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A P P U N T I

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MATERIA: Termodinamica e Trasmissione del calore temi d'esame. Prof.Giaretto

TEMI ESAME — TERMODINAMICA e TRASMISSIONE DEL CALORE

21 LUGLIO 2014

ES 1

$T^+ = 300°C = 573\,K$

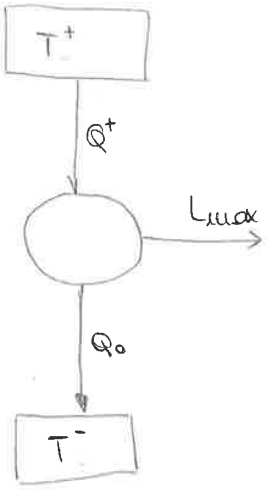
$Q^+ = 20\,MJ$

$T^- = 10°C = 283\,K$

$?\,L_{max}$

$?\,\eta = \frac{Q^+ - |Q_0|}{Q^+} = 1 - \frac{|Q^-|}{Q^+}$

$?\,Q_0$



$\frac{|Q^-|}{Q^+} = \frac{T^-}{T^+}$ $\quad |Q^-| = \frac{T^-}{T^+} \cdot Q^+ = 9877836\,J = |Q_0|$

$Q = -9877836\,J$

$L_{max} = Q^+ - |Q_0| = 10122164\,J$

$\eta = 0,506$

ES 2

$\bar{M}_{H_2O} = 18\,\frac{kg}{kmol}$ $\quad M_{TOT} = 0,36\,kg$

Vapore umido $\begin{cases} T_1 = 200°C \\ p_1 = 15,549\,bar \end{cases}$ $\quad m_{1e} = 5 \rightarrow M_{1e} = 0,09\,kg$ $\quad m_{1v} = 15 \rightarrow M_{1v} = 0,27\,kg$

$x_1 = \frac{M_{1v}}{M_{1v} + M_{1e}} = 0,25$

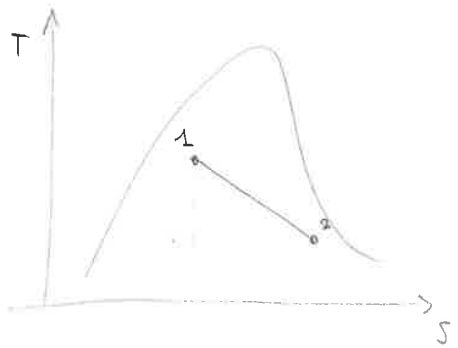
$s_1 = 3,355$

$\begin{cases} p_2 = 1\,bar \\ T_2 = 99,1632°C \end{cases}$ $\quad M_{2e} = \frac{M_{1e}}{2}$

$s_2 = 6,512$

① $\begin{cases} v_{1e} = 0,00011565 \\ v_{1v} = 0,1272 \\ h_{1e} = 852,37 \\ h_{1v} = 2790,9 \\ s_{1e} = 2,3307 \\ s_{1v} = 6,4278 \end{cases}$

② $\begin{cases} v_{2e} = 0,0010434 \\ v_{2v} = 1,694 \\ h_{2e} = 417,51 \\ h_{2v} = 2675,4 \\ s_{2e} = 1,3027 \\ s_{2v} = 7,3598 \end{cases}$



$v_{2e} \cdot M_{2e} = \frac{v_{1e} \cdot M_{1e}}{2} \rightarrow M_{2e} = \frac{v_{1e} \cdot M_{1e}}{2\,v_{2e}} = 0,0499\,kg$

$M_{2v} = M_{TOT} - M_{2e} = 0,31$ $\quad x_2 = \frac{M_{2v}}{M_{TOT}} = 0,86$

I° principio $\quad Q - L_1 = \Delta U$ $\quad dQ = \bar{T}\,dS$ $\quad \bar{T} = \frac{T_1 + T_2}{2} = 422,816\,K$

$\rightarrow q_{12} = \bar{T}(s_2 - s_1) = 1334,748\,\frac{kJ}{kg} \Rightarrow Q_{12} = 480,51\,kJ$

17 FEB 2014

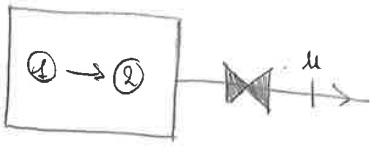
ES 1) $V = 0{,}1\ m^3$

(A) N_2 $\begin{cases} \bar{M}_A = 28\ \frac{kg}{kmol} \\ R_A = 297\ ;\ c_{pA} = 1039{,}3\ ;\ c_{vA} = 742{,}35 \\ V_A = 0{,}03\ m^3 \Rightarrow y_A = 0{,}3 \Rightarrow x_A = y_A \cdot \frac{\bar{M}_A}{\bar{M}} = 0{,}362 \end{cases}$

(B) CO_2 $\begin{cases} \bar{M}_B = 44\ kg/kmol \\ R_B = 189\ ;\ c_{pB} = 756\ ;\ c_{vB} = 567 \\ V_B = 0{,}03\ m^3 \Rightarrow y_B = 0{,}3 \Rightarrow x_B = 0{,}568 \end{cases}$

(C) He $\begin{cases} \bar{M}_C = 4\ \frac{kg}{kmol} \\ R_C = 2078{,}16\ ;\ c_{pC} = 5196{,}5\ ;\ c_{vC} = 3117{,}9 \\ V_C = 0{,}04 \Rightarrow y_C = 0{,}4 \Rightarrow x_C = 0{,}07 \end{cases}$

$\bar{M} = y_A \bar{M}_A + y_B \bar{M}_B + y_C \bar{M}_C = 23{,}2\ \frac{kg}{kmol}$; $R = x_A R_A + x_B R_B + x_C R_C = 360{,}37$



$T = 293\ K = Cost$

$Q = 50\ kJ$

$\phi - \cancel{W_t} = \frac{dU}{dt} + G h_u \rightarrow Q = U_2 - U_1 - (M_2 - M_1)(u_u + RT_u) = M_2 u_2 - M_1 u_1 - (M_2 - M_1)(u_u + RT_u) =$

$= (M_2 - M_1)(\cancel{u} - \cancel{u} - RT_u) = (M_1 - M_2)RT = \Delta M RT \rightarrow \Delta M = \frac{Q}{RT} = 0{,}47\ kg$

$M_1 = \frac{P_1 V}{RT}$; $M_2 = \frac{P_2 V}{RT} \rightarrow M_1 - M_2 = \Delta M = \frac{(P_1 - P_2)V}{RT} \Rightarrow \Delta P = \frac{\Delta M RT}{V} = 500000\ Pa = 5\ bar$

20 GIUGNO 2014

ES 1

$V = 100\,l = 100\,dm^3 = 0{,}1\,m^3$

$T_1 = 25°C = 298\,K$

$Q_{12} = 80\,kJ$

$T_2 = 200°C = 473\,K$

$p_2 = 10\,bar = 10^6\,Pa$

$\bar{M}_{N_2} = 28\,kg/kmol \qquad \bar{M}_{Ar} = 39{,}994\ \frac{kg}{kmol}$

$\gamma_{N_2} = 1{,}4 \qquad \gamma_{Ar} = 1{,}667$

? m_{TOT}

? c_v

? η_{Ar}

$$\bar{c}_{v_{N_2}} = \frac{c_{v_{N_2}}}{\bar{M}_{N_2}} = \frac{\frac{\bar{R}}{\bar{M}_{N_2}}}{\gamma_{N_2}-1} = \frac{\bar{R}}{\bar{M}_{N_2}^2(\gamma_{N_2}-1)} = 26{,}512$$

$$\bar{c}_{v_{Ar}} = \frac{\bar{R}}{\bar{M}_{Ar}^2(\gamma_{Ar}-1)} = 7{,}797$$

$$\bar{c}_{p_{N_2}} = \frac{\frac{\bar{R}}{\bar{M}_{N_2}}\gamma_{N_2}}{\frac{\gamma_{N_2}-1}{\bar{M}_{N_2}}} = \frac{\bar{R}\,\gamma_{N_2}}{\bar{M}_{N_2}^2(\gamma_{N_2}-1)} = 37{,}12$$

$$\bar{c}_{p_{Ar}} = \frac{\bar{R}\,\gamma_{Ar}}{\bar{M}_{Ar}^2(\gamma_{Ar}-1)} = 12{,}99$$

$Q_{12} - L_{12} = \Delta U_{12} = m_{TOT}\,\bar{M}_a\,c_v\,(T_2 - T_1)$

- $p_2 V = m_{TOT}\,\bar{R}\,T_2 \rightarrow m_{TOT} = \frac{p_2 V}{\bar{R} T_2} = 0{,}02543$ moli
- $p_1 V = m_{TOT}\,\bar{R}\,T_1 \rightarrow p_1 = \frac{m_{TOT}\,\bar{R}\,T_1}{V} = 630021\,Pa$
- $c_v = \frac{R}{\gamma-1} = \frac{\bar{R}}{\bar{M}_a}\frac{1}{\gamma-1} \rightarrow Q_{12} = M_a\,q_{12} = \left(\frac{\bar{R}}{\bar{M}_a}\cdot\frac{1}{\gamma-1}\right)\bar{M}_a\,m_{TOT}(T_2-T_1)$

(c_v; $M_a \cdot m_{TOT}$)

$$(\gamma-1) = \frac{\bar{R}\,m_{TOT}\,(T_2-T_1)}{Q_{12}} \Rightarrow \boxed{\gamma = 1{,}4625}$$

