



Corso Luigi Einaudi, 55 - Torino

Appunti universitari

Tesi di laurea

Cartoleria e cancelleria

Stampa file e fotocopie

Print on demand

Rilegature

NUMERO: 1132

DATA: 07/10/2014

A P P U N T I

STUDENTE: Bettale

MATERIA: Termodinamica appl. e Trasmis. del Calore Schemi-Tabelle

Prof. Giaretto

Il presente lavoro nasce dall'impegno dell'autore ed è distribuito in accordo con il Centro Appunti.

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ATTENZIONE: QUESTI APPUNTI SONO FATTI DA STUDENTIE NON SONO STATI VISIONATI DAL DOCENTE.
IL NOME DEL PROFESSORE, SERVE SOLO PER IDENTIFICARE IL CORSO.

TERMODINAMICA applicata e TRASMISSIONE del CALORE

di GIARETTO

- schemi e tabelle
da portare all'esame

Aria

$$\bar{M} = 29 \frac{\text{kg}}{\text{kmol}}$$

$$R = 287 \frac{\text{J}}{\text{kg K}}$$

$$C_v = 717 \frac{\text{J}}{\text{kg K}}$$

$$C_p = 1007,5 \frac{\text{J}}{\text{kg K}}$$

$$\gamma = 1,4$$

O₂

$$\bar{M} = 32$$

$$R = 259,8125$$

$$C_v = 649,531$$

$$C_p = 909,344$$

$$\gamma = 1,4$$

N₂

$$\bar{M} = 28$$

$$R = 297$$

$$C_v = 702,5$$

$$C_p = 1039,5$$

$$\gamma = 1,4$$

Ne

$$\gamma = 1,667$$

$$C_p = 1029$$

$$C_v = 617,4$$

$$R = 411,6$$

$$\bar{M} = 20,0$$

CO₂

$$\gamma = 1,33$$

$$C_p = 756$$

$$C_v = 567$$

$$R = 189$$

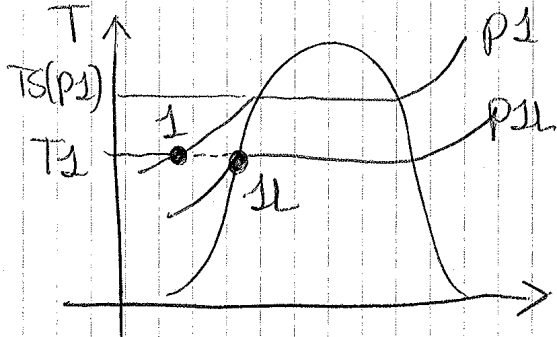
$$\bar{M} = 44$$

$$C_{pL} = 4186 \frac{\text{kJ}}{\text{kg K}}$$

$$C_{pL} = 4186 \frac{\text{J}}{\text{kg K}}$$

$$\bar{R} = 8314,3 \frac{\text{J}}{\text{kmol K}}$$

LIQUIDO SOTTORAFFREDDATO



T_2, p_1

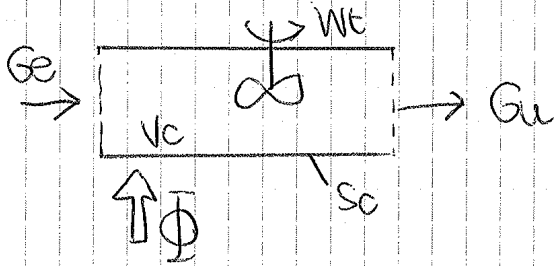
$T_2 < T_s(p_1)$

$$\begin{aligned}
 u_1 &= u_{1L} = h_{1L} - p_{1L} v_{1L} \\
 v_1 &\approx v_{1L} \\
 s_1 &\approx s_{1L} \\
 h_1 &\approx h_{1L} + v_{1L}(p_1 - p_{1L})
 \end{aligned}$$

T_2 : Tabella

$$\left\{ \begin{array}{l} p_{1L} = p_s(T_2) \\ v_{1L} \\ h_{1L} \\ s_{1L} \\ u_{1L} \end{array} \right.$$

SISTEMI APERTI (scambio di materia)



$\oplus G$ se esce (G_u)

$\ominus G$ se entra (G_e)

$G = \rho A W, G_v = \frac{G}{\rho}$

Le portate in materia si conservano quelle volumiche no

- condizioni stazionarie

$G_e = G_u, \frac{d}{dt} [x(t)]_{V_c} = 0$

- condizioni non stazionarie

serbatoio che si riempie
serbatoio che si svuota

$q = \frac{\Phi}{G}$

Derivata materiale

$\frac{dx(t)}{dt} = \left[\frac{dx(t)}{dt} \right]_{V_c} + \left[\sum \pm G_j x_j \right]_{sc}$

solo in condizioni stazionarie $G = G$

Bilancio materia $0 = \left(\frac{dM}{dt} \right)_{V_c} \pm \sum G_j$

secondo principio

(sistemi aperti)

$\left[\frac{dS}{dt} \right]_{V_c} + \sum \pm G_j s_j = \frac{\Phi}{T} + \sum irr$

$\Delta S + \Delta M s_j = \frac{Q}{T} + \sum irr$

se stazionario

$\sum \pm G_j s_j = \frac{\Phi}{T} + \sum irr$

$G \Delta s = \frac{\Phi}{T} + \sum irr$

$\Delta s = \frac{q}{T} + \sum irr$

teorema dell'energia cinetica (sistemi aperti)

$L_t + L_o + \Delta E_c + \Delta E_p + L_a + \int_r V dp = 0$

(con le masse)

$L_t + \left[L_o + \Delta E_c + \Delta E_p \right] + L_a + \int_r v dp = 0$

(senza le masse)

L_t e le altre vate trascurabili

$u = h - pv$

$h = u + pv$

PRIMO PRINCIPIO (sistemi aperti)

$\Phi - W_t = \frac{d}{dt} [u + E_c + E_p + p_0 V]_{V_c} + \sum_j \pm G_j (h + e_c + e_p)_j$

\downarrow non accelerata \downarrow ORIZ. \downarrow RIGIDO \downarrow non accelerata \downarrow ORIZ

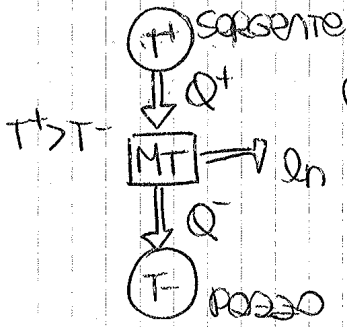
$\Phi - W_t = \frac{d}{dt} [U]_{V_c} + \sum_j \pm G_j (h)_j$ non acc, ORIZ, RIGIDO

$\Phi - W_t = \sum_j \pm G_j (h)_j$

se tutto stazionario: $Q - L_t = \sigma_2 - \sigma_1 \pm \Delta M(h)$
es C3

$q - l_t = \Delta h$

MOTORI TERMICI



$\Phi \rightarrow W_e$

$$\eta = \frac{L_n}{Q^+} = 1 - \frac{|Q^-|}{Q^+} = \frac{\text{Beneficio}}{\text{Spesa}}$$

MOTORE DI CARNOT

$$\eta = 1 - \frac{T^-}{T^+}$$

4 trasformazioni reversibili

TRASFORMAZIONI:

Reversibili

- Internamente
- condensazione
 - compressione ideale
 - espansione ideale
 - evaporazione
 - Cambiamenti di stato

