CE407 SEPARATIONS

Lecture 17

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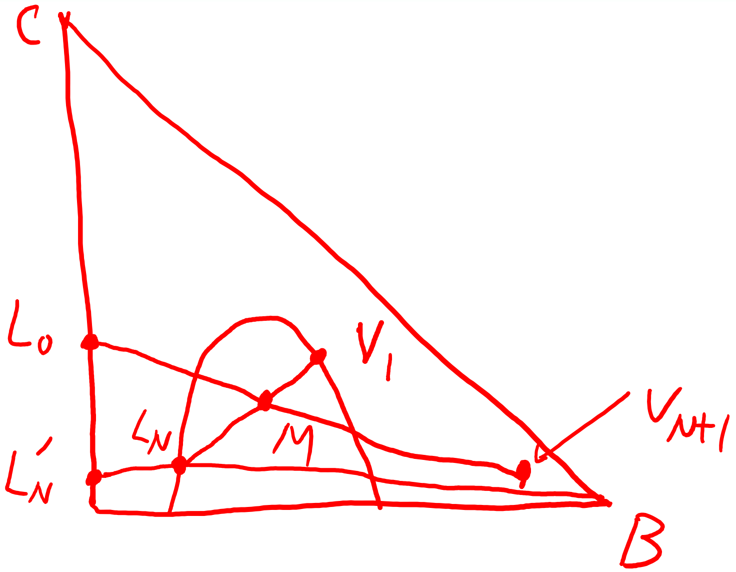
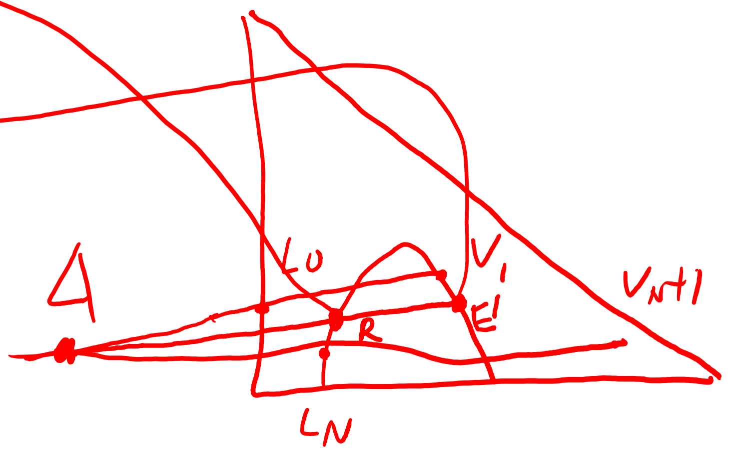
No. of ideal stages

1. Locate given points L_0, V_{N+1}, L_N'
2. Find M, L_N
3. Find V_1
4. Find Δ
5. Find points on op
6. plot EQ, OP
7. No. of stages



x_{c1} y_{c1}

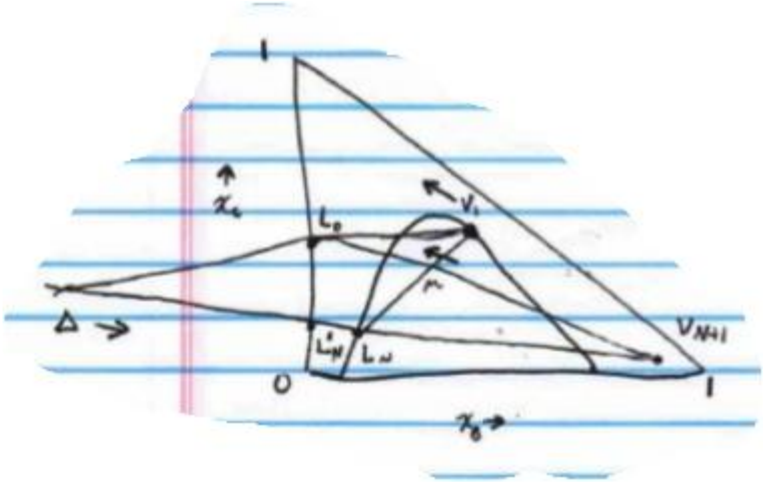
x_{c2} y_{c2}



Multi-Stage Countercurrent Extraction Treybal pp. 452 Fig 1040

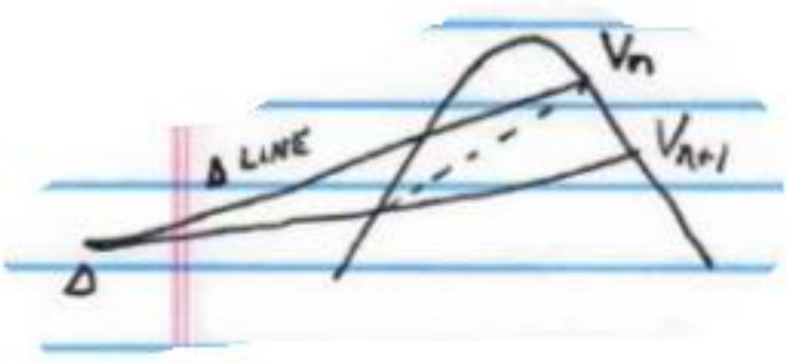
Minimum Entering Solvent Flow

- So far we have started with a given solvent flow, now we will see how to determine a reasonable flow
- **Point #1**
- Revisit the diagram for locating mixing point, **M**
- As the amount of solvent DECREASES
    - "**M**" moves toward $\mathbf{L_0}$
    - $\mathbf{V_1}$ moves to the left
    - Δ will move to the right
        - The line $\overline{V_1 L_0}$ becomes steeper