$y_{Ar} = (1 - y_{N_2})$

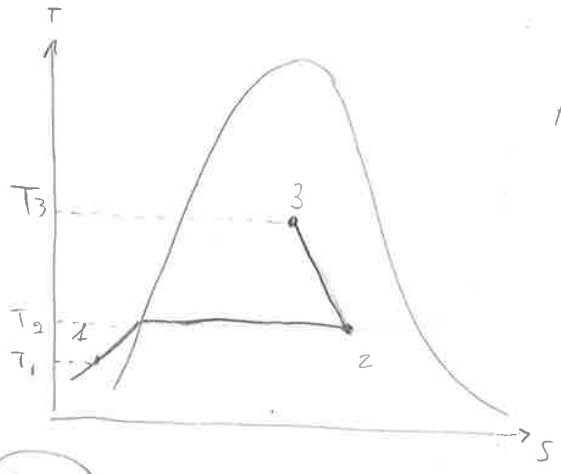
- $\bar{c}_v = y_{N_2}\bar{c}_{v_{N_2}} + y_{Ar}\bar{c}_{v_{Ar}} = y_{N_2}(\bar{c}_{v_{N_2}} - \bar{c}_{v_{Ar}}) + c_{v_{Ar}}$
- $\bar{c}_p = y_{N_2}\bar{c}_{p_{N_2}} + (1-y_{N_2})\bar{c}_{p_{Ar}} = y_{N_2}(\bar{c}_{p_{N_2}} - \bar{c}_{p_{Ar}}) + \bar{c}_{p_{Ar}}$

$$\gamma = \frac{y_{N_2}(\bar{c}_{v_{N_2}} - \bar{c}_{p_{Ar}}) + \bar{c}_{v_{Ar}}}{y_{N_2}(\bar{c}_{p_{N_2}} - \bar{c}_{p_{Ar}}) + \bar{c}_{p_{Ar}}} \rightarrow \gamma\,y_{N_2}(\bar{c}_{p_{N_2}} - \bar{c}_{p_{Ar}}) + \gamma\,\bar{c}_{p_{Ar}} = y_{N_2}(\bar{c}_{v_{N_2}} - \bar{c}_{v_{Ar}}) + \bar{c}_{v_{Ar}}$$

$$y_{N_2}\left[\gamma(\bar{c}_{p_{N_2}} - \bar{c}_{p_{Ar}}) - (\bar{c}_{v_{N_2}} - \bar{c}_{v_{Ar}})\right] = \bar{c}_{v_{Ar}} - \gamma\,\bar{c}_{p_{Ar}}$$

$\boxed{y_{N_2} = 0{,}517}$ $\qquad y_{Ar} = 1 - y_{N_2} = 0{,}483 = \frac{m_{Ar}}{m_{TOT}} \qquad m_{Ar} = y_{Ar}\cdot m_{TOT} = 0{,}0123$ mol

$\bar{M}_a = y_{N_2}\bar{M}_{N_2} + y_{Ar}\bar{M}_{Ar} = 33{,}179\ kg/kmol \qquad R = \frac{\bar{R}}{\bar{M}_a} = 246{,}715 \rightarrow c_v = \frac{R}{\gamma-1} = 533{,}44$



Adiab rev: $S_3 \neq S_2$!

Es 3 Sfera

$R = 0{,}001\ m$

$\rho c = 1\ \frac{J}{cm^3 K} = 10^6\ \frac{J}{m^3 K}$

$\begin{cases} S = 4\pi R^2 = 0{,}0125664\ m^2 \\ V = \frac{4}{3}\pi R^3 = 4{,}188 \cdot 10^{-9}\ m^3 \end{cases}$

$T_e = 30°C$

$T_w = 130°C$

$\alpha_e = 25\ \frac{W}{m^2 K}$

$H = 5 \cdot 10^8 J/m^3$

- $t_0 = \frac{\rho \cdot c \cdot V}{\alpha_e \cdot S} = 0{,}013331\ s$
- $\Phi_G = H \cdot V = 0{,}02094\ W$
- $\Theta_\infty = \frac{\Phi_G}{\alpha_e \cdot S} = 0{,}066654°C$
- $\Theta_0 = T_{agg} - T_{amb} = 30° - 130° = -100$
- $\Theta(t = 20s) = \Theta_\infty \left(1 - e^{-\frac{20}{t_0}}\right) + \Theta_0\, e^{-\frac{20}{t_0}} = 0{,}066654$
- $T_{agg} = \Theta(t = 20s) + T_{amb} = 130{,}067°C$
- T_{max} => Θ_∞ è l'eccesso di temperatura => $\Theta_\infty = 0{,}066654 \sim 0{,}067$ =>

$T_{max} \cong T_{agg}(t = 20s) = 130{,}067$

ES 2

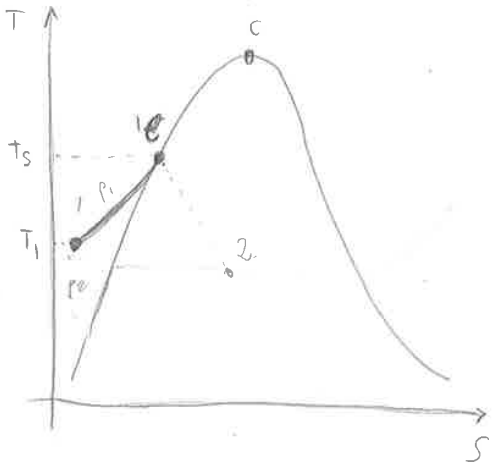
$G_{Va} = 100 \frac{dm^3}{h} = 2{,}778 \cdot 10^{-5} \frac{m^3}{s}$

① $\begin{cases} T_1 = 10°C = 283\,K \\ p_1 = 2\,bar \end{cases}$

→ T_S liquido saturo

laminazione $p_2 = \frac{p_1}{2} = 1\,bar$

$T_S = 120{,}23°C$



① $T_1 = 10°C$

$p_S(T_1) = 1227\,Pa$ sottoraffreddato

$\begin{cases} v_{le} = 0{,}0010003 \\ v_{lv} = 106{,}4 \\ h_{le} = 41{,}99 \\ h_{lv} = 2519{,}9 \\ s_{le} = 0{,}1510 \\ s_{lv} = 8{,}9020 \end{cases}$

$\begin{cases} v_1 = v_{le} \rightarrow G_a = \frac{G_{Va}}{v_1} = 0{,}0278\ kg/s \\ s_1 = s_{le} \\ h_1 = h_{le} + v_{le}\cdot(p_1 - p_S(T_1)) = 42{,}189\ kJ/kg \\ u_1 = u_{le} = h_{le} - p_S(T_1)\cdot v_{le} = 41989\ J/kg \end{cases}$

$\emptyset - W_t = G \cdot \Delta h \Rightarrow \emptyset = G_a(h_{le} - h_1) = -5{,}5322\ W$

Treev ext: $\frac{dS}{dt} + \sum G_j s_j = \frac{|\emptyset|}{T} + \dot{S}_{irr}$ $\quad \dot{S}_{irr} = +\frac{|\emptyset|}{T} = 0{,}014\ \frac{W}{K}$

Treev int: $\frac{dS}{dt} + \sum G_j s_j = \frac{\emptyset}{T} + \dot{S}_{irr}$ $\quad \dot{S}_{irr} = G(s_{le} - s_1$

FEB 2013

ES 1

$\bar{M}_{CO_2} = 44 \frac{kg}{kmol} = (A)$ $R_A = 188,96$ $\gamma_A = \frac{4}{3}$

$\bar{M}_{Ne} = 20.2 \frac{kg}{kmol} = (B)$ $R_B = 411,6$ $\gamma_B = \frac{5}{3}$

$V_1 = 50\ e = 50\ dm^3 = 0,05\ m^3$

$T_1 = 25°C = 298\ K$

$P_1 = 10^5\ Pa$

$V_{A1} = 0,01\ m^3$

$V_{B1} = 0,04\ m^3$

2) $V_2 = 0,017\ m^3$ adiabatica

$T_2 = 400°C$

b) $V_3 = V_2$ isocora

$T_3 = T_1 = 25°C = 298\ K$

c) $T_4 = T_3 =$ isoterma

$P_4 = P_1 = 10^5\ Pa$

1-2

adiab rev: $T_1 V_1^{\gamma-1} = T_2^{id} V_2^{\gamma-1} \Rightarrow T_2^{id} = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = 543,13\ K$

$P_1 V_1 = m \bar{R} T_1 \rightarrow m_{TOT} = \frac{P_1 V_1}{\bar{R} T_1} = 2,02$ moli

$\begin{cases} m_A = m_{TOT} \cdot \frac{V_{A1}}{V_1} = 0,404 \rightarrow y_A = 0,2 \\ m_B = 1,616 \rightarrow y_B = 0,8 \end{cases}$

$\bar{M}_{TOT} = y_A \bar{M}_A + y_B \bar{M}_B = 24,96 \frac{kg}{kmol} \rightarrow \begin{cases} x_A = y_A \frac{\bar{M}_A}{\bar{M}_{TOT}} = 0,35 \\ x_B = 0,65 \end{cases}$

- $R_{TOT} = x_A R_A + x_B R_B = 333,68$

$c_{p_A} = \frac{R_A \gamma_A}{\gamma_A - 1} = 755,84$ $\quad c_{v_A} = 566,88$ $\quad c_v = x_A c_{v_A} + x_B c_{v_B} = 599,718$

$c_{p_B} = \frac{R_B \gamma_B}{\gamma_B - 1} = 1029$ $\quad c_{v_B} = 617,4$

- $\gamma = \frac{x_A c_{p_A} + x_B c_{p_B}}{x_A c_{v_A} + x_B c_{v_B}} = 1,5564$

- $P_1 V_1 = M_{TOT} R T_1 \rightarrow M_{TOT} = \frac{P_1 V_1}{R T_1} = 0,0503\ kg$

$L_i^{id} = -M c_v (T_2^{id} - T_1) = +7394,46\ J$

$L_i = -M c_v (T_2 - T_1) = -11312,18$ $\rightarrow L_a = L_i^{id} - L_i = 3918\ J$

