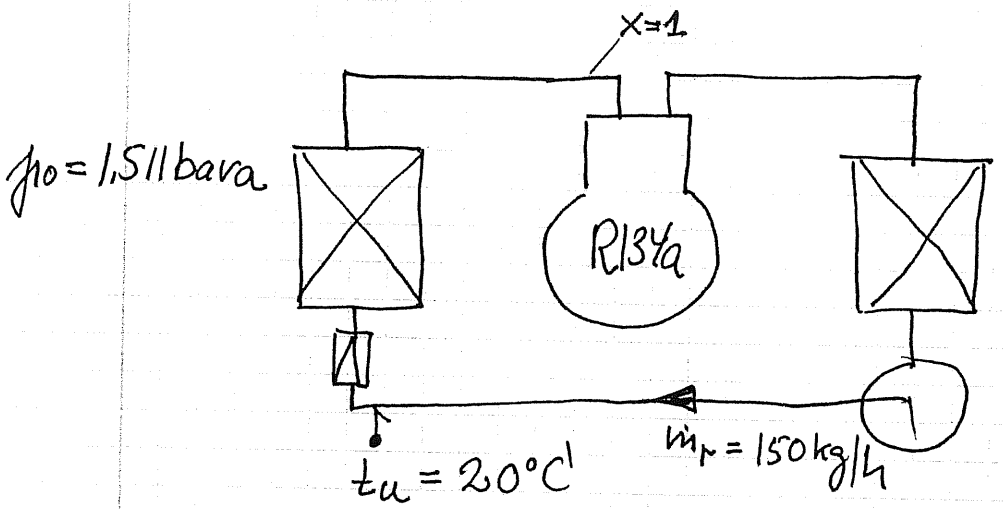
Øvelsesopgave nr. 1 (Køleteknik)



1.a. $\Delta h_{ford} = q_0 = h_{afg.} - h_u = 387,11 - 227,23 = \underline{\underline{159,9 \text{ kJ/kg}}}$

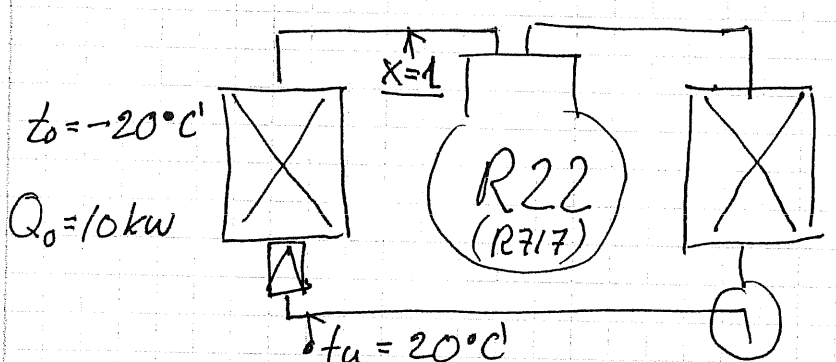
1.b $v_{ginds.} = \underline{\underline{0,1298}} \text{ m}^3/\text{kg}$

1.c. $\dot{Q}_0 = \dot{m}_r \cdot \Delta h_{ford.} = 150 \cdot 159,9 = \underline{\underline{23985}} \text{ kJ/h}$

$\text{ell. } \dot{Q}_0 = \frac{23985}{3600} = \underline{\underline{6,67 \text{ kW}}}$

1.d. $\dot{V}_{inds} = \dot{m}_r \cdot v_{ginds} = 150 \cdot 0,1298 = \underline{\underline{19,5 \text{ m}^3/\text{h}}}$

Opg 2



2a. $p_0 = \underline{\underline{2,448 \text{ bara}}}$

2b. $p_{eff.} \underline{\underline{\simeq 1,5 \text{ bar}}}$

2c. $\Delta h_{ford} = q_0 = h_{afg} - h_u = 397,48 - 224,07 = \underline{\underline{173,41 \text{ kJ/kg}}}$

