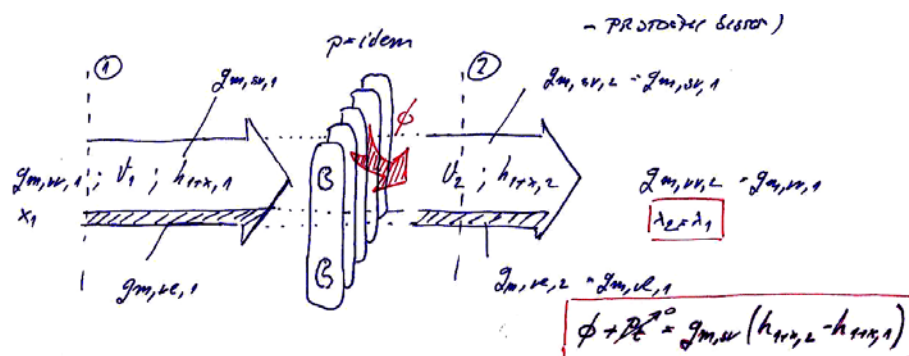


7.3.3 Osnovne promene stanja vlažnog vazduha

7.3.3.1 Izobarsko zagrevanje vlažnog vazduha

- Izobarsko zagrevanje vlažnog vazduha se u tehničkoj praksi izvodi njegovim prestrujavanjem preko zagrejanih površina (cevi, ploča, lamela,...)
- Protočni sistem



- Bilans mase

$$q_{m,vv,2} = q_{m,vv,1}$$

$$q_{m,sv,2} = q_{m,sv,1}$$

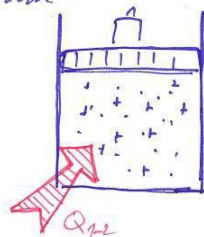
$$q_{m,sv}(1+x_1) = q_{m,sv}(1+x_2) \Rightarrow x_1 = x_2$$

- Bilans energije ($p = \text{idem}$)

$$q_{m,sv} \cdot h_{1+x,1} + \Phi_{zg} + \cancel{P_{teh}} = q_{m,sv} \cdot h_{1+x,2} \Rightarrow \Phi_{zg} = q_{m,sv} \cdot (h_{1+x,2} - h_{1+x,1})$$

- Zatvoren sistem - model izobarskog zagrevanja

$p = \text{idem}$



$p = \text{idem}$

masa

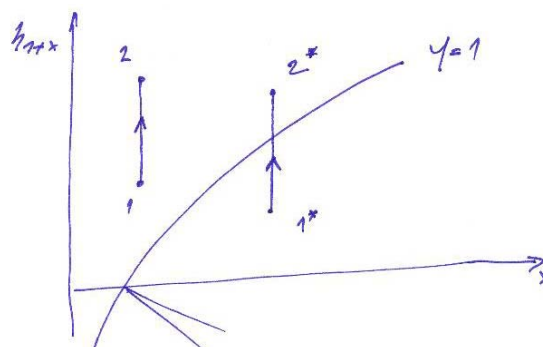
$$\left. \begin{array}{l} m_{v1} = \text{idem} \\ m_{sv} = \text{idem} \end{array} \right\} \Rightarrow x = \text{idem}$$

Energija

$$Q_{1-2} + \cancel{W_{teh,1-2}} = H_{vv,2} - H_{vv,1}$$

$$Q_{12} = m_{sv} (h_{1+x,2} - h_{1+x,1})$$

- Prikaz u Molijerovom dijagramu

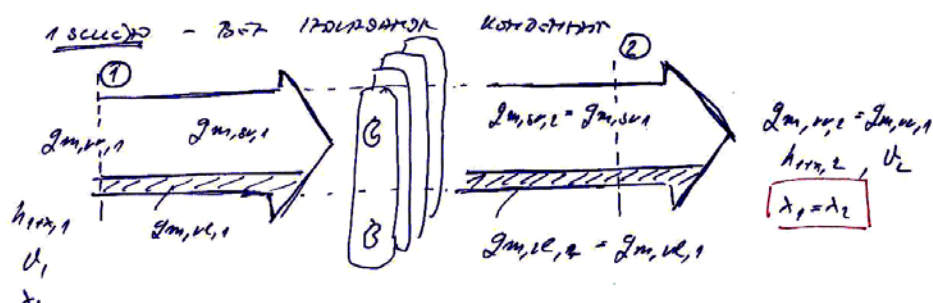


7.3.3.2 Izobarsko hlađenje vlažnog vazduha

- Izobarsko hlađenje vlažnog vazduha se u tehničkoj praksi izvodi njegovim prestrujavanjem preko hladnih površina (cevi, ploča, lamela,...)
- Protočni sistem