- $Q_{12} = 0$

③ ~~$T_2 p_2^{\frac{-\gamma+1}{\gamma}} = T_3^{id} p_3^{\frac{-\gamma+1}{\gamma}} \rightarrow T_3^{id} = T_2 \left(\frac{p_2}{p_3}\right)^{\frac{\gamma-1}{\gamma}} = 859{,}2\ K = 586°C$~~

$\gamma = 1{,}326$

$$\eta_{IS,C} = \frac{l_{t,C}^{id}}{l_{t,C}} = \frac{h_3^{id} - h_2}{h_3 - h_2} \rightarrow h_3 = \frac{h_3^{id} - h_2}{\eta_{IS,C}} + h_2 = 4032\ kJ/kg$$

3ed : vapore surriscaldato : adiab isoentropica $\Rightarrow s_3 = s_2 = 7{,}359$ kJ/kgK

$p_3 = 30$ bar } Mollier $h_3^{id} = 3625\ kJ/kg$

stato ③ h_3, p_3 } $T_3 = 745°C$, $s_3 = 7{,}185\ kJ/kgK$

④ $p_4 = p_3 = 30$ bar

sottraggo $q_{34} = -2313{,}5\ kJ/kg = h_4 - h_3$

$\rightarrow h_4 = h_3 + q_{34} = 1718{,}523\ kJ/kg$

$p_4 = 30$ bar
$T_4 = 233{,}84°C$
$h_{4e} = 1008{,}4$
$h_{4v} = 2802{,}3$
$s_{4e} = 2{,}6455$
$s_{4v} = 6{,}1837$

$h_4 = (1-x_4)h_{1e} + x_4 h_{1v}$ $\quad x_4 = \frac{h_4 - h_{4e}}{h_{4v} - h_{4e}} = 0{,}396$

$s_4 = (1-x_4)s_{4e} + x_4 s_{4v} = 3{,}8019$

▲ Entropia generata

$S_{irr} = (s_2 - s_1) + (s_3 - s_2) + (s_4 - s_3) = s_4 - s_1 = 3{,}435\ kJ/kgK$

▲ 12 isobara

$\Delta s_{12} = s_2 - s_1 = 6{,}9928\ kJ/kg$

$\int \frac{dQ}{T} = c_p e^{\alpha p} \frac{T_2}{T_1} = 4{,}219\ kJ/kg$

19 LUGLIO 2013

ES 1

$p_1 = 1$ bar

$M_{TOT} = 10$ kg

$t_e = 50°C = T_2$

$M_{1v} = 5 M_{1e}$

$M_{TOT} = M_{1v} + M_{1e} = 5M_{1e} + M_{1e} \Rightarrow M_{1e} = \frac{M_{TOT}}{6} = 1{,}67$ kg $\rightarrow M_{1v} = 8{,}33$

$x_1 = \frac{M_{1v}}{M_{TOT}} = 0{,}833$

① $p_1 = 1$ bar
$T_1 = 99{,}632°C$
$v_{1e} = 0{,}0010434$
$v_{1v} = 1{,}694$
$h_{1e} = 417{,}51$
$h_{1v} = 2675{,}4$
$s_{1e} = 1{,}3027$
$s_{1v} = 7{,}2598$

$v_1 = v_2 = 1{,}411$
$h_1 = 2298{,}33$
$s_1 = 6{,}3583$
$u_1 = h_1 - p_1 v_1 = 2157{,}23$ kJ/kg

② $T_2 = 50°C$
$p_2 = 0{,}12335$ Pa
$v_{2e} = 0{,}0010121$
$v_{2v} = 12{,}05$
$h_{2e} = 209{,}26$
$h_{2v} = 2592{,}2$
$s_{2e} = 0{,}7035$
$s_{2v} = 8{,}0776$

$x_2 = \frac{v_2 - v_{2e}}{v_{2v} - v_{2e}} = 0{,}117$
$h_2 = 488{,}1$
$s_2 = 1{,}5663$
$u_2 = h_2 - p_2 v_2 = 470{,}695 \frac{kJ}{kg}$

- $Q - \overset{0}{L_x} = \Delta U \Rightarrow \quad Q = \Delta U = M_{TOT}(u_2 - u_1) = -16865{,}3$ kJ
- $S_{irr\,ext} = \frac{|Q|}{T_e} = 52214{,}7$ J/K

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13 SETT 2013

ES 1)

$V = 50\,\ell = 50\,dm^3 = 0{,}05$

$M_{O_2} = 32\ \frac{kg}{mol} \rightarrow R = 260$

$V_A = 100\,\ell = 0{,}1\,m^3 \rightarrow T_0, p_0$

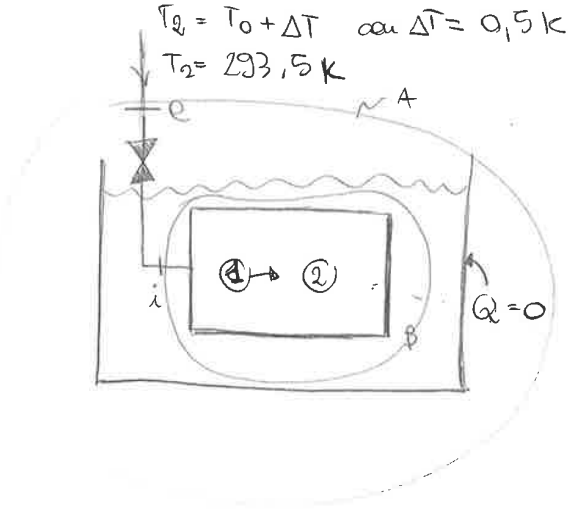
① $(p_0 = 10^5\ Pa\ ;\ T_0 = 293\,K)$ $\quad m_{O_2}\ ?$

assegnato ⓔ $\begin{cases} T_e = T_0 \\ p_e \end{cases}$

Stop $\Rightarrow$ $p_e = p_2$

$T_2 = T_0 + \Delta T$ con $\Delta T = 0{,}5\,K$

$T_2 = 293{,}5\,K$



ⓑ $\phi - \dot{W}_{vc}^{\,0} = \frac{dU}{dt} - G h_e$

$Q_G = U_2 - U_1 - (M_2 - M_1)(\mu_e + \overbrace{p_e v_e}^{RT_e}) =$

$= M_2 u_2 - M_1 u_1 - M_2 \mu_e - M_2 RT_e + M_1 \mu_e + M_1 RT_e =$

$= M_2(u_2 - \mu_e) - M_1(u_1 - \mu_e) - (M_2 - M_1)RT_e =$

$= M_2 c_v (T_2 - T_e) - M_1 c_v (T_1 - T_e) - (M_2 - M_1)RT_e$

- acqua $\Rightarrow$ $Q_A = M_{H_2O} \cdot C_{H_2O}\,(T_2 - T_1) = V_A \cdot \rho_{H_2O} \cdot C_{H_2O}\,(T_2 - T_1) = 209\ kJ$
- per il gas $Q_G < 0$ (perché lo riceve) $\Rightarrow$ $Q_G = -|Q_A|$

$M_1 = \frac{p_0 V_1}{RT_1} = 0{,}065\ kg$

$\rightarrow M_2 [c_v (T_2 - T_e) - RT_e] = Q_G + \overbrace{M_1 c_v (T_1 - T_e)}^{0} - M_1 RT_e \rightarrow M_2 = 2{,}82\ kg$

$\Delta M = 2{,}75$

8 FEB 2021

Es 1

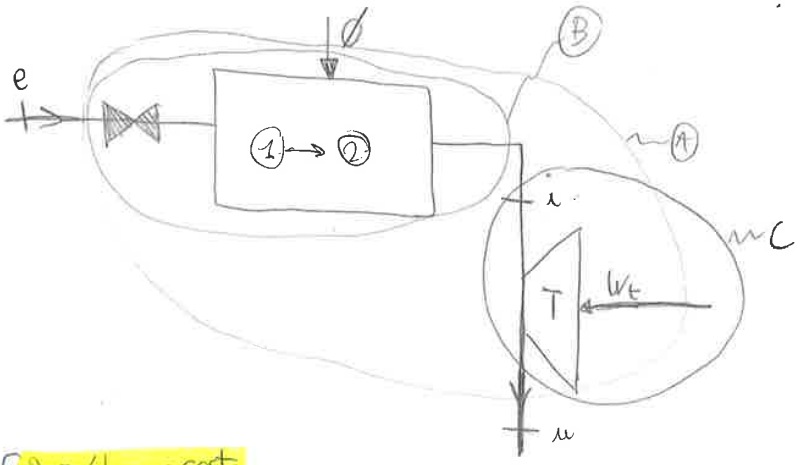
$p_1 = 4 \cdot 10^5$ Pa vapore saturo

$\eta_{s,e} = 0,75 = \frac{l_{t,e}}{l_{t,e}^{id}} = \frac{h_u - h_i}{h_u^{id} - h_i}$

$W_t = 50$ kW

acqua $\begin{cases} p_e = p_1 \\ T_e = 25°C \end{cases}$ G_e? ?$\emptyset$?Σ_{irr}

$p_u = 1$ bar



$\emptyset - W_t = \left(\frac{dU}{dt}\right)_{VC} - G_e h_e + G_u h_u$

@ liquido sottoraffreddato $T_e = 25°C$

$\begin{cases} p_s(T_e) = 3166 \text{ Pa} \\ v_{el} = 0,00100029 \\ h_{el} = 104,77 \end{cases}$

$p_1 = 4$ bar
$s_{el} = 0,367 = s_e$
$h_e = h_{el} + v_{el}(p_1 - p_s(T_e)) = 105,16 \frac{kJ}{kg}$