Irreversibili

- Attrito
- espansione libera di un gas
 - Miscelazione \square
 - Trafilazione \times
 - Fenomeni spontanei

secondo principio (gas ideali)

$$\Delta S = S_2 - S_1 = c_v \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{p_2}{p_1}\right)$$

$$= c_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{p_2}{p_1}\right)$$

- ① riferimento
- ② stato

TRASFORMAZIONE ciclica

$$\Delta S = \frac{Q}{T} \quad \text{Sim} = 0 \quad q = L_n$$

TRAFILAZIONE (sistema aperto)

- $\Phi = 0, q = 0$ adiab
- $W_0 = 0$ rigido
- $G_1 = G_2$ stazion.
- $\Delta e_p = 0$ orl
- $\Delta e_c = 0$ assenza

$W_t = 0$ non avvengono scambi di potenza tecnica

$$h_1 = h_2$$

$$S_2 > S_1 \quad \text{Sim} \neq 0$$

irreversibile

beneficio ideale $\rightarrow T_2 = T_1$

Miscela (\bar{R})

$$n = \frac{M}{\bar{M}} = \sum \frac{M_J}{\bar{M}_J}$$

$$p = \sum p_J$$

$$U = \sum U_J$$

$$\bar{M} = \frac{M}{n} = \sum y_J \bar{M}_J$$

$$M = n \bar{M}$$

$$R = \sum x_J R_J = \frac{R}{\bar{M}}$$

$$V = \sum V_J$$

$$S = \sum M_J S_J$$

$$s = \frac{S}{M} = \sum x_J S_J$$

$$h = \sum x_J h_J$$

$$H = \sum M_J h_J$$

$$U = M u$$

$$u = \sum x_J u_J$$

$$U = n \bar{u}$$

$$\bar{u} = \sum y_J \bar{u}_J$$

$$x_J = \frac{M_J}{M} = y_J \frac{\bar{M}_J}{\bar{M}}$$

$$y_J = \frac{n_J}{n} = \frac{p_J}{p} = \frac{V_J}{V}$$

$$R_J = \frac{R}{\bar{M}_J}$$

$$M_J = n_J \bar{M}_J$$

$$\bar{M}_J = \frac{M_J}{n_J}$$

$$V_J = \frac{n_J \bar{R} T}{p}$$

$$p_J = \frac{n_J \bar{R} T}{V}$$

$$C_{pJ} = \frac{\gamma_J}{\gamma_J - 1} R_J$$

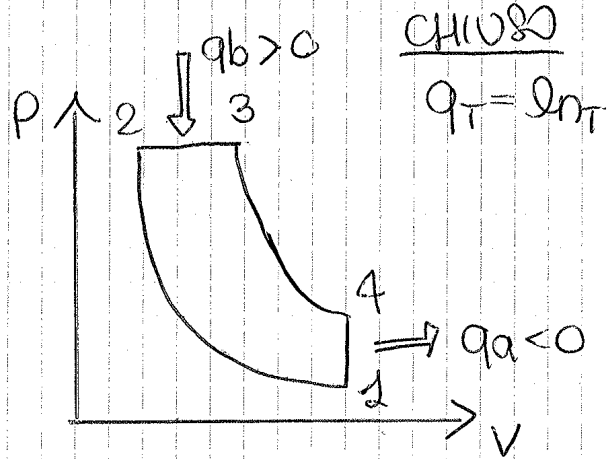
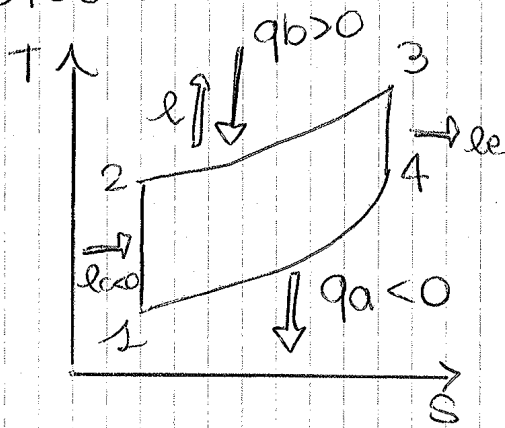
$$C_p = \sum x_J C_{pJ}$$

$$C_v = \sum x_J C_{vJ}$$

$$\gamma = \frac{C_p}{C_v}$$

① **UMIDIFICAZIONE**

② Diesel



⑫ compressione ad. rev. isoen.

$$q=0$$

$$l_c = l_{12}^{id} = -\Delta u = -c_v(T_2 - T_1) = c_v(T_1 - T_2) < 0$$

⑬ isobara p₂=p₃ che riceve calore

$$l_{23}^{id} = p_2 \Delta v = p_2 (v_3 - v_2) = p_3 (v_3 - v_2) > 0$$

$$q_b = c_p(T_3 - T_2) > 0$$

⑭ espansione ad. rev. isoen

$$q=0$$

$$l_e = l_{34}^{id} = -\Delta u = -c_v(T_4 - T_3) = c_v(T_3 - T_4) > 0$$

⑮ isocora che dona calore v₂=v₃

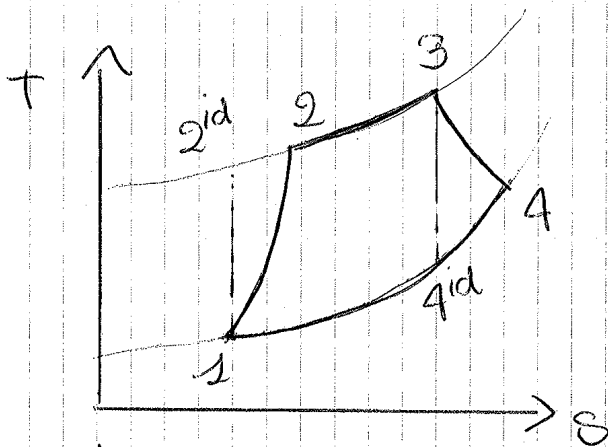
$$l_{41}^{id} = 0$$

$$q_a = c_v(T_1 - T_4) < 0$$

$$r_v = \frac{v_1}{v_2} = \frac{v_4}{v_2} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}} \quad r_c = \frac{v_3}{v_2} = \frac{T_3}{T_2}$$

$$\eta = 1 - \frac{|q_a|}{q_b} = 1 - \frac{1}{r} r_v^{1-\gamma} \left[\frac{r_c^\gamma - 1}{r_c - 1} \right]$$

② Joule reale (complex e expans)



$$l_{t^{re}} = l_{t^{id}} - l_{ac}$$

①② $T_p \frac{1-n_c}{n_c} \quad n_c = \frac{c_p - c_c}{c_v - c_c} > \gamma$
 P_v

③④ $T_p \frac{1-n_e}{n_e} \quad n_e = \frac{c_p - c_e}{c_v - c_e} < \gamma$
 T_p

$$l_{t_c^{id}} = +c_p(T_1 - T_2^{id}) < 0$$

$$l_{t_c^{re}} = c_p(T_1 - T_2)$$

$$l_{ac} = c_p(T_2 - T_2^{id}) > 0$$

$$\eta_{isc} = \frac{l_{t_c^{id}}}{l_{t_c^{re}}} = \frac{T_2^{id} - T_1}{T_2 - T_1} < 1$$

$$l_{t_e^{id}} = c_p(T_3 - T_4^{id}) > 0$$

$$l_{t_e^{re}} = c_p(T_3 - T_4)$$

$$l_{ae} = c_p(T_4 - T_4^{id})$$

$$\eta_{ise} = \frac{l_{t_e^{re}}}{l_{t_e^{id}}} = \frac{T_3 - T_4^{id}}{T_3 - T_4}$$

parametro x Gu es

$$T_2^{id} + \eta_{isc} \rightarrow T_2 \rightarrow n_c \rightarrow c_c \rightarrow q_{12} = c_c(T_2 - T_1)$$

