Note Title 9/24/2018

Depletion Project

- Assumptions

(1) M_{AQ} ($M_{Cole} \sim M_{Frisg}$)

(2) $q_g = \alpha$

$$J = \alpha \frac{kh}{\ln\frac{r_e}{r_w} - \frac{3}{4} + S} \cdot \lambda_x$$

Units & Flow Geometry

$$\lambda_x = \left(\frac{k_{rg}}{\mu_g B_g}\right)_{P_x}$$

SOLUTION GAS DRIVE M.B. (SGD)

- Oil $P_R \le P_b$ or $P_{Ri} \to P_b \to P_{Ra}$ (Ultimate Abandonment)

- Effect of solution gas being liberated from the RO on Oil Recovery

Good / Bad

If k_{rg}

$\lambda_g \sim 0$

Internal Gas Drive

- Driving Oil $\lambda_o > 0$

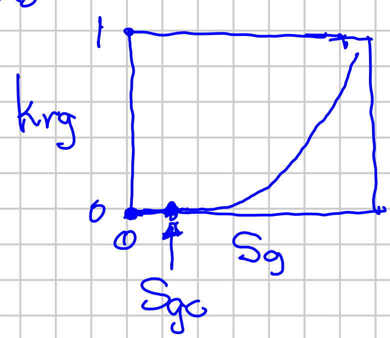
$S_o^{\,n \sim 2-4}$

$\Downarrow$

$\underbrace{k_{ro}/(\mu_o B_o)}_{\lambda_o}$

$\uparrow \downarrow$

$\mu_o B_o \uparrow$