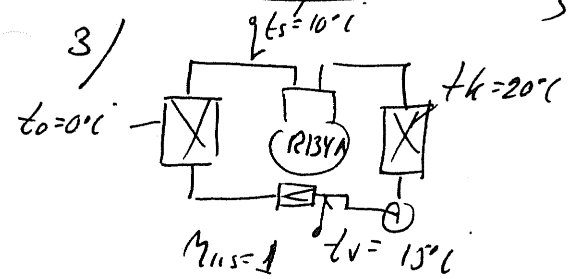
2d. $\dot{m}_r = \frac{Q_0 \times 3600}{\Delta h_{ford}} = \underline{\underline{207,6 \text{ kg/h}}}$

2e. $(v_{ginds} = 0,09286 \text{ m}^3/\text{kg}) \Rightarrow \dot{V}_{inds_{R22}} = \dot{m}_r \cdot v_{ginds} = 207,6 \cdot 0,09286 = \underline{\underline{19,3 \text{ m}^3/\text{h}}}$

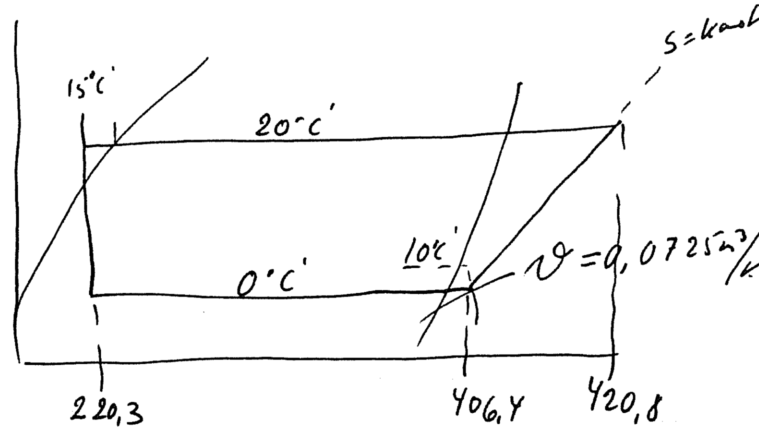
2f. $\dot{V}_{inds_{R717}} = \frac{Q_0 \cdot 3600 \cdot v_{ginds}}{(h_{afg} - h_u)} = \frac{10 \cdot 3600 \cdot 0,62274}{(1436,51 - 292,19)} = \underline{\underline{19,6 \text{ m}^3/\text{h}}}$

Køleteknik opgaver:

3/



3 a/



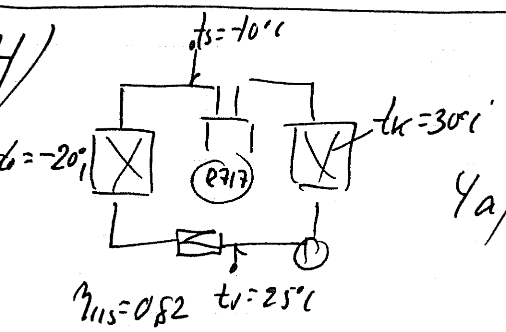
3b: p_o = 2,93 bar$_a$ $\quad t_{afg}$ = 32,3 °C

