NUMERO : 379

DATA : 17/10/2012

APPUNTI

STUDENTE : Gemello

MATERIA : Processi Separazione
Prof. Manna

SCRITTO → ESERCIZI → MAX 24
+
ORALE → TEORIA → DA 2

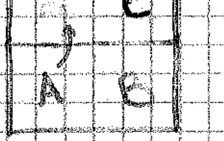
PROCESSI DI SEPARAZIONE

X RIMUOVERE UN COMPONENTE DA UNA FASE

PUÒ ESSERCI CATALLIZZATORE

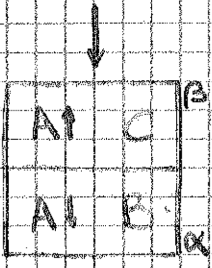
IMPUREZZE AVVELENANO CATALIZZAT.

SE OTTIMO REATTORE RISPARMIO NEI PROCESSI DI SEPARAZIONE



C IN FASE ≠ DA AB, DI CUI DOBBIAMO SEPARARE A,B

C MOLTO AFFINE AD A, POCO A B



SFRUTTO EQUILIBRIO

POTENZIALE CHIMICO $\mu_A^\alpha > \mu_A^\beta \rightarrow \mu_A^\alpha = \mu_A^\beta$

NON ∃ MISURATORE μ

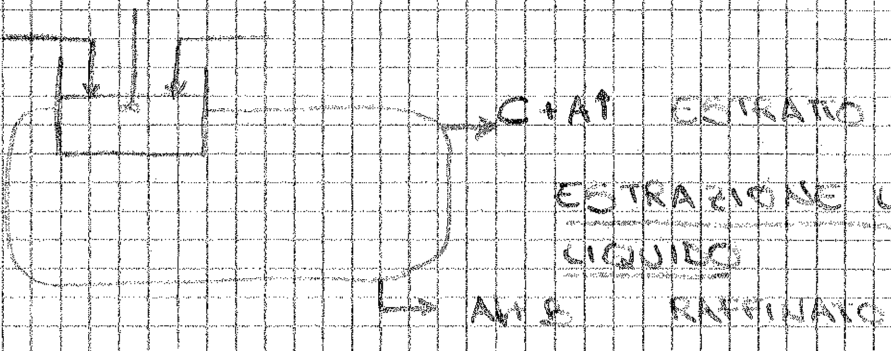
$T^\alpha > T^\beta \rightarrow T^\alpha = T^\beta$ EQ. TERMICO

$P^\alpha > P^\beta \rightarrow P^\alpha = P^\beta$ EQ. MECCANICO

$\mu = \mu(P, T, \text{COMP})$

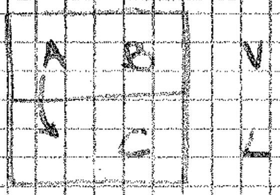
$$\mu_A^\alpha = \mu_A^\beta$$
$$\downarrow$$
$$y_A = \underbrace{K_A}_{} x_A$$

→ COEFF. DI RIPARTIZIONE

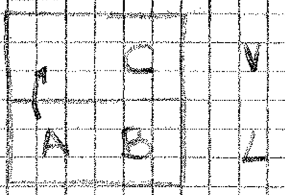


ESTRAZIONE LIQUIDO-LIQUIDO

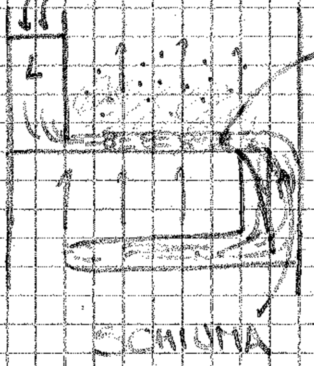
ASSORBIMENTO



DEASSORBIMENTO



GAS/VAPORE IL LIQUIDO



PIATTO FORATO
↓
GAS ENTRA
PERCOLAZIONE
LIQUIDO
↓
MISCELAZIONE
INTENSA
↓
POI A SFERICHE
GOCCIOLINE
RIDEPOSITANO

PIATTI IMPILATI

STADIO IDEALE

1) EQUILIBRIO TRA CORRENTI USCENTI

2) CORRENTI MONOFASICHE → SEPARAZ. PERFETTA TRA ≠ FASI

SISTEMI RISOLVIBILI

N EQUAZIONI (N_E) → VARIABILI (N_V) → $v_1, v_2, \dots, v_r$

↓ IN UN CERTO DOMINIO

$N_L = N_V - N_E$

↑ GRADI LIBERTÀ $N_L > 0 \rightarrow N_V > N_E$

VARIABILI → INCOGNITE
→ DI PROGETTO → DEVO SPECIFICARLE
(SPECIFICHE DI PROGETTO) ↳ POSSO DECIDERE IO POICHÉ $N_L > 0$

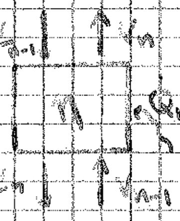
N_E → DEVONO ESSERE LINEARI, INDIPENDENTI

SOLUZIONI DEVONO ESSERE NEL MIO DOMINIO

↓ ES: x_A DEVE ESSERE COMPRESO TRA 0 E 1

DEVO FARE ANALISI GRADI LIBERTÀ

DOBBIAMO IMPORRE DELLE CONDIZ. DI EQUILIBRIO



$$\left.\begin{aligned} T_n^V &= T_n^L \\ P_n^V &= P_n^L \\ y_{i,n} &= K_{i,n} x_{i,n} \end{aligned}\right\} C+2 \qquad \begin{aligned} i &= 1, \dots, C \\ &\text{NUM. COMP.} \end{aligned}$$

POSSO SCRIVERE C EQUAZ. DEI BILANCI DI MATERIA

↓ C-1 BILANCI PARZIALI + BILANCIO TOTALE

$$x_{i,n-1} L_{n-1} + y_{i,n+1} V_{n+1} = x_{i,n} L_n + y_{i,n} V_n \qquad i = 1, \dots, C-1$$

$$L_{n-1} + V_{n+1} = L_n + V_n$$

+ INVARIANTI → CONS. ENERGIA, 3 CONS. QDM, 3 CONS. MOMENTO

SE 4 CORRENTI:

$N_L = N_V - N_E = 2(c+2)+2 = 2c+6$

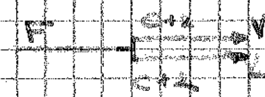
*SE ABBIAMO e CORRENTI ENTRANTI, u CORRENTI USCENTI:

$N_V = (e+u)(c+2)+1$

$N_E = c+1+\underbrace{(u-1)(c+2)}_{\text{CONDIZ. DI EQUILIBRIO}}$

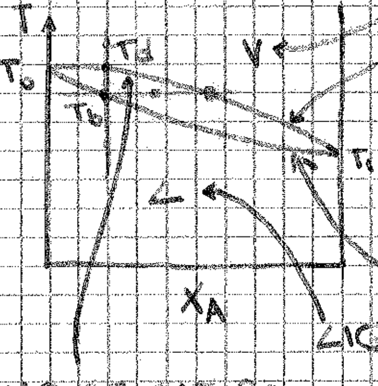
$\boxed{N_L = e(c+2)+2}$ ← SE CORRENTI MONOFASICHE

SE CORRENTI NON MONOFASICHE:



$N_L = 2(c+2) - \underbrace{(c+2)}_{\text{EQ. BILANCIO}} = \underbrace{c+2}_{\text{NON CAMBIA}}$

DIAGRAMMA DELLE FASI



VAPORE SURRISCALDATO

LINEE DI MONOVARIANZA
↳ EQ. BIFASICA

p = COST EQUILIBRIO L-V

LIQUIDO SATURO

LIQUIDO SOTTORAFFREDDATO

VAPORE SATURO

$y_i = k_i x_i$ ← IN ZONA EQ. L-V (ZONA BIFASICA)

X CALCOLARE TEMP. EBOLLIZIONE: (T_b)

$$\left\{\begin{array}{ll} y_i = k_i x_i & i = 1,\dots,c \\ x_i = z_i & \text{• SOLO FASE LIQUIDA} \end{array}\right\} \rightarrow y_i = k_i z_i$$

$\sum y_i = 1 = \sum k_i z_i$

$\sum k_i z_i = 1$ ⟺ TEMP. EBOLLIZIONE $\sum_i k_i(T_b)\, z_i = 1$

2 SOLUZIONI $\rightarrow \psi = 0 \rightarrow \sum_i z_i = 1 \Rightarrow$ SOLUZIONE CHE VIENE SEMPRE (BANALE) (IN T_b)

$\rightarrow$ RISULTATO

$$y_i = K_i x_i = \frac{K_i z_i}{1+(K_i-1)\psi}$$

$\sum_i \frac{K_i z_i}{1+(K_i-1)\psi} \Rightarrow$ SOLUZIONE BANALE $\psi = 1$ (IN T_d)

FACCIAMO DIFFERENZA TRA 2 EQUAZ. (COMBINAZ.)

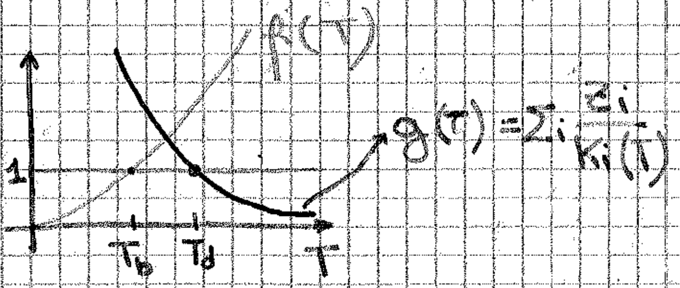
$$\boxed{\sum_i \frac{(1-K_i)z_i}{1+(K_i-1)\psi} = 0} \qquad f(\psi) = 0$$

EQUAZIONE DI RACHFORD-RICE

$T_b \rightarrow \sum_i K_i(T)\, z_i = 1$

$T_d \rightarrow \sum_i \frac{z_i}{K_i(T)} = 1$

$f(T) = \sum_i K_i(T)\, z_i$



$\sum_i K_i(T)\, z_i < 1 \rightarrow$ LIQUIDO SOTTORAFFREDDATO ($T<T_b$)

$\sum_i K_i(T)\, z_i = 1 \rightarrow T = T_b$

$\sum_i K_i(T)\, z_i > 1 \rightarrow T > T_b$

$\sum_i \frac{z_i}{K_i(T)} < 1 \rightarrow T > T_d \rightarrow$ VAPORE SURRISCALDATO

$\sum_i \frac{z_i}{K_i(T)} = 1 \rightarrow T = T_d$

$\sum_i \frac{z_i}{K_i(T)} > 1 \rightarrow T < T_d$

EQUILIBRIO LIQUIDO-VAPORE (ZONA BIFASICA)

$F, p_F, T_F, z_1, \dots, z_{C-1}, \underset{\overset{\shortparallel}{p}}{p^V}, \underset{\overset{\shortparallel}{T}}{T^V}$

1. $K_i = \dfrac{p_i^S(T)}{p}$

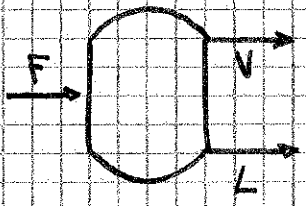
2. $\sum \dfrac{(1-K_i)z_i}{1-(1-K_i)\varphi} = 0 \Rightarrow \varphi \begin{cases} \nearrow V = \varphi F \\ \searrow L = (1-\varphi)F \end{cases}$

3. $x_i = \dfrac{z_i}{1+(K_i-1)\varphi}$; $y_i = K_i x_i$

4. $\tilde{Q} = (1-\varphi)h + \varphi H - h_F$ $\qquad \tilde{Q} = \dfrac{\dot{Q}}{F}$

FLASH

$$\sum_i \frac{(1-K_i)z_i}{1+(K_i-1)\varphi} = 0$$



$C+G$

$F, z_1, \dots, z_{C-1}, p_F, T_F, p_V, \left\{\begin{matrix} T^V \\ \varphi \\ Q \end{matrix}\right.$

$\textcircled{T^V}$ $T^V = T^L = T$ $\qquad R(T) = 0$

$K_i = \dfrac{p_i^S(T)}{p}$

$\textcircled{\varphi}$ $\sum \dfrac{[1-K_i(T)]z_i}{1+[K_i(T)-1]\varphi} = 0$ $\qquad R(T) = 0$

K_i DIPENDE DA T → + INTERAZIONI x CALCOLARE T

$\textcircled{Q}$ DOBBIAMO RISOLVERE TUTTE LE EQUAZ. INSIEME

$$F h_F + \dot{Q} = \underset{\substack{\downarrow \\ \text{FASE LIQUIDA}}}{L \cdot h} + V \cdot H \rightarrow \text{FASE VAPORE}$$

	A_i	B_i [°C]	C_i [°C]
n-C_6	6,92700	1197,320	227,26
n-C_7	6,90027	1266,870	216,76
n-C_8	6,92377	1355,126	209,517

TENGO TANTE CIFRE XKE' POI USO ESPONENZIALE

$$p_i^s = 10^{A_i - \frac{B_i}{C_i + T}}$$

$$K_i = \frac{p_i^s}{P}$$

$1\ at = 1 \frac{Kg_f}{cm^2}$ → CHILOGRAMMO FORZA

↳ 0 ALTITUDINE

45° LATITUDINE

$= 98066{,}5\ Pa$

$g = 9{,}80665\ m/s^2$

ata = PRESSIONE ASSOLUTA

$1\ atm = 760\ mmHg = 101325\ Pa$

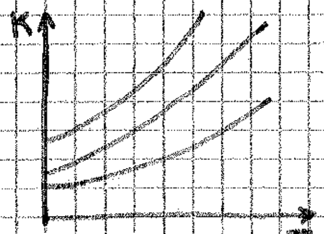
↳ A 0°C

0 ALTITUDINE

45 LATITUDINE

$1\ bar = 100000\ Pa$

ⓉⒹ $\sum_i \frac{z_i}{K_i(T)} = 1$ $\qquad \frac{z_6}{K_6(T)} + \frac{z_7}{K_7(T)} + \frac{z_8}{K_8(T)} = 1$



$$\frac{K_6(T)}{K_7(T)} = \alpha_{6,7} = \frac{y_6}{y_7} \cdot \frac{x_7}{x_6}$$

↓ VOLATILITA' RELATIVA

$\alpha_{i,r}$ → POSSO ASSUMERE $\alpha_{i,r}$ COSTANTI

↓

DIPENDE POCO DA T

3. $K_i(T_0)$; $\alpha_{ir}(T_0)$

4. $T_1 = g(T_0)$

5. $|T_1 - T_0| < 0{,}1$ °C ?