$\downarrow$ — $P_R(N_p)$

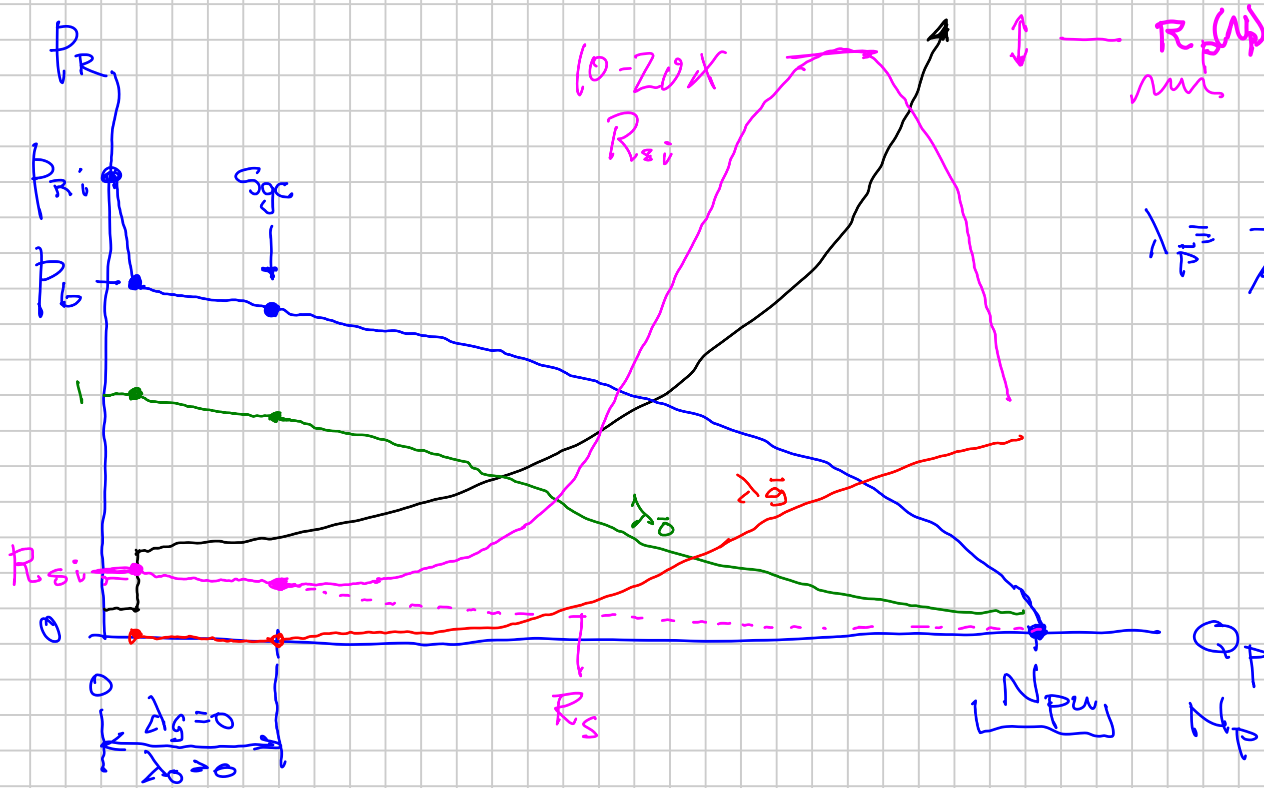
$\downarrow$ — $\lambda_o(N_p)$

$\uparrow$ — $\lambda_g(N_p)$

$\uparrow$ — $c_t(N_p)$

$\updownarrow$ — $R_p(N_p) = q_g / q_o$

$$\lambda_p = \frac{k_{rp}}{\mu_p B_p}$$



$$R_p = \frac{q_{t\bar{g}}}{q_{t\bar{o}}}$$

$$q_{t\bar{g}} = q_{tgR} / B_g = C \lambda_{\bar{g}} = C \cdot \frac{k_{rg}}{\mu_g B_g}$$

$$\underset{\uparrow}{} \qquad + q_{t\bar{o}} R_s$$

Free Gas Phase

$$q_{t\bar{o}} = q_{toR} / B_o = C \lambda_{\bar{o}} = C \frac{k_{ro}}{\mu_o B_o}$$

$$+ \cancelto{0}{q_{t\bar{o}g}}$$

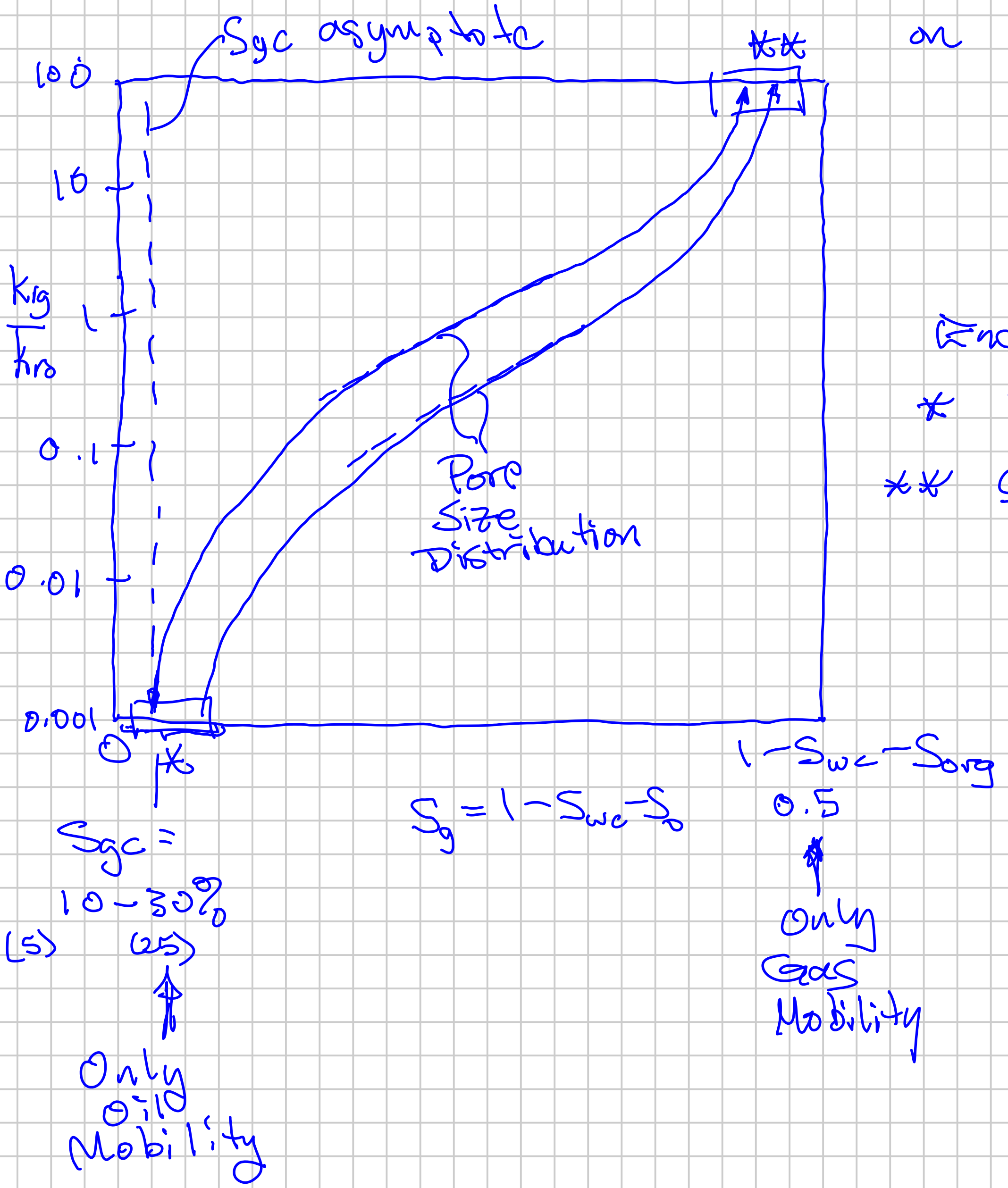
$$R_p = \frac{q_{t\bar{g}}}{q_{t\bar{o}}} = \frac{q_{t\bar{g}g} + q_{t\bar{g}o}}{q_{t\bar{o}o} + \cancelto{0}{q_{t\bar{o}g}}}$$