① $p_1 = 4$ bar $= cost$
$T_1 = 143,62$ °C
$v_{1e} = 0,0010839$
$v_{1v} = 0,4622$
$h_{1e} = 604,67$
$h_{1v} = 2737,8 = h_i$
$s_{1e} = 1,7764$
$s_{1v} = 6,8943 = s_i = s_u^{id}$

@ $p_u = 1$ bar
$T_u = 99,632$
$v_{ue} = 0,0010434$
$v_{uv} = 1,694$
$h_{ue} = 417,51$
$h_{uv} = 2675,4$
$s_{ue} = 1,3027$
$s_{uv} = 7,3598$

$x_u^{id} = \frac{s_u^{id} - s_{ue}}{s_{uv} - s_{ue}} = 0,9315$

$h_u^{id} = (1 - x_u^{id}) h_{ue} + x_u^{id} h_{uv} = 2520$

$\Downarrow$

$h_u = h_i + \eta_{s,e}(h_u^{id} - h_i) = 2574,4$

$x_u = \frac{h_u - h_{ue}}{h_{uv} - h_{ue}} = 0,95524$

$s_u = 7,0589$

▶ Sist (B) $\begin{cases} \emptyset = -G_e h_e + G_i h_i = G(h_u - h_e) = 806,5 \text{ MW} \\ G_e = G_i = G \end{cases}$

▶ Sist (C) $\begin{cases} -W_t = G h_u - G_i h_i = G(h_u - h_i) \rightarrow G = \frac{W_t}{h_i - h_u} = 306,37 \frac{kg}{s} \\ G_u = G_i = G \end{cases}$

STAZIONARIO

▶ Entropia generata

• Sistema (B) $\left(\frac{dS}{dt}\right) + \sum G_j s_j = \emptyset\left(\frac{1}{T_1} - \frac{1}{T_{amb}}\right) + G(s_i - s_e) = 275,152 \frac{kW}{K}$

$T_1 = 466,63$ K, $T_{amb} = 300$ K

• sistema (C): $\Sigma_{irr} = G(s_u - s_i) = 59,61 \frac{kW}{K}$

$\Sigma_{irr_{TOT}} = 281,13 \frac{kW}{K}$

18 FEB 2013

ES 1

$V = 0{,}05\ m^3$

$\tilde{M}_{N_2} = 28\ \frac{kg}{kmole}$ $R = 297$

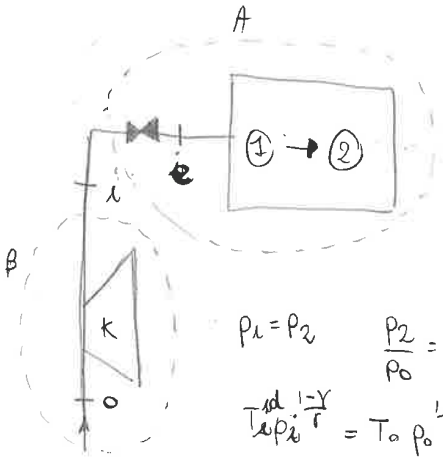
$T_1 = T_0 = 25°C$

$p_1 = p_0 = 10^5\ Pa$

$M_1 = 0$

$p_{2'} = 5 \cdot 10^5\ Pa$

$\eta_{is,c} = 0{,}7$



$p_i = p_2$ $\quad \frac{p_2}{p_0} = cost$

$T_{2p_i}^{id\ \frac{1-\gamma}{\gamma}} = T_0\, p_0^{\frac{1-\gamma}{\gamma}} \rightarrow T_i^{id} = T_0 \left(\frac{p_0}{p_2}\right)^{\frac{1-\gamma}{\gamma}} = 472k$

Sistema aperto + rigido + adiabatico (A)

$$\begin{cases} \dot{Q}^0 - \dot{W}_e^0 = \frac{dU}{dt} + \sum_j G_j h_j \rightarrow \frac{dU}{dt} - G h_i = 0 \rightarrow U_2 - U_1 - (M_2 - M_1) h_i = 0 \\ 0 = \frac{dM}{dt} - G \end{cases}$$

$M_2 u_2 - M_2 (u_i + p_i v_i) = e$ $\quad (p_i v_i = RT_i)$

$\rightarrow (u_2 - u_i) = RT_i \rightarrow c_v (T_2 - T_i) = RT_i \rightarrow T_2 = \frac{(R + c_v)}{c_v} T_i = \gamma T_i = 765{,}2\ k$

- $\eta_{is,c} = \frac{l_{t,c}^{id}}{l_{t,c}} = \frac{T_i^{id} - T_0}{T_i - T_0} \rightarrow T_i = \frac{(T_i^{id} - T_0)}{\eta_{is,c}} + T_0 = 546{,}6k$

$\rightarrow p_2 V = M_2 R T_2 \rightarrow M_2 = \frac{p_2 V}{R T_2} = 0{,}111\ kg$

$\rightarrow -l_{t_c} = c_p (T_i - T_0) \rightarrow l_{t_c} = \frac{R\gamma}{\gamma - 1} (T_0 - T_i) = -258420\ J$

Entropia => SIST B

$\left(\frac{dS}{dt}\right)_{Ve}^{0} + \sum_j^{} G_j s_j = \frac{\dot{Q}^0}{T} + \Sigma_{irr} \rightarrow \Sigma_{irr} = G(s_i - s_0) \rightarrow s_{irr} = M_2 (s_i - s_0) =$

$= M_2 \left[c_p \log\left(\frac{T_i}{T_0}\right) - R \log \frac{p_2}{p_i} \frac{p_2}{p_0} \right] = 16{,}7841\ J/kg\,k$

29 GENNAIO 2015

ES 1

$V = 0{,}05\ m^3$ $\quad \gamma = \frac{4}{3}$ $\quad$ gas VdW $\quad b = 0{,}4\ \frac{m^3}{kmol}$

$\Delta p = 20\ kPa$

$\Delta T = 9{,}0\ K$

$$p + \frac{a}{V^2} = \frac{m\bar{R}T}{V - b\cdot m}$$

$$\left(p_2 + \frac{a}{V^2}\right) - \left(p_1 + \frac{a}{V^2}\right) = \frac{m\bar{R}T_2}{V - bm} - \frac{m\bar{R}T_1}{V - b\cdot m}$$

$$(p_2 - p_1) = m\bar{R}\,\frac{(T_2 - T_1)}{V - b\cdot m} \rightarrow m = \frac{(p_2 - p_1)(V - bm)}{(T_2 - T_1)} = \frac{\Delta p\,(V - bm)}{\Delta T} \Rightarrow m = 5{,}5\ mol$$

Ciclo

▶ $Q - L = \Delta U \Rightarrow Q = \Delta U = M(u_2 - u_1) = Mc_v(T_2 - T_1) = Mc_v\Delta T = m\cdot\bar{M}\,\frac{\bar{R}}{\gamma - 1}\Delta T =$

$= m\,\frac{\bar{R}}{\gamma - 1}\Delta T = 2763{,}72\ J$

▶ gas ideale $\quad pV = m\bar{R}T \rightarrow \Delta pV = m\bar{R}\Delta T \rightarrow m = \frac{\Delta pV}{\bar{R}\Delta T} = 6\ mol$

$Q = \Delta U = n\,\frac{\bar{R}}{\gamma - 1}\Delta T = 29931\ J$

$$\rightarrow T_{A2} = \frac{p_{A2} V_{A2}}{m_{A2} \cdot \bar{R}} = 282{,}3\ K$$

Entropia

$$\frac{dS}{dt} + \Sigma \dot{G}_j S_j = \frac{\dot{\emptyset}}{T} + \Sigma_{irr} \rightarrow S_{irr} = S_2 - S_1 - (M_2 - M_1) s_e =$$

$$= M_2 s_2 - M_1 s_1 - (M_2 - M_1) s_e = M_2 (s_2 - s_e) - M_1 (s_1 - s_e) =$$

$$= M_2 \left[c_p \log\left(\frac{T_{A2}}{T_e}\right) - R \log\left(\frac{p_{A2}}{p_e}\right) \right] - M_1 \left[c_p \log\left(\frac{T_{A1}}{T_e}\right) - R \log\left(\frac{p_{A1}}{p_e}\right) \right] =$$

$$= \left[m_{A2} \cdot \bar{M}_A \cdot \frac{\bar{R}/\bar{M}_A \cdot \gamma_A}{\gamma - 1} \log\left(\frac{T_{A2}}{T_e}\right) - m_{A2} \bar{M}_A \frac{\bar{R}}{\bar{M}_A} \log\left(\frac{p_{A1}}{p_e}\right) \right] - \left[m_{A1} \frac{\bar{R} \gamma_A}{\gamma_A - 1} \log\left(\frac{T_{A1}}{T_e}\right) - m_{A1} \bar{R} \log\left(\frac{p_{A2}}{p_e}\right) \right] =$$

$$= m_{A2} \frac{\bar{R} \gamma_A}{\gamma_A - 1} \log \frac{T_{A2}}{T_e} - m_{A2} \bar{R} \log \frac{p_{A2}}{p_e} - m_{A1} \frac{\bar{R} \gamma_A}{\gamma_A - 1} \log \frac{T_{A1}}{T_e} + m_{A1} \bar{R} \log \frac{p_{A1}}{p_e} =$$

