

CORSO DI LAUREA

DATA 13/09/2012

ΔT m°	T °C	p KPa	h_1 (K)/Kg	Δh (K)/Kg	X
1	45,81	10	191,83	0,6493	0
2	≈ 45,81	15000	206,87	0,6493	< 0
3	342,24	15000	1610,5	3,6818	0
4	342,24	15000	2610,5	5,3098	1
5	500	15000	3308,6	6,3443	> 1
6	45,81	10	2008,02	6,3443	0,758

$$v_2 = 0,001010 \quad p_{prop} = 8,1502$$

$$h_2 = \Delta p v_2 + h_1 = 206,87 \text{ K)/(Kg)}$$

$$X_6 = \frac{h_6 - h_1}{p_{prop} - p_1} = 0,758$$

$$h_6 = X(h_5 - h_1) + h_1 = 0,758(3308,6 - 191,83) + 191,83 = 2008,02 \text{ K)/(Kg)}$$

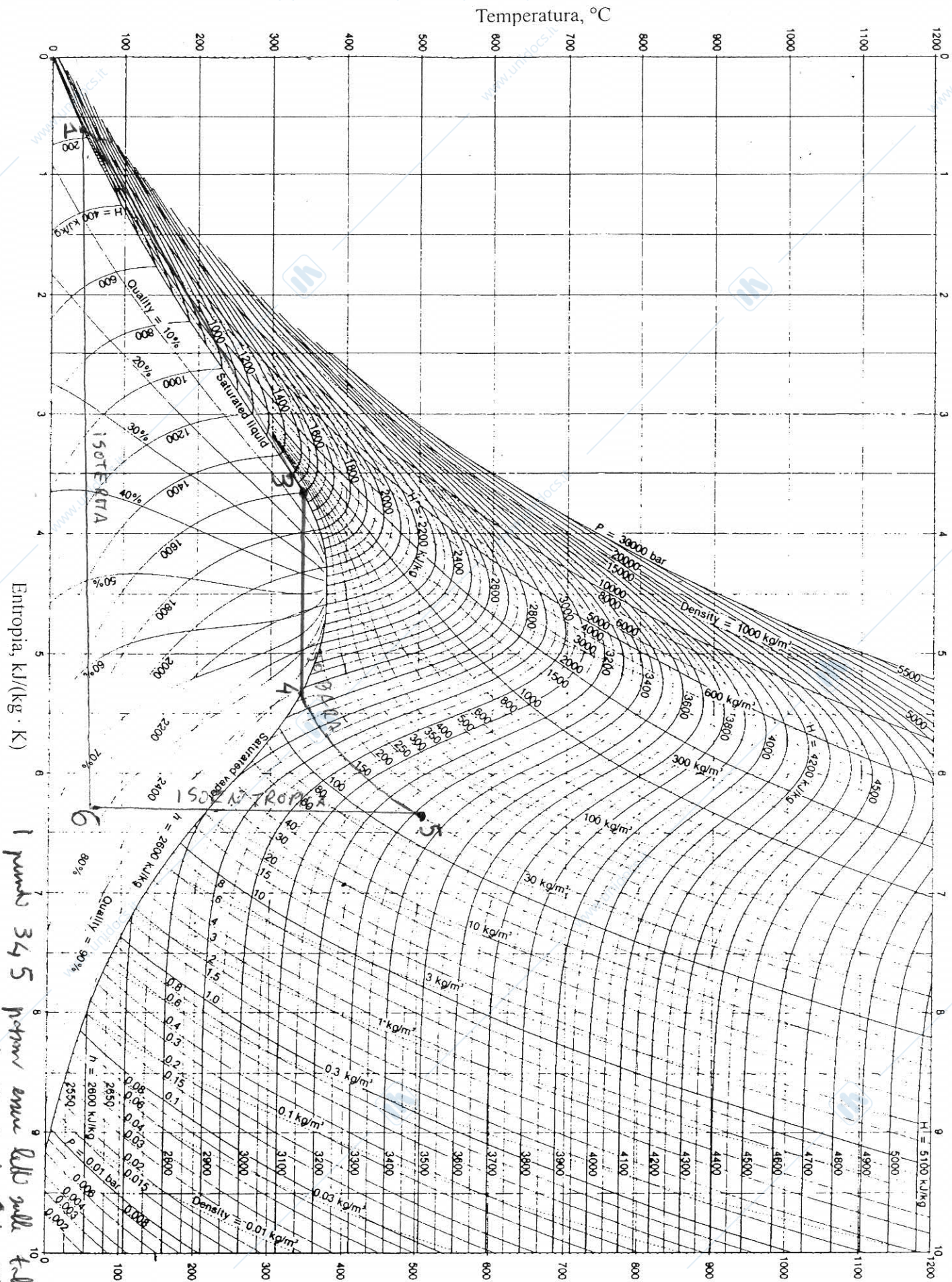
$$\eta_I = \frac{|\Delta h_{22}| - |\Delta h_{56}|}{|\Delta h_{25}|} = 0,41 \Rightarrow 41\%$$

$$\eta_C = 1 - \frac{T_1}{T_5} = 0,59 \Rightarrow 59\%$$

$$\eta_{II} = \frac{\eta_I}{\eta_C} = 0,68 \Rightarrow 68\%$$

$$\eta_I = \frac{L_{out}}{Q_{in}}$$

si ha un'idea del funzionamento della macchina termodinamica un rapporto tra il calore fornito e il lavoro in uscita dalla macchina.

