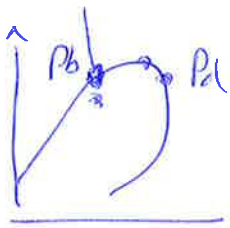
EQUILIBRIUM ~~CONCENTRATIONS~~ CALCULATIONS

5) $\sum x_i = \sum \frac{z_i}{L + K_i V} = 1$

6) $\sum y_i = \sum \frac{z_i}{\frac{L}{K_i} + V} = 1$



Equation are also valid at Pb and Pd at saturation pressures.

<u>At Pb and Pd</u>

Flash equations are valid

⊗ <u>Pb</u> - at bupple point

$L \approx 1$	$V \approx 0$	
~ 100% liquid	≈ 0 % gas	$z_i \approx x_i$

Flash equation no. 6)

$$\sum y_i = \sum \frac{z_i}{\underbrace{\frac{L}{K_i}}_{=1} + \underbrace{V}_{\approx 0}} = 1 \qquad L \approx 1 \quad V \approx 0$$

$$\sum y_i = \sum z_i \cdot K_i = 1$$

Solve by iteration:

1. Choose a value for P_b, we find the corresponding K_i-values for this pressure and a given temperature.
2. Calculate $\sum z_i \cdot K_i$. Should equal 1.
3. If $\neq 1$, we have to guess a new P_b and calculate $\sum z_i \cdot K_i$
4. Continue until $\sum z_i \cdot K_i = 1$.
   Correct P_b found.

Composition of the gas bubble is given

$$\sum y_i = \sum z_i \cdot K_i$$

If: $\sum z_i \cdot K_i > 1 \Rightarrow$ P_b is too low, inside the two-phase area

$\sum z_i \cdot K_i < 1 \Rightarrow$ P_b value is too high, outside two phase envelope

(*) At P_d : $V \approx 1 \quad L \approx 0$

$y_i \approx z_i$

Flash eq. 5) $$\sum x_i = \sum \frac{z_i}{L + K_i V} = 1$$ ($L \approx 0$, $V \approx 1$)

$$\sum x_i = \sum \frac{z_i}{K_i} = 1$$

Solve by iteration:

1. Guess a value for P_d, find correct K_i-values at P_d and T.
2. Calculate $\sum \frac{z_i}{K_i} = 1$
3. If $\neq 1$, guess a new value for P_d find new K_i-values
4. Re-calculate $\sum \frac{z_i}{K_i}$
5. Continue until $\sum \frac{z_i}{K_i} = 1$.

Composition of oil droplet:

$$\sum x_i = \sum \frac{z_i}{K_i}$$

④

If $\sum \frac{z_i}{K_i} > 1 \Rightarrow$ Pd is in two-phase area

If $\sum \frac{z_i}{K_i} < 1 \Rightarrow$ Pd is in the one-phase area

__Example__ Determining Pb

T = 180 °F

Comp.	K_i 2500 psia	2000 psia	1900 psia	1800 psia	z_i
C_1	1.8	2.4	2.5	2.6	0.3396
C_2	1.0	1.05	1.07	1.1	0.0646
C_3	0.66	0.61	~	~	0.0987
n-C_4	0.44	-	-	-	0.0434
n-C_5	0.26	~	-	-	0.0320
C_6	0.16	-	-	-	0.030
C_{7+}	0.05	-	-	-	0.3917
	$\sum z_i K_i = 0.7791$	$\sum z_i K_i$ 0.9733	1.0067	1.0407	

