David Frisk

(VVX)5. 12 kg/s H_2O. $60°C \rightarrow 95°C$, $c_{p,v} = 4{,}18$ kJ/kg·K

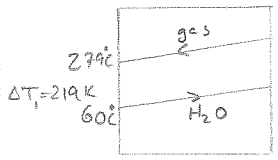
12 kg/s gaser, 425°C, $c_{p,g} = 1$ kJ/kg·K $U = 68$ W/m²·K

a) Bestäm rökgastemperaturen ut.

$$q_{upptaget} = \dot{m}_v \cdot c_{p,v} \cdot \Delta T_v = 12 \cdot 4{,}18 \cdot 10^3 \cdot (95-60) = 1{,}76 \cdot 10^6 \text{ J/s} = q_{upptaget}$$

$$\dot{m}_g \cdot c_{p,g} \cdot (T_{in,g} - T_{ut,g}) = q_{upptaget} \Rightarrow T_{ut,g} = T_{in,g} - \frac{q_{upptaget}}{\dot{m}_g \cdot c_{p,g}} = 279°C$$

b)



$$q_{överfört} = U A \cdot \Delta T_{lm}$$

$$A = \frac{q_{överfört}}{U \cdot \Delta T_{lm}} = \frac{1{,}76 \cdot 10^6}{68 \cdot \left(\frac{330-219}{\ln \frac{330}{219}}\right)} = 95{,}4 \text{ m}^2$$

(VVX)6 Luftförvärmare från VVX2, $U = 15$ W/m²·K

$\dot{V}_{luft} = 5000$ Nm³/h, $\dot{V}_{gas} = 6000$ Nm³/h. Motström

Luft: 50°C → ? Gas: 200°C → ?

$c_{p,luft} = 1{,}31 \cdot 10^3$ J/Nm³K

$c_{p,gas} = 1{,}36 \cdot 10^3$ J/Nm³·K

$A_{motström} = 267$ m²

$C_{min} = \dot{V}_l \cdot c_{p,l} = 1819$ J/s·K $C_{max} = \dot{V}_g \cdot c_{p,g} = 2267$ J/s·K

$$NTU = \frac{UA}{C_{min}} = \frac{267 \cdot 15}{1819} = 2{,}20 \quad \left[\frac{\text{W}}{\text{K}} \cdot \frac{\text{s} \cdot \text{K}}{\text{J}}\right]$$

$$\frac{C_{min}}{C_{max}} = 0{,}80 \Rightarrow \varepsilon = 0{,}73$$

$$q = \varepsilon \cdot C_{min} (T_{g,in} - T_{l,in}) = 0{,}73 \cdot 1819 \, (200-50) = 199{,}2 \cdot 10^3 \text{ J/s}$$

Luft $q = \dot{V}_l \cdot c_{p,l} \cdot (T_{l,ut} - T_{l,in}) \Rightarrow T_{l,ut} = T_{l,in} + \frac{q}{\dot{V}_l \cdot c_{p,l}} = 159{,}5°C$

Gas $q = \dot{V}_g \cdot c_{p,g} \cdot (T_{g,in} - T_{g,ut}) \Rightarrow T_{g,ut} = T_{g,in} - \frac{q}{\dot{V}_g \cdot c_{p,g}} = 112{,}1°C$

Svar: Luft: $T_{ut} = 159{,}5°C$

Gas: $T_{ut} = 112{,}1°C$

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(VVX) 8 Oljeflödet 0,2 kg/s kyls från $T_{o,in} = 70°C$ till $T_{o,ut} = 40°C$ av vattenflödet $\dot{m}_v$ som värms från $T_{v,in} = 15°C$ till $T_{v,ut} = 35°C$.

Bestäm totalt värmeutbyte, och hur stor del av värmeutbytet som sker i första halvan av medströms värmeväxlaren. $c_{p,o} = 2,2\ kJ/kg \cdot K$, $c_{p,v} = 4,18\ kJ/kg \cdot K$.

Totalt värmeutbyte: $q = \dot{m}_o \cdot c_{p,o} \cdot (T_{o,in} - T_{o,ut}) = \underline{13,2\ kW}$

Bestäm vattenflöde: $q = \dot{m}_v \cdot c_{p,v} \cdot (T_{v,ut} - T_{v,in}) \Rightarrow \dot{m}_v = 0,16\ kg/s$

$$\Delta T_{lm} = \frac{(70-15) - (40-35)}{\ln \frac{(70-15)}{(40-35)}} = 20,85\ K$$

$q = UA\Delta T_{lm} \Rightarrow U \cdot A = \frac{q}{\Delta T_{lm}} = 633\ W/K$. Bestäm ε.

