010217

GAS CONDENSATES

Produced liquid volumes $(\Delta V_o)_{i,sc}$

Calculate the liquid volume of each component in liquid phase, and add them together. (C_4, C_5, C_6, C_{7+})

We find the liquid volume (in Gal (US gallons)) by first finding the gas volumes of the components, then convert to liquid volume,

$$GPM = \frac{\text{gal (liquid)}}{1000 \text{ SCF gas}}$$ For every component.

$$C_4: \quad (V_L)_{C4} = \overbrace{a \cdot (z_{C4})_i \cdot (\Delta G_p)_i}^{\text{gas volume}} \cdot GPM_{C4}$$

- a: liquid recovery factor
- $(z_{C4})_i$: mole fraction
- $(\Delta G_p)_i$: produced wellstream
- GPM_{C4}: conversion from gas volume → liquid volume.

$$C_5: \quad (V_L)_{C5} = b \cdot (z_{C5})_i \cdot (\Delta G_p)_i \cdot GPM_{C5}$$

$$C_6: \quad (V_L)_{C6} = c \cdot (z_{C6})_i \cdot (\Delta G_p)_i \cdot GPM_{C6}$$

$$C_{7+}: \quad (V_L)_{C7+} = d \cdot (z_{C7+})_i \cdot (\Delta G_p)_i \cdot GPM_{C7+}$$

Total liquid volume $(\Delta V_o)_i$ in Gal.

$$(\Delta V_o)_i = (V_L)_{C4} + (V_L)_{C5} + (V_L)_{C6} + (V_L)_{C7+}$$

in Gal.

Convert to SBL (Barrels):

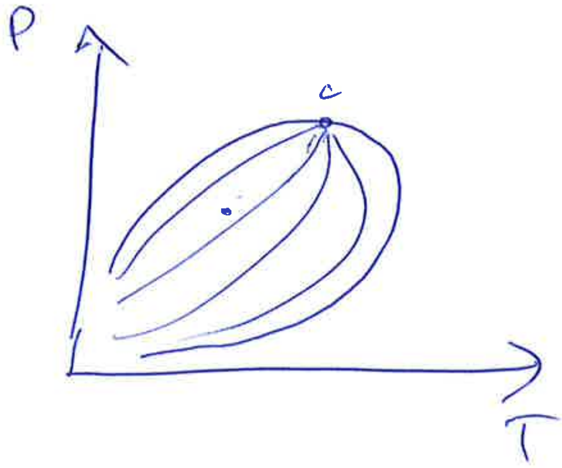
1 bbl = 42,117 Gal

⇒ GOR - gas oil ratio - in pressure interval i

$$GOR_i = \frac{(\Delta V_g)_i}{(\Delta V_o)_i}$$

Initial GOR can be found using initial reservoir fluid composition.

EQUILIBRIUM CALCULATIONS



Inside two-phase envelope gas in equilibrium with oil.

Both compisition of oil and gas, and volumes change inside the two phase envelope.

Eq. calculations to determine compositions and volumes of oil and gas at given P and T.

Reservoir fluid composition:

$$z_i = \frac{n_i}{\sum n_j} \qquad w_i = \frac{W_i}{\sum W_j}$$

$$\sum z_i = 1 \qquad \sum w_i = 1$$

Flash calculations: V mol fraction of gas

L mol fraction of liquid

can determine composition of oil and gas phase.

K-values are physical equilibrium constants determining the ratio of molefraction comp i in gas phase over mole fraction of comp i in liquid phase.

Defined by Daltons law for ideal gases and by Raoults law for ideal liquids.

The reservoir fluid is in the two-phase area, at given P and T:

For ideal gas:

$$P = \Sigma P_i \quad ; \quad P_i = y_i \cdot P$$

Daltons law

P = total pressure of the gas

P_i = partial pressure of comp i in the gas mixture

y_i = mol fraction of comp i in the gas

For an ideal liquid:

$$P_i = x_i \cdot P_{vi}$$

P_i = Partial vapor pressure for a component i in the liquid.

x_i = mole fraction of comp. i in the liquid.

