BLACK-OIL PVT (Ch. 7)

Flash Calculations

- Multistage separator test

z_{wi} (Wellstream) ⟶ Sellable Volumetric Products

$\bar{g}$: surface gas

$\bar{o}$: stock-tank oil

"Black-Oil" PVT Formulation:

Uses two pseudo-components to describe the gas and oil phases @ (p, T)

INSTEAD of composition (H_2 CO_2 C_1 C_2, ... C_7 ... C_{35+})

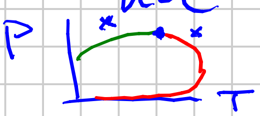
Two Pseudo-Components are:

"Surface Gas" ($\bar{g}$)

"Surface Oil" ($\bar{o}$)

} results of a specific surface Process $\underline{P}$

use volumes instead of moles

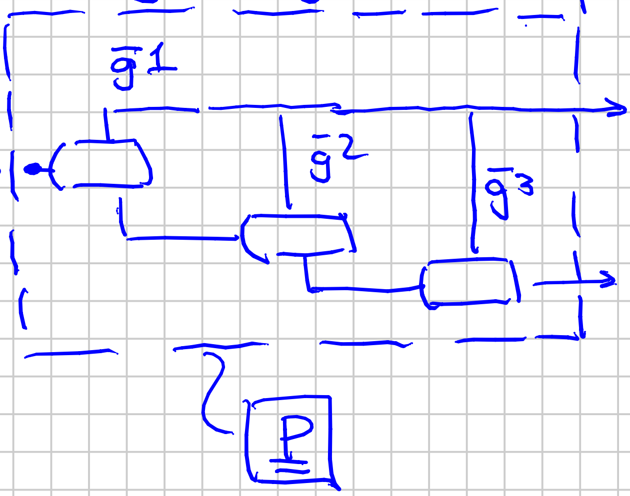


$\{z_i\}$ ⟶

Single Phase @ $(p, \underline{T})$ } g, o

$\boxed{V_p(p,T)}$

$p \in (g, o)$



$\bar{g}$ $\underline{V_{\bar{g}}}$ Sm^3 scf

$\bar{o}$ $\underline{V_{\bar{o}}}$ Sm^3 STB

Black-Oil PVT Model uses
VOLUME RATIOS to define PVT phase & volumetric behavior

$\{f_g\ y_i\ x_i\}$ $\{n, m, \rho\}$: Compositional

① Surface Volume Ratios

$$R_s \equiv \frac{V_{\bar{g}o}}{V_{\bar{o}o}}$$ for an oil phase

"Solution GOR" (R_s)

$R_s \neq \frac{1}{r_s}$ ✓

$$r_s \equiv \frac{V_{\bar{o}g}}{V_{\bar{g}g}}$$ for a gas phase

"Solution OGR" (r_s)

These quantities are the "pseudo" equivalents of x_i : R_s and y_i : r_s

$i \in \{\bar{g}, \bar{o}\}$ $M_{\bar{o}o}$ $\rho_{\bar{o}o}$

$R_s \rightarrow x_i$

$$\frac{[Sm^3]\ V_{\bar{g}o} \times \frac{1\ \text{kg-mole}}{23.68\ Sm^3}}{[Sm^3]\ V_{\bar{o}o} \times \rho_{\bar{o}o} / M_{\bar{o}o}} = \frac{n_{\bar{g}o}}{n_{\bar{o}o}} = 300 \frac{200}{(850)(23.68)}$$

R_s (300)

$= 0.03$

Ekofisk ~ 300 $Sm^3/Sm^3 = R_s$

$\rho_{\bar{o}o}$ ~ 850 kg/m^3

$M_{\bar{o}o}$ ~ 200 kg/kg-mole

$$x_{\bar g} = \frac{n_{\bar g o}}{n_{\bar g o} + n_{\bar o o}} \cdot \frac{\frac{1}{n_{\bar o o}}}{\frac{1}{n_{\bar o o}}} \qquad x_{\bar g} = \frac{\frac{n_{\bar g o}}{n_{\bar o o}}}{\frac{n_{\bar g o}}{n_{\bar o o}} + \frac{n_{\bar o o}}{n_{\bar o o}}}$$

$$= \frac{\frac{n_{\bar g o}}{n_{\bar o o}}}{\frac{n_{\bar g o}}{n_{\bar o o}} + 1} = \frac{1}{1 + \left(\frac{n_{\bar o o}}{n_{\bar g o}}\right)}$$

$$\frac{n_{\bar o o}}{n_{\bar g o}} = \frac{1}{R_s} \overline{23.68\,(\rho_{\bar o o}/M_{\bar o o})}$$

$$\boxed{x_{\bar g} = \left\{1 + \frac{1}{R_s} \cdot 23.68\left(\frac{\rho_{\bar o o}}{M_{\bar o o}}\right)\right\}^{-1}}$$

$$x_{\bar o} = 1 - x_{\bar g}$$

$R_s\ [Sm^3/Sm^3]$

$\rho\ [kg/m^3]$

$M\ [kg/kg\text{-mole}]$

$$\boxed{y_{\bar g} = \left\{1 + r_s\ 23.68\left(\frac{\rho_{\bar o g}}{M_{\bar o g}}\right)\right\}^{-1}}$$

$$y_{\bar o} = 1 - y_{\bar g}$$

Note: surface oil from oil phase $\bar{o}o$ is <u>physically</u> <u>NOT</u> going to be the surface oil from gas phase $\bar{o}g$