At Pb : $L \approx 1$ $V \approx 0$ $x_i \approx z_i$

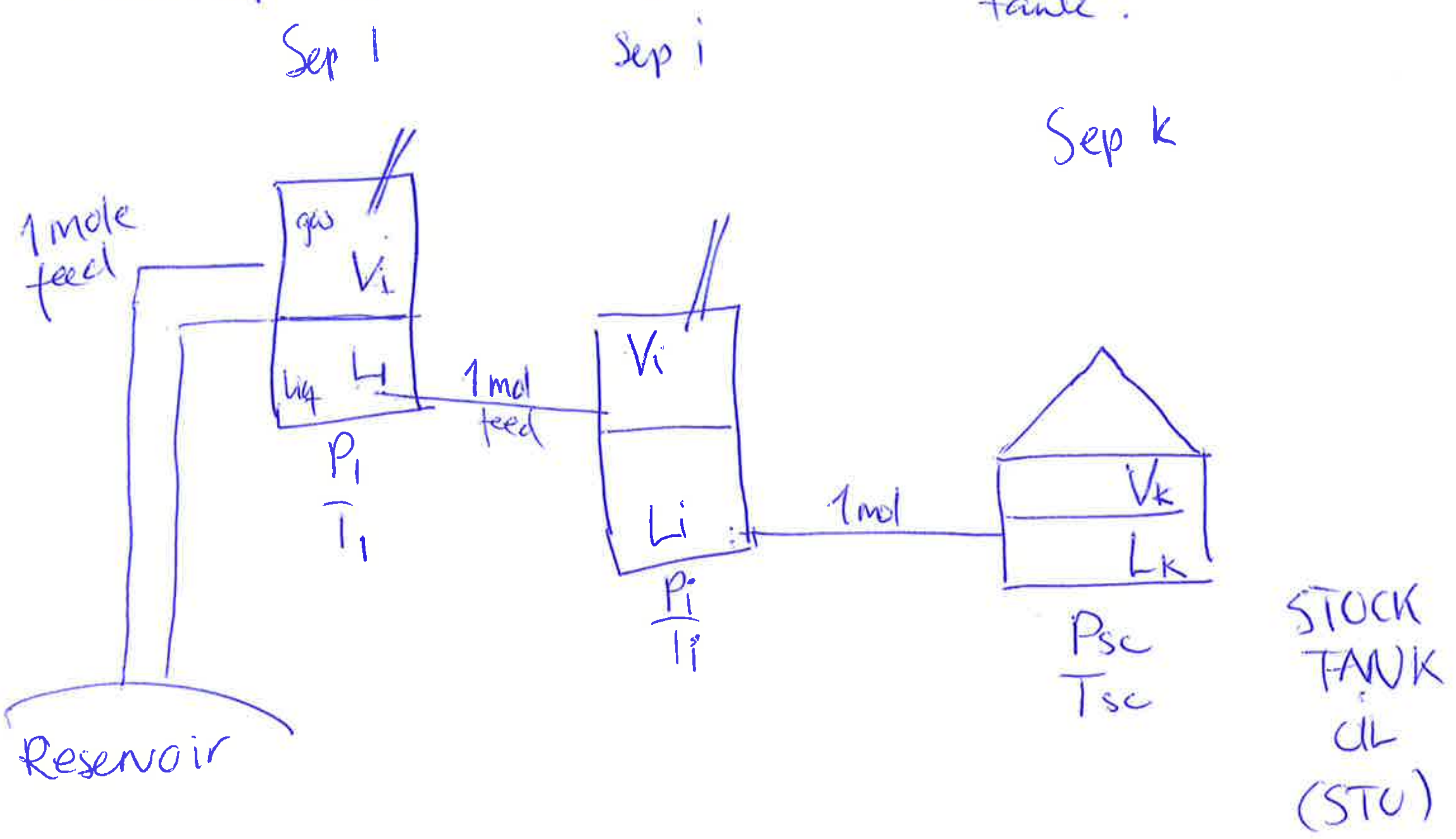
$$\sum y_i = \sum z_i K_i$$

1. Calculate $z_i K_i$ for all components
2. The pressure where $\sum z_i K_i \approx 1$
   $\Rightarrow$ corre Pb

Here : Pb ~ 1900 - 2000 psia

SEPARATOR CALCULATION

Multistep separator system : k separators, including tank.