p_k = 5,72 bar$_a$ $\quad v$ = 0,0725 m³/kg

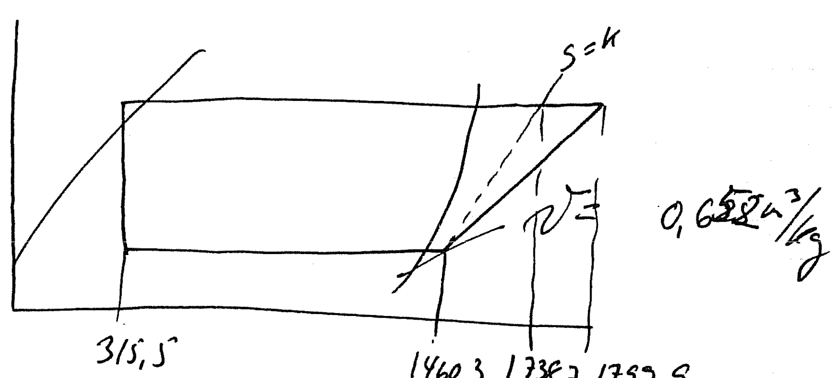
3c) $q_o = \Delta h_{ford} = 406,4 - 220,3 = 186,1$ kJ/kg

3d) $q_{ov} = \frac{q_o}{v} = \frac{186,1}{0,0725} = 2566,6$ kJ/m³

4/



4a/



4b/ p_o = 1,9 bar$_a$ $\quad t_{kompr.af}$ = 148,6 °C

p_k = 11,7 bar$_a$

4c) $\Delta h_{ford} = 1460,3 - 315,5 \approx 1145$ kJ/kg

4d/ $v = 0,652$ m³/kg $\Rightarrow q_{ov} = \frac{1145}{0,652} = 1756$ kJ/m³

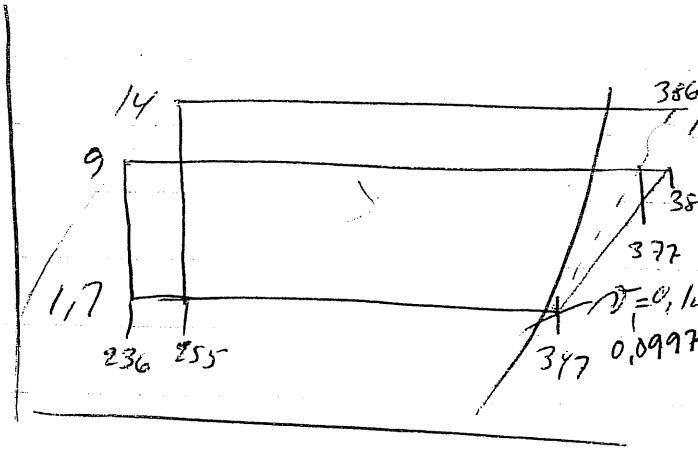
4e/ $w_i = \Delta h_{is\,kompr} = 1738,7 - 1460,3 = 278,4$ kJ/kg

4f $= \Delta h_{kompr} = \frac{\Delta h_{is}}{\eta_{is}} = \frac{278,4}{0,82} = 339,5$ kJ/kg

$\Rightarrow t_{afg}$ = 148,6

$\Rightarrow h_{afg} = 1460,3 + 339,5 \approx 1800$ kJ

Opgave nr. 5



$$V_{teo} = 6 \cdot \frac{\pi}{4} \cdot 0,1^2 \cdot 0,075 \cdot \frac{1450}{60} = 0,0854 \, m^3/sec$$

$$\dot{m}_r = \frac{0,0854 \cdot 0,7}{0,1} = \underline{0,598 \, kg/sec}$$

$$Q_e = 0,598 \cdot (347 - 236) = \underline{66,4 \, kw}$$

$$h_{a/g,1} = 347 + \frac{377 - 347}{0,85} \cong \underline{383 \, kJ/kg}$$

$$P_{e_1} = 0,598 (383 - 347) \cdot \frac{1}{0,95 \cdot 0,92} = \underline{24,2 \, kw}$$

$$\dot{m}_{r_2} = \frac{66,4}{(347 - 255)} = \underline{0,72 \, kg/sec}$$

$$V_{teo_2} = \frac{\dot{m}_m \cdot v}{0,59 (\eta_{v_2})} = \frac{0,72 \cdot 0,1}{0,59} = 0,122 \, m^3/sec$$