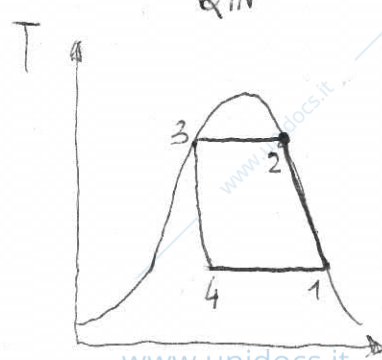
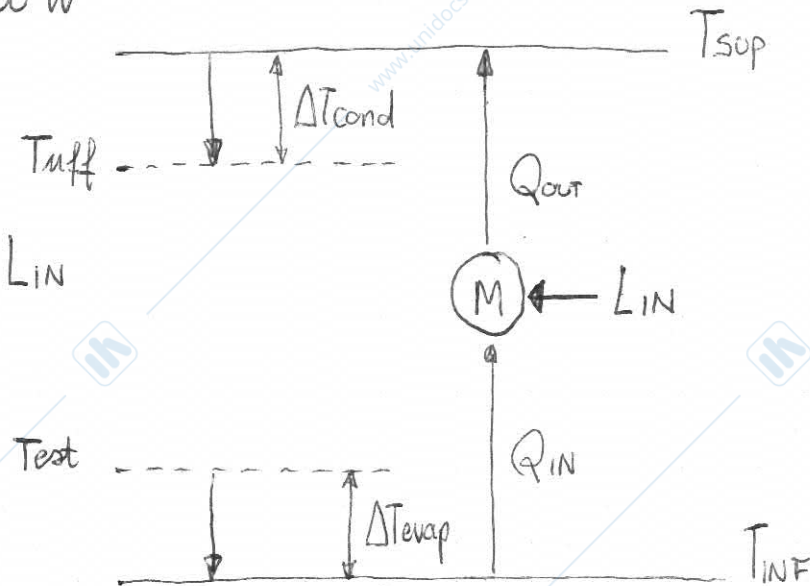
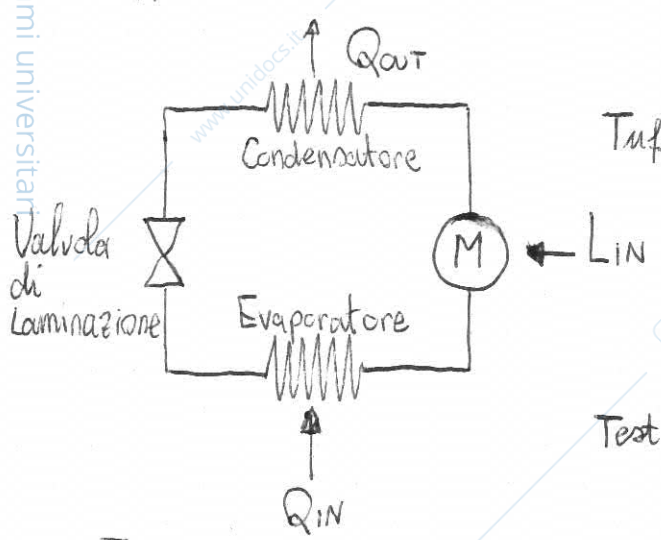


1 punto 345 per un'ora della valle (la
per quanto riguarda T, P, h, s (entropia))

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- 2) $T_{uff} = 21^\circ C$ $\Delta T_{cond} = 12^\circ C$
- 3) $T_{est} = 5^\circ C$ $\Delta T_{ev} = 4^\circ C$
- eff = 60 % $L_{IN} = 500 W$



$$COP_{id} = \frac{T_{sup}}{\Delta T} = \frac{306}{306-274} = 9,56$$

$$T_{sup} = T_{uff} + \Delta T_{cond} = 21 + 12 = 33^\circ C = 306 K$$

$$T_{inf} = T_{est} - \Delta T_{evap} = 5 - 4 = 1^\circ C = 274 K$$

$$COP_{re} = COP_{id} \cdot \text{eff} = 9,56 \cdot 0,6 = 5,74$$

$$Q_{sep} = Q_{out} = COP_{re} \cdot L_{in} = 2870 W$$

$$Q_{inf} = Q_{in} = Q_{sup} - L_{in} = 2370 W$$

Funzionamento: il liquido refrigerante è tenuto a una $T < T_{est}$; la T_{est} scalda il liquido (Q_{in}) che viene poi fatto condensare nel condensatore nel quale cede calore (Q_{out}) all'ambiente da scaldare.

