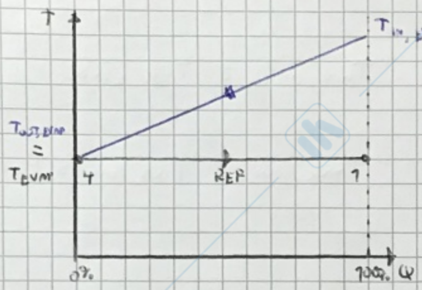
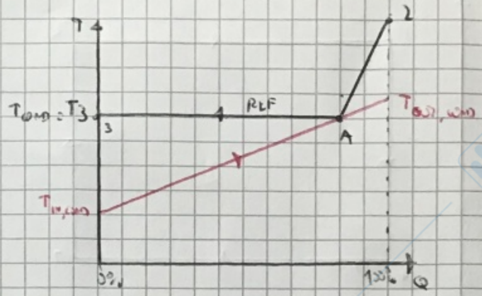
CICLO SEMPLICE IDEALE





$T_4 = T_1 = T_{EVAP} = T_{OUT,EVAP}$

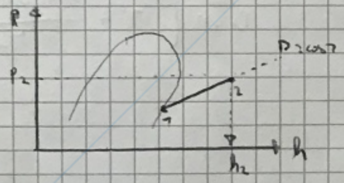
T_{COND} NON DA CALCOLO FINALE

PUNTI DEL CICLO:

① $$\left.\begin{array}{l} T_1 = T_{OUT,EVAP} \\ P_1 = P_{SAT}(T_1) \end{array}\right| \rightarrow h_1$$

③ $$\left.\begin{array}{l} T_3 = T_{COND} \\ P_3 = P_{SAT}(T_3) \end{array}\right| \rightarrow h_3$$

② $P_2 = P_3$



LEGGO h_2 , LEGGO T_2

④ $P_4 = P_1$

$h_4 = h_3$

$T_4 = T_1$

LEGGO x_4

CALCOLO LE POTENZE:

$$\dot{Q}_{EVAP} = \dot{m}\, c_P\, (T_{IN,EVAP} - T_{OUT,EVAP}) = \dot{m}_{REF}\, (h_1 - h_4) \rightarrow \dot{m}_{REF}$$

$$\dot{Q}_{COND} = \dot{m}_{REF}\, (h_2 - h_3)$$

$$\dot{W}_{COMPR} = \dot{m}_{REF}\, (h_2 - h_1)$$

VERIFICO: $\dot{Q}_{EVAP} + \dot{W}_{COMPR} = \dot{Q}_{COND}$

INFINE RICERCO SULLA TABELLA C e n CHE MEGLIO APPROSSIMA:

$$M_E = \sum M_{E,i} \leq C \left(\frac{\dot{m}_w}{\dot{m}_a} \right)^n$$

DALLA TABELLA OTTENGO:

$$h_{MAT} \quad e \quad V_{ARIA}$$

PER TROVARE IL VOLUME:

$$V = h_{MAT} \cdot \underbrace{A}_{} \; [m^3]$$

$$\hookrightarrow A = \frac{\dot{m}_a \cdot \overline{v}}{V_{ARIA}} \; [m^2]$$

VOL. SPECIFICO MEDIO

$$\overline{v} = \left(\frac{1}{\underbrace{MM_{as}}_{28{,}96 \, g/mol \cdot 10^{-3}}} + \frac{\overline{x}_a}{\underbrace{MM_w}_{18 \, g/mol}} \right) \cdot \frac{R \cdot \overline{T}_{a,BS}}{\underbrace{P_{AMB}}_{101\,325 \, Pa}} \; \left[\frac{m^3}{kg_{as}}\right] \quad R = 8{,}314$$

[K]

DOVE:

- $$\overline{T}_{a,BS} = \frac{T_{a,BS,in} + T_{a,BS,out}}{2}$$

ESSENDO $\phi_{out} = 100\%$ → $T_{a,BS,out} = T_{a,BU,out}$

TROVO $T_{a,BU,out}$ DA DIAGRAMMA o DA: $h_{a,out} = 21{,}58 \cdot 10^{-3} \, T_{a,BU,out}^{2{,}366} + 32{,}77$

↳ USANDO $\phi_a = 100\%$ e $h_{a,out}$ DA $\dot{Q} = \dot{m}_a (h_{a,out} - h_{a,in})$

- $$\overline{x}_a = \frac{x_{a,in} + x_{a,out}}{2} \; \left[\frac{g}{kg_{as}}\right]$$

PORTATA DI ACQUA EVAPORATA: $\dot{m}_{evap} = \dot{m}_a (x_{a,out} - x_{a,in})$

$$\dot{Q} = U \cdot A \cdot \Delta T_{ML}$$

DOVE:

$$\dot{Q} = \dot{m}_C \cdot cp_C \left(T_{C,IN} - T_{C,OUT}\right) = \dot{m}_F \cdot cp_F \left(T_{F,OUT} - T_{F,IN}\right)$$

$$\frac{1}{U \cdot A} = \frac{1}{L} \cdot \underbrace{\left[\frac{1}{h_C \cdot D_{IN,INT}\pi} + \frac{\ln\left(\frac{D_{EST,INT}}{D_{INT,INT}}\right)}{2\pi k_P} + \frac{1}{h_{EST} \cdot D_{EST,INT}\pi} \right]}_{E} = \frac{E}{L}$$

$$\downarrow$$

$$U \cdot A \left[\frac{W}{K}\right]$$

$$\Delta T_{ML,CC} = \frac{\left(T_{C,OUT} - T_{F,IN}\right) - \left(T_{C,IN} - T_{F,OUT}\right)}{\ln\left(\frac{\left(T_{C,OUT} - T_{F,IN}\right)}{\left(T_{C,IN} - T_{F,OUT}\right)}\right)}$$

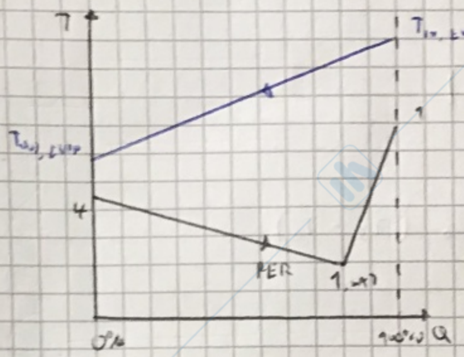
$$\Delta T_{ML,EC} = \frac{\left(T_{C,IN} - T_{F,IN}\right) - \left(T_{C,OUT} - T_{F,OUT}\right)}{\ln\left(\frac{\left(T_{C,IN} - T_{F,IN}\right)}{\left(T_{C,OUT} - T_{F,OUT}\right)}\right)}$$

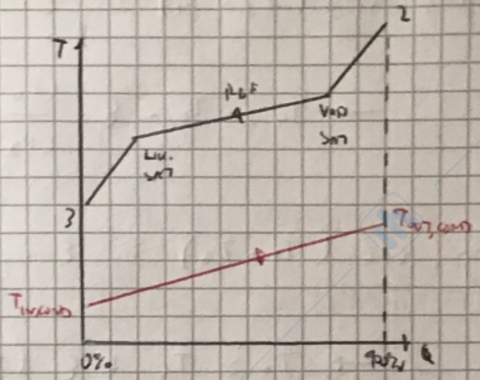
SE LUNGHEZZA DEI TUBI → ∞ ALLORA $A \to \infty$ e NTU → ∞

$$\varepsilon_{CC} = 1$$

$$\varepsilon_{EC} = \frac{1}{1 + R^*}$$

CICLO SEMPLICE REALE (POMPA DI CALORE)