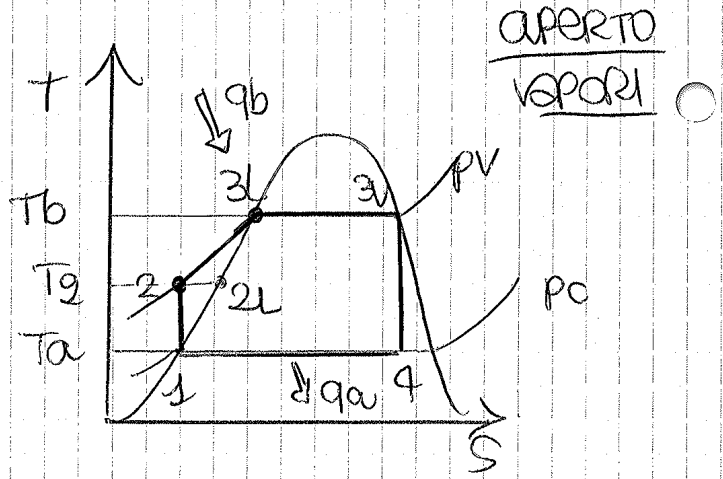
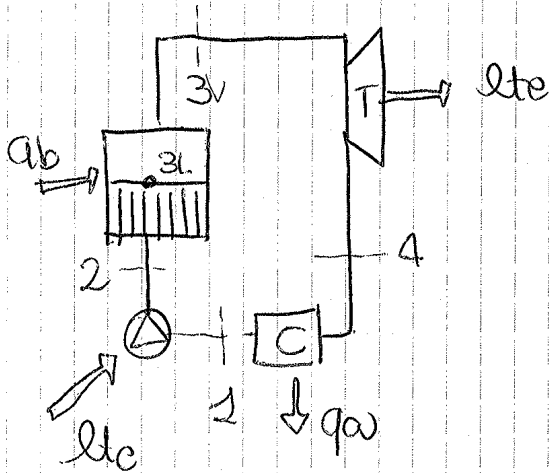
$$q_{34} = c_e(T_4 - T_3)$$

$$l_{ac} + l_{t_c^{re}} = l_{t_c^{id}}$$

$$l_{ac} = l_{t_c^{id}} - l_{t_c^{re}}$$

$$l_{ae} + l_{t_e^{re}} = l_{t_e^{id}}$$

② ciclo RANKINE



①② QDIOB.
 $S_1 = S_2$

② $h_2 \cong h_{2v} + v_{2L} (p_2 - p_{2L})$ FLUIDO INCOMPRESSIBILE
 $p_{2L} = p_s(T_2)$, $p_2 = p_v$
 se conosciuto T_2
 se è noto ①

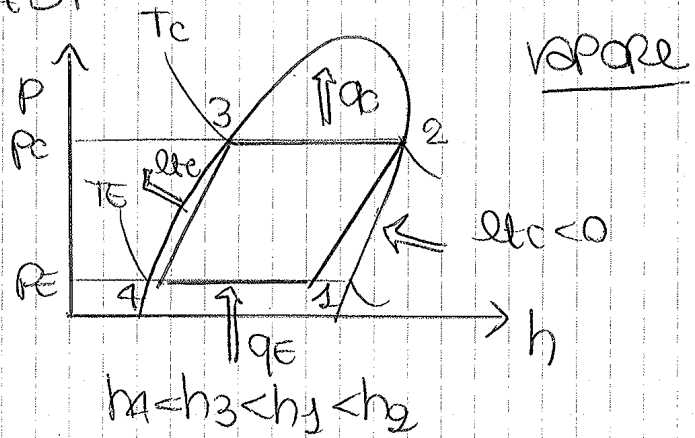
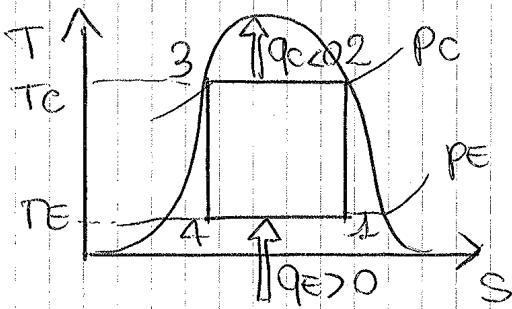
$h_2 \cong v_3 (p_2 - p_1) + h_1$

①② $l_{t_{12}} = h_2 - h_1 \cong v_1 (p_2 - p_1)$ V costante

- ③ L su p_v tabelle
- ③ v su p_v tabelle
- ① L su p_c tabelle
- ④ L+v su p_c tabelle

ciclo inverso $E_f = \frac{q_e}{|l_{e1}|} = COP$ $E_p = \frac{|q_c|}{|l_{e1}|}$ $q_e > 0$ $q_c < 0$ $E_p = E_f + 1$

1) ciclo inverso di Carnot



$$E_f = \frac{T_E}{T_C - T_E}$$

$$E_p = \frac{T_C}{T_C - T_E}$$

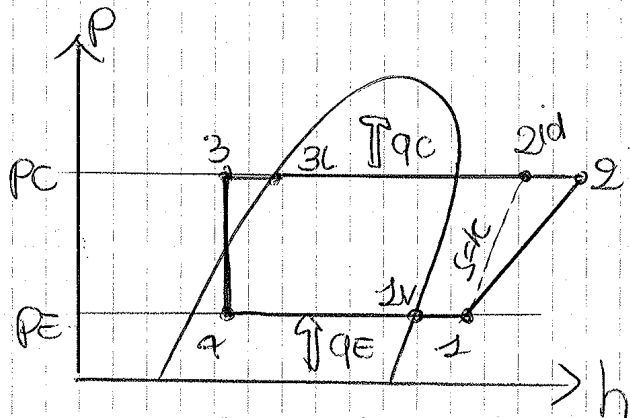
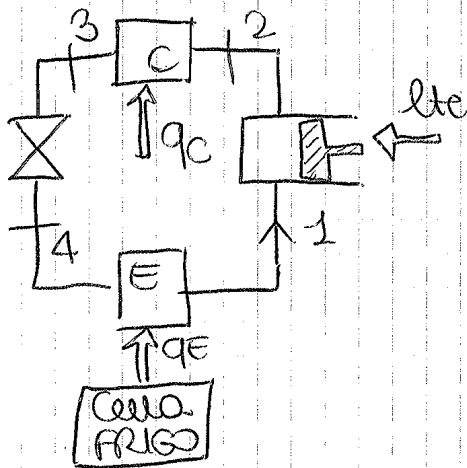
② compress. adiab $l_{te} = h_1 - h_2 < 0$