Model 1 – „površinsko“ hlađenje

1. slučaj – bez izdvajanja kondenzata



- Bilans mase

$$q_{m,vv,2} = q_{m,vv,1}$$

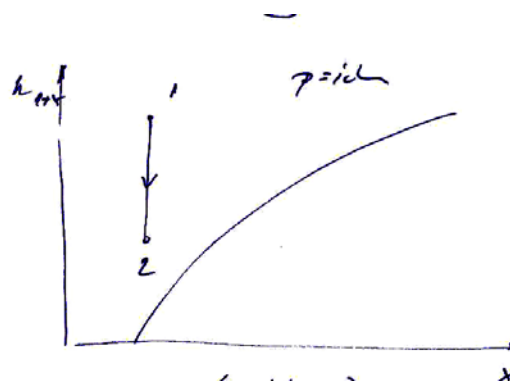
$$q_{m,sv,2} = q_{m,sv,1} = q_{m,sv}$$

$$q_{m,sv}(1 + x_1) = q_{m,sv}(1 + x_2) \Rightarrow \boxed{x_1 = x_2}$$

- Bilans energije ($p = \text{idem}$)

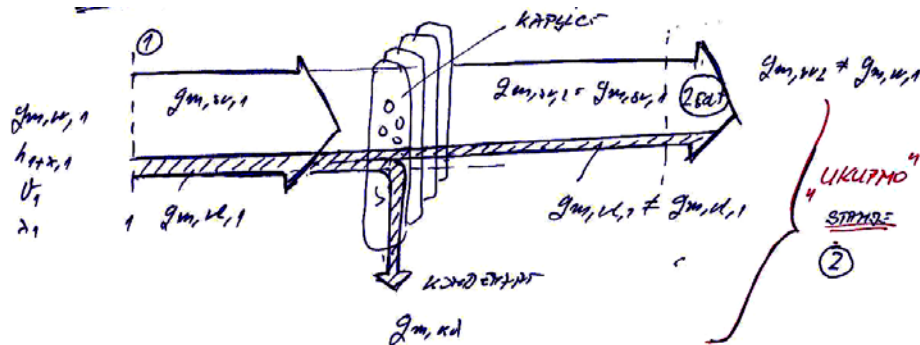
$$q_{m,sv} \cdot h_{1+x,1} + \cancel{P_{\text{teh}}} = \Phi_{\text{hl}} + q_{m,sv} \cdot h_{1+x,2} \Rightarrow \boxed{\Phi_{\text{hl}} = q_{m,sv} (h_{1+x,2} - h_{1+x,1})}$$

- Prikaz u Molijerovom dijagramu



• **Model 1 – „površinsko“ hlađenje**

2. slučaj – sa izdvajanjem kondenzata



• Bilans mase

– suv vazduh –

$$q_{m,sv,2} = q_{m,sv,1} = q_{m,sv}$$

– vlaga –

$$q_{m,vl,1} = q_{m,vl,2} + q_{m,kd}$$

– vlažan vazduh –

$$q_{m,vv,1} = q_{m,vv,2} + q_{m,kd}$$

$$q_{m,sv}(1+x_1) = q_{m,sv}(1+x_2) + q_{m,kd}$$

$$\Rightarrow \text{maseni protok kondenzata } \boxed{q_{m,kd} = q_{m,sv}(x_2 - x_1)}$$

$$q_{m,vv,2} \neq q_{m,vv,1}$$

$$q_{m,sv}(1+x_1) \neq q_{m,sv}(1+x_{2,sat}) \Rightarrow \boxed{x_1 \neq x_{2,sat}}$$