Separator calculations

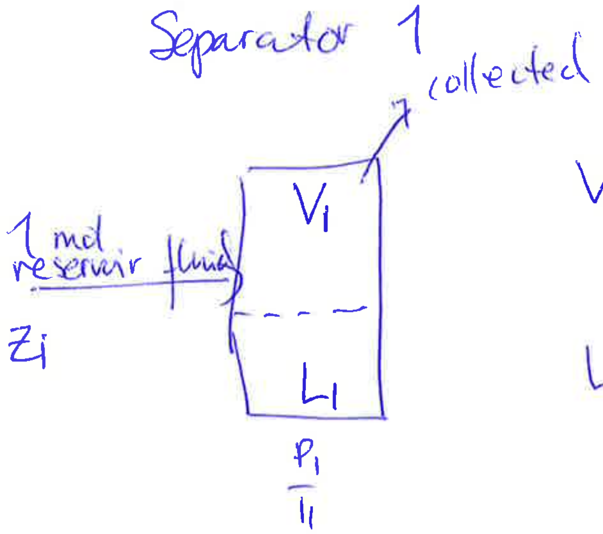
1. Determine Psep – separator pressure
   ⇒ produce maximum STO
   ⇒ Lowe GOR – gas oil ratio
2. Calculate compositions of separator gas and STO
3. Calculate GOR for each separator
   Total GOR
4. Determine Bo, formation volume factor
5. Determine IGIP and IOIP from a given reservoir unit.

Separator calculations are based on
1 mol initial fluid.

⊛ Moles STO and gas

3 - separator system.
We start with 1 mol reservoir fluid entering sep 1, where it splits in V_1 - molfraction gas and L_1 mol fraction liquid
The value of mole fraction is also the number of moles (because 1 mole initial fluid).

Separator 1



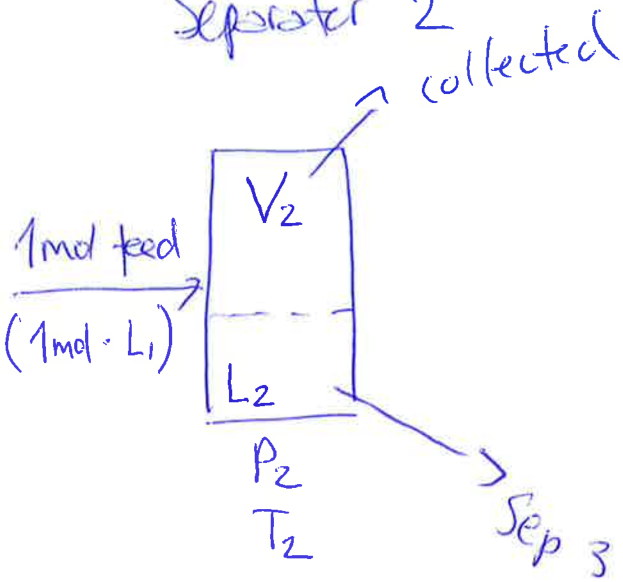
V_1 = mole fraction gas

L_1 = mole fraction liquid

A Number of moles in gas phase: $(n_g)_1 = 1\,\text{mol} \cdot V_1$
— " — oil phase: $(n_o)_1 = 1\,\text{mol} \cdot L_1$

Liquid phase (oil) is transferred to Sep 2, where it separates into gas and liquid phase.

Separator 2



V_2 = mole fraction gas

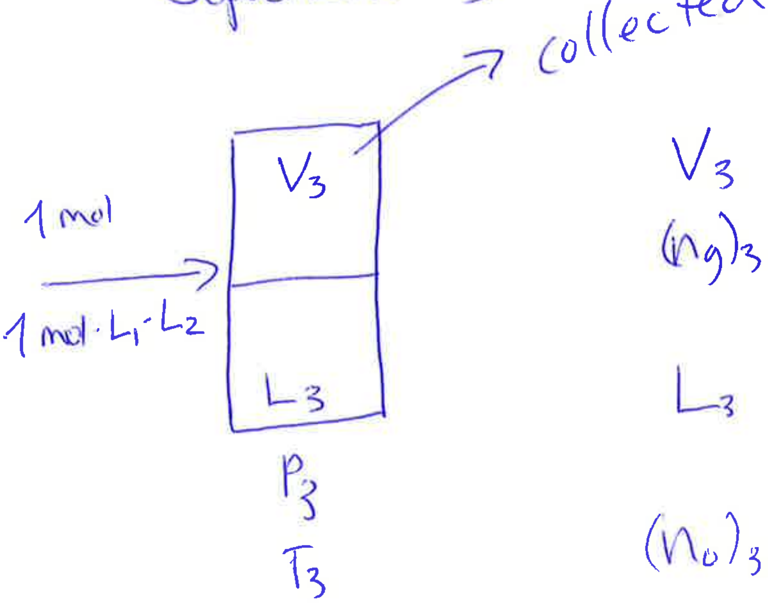
$(n_g)_2 = 1\,mol \cdot L_1 \cdot V_2$

L_2 = mole fraction oil

$(n_o)_2 = 1\,mol \cdot L_1 \cdot L_2$

Liquid phase to sep 3.

