

<u>Property / Quantity</u>	<u>BLACK-OIL PVT</u>	<u>COMPRESSIONAL</u>
Number Components	2 (\bar{g}, \bar{o})	N (> 5-8-20+)
Material Balance	$V_{\bar{g}}, V_{\bar{o}}$ (not m, n)	$\underline{n}_g \neq \underline{n}_o$
Model	4 Tables = $f(p, T)$	(*) $K_i(p, T, p_k)$
	Oil Phase ($S \neq u$) 2	Eqs / Tables
	Gas Phase ($S \neq u$) 2	$\Rightarrow n_g, n_o$ y_i, x_i
	$\int_{\bar{g}}, \int_{\bar{o}}$ (1)	$\left. \begin{matrix} p_o(x_i, p, T) \\ Z_g(y_i, p, T) \end{matrix} \right\}$
		(*) EOS
		Cubic (SRK/PR)
		$\mu_{gi}(p, T, y_i, p_g)$
		=
		$\mu_{oi}(p, T, x_i, p_o)$
		Theoretical R rigorous
		$\int_{\bar{g}}, \int_{\bar{o}} = \frac{M_o}{p_o}$
		$K_i = \frac{y_i}{x_i}$
		n_g, n_o, m_g, m_o V_g, V_o
overall (total) Known compositions	$R = \frac{V_{\bar{g}}}{V_{\bar{o}}} \mid r = \frac{V_{\bar{o}}}{V_{\bar{g}}}$	Z_i
By material balance	Total Gas-oil	
	$V_{\bar{g}} = V_{\bar{g}g} + V_{\bar{g}o}$	
	$V_{\bar{o}} = V_{\bar{o}g} + V_{\bar{o}o}$	
<u>Gas Phase</u> Composition	$R_s(p, T) = \frac{V_{\bar{o}g}}{V_{\bar{g}g}}$	$y_i(K_i(p, T))$
oil Phase Composition	$R_s(p, T) = \frac{V_{\bar{g}o}}{V_{\bar{o}o}}$	$x_i(K_i(p, T))$

Gas Phase Density

$$\rho_g(p, T) = \frac{\rho_g + \rho_o R_s(p, T)}{B_{gd}(p, T)}$$

$$\rho_g^{EOS} = \frac{V_g}{n_g}$$

Oil Phase Density

$$\rho_o(p, T) = \frac{\rho_o + \rho_g R_s(p, T)}{B_o(p, T)}$$

$$\rho_o^{EOS} = \frac{V_o}{n_o}$$

$$\rho = \frac{M(y_i \text{ or } x_i)}{V^{EOS}}$$

Phase Amounts

$$V_t = V_g + V_o \text{ known}$$

$$V_o = 1 \text{ STB}$$

Given Basis: "R"

$$V_g = f(\text{Basis}, p, T)$$

B_{gd}, R_s

$$V_o = f(\text{Basis}, p, T)$$

B_o, R_s

Eqns. 7.38-7.39

$$\Rightarrow \frac{V_o}{V_g + V_o}$$

$$\begin{matrix} (f_g & f_o) & RR \\ n_g & n_o & EOS \\ V_g = n_g & \frac{M_g}{\rho_g} \\ V_o = n_o & \frac{M_o}{\rho_o} \end{matrix}$$

Phase Viscosities

Table lookup
directly
 $\mu(p, T)$

Compositional
Correlation
eg. LBC (Ch. 3)

$$\mu(\underbrace{u_i}_{y_i}, \underbrace{p_i}_{x_i}, T, \underbrace{\theta_i}_{T_o, p_o, M_o})$$

V_{ci}

$$\mu \propto \rho^n$$

The liquid and vapor rates in the tubing or reservoir are given by

$$q_o = q_{\bar{o}} F_{\bar{o}o} B_o$$

$q_o(p, T)$

$q_{\bar{o}} = \text{surface oil volume (STB)}$

$$\text{and } q_g = q_{\bar{g}} (R_p - R_s F_{\bar{o}o}) B_{gd}, \dots \dots \dots (7.37)$$

