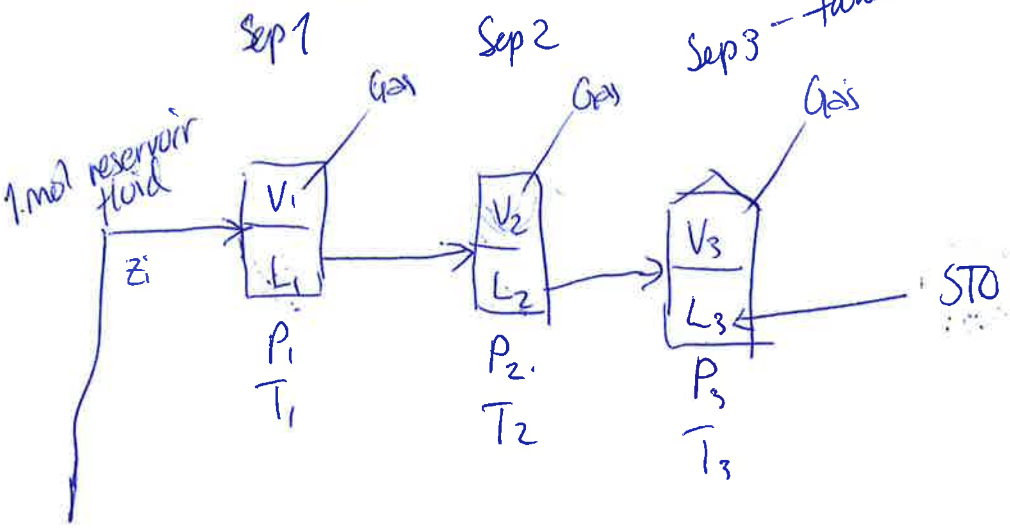
060217

GOR



$$GOR_{total} = \frac{V_{g,sc}}{V_{STO,sc}} = \frac{n_g \cdot V_m \cdot \rho_{STO}}{n_{STO} \cdot M_{STO}} = \frac{\left(1-\prod^{k} L_i\right) \cdot V_m \cdot \rho_{STO}}{\prod_{i=1}^{k} L_i \cdot M_{STO}}$$

GOR for separator i : Based on 1 mol initial fluid

$$GOR_i = \frac{(V_g)_i}{V_{STO}} = \frac{(n_g)_i \cdot V_m \cdot \rho_{STO}}{n_{STO} \cdot M_{STO}} = \frac{V_i \cdot \prod^{i-1} L_i \cdot V_m \cdot \rho_{STO}}{\prod_{i=1}^{k} L_i \cdot M_{STO}}$$

$(n_g)_i$ = number of moles gas in sep i.

$$GOR_i = \frac{V_i \cdot V_m \cdot \rho_{STO}}{\prod_{i=i}^{k} L_i \cdot M_{STO}}$$

Example: We have k separators,
k is stock tank

Find GOR for separator 4.

GOR_4 $i = 4$

$$GOR_i = \frac{V_i \cdot \left(\prod_{i=1}^{i-1} L_i\right) \cdot V_m \cdot \rho_{STO}}{\prod_{i=1}^{k} L_i \cdot M_{STO}}$$

$$GOR_4 = \frac{V_4 \cdot \cancel{L_1} \cdot \cancel{L_2} \cdot \cancel{L_3} \cdot V_m \cdot \rho_{STO}}{\cancel{L_1} \cdot \cancel{L_2} \cdot \cancel{L_3} \cdot L_4 \cdot L_5 \cdot \ldots\ldots L_k \cdot M_{STO}}$$

$$GOR_4 = \frac{V_4 \cdot V_m \cdot \rho_{STO}}{\prod_{i=4}^{k} L_i \cdot M_{STO}}$$

$$GOR_{tot} = GOR_1 + GOR_2 + \ldots + GOR_{tank}$$

Formation volume factor, B_o

B_o defined as the ratio between the reservoir volume of the oil and the stock tank volume of oil (at standard conditions)

\# If $P > P_b$, we have 1 mol reservoir oil (n_o), with molecular weight M_o

$$B_o = \frac{V_{reservoir\ oil}\ (V_o)}{V_{stock\ tank\ oil}\ (V_{STO})} = \frac{\dfrac{\overset{=1}{n_o} \cdot M_o}{\rho_o}}{\dfrac{n_{STO} \cdot M_{STO}}{\rho_{STO}}} = \frac{M_o \cdot \rho_{STO}}{\prod_{i=1}^{k} L_i \cdot M_{STO} \cdot \rho_o}$$

\# M_o = molar weight of reservoir oil
ρ_o = density of reservoir oil
M_{STO} = molar weight of STO
ρ_{STO} = density of STO
n_{STO} = number of moles STO

Units: m^3/Sm^3, bbl/SBL

Example : Calculate GOR and B_o - factor

A reservoir oil produced through a 3-step separator system.