• Bilans energije ($p = \text{idem}$)

$$q_{m,sv} \cdot h_{1+x,1} = \Phi_{hl} + q_{m,sv} \cdot h_{1+x,sat} + q_{m,kd} \cdot h_{kd}$$

$$q_{m,sv} \cdot h_{1+x,1} = \Phi_{hl} + q_{m,sv} \cdot \left\{ \left[c_{p,sv} \cdot \vartheta_2 + (r_{sat} + c_{p,vp} \cdot \vartheta_2) \cdot x_{2sat} \right] + (x_1 - x_{2,sat}) c_{p,t} \vartheta_{kd} \right\}$$

kako je

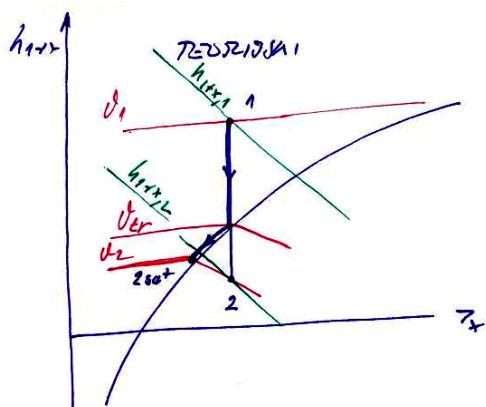
$$\boxed{\vartheta_2 = \vartheta_{kd}}$$

$$\Rightarrow q_{m,sv} \cdot h_{1+x,1} = \Phi_{hl} + q_{m,sv} \cdot h_{1+x,2}$$

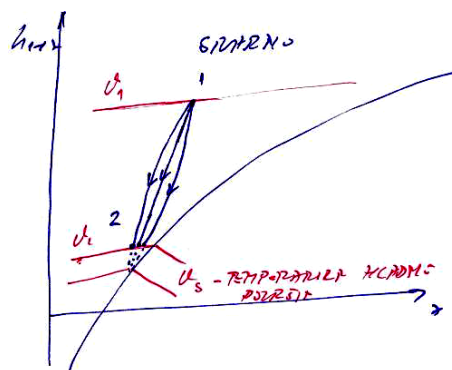
$$\Rightarrow \boxed{\Phi_{hl} = q_{m,sv} \cdot (h_{1+x,1} - h_{1+x,2})}$$

- Prikaz u Molijerovom dijagramu

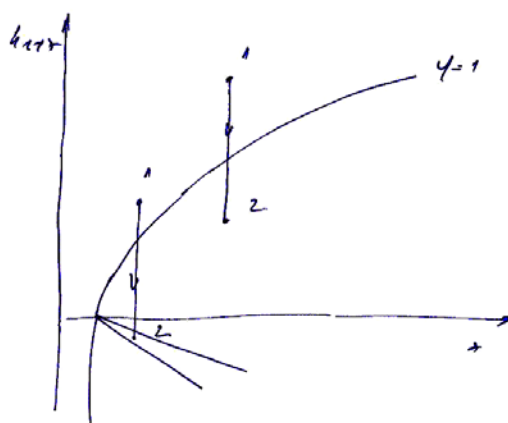
Teorijski



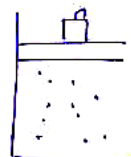
Stvarno



Model 2 – „zapreminsko“ hlađenje – u prirodi



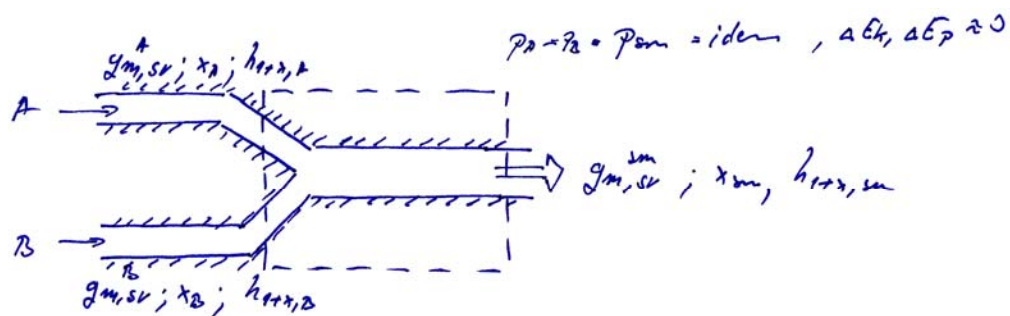
FTA. MODEL



$$\left. \begin{array}{l} m_{\text{v}} = \text{idem} \\ m_{\text{sv}} = \text{idem} \end{array} \right\} \boxed{x = \text{idem}}$$