6. $K_i(T_1)$ $\alpha_{i,r}(T_1)$

7. $T_2 = g(T_1)$ ... $T_0, T_1, T_2, \ldots \rightarrow T_d$

SVOLGIMENTO

$0{,}5\ [ata] = 367{,}79\ [mmHg]$

$$T_{b6} = \frac{B_6}{A_6 - \log_{10}(P)} - C_6 = 47{,}27\ °C$$

$T_{b7} = 75{,}50\ °C$ $T_{b8} = 101{,}42\ °C$

$T_0 = \sum_i z_i T_{bi} = 63{,}98\ °C$

$p_6^s(T_0) = 654{,}5687$ $p_7^s(T_0) = 244{,}1521$

$$\alpha_{6,7} = \frac{p_6^s(T_0)}{p_7^s(T_0)} = 2{,}6806 \qquad \alpha_{7,7} = 1$$

$p_8^7(T_0) = 93{,}102$

$$\alpha_{8,7} = \frac{p_8^s(T_0)}{p_7^s(T_0)} = 0{,}3813$$

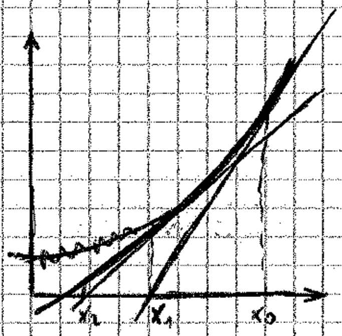
$$p_0^* = p \sum \frac{z_i}{\alpha_{ir}(T_0)} = 312{,}16\ [mmHg]$$

$$T_1 = \frac{B_7}{A_7 - \log(p_0^*)} - C_7 = 70{,}78\ °C$$

$e_1 = |T_1 - T_0| = 6{,}8\ °C$

$\alpha_{6,7}(T_1) = 2{,}6020$ $\alpha_{8,7}(T_1) = 0{,}3934$

$$p_1^* = p \sum \frac{z_i}{\alpha_{i,r}(T_1)} = 311{,}28\ [mmHg]$$



FUNZ. REGOLARE MONOTONA
↓
CONV. ABBASTANZA VELOCE

C'E' $f'(x)$ A DENOMINATORE
↓
NON VANNO BENE PUNTI A TG. ORIZZ. / $f'(x)$ DEVE ESSERE $\neq 0$

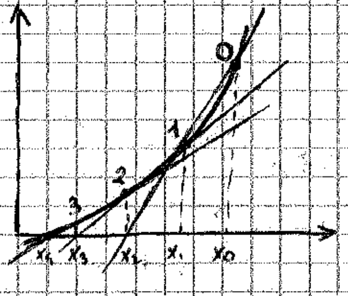
DEVO CALCOLARE f E f' DELLA FUNZ.

NON CONVIENE SE f' COMPLICATO

METODO DELLE SECANTI

$0 = f(x_0) + m(x - x_0)$ $\qquad x_{n+1} = x_n - \frac{f(x_n)}{m_n}$

PRENDO 2 PUNTI E CONSIDERO SECANTE PASSANTE X QUESTI 2 PUNTI



$$m_1 = \frac{f(x_1) - f(x_0)}{x_1 - x_0}$$

$$0 = f(x_1) + m_1(x_2 - x_1)$$

$$x_2 = x_1 - \frac{f(x_1)}{m_1}$$

+ NON SERVE f'
- 2 STIME INIZIALI
- CONV. + LENTA

SE f' FACILE → METODO TANGENTI

SE f' DIFFICILE → METODO SECANTI

EQUAZ. RADFORD-RICE → MONOTONA → 2 METODI PREC.

$f(\psi) = \Sigma_i \frac{(1-K_i)\, z_i}{1+(K_i-1)\psi}$ $\qquad K_i = \frac{p_i^S}{P}$

$$\sum_i \frac{(1-K_i)z_i}{1+(K_i-1)\varphi} \qquad \varphi(T) = \frac{\tilde{c}_{pL}(T_F-T)+\tilde{Q}}{\lambda} \qquad \varphi' = -\frac{\tilde{c}_{pL}}{\lambda}$$

$$f'(T) = \sum \frac{-K_i' z_i[1+(K_i-1)\varphi] - [K_i'\varphi+(K_i-1)\varphi']\cdot(1-K_i)z_i}{[1+(K_i-1)\varphi]^2}$$

$$= -\sum \frac{-\ln(10)B_i(C_i+T)^2 + z_i + (K_i-1)^2 \tilde{c}_{pL}/\lambda z_i}{[1+(K_i-1)\varphi]^2}$$

ESERCIZI

1) φ NOTA

ESANO (30%) ; EPTANO (35%) ; OTTANO

140°C 10 ata PORTATA ENTRANTE = 100 Kmol/h

$\varphi = 0{,}6$ CORRENTE USCENTE HA $p = 0{,}7$ ata

EQUILIBRIO TD, FASI USCENTI SEPARATE

$\dot{Q}$ = ? T = ? PORTATA E COMPOSIZ. CORRENTI USCENTI?

$e = 0{,}01$°C $\lambda = 8100$ Kcal/mol $\tilde{c}_{pL} = 60$ Kcal/Kmol °C

	A	B [°C]	C [°C]
n-C_6	6,91058	1189,640	266,280
n-C_7	6,89386	1264,370	216,640
n-C_8	6,93142	1358,800	209,855

$$\log_{10}(p_i^s / \text{mmHg}) = A_i - \frac{B_i}{C_i + T/°C}$$

$$\sum_{i=1}^{3} \frac{(1-K_i(T))z_i}{1+(K_i(T)-1)\varphi} = 0 = f(T) \qquad K_i = \frac{p_i^s}{p}$$

CALCOLO TEMPERATURA

NEWTON $\searrow T_{n+1} = T_n + \frac{f(T_n)}{f'(T_n)}$

$$f'(T) = -\ln(10)\sum \frac{B}{(C_i+T)^2} \cdot \frac{K_i(T)z}{[1+(K_i(T)-1)\varphi]^2}$$

$$z_i = x_i(1-\varphi) + (K_i x_i)\varphi$$

$$x_i = \frac{z_i}{(1-\varphi)+K_i\varphi} \qquad \sum x_i = \sum \frac{z_i}{(1-\varphi)+K_i\varphi} = 1$$

$$y_i = \frac{K_i z_i}{(1-\varphi)+K_i\varphi} \qquad \sum y_i = \sum \frac{K_i z_i}{1+(K_i-1)\varphi} = 1$$

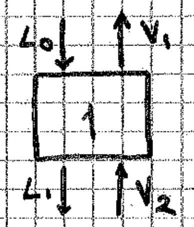
$$\frac{(1-K_i)\, z_i}{(1-\varphi)+K_i\varphi} = 0$$

$$T_b = \begin{cases} z_i = x_i \\ y_i = K_i z_i \end{cases} \qquad \sum_i K_i z_i = 1$$

$$T_d = \begin{cases} y_i = z_i \\ z_i = K_i x_i \end{cases} \qquad \sum_i \frac{z_i}{K_i} = 1$$

$\boxed{\text{ESTRAZIONE FRIGORIFERA}}$ LIQUIDO / LIQUIDO

2 CORRENTI e + 2 CORR. M



DEVO POI RECUPERARE SOLVENTE (DISTILLAZIONE)

T_2^V, P_2^V

$$N_L = 2(c+2)+2 = 2c+6$$

FASI CONDENSATE → TRASCURIAMO PERDITE PRESSIONE
↳ ISOBARA (INCOMPRIMIBILI)

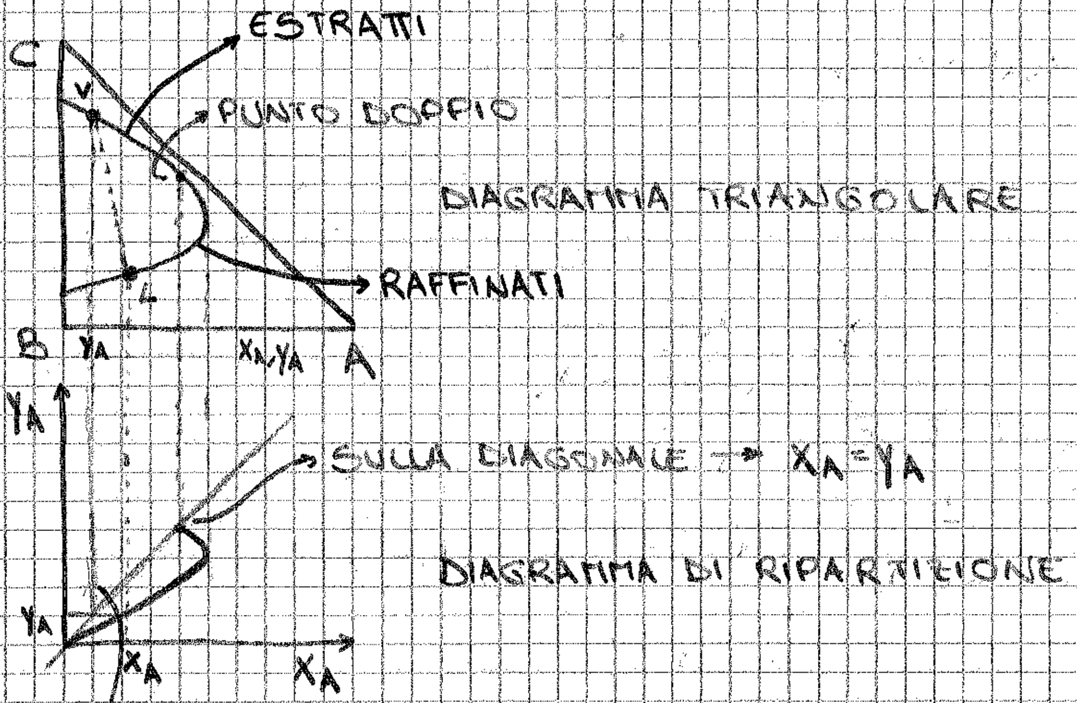
EFFETTO TERMICO TRASCURABILE → ISOTERMO

$$\left.\begin{array}{l} L_0;\ x_{0,1};\ x_{0,c-1},\ P_0^L,\ T_0^L \\ e_{01},\ e_{02};\ldots;\ e_{0c},\ P_0^L,\ T_0^L \end{array}\right\} \text{— UNA DELLE 2} \rightarrow c+2$$

$$V_2;\ y_{2,1};\ldots;\ y_{2,c-1};\ P_2^V,\ T_2^V \rightarrow c+2$$

$$P_1^V,\ T_1^V \longrightarrow 2$$

$$P \equiv P_0^L = P_2^V = P_1^V \qquad T \equiv T_0^L = T_2^V = T_1^V$$



ARRIVIAMO FINO ALLA DIAGONALE A POI ANDIAMO IN ORIZZONTALE

TRACCIO POI SEGM. ORIZZONTALE E LEGGO X_A

TRACCIO DA X_A VERTICALE PER TROVARE L

P, T

L_0, X_{0A}, X_{0C}

V_2, Y_{2A}, Y_{2C}

$L_0 + V_2 = L_1 + V_1$

$L_0 X_{0A} + V_2 Y_{2A} = L_1 X_{1A} + V_1 Y_{1A} = \Sigma \, z_{\Sigma A}$

$L_0 X_{0C} + V_2 Y_{2C} = L_1 X_{1C} + V_1 Y_{1C} = \Sigma \, z_{\Sigma C}$

$Y_{1A} = K_{1A} X_{1A}$

$Y_{1B} = K_{1B} X_{1B}$

$Y_{1C} = K_{1C} X_{1C}$

$X_{1B} = 1 - X_{1A} - X_{1C} \; ; \; Y_{1B} = 1 - Y_{1A} - Y_{1C}$

$$N_L = 2N\cancel{(C+2)} + 2N - 2N\cancel{(C+2)} + 2(C+2) + 1$$
$$= 2C + 2N + 5$$

NEL NOSTRO CASO ASSUMIAMO p, T COST. → $C + 2N$

$N_L = 2C + 1 + (C + 2N)$

$\left.\begin{matrix} V_{N+1}, y_{N+1,1}, \dots, y_{N+1,C-1} \\ L_0, x_{0,1}, \dots, x_{0,C-1} \end{matrix}\right\} 2C$ NUM. STADI

POSSO DETERMINARE NUM. STADI CHE SERVONO X ESTRAZIONE SAPENDO p, T, COMPOSIZ. INGRESSO E COMPOSIZ V_{USCITA} VOLUTO (CALCOLO PROGETTO)

SE CONOSCO NUM. STADI POSSO DETERMINARE COMPOSIZ. CORRENTE USCENTE (CALCOLO VERIFICA)

POSSO RISOLVERE ANCHE IN MODO SOTTOSPECIFICATO; SE RIDUCO PORTATA SOLVENTE SERVE UN NUMERO MAGGIORE DI STADI

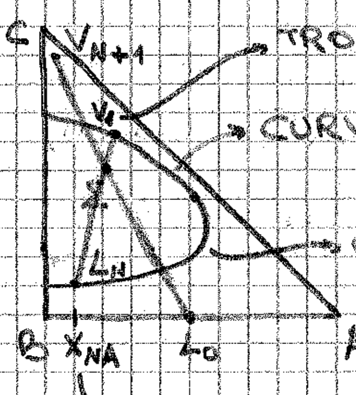
∃ UNA PORTATA MINIMA, AL DI SOTTO DEL QUALE SI RAGGIUNGE EQUILIBRIO PRIMA DEGLI ULTIMI STADI

CALCOLO DI PROGETTO

$L_0 + V_{N+1} = L_N + V_1$

$x_{0A} L_0 + y_{N+1,A} V_{N+1} = x_{NA} L_N + y_{1A} V_1 = z_{\Sigma A}$

$x_{0C} L_0 + y_{N+1,C} V_{N+1} = x_{NC} L_N + y_{1C} V_1 = z_{\Sigma C}$



→ TROVO V_1 POICHE' L_N, Σ, V_1 ALLINEATI

→ CURVA ESTRATTI

→ CURVA RAFFINATI

$\overline{V_1\Sigma} : L_N = \overline{\Sigma L_N} : V_1$

$$\frac{\overline{V_1\Sigma}}{\overline{V_1L_N}} = \frac{L_N}{V_1 + L_N} = \frac{L_N}{L_0 + V_{N+1}}$$

