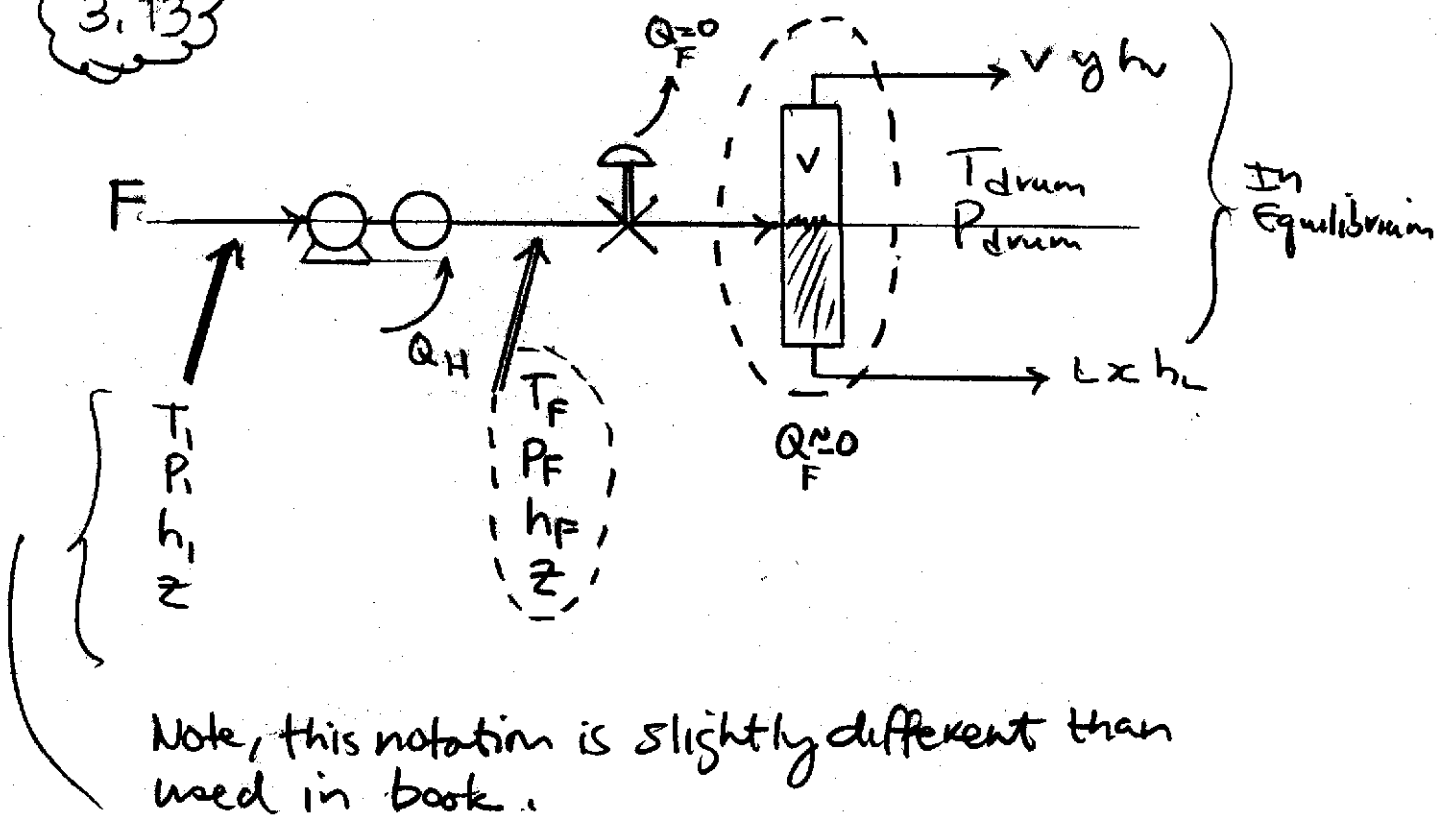
3.13



Note, this notation is slightly different than used in book.