$$\boxed{Q_{1,2} = m_{\text{sv}} (h_{\text{v},1} - h_{\text{v},2})}$$

7.3.3.3 Izobarsko i adijatermno (adijabatsko) mešanje dve struje vlažnog vazduha



- Bilans mase

– vlage –

$$q_{m,vl}^A + q_{m,vl}^B = q_{m,vl}^{sm}$$

– suvog vazduha –

$$q_{m,sv}^A + q_{m,sv}^B = q_{m,sv}^{sm}$$

– vlažnog vazduha –

$$q_{m,vv}^A + q_{m,vv}^B = q_{m,vv}^{sm}$$

$$q_{m,sv}^A (1 + x_A) + q_{m,sv}^B (1 + x_B) = q_{m,sv}^{sm} (1 + x_{sm}) = (q_{m,sv}^A + q_{m,sv}^B) \cdot (1 + x_{sm})$$

$$x_{sm} = \frac{q_{m,sv}^A x_A + q_{m,sv}^B x_B}{q_{m,sv}^A + q_{m,sv}^B} \quad (1)$$

- Bilans energije

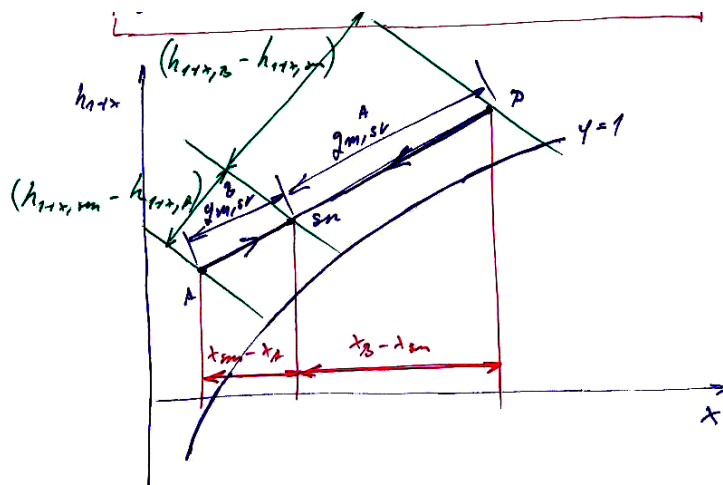
$$q_{m,sv}^A h_{1+x,A} + q_{m,sv}^B h_{1+x,B} = (q_{m,sv}^A + q_{m,sv}^B) \cdot h_{1+x,sm}$$

$$h_{1+x,sm} = \frac{q_{m,sv}^A h_{1+x,A} + q_{m,sv}^B h_{1+x,B}}{q_{m,sv}^A + q_{m,sv}^B} \quad (2)$$

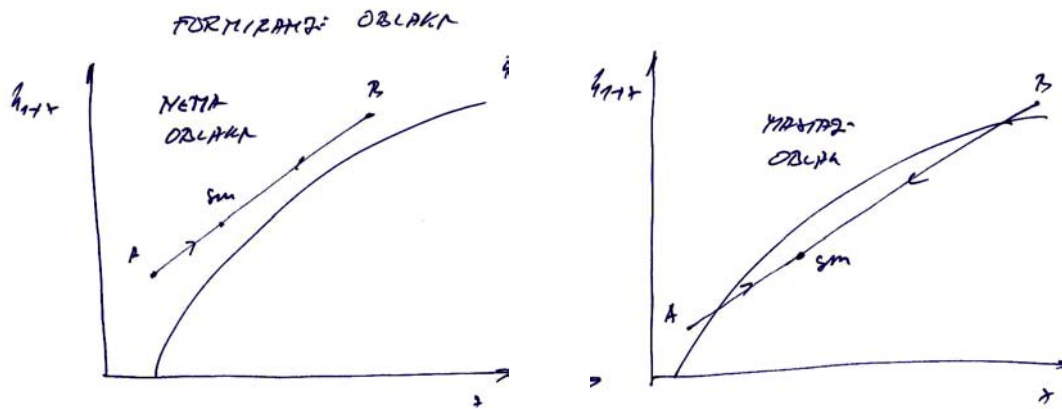
$$(1) \rightarrow q_{m,sv}^A (x_{sm} - x_A) = q_{m,sv}^B (x_B - x_{sm})$$