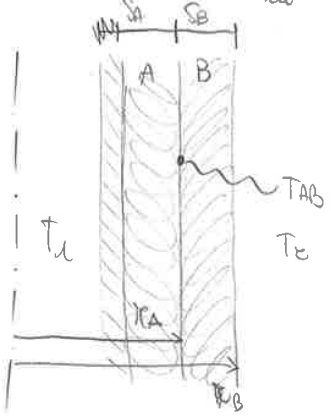
ES 3

$r_i = 0{,}005\ m$ $\quad T_i = 80\ K$ $\quad \alpha_i = 150\ \frac{W}{m^2 K}$

$T_e = 293\ K$ $\quad \alpha_e = 5\ \frac{W}{m^2 K}$

A: $S_A = 0{,}04\ m$ $\quad \lambda_A = 902\ \frac{W}{m K}$

B: $S_B = 0{,}01\ m$ $\quad \lambda_B = 0{,}2\ \frac{W}{m K}$



$$\varphi_L = \frac{2\pi (T_e - T_i)}{\frac{1}{\lambda_B} \log\left(\frac{r_B}{r_A}\right) + \frac{1}{\lambda_A} \log\left(\frac{r_A}{r_i}\right) + \frac{1}{\alpha_i r_i} + \frac{1}{\alpha_e r_B}} = 11{,}55\ \frac{W}{m}$$

$$\varphi_L = \frac{(T_{AB} - T_e) 2\pi}{\frac{1}{\lambda_B} \log \frac{r_B}{r_A} + \frac{1}{\alpha_e r_B}}$$

$r_B = 0{,}055$

$r_A = 0{,}045$

$$T_{AB} = T_e + \frac{\varphi_L}{2\pi} \left(\frac{1}{\lambda_B} \log \frac{r_B}{r_A} + \frac{1}{\alpha_e r_B} \right) = 301{,}53\ K$$

$$r_{cA} = \frac{\lambda_A}{\alpha_e} = 0{,}004\ m \qquad r_{cB} = \frac{\lambda_B}{\alpha_e} = 0{,}04$$

$r_c < r_e \Rightarrow r_c = r_{cA} = 0{,}004$

ES 2

$G = 1\ kg/s \quad R = 207{,}85 \quad \gamma = 5/3$

$T_{in} = 50°C = 323{,}15$

$A_u = 50 \cdot 10^{-4}\ m^2$

$\Phi = 500\ W$

$c_p = \frac{R\gamma}{\gamma - 1} = 519{,}625$

$p = cost = 10^5\ Pa$

$e_{c_u} = 0$

? T_u

- $p v = RT \rightarrow \frac{1}{v} = \frac{p}{RT} = \rho = 1{,}49$
- $G = \rho A_u \cdot w \rightarrow w = \frac{G}{\rho \cdot A_{in}} = 134{,}228\ \frac{m}{s}$
- 1° principio

$$\Phi - \dot{W}_t^{\,0} = G(\Delta h) + G\Delta e_c \rightarrow \Phi = G c_p (T_u - T_{in}) + G\left(0 - \frac{w^2}{2}\right)$$

$$T_u = \frac{-\Phi + G\frac{w^2}{2} + G c_p T_u}{G c_p} = 341{,}45$$

$$\Sigma_{irr} = \frac{\Phi}{T_u} = 1{,}46\ \frac{W}{K}$$

ES 3

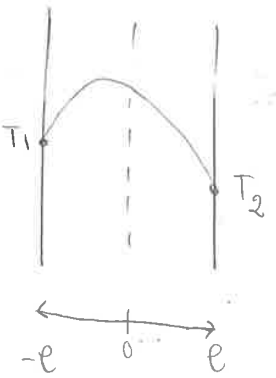
$S = 0{,}015\ m = 2e$

$H = 50\ \frac{kW}{m^3}$

$\lambda = 0{,}13\ \frac{W}{mK}$

$T_1 = 323\ k$

$T_2 = 303\ k$



$$\varphi_1 = -\lambda\left[-\frac{H}{\lambda}(-e) + \frac{T_2 - T_1}{2e}\right] = 25\ \frac{W}{m^2}$$

$$\varphi_2 = -\lambda\left[-\frac{H}{\lambda}(e) + \frac{T_2 - T_1}{2e}\right] = 775\ \frac{W}{m^2}$$

$$x_{max} = \frac{\lambda(T_2 - T_1)}{2eH} = -8 \cdot 10^{-3}$$

$$T_{max} = \left[\frac{T_2 + T_1}{2} + \frac{H}{2\lambda}(e^2 - x^2) + \frac{T_2 - T_1}{2} \cdot \frac{x}{e}\right]_{x = (-8 \cdot 10^{-3})} = 393{,}3\ k$$

ES 3

$\lambda = 15 \frac{W}{mK}$

$a = 3,9 \cdot 10^{-6} \ m^2/s = \frac{\lambda}{\rho \cdot c} \Rightarrow \rho \cdot c = \frac{\lambda}{a} = 3,85 \cdot 10^6$

$d = 0,01 m \Rightarrow V = \frac{4}{3}\pi r^3 = 5,23 \cdot 10^{-7} \ m^3$

1° TRANSITORIO: $H = 1,2 \cdot 10^9 \frac{W}{m^3}$ $t = 2s$ $\Phi_s = 0$

2° TRANSITORIO: Raffreddamento

$B_i = 0,5$

FASE 1

$k = 2,016$ $\quad cost = HV$

$\Phi_G = \underbrace{(\rho \cdot c \cdot V)}_{k} \frac{dT(t)}{dt} \rightarrow \Phi_G = k \frac{dT(t)}{dt} \rightarrow \Phi_G \int_0^t dt = k \Delta T \Rightarrow \Delta T = \frac{\Phi_G \cdot t}{k} =$

$= 0,002 °C$

FASE 2

$\frac{V}{S} = \frac{\frac{4}{3}\pi r^3}{4\pi r^2} = \frac{r}{3}$

$B_i = \frac{\alpha \cdot L}{\lambda} = \frac{\alpha r}{3\lambda} \rightarrow \alpha = \frac{3\lambda B_i}{r} = 4500 \frac{W}{m^2 K}$

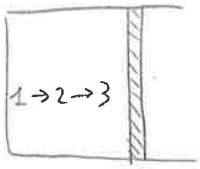
$t_0 = \frac{\rho c \cdot V}{\alpha S} = \frac{\rho c r}{3\alpha} = 1,426 s$

$\gamma = 0,95 \rightarrow \Delta t = [-\log(1-0,95)] t_0 = 4,3 s$

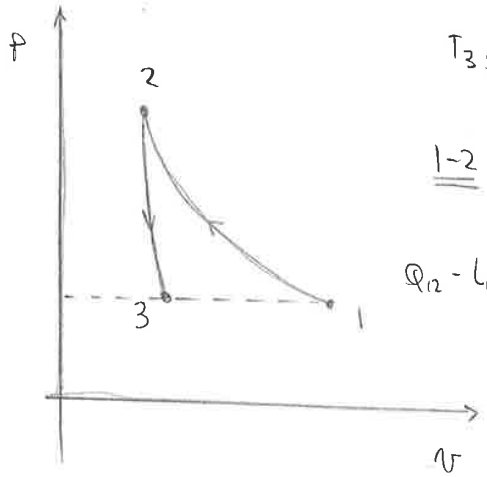
ES 2

$m = 1\,mol = 10^{-3}\,kmol$

$\bar{M} = 14\ kg/kmol \rightarrow M = 14 \cdot 10^{-3}\ kg$ $\quad R = 594$ $\quad c_v = 1782$



① $\begin{cases} T_1 = 323\,k \\ p_1 = 150\,kPa \\ v_1 = \frac{RT_1}{p_1} = 1{,}28\ \frac{m^3}{kg} \end{cases}$ $\xrightarrow[\text{isoterma rev}]{\text{comprimere}}$ ② $\begin{cases} T_2 = T_1 \\ \quad \end{cases}$ $\xrightarrow[\text{adiab rev}]{\text{espandere}}$ $\begin{cases} p_3 = p_1 = 150\,kPa \\ v_3 = 1{,}023\ \frac{m^3}{kg} \\ T_3 = \frac{p_3 v_3}{R} = 258{,}3\,k \end{cases}$



$T_3 p_3^{\frac{1-\gamma}{\gamma}} = T_2 p_2^{\frac{1-\gamma}{\gamma}} \rightarrow p_2 = p_3 \left(\frac{T_3}{T_2}\right)^{\frac{\gamma}{1-\gamma}} = 366778{,}9\,Pa$

1-2 $\quad l_t^{id} = -RT_1 \ln\left(\frac{p_2}{p_1}\right) = -171548{,}142\ \frac{J}{kg} \rightarrow L_{12} = -2402\,J$

$Q_{12} - L_{12} = \Delta U_{12}^{0} \Rightarrow Q_{12} = L_{12} = Q_{TOT}$

2-3 $\quad l_v^{id} = \frac{R}{1-\gamma}(T_3 - T_2) = 115295{,}4\,J/kg$

$L_{23} = 1614{,}13$

$L_{TOT} = L_{12} + L_{23} = -787{,}9\,J$

ES 3

$\lambda = 200\ \frac{W}{mK}$ $\quad s = 0{,}002\,m$ $\quad L = 0{,}025\,m$ $\quad b = 0{,}1\,m$ $\quad w_\infty = 2\,m/s$

$A = b \cdot s = 0{,}0002\,m^2$

$P = 2b + 2s = 0{,}204\,m$

fluido: $T_0 = 298\,k$ $\quad p_0 = 10^5\,Pa$ $\quad \nu = 15 \cdot 10^{-6}\ \frac{m^2}{s}$ $\quad \lambda_a = 0{,}03\ \frac{W}{mK}$ $\quad c_{p,a} = 1004{,}5$ $\quad Pr \simeq 1 = 0{,}7141$

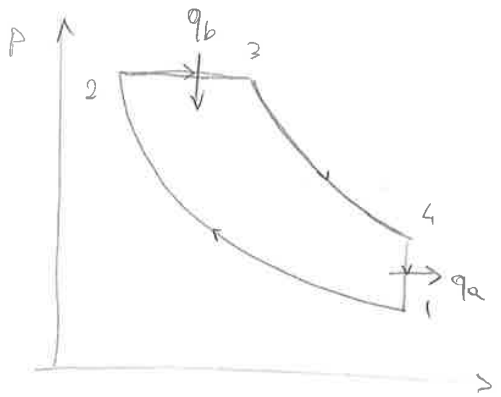
$Re = \frac{w_\infty \cdot L}{\nu} = 3333{,}33 \rightarrow$ transizione