③ isob. isot

④ expans. adiab $l_{te} = h_3 - h_4 > 0 \ll l_{te}$

⑤ isob. isot

2) ciclo a semplice compress



$T_1 = \text{Cella FRIGO}$
 $T_3 = T. \text{AMBIENTE}$

② $|l_{te}| = |h_3 - h_2| = h_2 - h_1$

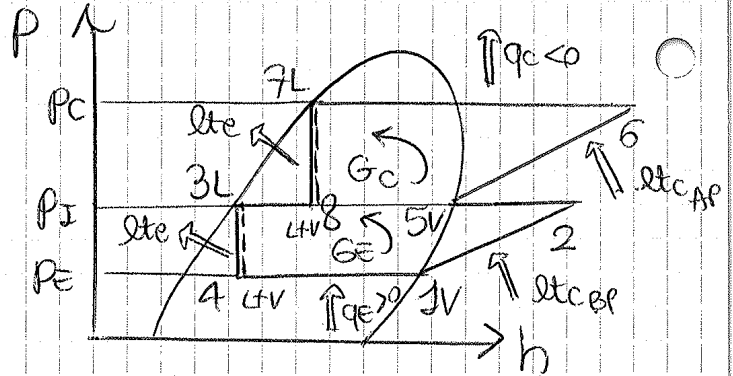
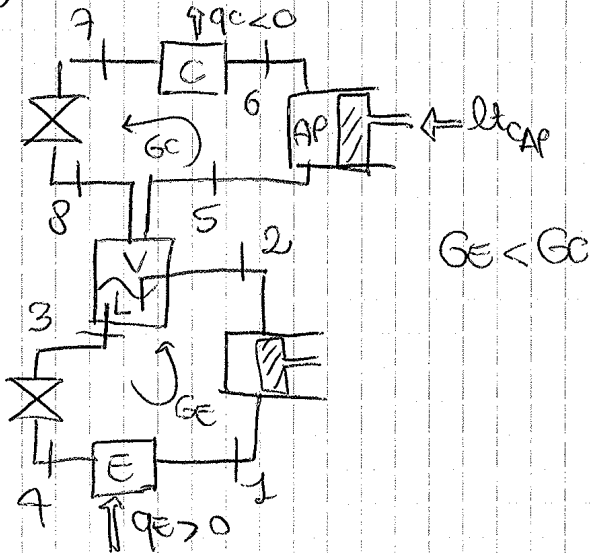
③

④

⑤ $q_e = h_2 - h_1 > 0$

$$E_f = \frac{q_e}{|l_{te}|} = \frac{\Phi_e}{|l_{te}|} = \frac{h_2 - h_1}{h_2 - h_1}$$

5) ciclo a 2x complessi 2x laminati + SRV



① V di p_e h_{3V}, s_{3V}

② p_I = √(p_Cp_E), s₁ = s₂

⑤ V di p_I

⑥ p_C, s₅ = s₆

⑦ L di p_C

⑧ h₇ = h₈, p_I

③ L di p_I

④ p_E, h₃ = h₄

⑫ l_{tc,CP} = h₂ - h₁

⑥ l_{tc,AP} = h₆ - h₅

⑦ q_c = h₇ - h₆ < 0

④ q_e = h₁ - h₄ > 0

BILANCIO SU SI

$$G_c h_8 + G_e h_2 = G_c h_5 + G_e h_3$$

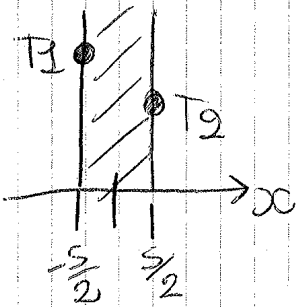
$$G_c (h_8 - h_5) = G_e (h_3 - h_2)$$

$$\frac{G_e}{G_c} = \frac{h_8 - h_5}{h_3 - h_2} < 1 \rightarrow G_e < G_c$$

$$\eta_f = \frac{G_e (h_1 - h_4)}{G_e (h_2 - h_1) + G_c (h_6 - h_5)} = \frac{\Phi_E}{|W_{tot}|}$$

CONDUZIONE STAZIONARIA SENZA GENERAZIONE DI CALORE

● STRATO PIANO : $T = C + Bx$; $\frac{dT}{dx} = B$

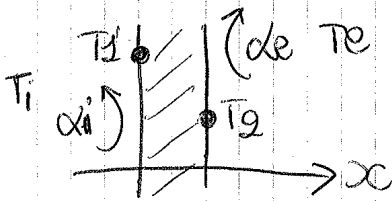


II TIPO : $T(-\frac{s}{2}) = T_1$, $T(\frac{s}{2}) = T_2$

→ RICAVO B e C

$$\varphi = -\lambda \frac{dT}{dx} \Big|_{x=\frac{s}{2}} = -\lambda \frac{dT}{dx} \Big|_{x=-\frac{s}{2}} = \frac{\lambda}{s} (T_1 - T_2)$$

$$\varphi = -\lambda B$$

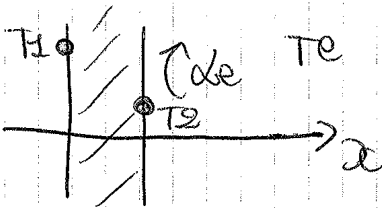
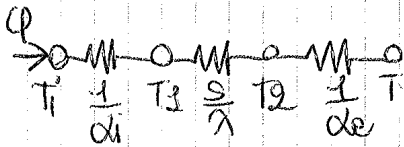


III TIPO : $\begin{cases} \varphi_{s/2} = \alpha_e (T_2 - T_e) \\ \varphi_{-s/2} = \alpha_i (T_1 - T_i) \end{cases}$

STRATO 3
FWSSI
UGIOW

II TIPO → $\varphi = \frac{\lambda}{s} (T_1 - T_2)$

$$\varphi = \frac{T_1 - T_e}{\frac{1}{\alpha_i} + \frac{s}{\lambda} + \frac{1}{\alpha_e}}$$



MISTE :

II TIPO → $\begin{cases} \varphi = \frac{\lambda}{s} (T_1 - T_2) \\ \varphi_{s/2} = \alpha_e (T_2 - T_e) \end{cases}$

$$\varphi = \frac{(T_1 - T_e)}{\frac{s}{\lambda} + \frac{1}{\alpha_e}}$$

- se c'è contatto

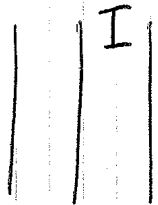
Φ_c, Φ_f, R_{ct}

pg 1017

- se λ dipende

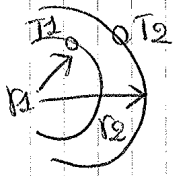
dalla T ($\varphi = \frac{\lambda m}{s} (T_1 - T_2)$)

pg 18/19



pg 15

STRATO sferico $T = C + \frac{B}{r}$; $\frac{dT}{dr} = -\frac{B}{r^2}$



I tipo: $T(r_1) = T_1, T(r_2) = T_2$

ricavo B e C

$$\varphi = -\lambda \frac{dT}{dr} = +\lambda \frac{B}{r^2} =$$

$$\frac{T_2 - T_1}{\frac{r_2^2}{\lambda} \left(\frac{1}{r_2} - \frac{1}{r_1} \right)}$$

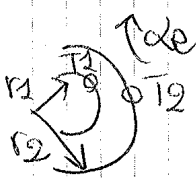
DIPENDE DA r_2

$$\varphi_{s1} = \varphi(r=r_1), \varphi_{s2} = \varphi(r=r_2)$$

$$\frac{\varphi_{s1}}{\varphi_{s2}} = \frac{r_2^2}{r_1^2}$$

$$\Phi = \varphi S = \varphi 4\pi r^2 = \frac{4\pi(T_2 - T_1)}{\frac{1}{\lambda} \left(\frac{1}{r_2} - \frac{1}{r_1} \right)}$$

non x sommare STRATI

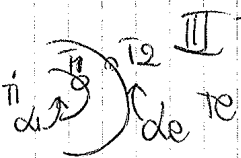


II tipo: $\varphi_{s2} = -\lambda \frac{B}{r^2} \Big|_{r=r_2} = \alpha_e (T_2 - T_e)$

