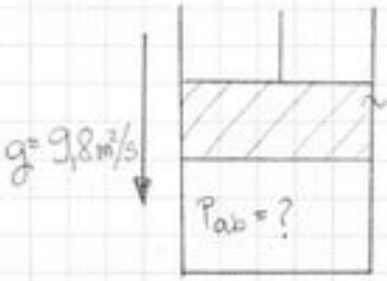
Primer: Bat cilindra napolnjen s plinom 60 kg in površina $0{,}04\ m^2$. Lokalni atm tlak znaša 0,97 bar, gravitacijski pospešek $9{,}8\ m/s^2$. Določi tlak v cilindru? Sistemu dodamo toliko toplote, da se volumen podvoji; kakšen tlak je v sistemu?

A = površina

$\sum_i F_i = 0$



$$P_{atm} A + \overbrace{m \cdot g}^{F} - P_{abs} A = 0 \;/ : A$$

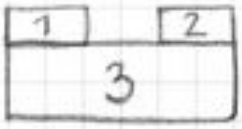
$$P_{abs} = P_{atm} + \frac{m \cdot g}{A}$$

$$P_{abs} = 0{,}97 \cdot 10^5 + \frac{60 \cdot 9{,}8}{0{,}04} = 1{,}117 \cdot 10^5\ Pa$$

8. TEMPERATURA

- Ničti zakon termodinamika (0-ti)

Če sta dve telesi v termičnem ravnovesju s tretjim telesom potem sta tudi v termičnem ravnovesju medseboj.



- 3 telo nadomestimo s termometrom

2 telesi sta v termičnem ravnovesju če obe izkazujeta enako temperaturo in tudi nista v kontaktu medseboj.

- CELZIJEVA TEM. SKALA
- KELVINOVA TEM. SKALA

$$T(K) = 273{,}15 + T\ (^\circ C)$$

Indeksiranje vrednosti:

tekočina = f

para = g

Primer: Tank nebuje 30 kg nasičene tekočine pri 90°C. Določi tlak v tanku in volumen tanka.

$m = 30\ kg$

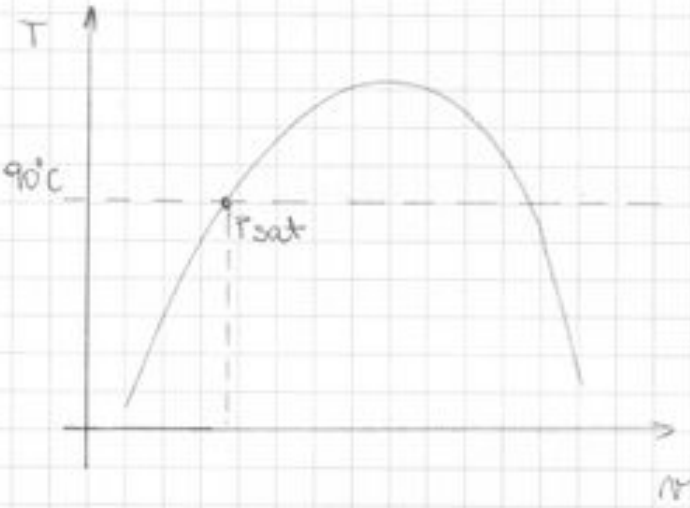
$T = 90°C$

nasičena tekočina

$p_{sat} = 70{,}14\ kPa = 0{,}7014\ bar$

L_0 odčitamo iz tabele

- $m = V \cdot \rho = \frac{V}{v}$ — V – VOLUMEN, v – SPECIFIČNI VOLUMEN
- $V = m \cdot v = 30\ kg \cdot 0{,}001036 = 0{,}03108\ m^3$
- $\rho = \frac{1}{v} = \frac{1}{0{,}001036} = 965{,}251\ kg/m^3$



2.) 200g nančene vode, popolnoma uparimo pri 100kPa. Določi spremembo volumna in količino dodane energije.