P_{vi} = vapor pressure of pure component in liquid

* Two-phase area at given P and T:
  gas and oil are <u>in equilibrium</u>

$$P_i\,(\text{gas}) = P_i\,(\text{liquid})$$

$$y_i \cdot P = x_i \cdot P_{vi}$$

$$\Downarrow$$

$$\boxed{K_i = \frac{y_i}{x_i} = \frac{P_{vi}}{P}}$$

K_i - K-values.

* Ratio of mol fraction comp i in ~~...~~ gas phase over liquid phase.

⇒ K_i can be found in handbooks
in PVT-simulations.

specific for each component at specified P and T.

Flash calculations

A flash process is also called a "constant mass expansion" – CME-process

CME: A certain amount of a fluid expands and two are formed, oil and gas.
Increase volume, pressure drops below the Pd, liquid is formed.

For a given P and T in two-phase area. Basis: 1 mole feed or 1 mole initial reservoir fluid.

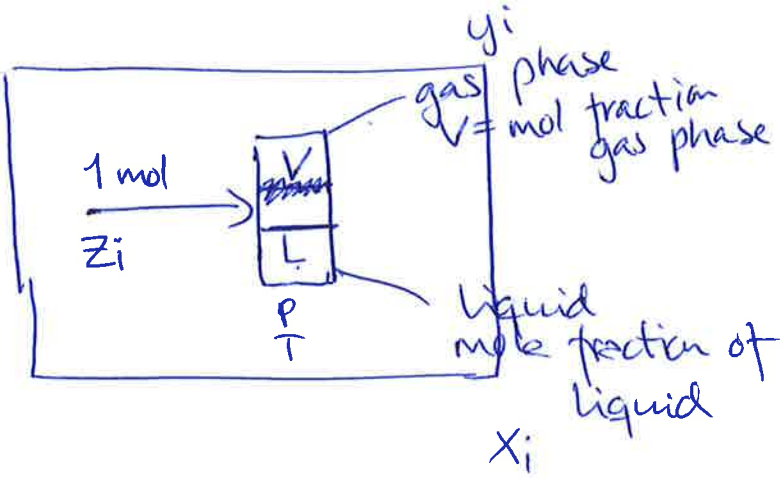
1) $V + L = 1$

2) $z_i = x_i L + y_i V$

3) $K_i = \frac{y_i}{x_i}$

4) $\sum x_i = \sum y_i = \sum z_i = 1$

V = mole fraction gas
L = mole fraction liquid
z_i = mole fraction of comp. i in reservoir fluid
x_i = mol fraction of comp. i in liquid phase
y_i = mol fraction of comp i in gas phas



Combine 2) and 3)

From 3) $y_i = K_i x_i$ and $x_i = \frac{y_i}{K_i}$

Inserted in 2): $y_i = K_i x_i$

$$z_i = x_i L + K_i x_i V$$

$$z_i = x_i (L + K_i V)$$

$$x_i = \frac{z_i}{L + K_i V}$$

y_i: $x_i = \frac{y_i}{K_i}$

$$z_i = \frac{y_i}{K_i} L + y_i V$$

$$z_i = y_i \left(\frac{L}{K_i} + V \right)$$

$$y_i = \frac{z_i}{\left(\frac{L}{K_i} + V \right)}$$

Inserted in 4):

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

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

FLASH EQUATIONS

Solving flash equations

Solve by iteration – "prøving og feiling"

Take one of the flash equations:

Pick a value for L, the $V = 1 - L$
Correct L and V values found should summarize to 1.