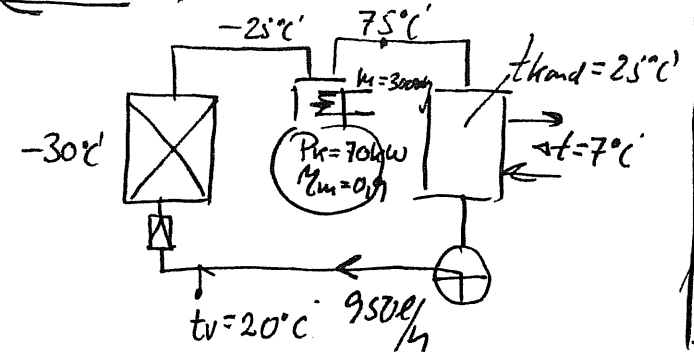
$$C_2 = \frac{0,122 \cdot 60}{\pi \cdot 0,1^2 \cdot 0,075 \cdot 1450} \cong 8,6 \, cyl = \underline{9 \, cyl}$$

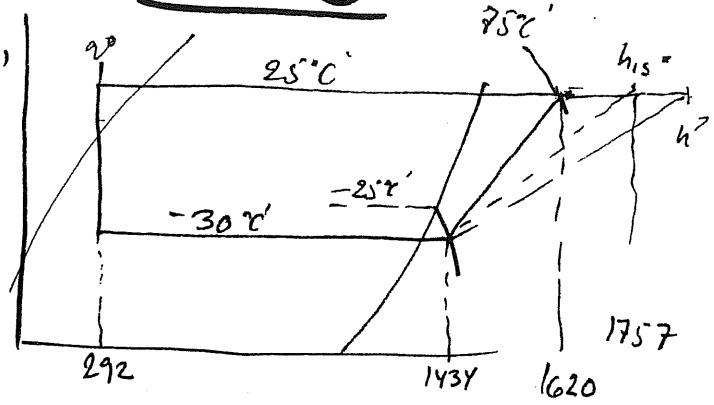
$$h_{a/g,2} = 347 + \frac{386 - 347}{0,85} = \underline{393 \, kJ/kg}$$

$$P_{e_2} = \frac{0,72 \cdot (393 - 347)}{0,95 \cdot 0,92} = \underline{37,9 \, kw}$$

(50 KFL)

Nr. 6





Væske ved 20°C' ⇒ spec. vol. = 1,638 l/kg ⇒ $\dot{m}_r = \frac{950}{1,638} = 580 kg/h = 0,161 kg/s$

1) $Q_{ford} = \dot{m}_r \cdot \Delta h_{ford} = 0,161 (1434 - 292) = 184 kW$

2) $Q_{kond} = \dot{m}_r \cdot \Delta h_{kond} = 0,161 (1620 - 292) = 214 kW$

$\dot{m}_{v\,kond} = \frac{Q_{kond} \cdot 3600}{7 \cdot 4,19} = \frac{214 \cdot 3600}{7 \cdot 4,19} = 26266 kg/h \sim 7,3 kg/s$

3) $Q_{ford} + P_k = Q_{kond.} + Q_{køle\,vand} \Rightarrow Q_{køle.} = Q_{ford} + P_k - Q_{kond.}$

$\Rightarrow Q_{køle} = 184 + 70 - 214 = 40 kW$ Þ)

$\Delta t_{køle.} = \frac{Q_{køle.} \cdot 3600}{\dot{m}_{k.v} \cdot 4,19} = \frac{40 \cdot 3600}{3000 \cdot 4,19} = 11,5°C'$

4) $P_{i\,kompr.} = P_k \cdot \eta_m = 70 \cdot 0,9 = 63 kW$

$\Delta h_{kompr.} = \frac{P_i}{\dot{m}_r} = \frac{63}{0,161} = 391 kJ/kg$

(endalpi efter kompr. uden køling = 1434 + 391 = 1825 kJ/kg)