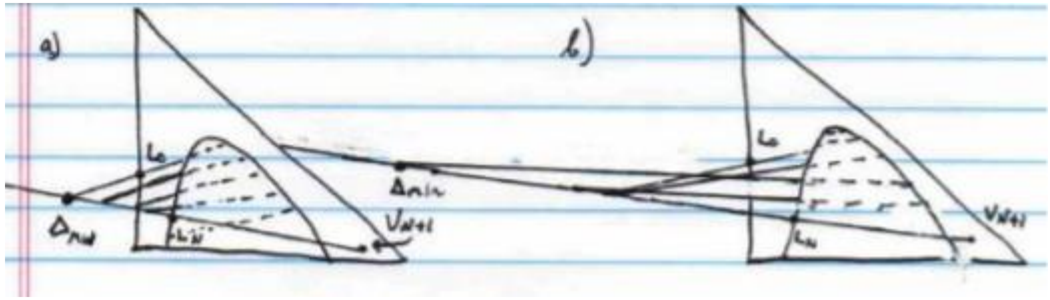
Minimum Entering Solvent Flow

- **Point #2: Review Hunter-Nash method**
- The # of steps are determined by alternating between:
  - Using Δ lines to do mass balances
  - Using tie lines to establish EQ relationships
- When the slopes of the Δ lines and tie lines are very different we make a lot of progress with each step
  - Similar to when OP lines and EQ curve are far apart
- When the slope of a Δ line is the same as the slope of a tie line we stop making progress
  - This is a pinch point
- The infinite number of steps corresponds to minimum solvent flow