$m = 200\,g$ (mas. voda)

$p_{sat} = 100\,kPa$

$T = 100\,°C$

$V = \frac{m}{\rho} = m \cdot v$

$\Delta V = m(v_g - v_f)$

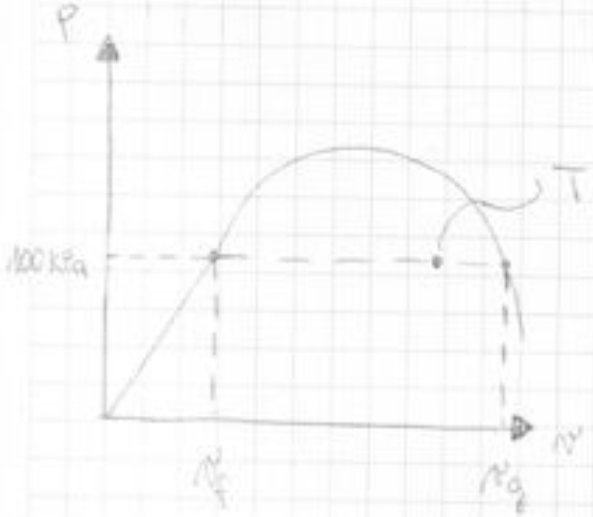
$= 0{,}2\,kg\,(1{,}6729 - 0{,}001044)\,m^3/kg$

$= 0{,}3343712\,m^3$

$\Delta E = \Delta H = h_{fg} \cdot m$

$\Delta H = 2257\,kJ/kg \cdot 0{,}2\,kg$

$\Delta H = 451{,}4\,kJ$



3) Tank vsebuje 10 kg vode pri 90°C. Če je 8 kg vode v obliki tekočine in ostalo v obliki par. Določi tlak in prostornino tanka. Nariši pripadajoči T-v diagram.

$m_t = 10\,kg$
$T = 90°C$
$m_f = 8\,kg$
$m_g = 2\,kg$

$P = ?$
$V_t = ?$

$v_f = 0{,}001036\ m^3/kg$
$v_g = 2{,}361\ m^3/kg$

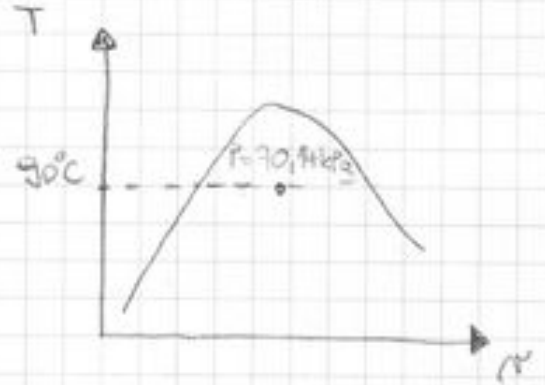
$V = \frac{m}{\rho} = m \cdot v$

$V_t = V_f + V_g$
$V_t = 0{,}001036 + 2{,}361$
$V_t = 0{,}008288\ m^3$

$V_g = m_g \cdot v_g$
$V_g = 2\,kg \cdot 2{,}361\ m^3/kg$
$V_g = 4{,}722\ m^3$

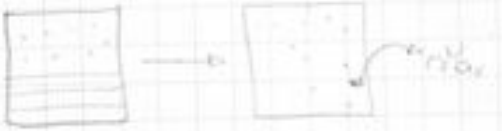
$V_t = 0{,}008288 + 4722 = 4{,}730288\ m^3$

$P = 70{,}14\ kPa = 0{,}7014\ bar$ (odčitamo iz tabele)



Analiza nasičene mešanice tekočine in pare

$$V = m\,v_{av}$$



v_{av} - povprečen specifični volumen

$$v_{av} = \frac{V_k}{m_k}$$

$$V_k = V_f + V_g$$

$$m\,v_{av} = m_f \cdot v_f + m_g \cdot v_g$$

Definicija kvalitete x

$$x = \frac{m_g}{m_k}$$

$$v_{av} = \frac{m_f}{m_k} v_f + \frac{m_g}{m_k} v_g$$

$$v_{av} = (1-x)\,v_f + x \cdot v_g$$

$$v_{av} = v_f - x\,v_f + x\,v_g$$

$$v_{av} = v_f + x(v_g - v_f)$$

$$v_{av} = v_f + x\,v_{fg}$$

V_k = celoten V
m_k = celotna m

$$\hat{U}_{av} = \hat{U}_f + x\,\hat{U}_{fg}$$

$$\hat{H}_{av} = \hat{H}_f + x\,\hat{H}_{fg}$$

FREON

4.) V 80 l posodi imamo 4 kg hladilnega sredstva R-12. Tlak je 160 kPa. Določi temperaturo, kvaliteto x, entalpijo R-12, volumen parne faze!

V = 80 l
p = 160 kPa

$$v_{av} = \frac{V_k}{m_k} = \frac{80 \cdot 10^{-3}\ m^3}{4\ kg} = 0{,}02\ \frac{m^3}{kg}$$

a) T = ?
b) x = ?
c) H = ?
d) V_g = ?