$\Delta T_{st,evap} = T_{in,evap} - T_{1,sat}$ 10°C

$\Delta T_{surr} = T_1 - T_{1,sat}$

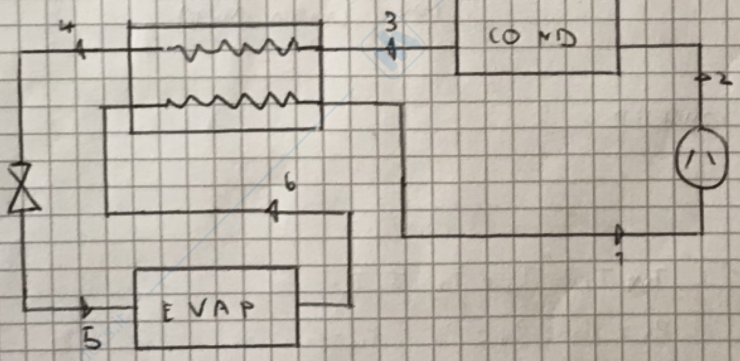
$\Delta T_{sat,evap} = T_4 - T_{1,sat}$

$\Delta T_{st,cond} = T_{sat}(P_3) - T_{out,cond}$ ≈ 2°C

$\Delta T_{sott} = T_{sat}(P_3) - T_3$

$\Delta T_{sat,cond} = T_{sat}(P_2) - T_{sat}(P_3)$

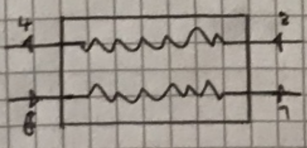
CICLO LL-SL HX



LATO CONDENSATORE (2-3) E LATO EVAPORATORE (5-6) NON CAMBIA NULLA

SI TRASCURANO LE PERDITE DI CARICO NELL LL-SL HX :

$$P_3 - P_4 = P_6 - P_7 = 0$$



$$\dot{Q} = \dot{m}_3 (h_3 - h_4) = \dot{m}_3 \cdot cp_3 (T_3 - T_4)$$

$$\dot{Q} = \dot{m}_6 (h_7 - h_6) = \dot{m}_6 \cdot cp_6 (T_7 - T_6)$$

$$\varepsilon_{LL\,SL\,HX} = \frac{\dot{Q}}{\dot{Q}_{max}}$$

DOVE $\dot{Q}_{max} = \underbrace{MIN(\dot{m}_3 cp_3 ; \dot{m}_6 cp_6)}_{} \underbrace{(T_3 - T_6)}_{\Delta T_{max}}$

cp_3 è LIQ, cp_6 è VAP → $cp_3 > cp_6$

$\dot{m}_3 = \dot{m}_4 = \dot{m}_6 = \dot{m}_7 = \dot{m}_{REF}$

$$\downarrow$$

$$\dot{Q} = \varepsilon \cdot \dot{Q}_{max}$$

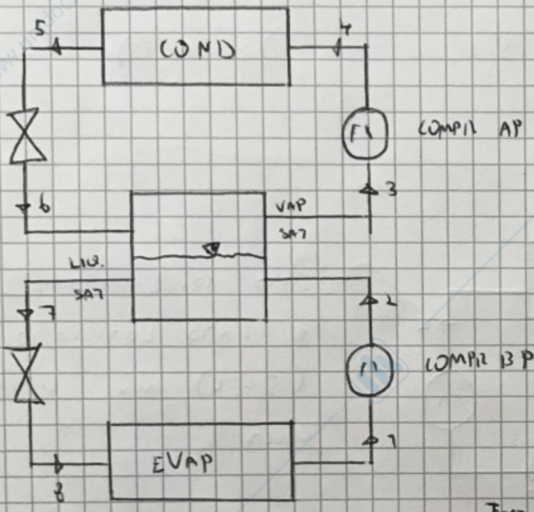
- $\cancel{\dot m_3} \cdot cp_3 \, (T_3 - T_4) = \varepsilon \cdot \cancel{\dot m_{REF}} \cdot cp_6 \cdot (T_3 - T_6)$

$$\rightarrow T_4 = T_3 - \varepsilon \cdot \frac{cp_6}{cp_3} (T_3 - T_6)$$

- $\cancel{\dot m_6} \, \cancel{cp_6} \, (T_7 - T_6) = \varepsilon \cdot \cancel{\dot m_{REF}} \cdot \cancel{cp_6} \, (T_3 - T_6)$

$$\rightarrow T_7 = T_6 + \varepsilon (T_3 - T_6)$$

CICLO A DOPPIO STADIO DI COMPRESSIONE



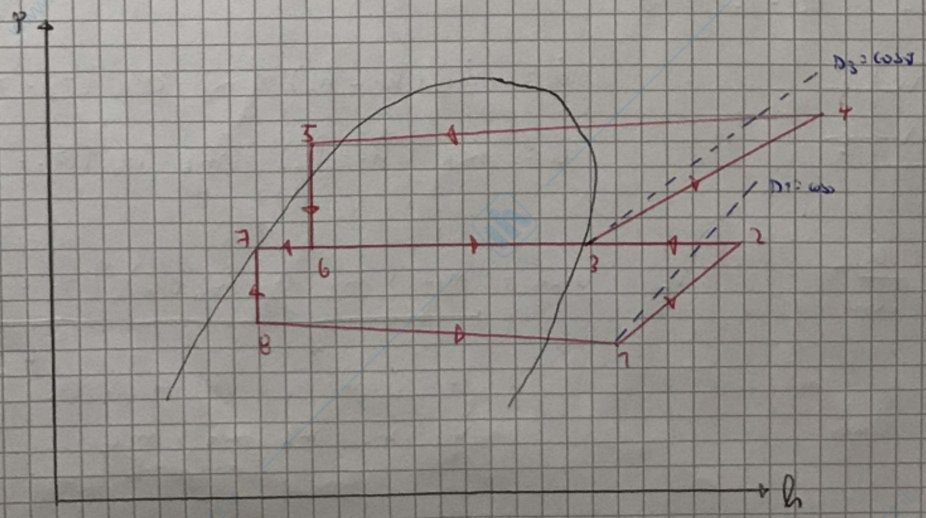
LATO CONDENSATORE (4 - 5) e
LATO EVAPORATORE (8 - 1)
NON CAMBIA NULLA

$T_3 = T_6 = T_7 \neq T_2$

$P_2 = P_3 = P_6 = P_7 = P_{INT}$

$P_{INT} = \sqrt{P_{EVAP} \cdot P_{COND}} = \sqrt{P_1 \cdot P_5}$

SEPARATORE DI FASE :



EVAP:

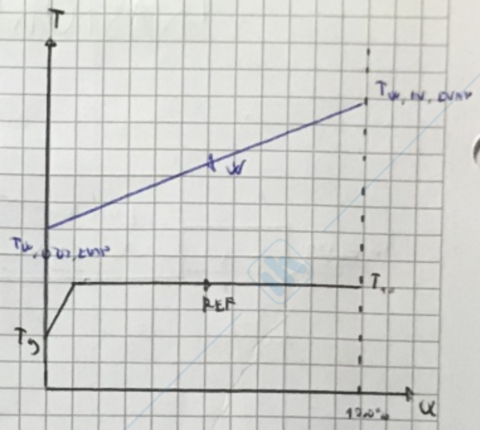
$\Delta T_{st,EVAP} = T_{w,IN,GEN} - T_{EVAP} \rightsquigarrow 15 \div 25\,°C$

$\Delta T_{SURR} = T_{10} - T_{EVAP} = 0\,°C$

$\Delta T_{SAT,EVAP} = T_{SAT}(P_{10}) - T_{SAT}(P_9) = 0\,°C$

$\longrightarrow T_{EVAP} = T_{w,IN,GEN} - \Delta T_{st,EVAP}$

$P_{EVAP} = P_{SAT}(T_{EVAP})$



COND:

$\Delta T_{st,COND} = T_{COND} - T_{w,IN,COND} \rightsquigarrow 7 \div 15\,°C$

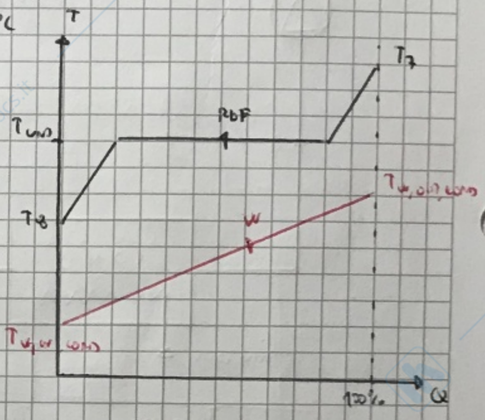
$\Delta T_{SUBC} = T_{COND} - T_8 \rightsquigarrow 3 \div 10\,°C$

$\Delta T_{SAT,COND} = T_{SAT}(P_7) - T_{SAT}(P_8) = 0\,°C$

$\longrightarrow T_{COND} = T_{w,IN,COND} + \Delta T_{st,COND}$

$P_{COND} = P_{SAT}(T_{COND})$

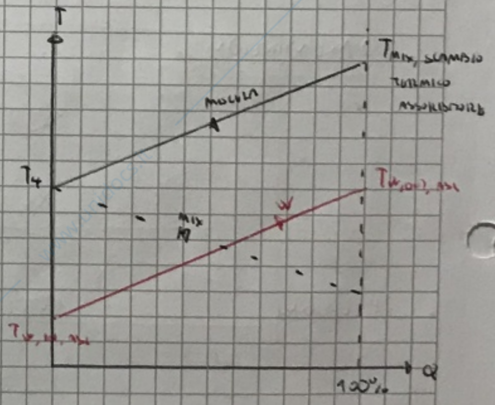
$\longrightarrow T_8 = T_{COND} - \Delta T_{SUBC}$



ASS:

$\Delta T_{st,ASS} = T_4 - T_{w,IN,ASS} \rightsquigarrow 5 \div 15\,°C$

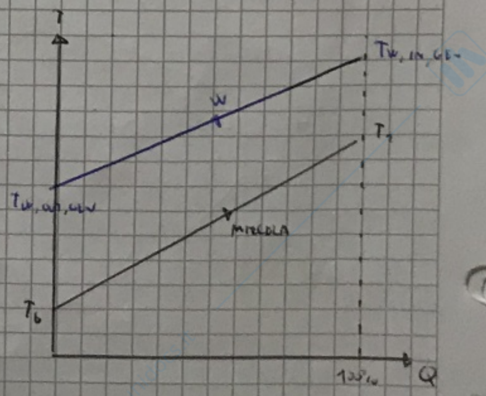
$\longrightarrow T_4 = T_{w,IN,ASS} + \Delta T_{st,ASS}$



GEN:

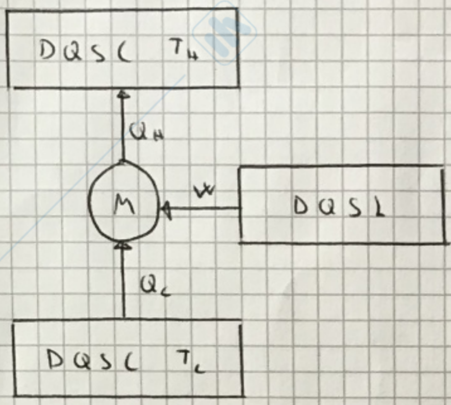
$\Delta T_{st,GEN} = T_{w,IN,GEN} - T_1 \rightsquigarrow 3 \div 10\,°C$

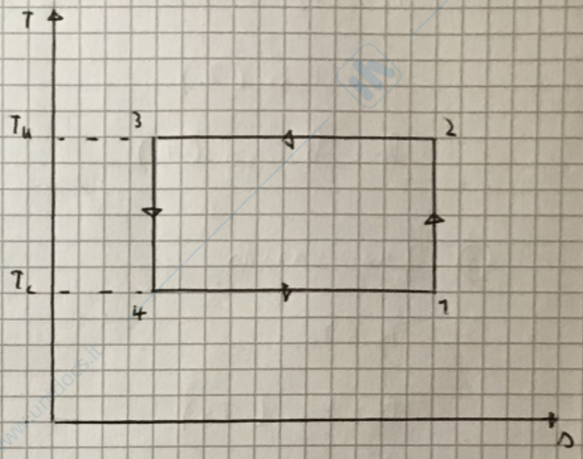
$\longrightarrow T_1 = T_{w,IN,GEN} - \Delta T_{st,GEN}$



PRODUZIONE DI ENERGIA TERMICA e FRIGORIFERA

CICLO DI CARNOT

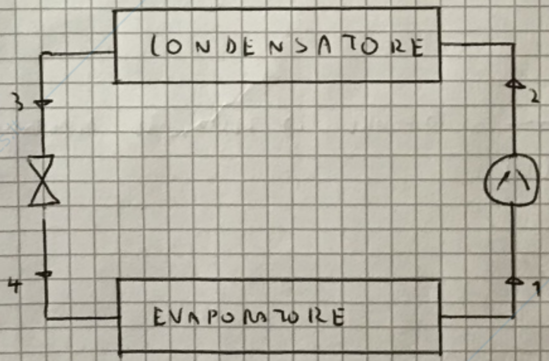




$$EER = \frac{Q_L}{W} = \frac{T_L}{T_H - T_L}$$

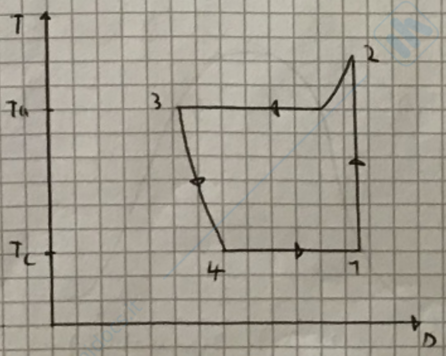
$$COP = \frac{Q_H}{W} = \frac{T_H}{T_H - T_L}$$

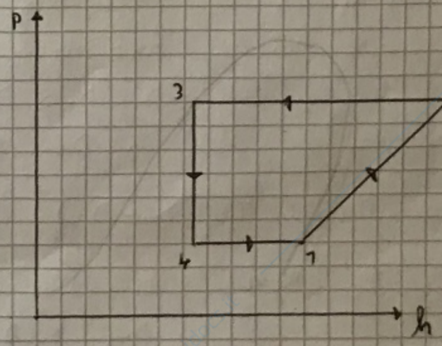
CICLO SEMPLICE IDEALE



$$EER = \frac{Q_{EVAP}}{W_{COMPR}} = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP = \frac{Q_{COND}}{W_{COMPR}} = \frac{h_2 - h_3}{h_2 - h_1}$$





PUNTI DEL CICLO:

① VAP. SATURO:

$T_1 = T_C$

$P_1 = P_{SAT}(T_1)$

$h_1 = h_{VAP,SAT}(T_1)$

③ LIQ. SATURO:

$T_3 = T_H$

$P_3 = P_{SAT}(T_3)$

$h_3 = h_{LIQ.SAT}(T_3)$

② $P_2 = P_3$

h_2 → LEGGO DAL DIAGRAMMA P-h SAPENDO CHE $s_2 = s_1$

④ $h_4 = h_3$

$P_4 = P_1$

$T_4 = T_C$

$$x_4 = \frac{h_4 - h_{LIQ.SAT}(T_4)}{h_{VAP.SAT}(T_4) - h_{LIQ.SAT}(T_4)}$$ OPPURE LO LEGGO DAL DIAGRAMMA

CALCOLO LE PERDITE:

$\Pi_{DES} = (h_2 - h_A) - T_H(s_2 - s_A)$

DOVE: $h_A = h_{VAP.SAT}(T_H)$

$s_2 = s_1 = s_{VAP.SAT}(T_C)$

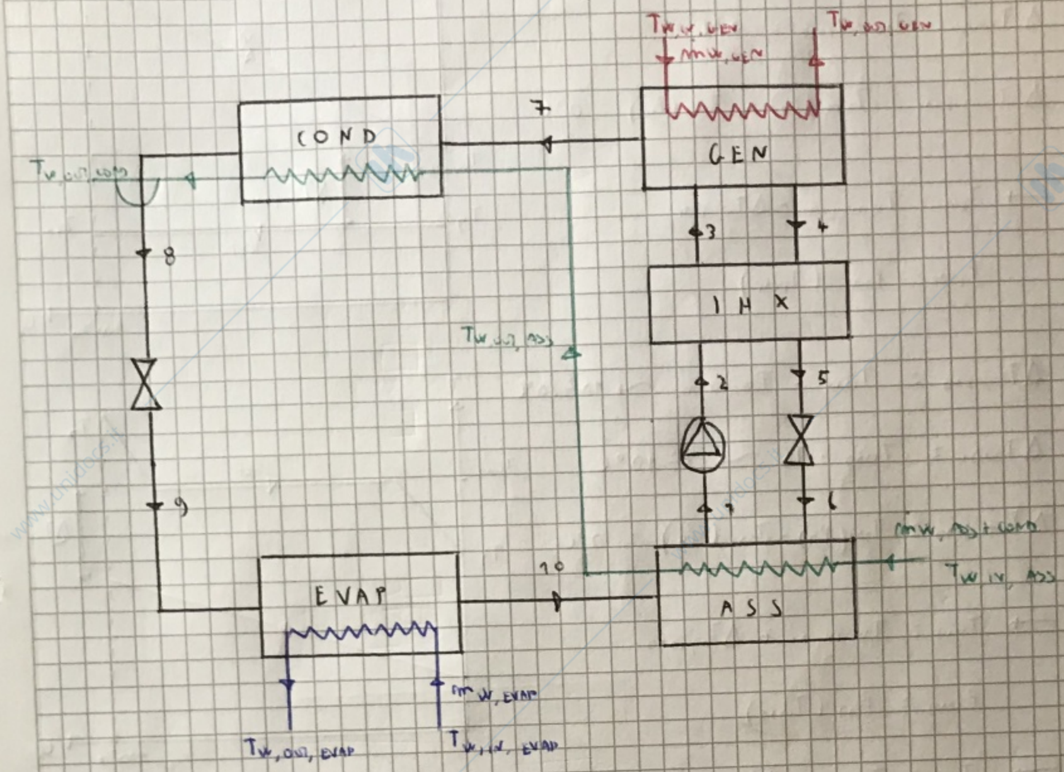
$s_A = s_{VAP.SAT}(T_H)$

$\Pi_{ESP} = T_H(s_4 - s_3) \gg \Pi_{DES}$

DOVE: $s_3 = s_{LIQ.SAT}(T_H)$

$s_4 = x_4\, s_{VAP.SAT}(T_C) + (1 - x_4)\, s_{LIQ.SAT}(T_C)$

MACCHINE AD ASSORBIMENTO



CONCENTRAZIONI : $x_1 = x_2 = x_3 = x_{RICCA}$

$x_4 = x_5 \; (= x_6) = x_{POVERA}$

$x_7 = x_8 = x_9 = x_{10} = 0\%$

PRESSIONI : $P_1 = P_6 = P_{10} = P_9 = P_{EVAP} = P_{SAT}(T_{EVAP})$

$P_2 = P_3 = P_4 = P_5 = P_7 = P_8 = P_{COND} = P_{SAT}(T_{COND})$

1 : LIQ. SAT

4 : LIQ. SAT

EQ. TERMO-MECCANICO:

$T_7 = T_{LS}\,(p^{7}, x_{ricca})$ → LEGGO SU DÜHRING

POTENZE:

$\dot{Q}_{ASS} = \dot{m}_3 \cdot h_3 + \dot{m}_{10} \cdot h_{10} - \dot{m}_4 \cdot h_4$ → RICAVO $\dot{m}_{10}$

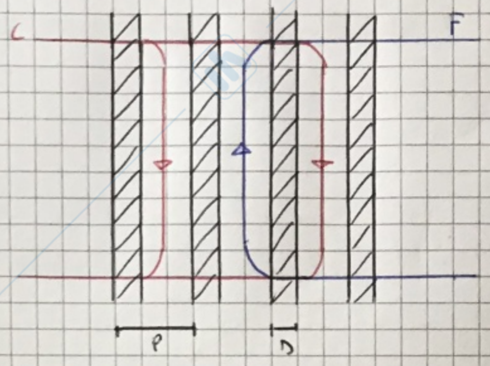
DA $\dot{m}_{10}$ RICAVO: $\dot{m}_R$ e $\dot{m}_P$

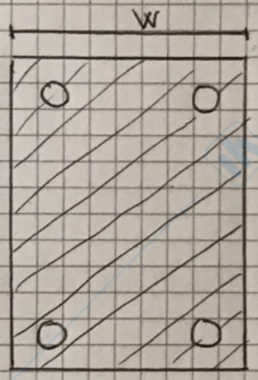
POSSO CALCOLARMI: $\dot{Q}_{COND}$, $\dot{Q}_{EVAP}$, $\dot{Q}_{GEN}$

VERIFICO CHE: $\dot{Q}_{GEN} + \dot{Q}_{EVAP} \simeq \dot{Q}_{ASS} + \dot{Q}_{COND}$

$$COP = \frac{\dot{Q}_{ASS}}{\dot{Q}_{GEN} + \dot{Q}_{EVAP}}$$

SCAMBIATORE A PIASTRE:



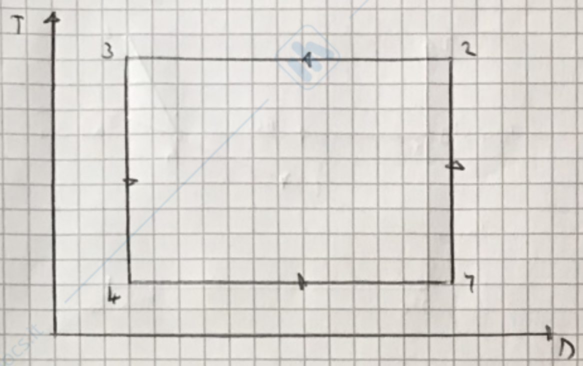


$$\frac{1}{U\cdot A} = \frac{1}{A}\cdot\left(\frac{1}{h_C}+\frac{D}{K_P}+\frac{1}{h_F}\right)\left(+R_{FOU}\right)$$

$$Re = \frac{\rho\cdot v\cdot D_H}{\mu} \qquad \text{CON} \qquad v = \frac{\dot{m}}{N_{CANALI\ C\ O\ F}}\cdot\frac{1}{\rho\cdot S_{PASSAGGIO}}$$

$$S_{PASSAGGIO} = W\cdot(P-D) \qquad [mm^2]$$

CICLO DI CARNOT



$T_{MIN,\,CARNOT} = T_{OUT,\,EVAP}$

$T_{MAX,\,CARNOT} = T_{OUT,\,COND} = ?$

$$\dot{Q}_{4-1} = \underbrace{\dot{m}} \cdot \underbrace{cp} \cdot (T_{IN,\,EVAP} - T_{OUT,\,EVAP}) \qquad [kW]$$

$$\rightarrow cp_A = 1{,}02\ \frac{kJ}{kg \cdot K} \quad o \quad cp_W = 4{,}186\ \frac{kJ}{kg \cdot K}$$

$$\rightarrow \dot{m}_A = \frac{V_A\left[\frac{m^3}{h}\right] \cdot \rho_A}{3600} \quad con \quad \rho_A = 1{,}225\ \frac{kg}{m^3} \quad o \quad \dot{m}_W$$

$$EER = \frac{\dot{Q}_{4-1}}{\dot{W}_{CARNOT}} = \frac{T_{MIN,\,CARNOT}}{T_{MAX,\,CARNOT} - T_{MIN,\,CARNOT}}$$