$$3) T_A = 12^\circ C$$

$$T_P = 25^\circ C$$

$$T_m = 18,18^\circ C$$

$$UR_A = 60\%$$

$$UR_P = 70\%$$

$$UR_m = 73\%$$

$$P_{sat_A} = 1418,6 Pa$$

$$P_{sat_P} = 3169 Pa$$

$$P_{sat_m} = 1540,1 Pa$$

$$P_{vap_A} = 851,16 Pa$$

$$P_{vap_P} = 2218,3 Pa$$

$$P_{vap_m} = 2108,26 Pa$$

$$X_A = 0,0053$$

$$X_P = 0,014$$

$$X_m = 0,0096$$

$$h_A = 25,32 KJ/Kg$$

$$h_P = 59,89 KJ/Kg$$

$$h_m = 42,605 KJ/Kg$$

Tabella in Temperatura

$$T_A = 12^\circ C \rightarrow \text{interpolazione}$$

$$P_{sat_A} = \left(\frac{12-10}{15-10} \right) \cdot (1705,1 - 1227,6) + 1227,6$$

$$= 1418,6 Pa$$

$$T_P = 25^\circ C \quad P_{sat_P} = 3169 Pa$$

$$P_{vap} = P_{sat} \cdot UR_x$$

$$P_{vap_A} = 1418,6 \cdot 0,6 = 851,16 Pa$$

$$P_{vap_P} = 3169 \cdot 0,7 = 2218,3 Pa$$

$$X_A = 0,622 \cdot \frac{P_{vap_A}}{101325 - P_{vap_A}} = 0,622 \cdot \frac{851,16}{101325 - 851,16} = 0,0053$$

$$X_P = 0,622 \cdot \frac{P_{vap_P}}{101325 - P_{vap_P}} = 0,622 \cdot \frac{2218,3}{101325 - 2218,3} = 0,0139$$

$$\text{Siccome } m_A = m_p \Rightarrow X_m = \frac{X_A + X_p}{2} = \frac{0,0053 + 0,0139}{2} = 0,0096$$

$$h_A = 1,005 \cdot 12 + 0,0053 (2501,3 + 1,82 \cdot 0,0053) = 25,32 \text{ kJ/Kg}$$

$$h_p = 1,005 \cdot 25 + 0,0139 (2501,3 + 1,82 \cdot 0,0139) = 59,89 \text{ kJ/Kg}$$

$$h_m = \frac{h_A + h_p}{2} = \frac{25,32 + 59,89}{2} = 42,605 \text{ kJ/Kg}$$

↙
Siccome $m_A = m_p$

$$T_m = \frac{h_m - 2501,3 \cdot X_m}{1,005 + 1,82 \cdot X_m} = \frac{42,605 - 0,0096 \cdot 2501,3}{1,005 + 1,82 \cdot 0,0096} = 18,18^\circ \text{C}$$

$$P_{vap,m} = \frac{101325 \cdot X_m}{0,622 + X_m} = \frac{101325 \cdot 0,0096}{0,622 + 0,0096} = 1540,1 \text{ Pa}$$

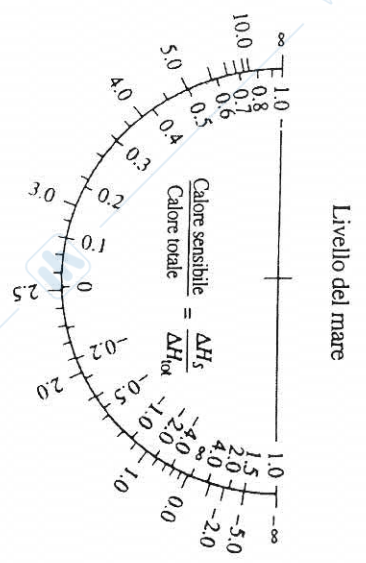
$$P_{sat,m} = \left(\frac{18,18 - 15}{20 - 15} \right) \cdot (2339 - 1705,1) + 1705,1 = 2108,26 \text{ Pa}$$

$$UR_m = \frac{P_{vap,m}}{P_{sat,m}} = \frac{1540,1}{2108,26} = 0,73 \quad UR_m \% = 73\%$$

