SET-5

Continuous Counter Current Extraction with Reflux:

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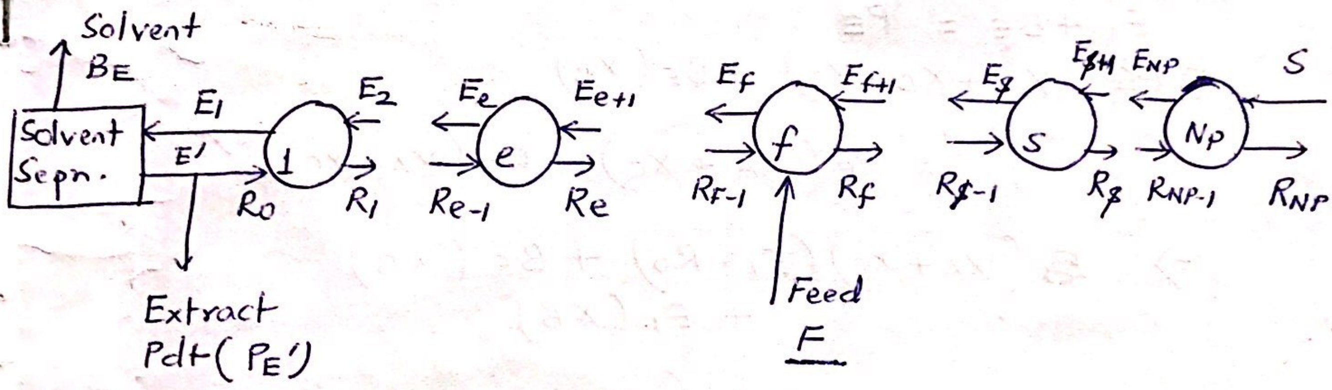
~~In a counter current extraction unit, the richest possible extract product that leaves the plant is at best only at equilibrium with.~~

The use of reflux at the extract end of the plant can lead to a riches product. (Similar to rectification section of a distillation column).

Reflux is however not needed at the raffinate end of the cascade, as unlike distillation, where heat must be carried in from the reboiler by a vapor reflux, in extraction the solvent (analog of heat) can enter without a carrier.



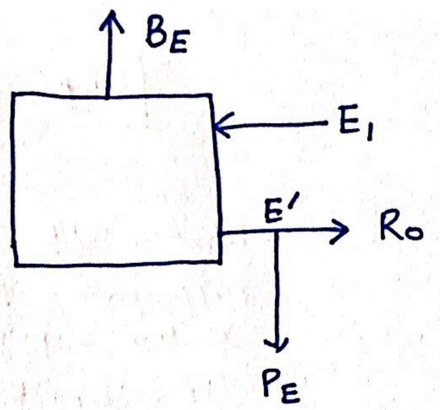
Feed is introduced at an appropriate location into the cascade; through which the extract and the raffinate are passing counter currently.

The conc. of solute C is increased in the Extract-Enriching section, by a counter current contact with. Raffinate Rich in C.

This is possible by removing the solvent from extract E_1 to produce a solvent free stream E', part of which is removed as the extract product P'_E and the other part returned as R_0.

The raffinate stripping section is same as the counter current extractor, and C is stripped from the raffinate by counter current contact with the solvent.

Balance Across the Solvent Separator.



*** Overall Balance.**

$$E_1 = B_E + R_o + P_E.$$

$$\Rightarrow \Delta_E = E_1 - R_o = P_E + B_E \quad \text{— (1)}$$

*** Balance on a B free Basis**

A+C Balance: $E' = P_E' + R_o'$

$$\Rightarrow \Delta_E' = E' - R_o' = P_E'$$

$$\therefore \Delta_E' = P_E' \quad \text{— (E2)}$$

To be noted

$P_E' = P_E$ (*)A

$R_o' = R_o$

$E_1' = E_1$

Also $Y_{E_1} = X_{P_E}$

On B Free Basis

Now C balance

$$C_{E_1} = \cancel{C_{B_E}}^{0} + C_{R_o} + C_{P_E} \quad \langle \text{From Eqn } 1 \rangle.$$

$$\Rightarrow C_{E_1} - C_{R_o} = C_{P_E} = X_{\Delta E}.$$

What is C in $P_E \Rightarrow X_{PE}$

$\therefore$ $\boxed{X_{\Delta_E} = X_{PE}}$

* Product Composition is Known. So X_{PE} is Known.

To obtain B balance, we do the following.

$$\Delta_E = P_E + B_E$$

and $\Delta_E' = P_E'$

Please note from (*)A that $P_E = P_E'$

Subtracting, $B_E = \Delta_E - \Delta_E'$

$$\Rightarrow B_E = \Delta_E - \Delta_{E'}$$

$$= \Delta_{E'}\left(\frac{\Delta_E}{\Delta_{E'}} - 1\right)$$

$$= \Delta_{E'}\left(\frac{\Delta A + \Delta B + \Delta C}{\Delta A + \Delta C} - 1\right).$$

$$= \Delta_{E'}\left(\frac{\Delta B}{\Delta A + \Delta C}\right).$$

↑ Difference Flow of B on a B Free. Basis. $N_{\Delta E}$.