+ PRIMO TIPO come su

$$\varphi_{s2} = \frac{T_2 - T_e}{\frac{r_2^2}{\lambda} \left(\frac{1}{r_1} - \frac{1}{r_2} \right) + \frac{1}{\alpha_e}}$$

$$\varphi_{s1} = \varphi_{s2} \frac{r_2^2}{r_1^2}$$



III tipo:

$$\varphi_{s1} = \frac{T_1 - T_e}{\frac{1}{\alpha_i} + \frac{r_1^2}{\lambda} \left(\frac{1}{r_1} + \frac{1}{r_2} \right) + \frac{r_1^2}{r_2^2} \frac{1}{\alpha_e}}$$

x STRATI cil e sferici

isolante come prima) + $r_0 = \frac{\lambda \Delta}{\alpha_e}$

e assumta la condizione $\frac{d\varphi}{dr} = 0$ x l'isolante

Conduzione stazionaria con generazione di calore

$$\Phi_G = HV$$

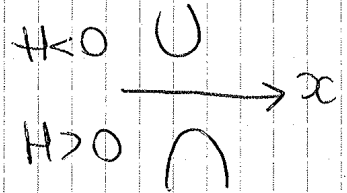
$$\Phi_G = \frac{\Phi_0}{S} = H \frac{V}{S} = Hs$$

STRATO PIANO

$$T = -\frac{H}{2\lambda} x^2 + Bx + C$$

$$B = \frac{T_2 - T_1}{s}$$

$$\frac{dT}{dx} = -\frac{H}{\lambda} x + B$$



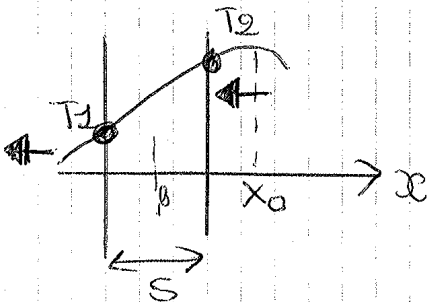
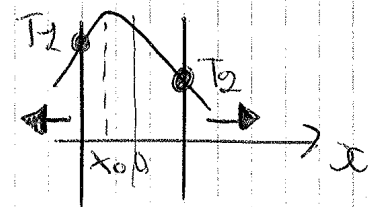
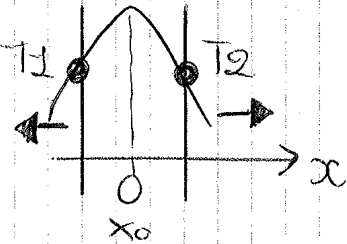
CONDIZIONI I TIPO

$$\Phi_G = \Phi_G S =$$

$$x_0 = 0 \quad T = T_1 + \frac{H}{S}(l^2 - x^2)$$

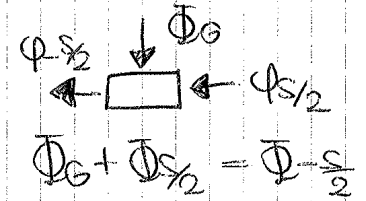
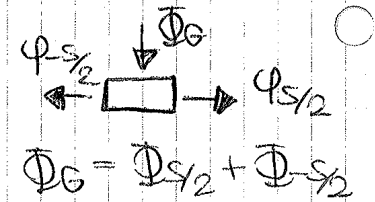
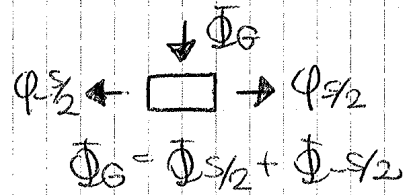
$$T_1 = T_2$$

$$l = \frac{s}{2}$$



$$\Phi_{s/2} = -\lambda \frac{dT}{dx} \Big|_{x=s/2}$$

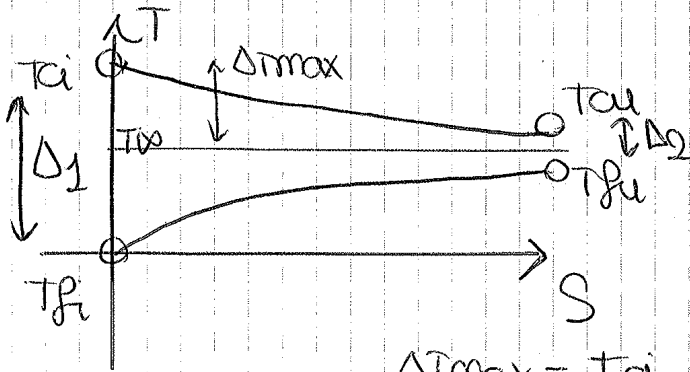
$$\Phi_{-s/2} = -\lambda \frac{dT}{dx} \Big|_{x=-s/2}$$



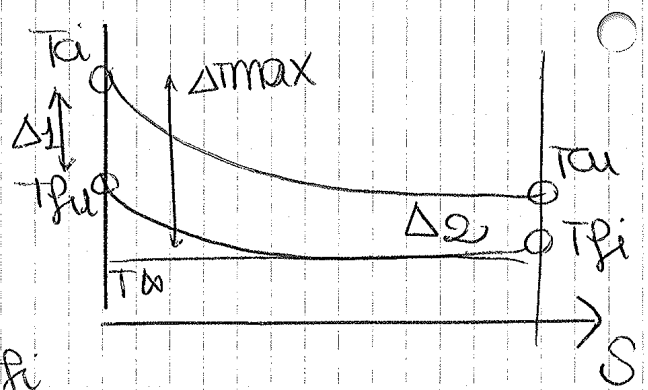
VALUTO $x_0 = \frac{\lambda}{H} \frac{T_2 - T_1}{S}$

SCAMBIATORI DI CALORE

EQVIC



CONTROCOR



$$\Delta T_{max} = T_{ai} - T_{fi}$$

$$C_c = G_c c_{pc}$$

$$C_f = G_f c_{pf}$$

grafici x $C_c < C_f$, $C_c = C_f$, $C_c > C_f$

$$M = \frac{1}{C_c} + \frac{1}{C_f}$$

$$M = -\frac{1}{k S_{TOT}} \ln\left(\frac{\Delta_2}{\Delta_1}\right)$$

$$M = \frac{1}{C_c} - \frac{1}{C_f}$$

//

$$\Phi = k S_{TOT} \Delta T_{me}$$

$$|\Phi_c| = C_c (T_{ai} - T_{au}) > 0$$

//

$$\Delta T_{me} = \frac{\Delta_2 - \Delta_1}{\ln\left(\frac{\Delta_2}{\Delta_1}\right)}$$