→ SPECIFICA DI PROGETTO → L_N ESCE DA STADIO EQUIL.

$$\frac{\overline{V_{N+1}\Sigma}}{\overline{V_N L_0}} = \frac{L_0}{L_0 + V_{N+1}}$$

$$V_{N+1} = 2,5\left(V_{N+1}\right)_{MIN} = 5769,231$$

$$\overline{V_{N+1}\Sigma} = \left(\frac{L_0}{L_0+V_{N+1}}\right)\overline{V_{N+1}L_0}$$

$$\overline{V_{N+1}\Sigma} = \left(\frac{2000}{7769,231}\right)\cdot 11,7 = 3,012$$

x il prof.
$V_{N+1} = 4915$ Kg/h

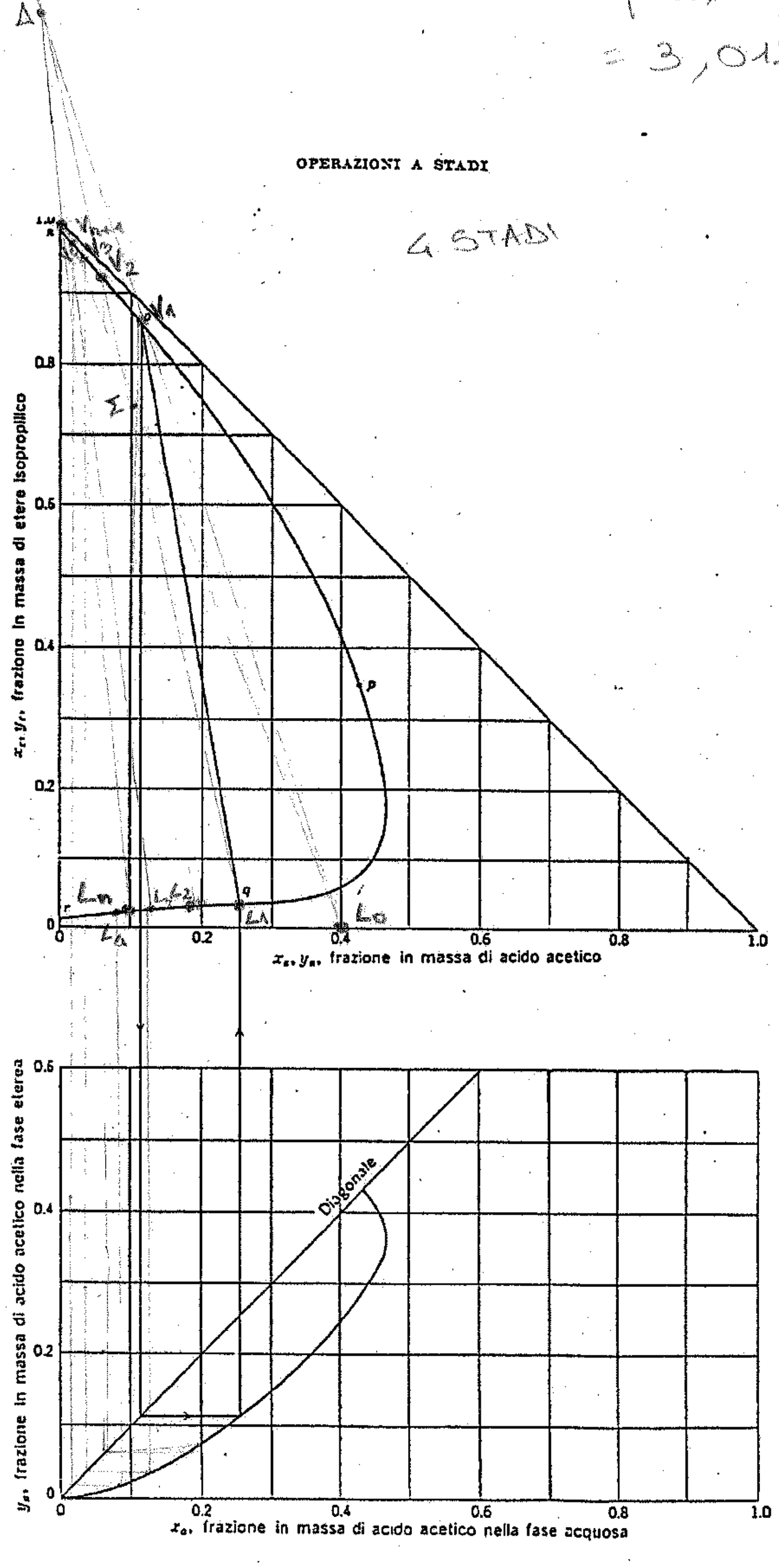
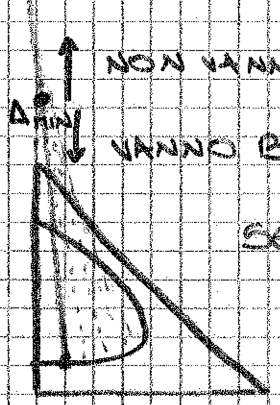


Fig. 3.8. - Sistema etere isopropilico-acido acetico-acqua a 20°C (7).



↑ NON VANNO BENE → INTERSEZ. LUOGO Δ CON LINEE CONIUG.

↓ VANNO BENE → DOVE NON CI SONO INTERSEZIONI

SE AUMENTO PORTATA V_{N+1} SI ABBASSA Δ

↓

DETERMINO PORTATA MINIMA DI V_{N+1} DA Δ_{MIN}

ESERCIZIO FOTOCOPIE

SOLUZIONE AC. ACETICO IN H_2O AL 40%
DEVE ESSERE SEPARATA X ESTRAZIONE UTILIZZANDO ETERE ISOPROPILICO
SI VUOLE OTTENERE RAFFINATO CON MAX 10% DI ACIDO ACETICO. DETERMINARE:

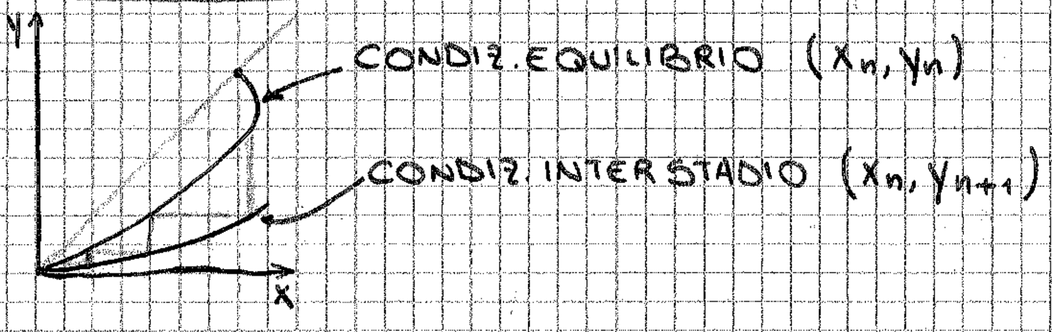
a) PORTATA MINIMA SOLVENTE
b) NUM. STADI X CONDIZ. DI LAVORO PARI A $V_{N+1} = 2,5$ VOLTE LA PORTATA MINIMA

$X_{A0} = 0,400$ $X_{AN} = 0,100$ $L_0 = 2000 \ Kg/h$

$\Delta = L_n - V_{n+1} = L_N - L_{N+1}$

$V_{N+1} = 2,5 \, (V_{N+1})_{MIN}$

DIAGRAMMA RIPARTIZIONE



CONDIZ. EQUILIBRIO (x_n, y_n)

CONDIZ. INTERSTADIO (x_n, y_{n+1})

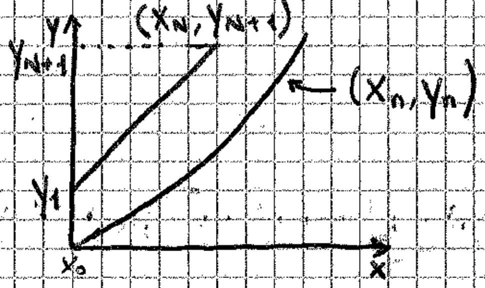
$y_i = m\, x_i$ $\quad$ $y_i P = p_i = H_i X_i$

$y_i = \left(\frac{H_i}{P}\right) x_i$ SE H_i, P NON DIPENDONO DA x_i

RELAZIONE LINEARE

SOLUZIONE DILUITA V_{N+1}

$$L_0 X_0 + y_{N+1} V_{N+1} = L_N X_N + y_1 V_1$$



$$y_{n+1} = \frac{L_n}{V_{n+1}} x_n + \frac{y_1 V_1 - L_0 X_0}{V_{n+1}}$$

A, B, C ← SOLVENTE ← GAS ← INQUINANTE

NO SOLVENTE VOLATILE
NO GAS CHE SI ASSORBA IN A → VARIAZ. PORTATA L, V MINIMA SE SUFFIC. DILUITO

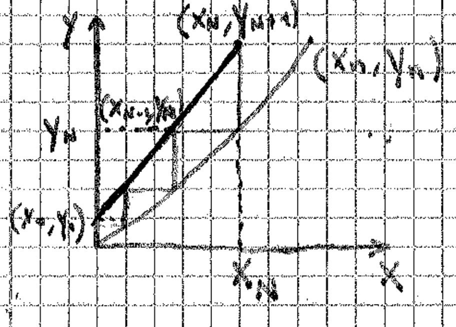
PORTATE COSTANTI LUNGO LE COLONNE

$$y_{n+1} = \frac{L}{V} X_n + \frac{y_1 V_1 - L_0 X_0}{V}$$ VIENE UNA RETTA

$$y = \frac{L}{V} X + y_1 - \frac{L}{V} x_0$$

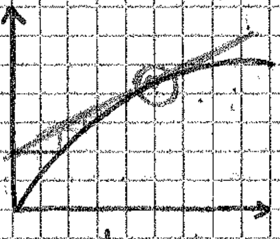
A SCALINI FINO A QUANDO y NON È INFERIORE A y_1

NUM STADI = PUNTI SU CURVA EQUIL.



∞ STADI SE INTERSEZ. TRA LINEA DI LAVORO CON LINEA EQUILIBRIO (PUNTO PINZA)

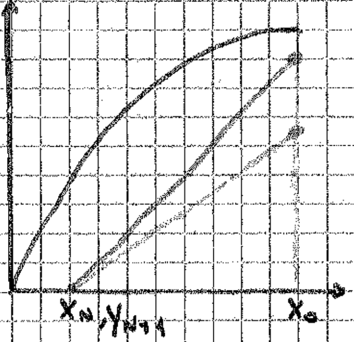
↳ X TROVARE L_{MIN}



SE eq LINEARE O CONCAVITÀ VS L'ALTO INTERSEZIONE IN $Y = Y_{N+1}$

SE eq CONCAVA VS IL BASSO PUNTO DI TANGENZA (O CONDIZ. FINALE)

DEASSORBIMENTO



FISSATA L_0 $X_0 \to X_N$

RIDUCENDO PORTATA VAPORE V PENDENZA AUMENTA

↓

C.LAVORO SI AVVICINA A C.EQUIL.

SE CONCAVITÀ CURVA EQ. VS L'ALTO POSSIAMO AVERE PUNTO PINZA IN UN PUNTO DI TANG.

INQUINANTE CONCENTRATO

C-B NON SI MESCOLANO

↓

POSSIAMO ANCORA CONSIDERARE CURVA DI LAVORO LINEARE (ANCHE SE A CONC.)

$L_0 = L_0 X_{0A} + L_0 X_{0B}$; $L_0 X_{0C} = L_0 X_{0A} + L'$.

$y_n = m x_n + C$ ← EQ. LINEARE NON PASSANTE PER L'ORIGINE.

$V(m x_{n+1} + C) + L x_{n-1} + L x_n + V(m x_n + C)$

$m V x_{n+1} - (L - mV) x_n + L x_{n-1} = 0$

$x_{n+1} - \left(\frac{L}{mV} + 1\right) x_n + \frac{L}{mV} x_{n-1} = 0$ FORMA CANONICA

$x_{n+1} + \underset{\uparrow}{b}\, x_n + \underset{\uparrow}{C}\, x_{n-1} = 0$

PARAMETRI

↑ EQUAZ. DELLE DIFFERENZE (SALTO FINITO)

EQUAZ. OMOGENEA A COEFF. COSTANTI DI 2 GRADO (2 SALTI)

EQUAZIONE DELLE DIFFERENZE

* 1 GRADO

SERVONO CONDIZ. AL CONTORNO

$x_{n+1} + b x_n = 0$

$x_0 = \alpha$

$x_n = f(x_n)$

$x_n + b x_{n-1} = 0$

$x_n = -b x_{n-1}$

$$x_{n+1} = -b x_n$$
$$= (-b)(-b) x_{n-1}$$
$$= (-b)^2 x_{n-1}$$

$$x_m = -b x_{m-1} = (-b)^2 x_{m-2} = (-b)^3 x_{m-3} = (-b)^m x_0$$

$$x_m = \lambda^m x_0$$

X EQUAZ. DIFF. DI 1 ORDINE OMOG:

$y' + by = 0 \longrightarrow y = e^{-bx} = e^{\lambda x} = (e^x)^\lambda$

$\lambda + b = 0 \longrightarrow \lambda = -b$

$x_{n+1} + b x_n = 0 \longrightarrow \lambda + b = 0$

$$\left.\begin{array}{l} x_n = C \lambda^n \\ x_0 = C \lambda_0 = C \end{array}\right\} x_n = x_0 \lambda^n$$

$$\frac{X_0 - X_N}{X_0 - X_{N+1}} = \frac{1-\frac{1}{S^N}}{1-\frac{1}{S^{N+1}}} = \frac{S^N - 1}{S^N - \frac{1}{S}} = X$$

$$X\left[S^N - \frac{1}{S}\right] = S^N - 1 \qquad S^N(X-1) - \frac{X}{S} + 1 = 0$$

$$S^N = \frac{-1+\frac{X}{S}}{X-1} = \frac{\frac{X}{S}-1}{X-1}$$

$$\frac{X_0 - X_{N+1}}{X_N - X_{N+1}} = \frac{1-\frac{1}{S^{N+1}}}{\frac{1}{S^N}-\frac{1}{S^{N+1}}} = \frac{\cancel{\frac{1}{S^N}}\left(S^N - \frac{1}{S}\right)}{\cancel{\frac{1}{S^N}}\left(1-\frac{1}{S}\right)}$$

$$N = \frac{\log\left[\left(\frac{X_0 - X_{N+1}}{X_N - X_{N+1}}\right)\left(1-\frac{1}{S}\right) - \frac{1}{S}\right]}{\log(S)}$$