$C_o = \dot{m}_o \cdot c_{p,o} = 0,2 \cdot 2,2 \cdot 10^3 = 440\ J/s \cdot K = C_{min}$

$C_v = \dot{m}_v \cdot c_{p,v} = 0,16 \cdot 4,18 \cdot 10^3 = 660\ J/s \cdot K = C_{max}$

$$q = \varepsilon \cdot C_{min}(T_{o,in} - T_{v,in}) \Rightarrow \varepsilon = \frac{q}{C_{min}(T_{o,in} - T_{v,in})} = 0,55$$

För medström gäller: $\varepsilon = \frac{1 - \exp\left(-NTU\left(1 + \frac{C_{min}}{C_{max}}\right)\right)}{1 + \frac{C_{min}}{C_{max}}} \Rightarrow NTU = 1,439$

$$NTU = \frac{UA}{C_{min}} \Rightarrow A = \frac{NTU \cdot C_{min}}{U}$$

Halvera Arean $\Rightarrow$ Halvera NTU. $NTU_{1/2} = 0,72$.

$$\Rightarrow \varepsilon_{1/2} = \frac{1 - \exp\left(-NTU_{1/2}\left(1 + \frac{C_{min}}{C_{max}}\right)\right)}{1 + \frac{C_{min}}{C_{max}}} = 0,419$$

$q_{Hel} = \varepsilon \cdot C_{min}(T_{o,in} - T_{v,in})$

$q_{Halv} = \varepsilon_{1/2} \cdot C_{min}(T_{o,in} - T_{v,in})$

$\Rightarrow$ Andel i 1:a halvan $= \frac{q_{Halv}}{q_{Hel}} = \frac{\varepsilon_{1/2}}{\varepsilon} = 0,768.$

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(VVX)9 Luft: $T_{in,luft} = 95°C$, $T_{ut,luft} = 50°C$ H_2O: $T_{in,v} = 30°C$, $T_{ut,v} = 50°C$

$q = 27{,}8\,kW = q_{avgivet} = q_{upptaget} = \dot{m}_v \cdot c_{p,v} \cdot (T_{v,ut} - T_{v,in})$

a) Motström, $U = 170\,W/m^2 \cdot K$

$C_v = \dot{m}_v \cdot c_{p,v} = \frac{q}{T_{v,ut} - T_{v,in}} = \frac{27800}{20} = 1390\ J/s \cdot K = C_{max}$

$C_l = \dot{m}_l \cdot c_{p,l} = \frac{q}{T_{l,in} - T_{l,ut}} = \frac{27800}{45} = 618\ J/s \cdot K = C_{min}$

$q = \varepsilon \cdot C_{min} (T_{l,in} - T_{v,in}) \Rightarrow \varepsilon = \frac{q}{C_{min}(T_{l,in} - T_{v,in})} = 0{,}69.$

Diagram, motström $\Rightarrow NTU = 1{,}45$

$NTU = \frac{UA}{C_{min}} \Rightarrow A = \frac{NTU \cdot C_{min}}{U} = \frac{1{,}45 \cdot 618}{170} = \boxed{5{,}27\,m^2}$

b) Korsström, vattnet blandes, $U = 230\,W/m^2 \cdot K$

22.13(b) $\frac{C_{mixed}}{C_{unmixed}} = \frac{1390}{618} = 2{,}25$, $\varepsilon = 0{,}69 \Rightarrow NTU = 1{,}75$

$A = \frac{NTU \cdot C_{min}}{U} = \frac{1{,}75 \cdot 618}{230} = \boxed{4{,}7\,m^2}$

c) Korsström, båda oblandade. $U = 285\,W/m^2 K$

22.13(a), $\frac{C_{min}}{C_{max}} = 0{,}44$, $\varepsilon = 0{,}67 \Rightarrow NTU = 1{,}55$

$A = \frac{NTU \cdot C_{min}}{U} = \frac{1{,}55 \cdot 618}{285} = \boxed{3{,}4\,m^2}$ – Minst

(VVX)10 Vatten, $\dot{m}_t = 3{,}8\,kg/s$ värms från $T_{t,in} = 38°C$ till $T_{t,ut} = 55°C$.