Flash equations and calculations, based on reservoir oil composition, z_i, corresponding K_i-values

Mole fractions of liquid and gas in every separation step.

Sep 1 : $V_1 = 0.5061$ $L_1 = 0.4939$

Sep 2 : $V_2 = 0.3145$ $L_2 = 0.6855$

Sep 3 : $V_3 = 0.2222$ $L_3 = 0.7778$

B_o (single flash) - only one separation $= 2.15\ m^3/Sm^3$

$\rho_{STO} = 882\ kg/Sm^3$ $\qquad$ ρ_o reservoir oil $= 567{,}8\ kg/m^3$

$M_{STO} = 169.3\ kg/kg\,mol$ $\qquad$ $M_o = 55.9\ kg/kg\,mol$

$V_m = 23.65\ Sm^3/kg\ mol$

Start with 1 kgmol feed

$$\text{Total } GOR_t = \frac{V_g}{V_{STO}} = \frac{n_g \cdot V_m}{\frac{M_{STO}}{\rho_{STO}}} = \frac{n_g \cdot V_m}{\frac{n_{STO} \cdot M_{STO}}{\rho_{STO}}}$$

$$= \frac{\left(1 - \prod_{i=1}^{k} L_i\right) \cdot V_m \cdot \rho_{STO}}{\prod_{i=1}^{k} L_i \cdot M_{STO}} = \frac{(1 - L_1 \cdot L_2 \cdot L_3) \cdot V_m \cdot \rho_{STO}}{L_1 \cdot L_2 \cdot L_3 \cdot M_{STO}}$$

$$= \frac{(1-0.263)^{kgmol} \cdot 23.65^{Sm^3/kgmol} \cdot 882\ kg/Sm^3}{0.263\ kgmol \cdot 169.3\ kg/kgmol} = \underline{\underline{345.1\ Sm^3/Sm^3}}$$

$n_o = 1\ kgmol$ feed

$$\underline{\underline{B_o}} = \frac{V_o}{V_{STO}} = \frac{\frac{m_o}{\rho_o}}{\frac{m_{STO}}{\rho_{STO}}} = \frac{\frac{n_o \cdot M_o}{\rho_o}}{\frac{n_{STO} \cdot M_{STO}}{\rho_{STO}}} = \frac{1\ kgmol \cdot 55.9\ kg/kgmol \cdot 882\ kg/Sm^3}{169.3\ kg/kgmol \cdot 567.8\ kg/m^3 \cdot \prod_{i=1}^{k} L_i\ (0.263)}$$

$$= \cancel{1\ kgmol \cdot M_o}$$

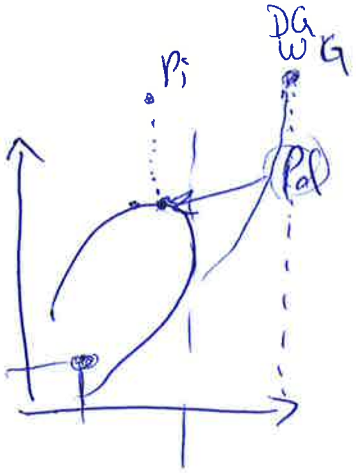
$$= \underline{\underline{1.95\ m^3/Sm^3}}$$

B_o (sep) < B_o (single flash)

Lower B_o means higher V_{STO}

$\Rightarrow$ separation process is good!

EXAM AUTUMN 2012



PROBLEM NO. 1

Given reservoir and fluid data:

Bulk volume: $10^6\ m^3$

$\phi = 0.23$

$S_{wi} = 0.15$

$P_i = 350$ bar, $(Z_g)_i = 1.107$

$P_d = 201$ bar

$T_{res} = 115\,°C$

Data from CVD - analysis:

$V_{celle} = 950\ cm^3$ at P_d and T_{res}

Pres bar	ΔV_l cm^3	% of V_d V_l	Z_g
201	0	0	0.771
170	170	6.2	0.794
136	220	8.2	0.805
102	340	10.1	0.835
68	550	7.9	0.875
34	1000	7.1	0.945

Composition of well stream in mol %

Pres bar	C1	C2	C3	C4	C5	C6	C7+	
201	75.2	7.7	4.4	3.1	2.2	2.2	5.2	100 %
170	78.3	7.7	4.3	2.8	1.9	1.6	3.4	100 %

Separation conditions:

$C_1 - C_4$: become gas

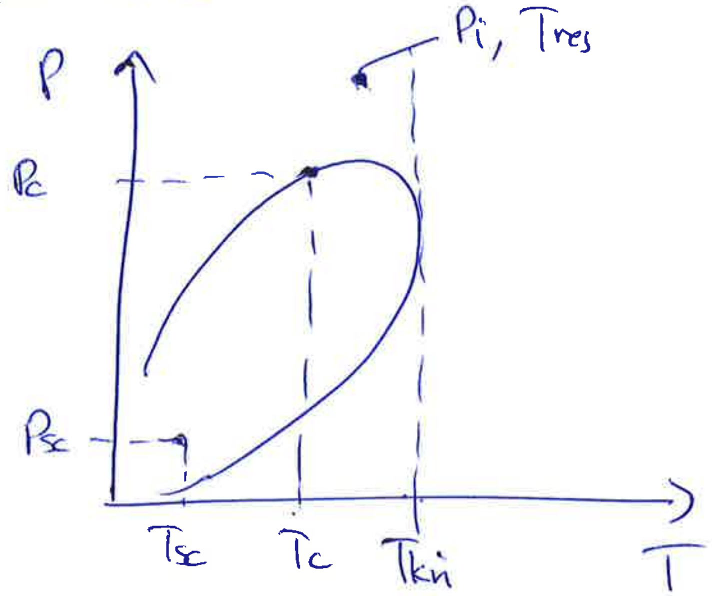
$C_5 - C_{7+}$: become STO

$\rho_{STO} = 775\ kg/m^3$ $\quad M_{STO} = \cancel{13}\ 143\ kg/kgmol$ $\quad P_i - P_d$

$\rho_{STO} = 750\ kg/m^3$ $\quad M_{STO} = 138\ kg/kgmol$ $\quad P_d - 170$ bar

a) 1. Characterize the reservoir fluid using a PT-diagram.

Gas condensate reservoir



$T_c < T_{res} < T_{kri}$

sc inside the two phase area

2. CVD-analysis:

- Used to simulate behavior of reservoir fluid in the reservoir ~~at~~ by depletion.
- Take separator gas and stock tank oil, recombined to same ~~co~~ composition as reservoir fluid at P_d, T_{res}, into a PVT-cell, at P_d and T_{res}. V_{celle} at P_d, T_{res} is noted.

- Increase cell volume to decrease pressure
  ΔV_1 , P_1

- Gas volume ΔV_1 is produced , P_R is held constant.

- Measure Z - factors
  Composition of oil and gas

- Retrograde liquid volume condensed, V_L

. Reduce pressure again to P_2

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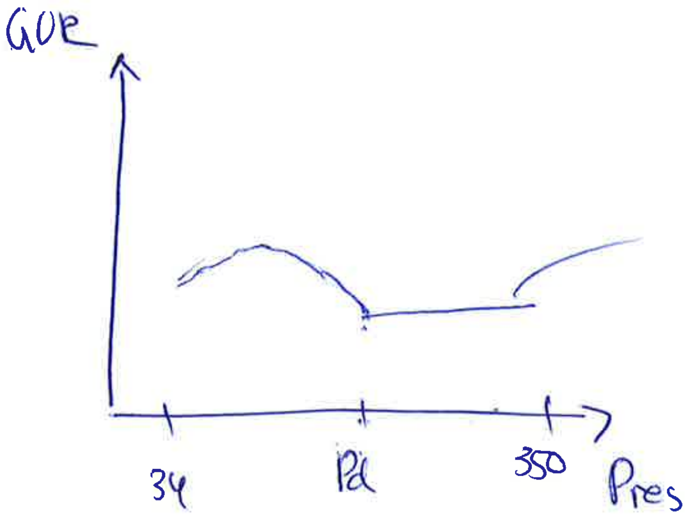
Continue until a certain pressure.

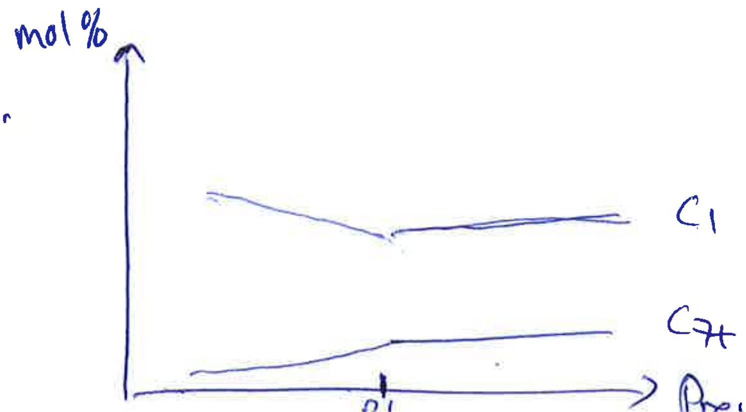
b) For P: $34 < P_{res} < 350$ bar

1.



constant GOR at $P_{res} > P_d$
reservoir fluid has constant composition.

2.



C_1
C_{7+}

3. Liquid volume