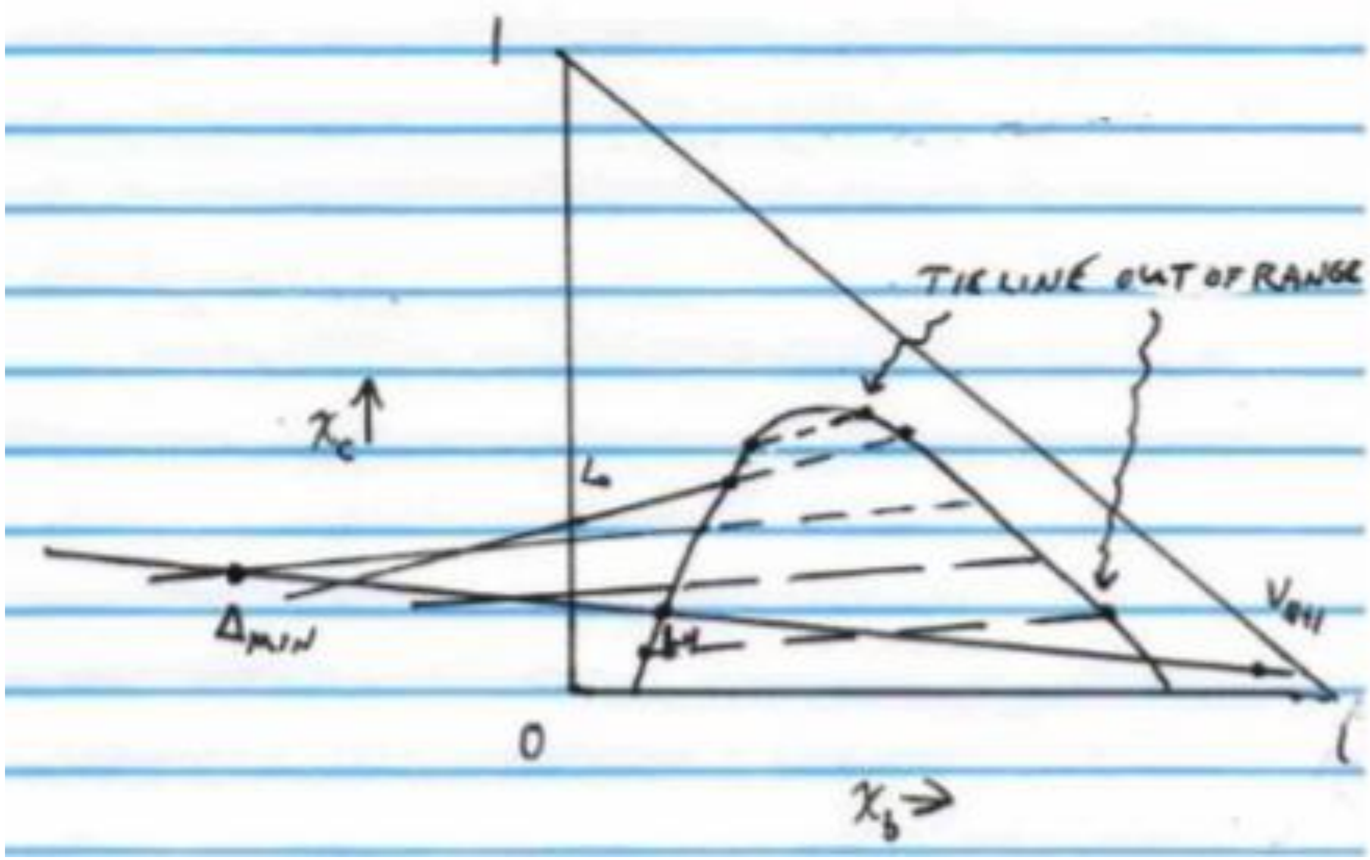
Minimum Entering Solvent Flow

- If we extend all of the relevant tie lines we see which leads to the furthest Δ location
  - Relevant tie lines are the those located between the tie line that passes through $\mathbf{L_0}$ and the one that passes through $\mathbf{L_N}$
- The Δ location furthest left corresponds to the largest flow that leads to a pinch point – this is the Minimum Solvent Flow
  - Note that all smaller flows will have a pinch point, we are looking for one where you reach the point where there are no more pinch points
  - When Δ lies to left of triangle it is furthest out, when Δ lies to right of triangle it is closest
- If the tie lines all have similar slopes this will be the tie line that crosses at $\mathbf{L_0}$ **(**Fig a)
- If the slopes vary, it could be a different tie line (Fig b)



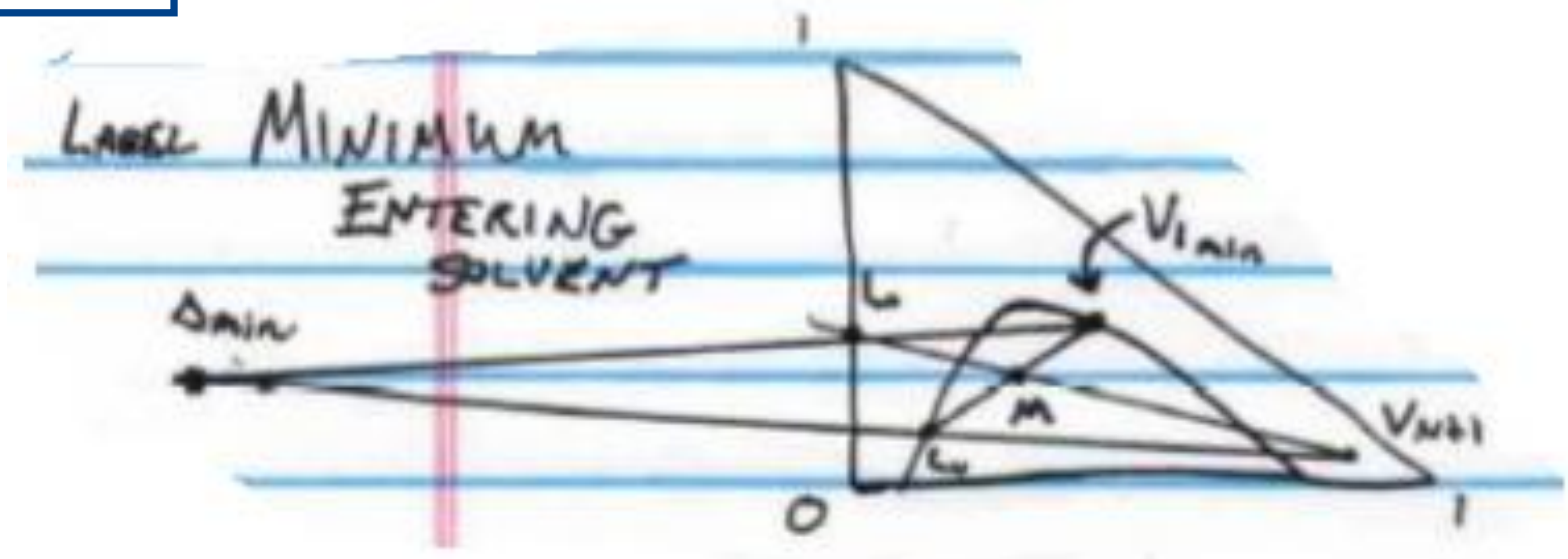
Minimum Entering Solvent Flow

- Label Leftmost intersection as Δ_{min}
- Notice the tie lines that are out of range are not used



Minimum Entering Solvent Flow

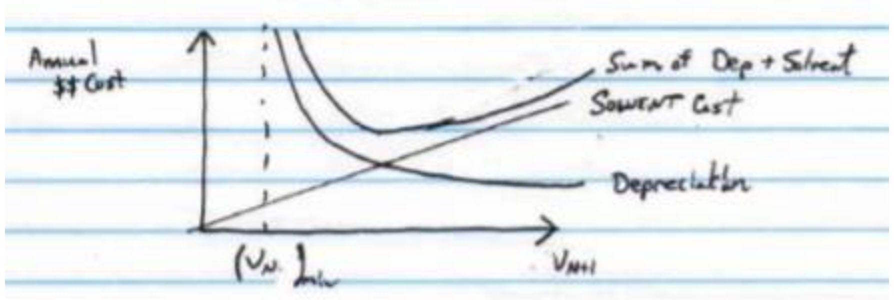
- Now draw a line from Δ_{min} to $\mathbf{L_0}$ and extend it to right hand side of phase boundary
- This determines $\mathbf{V_{1,min}}$
- Note that this line is NOT necessarily a tie line
- Draw in $\overline{L_N V_{1,min}}$ and $\overline{L_0 V_{N+1}}$, their intersection determines **M**
- $\boxed{\frac{(V_{N+1})_{min}}{L_0} = \frac{x_0 - x_M}{x_M - y_{N+1}}}$ this gives the ratio of minimum solvent flow to feed flow



What Flow Should We Use?