Vatten, $\dot{m}_s = 1{,}9\,kg/s$, $T_{s,in} = 94°C$. $U = 1420\,W/m^2 \cdot K$.

Tuberna har $d_i = 1{,}905\,cm$, $\bar{v} = 0{,}366\,m/s$.

$q = \dot{m}_t \cdot c_{p,t} \cdot (T_{t,ut} - T_{t,in}) = 3{,}8 \cdot 4{,}18 \cdot 10^3 \cdot (55 - 38) = 270\,028\ J/s$

$q = \dot{m}_s \cdot c_{p,s} \cdot (T_{s,in} - T_{s,ut}) \Rightarrow T_{s,ut} = T_{s,in} - \frac{q}{\dot{m}_s c_{p,s}} = 61°C$

$V_T = \frac{\dot{V}_T}{A_{TV}} \Rightarrow A_{TV} = \frac{\dot{V}_T}{V_T} = \frac{\dot{m}_T}{\rho_T \cdot V_T} = \frac{3{,}8}{989 \cdot 0{,}366} = 0{,}010492\,m^2$ – Total Tv-area.

$A_{tub} = \pi \cdot \frac{d_i^2}{4} = 2{,}85 \cdot 10^{-4}\,m^2$ Antal tuber $= \frac{A_{TV}}{A_{tub}} = 36{,}8 \approx \underline{37\,st}$

$\varepsilon = \frac{q}{C_{min}(T_{s,in} - T_{t,in})} = \frac{270028}{1{,}9 \cdot 4{,}19 \cdot 10^3 \cdot (94 - 38)} = 0{,}61$

$\frac{C_{min}}{C_{max}} = \frac{\dot{m}_s \cdot c_{p,s}}{\dot{m}_t \cdot c_{p,t}} = \frac{1{,}9 \cdot 4{,}19}{3{,}8 \cdot 4{,}18} = 0{,}50$

Shell-and-tube 22.12 c) $\Rightarrow NTU = 1{,}30$

$A = \frac{NTU \cdot C_{min}}{U} = \frac{1{,}30 \cdot \dot{m}_s c_{p,s}}{1420} = 7{,}27\,m^2$. Satt antal passager $= x = 2, 4, 6$

$A = n \cdot x \cdot \overbrace{d_i \cdot \pi \cdot L}^{A_{tub}}$. För $x = 2$: $L = \frac{A}{n x d_i \pi} = \frac{7{,}27}{37 \cdot 2 \cdot 0{,}01905 \cdot \pi} = 1{,}64\,m < L_{max} = 2{,}44\,m$

Svar: 37st tuber, 2 tubpasseger, Längd: 1,64 m

David Frisk

(VVX) 12. Lamellvärmeväxlare. - Tvärströmsapparat utan omblandning.

$U = 30 W/m^2K$. $(T_{H_2} - T_{C_1}) \cdot t_{drift} = 80\,000$, $\dot{V}_{luft} = 4500 m^3/h$

$$\frac{d\varepsilon}{d\left(\frac{UA}{C_{min}}\right)} = \frac{K_A}{U(T_{H_2}-T_{C_1}) \cdot t_{drift} \cdot \beta} = \left\{\begin{matrix} K_A = 30 SEK/m^2 \cdot år \\ \beta = 0{,}15 SEK/kWh \end{matrix}\right\} = \underline{0{,}0833}$$

Figur 11,13(a) Lutning 0,08 $\Rightarrow$ NTU = 2,4. $= \frac{UA}{C_{min}}$

$$A = \frac{NTU \cdot C_{min}}{U} = \frac{NTU \cdot C_p \cdot \dot{m}}{U} = \frac{NTU \cdot C_p \cdot \rho \cdot \dot{V}}{U} = \left\{\begin{matrix} \rho = 1{,}1769 kg/m^3 \\ C_p = 1{,}0063 kJ/kg \end{matrix}\right\} =$$

$$= \frac{2{,}4 \cdot 1{,}0063 \cdot 10^3 \cdot 1{,}1769 \cdot 4500}{30 \cdot 3600} = 118 m^2$$

(Pump) 3 Pumpa 600 l/min, $d = 0{,}08 m$, $h = 12 m$, $L = 200 m$

4 ventiler ($\zeta = 5$), 5 slussventiler ($\zeta = 0{,}2$), 1 backventil ($\zeta = 5$), 4 kröker ($\zeta = 0{,}3$)