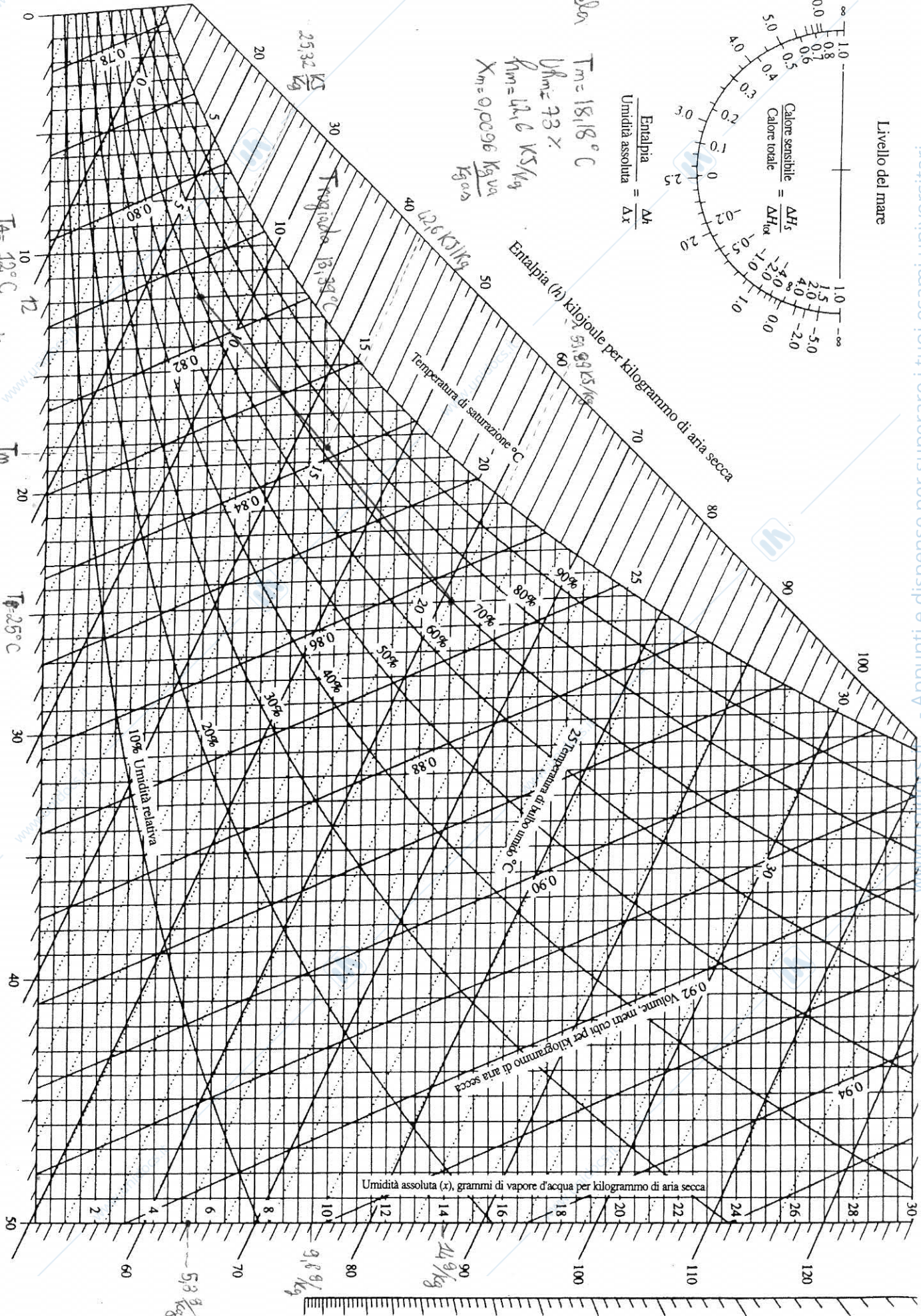
Trigiada	P [Pa]	T [°C]
1500		13,03
1540,1		
2000		17,5

$$T_{trigiada} = \left(\frac{1540,1 - 1500}{2000 - 1500} \right) \cdot (17,5 - 13,03) + 13,03 = 13,39^\circ \text{C}$$

Non vi sarà formazione di nuvole perché $T_{miscela} > T_{trigiada}$
Per $T < T_{trigiada}$ vi sarà formazione di nuvole



$T_m = 18,18^\circ C$
 $U_{hm} = 73\%$
 $\rho_{hm} = 12,6 \text{ KS/Mg}$
 $X_m = 0,0096 \text{ Kg/va}$
 $F_{Ga} =$