POSSIAMO USARE log CHE PREFERIAMO TANTO RAPPORTO

SE $S \neq 1$ (SE $S=1$ NON VALE)

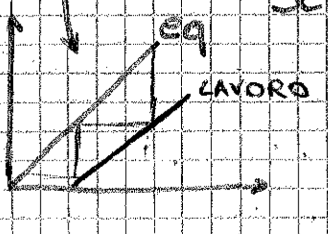
* SE $S = 1$

$$X_n = (C_1 n + C_2)\lambda^n = C_1 n + C_2 \leftarrow \lambda_1 = \lambda_2 = 1$$

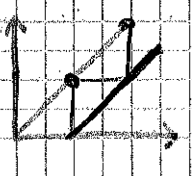
$$\left.\begin{array}{l} X_0 = C_2 \\ X_N = C_1 N + C_2 \\ X_{N+1} = C_1 (N+1) + C_2 \end{array}\right| \begin{array}{l} \Rightarrow X_0 - X_N = -C_1 N \\ \Rightarrow X_N - X_{N+1} = -C_1 \end{array} \qquad N = \frac{X_0 - X_N}{X_N - X_{N+1}}$$

$$S = \frac{mV}{L}$$

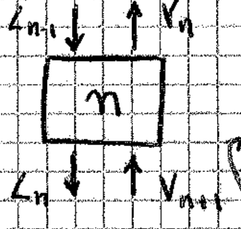
$$\text{SE } S = \frac{mV}{1} = 1 \Longrightarrow \frac{m}{L/V} = 1$$



2 PENDENZE =, QUINDI RETTE //



X V_{min} POSSO USARE eq TANTO PUNTO PINZA COINCIDE



$$V y_{n+1} - L x_n - V y_n + L x_{n-1} = 0$$

$$y_{n+1} - \frac{L}{m}(m x_n + C) - y_n + \frac{L}{mV}(m x_{n-1} + C)$$

LINEARE

$$A = \frac{L}{mV}$$

X ASSORBIM.

$$y_{n+1} - A y_n^* - y_n + A y_{n-1}^* = 0$$

X CASO IDEALE

$$\begin{cases} y_{n+1} - (A+1) y_n + A y_{n-1} = 0 \\ N = \dfrac{\log\left[\left(\dfrac{y_{n+1} - y_0}{y_1 - y_0}\right)\left(1 - \dfrac{1}{A}\right) + \dfrac{1}{A}\right]}{\log A} \quad A \neq 1 \\ N = \dfrac{y_{n+1} - y_0}{y_1 - y_0} \quad A = 1 \end{cases}$$

$$y_{n+1} - y_n^* = \frac{y_{n+1} - y_n}{E_v}$$

$$y_n^* = y_{n+1}\left(1 - \frac{1}{E_v}\right) + \frac{y_n}{E_v}$$

$$y_{n-1}^* = y_n\left(1 - \frac{1}{E_v}\right) + \frac{y_{n-1}}{E_v}$$

$$y_{n+1} - A\left(1 - \frac{1}{E_v}\right) y_{n+1} - A\frac{y_n}{E_v} - y_n + A\left(1 - \frac{1}{E_v}\right) y_n + \frac{A}{E_v} y_{n-1} = 0$$

$$y_{n+1}\left[1 - A\left(1 - \frac{1}{E_v}\right)\right] - \left[1 - A\left(1 - \frac{1}{E_v}\right) + \frac{A}{E_v}\right] y_n + \frac{A}{E_v} y_{n-1} = 0$$

$$y_{n+1} - \left[1 + \underbrace{\frac{A/E_v}{1 - A\left(1 - \frac{1}{E_v}\right)}}_{A'}\right] y_n + \frac{A/E_v}{1 - A\left(1 - \frac{1}{E_v}\right)} y_{n-1} = 0$$

$$\frac{y_{N+1}-y_0^*}{y_1-y_0^*}=\frac{A'^{N\cancel{-1+1}}-1/A}{1-\frac{1}{A}}=\frac{A'^{N}-1/A}{1-1/A}$$

$$N_\pi=\frac{\log\left[\left(\frac{y_{N+1}-y_0^*}{y_1-y_0^*}\right)\left(1-\frac{1}{A}\right)+\frac{1}{A}\right]}{\log(A')}$$

$$E_0=\frac{N}{N_\pi}=\frac{\log(A')}{\log(A)}=\frac{\log(1/A')}{\log(1/A)}=\frac{\log\left[E_V\left(\frac{1}{A}-1\right)+1\right]}{\log\left(\frac{1}{A}\right)}$$

ESERCIZIO

① 95% ACETONE IN ARIA (ARIA 97%, ACETONE) E' ASSORBITO CON H_2O PURA INVIATA IN CONTROCORRENTE IN UNA COLONNA A PIATTI.

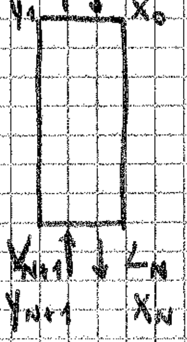
LA COLONNA OPERA A 20°C, 1 atm. IN QUESTE CONDIZ. LA RELAZ. EQ. ACETONE

$y=1,20\ x$

CALCOLARE L/V MIN; IL NUMERO DEGLI STADI IN CUI $L=1,25$ MIN.

IL NUMERO DI STADI REALI IN CUI $E_V=0,70$?

L'EFFICENZA GLOBALE DELLA COLONNA?



ASSUMIAMO SIST. DILUITO $\rightarrow L, V$ COST.

$y_{N+1}=0,03 \longrightarrow y_1=(1-\pi)\,y_{N+1}$

$\pi=0,95$ ABBATTIMENTO $\rightarrow V_{N+1}\,y_{N+1}\,(1-\pi)=V_1 y_1$

$V\,y_{N+1}\,(1-\pi)=V y_1 \longrightarrow y_{N+1}\,(1-\pi)=y_1$

$x_0=0$

$N = 8{,}07 \rightarrow N = 9$

SE DI DATI CI DAVA:

$$\begin{cases} x_0 = 0 \\ \pi = 0{,}95 \\ y = 1{,}20\,x \\ L = 1{,}25\,L_{min} \end{cases}$$

NON CI HA DATO y_{N+1}

$$A = \frac{L/V}{m} = \frac{1{,}25\,L_{min}/V}{1{,}20}$$

$$L_{min}/V = \frac{y_{N+1} - y_1}{y_{N+1}/m - 0} = m\left(\frac{y_{N+1} - y_1}{y_{N+1}}\right) = m\left(1 - \frac{y_1}{y_{N+1}}\right)$$

$$y_{N+1} = (1-\pi)\,y_1 \qquad \frac{y_{N+1}}{y_1} = 1 - \pi$$

$$\frac{L_{min}}{V} = m\left(1 - \frac{1}{1-\pi}\right)$$

SI PUÒ FARE SOLO SE $x_0 = 0$

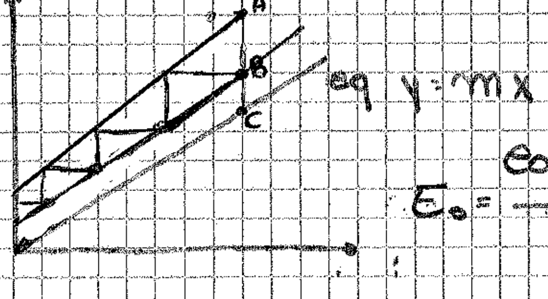
↓

NUM. STADI NON VARIA IN BASE A COMPOSIZ. INIZIALE V (PURCHE' DILUITO)

$$A = \frac{1{,}25\,L_{min}/V}{1{,}20}$$

$$A = \frac{1{,}25\,\cancel{m}\pi}{\cancel{m}} = 1{,}25\pi$$

X TROVARE CURVA p-eq



$\overline{AB} = E_V \cdot \overline{AC}$

$$E_o = \frac{\log\left[1 + E_V\left(1/A - 1\right)\right]}{\log(1/A)}$$

$$\frac{1}{A'} = 1 + E_V\left(\frac{1}{A} - 1\right) \qquad N_R = \frac{N}{E_o}$$

$E_o = 0{,}682$

$N_R = \frac{N}{E_o} = \frac{8{,}07}{0{,}682} = 11{,}8 \rightarrow N_R = 12$

$$\frac{m X_n}{1+(1-m)X_n} = \frac{Z'}{V'} X_{n-1} + \alpha \qquad \alpha = Y_{n+1} - \frac{Z'}{V'} X_n$$

$$m X_n = \frac{Z'}{V'} X_{n-1} + \frac{Z'}{V'}(1-m) X_{n-1} X_n + \alpha + \alpha(1-m) X_n$$

$$\frac{Z'}{V'}(1-m) X_n X_{n-1} + \left[\alpha(1-m) - m\right] X_n + \frac{Z'}{V'} X_{n-1} + \alpha = 0$$

$$X_n X_{n-1} + \underbrace{\frac{V'}{Z'}\left[\alpha \cancel{(1-m)} - \frac{m}{1-m}\right]}_{a} X_n + \underbrace{\frac{X_{n-1}}{1-m}}_{b} + \underbrace{\frac{V'}{Z'}\frac{\alpha}{1-m}}_{c} = 0$$

$$X_n X_{n-1} + a X_n + b X_{n-1} + c = 0$$

$$a = \frac{V'}{Z'}\left[Y_{n+1} - \frac{Z'}{V'} X_n - \frac{m}{1-m}\right] = \frac{V'}{Z'}\left(Y_{n+1} - \frac{m}{1-m}\right) - X_n$$

$$b = \frac{1}{1-m}$$

$$c = \frac{1}{1-m}\left[\frac{V'}{Z'} Y_{n+1} - X_n\right]$$

EQ. DEL 1 GENERE
NON OMOGENEA
NON LINEARE
A PARAMETRI COST.

$$X_m = Z_n + R_1$$

$$Z_n Z_{n-1} + Z_n R_1 + Z_{n-1} R_1 + R_1^2 + a(Z_n + R_1) +$$
$$+ b(Z_{n-1} + R_1) + c = 0$$

$$Z_n Z_{n-1} + (a + R_1) Z_n + (b + R_1) Z_{n-1} + R_1^2 + (a+b) R_1 + c = 0$$

PONGO R_1 IN MODO CHE VENGA OMOGENEA:

$$R_1^2 + (a+b) R_1 + c = 0 \rightarrow R_1, R_2 \in \mathbb{R}$$
$$\rightarrow R_1 = R_2 \in \mathbb{R}$$
$$\rightarrow R_1 = R_2^* \in \mathbb{C}$$

$$Z_n Z_{n-1} + (a + R_1) Z_n + (b + R_1) Z_{n-1} = 0$$

$$1 + (a + R_1)\frac{1}{Z_{n-1}} + (b + R_1)\frac{1}{Z_n} = 0$$

$$\theta_1 = \mathrm{ARCTG}\left(\frac{\sqrt{-\Delta}}{2X_n + a + b}\right)$$

$$\theta_2 = \mathrm{ARCTG}\left(\frac{\sqrt{-\Delta}}{2X_0 + a + b}\right)$$

$$\theta_3 = \mathrm{ARCTG}\left(\frac{\sqrt{-\Delta}}{a - b}\right)$$

FARE CALCOLI
IN RADIANTI

$$Y_m = \frac{L'}{V'} X_{n-1} + Y_{n+1} - \frac{L'}{V'} X_0 \longrightarrow Y = \frac{L'}{V'} X + \alpha$$

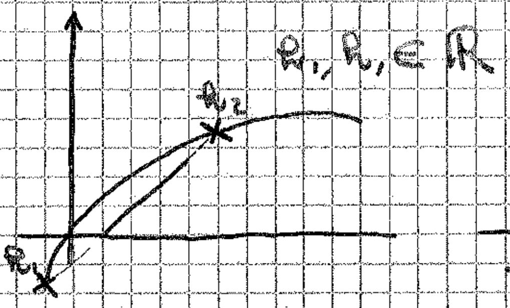
$$Y = \frac{mX}{1+(1-m)X} \qquad \frac{mX}{1+(1-m)X} = \frac{L'}{V'} X + \alpha$$

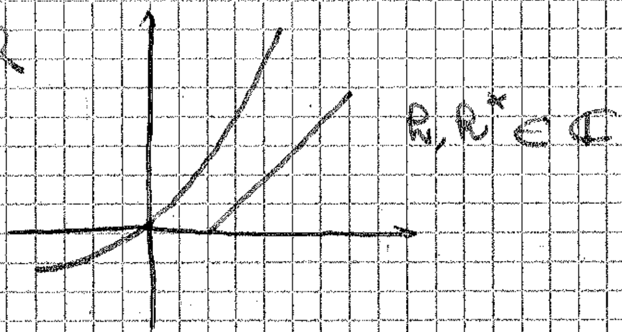
HA SOLUZ. PREC. SENZA DISTINGUERE X_n, X_{n-1}

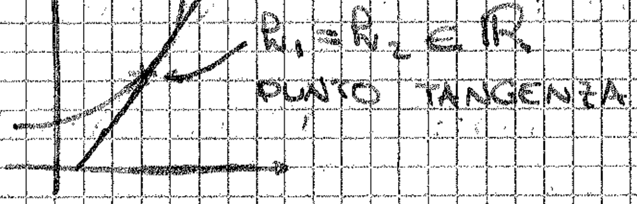
$$X^2 + (a+b)X + C = 0$$

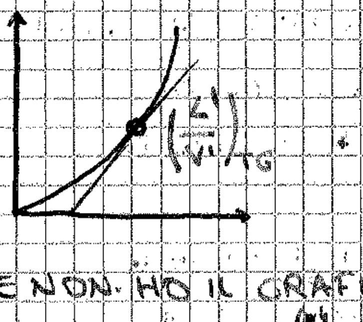
$$R^2 + (a+b)R + C = 0$$

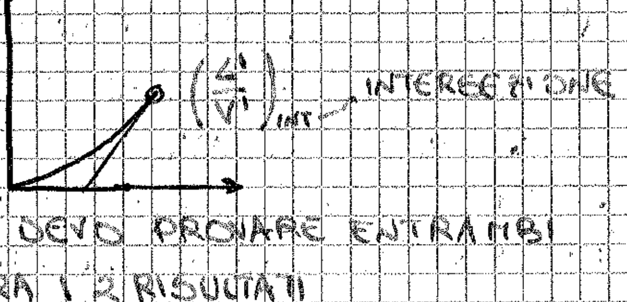
R RAPPRESENTA INTERSEZIONI TRA EQ E C









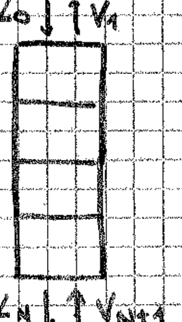


SE NON HO IL GRAFICO DEVO PROVARE ENTRAMBI CASI E TENERE $\left(\frac{L'}{V'}\right)_{min}$ TRA I 2 RISULTATI