$$\Phi_f = C_f (T_{fu} - T_{fi}) > 0$$

//

$$\Phi = |\Phi_c| = \Phi_f$$

$$\frac{\Delta_2}{\Delta_1} = e^{-k M S_{TOT}} = e^{-M C_{min} NTU}$$

$$\Phi = \frac{\Delta_2 - \Delta_1}{M}$$

$$C_{min} = C_c \rightarrow E = \frac{T_{ai} - T_{au}}{T_{ai} - T_{fi}}$$

$$C_{min} = C_f \rightarrow E = \frac{T_{fu} - T_{fi}}{T_{ai} - T_{fi}}$$

$$NTU = \frac{k S_{TOT}}{C_{min}}$$

ne $\frac{C_{min}}{C_{max}} = 1$

$$E = \frac{NTU}{1 + NTU}$$

ne $C_{max} \rightarrow \infty$

$$E = 1 - e^{-NTU}$$

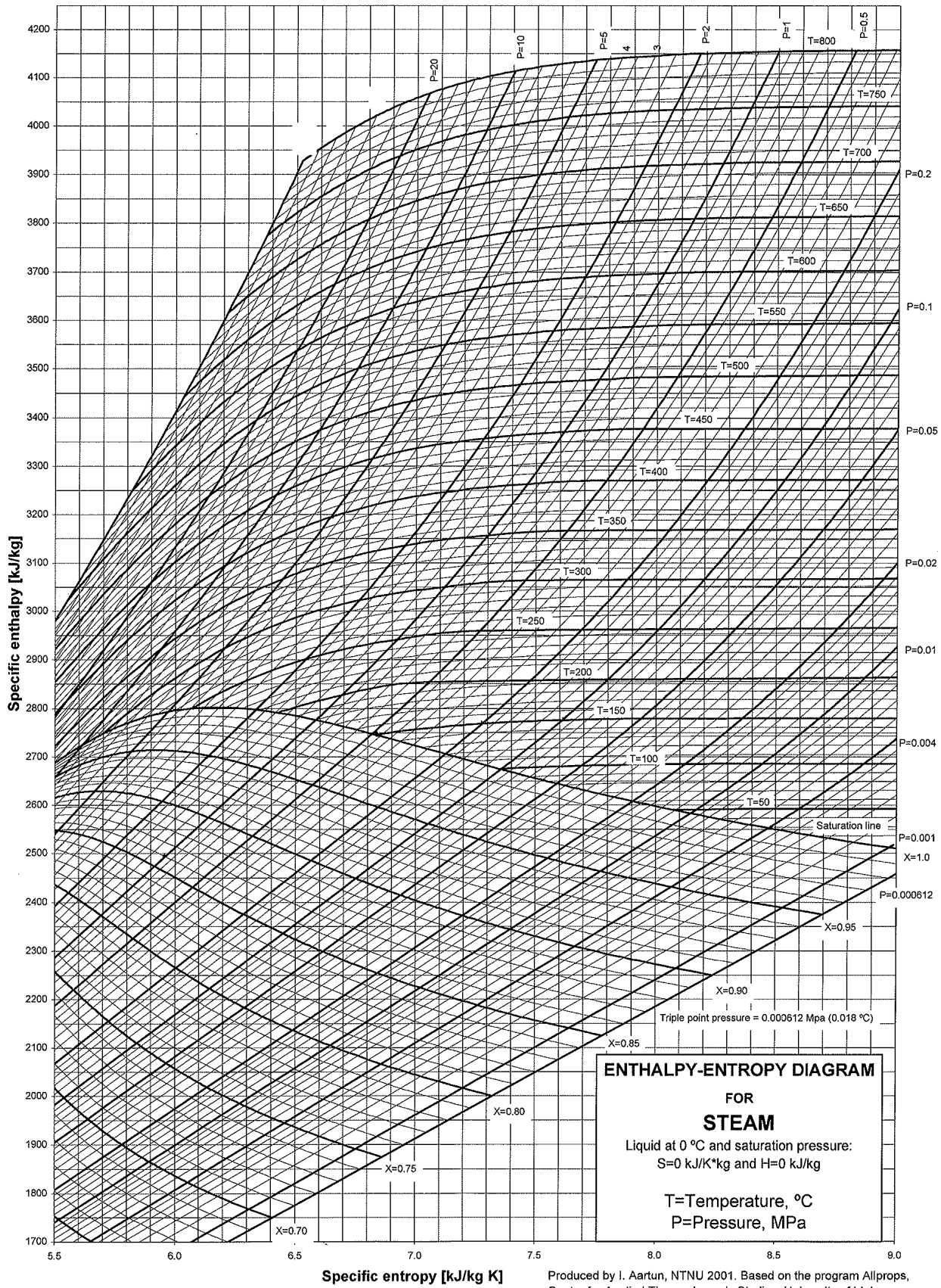
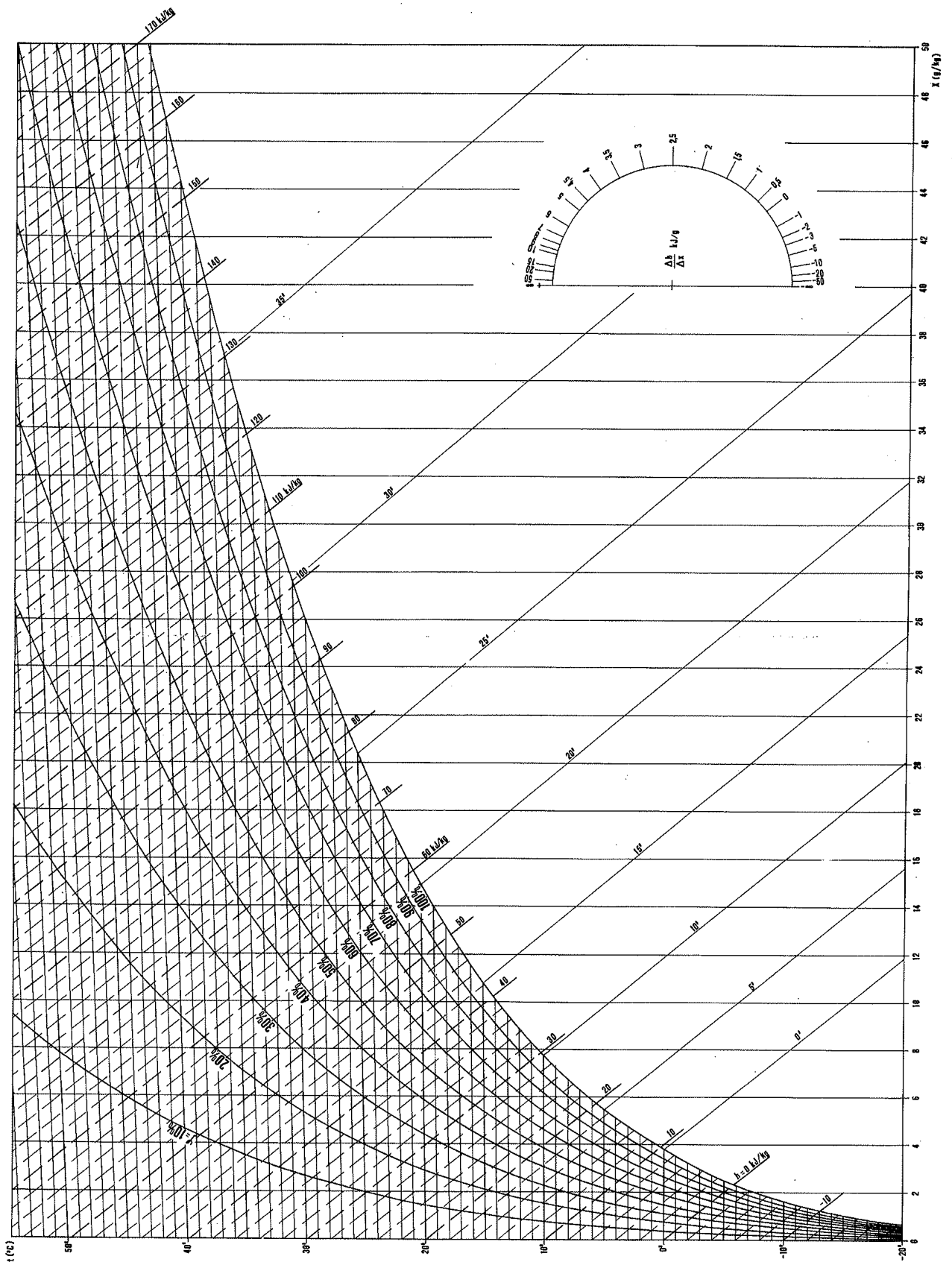