$$(2) \rightarrow q_{m,sv}^A (h_{1+x,sm} - h_{1+x,A}) = q_{m,sv}^B (h_{1+x,B} - h_{1+x,sm})$$

$$\frac{(2)}{(1)} \rightarrow \frac{q_{m,sv}^B}{q_{m,sv}^A} = \frac{x_{sm} - x_A}{x_B - x_{sm}} = \frac{h_{1+x,sm} - h_{1+x,A}}{h_{1+x,B} - h_{1+x,sm}} \rightarrow \text{jednačina prave}$$

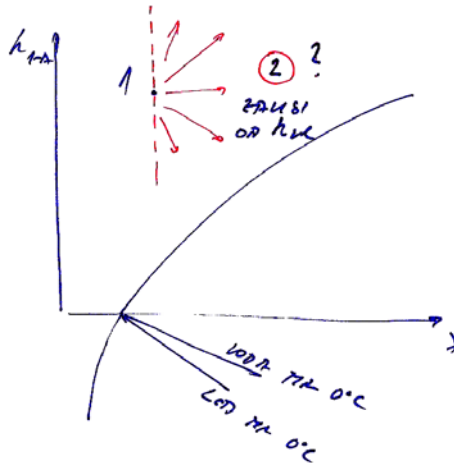
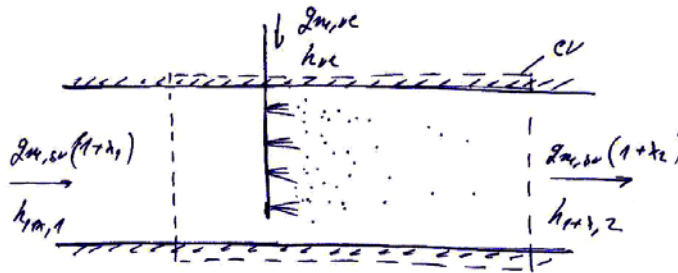


- Formiranje oblaka



7.3.3.4 Izobarno i adijatermno vlaženje vlažnog vazduha

- Vlaženje se obavlja u “maglenoj” komori – vodenom parom ili vodom (sitno raspršene kapljice)



- Bilans mase za kontrolnu zapreminu – maglenu komoru (ustaljen proces)

$$\underbrace{q_{m,sv}(1+x_1)}_{\text{ulaz u CV}} + q_{m,vl} = \underbrace{q_{m,sv}(1+x_2)}_{\text{izlaz iz CV}} \quad \Rightarrow \quad x_2 = x_1 + \frac{q_{m,vl}}{q_{m,sv}} \quad (1)$$

- Bilans energije za kontrolnu zapreminu – maglenu komoru (ustaljen proces)