- Same optimization as we did for other Unit Operations…

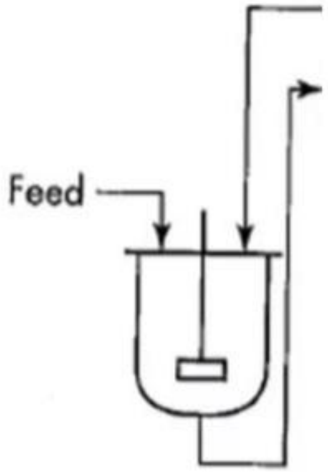
- Annual Cost = Depreciation + Solvent Cost



- Once again it turns out that it typically reaches a minimum at

$$(V_{N+1})_{opt} = 1.3(V_{N+1})_{min}$$

Batch Operation of a Stage



Think in terms of “before” and “after” the mixing and settling

- Charge Feed and Solvent to Vessel
- Mix thoroughly – need proper hold time
- Stop agitation and let phase settle
- Aqueous phase is more dense and will be on bottom
- Drain material from bottom of vessel
  - First material is aqueous phase
  - Switch to another receiver when organic phase starts to come out

Continuous Operation

Mixer-settlers

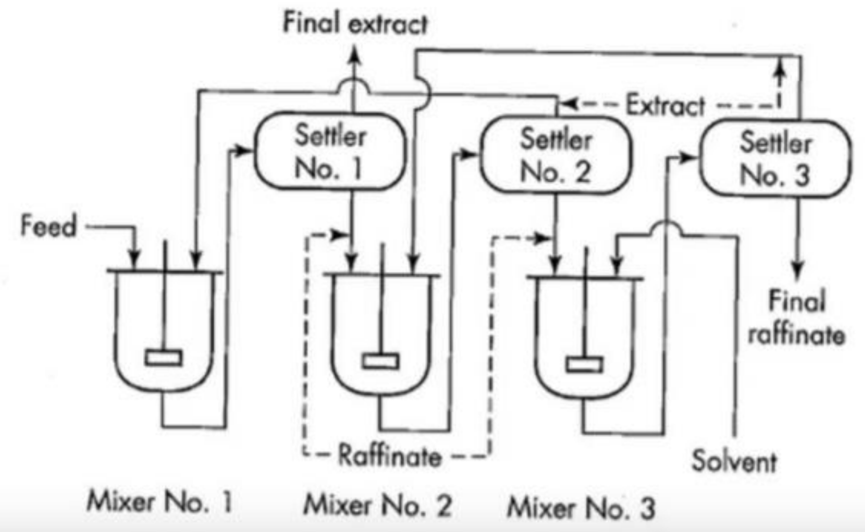


FIGURE 23.4

Think in terms of "flow in" and "flow out" each mixing and settling stage

- Continuous flow of Feed and Solvent to Mixing Vessel
- Mix thoroughly – need proper residence time
- Mixture is continuously flowing to settler
- The two phases separate in settler and exit as two streams