$T_{MAX,\,CARNOT} = ?$

$$\dot{Q}_{2-3} = \dot{Q}_{4-1} + \dot{W}_{CARNOT} = \dot{Q}_{4-1} + \frac{\dot{Q}_{4-1}}{EER} = \dot{Q}_{4-1}\left(1 + \frac{T_{MAX,\,CARNOT} - T_{MIN,\,CARNOT}}{T_{MIN,\,CARNOT}}\right)$$

$$= \dot{Q}_{4-1}\left(\frac{T_{MAX,\,CARNOT}}{T_{MIN,\,CARNOT}}\right)$$

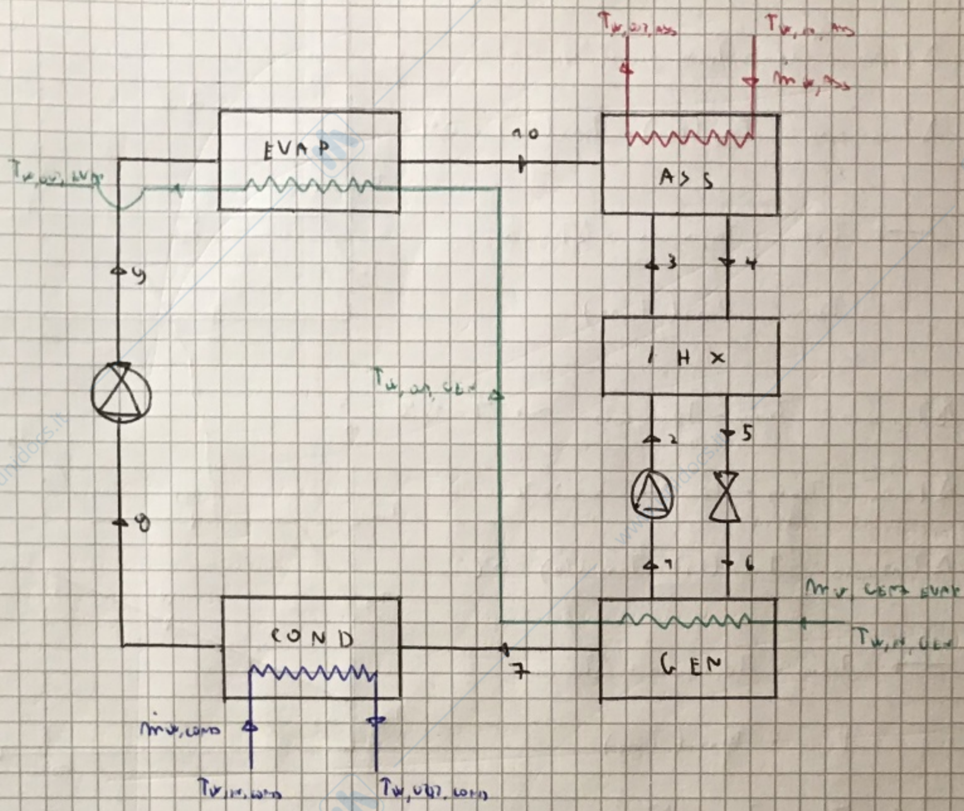
$$\dot{Q}_{2-3} = \dot{m} \cdot cp \cdot (T_{OUT,\,COND} - T_{IN,\,COND})$$

$$\rightarrow \dot{Q}_{4-3}\left(\frac{T_{MAX,\,CARNOT}}{T_{MIN,\,CARNOT}}\right) = \dot{m}\ cp\ (T_{OUT,\,COND} - T_{IN,\,COND})$$

$\rightarrow T_{MAX,\,CARNOT}$

$\rightarrow EER,\ \dot{W}_{COMPR.}$

TRASFORMATORE DI CALORE



CONCENTRAZIONI : $x_1 : x_2 : x_1 : x_{povera}$

$x_4 : x_3 = (x_6) = x_{ricca}$

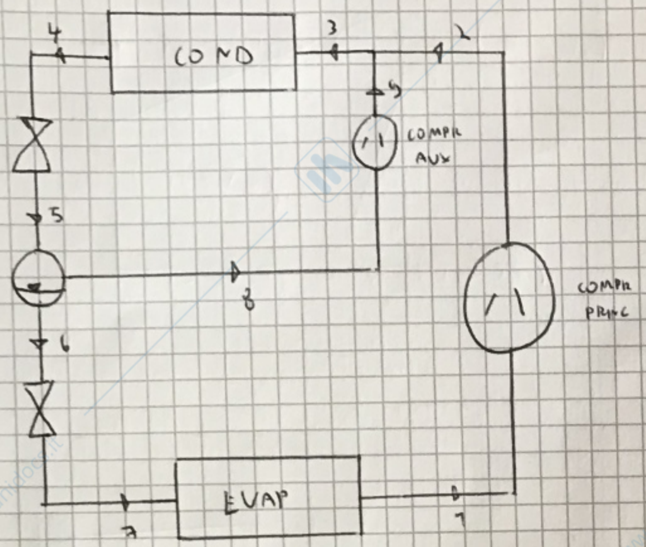
$x_7 = x_8 = x_9 = x_{10} : 0\,\%$

PRESSIONI : $P_1 : P_6 : P_7 : P_8 = P_{cond}$

$P_9 = P_{10} : P_3 : P_4 = P_2 = P_5 = P_{evap}$

4 : LIQ. SAT

CICLO A COMPRESSIONE PARALLELA (LAMINAZIONE FRAZIONATA)



LATO CONDENSATORE (3-4) e

LATO EVAPORATORE (7-1)

NON CAMBIA NULLA

6: LIQ. SAT, 8: VAP. SAT

$T_5 = T_6 = T_8 = T_{SAT}(P_{INT})$

SEPARATORE DI FASE:

$P_5 = P_6 = P_8 = P_{INT}$

$P_{INT} = \sqrt{P_{EVAP} \cdot P_{COND}} = \sqrt{P_7 \cdot P_4}$

MISCELAZIONE:

$P_2 = P_9 = P_3$ $\to$ NON

$$\begin{cases} \dot{m}_9 + \dot{m}_2 = \dot{m}_3 \\ \dot{m}_9 h_9 + \dot{m}_2 h_2 = \dot{m}_3 \cdot h_3 \\ \dfrac{\dot{m}_9}{\dot{m}_3} = x_5 \end{cases}$$

$\longrightarrow 1 = \underbrace{\dfrac{\dot{m}_9}{\dot{m}_3}}_{x_5} + \dfrac{\dot{m}_2}{\dot{m}_3}$

$\to$ RICAVO h_3

$\dot{Q}_{COND} = \dot{m}_3 (h_3 - h_4) \longrightarrow$ RICAVO $\dot{m}_3$

$\to$ RICAVO $\dot{m}_9$ e $\dot{m}_2$

NEL GENERATORE ABBIAMO EQ. TERMO-MECCANICO TRA VAPORE E MISCELA:

$T_7 : T_{LS}(P_3, x_3)$ → LEGGO SU DÜHRING

(P_7, x_{RICCA})

POTENZE:

$\dot{Q}_{EVAP} : \dot{m}_7 (h_{10} - h_9)$ → RICAVO $\dot{m}_7$

DA $\dot{m}_7$ RICAVO: $\dot{m}_R$ e $\dot{m}_P$

POSSO CALCOLARMI: $\dot{Q}_{COND}$, $\dot{Q}_{ASS}$, $\dot{Q}_{GEN}$

VERIFICO CHE: $\dot{Q}_{GEN} + \dot{Q}_{EVAP} \simeq \dot{Q}_{ASS} + \dot{Q}_{COND}$