What is ΔE

Difference in Flow. in the Seperator.

$\Delta E = E_1 - R_0$.

↓

$\Delta A + \Delta B + \Delta C$

What about

$\Delta E' = \Delta A + \Delta C$.

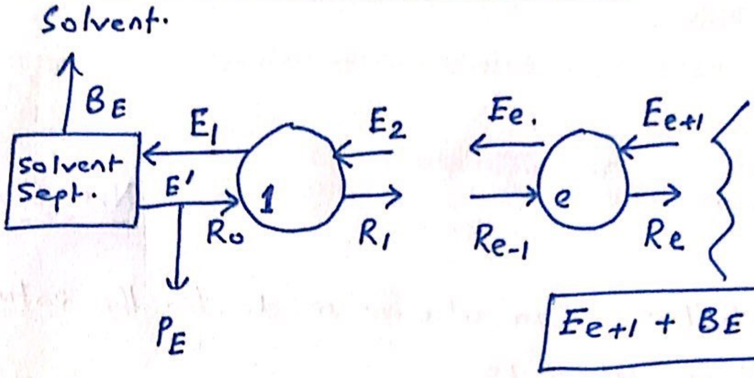
$$\therefore B_E = \Delta_{E'} \cdot N_{\Delta E}$$

We now have the Co-ordinates of the difference. point on B Free Basis, and there fore the difference point can be located on a N-X-Y diagram.

Co-ordinates.

$$\Delta_E' = \begin{cases} N_{\Delta E} = \dfrac{B_E}{\Delta_{E'}} \\ X_{\Delta E} = X_{P_E} \end{cases}$$

Let's Look in to the Rectification Section



$$\boxed{E_{e+1} + B_E = P_E + R_e.}$$

(A+C) balance or B free balance, of all stages in the Rectification Section thru' 'e' is.

$$E_{e+1}' = P_E' + R_e'$$

Now we have shown that $P_E' = \Delta_E'$.

$$\Rightarrow \boxed{E_{e+1}' = \Delta_E' + R_e'}$$

Corresponding C balance is.

$$Y_{e+1} E_{e+1}' = X_{PE}. P_E' + X_{Re}. R_e'$$

Now.
$X_{PE}. P_E'$
$= X_{\Delta E}. \Delta_E'$

$$\Rightarrow \boxed{Y_{e+1} = \frac{R_e'}{E_{e+1}'} \cdot X_{Re} + \frac{\Delta_E'. X_{\Delta E}}{E_{e+1}'}}$$

* This is the operating line with Slope $\frac{R_e'}{E_{e+1}'}$

Corresponding B Balance.

$$B_E = (\text{amount of } B)_{E_{e+1}} - (\text{amount of } B)_{R_e}.$$

$$\Rightarrow \Delta_E'. N_{\Delta E} = E_{e+1}'. N_{e+1} - R_e'. N_{Re}.$$

Equations to Solve:-

$$E_{e+1}' = \Delta_E' + R_e'$$

$$\Delta_E' X_{\Delta E} = E_{e+1}' Y_{e+1} - R_e' X_{Re}.$$

$$\Delta_E' N_{\Delta E} = E_{e+1}' N_{e+1} - R_e' N_{Re}.$$

$\Delta_E' =$

$$\Delta_E' X_{\Delta E} = E_{e+1}' Y_{e+1} - R_e' X_{Re}$$

$$\Delta_E' N_{\Delta E} = E_{e+1}' N_{E_{e+1}} - R_e' N_{Re}$$

$$(E_{e+1}' - R_e') X_{\Delta E} = E_{e+1}' Y_{e+1} - R_e' X_{Re}.$$

$$\Rightarrow \quad E_{e+1}' (X_{\Delta E} - Y_{e+1}) = R_e' (X_{\Delta E} - X_{Re}).$$

$$\frac{R_e'}{E_{e+1}'} = \frac{X_{\Delta E} - Y_{e+1}}{X_{\Delta E} - X_{Re}}.$$

Bottom Figure.

Slope of the line.

From the other Expression.

$$\frac{R_e'}{E_{e+1}'} = \frac{N_{\Delta E} - N_{E\,e+1}}{N_{\Delta E} - N_{Re}} = \frac{\text{line } \Delta_E . E_{e+1}}{\text{line } \Delta_E . R_e}.$$

Top Figure.

Internal reflux ratio at any stage.

