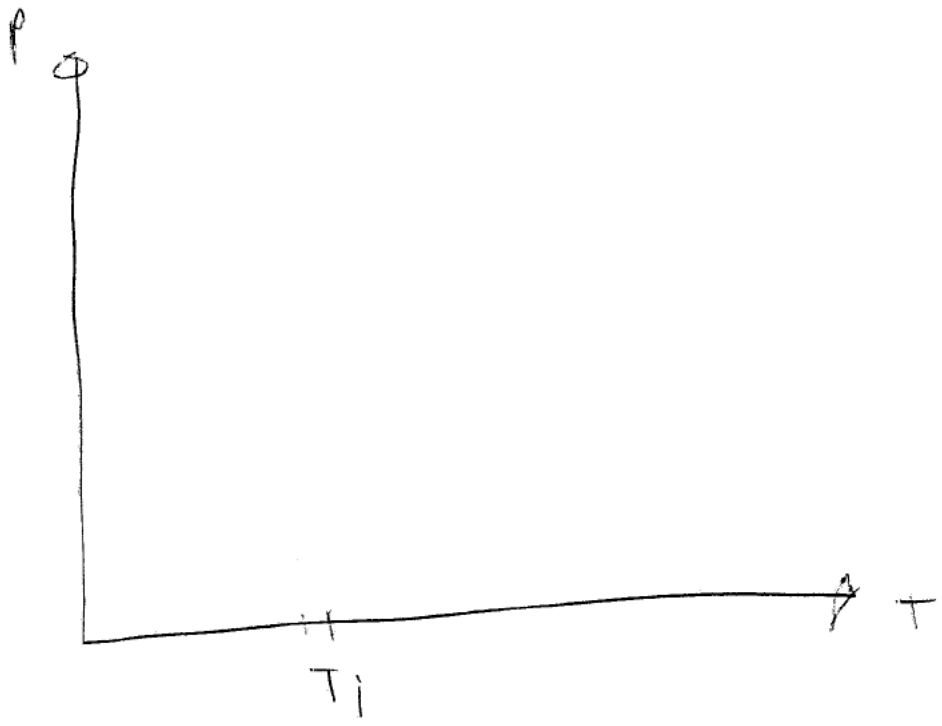
$u_{Fest} = -333.458$

$x_{Fl} = 0.44$ → $x_{Eis,2} = 0.600$

$x_{Eis2} = 0.55992$

A4) a)





A4) b) $T_i = -10°C$

		p	T	h	s
	1	1.5748	-16		
x=1	2	p_1	-16		
	3	8			s_2
x=0	4	8			

$T_{1,2} = T_i - 6K = -16°C$

$h_2 = h_g(-16°C) \Rightarrow A10$

$h_2 = 237.74 \frac{kJ}{kg}$

$s_2 = s_3 = s_g(-16°C) = 0.9298 \frac{kJ}{kgK}$

$p_3 = 8 bar \Rightarrow$ ~~A-11~~

~~$h_3 = h$~~ via A-11 sehe ich, wir sind im Dampf-gebiet

$\Rightarrow$ A-12

$$h_3 = h_{sat} + \frac{(h(40) - h_{sat})}{s(40) - s_{sat}} \cdot (s_3 - s_{sat})$$

$h(40) = 273.66$
$h_{sat} = 264.15$
$s_{sat} = 0.9066$
$s(40) = 0.9374$

$h_3 = 271.3 \frac{kJ}{kg}$

$h_2 = 237.74$

$h_3 = 271.3$

$2 \to 3$ 1. HS

$$0 = \dot{m}(h_2 - h_3) + \cancel{\dot{Q}}^{\text{adiabat}} - \dot{W}$$

$\dot{W} \rightarrow -28\ \cancel{kW}$

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

~~$\dot{m} = 0.834\ kg/s$~~ $\quad \dot{m} = 0.834\ g/s$

c) ich nehme $\dot{m} = 4\ kg/h$ für safety $= \frac{4}{3600}\ kg/s$

$$0 = \dot{m}(h_1 - h_2) + \dot{Q}_K$$

$$-\frac{\dot{Q}_K}{\dot{m}} + h_2 = h_1$$

$h_3 = 271.3\ \frac{kJ}{kg}$

$3 \to 4$ isochor $\quad 2_4$: Sbar $\quad x = 0 \quad h_4 = h_f(8\,bar)$

$h_4 \overset{+11}{=} 93.42\ \frac{kJ}{kg}$

$$\dot{m}(h_3 - h_4) + \dot{Q} = 0$$

$$Q = 0.198\ kW$$

Aufgrund Kreisprozess: $W + \sum Q_{zu} = 0$

4c)

$$-28W * -197.6W + \dot{Q}_K = 0$$

$$\dot{Q}_K = 225.6W$$

$$\dot{m}(h_1 - h_2) + \dot{Q} = 0$$

$$h_1 = \frac{-\dot{Q}}{m} + h_2 =$$