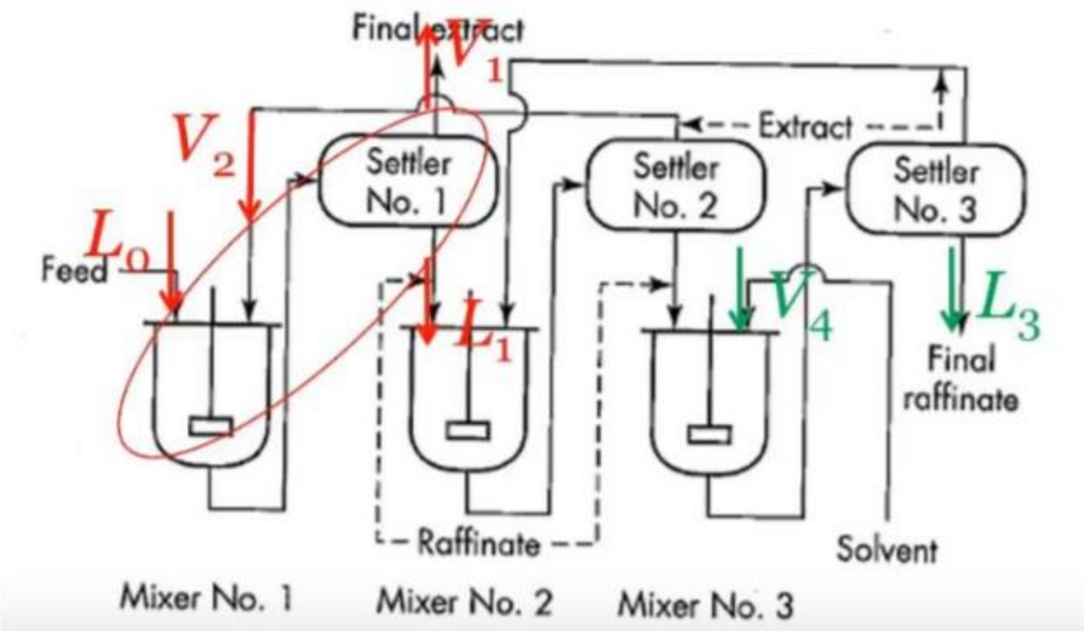


FIGURE 23.4

- Ellipse represents Stage 1
- L_0 is Feed into Stage 1
- V_2 is extract from Stage 2 feeding into Stage 1
- L_1 is raffinate flow leaving Stage 1
- V_1 is extract flow leaving Stage 1
- V_4 is solvent flow entering Stage 3, ie V_{N+1}
- L_3 is final raffinate flow exiting Stage 3, ie L_N

Packed and plate towers

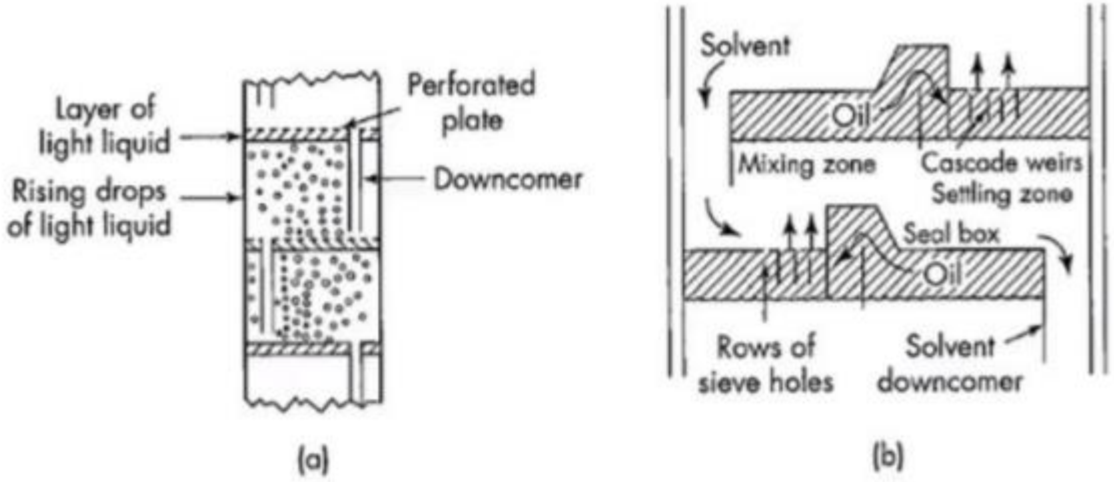


FIGURE 23.5
Perforated-plate extraction towers: (*a*) perforations in horizontal plates; (*b*) cascade weir tray with mixing and settling zones. (*After Bushell* and *Fiocco.*[4])