Problems of this sort usually specify

F, z, T_1, P_1 and P_{drum}

One variable still needs to be specified

(1) T_{drum}

(2) $\psi = V/F$ or $(1-\psi) = L/F$

(3) y or x

Other permutations are also possible.

Available equations

MB: C eqns $\quad F = V + L$

$Fz = Vy + Lx$

EB: 1-eqxn $F h_F + \overset{\cdot}{Q}_F^{\,\cdot 0} = V h_V + L h_L$

or $F h_1 + Q_H + Q_F = V h_V + L h_L$

EE: C-eqxns $y_i = K_i x_i$

STOI: $\Sigma x_i = 1$ $\Sigma y_i = 1$ etc.

Binary Cases (C=2)

- Sequential Method, last variable is drum specification
- Simultaneous Method, " " is not " "

Case B_1 - Specify y or x or T_{drum} (only one)

Method

1. Use EE to find the other two.
2. Use MB to find L & V.

Expansion of Method.

1. Use $K_i(T_{drum})$

   or x-y diagram

   or Txy diagram

   or Hxy diagram etc...

2. $F = L + V$ (A)

$Fz = Lx + Vy$ (B)

Two eqns, two unknowns

∴ Solve for $L \& V$

Case B_2 - Specify $Y_F = \Psi$ or Y_F

Method

1. Combine (A) & (B) to get op. line (q-line)

$$y = -\frac{L}{V}x + \frac{F}{V}z$$

2a. Find intersection of MB (q-line) with EE (graphical) {slope, int, x=y=z, etc)

2b. Analytically find solution if EE is analytical.

Case B_1 & B_2 Followup

Method is sequential and MB & EE have been solved (x, y, T trum, L, V known)

Method can't

3a Find h_V h_L h_F from enthalpy conc. diagram (HXY)

3b. Solve h_V h_L h_F from appropriate Cp data etc.

4. $Fh_F = Vh_V + Lh_V$

$$Q_H + Fh_1 = Fh_F$$

Solve for Q_H (heat requirement)

P_F can be any pressure $> P_{min}$ at T_F to prevent boiling in the heat exchanger.

5. T_F can be found from h_F (and z_F) on Hxy diagram.

Case B_3 (Simultaneous Solution Techniques)

Non-drum condition specified (usually T_F).

The MB & EB & EE must be solved simultaneously (that is, iteratively by Trial & Error Methods (TE)).

Note: If T_F & z are known h_F is also able to be determined

$$h_F = h_F(T_F, z)$$

Method

1. Calculate or find h_F
2. Guess T_{drum}

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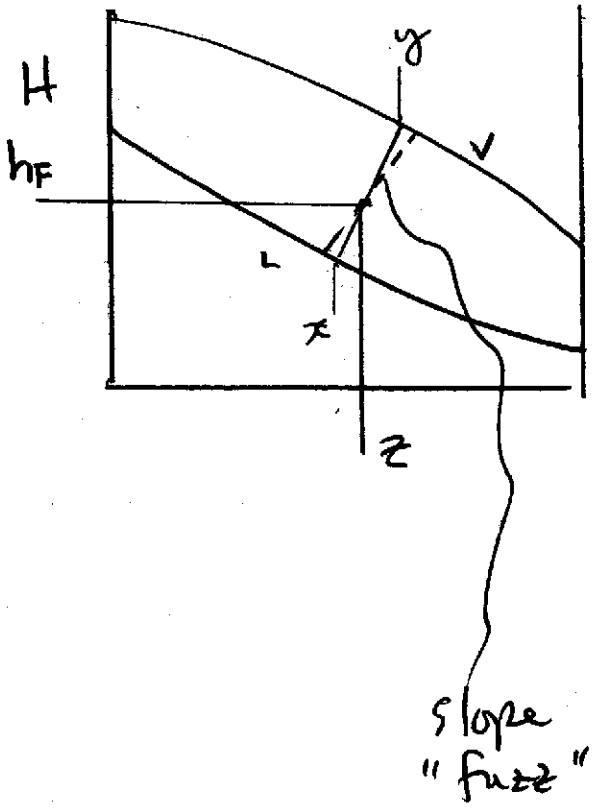
3. Find x & y from EE
4. Find L & V from MB (q-line)
5. Calculate h_L & h_V (knowing x & y)
6. Check if EB satisfied