CALCOLARE NUM. STADI IDEALI NECESSARI X ESEGUIRE LA SEPARAZIONE

$p^s = 100,0$ mmHg

$m = \frac{p^s}{p}$ $y = m x$ $yp = x p^s$



$y_{N+1} = 0,05$

$\tau = 0,95$

$V_{N+1} \, y_{N+1} \, (1-\tau) = V_1 y_1$

$V' Y_{N+1} (1-\tau) = V' Y_1$

$Y_1 = Y_{N+1} (1-\tau)$

$y_1 = \frac{Y_1}{1+Y_1}$

$Y_{N+1} = \frac{y_{N+1}}{1-y_{N+1}}$

$V_{N+1} = \frac{\phi_v}{\tilde{V}}$

$X_0 = \frac{x_0}{1-x_0}$

$V' = V_{N+1} (1 - y_{N+1})$

$L' = L_0 (1 - x_0)$

$Y_{N+1} = \frac{0,05}{1-0,05} = 0,526$

$Y_1 = 0,00263$

$x_0 = 0,055$

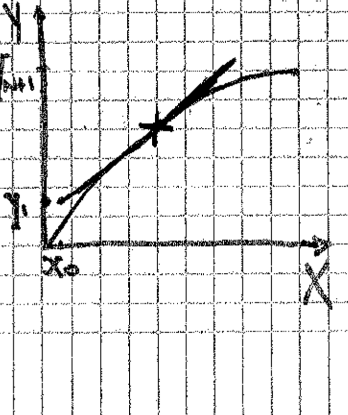
$X_0 = 0,00503$

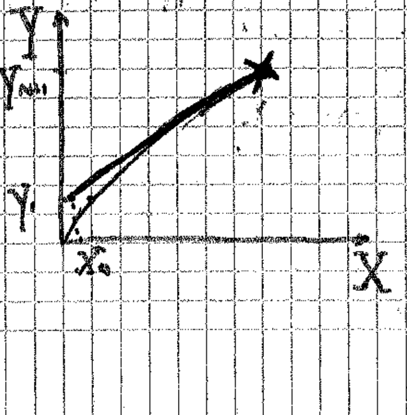
$R = 8,316510$ J/moeK

$\tilde{V} = \frac{RT}{p} = 0,0232$ m^3/moe

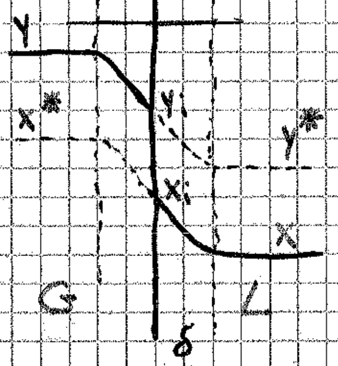
$V_{N+1} = 10,77$ moe/s

$V' = V_{N+1} (1 - y_{N+1}) = 10,23$ moe/s





TEORIA FILM



SPESSO SI TRASCURA LA RESIST. ALL'INTERFACCIA

$y_i = m x_i$; EQ. ALL'INTERFACCIA

FORZA SPINGENTE

$A N_A = k_y A (y - y_i) = k_x A (x_i - x)$

$= K_{oy} (y - y^*) = K_{ox} A (x^* - x)$

AREA SUP.

OVERALL

INTENSITA' DI FLUSSO

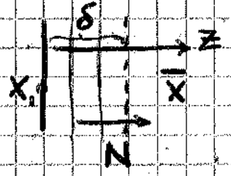
$$\begin{cases} y^* = m x \\ x^* = \frac{y}{m} \end{cases}$$

SIST. DILUITO | CONTRODIFFUSIONE EQUIMOLARE → k'_y

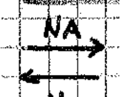
DIFFUSIONE IN MEZZO STAGNANTE → k_y SI RICAVA DA MANUALE

SI CALCOLA DA k'_y

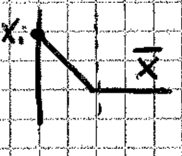
$$N_A = \underbrace{x N}_{\text{CONVETTIVO}} - \underbrace{D_A c \frac{dx}{dz}}_{\text{DIFFUSIVO}}$$



CONTRODIFFUSIONE EQUIMOLARE / SIST. DILUITO



$N = 0$ $\quad N_A = -D_A c \frac{dx}{dz} =$ COST.



$N_A = -D_A c \frac{(\bar{x} - x_i)}{\delta} = -k'_x (\bar{x} - x_i)$

$N_A = \frac{D_A c}{\delta} (x_i - \bar{x}) = k'_x (x_i - \bar{x})$

DIFFUSIONE IN MEZZO STAGNANTE

$N_B = 0$ $\quad N = N_A$ $\quad N_A = x N_A - \frac{D_A c}{1} \frac{dx}{dz}$

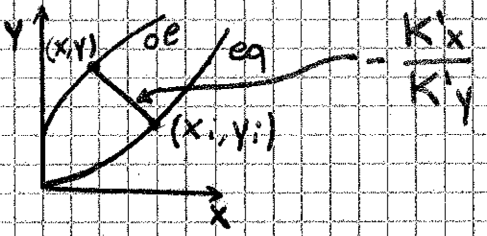
$y = \frac{L}{V} x + y_2 - \frac{L}{V} x_2$ RETTA DI LAVORO

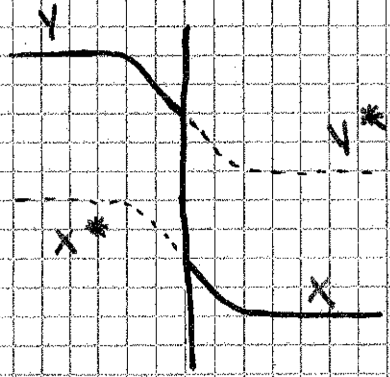
SE MEZZO STAGNANTE: → CURVA LAVORO NON RETTILINEA

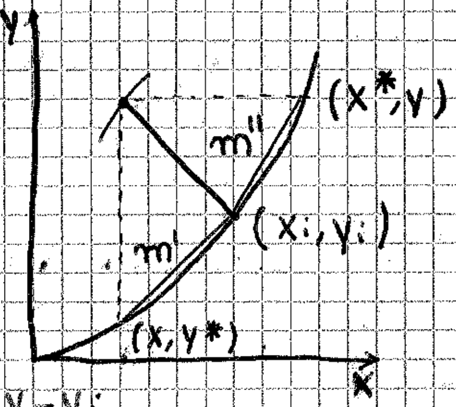
$V' = V(1-y)$

$K'_y (y - y_i) = K'_x (x_i - x)$ $\qquad \frac{y - y_i}{x - x_i} = -\frac{K'_x}{K'_y}$

$= K'_{oy}(y - y^*) = K'_{ox}(x^* - x)$







$m' = \frac{y_i - y^*}{x_i - x}$ $\qquad m'' = \frac{y - y_i}{x^* - x_i}$

$y - y^* = y - y_i + y_i - y^* = y - y_i + m'(x_i - x)$

$$\frac{N_A}{K'_{oy}} = \frac{N_A}{K'_y} + m' \frac{N_A}{K'_x}$$

$\frac{1}{K'_{oy}} = \frac{1}{K'_y} + \frac{m'}{K'_x}$ RESISTENZE IN SERIE

$$\frac{1}{K'_{ox}} = \frac{1}{m'' K'_y} + \frac{1}{K'_x}$$

$$z = \int_1^2 dz = \int_1^2 \frac{d(Vy)}{K_y' a S (y_i - y)} = \int_1^2 \frac{d(Vy)}{K_{oy}' a S (y^* - y)} =$$

$$= \int_1^2 \frac{d(Vy)}{K_x a S (x - x_i)} = \int_1^2 \frac{d(Vy)}{K_{ox}' a S (x - x^*)}$$

EQUAZIONI DI PROGETTO

X FILM STAGNANTE TOLGO APICE A K

$K_y' a \propto V^{0,8}$ ← REGIME TURBOLENTO

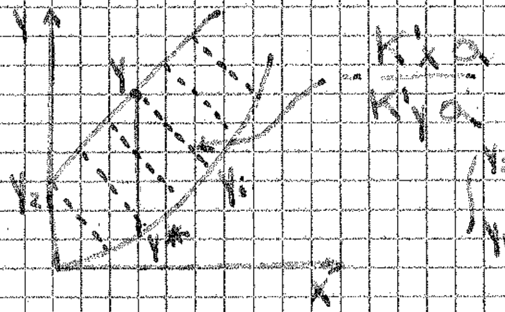
$$z = \left(\frac{V}{K_y' a S}\right) \int_1^2 \frac{dy}{y_i - y} = H_y N_y$$

ALTEZZA DI OGNI UNITÀ DI SCAMBIO

NUMERO UNITÀ DI SCAMBIO

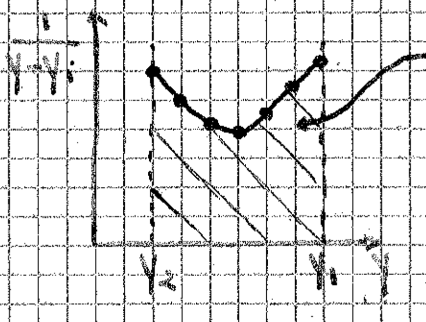
$$z = H_y N_y = H_{oy} N_{oy} = H_x N_x = H_{ox} N_{ox}$$

ASSORBIMENTO IN SIST. DILUITO



$$\int_{y_1}^{y_2} \frac{dy}{y_i - y} = \int_{y_2}^{y_1} \frac{dy}{y - y_i}$$

y	y_i
⋮	⋮



AREA = INTEGRALE
↓
ES: METODO DEI TRAPEZI

CONTROLLO PURE SE AREA STA TRA RETTANGOLO MAX E RETTANGOLO MIN

CON RAPPORTI MOLARI:

$$\frac{(1-y)+(1-y_i)}{2(1-y)(y_i-y)}\,dy = \qquad y=\frac{Y}{1+Y}$$

$$=\frac{\frac{1}{1+Y}+\frac{1}{1+Y_i}}{2\frac{1}{1+Y}\left(\frac{Y_i}{1+Y_i}-\frac{Y}{1+Y}\right)}\,d\left(\frac{Y}{1+Y}\right)$$

$$1-y=1-\frac{Y}{1+Y}=\frac{1+Y-Y}{1+Y}=\frac{1}{1+Y}$$

$$d\left(\frac{Y}{1+Y}\right)=\frac{1+Y-Y}{(1+Y)^2}\,dY=\frac{dY}{(1+Y)^2}$$

$$\frac{\frac{1+Y_i+1+Y}{(1+Y)(1+Y_i)}}{2\left[\frac{Y_i+Y_iY-Y-Y_iY}{(1+Y)(1+Y_i)}\right]}=\frac{1+Y_i+1+Y}{2(1+Y)(Y_i-Y)}\,dY=$$

$$=\frac{2(1+Y)+Y_i-Y-1+1}{2(1+Y)(Y_i-Y)}\,dY=\frac{dY}{Y_i-Y}+\frac{1}{2}\frac{dY}{1+Y}$$

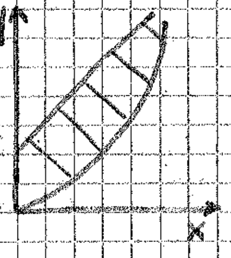
$$N_Y=\int_1^2\frac{dY}{Y_i-Y}+\frac{1}{2}\ln\left(\frac{1+Y_2}{1+Y_1}\right)$$

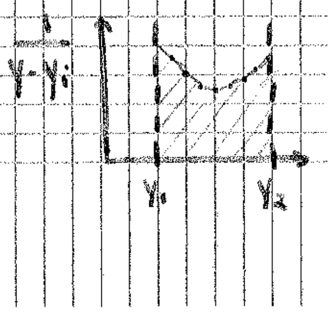
$$N_X=\int_1^2\frac{dX}{X-X_i}+\frac{1}{2}\left(\frac{1+X_2}{1+X_1}\right)$$

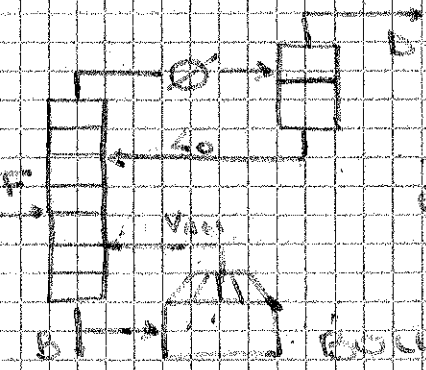
SIST. DILUITO

$$\frac{Y-Y_i}{X-X_i}=-\frac{k'_x a}{k'_y a}$$

$$\int_1^2\frac{dY}{Y_i-Y}=\int_{Y_2}^{Y_1}\frac{dY}{Y-Y_i}$$



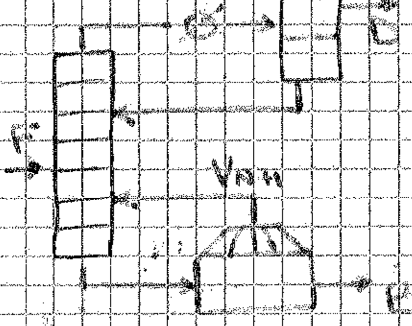




CONDENSATORE PARZIALE
↓
EQ. L/V IN CONDENSATORE
↳ + 1 STADIO DI EQUILIBRIO

BOLLITORE TOTALE

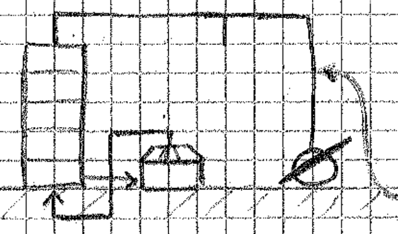
NUM. STADI = NUM. PIATTI + 1



CONDENSATORE PARZIALE

NUM. STADI = NUM. PIATTI + 2

BOLLITORE PARZIALE



IN IMPIANTI REALI CONDENSATORI E BOLLITORI A TERRA (CON TUBI COIBENTATI)

GRADI DI LIBERTÀ

* 1 CONDENSATORE TOTALE + 1 BOLLITORE TOTALE

$N_L = \sum_i N_{L,i} - \sum N_{eq} + N_v$

GRADI DI LIBERTÀ SE GLI STADI FOSSERO INDIP.

