

# Esercizio 1

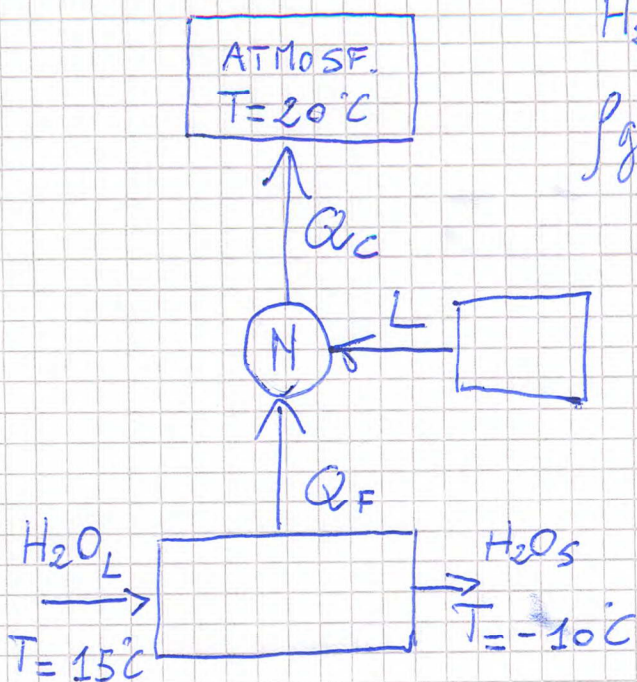
PISTA RETTANGOLARE  $L_1 = 30\text{m}$   $L_2 = 20\text{m}$   $S = 20\text{cm}$

$\text{H}_2\text{O}_g$   $T_g = -10^\circ\text{C} = 263,15\text{K}$

$\rho_g = 900 \text{ kg/m}^3$   $h_{LS} = -334 \frac{\text{kJ}}{\text{kg}}$   $C_g^* = 1940 \frac{\text{J}}{\text{kgK}}$

$\text{H}_2\text{O}_L$   $T_L = 15^\circ\text{C} = 288,15\text{K}$

$\eta = \frac{L_{ID}}{L_{REALE}} = 0,8$   $\Delta t = 15\text{h}$   
 $= 54000\text{s}$

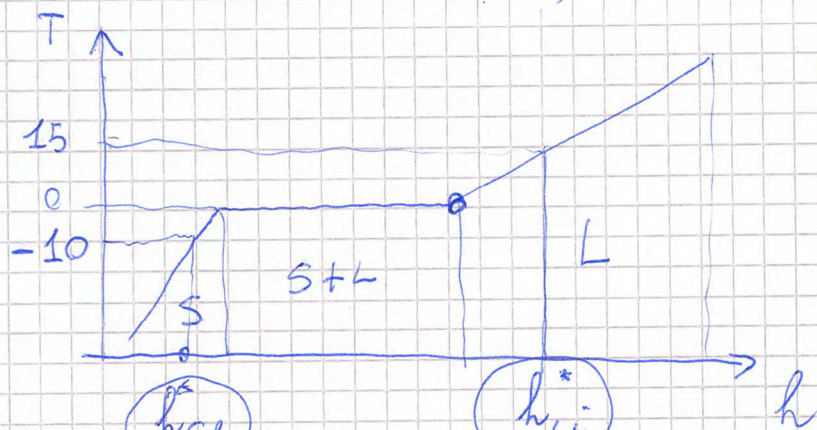


$\Delta U_N = Q_F - Q_C + L = 0$   
 $L = Q_C - Q_F$

BILANCIO ENERGO.  $L = Q_C - Q_F$

BILANCIO ENTROPICO  
 MACCHINA ID.

$\Delta S_{TOT} = \Delta S_C + \Delta S_F = 0$  ↑ MACCHINA REVERSIBILE



$Q_F = M(h_L^* - h_{LS}^* - h_g^*)$

$M = \rho \cdot V_g = M_L = M$

$V_g = L_1 \cdot L_2 \cdot S$

$V_g = 30 \cdot 20 \cdot 20 \cdot 10^{-2} = 120 \text{ m}^3$

$M_g = 900 \cdot 120 = 108000 \text{ kg}$

$h_{Li}^* = 4,1868 \cdot 15 = 62,802 \frac{\text{kJ}}{\text{kg}}$

$h_{Sf}^* = 1,940 \cdot (-10) = -19,40 \frac{\text{kJ}}{\text{kg}}$

$Q_F = 108000 \cdot (62,802 + 334 + 19,40) = 44949816 \text{ kJ}$



$$\Delta S_F = M \left( c_p^* \ln \left( \frac{T_{ref}}{T_{Li}} \right) + \frac{h_{LS}}{T_{REF}} + c_s \ln \frac{T_{sf}}{T_{af}} \right)$$