$$\cancel{Q_C} + F h_F \overset{?}{=} V h_V + L h_L$$

(h_V, h_L: depend on T_{drum})

7. Guess new T_{drum} until EB OK!

or Graphical Method



1. Calculate h_F
2. Plot feed enthapy (h_F, z)
3. T_{drum} isotherm goes through h_F, z
4. Find x & y from isotherm
5. Calculate L, V by ±LAR (lever arm)

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MC - Multicomponent Cases

There are no techniques which employ graphics. Only analytical methods are used.

Available methods

EE $y_i = K_i x_i \quad i = 1,, C$

$K_i = K_i(T_{drum}, P_{drum}, x_i\text{'s etc})$

for ideal systems

$K_i = K_i(T_{drum}, P_{drum})$

STOI $\Sigma x_i = 1 \quad \Sigma y_i = 1$

MB $F = L + V$

$Fz_i = Lx_i + Vy_i$

EE $Fh_F + Q_F = Vh_V + Lh_L$

Case M_1 (T_{drum} specified)

This case has a sequential solution similar to B_1.

If we can assume ideal solutions

$K_i \neq f(\vec{x_i}) \quad K_i = f(T_{drum}, P_{drum})$

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Start w/ MB $\quad Fz_i = Lx_i + Vy_i$

since $y_i = K_i x_i$

$$Fz_i = Lx_i + V K_i x_i$$

$$\therefore \quad x_i = \frac{Fz_i}{L + VK_i}$$

w/ $L = F - V$

$$x_i = \frac{Fz_i}{F - V + K_i V}$$

$$x_i = \frac{z_i}{1 + (K_i - 1)\,V/F} \qquad (A)$$

$$y_i = \frac{K_i z_i}{1 + (K_i - 1)\,V/F} \qquad (B)$$

and as before $\sum x_i = 1 \quad \sum y_i = 1$

and as before, we have derived the Rachford Rice Eqn

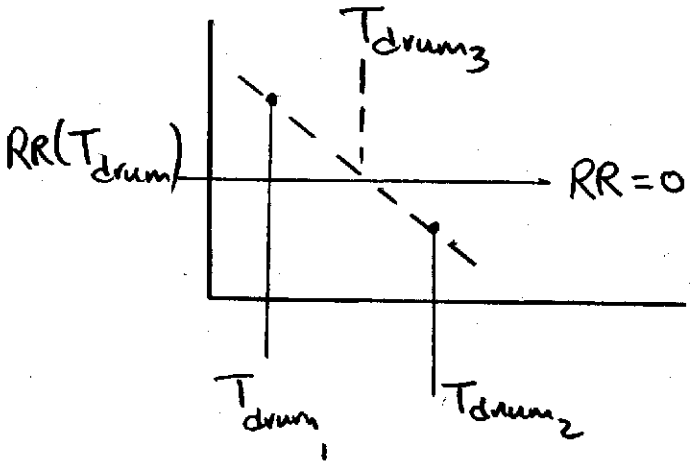
$$0 = f(\psi) = \sum \frac{(K_i - 1)\, z_i}{1 + (K_i - 1)\,\psi}$$

Procedure

1. Given z_i, T_{drum}, P_{drum}
2. Calculate $K_i\,(T_{drum})$
3. T&E to find $0 < V/F < 1$

3. Check $RR = f(T_{drum})$

4. Determine new T_{drum}



If implimented numerically, use

$$K_{ref}(T_{new}) = \frac{K_{ref}(T_{old})}{1 + d(RR(T_{old}))}$$

$d \leq 1.0$ damping factor

Case M3 (Specify x_{ref} or y_{ref})

Only components composition can be specified in either the V or L phase.