$\Delta h_{is\,kompr.}$ iflg. diagram = 1757 - 1434 = 323 kJ/kg

$\eta_i = \frac{\Delta h_{is\,kompr}}{\Delta h_{kompr}} = \frac{323}{391} = 0,82$

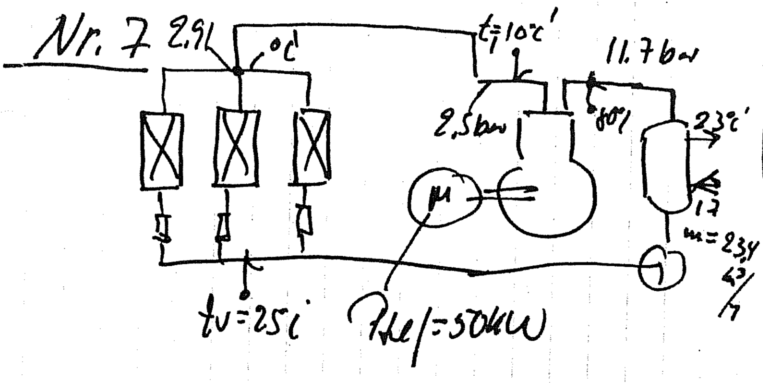
Þ) $Q_{køle\,vand}$ kan også beregnes således: $Q_{Mekanisk\,tab}$: 70 · (1-0,9) = 7 kW

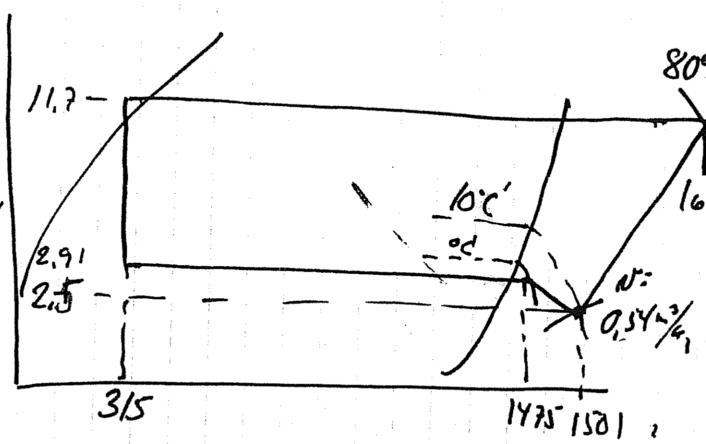
Q_{proces}: 0,161 (1825 - 1620) = 33 kW

Q_{vand} = 40 kW

Eller: 70 - 0,161 (1620 - 1434) = 70 ÷ 29,946 = 40,054 kW

Nr. 7





$$Q_{kond} = \dot m \cdot c \cdot \Delta t = \frac{23400}{3600} \cdot 4{,}19 \cdot (23-17) = 163{,}4\ kW$$

$$\Delta h_{kond} = 1630 - 315 = 1315\ kJ/kg \Rightarrow \dot m_r = \frac{163{,}4}{1315} = 0{,}124\ kg/s\ (\approx 447\ kg/h)$$

a) $\Delta h_{ford.} = 1475 - 315 = 1160\ kJ/kg \Rightarrow Q_0 = 0{,}124 \cdot 1160 = \underline{\underline{143{,}8\ kW}}$

$V_{teo} = 8 \cdot \frac{\pi}{4} \cdot 0{,}1^2 \cdot 0{,}1 \cdot \frac{970}{60} = \underline{0{,}1016\ m^3/sec}$ ell: $\frac{970}{1500} \cdot \frac{565}{3600} = \underline{0{,}1015\ m^3/s}$