$p = 160\ kPa = 0{,}16\ MPa$

$T = -18{,}49\,°C$

$v_{av} = v_f + x \cdot v_{fg}$

$$x = \frac{v_{av} - v_f}{v_{fg}} = \frac{0{,}02\ \frac{m^3}{kg} - 0{,}000677}{0{,}10231 - 0{,}000677}$$

$x = 0{,}1919$

$$\hat{h} = \hat{h}_f + x(\hat{h}_{fg})$$

$$h = h_f + x\,h_{fg}$$

$$h = 19{,}18\ kJ/kg + 0{,}1919(160{,}23)\ kJ/kg$$

$h = 49{,}9\ kJ/kg$

$H = h \cdot m_k = 49{,}9\ kJ/kg \cdot 4\ kg = 199{,}6\ kJ$

$V_g = m_g \cdot v_g = 4\,kg \cdot 0,1919 \cdot 0,103\,m^3/kg = 79,139\,l$

3. predavanje; 15.10.2012

ENAČBA STANJA

med enačbe stanja uvrščamo: $P, T, V\,(v)$

1. Plinska enačba - idealni plini

$P \cdot V = n \cdot R \cdot T \qquad \left(R = \frac{R'}{M}\right)$

↳ relativna plinska konstanta

$R = 8,314\ \frac{kPa \cdot m^3}{K\,mol\,l}$.

1.) Določi maso zraka v sobi. Soba ima 4×5×6 m, tlak je 100 kPa, temperatura je 25°C.

$M_{zrak} = 29\,g/mol$
$P = 100\,kPa$
$T = 25°C$
$V = 4 \times 5 \times 6$

$P \cdot V = nRT = \frac{m}{M} \cdot RT$

$m = \frac{P \cdot V \cdot M}{R \cdot T}$

$m = \frac{100\,kPa\ (4 \times 5 \times 6)\,m^3 \cdot 29 \cdot 10^3\,g\,K \cdot mol\,k}{mol \cdot 8,314\,kPa\,m^3\,(273+25)\,K^{\prime\prime}}$

$m = 140,46\,kg$

2. Plinska enačba - neidealni plini

Faktor kompresibilnosti: Z

Definicija: $Z = \frac{V_{dej}}{V_{id}}$

2 parametra: • reducirani tlak $P_r = \frac{P}{P_{kr}}$

• reducirana temperatura $T_r = \frac{T}{T_{kr}}$

↳ kritična T

Realno telo:

ε .. emisivnost (-) $\quad 0 \leq \varepsilon \leq 1$

Realna telesa: $\varepsilon \sim 0{,}8$

$\dot{Q} = \varepsilon \cdot A \cdot \sigma \cdot T_s^4$

$\dot{Q}_{neto} = \varepsilon \cdot A \cdot \sigma \cdot T_s^4 - \alpha \cdot A \cdot \sigma \cdot T_{ok}^4$

α = absorbitivnost $\quad 0 \leq \alpha \leq 1$

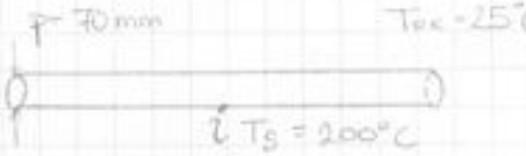
DEFINICIJA SIVEGA TELESA: $\varepsilon \cong \alpha$

$\dot{Q}_{neto} = \varepsilon \cdot A \cdot \sigma \left(T_s^4 - T_{ok}^4 \right)$

$\dot{Q}_{neto}$ ... neto efekt izsevane energije sivega telesa, kjer je približek realnega telesa

4. predavanje, 22.10.2012

1.) Cev za transport pare iz ogrevanja v laboratoriju. Temperatura stene in zraka je 25°C.