IDENTITÀ TRA STADI

VARIABILI AGGIUNTIVE

1° METODO: SCOMPONIAMO LA COLONNA DI DISTILLAZIONE NEI SUOI ELEMENTI.

2° METODO: NON LA SPEZZETIAMO

$C+2+2(N+4)+4=C+14+2\underline{N}$ — NUM. STADI ARRICCHITI ED ESAURITI + SPLITTER

T, p N. PIATTI → 2 SPLITTER + BOLLITORE + CONDENS.

ISOBARA → p cost. → P_n N+4

ADIABATICA Q_n N+2

↳ x PIATTI + SPLITTER N+4

T_C v $\varphi=0$ (CONDENS.) 1 ← L SATURO O TEMP. SOTTORAFFR.

T_B v $\varphi=1$ (BOLLIT.) 1

F (CORRENTE ALIMENTATA) C+2 → SE NON INDICATO NEL TESTO L/V SATURI

ESERCIZIO

85% BENZENE ABBATTUTO IN COLONNA RIEMPIMENTO

OLIO IN CONTROCORRENTE $L_2 = 1,76$ mol/h

$T^V = 26°C$ $p^V = 803$ mmHg $\dot{V} = 900$ m³/h

$p^S = 100$ mmHg $y_1 = 8\% = 0,08$ $x_2 = 0,005$

$K'_x a = 13,77 \frac{mol}{m^2 h}$ $K'_y a = 71,9 \frac{mol}{m^2 h}$

$D_c = 600$ mm MEZZO STAGNANTE

ALTEZZA NECESSARIA = ? USARE RAPPORTI MOLARI

$$H_y = \frac{V_{av}}{K_y a S} \qquad V_{av} = \frac{V_1+V_2}{2}$$

$$N_y = \int_{y_2}^{y_1} \frac{(1-y)_{iml}}{(1-y)(y_i-y)}dy = \int_{y_2}^{y_1} \frac{(1-y)_{iml}}{(1-y)(y-y_i)}dy = \int_{y_2}^{y_1} \frac{dy}{y-y_i} + \frac{1}{2}\ln\left(\frac{1-y_2}{1-y_1}\right)$$

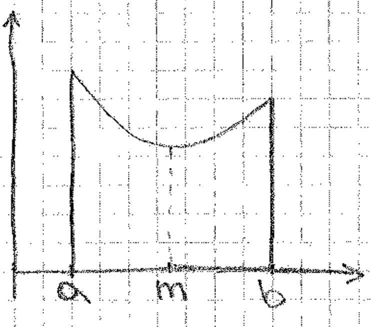
$$m = \frac{p^S}{p}$$

$$\frac{y-y_i}{x-x_i} = -\frac{k_x a}{k_y a} = -\frac{k'_x a\,(1-y)_{iml}}{k'_y a\,(1-x)_{iml}} \simeq \underbrace{-\frac{k'_x a}{k'_y a}\left[\frac{(1-y)}{(1-x)}\right]_{av}}_{cost}$$

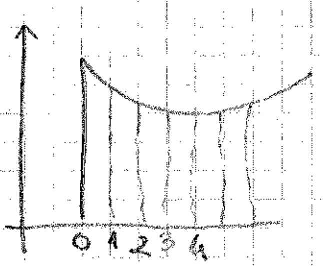
$$\frac{1}{2}\left[\frac{1-y_1}{1-x_1}+\frac{1-y_2}{1-x_2}\right] = \left(\frac{1-y}{1-x}\right)_{av} = 1{,}15$$

$$\frac{y-y_i}{x-y_i/m_i} = -\frac{k'_x a}{k'_y a}\left[\frac{1-y}{1-x}\right]_{av} = -\alpha = -0{,}22$$

$$y_i = \frac{y+\alpha x}{1+\alpha/m_i}$$



$$I = \frac{b-a}{6}\left[f(a)+4f(m)+f(b)\right]$$ FORMULA DI SIMPSON



$2h$ $\quad h = \frac{x_2-x_1}{n}$

$\frac{h}{3}\left[f_0+4f_1+f_2\right]$ DA 0 A 2

$\frac{h}{3}\left[f_0+4f_1+f_2+f_2+4f_3+f_4+f_4+4f_5+f_6\right]$ DA 0 A 6

$\frac{h}{3}\left[f_0+4f_1+2f_2+4f_3+2f_4+4f_5+f_6\right]$ DA 0 A 6

	NODI		y	y_i	$f=\frac{1}{y-y_i}$
$y.$	3	5			
y_2	0	0	0,01288	0,00505	127,7
		1	0,02266	0,01821	87,3
	1	2	0,04644	0,0309	62,3
		3	0,06322	0,04178	46,7
y_1	2	6	0,08	0,05253	36,4

GRADI DI LIBERTÀ

* BOLLITORE TOTALE + CONDENSATORE TOTALE

$N_L = C+2+2(N+4)+4$

F	$C+2$	
P_n	$N+4$	→ $2(N+4)$ → SPESSO SOTTOINTESI
$\dot{Q}=0$	$N+2$	
$T_c / \varphi=0$	1	
$T_b / \varphi=1$	1	
$R=\frac{L_0}{D}$	1	
$\frac{D}{F}$ OPPURE $x_{B,A}$	1	
$x_{D,A}$	1	
ALIMENTAZIONE NEL PIATTO OTTIMALE (N_{opt})	1	

* CONDENSATORE PARZIALE + BOLLITORE TOTALE

NON C'È + SPLITTER SUPERIORE

OPPURE COND. TOTALE + BOLLITORE PARZIALE

AVEVA $\sum_i N_i L_i = C+5$

$\sum N_{eq} = \underbrace{C+2}_{3}$ → 1 CORRENTE IN MENO

SE TOLGO SPLITTER HO 3 GRADI DI LIBERTÀ IN MENO

$N_L = C+2+2(N+3)+3$

NO $T_c / \varphi=0$

NO P_n x SPLITTER

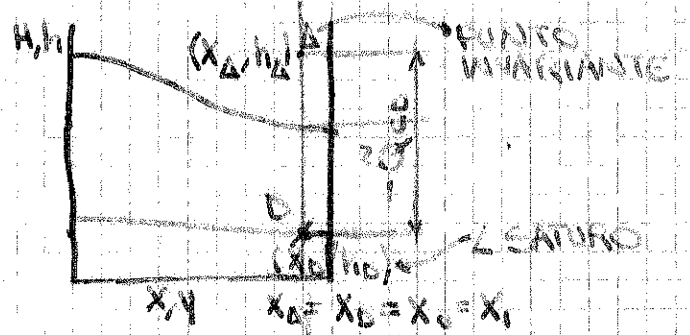
NO ADIABATICITÀ x SPLITTER

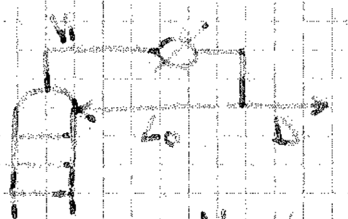
* COND. PARZIALE + BOLLITORE PARZIALE → $N_L = C+2+2(N+2)+2$

$V_{n+1} H_{n+1} + \dot{Q}_c = L_n h_n + h_D D$

$L_n h_n - V_{n+1} H_{n+1} = - h_D D + \dot{Q}_c$ $\qquad \check{Q}_{cD} = \frac{\dot{Q}_c}{D} < 0$

$= -D \left(h_D - \check{Q}_{cD} \right) = \Delta \left(h_\Delta \right)$ $\qquad h_\Delta = h_D - \check{Q}_{cD}$





$V_1 = L_0 + D$

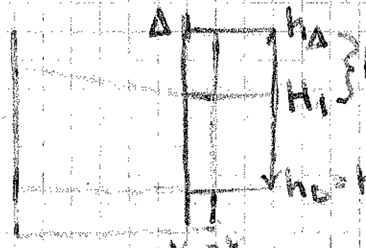
$R = \frac{L_0}{D}$ RAPPORTO DI FLUSSO

$V_1 H_1 + D \check{Q}_{cD} = L_0 h_0 + h_D D$

$\Delta h_\Delta = -D h_D = L_0 h_0 - V_1 H_1 = L_0 h_0 - (L_0 + D) H_1$

$h_\Delta = - \frac{L_0}{D} h_0 + \frac{L_0}{D} H_1 + H_1 = H_1 + R (H_1 - h_0)$

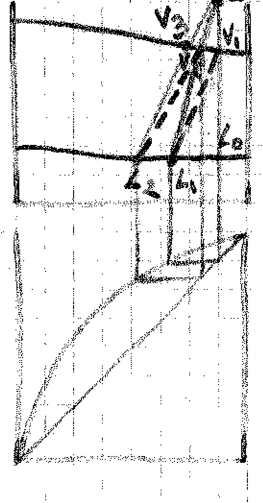
CONDENSATORE TOTALE



$y_1 = x_0 = x_D$

$h_\Delta - H_1 = R (H_1 - h_0)$

$R = \frac{h_\Delta - H_1}{H_1 - h_0}$



$\Delta = L_n - V_{n+1}$

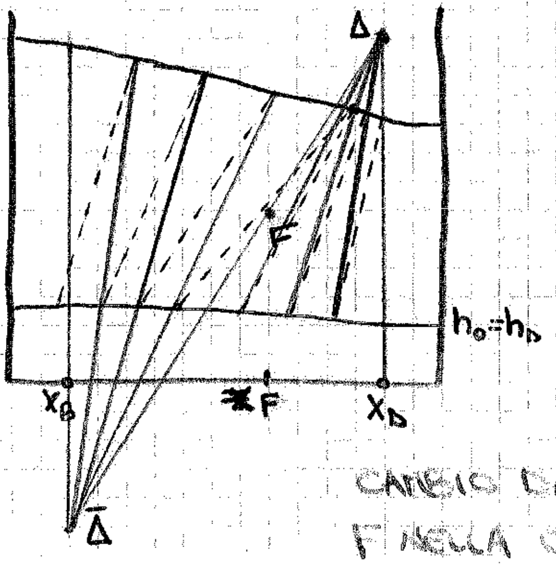
$\Delta = L_1 - V_2$

$x_\Delta \Delta = x_1 L_1 - y_2 V_2$

$h_\Delta \Delta = h_1 L_1 + H_2 V_2$

} L_1, V_2, Δ ALLINEATI

ALIMENTAZIONE OTTIMALE → PIATTO SIMILE A F



A UN CERTO PUNTO LINEA CONIUGATA SUPERA F

↓

DA LÌ IN POI USO $\bar{\Delta}$, FINO A QUANDO NON ARRIVO A CONDIZ. VOLUTA

↓

SE IN PIATTO OTTIMALE

↓

CAMBIO DA Δ A $\bar{\Delta}$ QUANDO INTRODUCO F NELLA COLONNA FISICAMENTE

↓

PUÒ ESSERE INTRODOTTA F ANCHE PRIMA O DOPO

DETERMINAZIONE Δ_{MIN}

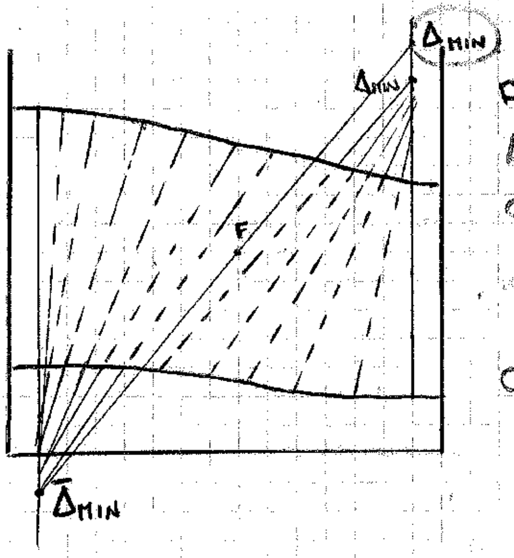
RAPPORTO DI RIFLUSSO MINIMO

↓

DOVRÒ OPERARE CON RAPPORTO MAGGIORE

↳ SPESSO MOLTIPLICATO PER 1,1 ÷ 1,3

TRACCIO LINEE CONIUGATE E TROVO INTERSEZ.