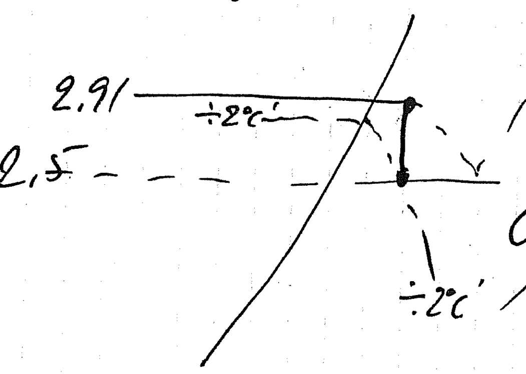
$V_{inds} = \dot m_r \cdot v = 0{,}124 \cdot 0{,}54 \approx \underline{0{,}067\ m^3/sec}$

b) $\eta_v = \frac{V_{inds}}{V_{teo}} = \frac{0{,}067}{0{,}1016} \cong \underline{\underline{0{,}66}}$

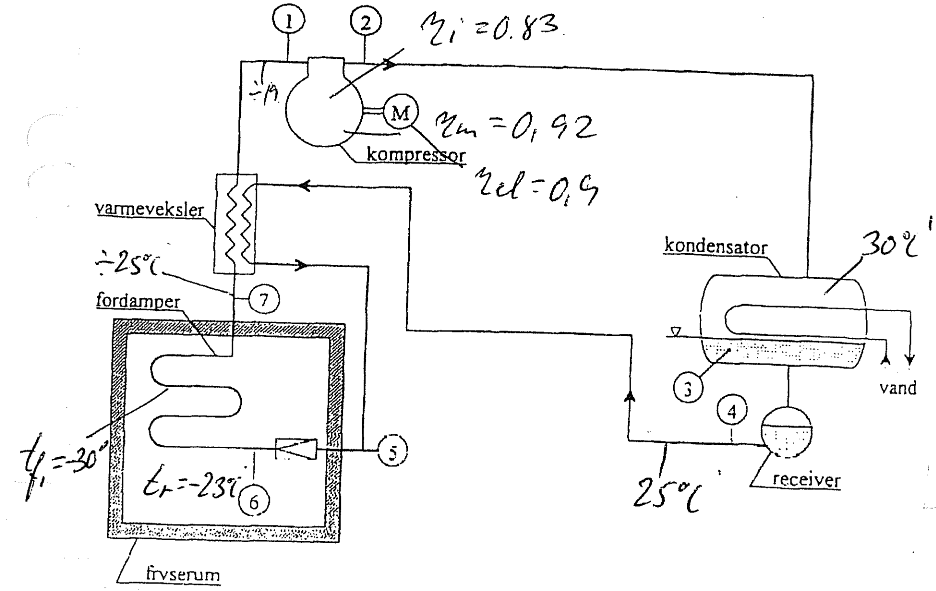
c) Varmetab i sugeledningen:

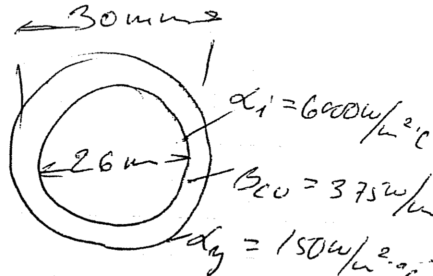
$$Q_{sugeledning} = \dot m_r \cdot \Delta h_{sug} = 0{,}124\,(1501-1475) = \underline{\underline{3{,}2\ kW}}$$

Isolering ⇒ ingen tilført effekt – kun trykfald.