But in our use of Black-Oil PVT we use the assumption that

$$\bar{o}o = \bar{o}g$$

$$\rho_{\bar{o}o} \cong \rho_{\bar{o}g}$$ Used — Not particularly good

$$(M_{\bar{o}o} = M_{\bar{o}g})$$

$$\bar{g}o = \bar{g}g$$

$$\rho_{\bar{g}o} \cong \rho_{\bar{g}g}$$ Used — so-so

Volume balance → 0 (ϵ)

- Still get a mass balance error ✓

{ $\rho_{\bar{o}o} \neq \rho_{\bar{o}g}$ and $\rho_{\bar{g}o} \neq \rho_{\bar{g}g}$

Affects the calculation accuracy of phase densities }

② (FORMATION) VOLUME FACTOR "FVF" (B)

$$B_p \equiv \frac{V_p(P,T)}{V_{\bar{p}p}}$$

$$B_o = \frac{V_o(P,T)}{V_{\bar{o}o}}$$ Oil FVF

1.0x – 3

(1.2 – 2) Most Oil Fields

$$b_o \equiv \frac{1}{B_o} = \frac{V_{\bar{o}o}}{V_o(P,T)}$$

⇒ Shrikage Term

Shrinkage Factor $= 100\% \left(1 - \frac{1}{B_o}\right) = 100\% (1 - b_o)$

$B_o = 2$	$b_o = \frac{1}{2}$	$SF = 50\%$
$B_o = 1.5$	$b_o = \frac{2}{3}$	$SF = 33\%$
$B_o = 3$	$b_o = \frac{1}{3}$	$SF = 67\%$
$B_o = 1.1$	$b_o = 0.9$	$SF = 10\%$

Gas FVF : B_g

$$B_g \equiv \frac{V_g(\underline{\underline{p}}, T)}{V_{\bar{g}g}}$$

$$b_g = \frac{1}{B_g} = \frac{V_{\bar{g}g}}{V_g(p,T)}$$ = gas expansion factor

100 – 250

99% Text books assume $r_s = 0$

$$B_{gw} = \frac{p_{sc}}{T_{sc}} \cdot \frac{T Z_{(p,T)}}{p}$$

: $n_{\bar{g}g} = n_g$

$n_{\bar{o}g} = 0$

True $B_{gd} = \frac{V_g(p,T)}{V_{\bar{g}g}}$ | Gas Condensate Reservoirs

$$B_{gd} = \left[\frac{p_{sc}}{T_{sc}} \cdot \frac{TZ}{p}\right] \cdot \frac{1}{\left(1 - \frac{n_{\bar{o}g}}{n_g}\right)}$$

Use in your engineering !

Text Book Gas FVF B_{gw}

$\frac{n_{\bar{g}g}}{n_g} \sim 0.85 - 0.99$

$\left(\frac{n_{\bar{o}g}}{n_g}\right) \sim 0.15 - 0.01$

Est.

$\sim \underline{y_{6+}}$ or $\underline{y_{5+}}$

d : dry — means that the surface gas is "dried" by removing surface oil $\bar{o}g$ from the surface gas

w : wet — means that we assume all of the surface gas = reservoir gas ($n_{\bar{g}g} = n_g$)

wet surface gas because it still contains $\bar{o}g$

How to calculate oil phase and gas phase densities :

Know $\{ R_s \quad B_o \qquad r_s \quad B_{gd} \}$ @ $(\underline{\underline{p, T}})$

? $\qquad \rho_o(p,T) \qquad \rho_g(p,T)$

Need for eng. calculations involving transport or hydrodynamics influence by gravity.

$$\rho_g(p,T) = \frac{\rho_{\bar{g}} + \rho_{\bar{o}} \cdot r_s(p,T)}{B_g(p,T)}$$

$$\rho_o(p,T) = \frac{\rho_{\bar{o}} + \rho_{\bar{g}} \cdot R_s(p,T)}{B_o(p,T)}$$

Need $\boxed{\rho_{\bar{g}}}$ $\boxed{\rho_{\bar{o}}}$

~ TWO CONSTANTS ~

even though $\rho_{\bar{g}g}(p,T) \neq \rho_{\bar{g}o}(p,T)$

$\rho_{\bar{o}o}(p,T) \neq \rho_{\bar{o}g}(p,T)$