$Nu = \frac{\alpha L}{\lambda_a} = 0{,}664 \cdot Re|_{x=L}^{0{,}5} \cdot Pr^{\frac{1}{3}} = 34{,}266$

$\Rightarrow \alpha = \frac{\lambda_a Nu}{L} = 41{,}12\ \frac{W}{m^2 K}$

$\beta = \sqrt{\frac{\alpha P}{\lambda A}} = 14{,}5$ $\quad \eta_{al} = \frac{\tanh(\beta \cdot L)}{\beta L} = 0{,}96$

(ES 2)



$\eta = 1 - \frac{|q_a|}{q_b}$

$|q_a| = c_v (T_4 - T_1)$

$q_b = c_p (T_3 - T_2)$

$\tau_v = \frac{v_1}{v_2} = \frac{v_4}{v_2}$

$\tau_c = \frac{v_3}{v_2}$

$\ell_{t,m} = q_b - |q_a|$

$T_1 = 313$

$p_1 = 1,5 \cdot 10^5$ Pa

$T_3 = 1873$

$p_3 = 35 \cdot 10^5$ Pa $= p_2$

$p_1 v_1 = R T_1 \quad v_1 = \frac{R T_1}{p_1} = 0,599 \frac{m^3}{kg} = v_4 \qquad v_3 = \frac{R T_3}{p_3} = 0,153586$

$p_1 v_1^{\gamma} = p_2 v_2^{\gamma} \rightarrow \quad v_2 = v_1 \left(\frac{p_1}{p_2}\right)^{\frac{1}{\gamma}} = 0,06313 \frac{m^3}{kg}$

$p_2 v_2 = R T_2 \rightarrow \quad T_2 = \frac{p_2 v_2}{R} = 769,83\ k$

$T_3 v_3^{\gamma-1} = T_4 v_4^{\gamma-1} \rightarrow T_4 = T_3 \left(\frac{v_3}{v_4}\right)^{\gamma-1} = 1087\ k$

$|q_a| = c_v (T_4 - T_1) = 555345$

$q_b = 1108136,3$

$\ell_{t,n} = 553 \frac{kJ}{kg} \qquad \eta = 0,499$

(ES 3)

$T_0 = 20°C = 293\ k$

$T_e = 80\ k$

$t = 3s \rightarrow \Delta T = 200°C$

$\lambda = \infty$

$\Theta_0 = T_0 - T_e = 213°C$

- $T_1 = 20°C - 200°C = -180°C = 93\ k \qquad \Theta(t=3s) = T_1 - T_e = 13$
- $\Theta(t=3s) = 13 = \Theta_0 e^{-\frac{t}{t_0}} \rightarrow \log\left[\frac{13}{\Theta_0}\right] = -\frac{t}{t_0} \rightarrow t_0 = -\frac{t}{\log\left(\frac{13}{\Theta_0}\right)} = 1,073\ s$

ES 2

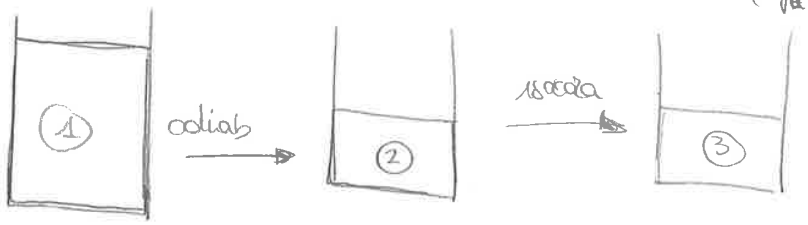
(a) $n_{N_2} = 5 \cdot 10^{-3}$ kmol $\quad \gamma_a = 1,4$ $\quad$ (1) $T_0 = 25°C = 298\,K = T_1$, $P_0 = 10^5\,Pa = p_1$

$\tilde{M}_{N_2} = 28 \frac{kg}{kmol} \quad M_a = 0,14\,kg$

(2) $p_2 = 2 \cdot 10^5\,Pa$ $\quad$ (3) $T_3 = T_0$

(b) $n_{CO_2} = 6 \cdot 10^{-3}$ kmol $\quad \gamma_b = \frac{4}{3}$ $\quad$ adiab + isocora (reversibili)

$\tilde{M}_{CO_2} = 44 \frac{kg}{kmol} \quad M_b = 0,264\,kg \quad M_{TOT} = 0,404\,kg$ $\quad \begin{cases} x_a = 0,346 ; x_b = 0,654 \\ y_a = 0,454 ; y_b = 0,546 \end{cases}$



$R_a = 297 \quad R_b = 189 \rightarrow R = x_a R_a + x_b R_b = 226,37$

$c_{pa} = 1039,5 \quad c_{pb} = 756 \rightarrow c_p = x_a c_{pa} + x_b c_{pb} = 854,1$

$c_{va} = 742,5 \quad c_{vb} = 567 \rightarrow c_v = x_a c_{va} + x_b c_{vb} = 628$

$\gamma = \frac{c_p}{c_v} = 1,36$

1-2 compressione adiab

$p_1 V_1 = MRT_1 \rightarrow V_1 = \frac{MRT_1}{p_1} = 0,2725\,m^3$

$p_1 V_1^{\gamma} = p_2 V_2^{\gamma} \rightarrow V_2 = \left(\frac{p_1}{p_2}\right)^{\frac{1}{\gamma}} V_1 = 0,164\,m^3$

$T_2 = \frac{p_2 V_2}{MR} = 358\,k$

▲ SIST chiuso

$l_t = \frac{R\gamma}{1-\gamma}(T_2 - T_1) = -51310 \frac{J}{kg} \rightarrow L_t = 20729\,J$

2-3 isocora

$Q - L_t = \Delta U = M c_v (T_3 - T_2) = -15223\,J$

$P_3 = \frac{MRT_3}{V_3} = 166178\,Pa$

▲ 2-3 $\rightarrow S_{irr} = S_3 - S_2 + \frac{|Q|}{T} = M\left[c_p \ln \frac{T_3}{T_2} - R \ln \frac{P_3}{P_2}\right] + \frac{|Q|}{T_0} = 4,73\,J/K$

23 FEB 2011

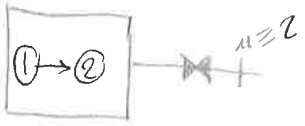
ES 1 $V = 0{,}185\ m^3$

① $T_1 = 260°C$, $P_1 = 46{,}943$ bar, $v_{1e} = 0{,}0012756$, $v_{1v} = 0{,}04213$, $h_{1e} = 1134{,}9$, $h_{1v} = 2796{,}4$, $s_{1e} = 2{,}8248$, $s_{1v} = 6{,}0010$

$x_1 = 0{,}7$, $v_1 = 0{,}02999$, $h_1 = 2297{,}95$, $s_1 = 5{,}06614$, $u_1 = h_1 - p_1 v_1 = 2157{,}59$

② $p = cost$, $T = cost$ → saturo (vapore)

$u_2 = h_{1v} - p_1 v_{1v} = 2598{,}63$



$\emptyset - \cancel{W_{tc}}^{0} = \frac{dU}{dt} + G h_u \rightarrow Q = U_2 - U_1 - (M_2 - M_1)(n_u)$

$M_1 = \frac{V}{v_1} = 28{,}43\ kg$ $M_{1v} = 19{,}9\ kg$ $M_2 = \frac{V}{v_2} = \frac{V}{v_{1v}} = 20{,}2\ kg = M_{2v}$

$\frac{M_{1v}}{M_{2v}} = 0{,}986$

$\rightarrow Q = M_2 u_2 - M_1 u_1 - (M_2 - M_1) h_2 = 14166{,}414\ kJ$

ES 2

$\overline{M}_{CO_2} = 44\ \frac{kg}{kmol}$ $R = 189$ $c_p = 756$ $c_v = 567$

$\eta_{is,c} = 0{,}8 = \frac{l_{t,c}^{id}}{l_{t,c}} = \frac{T_2^{id} - T_1}{T_2 - T_1} \rightarrow T_2 = T_1 + \frac{T_2^{id} - T_1}{\eta} \rightarrow \boxed{\frac{T_2}{T_1} = 1 + \frac{\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1}{\eta}} =$

$\boxed{r_p = \frac{p_2}{p_1} = 15}$

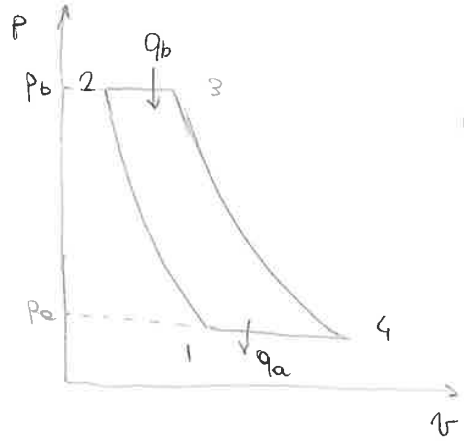
$T_2^{id}\, p_2^{\frac{1-\gamma}{\gamma}} = T_1 p_1^{\frac{1-\gamma}{\gamma}} \rightarrow \frac{T_2^{id}}{T_1} = \left(\frac{p_1}{p_2}\right)^{\frac{1-\gamma}{\gamma}}$

$\eta_c = \frac{\log r_p}{\log r_p - \log\left[1 + \frac{r_p^{\frac{\gamma-1}{\gamma}} - 1}{\eta_{is}}\right]} = 1{,}4141 \rightarrow c_c = c_v \frac{\gamma - m_c}{1 - m_c} = 110{,}6$