DIAGRAMMA N° 2 Campo Temperature + 50 °C - 20 °C



R134 a

PRESSURE P	SPEC. VOLUME		ENTHALPY			ENTROPY		SPEC. HEAT CAP.		T
	v'	v''	h'	h''-h'	h''	s'	s''	cp'	cp''	
	dm ³ /kg		kJ/kg			kJ/(kg K)		kJ/(kg K)		
bar	liquid	vapour	liquid	latent	vapour	liquid	vapour	liquid	vapour	
0.01	0.6327	25000	77.3	250.0	337.2	0.4448	1.9460	1.155	0.592	.
0.01	0.6382	15385	83.0	257.1	340.1	0.4776	1.9209	1.151	0.603	.
0.02	0.6439	9709	88.8	254.3	343.1	0.5095	1.8982	1.153	0.614	.
0.02	0.6496	6329	94.6	251.6	346.2	0.5406	1.8778	1.157	0.626	.
0.04	0.6554	4255	100.4	248.8	349.2	0.5710	1.8594	1.164	0.637	.
0.05	0.6614	2933	106.2	246.1	352.3	0.6009	1.8428	1.172	0.649	.
0.08	0.6674	2058	112.1	243.3	355.4	0.6302	1.8279	1.180	0.662	.
0.11	0.6736	1477	118.0	240.5	358.5	0.6590	1.8144	1.190	0.674	.
0.16	0.6799	1080	124.0	237.7	361.7	0.6873	1.8024	1.200	0.687	.
0.22	0.6864	803.2	130.0	234.8	364.8	0.7152	1.7916	1.210	0.701	.
0.29	0.6930	606.8	136.1	231.9	368.0	0.7428	1.7819	1.220	0.714	.
0.39	0.6999	465.3	142.2	228.9	371.1	0.7699	1.7732	1.230	0.729	.
0.51	0.7069	361.4	148.4	225.9	374.3	0.7967	1.7655	1.241	0.744	.
0.66	0.7142	284.3	154.8	222.8	377.4	0.8231	1.7586	1.252	0.759	.
0.84	0.7217	226.0	160.9	219.6	380.6	0.8492	1.7525	1.263	0.775	.
1.06	0.7294	181.7	167.3	216.4	383.7	0.8750	1.7470	1.275	0.792	.
1.33	0.7375	147.4	173.7	213.1	386.8	0.9005	1.7422	1.287	0.810	.
1.64	0.7458	120.7	180.2	209.7	389.8	0.9257	1.7379	1.299	0.828	.
2.01	0.7545	99.56	186.7	206.2	392.9	0.9507	1.7341	1.313	0.847	.
2.43	0.7637	82.77	193.3	202.5	395.9	0.9755	1.7308	1.326	0.867	.
2.93	0.7732	69.28	200.0	198.8	398.8	1.0000	1.7278	1.341	0.888	.
3.50	0.7833	58.34	206.8	194.9	401.7	1.0244	1.7252	1.357	0.911	.
4.15	0.7938	49.42	213.6	190.9	404.5	1.0485	1.7229	1.373	0.934	.
4.89	0.8050	42.07	220.5	186.8	407.3	1.0726	1.7208	1.391	0.960	.
5.72	0.8167	35.98	227.5	182.5	410.0	1.0964	1.7189	1.410	0.987	.
6.66	0.8293	30.90	234.6	178.0	412.6	1.1202	1.7171	1.431	1.016	.
7.71	0.8427	26.64	241.8	173.3	415.1	1.1439	1.7155	1.454	1.048	.
8.88	0.8570	23.03	249.2	168.3	417.5	1.1676	1.7138	1.479	1.084	.
10.18	0.8725	19.97	256.8	163.2	419.8	1.1912	1.7122	1.507	1.123	.
11.61	0.8893	17.35	264.2	157.7	421.9	1.2148	1.7105	1.539	1.168	.
13.19	0.9076	15.10	271.9	151.9	423.8	1.2384	1.7088	1.576	1.220	.
14.93	0.9277	13.15	279.8	145.8	425.6	1.2622	1.7064	1.619	1.282	.
16.83	0.9501	11.46	287.9	139.2	427.1	1.2861	1.7039	1.670	1.356	.
18.91	0.9753	9.97	296.2	132.1	428.3	1.3102	1.7009	1.732	1.450	.
21.17	1.0041	8.66	304.8	124.4	429.1	1.3347	1.6971	1.812	1.572	.
23.64	1.0377	7.50	313.7	115.8	429.5	1.3597	1.6924	1.918	1.739	.
26.33	1.0778	6.45	322.9	106.3	429.2	1.3854	1.6863	2.068	1.986	.
29.25	1.1278	5.50	332.8	95.3	428.1	1.4121	1.6782	2.304	2.390	.
32.43	1.1943	4.60	343.4	82.1	425.5	1.4406	1.6668	2.744	3.167	.
35.89	1.2948	3.73	355.6	64.9	420.5	1.4727	1.6489	3.917	5.261	.
39.70	1.5352	2.66	373.2	33.8	407.0	1.5187	1.6092	18.008	27.554	.

ACQUA

Tabelle di saturazione

t	p	ν_1	ν_2	h_1	h_2	s_1	s_2
(°C)	(bar)	(m ³ /kg)	(m ³ /kg)	(kJ/kg)	(kJ/kg)	(kJ/kg K)	(kJ/kg K)
45	0,09582	0,0010099	15,28	188,35	2583,3	0,6383	8,1661
46	0,10086	0,0010103	14,56	192,53	2585,1	0,6514	8,1481
47	0,10612	0,0010107	13,88	196,71	2586,9	0,6645	8,1302
48	0,11162	0,0010112	13,23	200,89	2588,6	0,6776	8,1125
49	0,11736	0,0010117	12,62	205,07	2590,4	0,6906	8,0950
50	0,12335	0,0010121	12,05	209,26	2592,2	0,7035	8,0776
51	0,12961	0,0010126	11,50	213,44	2593,9	0,7164	8,0603
52	0,13613	0,0010131	10,98	217,62	2595,7	0,7293	8,0432
53	0,14293	0,0010136	10,49	221,80	2597,5	0,7422	8,0262
54	0,15002	0,0010140	10,02	225,98	2599,2	0,7550	8,0093
55	0,15741	0,0010145	9,579	230,17	2601,0	0,7677	7,9926
56	0,16511	0,0010150	9,159	234,35	2602,7	0,7804	7,9759
57	0,17313	0,0010156	8,760	238,53	2604,5	0,7931	7,9595
58	0,18147	0,0010161	8,381	242,72	2606,2	0,8058	7,9431
59	0,19016	0,0010166	8,021	246,91	2608,0	0,8184	7,9269
60	0,19920	0,0010171	7,679	251,09	2609,7	0,8310	7,9108
61	0,2086	0,0010177	7,353	255,28	2611,4	0,8435	7,8948
62	0,2184	0,0010182	7,044	259,46	2613,2	0,8560	7,8790
63	0,2286	0,0010188	6,749	263,65	2614,9	0,8685	7,8633
64	0,2391	0,0010193	6,469	267,84	2616,6	0,8809	7,8477
65	0,2501	0,0010199	6,202	272,02	2618,4	0,8933	7,8322
66	0,2615	0,0010205	5,948	276,21	2620,1	0,9057	7,8168
67	0,2733	0,0010211	5,706	280,40	2621,8	0,9180	7,8015
68	0,2856	0,0010217	5,476	284,59	2623,5	0,9303	7,7864
69	0,2984	0,0010223	5,256	288,78	2625,2	0,9426	7,7714
70	0,3116	0,0010228	5,046	292,97	2626,9	0,9548	7,7565
71	0,3253	0,0010235	4,846	297,16	2628,6	0,9670	7,7417
72	0,3396	0,0010241	4,656	301,35	2630,3	0,9792	7,7270
73	0,3543	0,0010247	4,474	305,55	2632,0	0,9913	7,7124
74	0,3696	0,0010253	4,300	309,74	2633,7	1,0034	7,6979
75	0,3855	0,0010259	4,134	313,94	2635,4	1,0154	7,6835
76	0,4019	0,0010266	3,976	318,13	2637,1	1,0275	7,6693
77	0,4189	0,0010272	3,824	322,33	2638,7	1,0395	7,6551
78	0,4365	0,0010279	3,680	326,52	2640,4	1,0514	7,6410
79	0,4547	0,0010285	3,541	330,72	2642,1	1,0634	7,6271
80	0,4736	0,0010292	3,409	334,92	2643,8	1,0753	7,6132
81	0,4931	0,0010299	3,283	339,11	2645,4	1,0871	7,5995
82	0,5133	0,0010305	3,162	343,31	2647,1	1,0990	7,5858
83	0,5342	0,0010312	3,046	347,51	2648,7	1,1108	7,5722
84	0,5557	0,0010319	2,935	351,71	2650,4	1,1225	7,5588
85	0,5780	0,0010326	2,829	355,92	2652,0	1,1343	7,5454
86	0,6011	0,0010333	2,727	360,12	2653,6	1,1460	7,5321
87	0,6249	0,0010340	2,630	364,32	2655,3	1,1577	7,5189
88	0,6495	0,0010347	2,536	368,53	2656,9	1,1693	7,5058
89	0,6749	0,0010354	2,447	372,73	2658,5	1,1809	7,4928