$$= R_s + \frac{k_{rg} / \mu_g B_g}{k_{ro} / \mu_o B_o}$$

$$= R_s(p_R) + \left(\frac{\mu_o B_o}{\mu_g B_g}\right)_{p_R} \cdot \underbrace{\frac{k_{rg}}{k_{ro}}(\underline{\underline{S_g}})}_{\text{Relative Permeability Ratio}}$$

$$\simeq R_s + \frac{\lambda_{\bar{g}}}{\lambda_{\bar{o}}}$$

GAS-OIL REL. PERM. RATIO – 1st Order Impact on $p_R(N_p)$



$\downarrow$

N_{pu}

10% 25-30%

End-Point Sat.

* S_{gc}

** S_{org}

Estimation of S_o from knowledge of p_R & N_p $p_R(N_p)$

Assume HCPV = constant

IOIP

$$V_{oi} = HCPV_i = HCPV = N \cdot B_{oi}$$

$$HCPV = NB_{oi} \quad \frac{STB}{Sm^3}$$

$$V_o\,(@\bar{p}_R) = \underbrace{(N - N_p)}_{\text{STB Remaining in Reservoir}} \cdot B_o\,(@\bar{p}_R)$$

$$S_o \equiv \frac{V_o}{HCPV} = \frac{(N - N_p)\, B_o}{N\, B_{oi}}$$

$$\boxed{S_o = \Big(1 - \underbrace{\frac{N_p}{N}}_{RF_o}\Big) \frac{B_o}{B_{oi}}} \longrightarrow \frac{k_{rg}}{k_{ro}}(S_o)$$

Saturation Relationship used in conventional SG-D M.B

- HCPV = constant
- $\left.\begin{array}{l} q_{\bar{o}} \\ N_p \end{array}\right\}$ only from Res. Oil Production

$q_{\bar{t}g} \sim 0$

SOLUTION GAS DRIVE MAT. BAL.