DINZA PUÒ VENIRE SIA DA Δ, CHE DA $\bar{\Delta}$ (DA ARRICCHIM. O DA ESAURIMENTO)

↓

TENGO Δ_{MIN} + GRANDE

OTTENUTO Δ_{MIN} CALCOLO R_{MIN}

SEZIONE ARRICCHIMENTO

$y_{n+1} V_{n+1} = L_n x_n + D x_D$

$y_{n+1} = \frac{L_n}{V_{n+1}} x_n + \frac{x_D D}{V_{n+1}}$

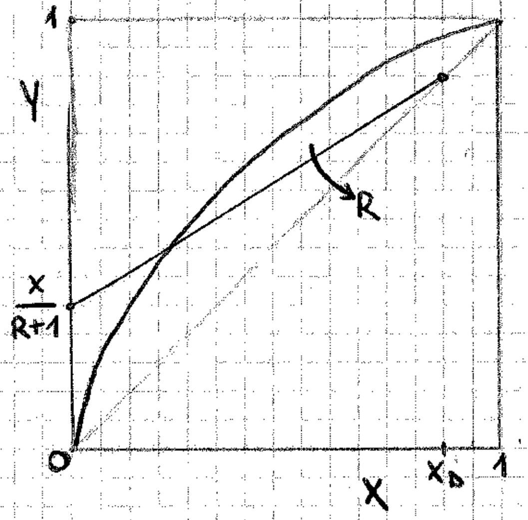
L, V COST. $\Rightarrow y_{n+1} = \frac{L}{V} x_n + \frac{x_D D}{V}$

$R = \frac{L_0}{D} = \frac{L}{D}$ $\quad \frac{L}{V} = \frac{L}{L+D}$ $\quad V_1 = L_0 + D = (R+1)D$

$L_0 = RD$

$L = RD \quad V = (R+1)D$

$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1} \leftarrow \frac{L}{V} = \frac{L}{L+D} = \frac{RD}{(R+1)D}$



SE $x = x_D \Rightarrow y_{n+1} = \frac{R}{R+1} x_D + \frac{x_D}{R+1}$

$= \frac{R+1}{R+1} x_D = x_D$

SE $x = 0 \Rightarrow y_{n+1} = \frac{x_D}{R+1} + 0$

$\angle \frac{R}{R+1}$

SEZIONE ESAURIMENTO

$y_m \bar{V}_m = \bar{L}_{m-1} x_{m-1} - x_B B$

$y_m = \frac{\bar{L}_{m-1}}{\bar{V}_m} x_{m-1} - \frac{B}{\bar{V}_m} x_B \qquad y_m = \frac{\bar{L}}{\bar{V}} x_{m-1} - \frac{x_B B}{\bar{V}}$

$\bar{R} = \frac{\bar{L}}{B} \quad \bar{L} = \bar{V} + B \quad \bar{V} = \bar{L} - B = B(\bar{R} - 1)$

$y_m = \frac{\bar{R} B}{B(\bar{R}-1)} x_{m-1} - \frac{x_B B}{(\bar{R}-1)B}$

$y_m = \frac{\bar{R}}{\bar{R}-1} x_{m-1} - \frac{x_B}{(\bar{R}-1)}$

$\frac{\bar{V}-V}{F} = \frac{\bar{L}-L}{F} - 1$

$y\,\frac{\bar{V}-V}{F} = \frac{\bar{L}-L}{F}\,x - z_F$

$H\,\frac{\bar{V}-V}{F} = \frac{\bar{L}-L}{F}\,h - h_F \qquad \frac{\bar{L}-L}{F}(H-h) = H - h_F$

$\frac{\bar{L}-L}{F} = \frac{H-h_F}{H-h}$

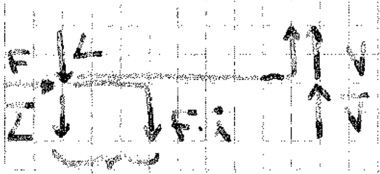
$i = \frac{H-h_F}{H-h}$ X DEFINIZIONE

F LIQUIDO SATURO $h_F = h \Rightarrow i = 1$

F VAPORE SATURO $h_F = H \Rightarrow i = 0$

F LIQUIDO/VAPORE $\Rightarrow i \in (0;1)$

$\bar{L} = iF + L$



i = FRAZ. LIQUIDO

$\frac{\bar{V}-V}{F} = i-1$

$\bar{V} = V + (i-1)F$

$V = \bar{V} + (1-i)F$

$i = \frac{H-h_F}{H-h}$

F LIQUIDO SOTTORAFFR. $h_F < h \Rightarrow i > 1$

$\bar{L} = L + iF$ SOTTRAE DEL VAPORE CHE TRASFORMA IN LIQUIDO, POICHE' UNA PARTE CONDENSA

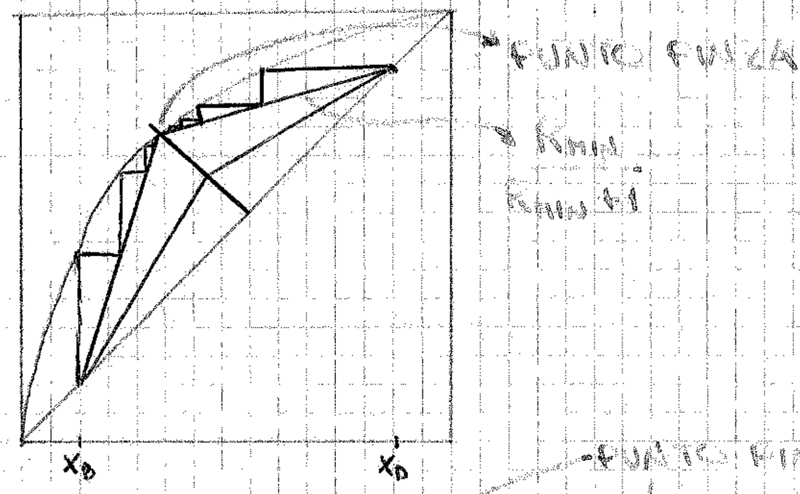
F VAPORE SURRISCALDATO $h_F > H \Rightarrow i < 0$

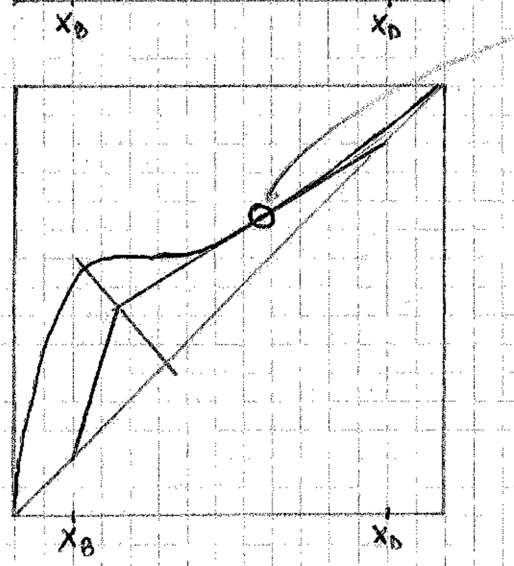
PARTE DEL LIQUIDO VAPORIZZA

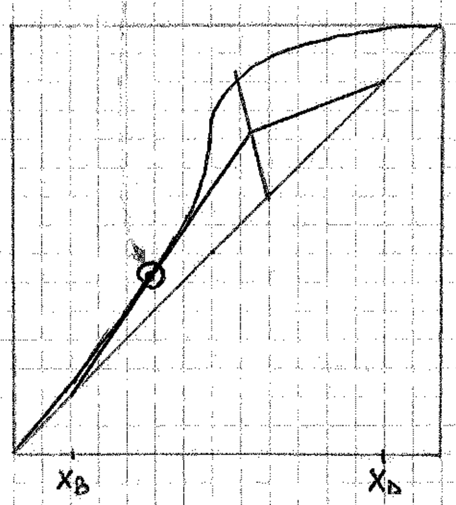
$y(i-1) = ix - z_F$

$y = \frac{i}{i-1}x - \frac{z_F}{i-1}$

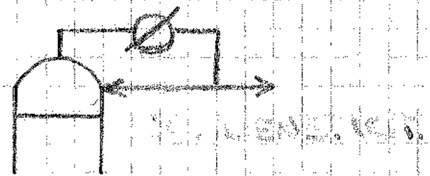
RAPPORTO DI RIFLUSSO MINIMO [illegible]

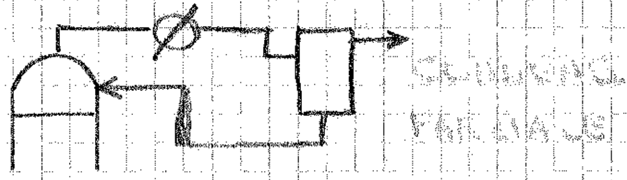






[illegible]





Q_c [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

X SEZ. ESAURIMENTO

$Y = \frac{\alpha X}{1+(\alpha-1)X}$

$Y_{m+1} = \frac{R'}{R'-1} X_{m} - \frac{X_B}{R'-1}$ [illegible] X_{m+1} $\frac{X_B}{(-R')}$ [illegible]

ESPRESSO A PRECEDENTE CON

$-R' \to R$ $X_B \to X_D$ [illegible] RETTA (x_F, y_F) [illegible] (x_B, x_B)

$X_m X_{m+1} + \left[\frac{X_B}{-R'} \ldots \frac{\alpha}{\alpha-1} \ldots\right] \ldots \frac{X_{m+1}}{\alpha-1} + \frac{X_B}{(-R')(\alpha-1)}$ [illegible]

$$N = \frac{\log\left(\ldots X_{B} \ldots\right)}{\log\left(\ldots\right)}$$

X RETTE UNITE (x_F, y_F)

$y_F = \frac{R}{R+1} X_F + \frac{X_D}{R+1}$

$Y_F = \frac{q}{q-1} X_F - \frac{z_F}{q-1}$

$\to \left(\frac{R}{R+1} - \frac{q}{q-1}\right) X_F = -\frac{X_D}{R+1} - \frac{z_F}{q-1}$

$$X_F = \frac{\frac{X_D}{R+1} + \frac{z_F}{q-1}}{\frac{q}{q-1} - \frac{R}{R+1}}$$

A R MIN FINITA: (X^*, Y^*)

$Y^* = \frac{\alpha X^*}{1+(\alpha-1)X^*}$

$Y^* = \frac{q}{q-1} X^* - \frac{z_F}{q-1}$

$\frac{X_D - Y^*}{X_D - X^*} = \frac{R_{min}}{R_{min}+1}$

$$y = \frac{\bar{R}}{\bar{R}-1}x - \frac{x_B}{\bar{R}-1}$$

$$\bar{V} = V + (i-1)F = L + D + (i-1)F = (R+1)D + (i-1)F$$

$$\dot{Q}_{eb} = \frac{\bar{V}\lambda}{B} = \frac{(\bar{V}/F)\lambda}{B/F} \qquad \frac{\bar{V}}{F} = (R+1)\frac{D}{F} + (i-1)$$

$$\dot{Q}_{eb}\frac{B}{F} = \left[(R+1)\frac{D}{F} + i - 1\right]\lambda$$

$$\bar{R} = \frac{\dot{Q}_{eb}/\lambda \cdot B/F) + 1 - i}{D/F} - 1$$

E' + MEGLIO RICAVARE $\bar{R}$ E POI TRACCIARE RETTA ARRICCHIM. IN MODO GRAFICO

R_{MIN} LO CALCOLO O IN MANIERA GRAFICA O IN MODO NUMERICO, SFRUTTANDO IL FATTO CHE LA PENDENZA DELLA RETTA ARRICCHIMENTO È $R_{min}/(R_{min}+1)$

$$\begin{cases} y = \frac{i}{i-1}x - \frac{z_F}{i-1} \\ y = \frac{\alpha x}{1+(\alpha-1)x} \end{cases} \qquad x_F^{*2} + b x_F^* + c = 0 \qquad x_F^* \in (0;1)$$

$$b = \frac{1}{\alpha-1} - \frac{z_F}{i} - \frac{\alpha/(\alpha-1)}{i/(i-1)} = \frac{5}{6}$$

$$y_F^* = \frac{\alpha x_F^*}{1+(\alpha-1)x_F^*} \qquad c = -\frac{z_F}{i(\alpha-1)} = -\frac{1}{3}$$

$$R_{min} = \frac{x_D - y_F^*}{y_F^* - x_F^*} \qquad \begin{matrix} x_1 = 0,29 \rightarrow x_F^* = 0,29 \\ x_2 = -1,12 \end{matrix}$$

$y_F^* = 0,55$ $\quad R_{MIN} = 1,309$

$$y = \frac{\bar{R}}{\bar{R}-1}x - \frac{x_B}{\bar{R}-1}$$

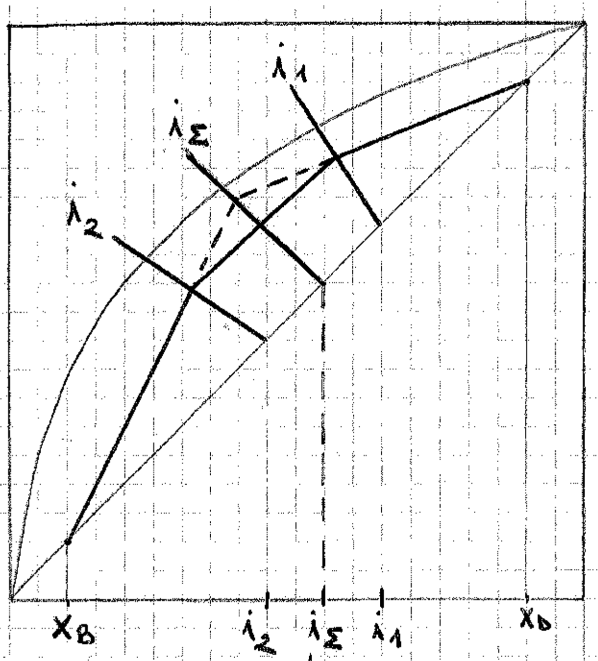
$$\frac{\bar{\bar{L}}-L}{\Sigma} = \frac{H-h_\Sigma}{H-h} \qquad i_\Sigma = \frac{H-h_\Sigma}{H-h} = \frac{\bar{\bar{L}}-L}{F_1+F_2}$$

$$\bar{L} = L + i_1F_1$$

$$\bar{\bar{L}} = \bar{L} + i_2F_2 = L + i_1F_1 + i_2F_2$$

$$\bar{\bar{L}} - L = i_1F_1 + i_2F_2$$

$$i_\Sigma = \frac{\bar{\bar{L}}-L}{F_1+F_2} = \frac{i_1F_1+i_2F_2}{F_1+F_2}$$



$$y = \frac{i_1}{i_1-1}x - \frac{z_{F1}}{i_1-1}$$

$$y = \frac{i_2}{i_2-1}x - \frac{z_{F2}}{i_2-1}$$

$$y = \frac{R}{R+1}x + \frac{x_D}{R+1}$$

$$y = \frac{\bar{R}}{\bar{R}-1}x - \frac{x_B}{\bar{R}-1}$$

ALIMENTAZ. FITTIZIA Σ

PRIMA TRACCIO RETTA ESAURIM., SAPENDO RETTA ARRICCHIM E INTERSECANDOLA CON i_Σ-LINE (COME AVESSI UNA SINGOLA ALIMENTAZ. Σ) TRACCIO POI i_1-LINE E i_2-LINE, TROVO X OGNUNA INTERSEZ. CON RETTA DI LAVORO, UNISCO QUINDI LE 2 INTERSEZIONI (RETTA DI LAVORO INTERMEDIA)

SISTEMA MULTICOMPONENTE - METODO UNDERWOOD

ASSUMIAMO α (VOLATILITÀ RELATIVA) COST. $\alpha_{i,r} = \frac{K_i}{K_r}$

$$y_i = K_i x_i = \frac{K_i x_i}{\sum_j K_j x_j = 1} = \frac{(K_i / K_r) x_i}{\sum_j (K_j / K_r) x_j} = \frac{\alpha_{ir} x_i}{\sum_j \alpha_j x_j}$$

$$y_{n+1,i} = \frac{L}{V} x_{ni} + \frac{x_{Di} D}{V} = \frac{\alpha_i x_{n+1\,i}}{\sum_j \alpha_j x_{n+1\,j}}$$ S. ARRICCHIMENTO