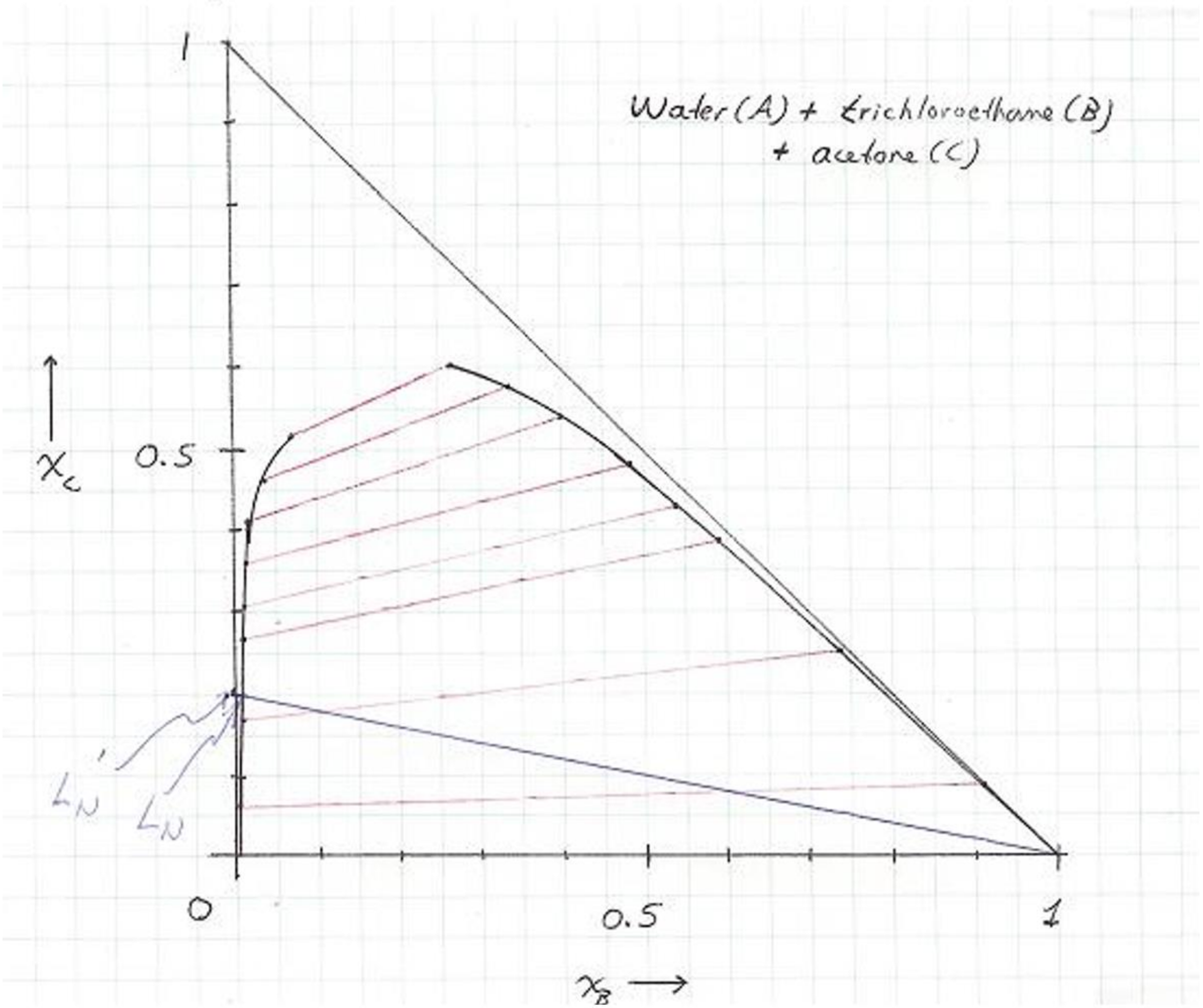
Very similar to the trays we have discussed in a Distillation Column

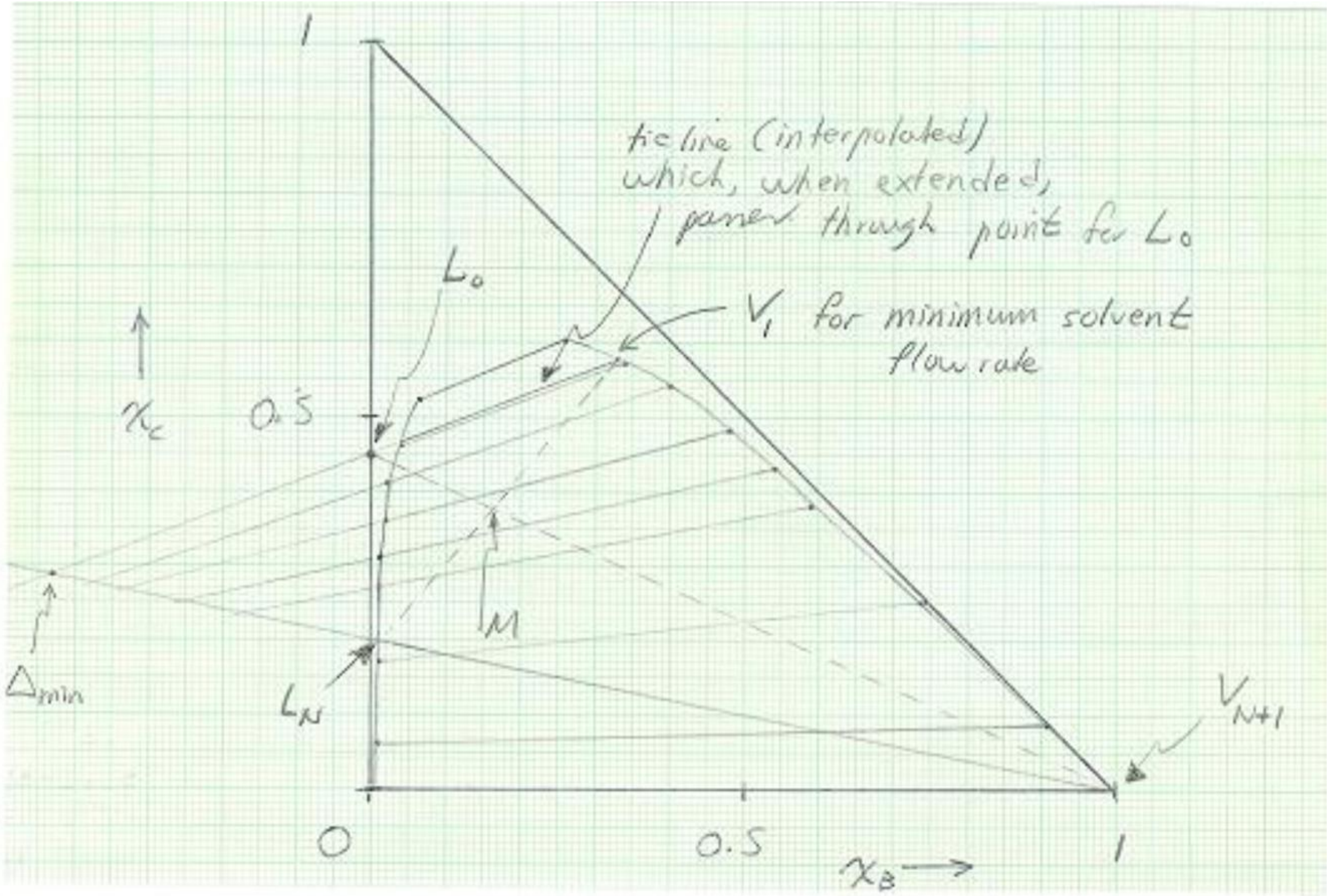
- Density difference is orders of magnitude lower than in a rectifying gas/liquid column (sp gr of 1 for aqueous and around 0.7 for organic)
- Both phases will be relatively high viscosity as opposed to the low viscosity vapor phase in distillation (velocities will be lower than in distillation column)
- Aqueous phase is more dense and will travel downward, organic phase will travel upward