Note Title 9/26/2018

Ch. 7 Borthne MBO Mat. Bal.

$V_b = 1$ bbl

$V_p = V_b \phi = \phi$

$V_{HC} = V_p(1-S_w) = V_{oR} + V_{gR}$

(Modified)

Black-Oil PVT Formulation: $\rho_{\bar{g}g} = \rho_{\bar{g}o} = \text{const.}$! $\rho_{\bar{o}o} = \rho_{\bar{o}g} = \text{const.}$! ECLIPSE :

Conserve Surface Product Volumes

$(\bar{g}, \bar{o})$

G.B.: Mass conservation $\Rightarrow$ $\underbrace{\rho_{\bar{o}o} \neq \rho_{\bar{o}g} \quad \rho_{\bar{g}g} \neq \rho_{\bar{g}o}}_{f(p)}$

Vid. 30 : $\dfrac{\gamma_{\bar{o}o}}{\gamma_{\bar{o}g}} = 1 \qquad \dfrac{\gamma_{\bar{g}g}}{\gamma_{\bar{g}o}} = 1$

"$\bar{o}$" $\quad \phi\left[\underbrace{\dfrac{S_o}{B_o}}_{V_{\bar{o}o}} + \underbrace{\underbrace{\dfrac{\overset{(1-S_w-S_o)}{S_g}}{B_{gd}}}_{V_{\bar{g}g}} \cdot r_s}_{V_{\bar{o}g}}\right] = V_{\bar{o}}$ @ t, p_R

$r_s = \dfrac{V_{\bar{o}g}}{V_{\bar{g}g}}$

$= (N - N_p)$

"$\bar{g}$" $\quad \phi\left[\underbrace{\dfrac{S_o}{B_o} R_s}_{V_{\bar{g}o}} + \underbrace{\dfrac{\overset{(1-S_w-S_o)}{S_g}}{B_{gd}}}_{V_{\bar{g}g}}\right] = V_{\bar{g}}$ @ t, p_R

$= (G - G_p)$

p_{Ri} S_{oi}, S_{gi} $\Rightarrow$ $V_{\bar{o}} = N = \underset{6\cdot 10^9 \text{ STB}}{N_o} + \underset{0}{N_g}$

p_{Ri} S_{oi}, S_{gi} $V_g = G = G_o + G_g$

$7 \cdot 10^{12}$ scf

$S_g = (1-S_w) - S_o$ $[r_s \equiv R_v]$

SPE walsh/ E100

$$\frac{\phi\left[\frac{S_o}{B_o} + \frac{(1-S_w)-S_o}{B_{gd}} \cdot r_s\right]}{\phi\frac{(1-S_w)}{B_{oi}}} = \frac{N - N_p}{N}$$

For $S_{oi} = 1 - S_w$ $(S_{gi} = 0)$: "Initial Res. Oil"

$$\frac{1}{(1-S_w)}\frac{B_{oi}}{B_o} S_o + \frac{r_s}{B_{gd}} B_{oi} - \frac{S_o}{(1-S_w)}\frac{r_s}{B_{gd}} B_{oi} = 1 - \frac{N_p}{N}$$

$$S_o = (1-S_w)\left[\frac{\left(1-\frac{N_p}{N}\right) - \frac{r_s}{B_{gd}} B_{oi}}{\frac{B_{oi}}{B_o} - \frac{r_s}{B_{gd}} B_{oi}}\right] \frac{B_o B_{gd}}{B_o B_{gd}}$$

$\underset{\sim\sim\sim}{r_s = 0}$

$$S_o = (1-S_w)\left(1 - \underbrace{\frac{N_p}{N}}_{RF_o}\right)\frac{B_o}{B_{oi}}$$

Monday

Walsh: Eq. 2

$$S_o = (1-S_w)\left[\frac{\left(1-\frac{N_p}{N}\right)B_o B_{gd} - r_s B_o B_{oi}}{B_{oi}\left(B_{gd}-r_s B_o\right)}\right]$$

Need to deal with the surface gas also.