$\Delta s = s_{ver} = c_p \log\left(\frac{T_2}{T_1}\right) - R \log\left(\frac{p_2}{p_1}\right) = 88\ J/kgK$

12 LUGLIO 2011

ES 1) Ciclo Joule aria standard



$\frac{|q_a|}{q_b} = r_p^{\frac{1-\gamma}{\gamma}}$

$\gamma_b = 4$

$T_1 = 15°C = 288\ K$

$\Delta s_{max} = 0{,}6\ \frac{kJ}{kg\,K}$

$\frac{T_1}{T_2} = \frac{T_4}{T_3} = r_p^{\frac{1-\gamma}{\gamma}} \rightarrow T_2 = \frac{T_1}{r_p^{\frac{1-\gamma}{\gamma}}} = 428\ K$

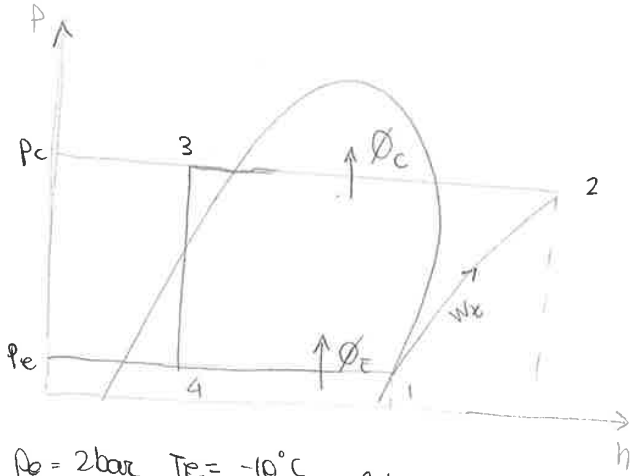
$\Delta s = c_p \ln\frac{T_3}{T_2} \rightarrow e^{\left(\frac{\Delta s}{c_p}\right)} = \frac{T_3}{T_2} \rightarrow T_3 = T_2\, e^{\frac{\Delta s}{c_p}} = 778\ K$

$T_4 = T_3 \cdot \frac{T_1}{T_2} = 523{,}5\ K$

$|q_a| = c_p (T_4 - T_1) = 236{,}6\ kJ/kg$

$q_b = c_p (T_3 - T_2) = 351{,}6\ kJ$

ES 2



$P_e = 2 \cdot 10^5\ Pa$

$P_c = 15 \cdot 10^5 P_a$

$G = 0{,}022\ kg/s$

$COP = 3{,}5 = \frac{h_2 - h_3}{h_2 - h_1}$

$l_{tc} = h_2 - h_1$

$|\Phi_c| = h_2 - h_3$

$x_4 = 0{,}25$

$h_1 - h_4 = 160\ \frac{kJ}{kg}$

- $P_b = 2\ bar$ $T_e = -10°C$

$v_e = 0{,}000\,1545$

$v_v = 0{,}09956$

$h_e = 186{,}7$

$h_v = 392{,}9$

$S_e = 0{,}9507$

$S_v = 1{,}7341$

① $\begin{cases} h_1 = 392{,}9 \\ v_1 = 0{,}09956 \\ S_1 = 1{,}7341 \end{cases}$

④ $\begin{cases} h_4 = 238{,}25 \\ v_4 = 0{,}02545 \\ S_4 = 1{,}14655 \end{cases}$

- $P_c = 15\ bar$ $T_c = 55°C$

$v_e = 0{,}0009277$

$v_v = 0{,}01315$

$h_e = 279{,}18$

$h_v = 425{,}8$

$S_e = 1{,}2622$

$S_v = 1{,}7064$

③ $h_3 = h_4 = 238{,}25$

② $P_2 = 1{,}5\ MPa$, $S_2 = S_1 = 1{,}7341$ $\Big\}\ h_2 = 432\ \frac{kJ}{kg}$

$W_{t,c} = G \cdot l_{t,c} = G(h_2 - h_1) = 860{,}2\ W$

$|\Phi_c| = G(h_2 - h_3) = 4262{,}5\ W$

8 SETTEMBRE 2011

ES 1 $\gamma = 1,4$

① $\begin{cases} P_1 = 1 \text{ bar} = 10^5 \text{ Pa} \\ T_1 = T_0 = 298 \text{ K} \end{cases}$ —adiab→ $P_2 = P_e = 25 \text{ bar}$, $T_e = -60°C = 213$ — e → ⋈ — ①→②

$\dot{Q}^{\,0} - \dot{W}_t^{\,0} = \frac{dU}{dt} + \sum_j \pm G_j h_j \rightarrow U_2 - U_1 - G(h_e) = 0$ ($h_e = u_e + Pe v_e$) $\rightarrow M_2 u_2 - M_1 u_1 - (M_2 - M_1)(u_e + RT_e) = 0$

$+ M_2(u_2 - u_e) - M_1(u_1 - u_e) - (M_2 - M_1)RT_e = 0 \Rightarrow M_2 c_v (T_2 - T_e) - M_1 c_v (T_1 - T_e) - (M_2 - M_1)RT_e = 0$

$M_2 [c_v T_2 - c_v T_e - RT_e] = M_1 [c_v T_1 - c_v T_e - RT_e]$

$\frac{M_2}{M_1} [c_v T_2 - c_p T_e] = c_v T_1 - c_p T_e$

$P_1 V = M_1 R T_1$

$P_2 V = M_2 R T_2$

$\frac{M_2}{M_1} = \frac{P_2 V}{RT_2} \cdot \frac{RT_1}{P_1 V} = \frac{P_2}{P_1} \cdot \frac{T_1}{T_2} = 24,92$

$\rightarrow \frac{P_2 T_1}{P_1 T_2} \cdot c_v T_2 = \frac{P_2 T_1}{P_1 T_2} c_p T_e = c_v T_1 - c_p T_e \rightarrow c_p \frac{P_2 T_1 T_e}{P_1 T_2} = \frac{c_v P_2 T_1}{P_1} - c_v T_1 + c_p T_e$

$(T_2) = \frac{c_p P_2 T_1 T_e}{P_1 \left[\frac{c_v P_2 T_1}{P_1} - c_v T_1 + c_p T_e\right]} = \frac{\gamma}{c_v} \cdot \frac{P_2 T_1 T_e}{P_1 \left[\frac{P_2 T_1}{P_1} - T_1 + \frac{\gamma}{c_v} T_e\right]} = 299 \text{ K}$

$\rightarrow \frac{dS}{dt} - G s_e = \frac{\dot{Q}^{\,0}}{T} + \Sigma_{irr} \rightarrow S_{irr} = M_2 s_2 - M_1 s_1 - (M_2 - M_1) s_e = M_2 (s_2 - s_e) - M_1 (s_1 - s_e) \Rightarrow$

$\frac{S_{irr}}{M_1} = \frac{M_2}{M_1} \left[c_p \log \frac{T_2}{T_e}\right] - \left[c_p \log \frac{T_1}{T_e} - R \log \frac{P_1}{P_e}\right] =$

T_2

19 GEN 2010

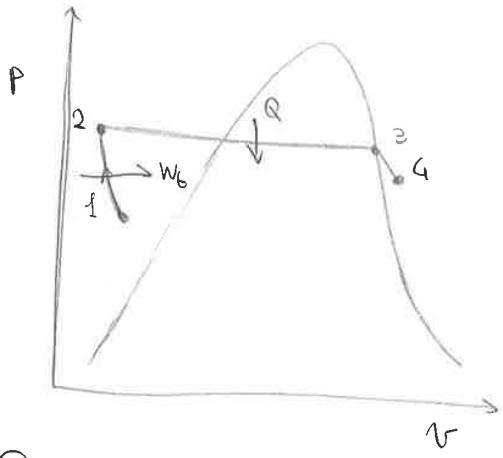
ESI $G = 0{,}167\ kg/s$

① $T_1 = 20°C = 293\ K$, $p_1 = 1\ bar = 10^5\ Pa$ } sottoraffreddato

1→2 comprimere adiab rev ② { $s_1 = s_2$, liquido saturo, $p_2 = 2\ bar$

2→3 { fornire calore, per completo vaporizzazione

③ → laminazione ⇒ { $h_3 = h_4$, $p_4 = 2\ bar$, $T_4 = 150°C$



Trasf 1-2 : compressione adiab rev : $Q = 0$ ($\phi = 0$)

$T_1 = 20°C$
$p_s = 0{,}02337$
$v_{1e} = 0{,}0010017$
$v_{1v} = 57{,}84$
$h_{1e} = 83{,}86$
$h_{1v} = 2538{,}2$
$s_{1e} = 0{,}2963$
$s_{1v} = 8{,}6684$

① { $v_1 = v_{1e}$, $s_1 = s_{1e}$, $h_1 = h_{1e} + v_{1e}(p_1 - p_s(T_1)) = 83{,}958\ kJ/kg$, $u_1 = u_{1e} = h_{1e} - p_s(T_1)\cdot v_{1e} = 83{,}858\ kJ/kg$

→ $l_{t,c} = h_2 - h_1 = -\int_1^2 v\,dp = -v_{1e}(p_2 - p_1)$ (cost)

$= -6{,}412\ J/kg$

• $W_{t,c} = G \cdot l_{t,c} = -1{,}071\ W$

② $p_2 = p_3 = 65\ bar$
$s_2 = s_1 = 0{,}2963$

④ $T_4 = 150°C$, $p_4 = 2\ bar$ } $h_4 = h_3 = h_{3v} = 2779{,}5\ kJ/kg$ → cerco lo stato saturo h_{3v} sulle tabelle!
$s_4 = 7{,}2785\ kJ/kgK$