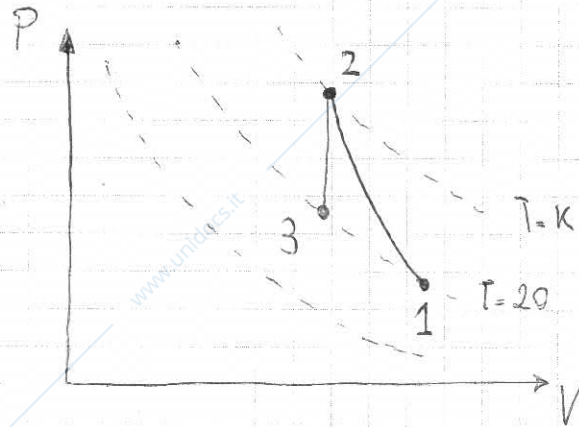


$T_A = 12^\circ C$
 $X_A = 0,0053 \text{ Kg/va/Kg a.a.}$
 $h_A = 25,32 \text{ KS/Kg}$

$T_p = 25^\circ C$
 $X_p = 0,014 \text{ Kg/va/Kg a.a.}$

CORSO DI LAUREA

DATA

4) $V_1 = 10$ litri N_2 (Gas perfetto $M_m = 28,01$ Kg/Kmol) $P_1 = 5$ bar $T_1 = \text{ambiente} = 20^\circ \text{C}$ $V_2 = \frac{V_1}{2} = 5$ litri $V_3 = V_2 = 5$ litri $T_3 = \text{ambiente} = 20^\circ \text{C}$ 

$$PV = mRT$$

$$R = \frac{8314}{28,01} = 296,82 \text{ J/Kg}$$

$$\frac{P_1 V_1}{RT_1} = \frac{P_2 V_2}{RT_2} = \frac{P_3 V_3}{RT_3}$$

$$P_1 V_1 = P_3 V_3$$

$$5 \cdot 10^5 \cdot 0,01 = P_3 \cdot 0,005$$

$$P_3 = 5 \cdot 10^5 \cdot \frac{0,01}{0,005} = 10 \cdot 10^5 \text{ Pa}$$

Compressione reversibile: $\Delta S = 0$

$$\Delta S = m \left(C_p \ln \left(\frac{T_2}{T_1} \right) - R \ln \left(\frac{V_2}{V_1} \right) \right)$$

$$C_p \ln \left(\frac{T_2}{T_1} \right) = R \ln \left(\frac{V_2}{V_1} \right)$$

$$\ln \frac{T_2}{T_1} = \frac{R}{C_p} \ln \left(\frac{V_2}{V_1} \right) = -0,277$$

$$T_2 = T_1 \cdot e^{(-0,277)} = 386 \text{ K}$$

(?)

è più sileca
usare la relazione
dell'isocentropica

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{\gamma-1}$$

$$\Delta S_{23} = m C_{pV} \ln \frac{T_3}{T_2} = 0,0575 \cdot \frac{5}{2} \cdot 296,82 \cdot \ln \frac{293}{386} = -16,5 \frac{\text{J}}{\text{kg K}}$$

$$= -11,8 \text{ [J/K]}$$

$$PV = mRT$$

$$m = \frac{PV}{RT} = \frac{5 \cdot 10^5 \cdot 0,01}{296,82 \cdot 293} = 0,0575 \text{ Kg}$$

$$T_3 = \frac{P_3 V_3}{mR} = 293 \text{ K}$$

$$\Delta U_{23} = Q_{23} \quad L_{23} = 0$$

$$Q_{23} = m C_V \Delta T = 0,0575 \cdot \frac{5}{2} \cdot 296,82 \cdot (293 - 386) = -3994$$

$$\text{Nota: } T_3 = T_1 \rightarrow U_3 = U_1$$

$$Q_{in} - L_{out} = \Delta U$$

$$Q_{13} - L_{13} = \Delta U_{1-3}$$

$$(\underbrace{Q_{12}}_{=0} + Q_{23}) - (L_{12} + \underbrace{L_{23}}_{=0}) = \Delta U_{1-3}$$

$$Q_{23} - L_{12} = 0$$

$$Q_{23} = L_{12}$$

$$L_{12 \text{ OUT}} = -3994 \Rightarrow L_{12 \text{ IN}} = 3994$$

$$\Delta S_{AMB} = \frac{Q_{in-AMB}}{T_{AMB}} = \frac{3994}{293} = 13,63$$

$$\Delta S_{TOT} = \Delta S_{gas} + \Delta S_{AMB} = 13,63 - 11,8 = 1,80 \text{ J/K}$$

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DATA

E_s m³ S 5/4 Innotizata Area del vetro 1 m²

Vetro

$$\lambda_v = 1,4 \text{ W/mK}$$

$$S_v = 4 \text{ mm}$$

Aria

$$\lambda_a = 0,0253 \text{ W/mK}$$

$$S_a = 16 \text{ mm}$$

Interni

$$T_{int} = 20^\circ\text{C}$$

$$h_{int} = 8 \text{ W/m}^2\text{K}$$

Esterni

$$T_{ext} = -9^\circ\text{C}$$

$$h_{ext} = 17 \text{ W/m}^2\text{K}$$

$$R_{ovv} = \frac{L}{\lambda A} = 0,002857 \text{ K/W} \frac{\text{m}}{\text{W/m}^2}$$