Using the approximate reservoir rate equations for $\bar{g}$ and $\bar{o}$:

$$q_{gR} = C \cdot \int_{p_{wf}}^{p_R} \frac{k_{rg}}{\mu_g}\, dp$$

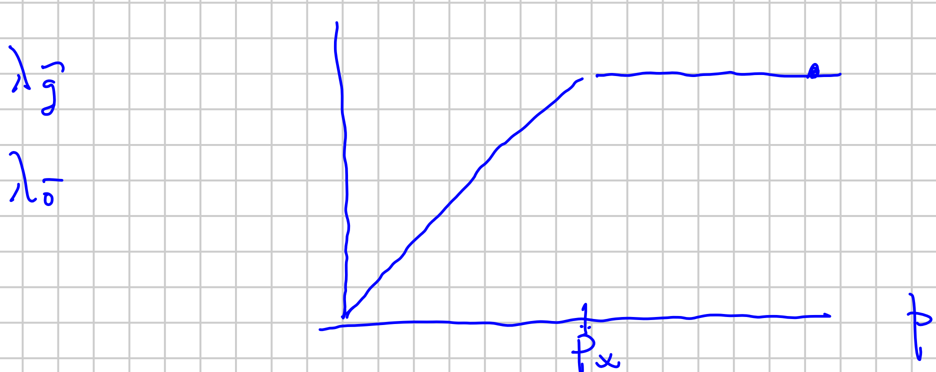
$$q_{\bar{g}g} = q_{gR} / B_{gd}$$

$$q_{\bar{g}g} = C \cdot \int_{p_{wf}}^{p_R} \underbrace{\frac{k_{rg}}{\mu_g B_{gd}}}_{\lambda_{\bar{g}}}\, dp \simeq \overline{\left(\frac{k_{rg}}{\mu_g B_{gd}}\right)}_{p_R} \cdot (p_R - p_{wf})$$

Surface Oil Product

$$q_{\bar{o}o} = C \cdot \int_{p_{wf}}^{p_R} \underbrace{\frac{k_{ro}}{\mu_o B_o}}_{\lambda_{\bar{o}}}\, dp \simeq \overline{\left(\frac{k_{ro}}{\mu_o B_o}\right)}_{p_R} (p_R - p_{wf})$$

All SGD M.B. eqs. (Tarner, Standing, Walsh, Borthne)



Conventional BOPVT

$p_{wf} > p_x \Rightarrow$ OK Approx.

$$R_p = R_s + \frac{k_{rg}}{k_{ro}} \frac{\mu_o B_o}{\mu_g B_g}$$

Modified BO : $r_s > 0$

$$R_p = \frac{q_{\bar{g}}}{q_{\bar{o}}} = \frac{q_{\bar{g}g} + q_{\bar{g}o}}{q_{\bar{o}o} + q_{\bar{o}g}}$$

$$R_s = \frac{q_{\bar{g}o}}{q_{\bar{o}o}} \qquad r_s = \frac{q_{\bar{o}g}}{q_{\bar{g}g}}$$

$$R_p = \frac{q_{\bar{g}g} + R_s\, q_{\bar{o}o}}{q_{\bar{o}o} + q_{\bar{g}g}\, r_s}$$

$$q_{\bar{g}g} \simeq C \left(\frac{k_{rg}}{\mu_g B_{gd}}\right)_{p_R} (p_R - p_{wf})$$

$$q_{\bar{o}o} \simeq C \left(\frac{k_{ro}}{\mu_o B_o}\right)_{p_R} (p_R - p_{wf})$$

$$R_p = \frac{\left[\frac{k_{rg}}{k_{ro}} \frac{\mu_o B_o}{\mu_g B_{gd}} + R_s\right]}{\left[1 + \frac{k_{rg}}{k_{ro}} \frac{\mu_o B_o}{\mu_g B_{gd}} \cdot r_s\right]} = \frac{[E_g]}{[E_o]}$$

< >

< Derive $\frac{k_{rg}}{k_{ro}} = f\left(R_p \mid PVT(p)\right)$ >