Newton-Raphson method to be used
Find L and V so that

$$L + V = 1$$
$$\sum x_i = 1$$
$$\sum y_i = 1$$

Newton-Raphson method

Flash eq. (5)

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

Make a function out of it; F

$$F = \sum \frac{z_i}{L + K_i V} - 1 = 0$$

$$F(L) = \sum \frac{z_i}{L + K_i V} - 1 = 0$$

$$f(x) = \frac{u(x)}{v(x)}$$

$$f'(x) = \frac{u'(x) \cdot v(x) - v'(x) \cdot u(x)}{(v(x))^2}$$

The derivative $F'(L)$:

$$F'(L) = \frac{dF}{dL} = \sum \frac{(K_i - 1) z_i}{[L + K_i(1-L)]^2}$$

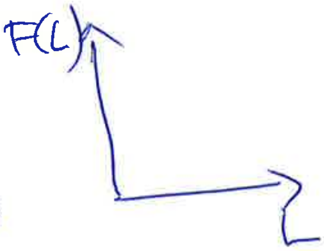
To find correct L and V, procedure:

1). Find correct Ki-values at given P and T, for each component. Z_i is known.
From handbooks...

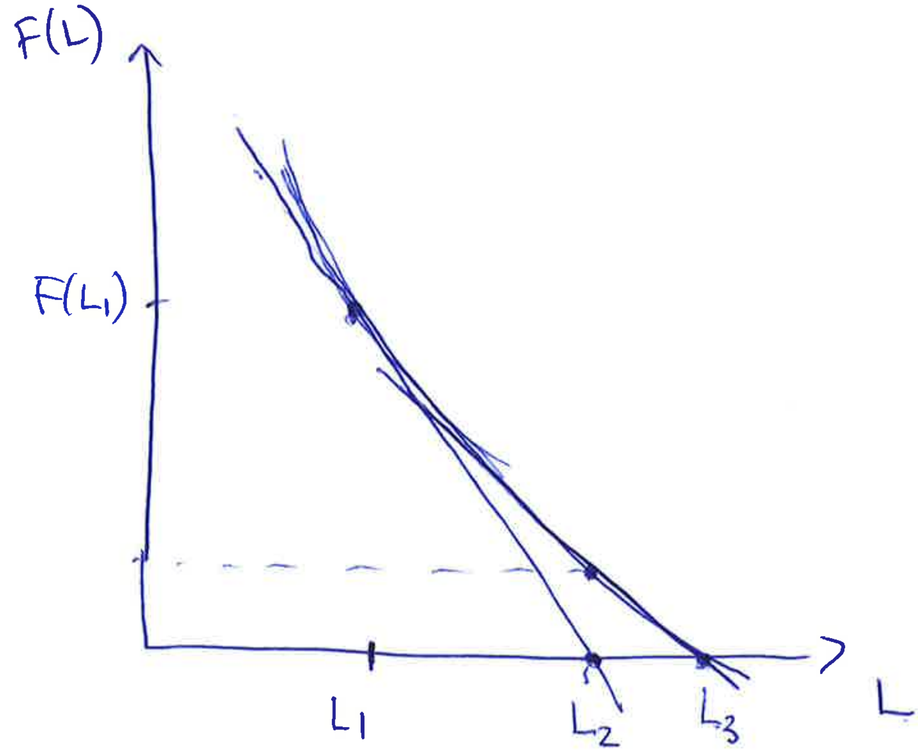
2) Assume a value for L $0 < L < 1$ L_1
$(V = 1 - L)$

3) Insert L_1 into F(L) and F'(L)
calculate F(L) and F'(L).

4) To have a point on a curve $(L_1, F(L_1))$, $F'(L_1)$
└ slope of tangent



5) Find new L_2 at $F(L) = 0$
6) Use new L_2 as new value for L
7 Repeat until $F(L) = 0$



$F(L_3) \approx 0$, Then L_3 is correct mole fraction liquid. $V = 1 - L_3$

Insert correct values of L and V into flash equations.
Can calculate compositions of oil and gas:

$$\text{oil: } \sum x_i = \sum \frac{z_i}{L + K_i V} = 1$$

$$\text{gas: } \sum y_i = \sum \frac{z_i}{\frac{L}{K_i} + V} = 1$$