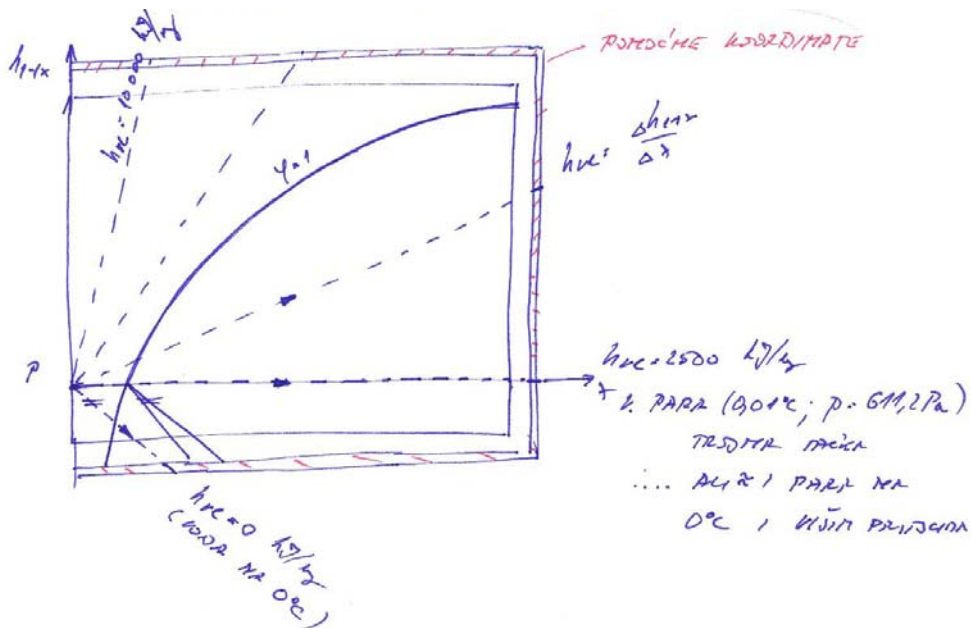
$$\underbrace{q_{m,sv} h_{1+x,1} + q_{m,vl} \cdot h_{vl}}_{\text{ulaz u CV}} = \underbrace{q_{m,sv} h_{1+x,2}}_{\text{izlaz iz CV}} \quad h_{1+x,2} = h_{1+x,1} + \frac{q_{m,vl}}{q_{m,sv}} \cdot h_{vl} \quad (2)$$

$$\text{iz (1)} \Rightarrow x_2 - x_1 = \frac{q_{m,vl}}{q_{m,sv}} \quad (1')$$

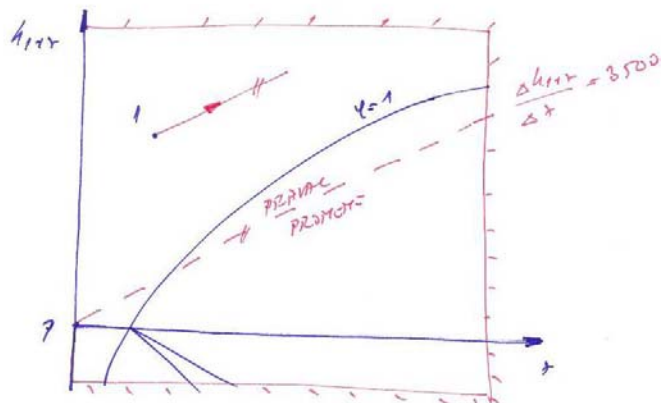
$$\text{iz (2)} \Rightarrow h_{1+x,2} - h_{1+x,1} = \frac{q_{m,vl}}{q_{m,sv}} \cdot h_{vl} \quad (2')$$

$$\frac{(1')}{(2')} \Rightarrow h_{vl} = \frac{h_{1+x,2} - h_{1+x,1}}{x_2 - x_1} = \frac{\Delta h_{1+x}}{\Delta x} = \frac{d h_{1+x}}{d x}$$

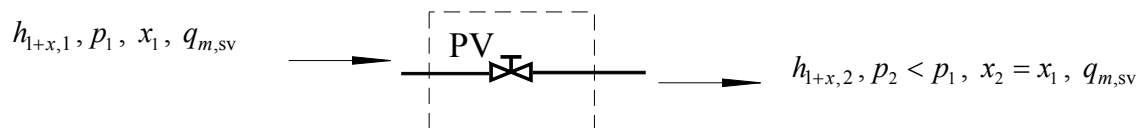
- $d h_{1+x} / d x$ – koeficijent pravca promene koja opisuje proces vlaženja u $h_{1+x} - x$ koordinatnom sistemu



- npr. $h_{vl} = 3500 \text{ kJ/kg}$
 $h_{vl} = f(p_{vl}, v_{vl})$



7.3.3.5 Proces adijatermnog prigušivanja vlažnog vazduha ($p \neq \text{idem}$)



- Bilans mase za kontrolnu zapreminu (ustaljen proces)