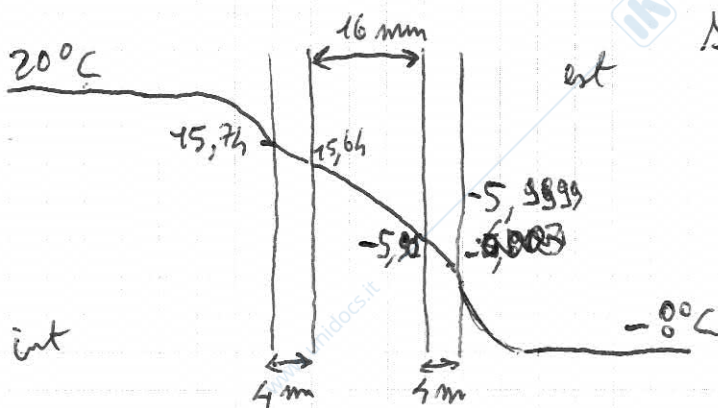
$$R_{ava} = \frac{L}{\lambda A} = 0,6324 \text{ K/W}$$

$$R_{int} = \frac{1}{hA} = 0,125 \text{ K/W}$$

$$R_{ext} = \frac{1}{hA} = 0,0588 \text{ K/W}$$

$$R_{TOT} = 2R_v + R_a + R_{int} + R_{ext} = 0,8219$$

$$\dot{Q} = \frac{\Delta T}{R_{TOT}} = \frac{28}{R_{TOT}} = 34,07 \text{ W}$$



$$\Delta T_1 = \Delta T_2 = 4,25875$$

$$\Delta T_3 = 0,89734$$

$$\Delta T_4 = 21,5459$$

$$\Delta T_5 = 2,0001$$

$$s) T_i = 20^\circ\text{C} = 293\text{ K} \quad 4.5/5$$

$$h = 4\text{ W/m}^2\text{K}$$

$$\rho = 648\text{ kg/m}^3$$

$$\alpha = 1,43 \cdot 10^{-7}\text{ m}^2/\text{s}$$

$$c_p = 4184\text{ J/mK}$$

$$\lambda = 0,599\text{ W/mK}$$

$$\theta_{(x=0)} = \frac{T - T_\infty}{T_0 - T_\infty} = \frac{0 - (-15)}{20 - (-15)} = 0,428$$

$$\xi = \frac{x}{2\sqrt{\alpha t}} \Rightarrow x = \xi = 0$$

$$1 - \theta_{(x=0)} = 0,572$$

$$\begin{cases} 1 - \theta = 0,572 \\ \xi = 0 \end{cases}$$

$$\Rightarrow \frac{h\sqrt{\alpha t}}{\lambda} \cong 0,95$$

$$\alpha t = \left(\frac{0,95 \lambda}{h} \right)^2$$

$$t = \left(\frac{0,95 \lambda}{h} \right)^2 \cdot \frac{1}{\alpha}$$

$$= \left(\frac{0,95 \cdot 0,599}{4} \right)^2 \cdot \frac{1}{1,43 \cdot 10^{-7}} = 141529\text{ s}$$

$$\xi = \frac{x}{2\sqrt{\alpha t}} = \frac{0,01}{2\sqrt{1,43 \cdot 10^{-7} \cdot 141529}} = 0,035$$

$$\frac{h\sqrt{\alpha t}}{\lambda} \cong 0,95$$

$$1 - \theta \cong \frac{0,3}{0,53}$$

$$\theta = \frac{0,7}{0,47}$$

$$T = \theta(T_0 - T_\infty) + T_\infty = 1,5$$

$$= \frac{0,7}{0,47}(20 - (-15)) + (-15) = 9,5^\circ\text{C}$$

$$\frac{T(x,t) - T_i}{T_s - T_i} = \operatorname{erfc}\left(\frac{x}{2\sqrt{\alpha t}}\right) \quad (11.24)$$

$$\frac{T(x,t) - T_i}{T_\infty - T_i} = \operatorname{erfc}\left(\frac{x}{2\sqrt{\alpha t}}\right) - \exp\left(\frac{hx}{\lambda} + \frac{h^2 \alpha t}{\lambda^2}\right) \left[\operatorname{erfc}\left(\frac{x}{2\sqrt{\alpha t}} + \frac{h\sqrt{\alpha t}}{\lambda}\right) \right] \quad (11.22)$$