- This means to location of the extract leaving the column depends on whether the extract is the aqueous phase or whether it is the organic phase

3. A 500 kg/h feed stream with composition 45 mass % acetone (solute, C) and 55 mass % water (diluent, A) is to be contacted with trichloroethane (solvent, B) in a countercurrent liquid extraction battery. Entering trichloroethane is pure. The exiting raffinate should contain 20.2 mass % acetone on a trichloroethane-free basis. Our very good friend Elroy poses the following two questions:

(a) What is the minimum flow rate of trichloroethane required to achieve the desired composition of the exiting raffinate (corresponding to an infinite number of stages)?





$$\frac{(V_{N+1})_{min}}{L_0} = \frac{x_0 - x_M}{x_M - y_{N+1}}$$

$$= \frac{0{,}45 - 0{,}38}{0{,}38 - 0} = 0{,}194$$

$$L_0 = 500$$

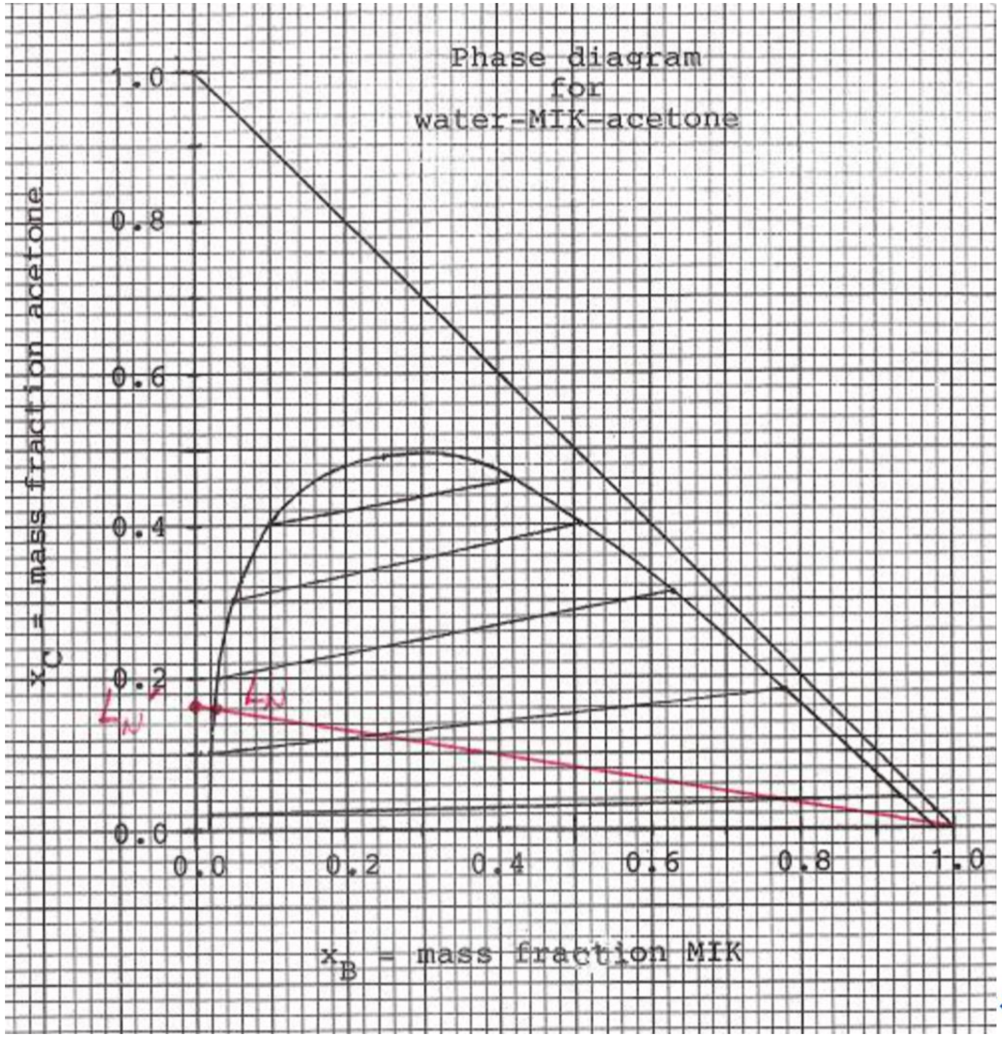