EER: $\dfrac{\dot{Q}_{EVAP}}{\dot{Q}_{GEN}}$

EVAP:

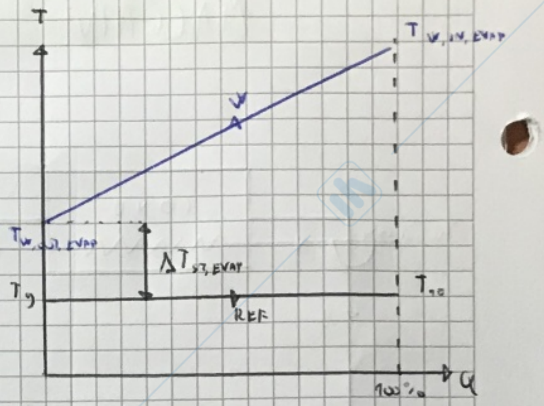
$\Delta T_{ST,EVAP} = T_{W,OUT,EVAP} - T_{EVAP} \rightsquigarrow 1 \div 4°C$

$\Delta T_{SURR} = T_{10} - T_{EVAP} = 0°C$

$\Delta T_{SAT,EVAP} = T_{SAT}(P_9) - T_{SAT}(P_{10}) = 0°C$

$\longrightarrow T_{EVAP} = T_{W,OUT,EVAP} - \Delta T_{ST,EVAP}$

$P_{EVAP} = P_{SAT}(T_{EVAP})$



COND:

$\Delta T_{ST,COND} = T_{COND} - T_{W,IN,ASS} \rightsquigarrow 10 \div 20°C$

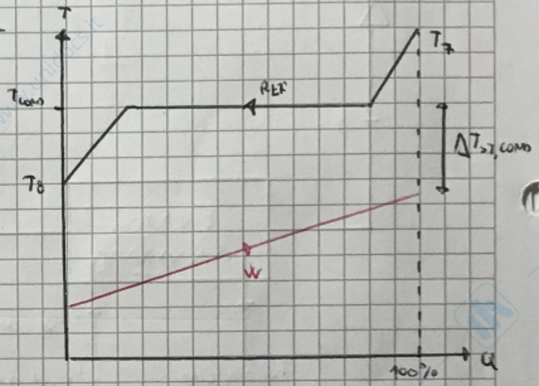
$\Delta T_{SUBC} = T_{COND} - T_8 \rightsquigarrow 3 \div 10°C$

$\Delta T_{SAT,COND} = T_{SAT}(P_7) - T_{SAT}(P_8) = 0°C$

$\longrightarrow T_{COND} = T_{W,IN,ASS} + \Delta T_{ST,COND}$

$P_{COND} = P_{SAT}(T_{COND})$

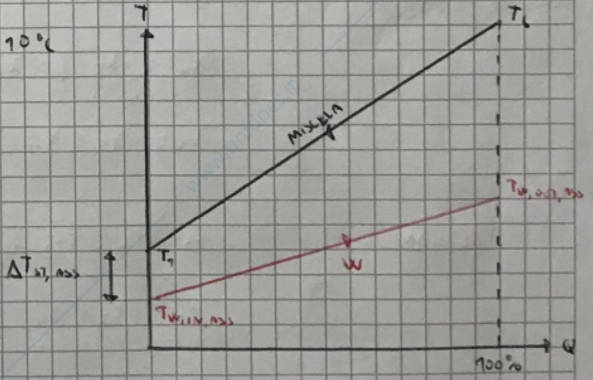
$\longrightarrow T_8 = T_{COND} - \Delta T_{SUBC}$



ASS:

$\Delta T_{ST,ASS} = T_1 - T_{W,IN,ASS} \rightsquigarrow 3 \div 10°C$

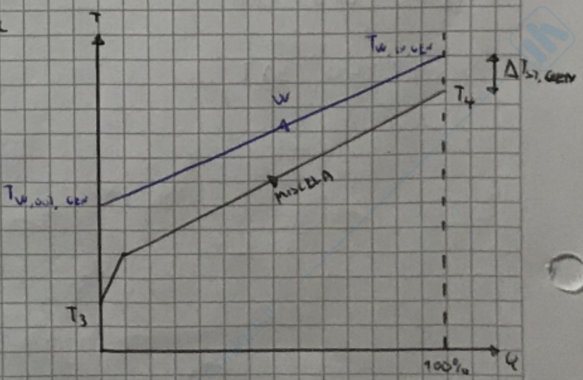
$\longrightarrow T_1 = T_{W,IN,ASS} + \Delta T_{ST,ASS}$



GEN:

$\Delta T_{ST,GEN} = T_{W,IN,GEN} - T_4 \rightsquigarrow 3 \div 10°C$

$\longrightarrow T_4 = T_{W,IN,GEN} - \Delta T_{ST,GEN}$



PUNTI DEL CICLO:

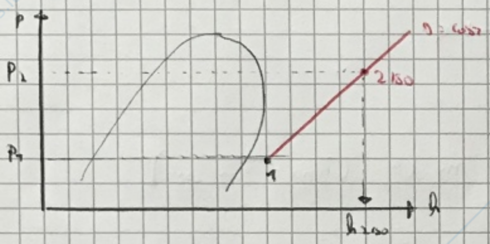
① $T_1 = T_{OUT,EVAP} - \Delta T_{ST,EVAP} + \Delta T_{SURR}$

$P_1 = P_{SAT}(T_{1,SAT}) = P_{SAT}(T_{OUT,EVAP} - \Delta T_{ST,EVAP})$ $\vdash\!\rightarrow h_1$

③ $T_3 = T_{IN,COND} + \Delta T_{ST,COND} - \Delta T_{SUBC}$

$P_3 = P_{SAT}(T_{IN,COND} + \Delta T_{ST,COND})$ $\vdash\!\rightarrow h_3$

② $P_2 = P_{SAT}(T_{IN,COND} + \Delta T_{ST,COND} + \Delta T_{SAT,COND})$



$$\boxed{2ISO}\begin{cases} P_{2ISO} = P_2 \\ S_{2ISO} = S_1 \end{cases} \vdash\!\rightarrow h_{2ISO}$$

$$\eta_{ISO,COMPR} = \frac{h_{2ISO} - h_1}{h_2 - h_1} \longrightarrow h_2$$

$\longrightarrow T_2$

④ $h_4 = h_3$

$T_4 = T_{OUT,EVAP} - \Delta T_{ST,EVAP} + \Delta T_{SAT,EVAP}$

$P_4 = P_{SAT}(T_4)$

$$x_4 = \frac{h_4 - h_{LIQ.SAT}(P_4)}{h_{VAP,SAT}(P_4) - h_{LIQ.SAT}(P_4)}$$

CALCOLO LE POTENZE:

$\dot{Q}_{EVAP} = \dot{m} \cdot cp \cdot (T_{IN,EVAP} - T_{OUT,EVAP}) = \dot{m}_{REF}(h_1 - h_4) \longrightarrow \dot{m}_{REF}$