PRENDIAMO $\frac{\alpha_i}{\alpha_i + \phi}$ TERMINE ARBITRARIO

$$\frac{\frac{\alpha_i^2}{\alpha_i - \phi} x_{n+1\,i}}{\sum_j \alpha_j x_{n+1\,j}} = \frac{L}{V} \frac{\alpha_i x_{ni}}{\alpha_i - \phi} + \frac{\alpha_i x_{Di} D}{(\alpha_i - \phi) V}$$

$$\frac{\sum_i \frac{\alpha_i^2}{\alpha_i - \phi} x_{n+1,i}}{\sum_j \alpha_j x_{n+1\,j}} = \frac{L}{V} \sum_i \frac{\alpha_i x_{ni}}{\alpha_i - \phi} + \underbrace{\sum_i \frac{\alpha_i x_{Di}}{\alpha_i - \phi} \frac{D}{V}}_{=1}$$

$$\sum_i \frac{\alpha_i x_{Di}}{\alpha_i - \phi} = \frac{V}{D} = R+1$$ ← PRENDO ϕ IN MODO CHE SODDISFI TALE CONDIZ.

$$\frac{\sum_i \left(\frac{\alpha_i^2}{\alpha_i - \phi} x_{n+1,i} \mp \alpha_i x_{n+1\,i} \right)}{\sum_i \alpha_i x_{n+1,i}} = \frac{L}{V} \sum_i \frac{\alpha_i x_{ni}}{\alpha_i - \phi}$$

$$\sum_i \left(\frac{\alpha_i}{\alpha_i - \phi} - 1 \right) \alpha_i x_{n+1,i}$$

$$\parallel$$

$$\frac{\alpha_i - \alpha_i + \phi}{\alpha_i - \phi}$$

$$\frac{\phi \sum_i \frac{\alpha_i}{\alpha_i - \phi} x_{n+1,i}}{\sum_i \alpha_i x_{n+1,i}} = \frac{L}{V} \sum_i \frac{\alpha_i x_n}{\alpha_i - \phi}$$

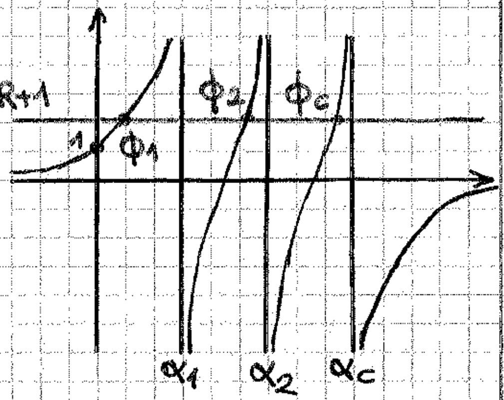
POSSO USARLO IN REALTÀ SOLO SE SIST. BINARIO PERCHÈ
X_{Di} NON VIENE DATO x TUTTI I COMPONENTI

SEZ. ARRICCHIMENTO

$$\sum_i \frac{\alpha_i X_{iD}}{\alpha_i - \phi} = \frac{V}{D} = R+1$$

$$\overset{\shortparallel}{R(\phi)} \text{ MONOTONA CRESC.}$$

$$\text{SE } \phi = \alpha_i \ \forall i \Rightarrow R \to \infty$$



$\phi_1 \in (0, \alpha_1)$
$\phi_2 \in (\alpha_1, \alpha_2)$
$\phi_c \in (\alpha_{c-1}, \alpha_c)$

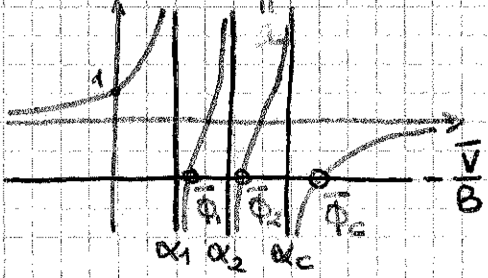
SEZ. ESAURIMENTO

$$\begin{cases} Y_m = \frac{\bar{L}}{\bar{V}} X_{m-1} - \frac{X_{Bi} B}{\bar{V}} \\ Y_{mi} = \frac{\alpha_i X_{mi}}{\sum_j \alpha_j X_{mj}} \end{cases} \qquad \frac{\alpha_i}{\alpha_i - \bar{\phi}}$$

$$\frac{\frac{\alpha_i^2 X_{mi}}{\alpha_i - \bar{\phi}}}{\sum_j \alpha_j X_{mj}} = \frac{\bar{L}}{\bar{V}} \frac{\alpha_i X_{m-1,i}}{\alpha_i - \bar{\phi}} - \frac{\alpha_i X_{Bi}}{\alpha_i - \bar{\phi}} \frac{B}{\bar{V}}$$

$$\frac{\sum \frac{\alpha_i^2 X_{m,i}}{\alpha_i - \bar{\phi}}}{\sum_j \alpha_j X_{mj}} = \frac{\bar{L}}{\bar{V}} \sum_i \frac{\alpha_i X_{m-1,i}}{\alpha_i - \bar{\phi}} + \overbrace{\left(- \sum_i \frac{\alpha_i X_{Bi}}{\alpha_i - \bar{\phi}} \frac{B}{\bar{V}} \right)}^{=1}$$

$$\sum_i \frac{\alpha_i X_{Bi}}{\alpha_i - \bar{\phi}} = - \frac{\bar{V}}{B}$$



$\phi_1 \in (\alpha_1, \alpha_2)$
$\phi_2 \in (\alpha_2, \alpha_3)$
$\phi_c \in (\alpha_c, \infty)$

X SIST. BINARIO

$$\sum_i \frac{\alpha_i x_{Di}}{\alpha_i - \phi} = R+1 \qquad \frac{\alpha x_D}{\alpha - \phi} + \frac{(1-x_D)\cdot 1}{1-\phi} = R+1 \quad \leftarrow \alpha_{x,x}=1$$

$$\sum_i \frac{\alpha_i x_{Bi}}{\alpha_i - \bar{\phi}} = -\frac{\bar{V}}{B} \qquad \frac{\alpha x_B}{\alpha - \bar{\phi}} + \frac{1-x_B}{1-\bar{\phi}} = -\frac{\bar{V}}{B}$$

X SIST. BINARIO VIENE EQUAZ. 2° GRADO CON METODO DI UNDERWOOD, COME X METODO DI RICCATI

DISTILLAZIONE MULTI-COMPONENTE

$F, z_{F1}, z_{F2}, \dots, z_{FC-1}, P, T \rightarrow C+2$

$f_i = z_i F \qquad d_i = x_{Di} D \qquad b_i = x_{Bi} B$

$f_1; f_2; \dots; f_C$

$d_1; d_2; \dots; d_C$

$b_1; b_2; \dots; b_C$

$d_i = S_i f_i$

↓ COEFF. DI RIPARTIZIONE DI i

↳ CONDIZ. ANALOGA A $x_{Di} D = 0{,}98\, z_F F$

2 COMPONENTI CHIAVE + ALTRI COMPONENTI

↗ LEGGERO → ESCE DI + DA D

↘ PESANTE → ESCE DI + DA B

ℓk = LIGHT KEY → CHIAVE LEGGERO

hk = HARD KEY → CHIAVE PESANTE

	f	d	b
	f_1	$d_1 = f_1$	$b_1 = 0$
$\overline{\ell k}$	f_2	$d_{\ell k} = S_{\ell k} f_{\ell k}$	$b_{\ell k} = f_{\ell k} - d_{\ell k}$
	f_3	d_3 (SCONOSCIUTO)	$b_3 = f_3 - d_3$ (INCOGNITO)
$\overline{hk}$	f_4	$d_{hk} = S_{hk} f_{hk}$	$b_{hk} = f_{hk} - d_{hk}$
	f_5	$d_5 = 0$	$b_5 = 1$

$$\sum_i \frac{\alpha_i d_i}{\alpha_i - \phi} = (R_{MIN}+1)\sum_i d_i$$

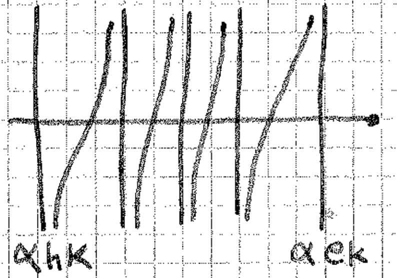
$d_1 = \beta_1$
$d_2 = \beta_2$
$\left.\begin{array}{l} d_{eK} \\ d_i \\ d_{hK} \end{array}\right] n_d \rightsquigarrow$

$d_c = 0$

INCOGNITE:
R
$nd-2$ $\Big\}$ nd-1 INCOGNITE

$$\sum \frac{\alpha_i d_i}{\alpha_i - \phi_K} = (R_{MIN}+1)\sum_i d_i \qquad K = 1, 2, \dots, nd-1$$

nd-1 EQUAZIONI



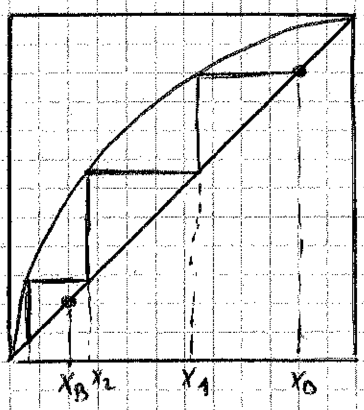
$\phi = \bar{\phi}$ SE $\in (\alpha_{hK}, \alpha_{eK})$

$$\sum_i \frac{\alpha_i z_{Fi}}{\alpha_i - \phi} = 1 - i\phi$$

DETERMINO I VARI $\phi \rightarrow \phi_1, \phi_2, \dots, \phi_{nd-1}$

SE I COMP. DISTRIBUITI SONO SOLO I 2 CHIAVE
$\downarrow$ SOLO UNA $\phi \rightarrow$ 1 EQUAZIONE $\qquad \downarrow$ 1 INCOGNITA (R_{MIN})

METODO DI FENSKE - CALCOLO N_{MIN}

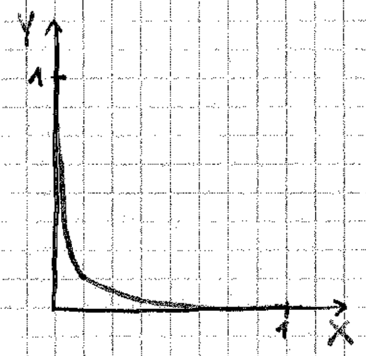


$N_{MIN} \longrightarrow$ RETTA LAVORO = DIAGONALE

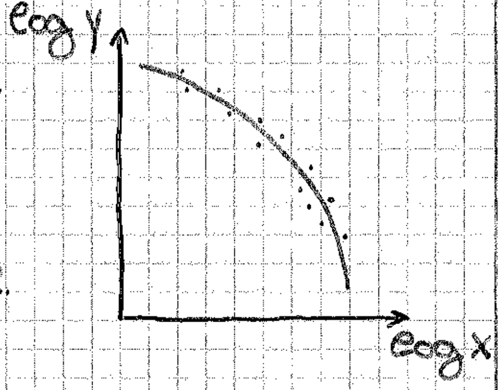
$x_{Di} = y_{1i} = K_{1i} x_{1i} = K_{1i} y_{2i} = K_{1i} K_{2i} x_{2i}$

$x_{Di} = K_{1i} K_{2i} K_{3i} x_{3i}$

$x_{Di} = \left(\prod_1^{N_{MIN}} K_{ni}\right) x_{Bi}$



POCO LEGGIBILE
POICHE' MOLTO
SCHIACCIATO
↓
USANDO DIAGR.
DOPPIO log



$$\frac{N-N_{MIN}}{N+1} = 1 - EXP\left[f(X)\right]$$

FUG → FENSKE
UNDERWOOD
GILLILAND

WUG → WINN
UNDERWOOD
GILLILAND

POSIZIONE ALIMENTAZIONE

N_R = NUM. STADI SEZ. ARRICCHIM.

$(N_R)_{MIN}$ ⇒ USO FENSKE DA x_D A z_F (SEZ. ARRICCHIM.)

$$\frac{N_R}{N} = \frac{(N_R)_{MIN}}{N_{MIN}}$$

SE $R = 1,2\,R_{MIN} \Rightarrow N \cong 2\,N_{MIN}$

↓
DA 1,1 A 1,3

NON USARE NEL
COMPITO, MA SOLO
X CONTROLLO.

$$0 = x_D \dot{D} + \frac{d(x_B B)}{d\tau}$$ TRASCURO VELOC. ACCUMULO SUI PIATTI

$$0 = x_D \dot{D} + x_B \frac{dB}{d\tau} + B \frac{dx_B}{d\tau}$$

$$0 = -x_D \frac{dB}{d\tau} + x_B \frac{dB}{d\tau} + B \frac{dx_B}{d\tau}$$

$$\frac{dB}{d\tau}(x_D - x_B) = B \frac{dx_B}{d\tau}$$

$$\frac{dB}{B} = \frac{dx_B}{x_D - x_B} \qquad \ln\left(\frac{B}{F}\right) = \int_{z_F}^{x_B} \frac{dx_B}{x_D - x_B}$$

2 FUNZIONAMENTI POSSIBILI → R COSTANTE → x_D VARIABILE
→ x_D COSTANTE → R VARIABILE

CALCOLI DI VERIFICA E NON DI PROGETTO

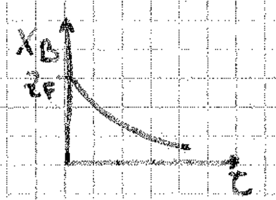
BOLLITORE PARZIALE → UNO STADIO IN + DEI PIATTI

CONDENSATORE TOTALE → $N = N_p + 1$

$\boxed{\text{R COSTANTE}}$

$F \quad z_F \rightarrow x_B(\tau)$

$x_D(\tau)$



$$z_F F = x_B B + \underbrace{\bar{x}_D}_{\text{MEDIA}} D$$

SE VALGONO IPOTESI MC CABE-THIELE, IN COLONNA ARRICCHIM:

$$y_{n+1} \dot{V} = \dot{L} x_n + x_D \dot{D} + \sum \cancel{\frac{d(L_n x_n)}{d\tau}} + \sum \cancel{\frac{d(V_n y_n)}{d\tau}}$$

PSEUDO-STAZIONARIETÀ