$q_g(p, T)$

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

where $F_{\bar{o}o}$ = fraction of total surface oil coming from the flowing liquid (Eq. 7.6)

$$F_{\bar{o}o} = \frac{q_{\bar{o}o}}{q_{\bar{o}}} = \frac{1 - R_p r_s}{1 - R_s r_s} \dots \dots \dots (7.38)$$

$$F_{\bar{o}o} = \frac{q_{\bar{o}o}}{q_{\bar{o}}}$$

PVT properties used to calculate q_o and q_g are evaluated at the pressure and temperature in the reservoir or the production tubing.

Evaluation of the integrals in Eq. 7.36 is not straightforward. In fact, using only one of the two rate equations would be logical, depending on which phase was dominant. For a predominantly oil system, the oil rate in Eq. 7.36 should be used for $q_{\bar{o}}$ and the gas rate could be calculated from the total producing GOR. Likewise, for a predominantly gas system, the gas rate in Eq. 7.36 should be used for $q_{\bar{g}}$ and the oil rate can be calculated from the total producing GOR. Producing GOR would be available from material-balance calculations.

The volumetric fraction of reservoir fluids flowing as an oil phase at wellbore conditions is

$$\frac{q_o}{q_o + q_g} = \frac{q_{\bar{o}} B_o}{q_{\bar{o}} B_o + q_{\bar{g}} B_{gd}} = \left[1 + \frac{(R_p - R_s F_{\bar{o}o}) B_{gd}}{5.615 F_{\bar{o}o} B_o} \right]^{-1} \dots \dots \dots (7.39)$$

$$= \frac{V_o}{V_g + V_o}$$

where B_o , R_s , B_{gd} , and r_s are evaluated at the wellbore flowing pressure (p, T) of interest.



$$B_o(p, T) \quad R_s(p, T) \quad \left| \quad \frac{B_{gd}(p, T)}{r_s(p, T)} \right.$$

$$R < R_s(p, T) \Rightarrow \text{Only Oil Phase (O)}$$

$$R > \frac{1}{r_s(p, T)} \Rightarrow \text{Only Gas Phase (G)}$$

$$\frac{1}{r_s(p, T)} \geq R \geq R_s(p, T) \Rightarrow \text{Two-Phase Gas+Oil (S)}$$