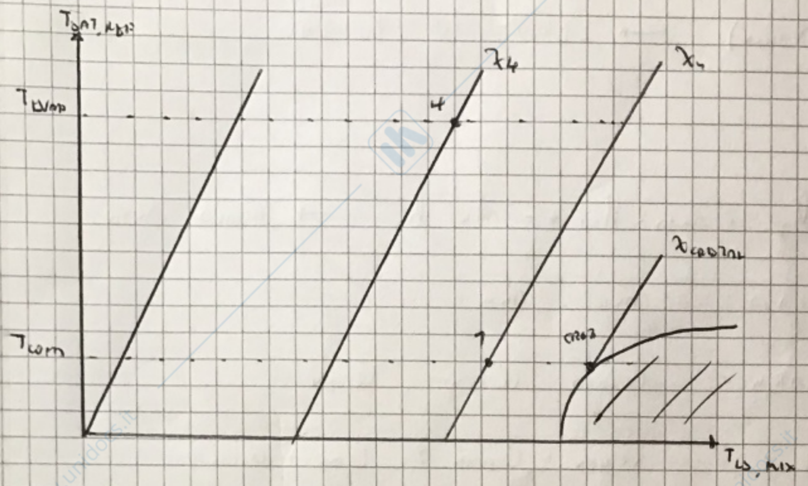
$\dot{Q}_{COND} = \dot{m}_{REF}(h_2 - h_3)$

VERIFICO: $\dot{Q}_{EVAP} + \dot{W}_{COMPR} = \dot{Q}_{COND}$

$\dot{W}_{COMPR} = \dot{m}_{REF}(h_2 - h_1)$

$$EER = \frac{\dot{Q}_{EVAP}}{\dot{W}_{COMPR}}$$

PER TROVARE LE CONCENTRAZIONI USO IL DIAGRAMMA DI DÜHRING:



$x_1 = x_2 = x_3 = x_{POVERA}$

$x_4 = x_5 = (x_6) = x_{RICCA}$

VERIFICO:

- $x_{RICCA} < x_{POVERA}$
- $x_{CRIST} > x_{POVERA}$ DI > 4%.

$$\eta_{ISO,POMPA} = \frac{\frac{P_2 - P_1}{\rho_1}}{h_2 - h_1}$$

DAL BILANCIO DI MASSA ALL'ASSORBITORE:

$$\begin{cases} \dot{m}_{RICCA} = \dfrac{x_{POVERA}}{x_{POVERA} - x_{RICCA}} \cdot \dot{m}_{10} \\ \dot{m}_{POVERA} = \dfrac{x_{RICCA}}{x_{POVERA} - x_{RICCA}} \cdot \dot{m}_{10} \end{cases}$$

IHX:

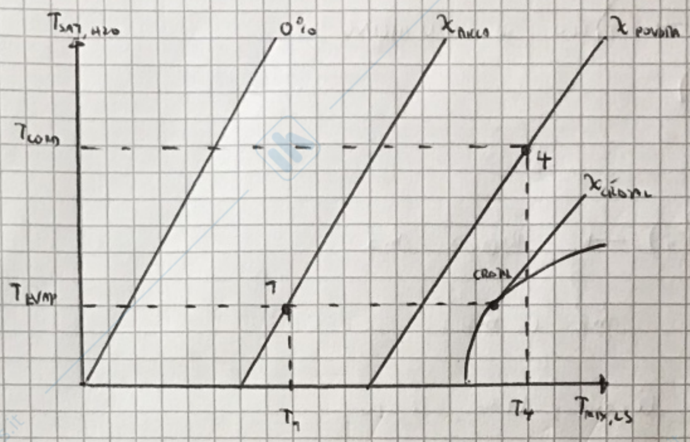
$$\varepsilon = \frac{Q}{Q_{MAX}} = \frac{\dot{m}_2 \cdot \overset{CP_1}{CP_2} \cdot (T_3 - T_2) \,|\, \dot{m}_4 \cdot CP_4 (T_4 - T_5)}{MIN(\dot{m}_2 CP_2 ; \dot{m}_4 CP_4)\ (T_4 - T_2)}$$ MA $\dot{m}_4 CP_4 > \dot{m}_2 CP_2$

$$\rightarrow \varepsilon = \frac{T_3 - T_2}{T_4 - T_2}$$

E SOSTITUENDO IL BILANCIO DI MASSA ALL'ASSORBITORE TROVO:

$$\rightarrow \varepsilon = \frac{\dot{m}_{RICCA} \cdot CP_4 (T_4 - T_5)}{\dot{m}_{POVERA}\ CP_1 \ (T_4 - T_1)}$$

PER TROVARE LE CONCENTRAZIONI USO IL DIAGRAMMA DI DÜHRING:



$x_1 = x_{RICCA} = x_2 = x_3$

$x_4 = x_{POVERA} = x_5 \; (= x_6)$

VERIFICHE SULLE CONCENTRAZIONI:

- $x_{RICCA} < x_{POVERA}$
- $x_{CRISTAL} > x_{POVERA}$ DI CIRCA IL 4%

$$\eta_{iso,pompa} = \frac{(h_2 - h_7)_{iso}}{h_2 - h_7} = \frac{\frac{p_2 - p_7}{\rho_7}}{h_2 - h_7} \longrightarrow \text{trovo } h_2$$

DAL BILANCIO DI MASSA AL GENERATORE TROVO:

$$\begin{cases} \dot{m}_{RICCA} = \dfrac{x_{POVERA}}{x_{POVERA} - x_{RICCA}} \cdot \dot{m}_7 \\ \\ \dot{m}_{POVERA} = \dfrac{x_{RICCA}}{x_{POVERA} - x_{RICCA}} \cdot \dot{m}_7 \end{cases}$$

IHX:

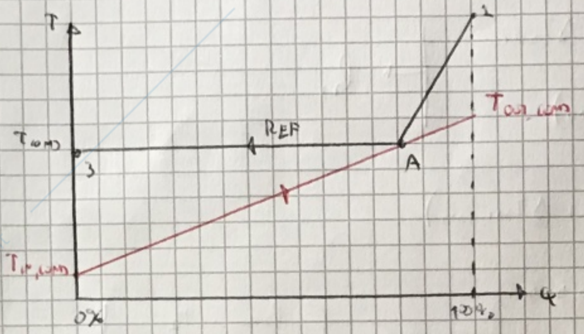
$$\varepsilon_{IHX} = \frac{\dot{Q}}{\dot{Q}_{MAX}} = \frac{\dot{m}_2 \cdot \overset{cp_7}{cp_2} (T_3 - T_2) \; | \; \dot{m}_4 \cdot cp_4 (T_4 - T_5)}{\min(\dot{m}_2 \, cp_2 , \dot{m}_4 \, cp_4) \; (T_4 - T_2)}$$

SOSTITUENDO IL BILANCIO DI MASSA AL GENERATORE TROVO:

$$\varepsilon_{IHX} = \frac{x_{POVERA} \cdot cp_7 \cdot (T_3 - T_1)}{x_{RICCA} \cdot cp_4 \; (T_4 - T_2)} \quad \text{o} \quad \varepsilon_{IHX} = \frac{T_4 - T_5}{T_4 - T_2}$$

$$EER = \frac{\dot{Q}_{EVAP}}{\dot{W}_{COMPR}}$$

VEDIAMO COME È STATO CALCOLATO T_{COND}:

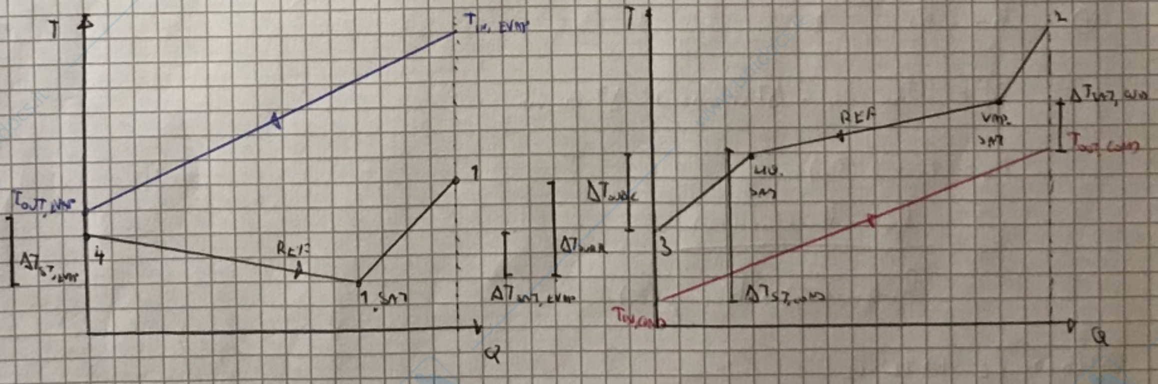


$$\dot{Q}_A = \dot{m} \cdot cp \cdot (T_A - T_{IN,COND}) = \dot{m} \cdot cp \cdot (T_{COND} - T_{IN,COND})$$

$$\dot{Q}_{REF,COND} = \dot{m}_{REF} [h_A - h_3] = \dot{m}_{REF} [h_{VAP,SAT}(T_{COND}) - h_{LIQ,SAT}(T_{COND})]$$