Denote this component as "ref"

Note $x_{ref} = \frac{z_{ref}}{1 + (K_{ref} - 1)V/F}$ (C)

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Note (C) allows us to express Kref or V/F in terms of x_{ref}.

Procedure (1)

1. Guess T_{drum} and calculate Kref from EE
2. Solve (C) for V/F
3. Use RR(V/F) to check for correct T_{drum}
4. When converged use (A) & (B) to get compositions, etc.

Procedure (2)

1. Guess V/F
2. Calculate Kref from (C)
3. Determine T_{drum} from Kref
4. Check RR(T_{drum})

5. (Both Procedures): Calculate V, L, h_L, h_V, etc.

MC Simultaneous Methods

Case M4 (T_F specified)

1. Begin by selecting an appropriate P_F
2. Next determine feed enthalpy

$$h_F = f(T_F) = \sum z_i h_{Fi}$$

Two methods are possible. One is favored for wide boiling mixtures (WBM) with easy separations (> 80-100°C)

The second procedure is favored for narrow boiling mixtures (NBM) with difficult separations.

Procedure WBM:

3. Guess T_{drum}
4. Guess V/F
5. Use $RR(V/F) = 0$ to find V/F for the guessed T_{drum}
6. Calculate x_i, y_i, L, V, h_V, h_L
7. Check EB

$$F h_F + Q_F \stackrel{?}{=} L h_L + V h_V$$

8. To improve T_{drum} guess

Define

$$E_K(T_{drum}) = Vh_V + Lh_L - Fh_F - Q_F$$

Then

$$\Delta T_{drum} = \frac{-E_K}{\frac{dE_K}{dT_{drum}}}$$

where

$$\frac{dE_K}{dT_{drum}} = VCp_V + LCp_L$$

Procedure NBM

3. Estimate (Guess) V/F
   $(0 < V/F < 1)$
4. Estimate T_{drum}
5. Calculate $K_i(T_{drum})$
6. Solve $RR(V/F, T_{drum})$ to find T_{drum}
7. Calculate x_i y_i L V h_V h_L
8. Check EB

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To improve V/F estimate

$$\left(\frac{V}{F}\right)_{new} = \frac{\frac{Q_F}{F} + h_F + h_L}{h_V - h_L}$$

when $\left(\frac{V}{F}\right)_{new} \simeq \left(\frac{V}{F}\right)_{old}$ converged!

Special Cases

MC Bubble Pt

For BP, $\Psi = 0$ $\left(\frac{V}{F}\right)$ ∴ RR yields

$$f(0) = \sum z_i(1-K_i) = \sum z_i - \sum z_i K = 0$$

but $\sum z = 1$

$$\therefore \quad \sum z_i K_i = 1 \qquad \{RR\ BP\}$$

MC Dew Pt

For DP, $\Psi = 1$ ∴ RR yields

$$f(1) = \sum \frac{z_i(1-K_i)}{K_i} = \sum \frac{z_i}{K_i} - \sum z_i = 0$$

$$\therefore \quad \sum \frac{z_i}{K_i} = 1$$

8. To improve T_{drum} guess

Define

$$E_K(T_{drum}) = Vh_V + Lh_L - Fh_F - Q_F$$

Then

$$\Delta T_{drum} = \frac{-E_K}{\frac{dE_K}{dT_{drum}}}$$

where

$$\frac{dE_K}{dT_{drum}} = VCp_V + LCp_L$$

Procedure NBM

3. Estimate (Guess) V/F
   ($0 < V/F < 1$)
4. Estimate T_{drum}
5. Calculate K_i (T_{drum})
6. Solve RR (V/F, T_{drum}) to find T_{drum}
7. Calculate x_i y_i L V h_V h_L
8. Check EB