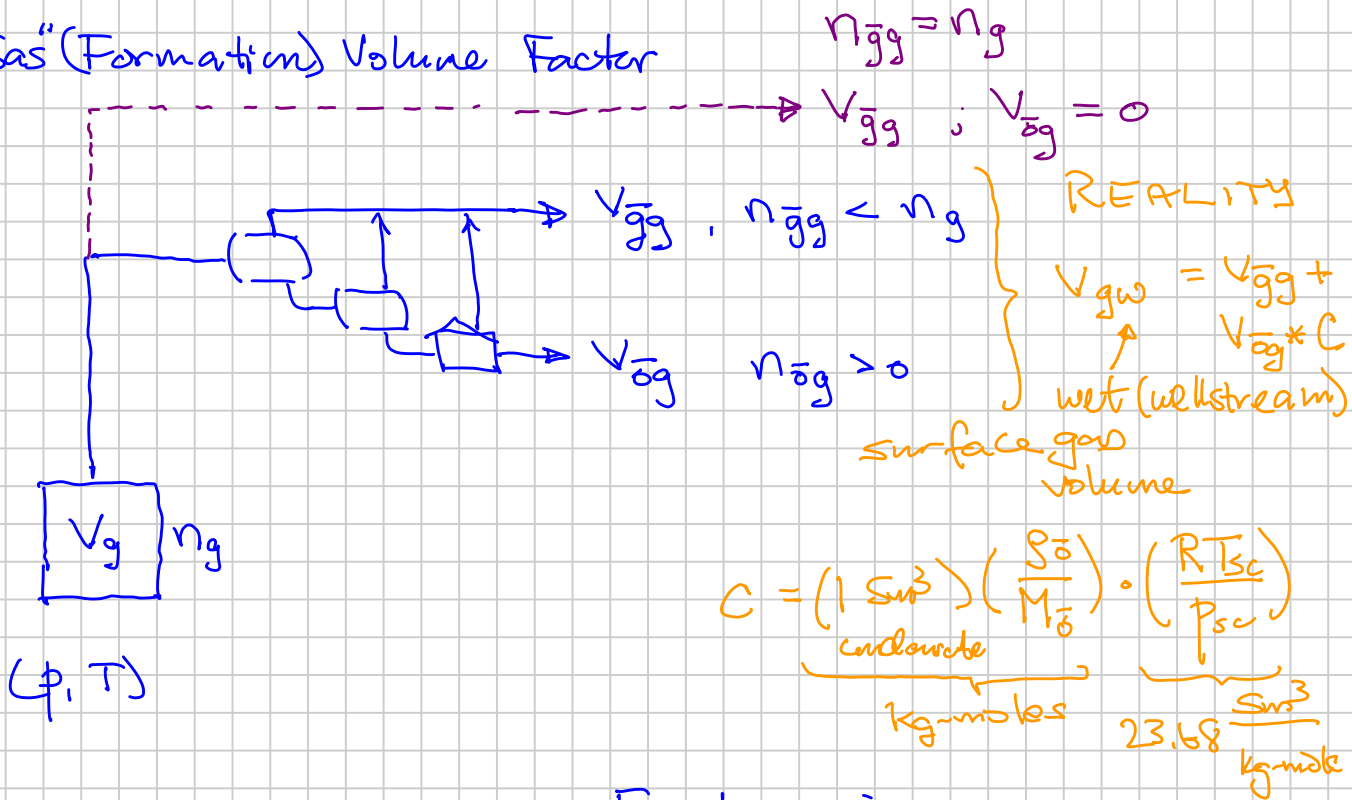
which table to get B_o R_s B_{gd} r_s
 μ_o μ_g

$$R = \frac{q_g}{q_o} \neq \frac{q_g(p, T)}{q_o(p, T)}$$

$$P_R > P_b$$

$$P_{wf} > P_b$$

"Dried Gas" (Formation) Volume Factor



Engineering:

Need convert surface produced volumes to reservoir volume

OLD SCHOOL

$$n_{gg} = n_g$$

$$B_g = \frac{V_g(p, T)}{V_{gg}} = \frac{P_{sc} T Z_g}{T_{sc} P}$$

100's of books of notes & ...

$$= B_{gw} = \text{wet gas FVF}$$

$$pV = nRTZ_g$$

to use "old school" gas equations with a production term that

is "wet gas" - i.e.

$$\boxed{\bar{g}_w} = \bar{g}_g + (\bar{o}_g) \text{Converted}$$

- Gas Material Balance
- Gas Rate Eqs.
- Pipeflow Eqs for Gas

For reservoir simulation (and some other more modern) calculations,

$$q_{\bar{g}} = \underbrace{q_{\bar{g}g}} + \underbrace{q_{\bar{g}o}}$$

$$q_o = \underbrace{q_{oog}} + \underbrace{q_{og}}$$

$$B_{gd} = \frac{V_g}{V_{\bar{g}g}} \quad \frac{\text{gas phase volume}}{\text{surface gas volume from that gas phase}}$$

$$B_{gd} = \underbrace{\left(\frac{p_{sc}}{T_{sc}} \cdot \frac{T Z_g}{p} \right)}_{B_{gw}} \cdot \frac{1}{\left(1 - \frac{\sum \bar{o}_g}{\sum g} \right)}$$

$$\underbrace{\qquad\qquad\qquad}_{B_{gw}} \qquad\qquad\qquad \frac{1}{\left(1 - \frac{\sum \bar{o}_g}{\sum g} \right)}$$

$$\underbrace{\qquad\qquad\qquad}_{B_{gw}} \qquad\qquad\qquad \frac{1}{\left(1 - \frac{\sum \bar{o}_g}{\sum g} \right)}$$