→ RICAVO T_{COND} PER TENTATIVI

CICLO SEMPLICE REALE (REFRIGERATORE)



$\Delta T_{ST,EVAP} = T_{OUT,EVAP} - T_{1,SAT}$ 5°C

$\Delta T_{SAT,EVAP} = T_4 - T_{1,SAT}$

$\Delta T_{SURR} = T_1 - T_{1,SAT}$

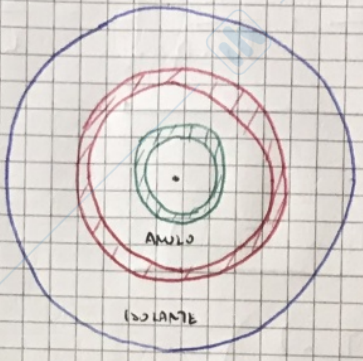
$\Delta T_{ST,COND} = T_{SAT}(P_3) - T_{IN,COND}$ 10°C

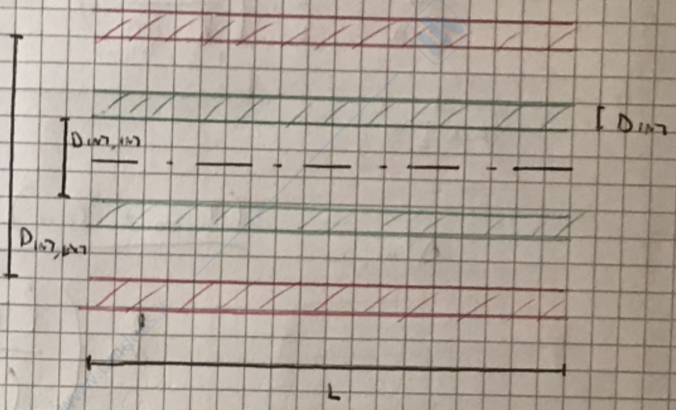
$\Delta T_{SAT,COND} = T_{SAT}(P_2) - T_{SAT}(P_3)$

$\Delta T_{SUBC} = T_{SAT}(P_3) - T_3$

SCAMBIATORI DI CALORE

A TUBI COASSIALI





$$\Delta P = f \cdot \frac{L}{D_H} \cdot \rho \frac{v^2}{2}$$

D_H → DIAMETRO IDRAULICO

f → $f(R_e) \rightarrow R_e = \frac{\rho \cdot v \cdot D_H}{\mu}$, $v = \frac{\dot{m}}{\rho \cdot A \cdot N_{TUBI}} \left[\frac{m}{s}\right]$

A → AREA PASSAGGIO FLUIDO

$$N_u = \frac{h_{conv} \cdot D_H}{k} \rightarrow h_{conv}\left[\frac{W}{m^2 \cdot K}\right] \qquad P_R = \frac{\mu\, c_p}{k}$$

METODO ε-NTU:

$$\varepsilon = \frac{\dot{Q}}{\dot{Q}_{max}} = \frac{\dot{Q}}{MIN\left(\frac{\dot{m}\, c_P}{N_{TUBI}}\right) \cdot \Delta T_{max}} \longrightarrow \dot{Q} = \dot{Q}_{max} \cdot \varepsilon$$

$$U \cdot A = \frac{1}{R_{tot}} \longrightarrow \text{DOVE } R_{tot} = \frac{1}{h_c \cdot A_c} + \frac{\ln\left(\frac{D_{EXT,INT}}{D_{INT,INT}}\right)}{2\pi\, k_p \cdot L} + \frac{1}{h_e \cdot A_e} + (R_{FOU})$$

$U \cdot A$ → $\left[\frac{W}{K}\right]$

A_c → $\pi D \cdot L$

$$NTU = \frac{U \cdot A}{MIN\left(\frac{\dot{m}\, c_P}{N_{TUBI}}\right)}$$

$$\varepsilon_{cc} = \frac{1 - e^{-NTU\,(1 - R^*)}}{1 - R^* \cdot e^{-NTU\,(1 - R^*)}} , \qquad \varepsilon_{EC} = \frac{1 - e^{-NTU\,(1 + R^*)}}{1 + R^*}$$

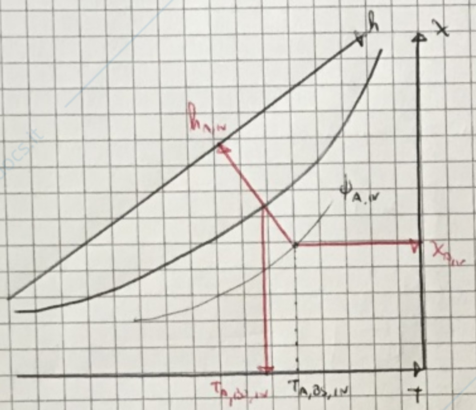
$$\text{DOVE} \qquad R^* = \frac{MIN\,(\dot{m}\, c_p)}{MAX\,(\dot{m}\, c_p)}$$

TORRI DI RAFFREDDAMENTO

$\dot{Q} = \dot{m}_w \cdot c_{p_w} \cdot (T_{w,in} - T_{w,out})$ [kW]

$\quad \llcorner\ 4,186 \frac{kJ}{kg \cdot K}$

NOTI $T_{A,BS,IN}$ e $\phi_{A,IN}$ TROVO DAL DIAGRAMMA PSICROMETRICO:



$h_{A,IN}$

$x_{A,IN}$

$T_{A,BU,IN}$

ΔT_{APP} : $T_{w,out} - T_{A,BU,IN}$

ΔT_{RANGE} : $T_{w,in} - T_{w,out}$

$$M_E = \frac{K_{sm} \cdot a \cdot V}{\dot{m}_w} = \sum \frac{c_{p_w} \cdot \Delta T_{w,scelto}}{\bar{h}_{w,i} - \bar{h}_{A,i}}$$

COSTRUISCO LA TABELLA:

i	T_w	h_w	h_A	$M_{E,i}$
1	$T_{w,out}$		$h_{A,IN}$	X

1) SCELGO $\Delta T_{w,scelto}$

2) $T_{w,i} = T_{w,i-1} + \Delta T_{w,scelto}$

3) $h_{w,i} = 27,58 \cdot 10^{-3} \cdot T_{w,i}^{2,366} + 33,77$

4) $h_{A,i} = h_{A,i-1} + \frac{\dot{m}_w \cdot c_{p_w} \cdot \Delta T_{w,scelto}}{\dot{m}_A}$

5) $\bar{h}_{A,i} = \frac{h_{A,i} + h_{A,i-1}}{2}$ $\qquad \bar{h}_{w,i} = \frac{h_{w,i} + h_{w,i-1}}{2}$

6) $M_{E,i} = \frac{c_{p_w} \cdot \Delta T_{w,scelto}}{\bar{h}_{w,i} - \bar{h}_{A,i}}$

7) $M_E = \sum M_{E,i}$