The external reflux can be calculated as:-

$$\frac{R_o'}{P_E'} = \frac{R_o}{P_E'} = \frac{N_{\Delta E} - N_{E1}}{N_{E1}}$$

New
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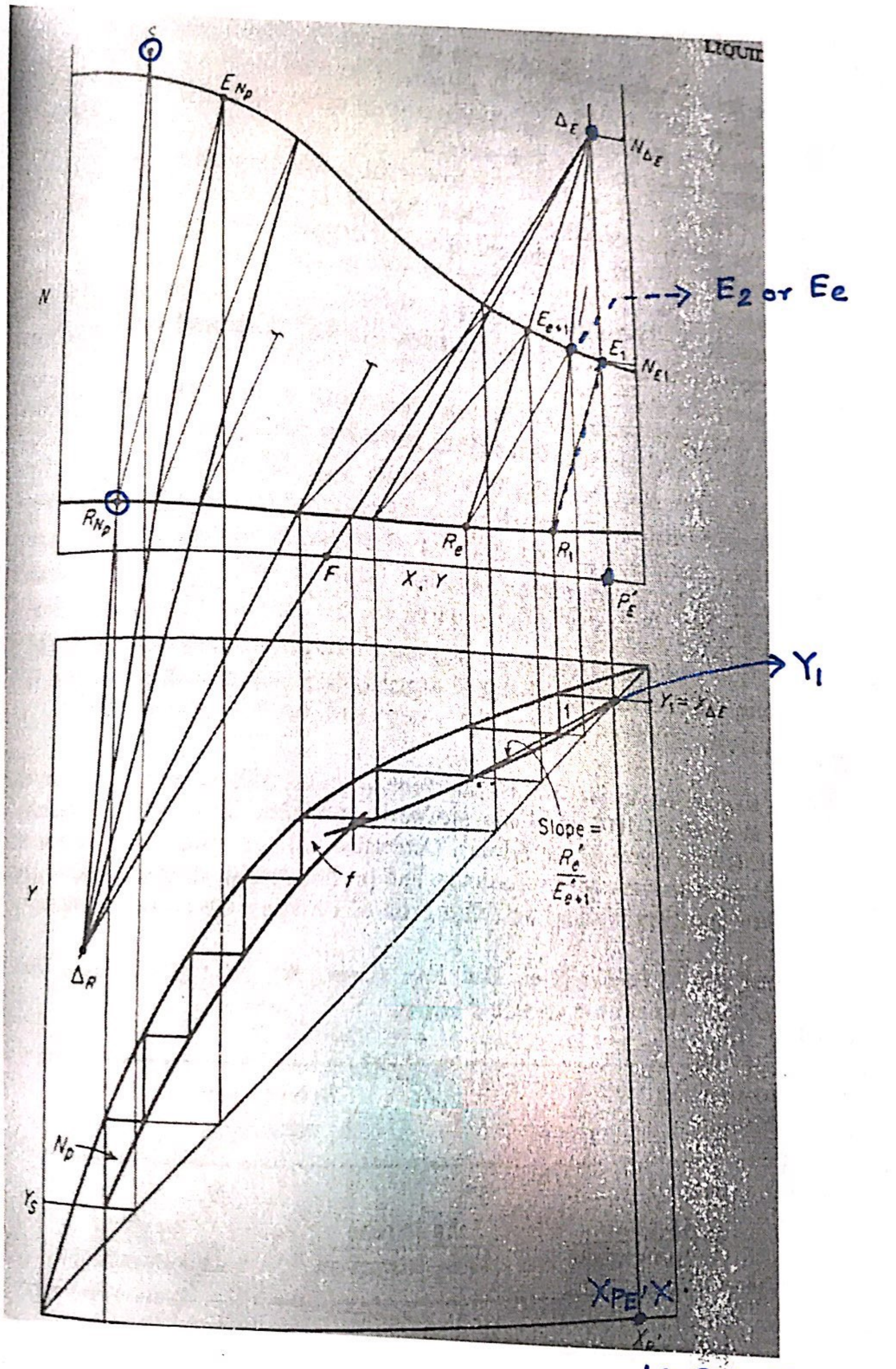
Since e is any stage in the rectification section, lines radiating from point Δ_E cuts the solubility lines at two points representing the extract and raffinate flowing between any two adjacent stages.



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Material Balance can also be made for the entire plant. On B free basis, which is.

$$F' + S' = P_E' + R_{NP}'$$

We can write $R_{NP}' - S' = \boxed{F' - P_E' = \Delta_R'}$

Also we have shown $\boxed{P_E' = \Delta_E'}$

∴ Combining the above two equations we get-

$$F' = \Delta_R' + \Delta_E'$$

~~If we assume F~~ We all know that Feed is generally Solvent Free.

∴ $F' = F$ will lie on the line joining the two difference points.

Optimum location of the Feed stage is represented by, the tie line which crosses line $\Delta_E\, F\, \Delta_R$, as shown.