Temp. okol. $T_{ok} = 25°C$

$T_s = 200°C$

$h = 15\ W/m^2$

$L = 1\ m$

sivo telo: $\varepsilon = \alpha \cong 0{,}8 \quad h = 15\ W/m^2$

$\dot{Q}_{izgube} = \dot{Q}_{konv.} + \dot{Q}_{neto\ radiacija}$

$\dot{Q}_{izgube} = h \cdot A \left(T - T \right) + \varepsilon \cdot \sigma \cdot \left(T_s^4 - T_{ok}^4 \right)$

$\dot{Q}_{izgube} = \frac{15\ W}{K\ m^2} \cdot \pi \cdot 0{,}07m \cdot 1m \cdot (200-25)K + 0{,}8 \cdot 5{,}67 \cdot 10^{-8} \frac{W}{m^2 K^4} \cdot$

$\cdot \left(\pi \cdot 0{,}07 \cdot 1 \right) \left((200+273) - (25+273) \right)^4 =$

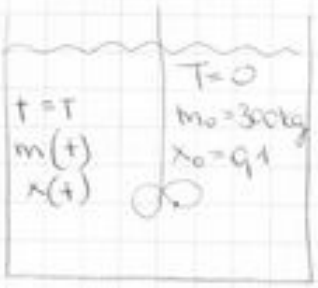
$= 557\ W + 421\ W = 998{,}35\ W$

1.) NALOGA:

V mešalniku je 300kg 10% raztopine snovi, v mešalniku odteka voda s pretokom 10 kg/h; iztok raztopine je enaka utoku. Napiše zvezo med koncentracijo snovi v mešalniku in časom.

a) V mešalniku predpostvi popolno premešanje

b) Osnovne lastnosti so neodvisne od koncentracije snovi in enake čisti vode



① $\phi m_1 = 100\ kg/h$

$x_1 = 0$

② $\phi m_2 - \phi m_1 = 100\ kg/h$

$x_2 = x(t)$

MB: za celotno raztopino

$$\frac{d(m)}{dt} = \phi m_1 - \phi m_2 = 0$$

MB: za sol

$$\frac{d(mx)}{dt} = \phi m_1 x_1 - \phi m_2 x_2$$

$$\frac{m\,dt}{dt} = \phi - \phi m \cdot x$$

$$\int_{x_0}^{x} \frac{dx}{x} = \frac{\phi m}{m} \cdot \int_0^t dt$$

$$\ln \frac{x}{x_0} = -\frac{\phi m}{m} \cdot t$$

$$\frac{x}{x_0} = e^{-\frac{\phi m}{m} \cdot t}$$

$$x = x_0 \cdot e^{-\frac{\phi m t}{m}}$$

$x = \frac{x_0}{\alpha}$; $t = ?$

$$\ln \frac{x}{x_0} = -\frac{\phi m t}{m}$$

$$t = -\left(\ln \frac{x_0}{x}\right) \cdot \frac{m}{\phi m}$$

$$t = -\left(\ln \frac{1}{2}\right) \frac{300}{100}\ h$$

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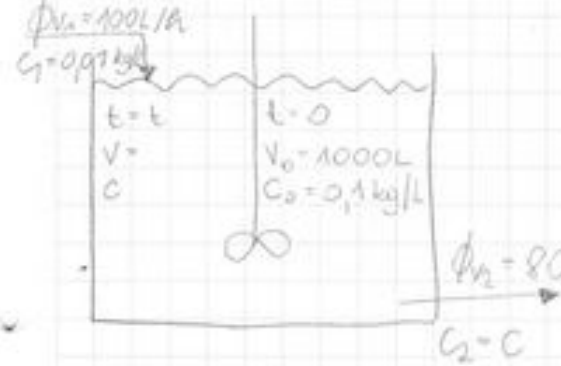
Predavanje, 5.11.2012

2.) Rezervoar vsebuje 1000 L vodne raztopine soli s koncentracijo 0,1 kg/L. V rezervoar vodimo vodno raztopino soli z 0,01 kg/L in s pretokom 100 L/h. Kakšna bo koncentracija soli v rezervoarju po 2 h, če:

a) ni iztoka ! (DOMAČA NALOGA)
b) ima iztok 80 L/h ?



NESTACIONAREN SISTEM

$V_0 = 1000$ L
$C_0 = 0,1$ kg/L
$C_1 = 0,01$ kg/L
$\phi_{V_1} = 100$ L/h
$t = 2$ h
$\phi_{V_2} = 80$ L/h