$$= 108000 \left( 4,1868 \ln \frac{273,15}{288,15} - \frac{334}{273,15} + 1,94 \ln \frac{263,15}{273,15} \right) = -164046,997 \frac{\text{kJ}}{\text{K}}$$

$$\Delta S_C = -\Delta S_F = \frac{Q_C}{T_C} \rightarrow Q_C = T_C \cdot \Delta S_C$$

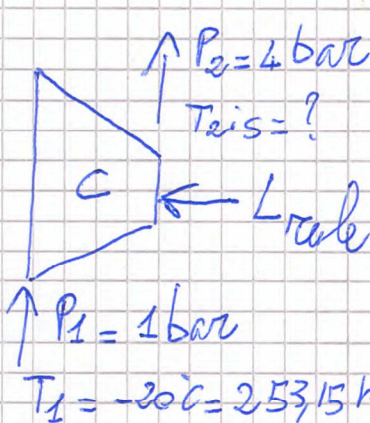
$$= 293,15 \cdot 164046,997 = 48090377,16 \text{ kJ}$$

$$L_{id} = Q_C - Q_F \rightarrow L_{id} = 48090377,16 - 44949816 = 3140561,16 \text{ kJ}$$

$$\eta = \frac{L_{id}}{L_{reale}} \rightarrow L_{reale} = \frac{L_{id}}{\eta} = \frac{3140561,16}{0,8} = 3925701,45 \text{ kJ}$$

$$E_F = \text{COP}_F = \frac{Q_F}{L_{reale}} = \frac{44949816}{3925701,45} = 11,45 \quad \boxed{E_F}$$

COMPRESSORE ADIABATICO



$$\dot{L} = \frac{L}{t} = \frac{3925701,45}{36000} = 109,047 \text{ kW}$$

$$\dot{L} = \dot{m}_r (h_{2is} - h_1) = \dot{m}_r \cdot c_{p,r}^* (T_{2is} - T_1)$$

$$c_{p,r}^* = 4 \frac{\text{kJ}}{\text{kg K}} = 4 \frac{8314,5}{102} = 326,06 \frac{\text{J}}{\text{kg K}}$$

ADIABATICA

QUASI STATICA

$$P_1 \frac{1-\kappa}{\kappa} T_1 = P_2 \frac{1-\kappa}{\kappa} T_{2is} \quad \kappa = \frac{c_p}{c_v} = 1,33 \text{ POLIAT.}$$

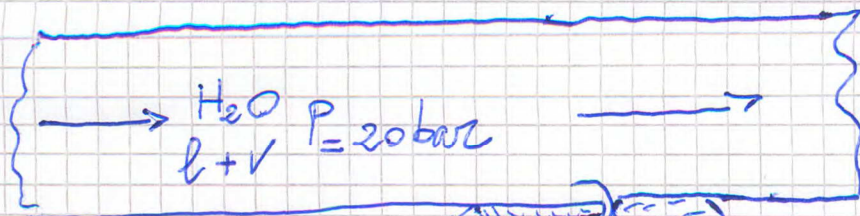
$$T_{2is} = T_1 \left( \frac{P_1}{P_2} \right)^{\frac{1-\kappa}{\kappa}} = 253,15 \left( \frac{1}{4} \right)^{\frac{1-1,33}{1,33}} = 357,08 \text{ K}$$

$$\approx 83,93^\circ\text{C}$$

$$\dot{m}_r = \frac{\dot{L}}{c_{p,r}^* (T_{2is} - T_1)} = \frac{109,047 \cdot 10^3}{326,06 (357,08 - 253,15)} = 2,145 \frac{\text{kg}}{\text{s}} \quad \boxed{2,145 \frac{\text{kg}}{\text{s}}}$$