p	t	v_t	v_s	h_t	h_s	s_t	s_s
(bar)	(°C)	(m³/kg)	(m³/kg)	(kJ/kg)	(kJ/kg)	(kJ/kg K)	(kJ/kg K)
(*)0,006112	0,01	0,0010002	206,2	0,00	2501,6	0,0000	9,1575
0,010	6,9828	0,0010001	129,20	29,34	2514,4	0,1060	8,9767
0,015	13,036	0,0010006	87,98	54,71	2525,5	0,1957	8,8288
0,020	17,513	0,0010012	67,01	73,46	2533,6	0,2607	8,7246
0,025	21,096	0,0010020	54,26	88,45	2540,2	0,3119	8,6440
0,030	24,100	0,0010027	45,67	101,00	2545,6	0,3544	8,5785
0,035	26,694	0,0010033	39,48	111,85	2550,4	0,3907	8,5232
0,040	28,983	0,0010040	34,80	121,41	2554,5	0,4225	8,4755
0,045	31,035	0,0010046	31,14	129,99	2558,2	0,4507	8,4335
0,050	32,898	0,0010052	28,19	137,77	2561,6	0,4763	8,3960
0,055	34,605	0,0010058	25,77	144,91	2564,7	0,4995	8,3621
0,060	36,183	0,0010064	23,74	151,50	2567,5	0,5209	8,3312
0,065	37,651	0,0010069	22,02	157,64	2570,2	0,5407	8,3029
0,070	39,025	0,0010074	20,53	163,38	2572,6	0,5591	8,2767
0,075	40,316	0,0010079	19,24	168,77	2574,9	0,5763	8,2523
0,080	41,534	0,0010084	18,10	173,86	2577,1	0,5925	8,2296
0,085	42,689	0,0010089	17,10	178,69	2579,2	0,6079	8,2082
0,090	43,787	0,0010094	16,20	183,28	2581,1	0,6224	8,1881
0,095	44,833	0,0010098	15,40	187,65	2583,0	0,6361	8,1691
0,10	45,833	0,0010102	14,67	191,83	2584,8	0,6493	8,1511
0,11	47,710	0,0010111	13,42	199,68	2588,1	0,6738	8,1177
0,12	49,446	0,0010119	12,36	206,94	2591,2	0,6963	8,0872
0,13	51,062	0,0010126	11,47	213,70	2594,0	0,7172	8,0592
0,14	52,574	0,0010133	10,69	220,02	2596,7	0,7367	8,0334
0,15	53,997	0,0010140	10,02	225,97	2599,2	0,7549	8,0093
0,16	55,341	0,0010147	9,433	231,59	2601,6	0,7721	7,9869
0,17	56,615	0,0010154	8,911	236,93	2603,8	0,7883	7,9658
0,18	57,826	0,0010160	8,445	241,99	2605,9	0,8036	7,9460
0,19	58,982	0,0010166	8,027	246,83	2607,9	0,8182	7,9272
0,20	60,086	0,0010172	7,650	251,45	2609,9	0,8321	7,9094
0,21	61,145	0,0010178	7,307	255,88	2611,7	0,8453	7,8925
0,22	62,162	0,0010183	6,995	260,14	2613,5	0,8581	7,8764
0,23	63,139	0,0010189	6,709	264,23	2615,2	0,8702	7,8611
0,24	64,082	0,0010194	6,447	268,18	2616,8	0,8820	7,8464
0,25	64,992	0,0010199	6,204	271,99	2618,3	0,8932	7,8323
0,26	65,871	0,0010204	5,980	275,67	2619,9	0,9041	7,8188
0,27	66,722	0,0010209	5,772	279,24	2621,3	0,9146	7,8058
0,28	67,547	0,0010214	5,579	282,69	2622,7	0,9248	7,7933
0,29	68,347	0,0010219	5,398	286,05	2624,1	0,9346	7,7812
0,30	69,124	0,0010223	5,229	289,30	2625,4	0,9441	7,7695
0,32	70,615	0,0010232	4,922	295,55	2628,0	0,9623	7,7474
0,34	72,029	0,0010241	4,650	301,48	2630,4	0,9795	7,7266
0,36	73,374	0,0010249	4,408	307,12	2632,6	0,9958	7,7070
0,38	74,658	0,0010257	4,190	312,50	2634,8	1,0113	7,6884

p	t	ν_t	ν_s	h_t	h_s	s_t	s_s
(bar)	(°C)	(m ³ /kg)	(m ³ /kg)	(kJ/kg)	(kJ/kg)	(kJ/kg K)	(kJ/kg K)
65	280,82	0,0013350	0,02972	1241,1	2779,5	3,0759	5,8527
70	285,79	0,0013513	0,02737	1267,4	2773,5	3,1219	5,8162
75	290,50	0,0013677	0,02533	1292,7	2766,9	3,1657	5,7811
80	294,97	0,0013842	0,02353	1317,1	2759,9	3,2076	5,7471
85	299,23	0,0014009	0,02193	1340,7	2752,5	3,2479	5,7141
90	303,31	0,0014179	0,02050	1363,7	2744,6	3,2867	5,6820
95	307,21	0,0014351	0,01921	1386,1	2736,4	3,3242	5,6506
100	310,96	0,0014526	0,01804	1408,0	2727,7	3,3605	5,6198
110	318,05	0,0014887	0,01601	1450,6	2709,3	3,4304	5,5595
120	324,65	0,0015268	0,01428	1491,8	2689,2	3,4972	5,5002
130	330,83	0,0015672	0,01280	1532,0	2667,0	3,5616	5,4408
140	336,64	0,0016106	0,01150	1571,6	2642,4	3,6242	5,3803
150	342,13	0,0016579	0,01034	1611,0	2615,0	3,6859	5,3178
160	347,33	0,0017103	0,009308	1650,5	2584,9	3,7471	5,2531
170	352,26	0,0017696	0,008371	1691,7	2551,6	3,8107	5,1855
180	356,96	0,0018399	0,007498	1734,8	2513,9	3,8765	5,1128
190	361,43	0,0019260	0,006678	1778,7	2470,6	3,9429	5,0332
200	365,70	0,0020370	0,005877	1826,5	2418,4	4,0149	4,9412
210	369,78	0,0022015	0,005023	1886,3	2347,6	4,1048	4,8223
220	373,69	0,0026714	0,003728	2011,1	2195,6	4,2947	4,5799
(*) 221,20	374,15	0,00317		2107,4		4,4429	