Masna bilanca: za celo raztopino

akumulacija = vtok - iztok

$$\frac{d(V)}{dt} = \phi_{V_1} - \phi_{V_2}$$

KONSTANTEN DIFERENCIAL

$$\frac{dV}{dt} = \phi_{V_1} - \phi_{V_2}$$

$$\int_{V_0}^{V} dV = (\phi_{V_1} - \phi_{V_2}) \int_0^t dt$$

$$V - V_0 = (\phi_{V_1} - \phi_{V_2}) \cdot t$$

$$V = V_0 + (\phi_{V_1} - \phi_{V_2}) \cdot t$$

$$\int \frac{dx}{a+bx} = \frac{1}{b} \ln x$$

Masna bilanca: za sol

ak - vtok - iztok

$$\frac{d(V \cdot C)}{dt} = \phi_{V_1} \cdot C_1 - \phi_{V_2} \cdot C$$

$$V \frac{dC}{dt} + C \cdot \frac{dV}{dt} = \phi_{V_1} \cdot C_1 - \phi_{V_2} \cdot C$$

$$\left[V_0 + (\phi_{V_1} - \phi_{V_2}) \cdot t \cdot \frac{dC}{dt}\right] + C \cdot (\phi_{V_1} - \phi_{V_2}) = \phi_{V_1} \cdot C_1 - \phi_{V_2} \cdot C$$

$$\left[V_0 + (\phi_{V_1} - \phi_{V_2}) \cdot t \cdot \frac{dC}{dt}\right] = \phi_{V_1} C_1 - \cancel{\phi_{V_2} C} - \phi_{V_1} C + \cancel{\phi_{V_2} C}$$

— " —

$$= \phi_{V_1} C_1 - \phi_{V_1} \cdot C$$

$$\frac{dC}{\phi_{V_1}(C_1 - C)} = \frac{dt}{V_0 + (\phi_{V_1} - \phi_{V_2}) \cdot t}$$

$$\int_0^C \frac{dC}{\phi_{V_1} C_1 - \phi_{V_1} C} = \int_0^t \frac{dt}{V_0 + (\phi_{V_1} - \phi_{V_2}) t}$$

OBRNI

$$-\frac{1}{\phi_{V1}} \ln \frac{\phi_{V1} \cdot C_1 - \phi_{V2} \cdot C}{\phi_{V1} C_1 - \phi_{V1} \cdot C_0} = \frac{1}{\phi_{V1} - \phi_{V2}} \ln \frac{V_0 + (\phi_{V1} - \phi_{V2}) \cdot t}{V_0} \quad / \cdot (-\phi_{V1})$$

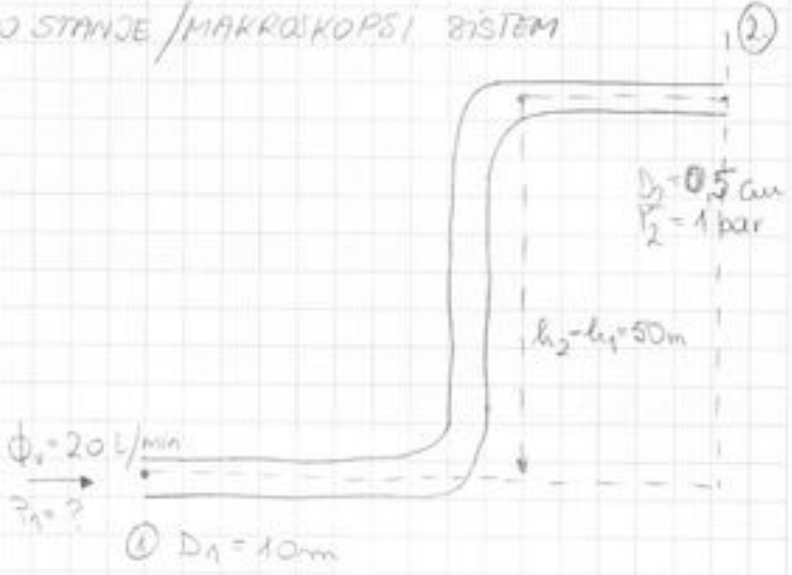
$$\ln \frac{\phi_{V1} C_1 - \phi_{V2} \cdot C}{\phi_{V1} \cdot C_1 - \phi_{V1} \cdot C_0} = \frac{1 \cdot \phi_{V1}}{\phi_{V1} - \phi_{V2}} \cdot \ln \frac{V_0 + (\phi_{V1} - \phi_{V2}) \cdot t}{V_0}$$

$C(t = 2\,h) = ?$ DOMAČA NALOGA; ENOTE!

$C = 0{,}02317 \ kg/L$

3) Vodo v količini 20 l/minuto želimo spraviti po cevovodu na 50 m višji nivo po cevovodu, ki je prikazan na sliki.