Inlopp/Utlopp ($\zeta = 0{,}5$; $1{,}0$). $c = \frac{\dot{V}}{A_{tv}} = 1{,}99 m/s$

$$\Delta p = \cancel{p_2 - p_1} + (h_2 - h_1)\rho g + \cancel{\frac{c_2^2 - c_1^2}{2}\rho} + \Delta p_{fl,2} = (h_2 - h_1)\rho g + \left(\lambda \frac{L}{d} + \sum \zeta\right)\frac{c^2}{2}\rho$$

$$= 12 \cdot 1000 \cdot 9{,}82 + \left(0{,}025 \cdot \frac{200}{0{,}08} + (4 \cdot 5 + 5 \cdot 0{,}2 + 5 + 4 \cdot 0{,}3 + 0{,}5 + 1{,}0)\right) \cdot \frac{c^2}{2} \cdot 1000 =$$

$$= 298\,318 Pa$$

Uppfodringshöjd $H_{pump} = \frac{\Delta P_{pump}}{\rho g} = \frac{298318}{1000 \cdot 9{,}82} = 30{,}4 m$

$$P = \frac{\rho g \dot{V} H}{\eta} = \frac{\dot{V} \cdot \Delta p}{\eta} = \frac{0{,}01 \cdot 298318}{0{,}6} = 4972 W$$

(Pump) 5

$$\Delta p = \cancel{p_2 - p_1} + (h_2 - h_1)\rho g + \cancel{\frac{c_2^2 - c_1^2}{2}\rho} + \left(\lambda \cdot \frac{L}{d} + \sum \zeta\right)\frac{c^2}{2}\rho =$$

$$= (40)\rho g + \left(\lambda \cdot \frac{L}{d} + (8 \cdot 0{,}15 + 4 \cdot 2 + 1{,}5 + 1)\right) \cdot \frac{c^2}{2}\rho$$

▸ Rent: $\Delta p = 40\rho g + \left(0{,}025 \cdot \frac{4000}{0{,}5} + 11{,}7\right) \cdot \frac{1{,}0^2}{2} \cdot \rho = 498\,650 Pa$

$\dot{V} = c \cdot \pi d^2 \cdot 0{,}25 = 0{,}19 m^3/s$

$P_{nyttig} = \dot{V} \Delta p = 97{,}9 kW$

▸ Smutsigt: $\Delta p = 40\rho g + \left(0{,}035 \cdot \frac{4000}{0{,}5} + 11{,}7\right) \cdot \frac{1{,}25^2}{2} \cdot \rho = 620\,697 Pa$

$\dot{V} = 0{,}24 m^3/s$

$P_{nyttig} = \dot{V} \cdot \Delta p = 152{,}3 kW$

Effektbehovet ökar med $(152{,}3 - 97{,}9) = \underline{54{,}4 kW}$

(Pump)7 $\Delta p = p_2 - p_1 + \rho g(h_2 - h_1) + \frac{c_2^2 - c_1^2}{2}\rho + \Delta p_{f1,2}$

$\Delta p_{f1,2} = \left(\lambda \frac{l}{d} + \sum_i \zeta_i\right)\frac{c^2}{2}\rho$

$H = H_{stat} + \Delta h_f$, $H_{stat} = 9 + 10 = 19$ mvp, $\Delta h_f = \frac{\Delta p_f}{\rho g} = \frac{\left(0{,}02 \cdot \frac{300}{0{,}3} + 4\right) \cdot \frac{c^2}{2} \cdot 1000}{\rho g} =$

$= \frac{12000\, c^2}{\rho g} = \left\{ \dot{V} = c \cdot A = c \cdot \frac{\pi \cdot 0{,}3^2}{4} \Rightarrow c = \frac{4\dot{V}}{\pi \cdot 0{,}3^2} \right\} = \frac{2401687\, \dot{V}^2}{\rho g} =$

$= 244{,}6\, \dot{V}^2$

$\Rightarrow H = 19 + 244{,}6\, \dot{V}^2$. Skärning i $\eta = 0{,}85$, $\dot{V} = 0{,}2$

$P = \frac{\Delta p \cdot \dot{V}}{\eta} = \frac{\rho g H \cdot \dot{V}}{\eta} = \frac{1000 \cdot 9{,}82 \cdot 28 \cdot 0{,}2}{0{,}85} = 64{,}7$ kW