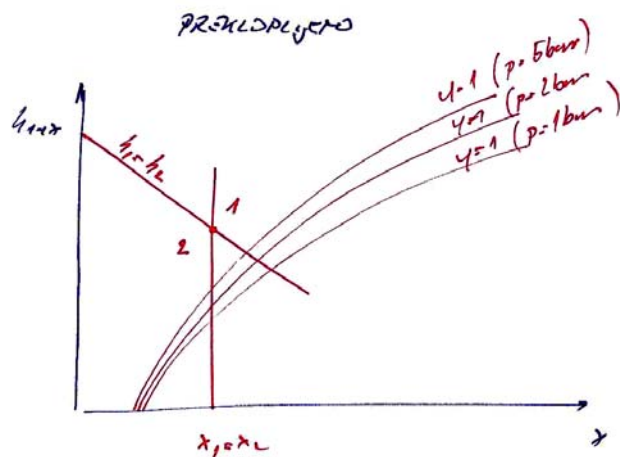
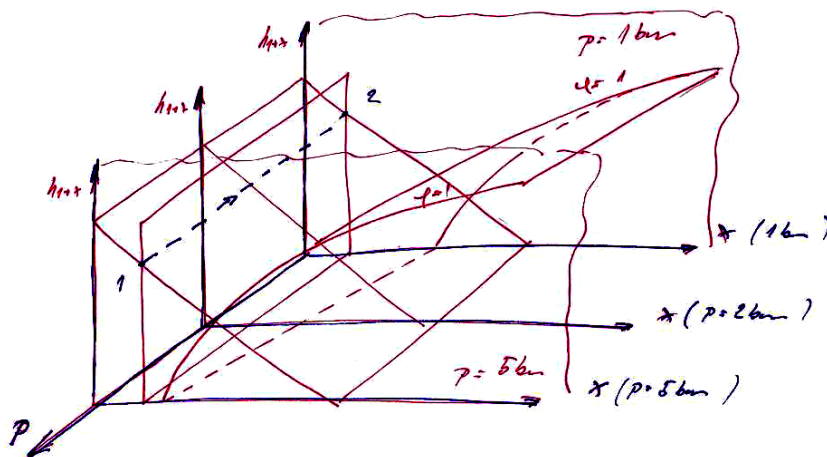
$$\underbrace{q_{m,sv} (1 + x_1)}_{\text{ulaz u CV}} = \underbrace{q_{m,sv} (1 + x_2)}_{\text{izlaz iz CV}}$$

$$\Rightarrow \boxed{x_2 = x_1}$$

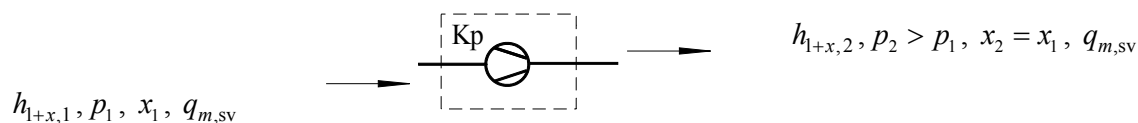
- Bilans energije za kontrolnu zapreminu – maglenu komoru (ustaljen proces)

$$\underbrace{q_{m,sv} h_{l+x,1} + \cancel{\Phi} + \cancel{P_{\text{teh}}}}_{\text{ulaz u CV}} = \underbrace{q_{m,sv} h_{l+x,2}}_{\text{izlaz iz CV}}$$