STACIONARNO STANJE / MAKROSKOPSKI SISTEM



$\phi_{v_1} = \phi_{v_2} = \phi_v = 20$ L/min

$\Delta h = 50$ m; $\Delta h = h_2 - h_1$

$D_1 = 0,01$ m
$D_2 = 0,005$ m
$P_2 = 1$ bar
$P_1 = ?$

BERNULIJEVA ENAČBA:

$$\Delta\left(\frac{\bar{v}^2}{2} + g \cdot h + \frac{P}{\rho}\right) = 0$$

$$\Delta\frac{\bar{v}^2}{2} + \Delta(g \cdot h) + \Delta\frac{P}{\rho} = 0$$

$$\left(\frac{\bar{v}_2^2}{2} - \frac{\bar{v}_1^2}{2}\right) + g(h_2 - h_1) + \frac{P_2 - P_1}{\rho} = 0$$

$$P_1 - P_2 = 1000\left[\left(\frac{16,96^2}{2} - \frac{4,24}{2}\right) + 9,8(50)\right]$$

$$P_1 - P_2 = 1000[134,8 + 490]$$

$$P_1 - P_2 = 624,8 \cdot 10^3 = \underline{6248 \cdot 10^5 \text{ Pa}}$$

$\phi_v = S \cdot \bar{v}$

$$\bar{v}_1 = \frac{20 \cdot 10^{-3} m^3 \cdot 4}{\pi \cdot (0,01)^2 m^2 \cdot 1 \cdot 60 s}$$

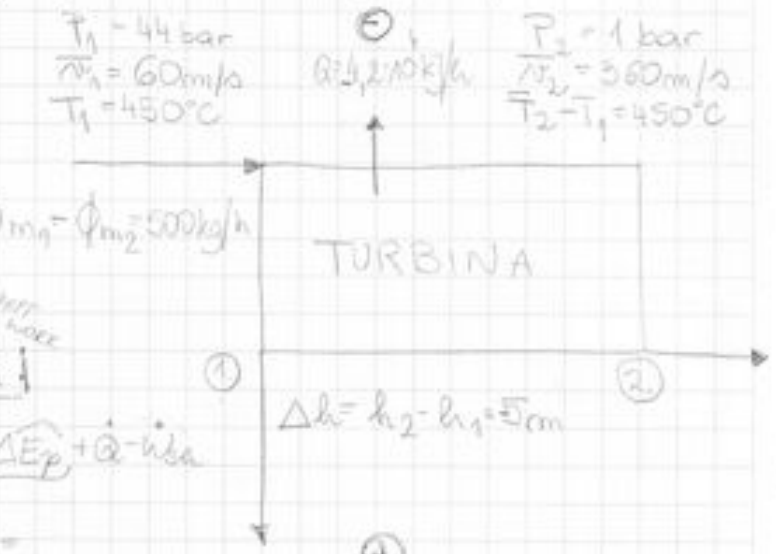
$$\underline{\bar{v}_1 = 4,24 \text{ m/s}}$$

$$\underline{\bar{v}_2 = 4 \cdot \bar{v}_1 = 16,96 \text{ m/s}}$$

toplotne, mehanske

4.) Parno turbino pogonja 500 kg pare na uro. Para vstopa v turbino pri 44 barih, 450°C in 60 m/s. Izstopa pa 5m nižje pri atmosferskem tlaku 1 bar in 360 m/s. Turbina opravlja delo 700 kW. Toplotne izgube znašajo $4{,}2 \cdot 10^4$ kJ/h. Izračunaj spremembo entalpije v procesu.

STACIONARNO STANJE/
MAKROSKOPSKI SISTEM



ENERGIJSKA BILANCA:

$$\dot{m}\,\Delta\left(\hat{E}_k + \hat{E}_p + \hat{H}\right) = \dot{Q} - \dot{W}_{sk}$$

$$\dot{m}\cdot\Delta\hat{H} = -\dot{m}\cdot\Delta\hat{E}_k - \dot{m}\cdot\Delta\hat{E}_p + \dot{Q} - \dot{W}_{sk}$$

$$-\dot{m}\cdot\Delta\hat{E}_k = -\dot{m}\left(\frac{v_2^2}{2} - \frac{v_1^2}{2}\right) =$$

$$= -\frac{500\,kg}{3600\,s}\left(\frac{360^2\,m^2}{2} - \frac{60^2\,m^2}{2\,s^2}\right) =$$

$$\approx 6{,}8\,W$$

$$\dot{m}\cdot\Delta\hat{H} = -8750\,W + 6{,}8\,W - \frac{4{,}2\cdot 10^4\,kJ\cdot 10^3}{3600\,s} - 700\cdot 10^3\,W =$$

$$\approx 703\,kW$$

! * medij brez viskoznosti: Bernulijeva enačba