## ESERCIZIO 2



ATMOSFERA  $P \approx 0,1 \text{ MPa}$

$T = 120^\circ\text{C} \Rightarrow$  VAPORE SURRISCALDATO

SPILLAMENTO ADIABATICO  $\Rightarrow$  LAMINAZIONE ISOENTALPICA

VAPORE SURRISCALDATO A  $P_f = 0,1 \text{ MPa}$   $T_f = 120^\circ\text{C} = 393,15 \text{ K}$

$$\rho_f = 0,55467 \frac{\text{kg}}{\text{m}^3}$$

$$h_f^* = 2716,6 \frac{\text{kJ}}{\text{kg}}$$

$$s_f^* = 7,4678 \frac{\text{kJ}}{\text{kg K}}$$

MISCELA LIQUIDO-VAPORE

$P = 20 \text{ bar}$   
 $\approx 2 \text{ MPa}$

$$h_i^* = 2716,6 \frac{\text{kJ}}{\text{kg}} = h_f^*$$

$$T_i = 485,53 \text{ K} \quad P_i = 2 \text{ MPa}$$

$$h_{LS}^* = 908,50 \frac{\text{kJ}}{\text{kg}}$$

$$h_{VS}^* = 2798,3 \frac{\text{kJ}}{\text{kg}}$$

$$s_{LS}^* = 2,4468 \frac{\text{kJ}}{\text{kg K}}$$

$$s_{VS}^* = 6,3330 \frac{\text{kJ}}{\text{kg K}}$$

$$h_i^* = (1-x) h_{LS}^* + x h_{VS}^* \rightarrow x_i = \frac{h_i^* - h_{LS}^*}{h_{VS}^* - h_{LS}^*} = \frac{2716,6 - 908,50}{2798,3 - 908,50} = 0,9568$$

$95,68\%$

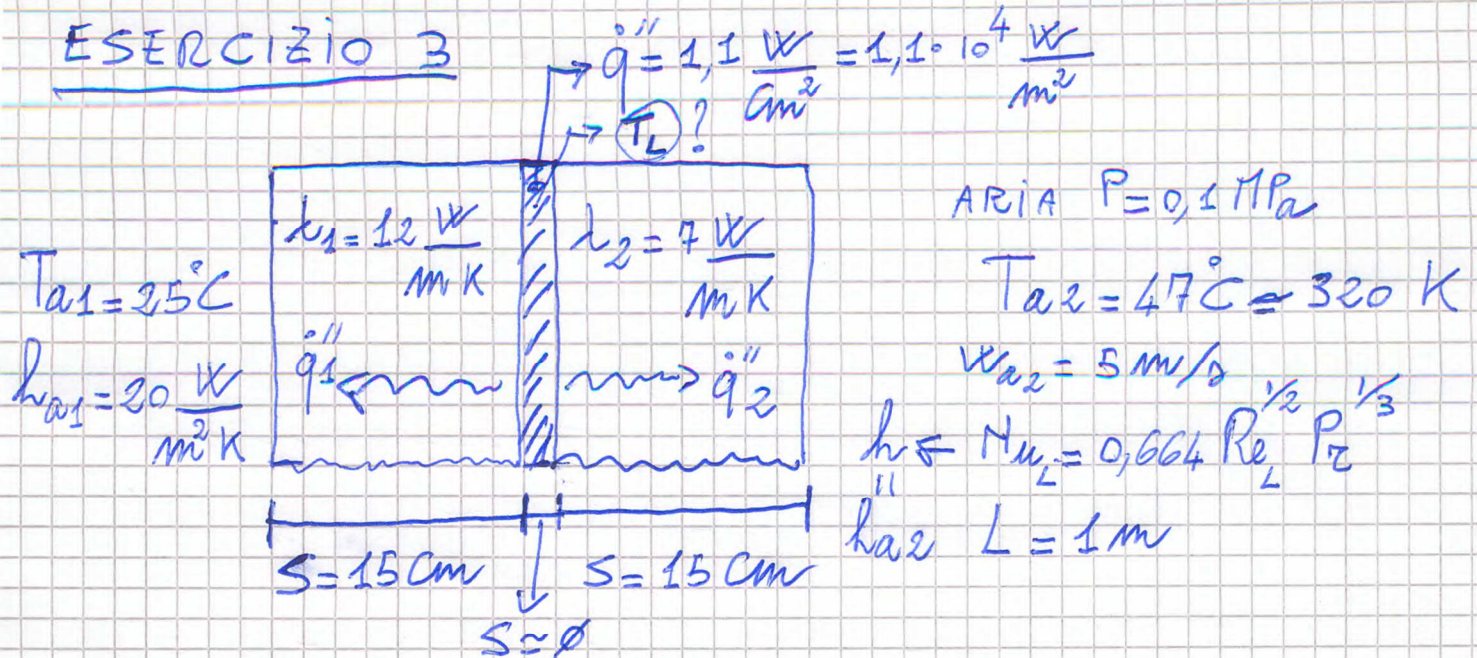
$$s_i^* = (1-x) s_{LS}^* + x s_{VS}^* \rightarrow s_i^* = (1-0,9568) \cdot 2,4468 + 0,9568 \cdot 6,3330 = 6,1708 \frac{\text{kJ}}{\text{kg K}}$$