$$\boxed{h_{l+x,2} = h_{l+x,1}}$$



7.3.3.6 Adijatermno sabijanje vlažnog vazduha ($p \neq \text{idem}$)

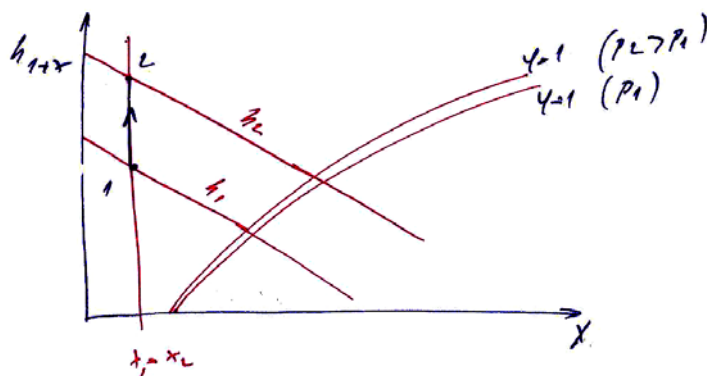
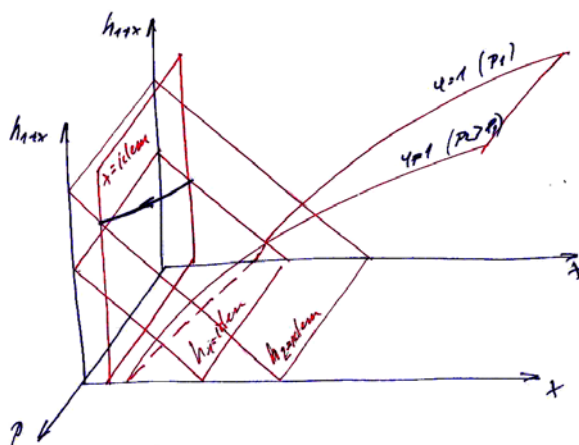


- Bilans mase za kontrolnu zapreminu (ustaljen proces)

$$\underbrace{q_{m,sv} (1 + x_1)}_{\text{ulaz u CV}} = \underbrace{q_{m,sv} (1 + x_2)}_{\text{izlaz iz CV}} \Rightarrow \boxed{x_2 = x_1}$$

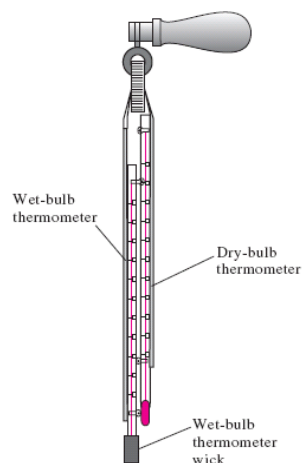
- Bilans energije za kontrolnu zapreminu – maglenu komoru (ustaljen proces)

$$\underbrace{q_{m,sv} h_{1+x,1} + \cancel{\Phi} + P_{\text{teh}}}_{\text{ulaz u CV}} = \underbrace{q_{m,sv} h_{1+x,2}}_{\text{izlaz iz CV}} \Rightarrow P_{\text{teh}} = q_{m,sv} (h_{1+x,2} - h_{1+x,1})$$

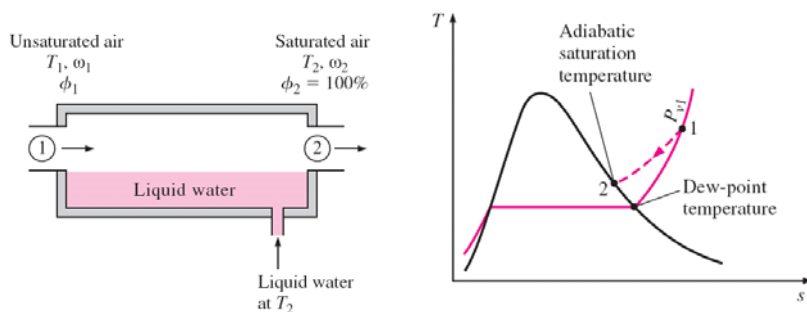


7.3.3.7 Određivanje stanja vlažnog vazduha Asmanovim (Assmann) psihometrom

- Psihrometar (grč. *psyhro*, hladan, *metron*, mera, merilo)
- Assmanov psihrometar – instrument koji se sastoji od dva termometra na istom postolju, od kojih jedan pokazuje temperaturu vazduha, a drugi navlažen vodom, usled isparavanja tečnosti, pokazuje nižu temperaturu i to u toliko nužu ukoliko je vazduh suvlji (jer tada je isparavanje intenzivnije).



- Energetska analiza (prevazilazi okvir ovog kursa termodinamike)



- Ako imamo Molijerov $h_{1+x,1} - x$ dijagram za vlažen vazduh pritiska p