Separator 3



V_3 = mole fraction of gas

$(n_g)_3 = 1\,mol \cdot L_1 \cdot L_2 \cdot V_3$

L_3 = mole fraction of oil in sep 3.

$(n_o)_3 = 1\,mol \cdot L_1 \cdot L_2 \cdot L_3$

We have number of moles of gas and oil in each separator.

If Sep 3 is the stock tank, no oil moles removed:

$$n_{STO} = (n_o)_3 = \underset{\text{res. fluid}}{1\,\text{mol}} \cdot L_1 \cdot L_2 \cdot L_3$$

To find total number of moles of gas, we must add the number of moles from each separater

$$n_g = (n_g)_1 + (n_g)_2 + (n_g)_3$$
$$= V_1 + L_1 \cdot V_2 + L_1 \cdot L_2 \cdot V_3$$

General expressions

If we have "j" number of separaters

number of moles liquid / mole fraction of liquid entering separator j : — last separator

$$(n_o)_j = (1 \text{ mol res fluid}) \cdot L_1 \cdot L_2 \cdot L_3 \cdot \ldots \cdot L_j$$
$$= \prod_{i=1}^{j} L_i$$

If sep k is stock tank, at standard conditions,

$$\boxed{n_{STO} = \prod_{i=1}^{k} L_i}$$

For gas: Number of moles from sep $1 \to k$, mole fraction of gas:

$$(n_g)_k = 1 \text{ mol res fluid} \cdot V_1 + L_1 \cdot V_2 + L_1 L_2 V_3 + \ldots + L_1 L_2 \ldots L_{k-1} \cdot V_k$$

$$n_g = \sum_{i=1}^{k} V_i \cdot \prod_{j=0}^{i-1} L_j \qquad L_0 = 1$$

$$\boxed{n_g = 1 - n_{STO} = 1 - \prod_{i=1}^{k} L_i}$$

Sum of moles should equal 1 mol res fluid.

Volumes of separator gas and STO

- Total volume of separator gas produced:

$$V_g = \underset{\text{number of}}{\text{antall}} \text{ moles} \cdot \underset{\substack{\text{volume of 1 mole gas} \\ \text{at sc.}}}{\text{molar volume}}$$

$$V_g = n_g \cdot V_m = (1 - n_{STO}) \cdot V_m = \left(1 - \prod_{i=1}^{k} L_i\right) \cdot V_m$$

- Volume STO:

$$V_{STO} = \frac{m_{STO}}{\rho_{STO}} = \frac{n_{STO} \cdot M_{STO}}{\rho_{STO}} = \frac{\prod_{i=1}^{k} L_i \cdot M_{STO}}{\rho_{STO}}$$

m_{STO} = mass STO

ρ_{STO} = density STO

M_{STO} = molecular weight

n_{STO} = moles STO

$$\rho = \frac{m}{V}$$

$$V = \frac{m}{\rho}$$

$$n = \frac{m}{M_m}$$

$$m = n \cdot M$$

⊗ Total GOR

GOR: Ratio between produced gas and oil

Total GOR – from reservoir fluid to the tank

~~Mor~~ Given at standard conditions (SCF/SBL)

$$GOR_t = \frac{V_g}{V_{STO}} = \frac{n_g \cdot V_m \cdot \rho_{STO}}{n_{STO} \cdot M_{STO}} = \frac{\left(1 - \prod_{i=1}^{k} L_i\right) \cdot V_m \cdot \rho_{STO}}{\prod_{i=1}^{k} L_i \cdot M_{STO}}$$