PRODUZIONE ENTROPICA DEL PROCESSO

$$s_f^* - s_i^* = s_p^* = 7,4678 - 6,1708 = 1,297 \frac{\text{kJ}}{\text{kg K}}$$



# ESERCIZIO 3



BILANCIO ENERGETICO  $\dot{q}'' = \dot{q}_1'' + \dot{q}_2''$

FLUSSO AREEICO A SX  $\dot{q}_1'' = \frac{T_L - T_{a1}}{\frac{s}{\lambda_1} + \frac{1}{h_{a1}}}$

FLUSSO AREEICO A DX

$$\dot{q}_2'' = \frac{T_L - T_{a2}}{\frac{s}{\lambda_2} + \frac{1}{h_{a2}}}$$

Determiniamo  $h_{a2}$ , proprietà aria a 320 K  $\lambda_a = 27,854 \cdot 10^{-3} \frac{W}{mK}$

$$\mu_a = 19,488 \cdot 10^{-6} Pa \cdot s$$

$$Re_L = \frac{\rho_a w_{a2} \cdot L}{\mu_a}$$

$$\frac{P}{\rho_a} = R^* T_a \rightarrow \rho_a = \frac{P}{R^* T_a}$$

$$\rho_a = \frac{10^5 \cdot 325}{8314,5 \cdot 320} = 1,10 \frac{kg}{m^3}$$

$$Re_L = \frac{1,10 \cdot 5 \cdot 1}{19,488 \cdot 10^{-6}} \approx 282225$$

$$Pr = \frac{\mu_a C_{pa}^*}{\lambda_a}$$

$$C_{pa}^* = \frac{4}{2} \frac{8314,5}{28,96} = 1004,86 \frac{J}{kg \cdot K}$$

$$Pr = \frac{19,488 \cdot 10^{-6} \cdot 1004,86}{27,854 \cdot 10^{-3}} = 0,70$$



$$N_{mL} = 0,664 \cdot (282225)^{\frac{1}{2}} \cdot (0,70)^{\frac{1}{3}} = 313,207$$

$$N_{mL} = \frac{hL}{\lambda} \Rightarrow h = \frac{N_{mL} \cdot \lambda}{L} = \frac{313,207 \cdot 27,854 \cdot 10^{-3}}{1} = 8,724 \frac{W}{m^2 K}$$

$$\dot{q}_1'' = \frac{T_L - 25}{\frac{15 \cdot 10^{-2}}{12} + \frac{1}{20}} = \frac{T_L - 25}{0,0625}$$

$$\dot{q}'' = \dot{q}_1'' + \dot{q}_2'' = 1,1 \cdot 10^4 \frac{W}{m^2}$$

$$\dot{q}_2'' = \frac{T_L - 47}{\frac{15 \cdot 10^{-2}}{7} + \frac{1}{8,724}} = \frac{T_L - 47}{0,1361}$$

$$= \frac{T_L - 25}{0,0625} + \frac{T_L - 47}{0,1361}$$

RICAVO  $T_L$   $1,1 \cdot 10^4 = \frac{T_L}{0,0625} - \frac{25}{0,0625} + \frac{T_L}{0,1361} - \frac{47}{0,1361}$

$$1,1 \cdot 10^4 + \frac{25}{0,0625} + \frac{47}{0,1361} = T_L \left( \frac{1}{0,0625} + \frac{1}{0,1361} \right)$$

$$T_L = 11745,33 \cdot \left( \frac{1}{0,0625} + \frac{1}{0,1361} \right)^{-1} = \boxed{503,06 \text{ } ^\circ\text{C}}$$

$$\dot{q}_1'' = \frac{503,06 - 25}{0,0625} = \boxed{7648,96 \frac{W}{m^2}}$$

$$\dot{q}_2'' = \frac{503,06 - 47}{0,1361} = \boxed{3350,92 \frac{W}{m^2}}$$

VERIFICO BILANCIO  $\dot{q}_1'' + \dot{q}_2'' = 7648,96 + 3350,92 = 10999,88 \frac{W}{m^2}$   
OK  $m^2$

$$\approx 11000 \frac{W}{m^2}$$