③ $h_3 = h_{3v}$

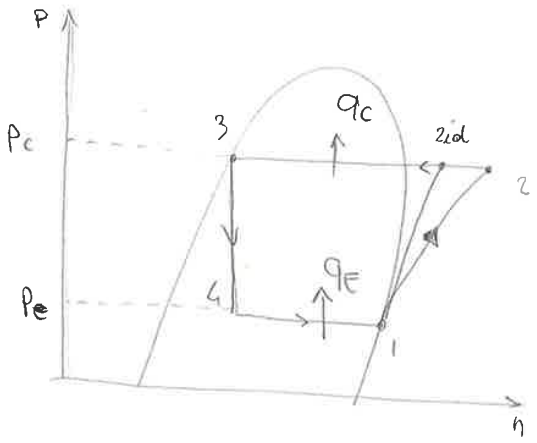
$h_2 = l_{t,c} + h_1 = 77547\ J/kg$

$q = h_3 - h_2 = 2701953\ J/kg$ → $\phi = G \cdot q = 451{,}23\ kW$

30 FEB 2010

ES 1)

$$\eta_{is,C} = \frac{h_2^{id} - h_1}{h_2 - h_1}$$



$T_E = -20°C$

$T_C = 40°C$

$$COP = \frac{q_E}{|e_{t,C}|} = \frac{h_1 - h_4}{h_2 - h_1} = 2,5$$

① $\begin{cases} T_E = -20°C = T_1 \\ P_E = 1,33 \text{ bar} \\ h_{1v} = h_1 = 386,8 \text{ kJ/kg} \\ S_1 = 1,7422 = S_2^{id} \end{cases} \Rightarrow 2^{id} \begin{cases} P_2 = 10,18 \text{ bar} \\ S_2^{id} = S_1 \end{cases} \Rightarrow h_2^{id} = < h_2$

③ $P_3 = 10,18 \text{ bar}$

$h_3 = h_{3e} = 256,8 = h_4$

$$\rightarrow h_2 = h_1 + \frac{h_1 - h_4}{COP} = 438,8$$

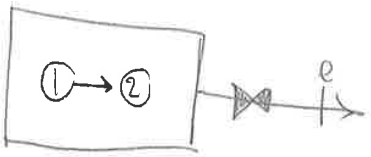
ES 2)

$V = 0,1 \text{ m}^3$ $\quad P_1 V = M R T_1 \rightarrow M_1 = \frac{P_1 V}{R T_1} = 6,45 \text{ kg}$ $\quad M_2 = \frac{P_2 V}{R T_1} = 0,26 \Rightarrow \Delta M = 6,2 \text{ kg}$

O_2 $\quad R = 260$ $\quad c_p = 909,4$ $\quad c_v = 649,55$

$P_1 = 50 \text{ bar}$

$P_2 = 2 \text{ bar}$ $\quad T = 298 \text{ k} = \text{cost} = T_e$



$$\phi - \cancel{W_t}^{0} = \frac{dU}{dt} + G_{he}$$

$$Q = U_2 - U_1 - (M_2 - M_1)(u_e + p_e v_e) = (M_2 - M_1)(\cancel{u_2}^{0} - u_e)$$

$$-(M_2 - M_1) R T_e = \Delta M R T_1 = 47946 \text{ J} > 0 \text{ fornito}$$

$$\frac{dS}{dt} + \Sigma_j G_j S_j = + \Sigma_{irr} \rightarrow S_{irr} = -(M_2 - M_1) S_e + M_2 S_2 - M_1 S_1 =$$

$$= -M_2(S_e - S_2) + M_1(S_e - S_1) = +M_2 R \cancel{\log \frac{P_e}{P_2}}^{0} - M_1 \log \frac{P_e}{P_1} = 21 \text{ J/k} \approx 0$$

internamente reversibile

10 SETT 2012

ES 1

$\begin{cases} T_e = 298\ k = 25°C \\ P_e = 2 \cdot 10^5\ P_a = 2\ bar \end{cases}$ $M_p = 15\ kg$, $S_p = 10 \cdot 10^{-4}\ m^2$ $k = 10\ kN/m$

① $\begin{cases} M = 0{,}01\ kg \\ T_1 = T_e \\ P_1 = P_e \end{cases}$ ② Vapore umido $\Delta z = 0{,}2\ m$

Sist chiuso: $Q - L_t = \Delta U \rightarrow Q = L_t + M(u_2 - u_1)$

- Stato 1

$T_1 = 25°C$
$P_s(T_1) = 0{,}03166\ bar$
$v_{1e} = 0{,}0010029$
$v_{1v} = 43{,}40$
$h_{1e} = 104{,}77$
$h_{1v} = 2547{,}3$
$s_{1e} = 0{,}3670$
$s_{1v} = 8{,}1592$

$v_1 = v_{1e} = 0{,}0010029\ m^3/kg \Rightarrow v_1 = \frac{V_1}{M} \rightarrow V_1 = M v_1 = 1{,}0029 \cdot 10^{-5}\ m^3$
$s_1 = s_{1e}$
$h_1 = h_{1e} + v_{1e}\left[P_1 - P_s(T_1)\right] = 104{,}967\ kJ/kg$
$u_1 = u_{1e} = h_{1e} - P_s(T_1) v_{1e} = 104{,}767\ kJ/kg$

- Teo en cinetica

$L_t = L_0 + L_t + \cancel{\Delta_0}^{0} + \cancel{\Delta E_p}^{0} + \Delta E_c$

$L_0 = P_e \Delta V = P_e \cdot S_p \cdot \Delta z = 40\ J$
$L_t = k\frac{\Delta z^2}{2} = 200\ J$
$\rightarrow L_t = 240\ J$

- Equilibrio forze $P = \frac{F}{S}$

① $M_p \cdot g + P_e S_p = P_1 S_p \rightarrow P_1 = \frac{M_p \cdot g + P_e S_p}{S_p}$

② $M_p \cdot g + k\Delta z + P_e \cdot S_p = P_2 S_p \quad P_2 = 2347150\ P_a = 23{,}5\ bar$

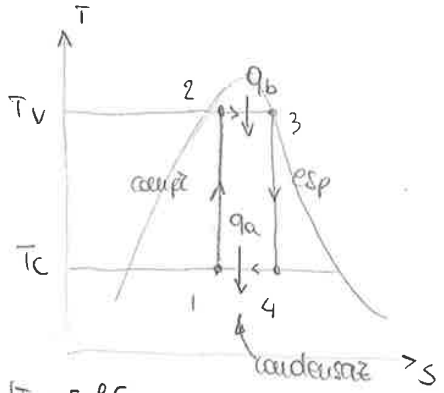
$u_2 = h_2 - P_2 v_2 = 2601{,}125\ kJ/kg$

$\rightarrow Q = L_t + M(u_2 - u_1) = 25203{,}6\ J$

2 LUGLIO 2013

ES 1

$\eta = \frac{L(c)}{Q^+} = 1 - \frac{|Q^-|}{Q^+} = 1 - \frac{T^-}{T^+} = 0,3 = 1 - \frac{T_C}{T_V}$ $\quad \ell_m ? \quad x_4 ?$



$T_C = 50°C = 323\,k$

$\frac{T_C}{T_V} = 1 - \eta_t \rightarrow T_V = \frac{T_C}{1-\eta_t} = 461\,k$

- $T_V = 188°C$
- $P_s(T_V) = P_V = 12,551\,bar$
- $h_{le} = 807,53$
- $h_V = 2784,3$
- $s_e = 2,2356$
- $s_V = 6,5036$

calore specifico $x_e = 1976,78$

$\rightarrow q_b = 0,8 \cdot x = 1581,424$

- $T_C = 50°C$
- $P_C = 0,12335\,bar$
- $h_{le} = 209,26$
- $h_V = 2592,2$
- $s_e = 0,7035$
- $s_V = 8,0776$

$\rightarrow x_4 = \frac{s_4 - s_{4e}}{s_{4v} - s_{4e}} = 0,786$

$s_3 = s_4 = 6,5036$

$h_2 = h_{3v} - q_b = 1202,876 \rightarrow x_2 = \frac{h_2 - h_{le}}{h_{2v} - h_{le}} = 0,2$

$s_2 = 3,0892 = s_1$

$|q_a| = T_C(s_4 - s_1) = 1102,85$

$\ell_M = q_b - |q_a| = 478,6 \frac{kJ}{kg}$

ES 2

$G_A = 0,0278 \frac{kg}{s}$ $\quad \bar{M}_A = 4\,kg/kmol$; $\gamma_A = 1,3$; $R_A = \frac{\bar{R}}{M_A} = 2078,6$

$G_B =$ $\quad \bar{M}_B = 2kg/kmol$; $\gamma_B = \gamma_A = 1,3$; $R_B = \frac{\bar{R}}{M_B} = 4157,15$

$\%V_B = 30\% \rightarrow \begin{cases} y_B = 0,3 \rightarrow x_B = y_B \frac{\bar{M}_B}{\bar{M}} = 0,18 \\ y_A = 0,7 \rightarrow x_A = 0,82 \end{cases}$

$R = x_A R_A + x_B R_B = 2452,74$

- $\bar{M} = y_A \bar{M}_A + y_B \bar{M}_B = 3,4 \frac{kg}{kmol}$
- $\frac{G_A}{G_B} = \frac{M_A}{M_B}$ $\quad G = G_A + G_B$ $\quad M_A = x_A \cdot M \Rightarrow G_A = x_A \cdot G \rightarrow G = \frac{G_A}{x_A} = 0,0339 \Rightarrow G_B = 0,0061$
- $s_2 - s_1 = -\left[G_A R_A \ln\frac{1}{y_A} + G_B R_B \ln\frac{1}{y_B}\right] = 51,14 \frac{W}{K}$