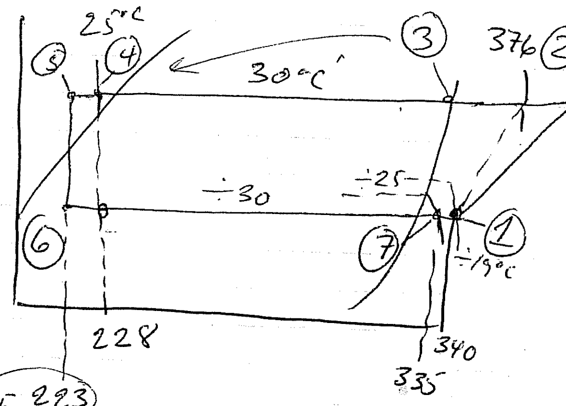


dt aflæses til ca. ÷2°C





$l = 1390$ meter



$$k_{rør,1} = \frac{\pi}{\frac{1}{6000 \cdot 0{,}026} + \frac{\ln\frac{30}{26}}{2 \cdot 375} + \frac{1}{150 \cdot 0{,}03}} = 13{,}73\ W/m°C$$

$$Q_0 = l \cdot k \cdot \Delta t_m = 1390 \cdot 13{,}73 \cdot (-23-(-30)) = \underline{133{,}6\ kW}$$

$$\dot m_{r,1} = \frac{Q_0}{\Delta h_{fd}} = \frac{133{,}6}{335-223} = \underline{1{,}185\ kg/s}$$

h_5 223

$$h_5 = h_4 - (h_1 - h_7) = 228 - (340 - 335) = \underline{223\ kJ/kg}$$

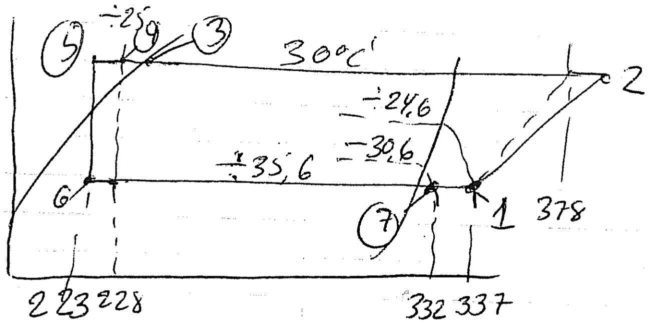
$$h_{2,1} = 340 + \frac{(376-340)}{0{,}83} = \underline{383\ kJ/kg}\ (\Delta h_k = 43\ kJ/kg)$$

b) $$P_{til/el,1} = \frac{\dot m_r \cdot \Delta h_{kompr}}{\eta_m \cdot \eta_{el}} = \frac{1{,}185 \cdot 43}{0{,}92 \cdot 0{,}9} = \underline{\underline{61{,}5\ kW}}$$

— — — — — med isbelægning ————————

$$k_{rør,2} = \frac{\pi}{\frac{1}{6000 \cdot 0{,}026} + \frac{\ln\frac{30}{26}}{2 \cdot 375} + \frac{\ln\frac{0{,}040}{0{,}03}}{2 \cdot 0{,}6} + \frac{1}{150 \cdot 0{,}04}} = \underline{7{,}61\ W/m°C}$$

$$Q_{0,2} = Q_{0,1} = 133{,}6 = L \cdot k_{rør,2} \cdot \Delta t_2 = 1390 \cdot 7{,}61 \cdot \Delta t_2 \Rightarrow \Delta t_2 = \underline{12{,}6°C} \Rightarrow t_{0,2} = -23 - 12{,}6 = \underline{-35{,}6\ °C}$$



$$\dot m_{r2} = \frac{Q_0}{\Delta h_2} = \frac{133{,}6}{332-223} = \underline{1{,}217\ kg/s}$$

$$h_{2,2} = 337 + \frac{378-337}{0{,}83} = \underline{386\ kJ/kg}$$

$$P_{til/2} = \frac{\dot m_{r2} \cdot \Delta h_{k2}}{\eta_m \cdot \eta_{el}} = \frac{1{,}217 \cdot (386-337)}{0{,}9 \cdot 0{,}92} = \underline{72\ kW}\ (P_i \approx 59{,}6\ kW)$$

COP = 133,6 ...