$$(V_{N+1})_{min} = 96 \text{ kg/h}$$

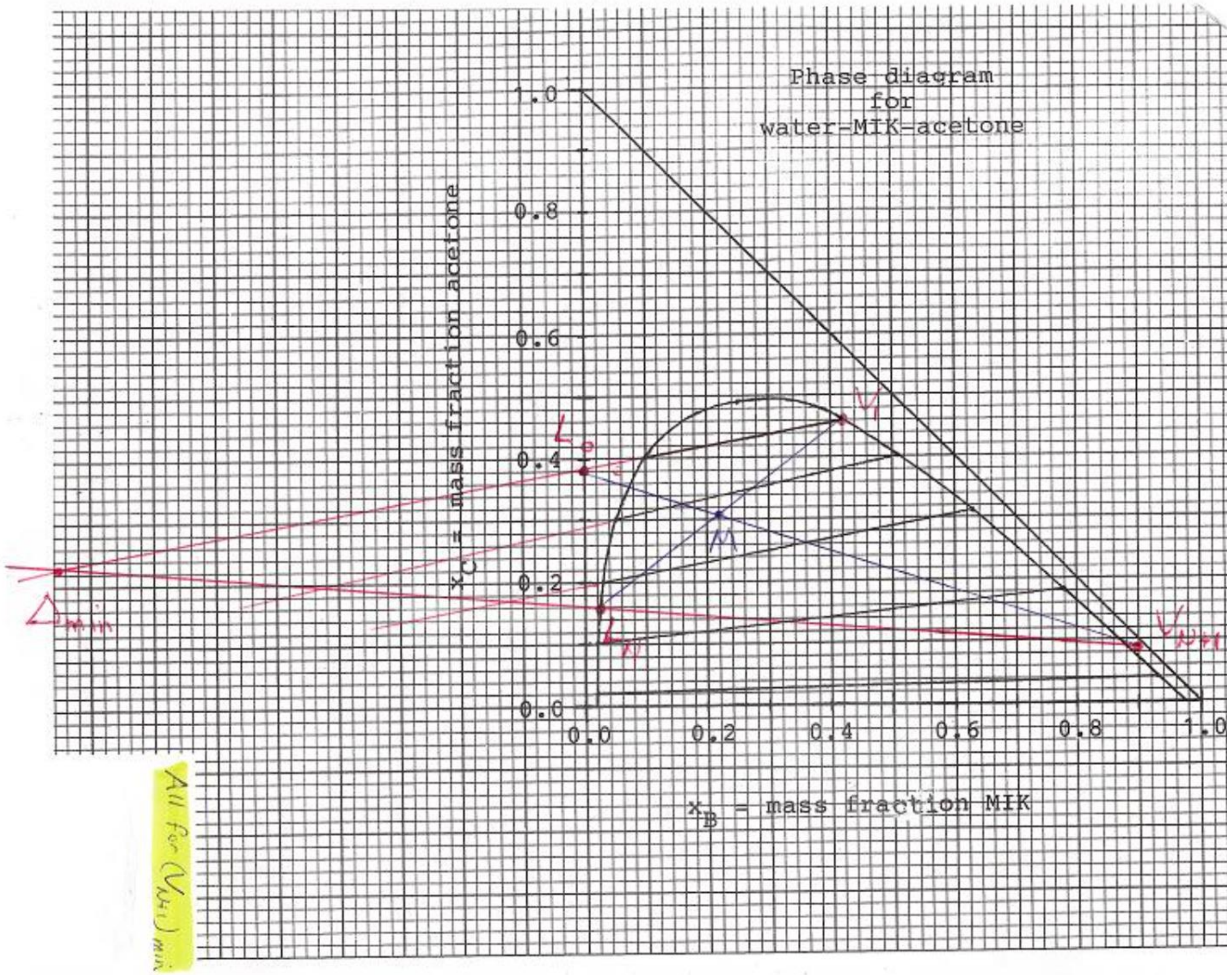
$$V_{N+1} = 1{,}3 \times (V_{N+1})_{min}$$

$$= 125$$

5. A 450 kg/h feed stream with composition 38 mass % acetone (solute, C) and 62 mass % water (diluent, A) is to be contacted countercurrently with an MIK(solvent B)-rich solution of which the precise composition is 90 mass % MIK, 9 mass % acetone and the balance water. The exiting raffinate should contain 16.5 mass % acetone (C) and 83.5 mass % water (A) on an MIK(B)-free basis.

(a) What is the minimum flow rate $(V_{N+1})_{\min}$ of the entering MIK-rich solvent stream required to achieve the desired separation (corresponding to an infinite number of stages)?





$$\frac{(V_{N+1})_{min}}{L_0} = \frac{x_0 - x_M}{x_M - y_{N+1}}$$

$$= \frac{0.38 - 0.31}{0.31 - 0.09}$$

$$= 0.33$$

$$(V_{N+1})_{min} = 450 \times 0.33 \approx 150$$

$$V_{N+1} = 1.3 \times \quad = 195$$