TABELLA 11.3
Il complemento della funzione degli errori

ξ	$\operatorname{erfc}(\xi)$	ξ	$\operatorname{erfc}(\xi)$	ξ	$\operatorname{erfc}(\xi)$	ξ	$\operatorname{erfc}(\xi)$	ξ	$\operatorname{erfc}(\xi)$	ξ	$\operatorname{erfc}(\xi)$
0.00	1.00000	0.38	0.5910	0.76	0.2825	1.14	0.1069	1.52	0.03159	1.90	0.00721
0.02	0.9774	0.40	0.5716	0.78	0.2700	1.16	0.10090	1.54	0.02941	1.92	0.00662
0.04	0.9549	0.42	0.5525	0.80	0.2579	1.18	0.09516	1.56	0.02737	1.94	0.00608
0.06	0.9324	0.44	0.5338	0.82	0.2462	1.20	0.08969	1.58	0.02545	1.96	0.00557
0.08	0.9099	0.46	0.5153	0.84	0.2349	1.22	0.08447	1.60	0.02365	1.98	0.00511
0.10	0.8875	0.48	0.4973	0.86	0.2239	1.24	0.07950	1.62	0.02196	2.00	0.00468
0.12	0.8652	0.50	0.4795	0.88	0.2133	1.26	0.07476	1.64	0.02038	2.10	0.00298
0.14	0.8431	0.52	0.4621	0.90	0.2031	1.28	0.07027	1.66	0.01890	2.20	0.00186
0.16	0.8210	0.54	0.4451	0.92	0.1932	1.30	0.06599	1.68	0.01751	2.30	0.00114
0.18	0.7991	0.56	0.4284	0.94	0.1837	1.32	0.06194	1.70	0.01612	2.40	0.00069
0.20	0.7773	0.58	0.4121	0.96	0.1746	1.34	0.05809	1.72	0.01500	2.50	0.00041
0.22	0.7557	0.60	0.3961	0.98	0.1658	1.36	0.05444	1.74	0.01387	2.60	0.00024
0.24	0.7343	0.62	0.3806	1.00	0.1573	1.38	0.05098	1.76	0.01281	2.70	0.00013
0.26	0.7131	0.64	0.3654	1.02	0.1492	1.40	0.04772	1.78	0.01183	2.80	0.00008
0.28	0.6921	0.66	0.3506	1.04	0.1413	1.42	0.04462	1.80	0.01091	2.90	0.00004
0.30	0.6714	0.68	0.3362	1.06	0.1339	1.44	0.04170	1.82	0.01006	3.00	0.00002
0.32	0.6509	0.70	0.3222	1.08	0.1267	1.46	0.03895	1.84	0.00926	3.20	0.00001
0.34	0.6306	0.72	0.3086	1.10	0.1198	1.48	0.03635	1.86	0.00853	3.40	0.00000
0.36	0.6107	0.74	0.2953	1.12	0.1132	1.50	0.03390	1.88	0.00784	3.60	0.00000

or

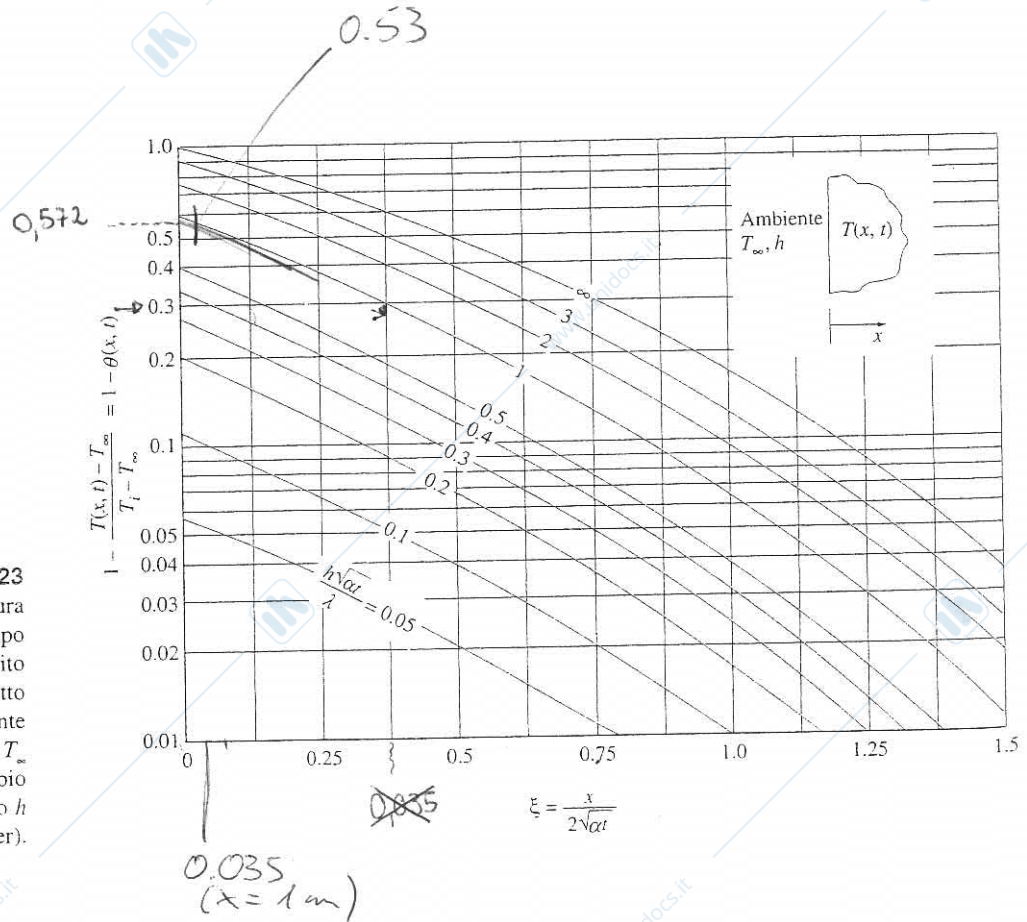


FIGURA 11.23
Variazione di temperatura con la posizione e con il tempo in un solido semi-infinito inizialmente a T_i soggetto a convezione verso un ambiente a temperatura T_∞ con un coefficiente di scambio termico convettivo h (da P.J. Schneider).

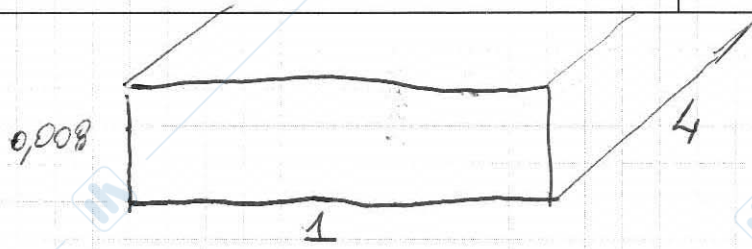
CORSO DI LAUREA

DATA

$$E_s = 7 \text{ m}^2$$

$$T_{\text{ag}} = 90^\circ\text{C}$$

$$T_{\text{amb}} = 30^\circ\text{C}$$



$$L_c = \frac{V}{A}$$

$$\dot{Q} = 500 \text{ W/m}^2 \quad h = \frac{\dot{Q}}{A \Delta T} = 8,33 \text{ W/m}^2\text{K}$$

$$\dot{Q} = 8040 \text{ W}$$

$$V = 0,032 \text{ m}^3$$

$$A = 4 \cdot 1 + 1 \cdot 0,008 \cdot 2 + 4 \cdot 0,008 \cdot 2 = 4,08 \text{ m}^2$$

$$L_c = 0,00784$$

$$Biot = \frac{L_c h}{k} = 0,00109 < 0,1$$

Parametro concentrato

$$\tau = mch / hA = 3199,6$$

$$m = 250,56 \text{ kg}$$

$$\frac{50 - 30}{90 - 30} = e^{-t/\tau}$$

$$t = 3515 \text{ sec} = 58,58 \text{ min} \approx 1 \text{ ora}$$

~~Al~~ Alla lastra vengono ^{forniti} ~~data~~ 500 W/m^2 di potenza finché il sale \bar{a} presenta \bar{a} ipotesi che il sale venga riscaldato all'istante. Quando per tornare alle condizioni ^{finale} ~~iniziali~~ $T = 30^\circ\text{C}$ da 90°C l'ora dovrà esser fornita la stessa quantità di calore data dal sole.

$$8) T_{amb} = 20^{\circ}C : h_p$$

$$3/3 \text{ Fattore di vista piastra - forno} = 1 = F_{PF}$$

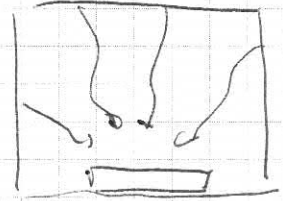
Calcolo \dot{Q}_{PF} \rightarrow la potenza scambiata sarà $-\dot{Q}_{PF}$ perché è il forno che cede calore alla piastra

$$\dot{Q}_{PF} = \frac{5,67 \cdot 10^{-8} (293^4 - 473^4)}{\frac{1-0,8}{0,1256 \cdot 0,8} + \frac{1}{1 \cdot 0,1256} + \frac{1-0,9}{1,8 \cdot 0,9}} = -241,7 \text{ W}$$

$$A_{PIASTRA} = \pi r^2 = \pi \cdot \left(\frac{0,4}{2}\right)^2 = 0,1256$$

$$A_{FORNO} = (0,6 \cdot 0,6) \cdot 5 = 1,8$$

ipotesi
1 sola faccia?



$$\dot{Q}_{FP} = -\dot{Q}_{PF} = 241,7 \text{ W}$$

Con il passare del tempo la \dot{Q} scambiata diminuisce perché il forno tende a raffreddarsi, la piastra si scalda ma la diff. delle T^4 diminuisce.