Note Title 2013-08-29

Q & A's

VOLUME FACTORS (RATIO) $(B$ or $b \equiv 1/B)$

FORMATION VOLUME FACTOR, FVF

"Reservoir Rock" (pores)

Generic Definition: VF

$$B_p \equiv \frac{V_p(p,T)}{V_{\bar{p}}(p_{sc},T_{sc})} \quad ; \; p \in \{g, o, w\}$$

@ S.C.

B_g

B_o

B_w

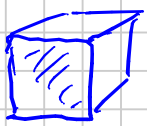
p_{sc}: 1 atm, 14.696 psi, 1.0135 bar, $1.0135 \cdot 10^5$ Pa

&

T_{sc}: 60°F, 15.56°C

[Standard Conditions] (Surface) "Ambient" "Stock Tank"

"Process"



$\} V_p(p,T)$

@ p, T

b "Shrinkage Factor" (Sometimes used, not good "term")

Inverse Volume Factor

$$B_{oi} = 1.5 \frac{m^3}{Sm^3} \quad \frac{RB}{STB}$$

std m³ — RB: reservoir — STB: stock-tank

Statfjord

$b_{oi} = 0.667$ STB/RB Sm^3/m^3

Oil "Shrinkage" of $V_{oi} \rightarrow V_{\bar{o}}$

% reduction in volume from (p,T) to (p_{sc}, T_{sc})

Shrinkage: $1 - b = 33.3\%$

Shrinkage of oil @ (p,T) to lesser oil (STO) @ STC (p_{sc}, T_{sc}) is due to the "loss of" mass at STC becoming surface gas.

$\Rightarrow B_o > 1$ RB/STB

$B_{oi} \sim 1^{+} - 4$
$(1.2 - 2.5)$

~

GAS FVF B_g (b_g)

Assumption: (1) Ideal Gas Law $pV = nRT$

absolute psia kPa(a) bar(a) (for p)

absolute units K °R (for T)

Assumption

(2) $V_g(p,T)$: n_g

$V_{\bar{g}}(p_{sc}, T_{sc})$: $n_{\bar{g}}$ } =

$V_g = \frac{n_g R T_R}{p}$

$V_{\bar{g}} = \frac{n_{\bar{g}} R T_{sc}}{p_{sc}}$

"$F_g(p)$" $= \frac{n_{\bar{g}}}{n_g}$

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

Derive $B_g = \dfrac{V_g(p,T)}{V_g(p_{sc},T_{sc})} = \dfrac{n_g RT/p}{n_g R T_{sc}/p_{sc}} = \dfrac{p_{sc}}{T_{sc}} \cdot \dfrac{T}{p}$

Example Calculations:

$p_{Ri} = 1500$ psia (Initial Reservoir Pressure)

$T_R = 160$ °F (Reservoir Temperature)

$p_{sc} = 1$ atm $= 14.696$ psia

$T_{sc} = 60$ °F

Determine B_{gi} & b_{gi}

units B_g	b_g
m^3/Sm^3	Sm^3/m^3
ft^3/scf	scf/ft^3
RB/Mscf	Mscf/RB

$14.50377 \dfrac{psi}{bar}$

$T_{°C} = (T_{°F} - 32)/1.8$

$T_K = T_{°C} + 273.15$ $\qquad$ $T_R = T_F + 459.67$

$35.31 \dfrac{ft^3}{m^3}$ $\qquad$ $5.6146\ ft^3/bbl$

Mscf $= 10^3$ scf

SI: (bar, °C)

$\dfrac{p_{sc}}{T_{sc}} = \dfrac{1.0135 \text{ bara}}{15.56 + 273.15} =$

0.003510

$B_g \ll 1$

$B_g = 0.00351 \dfrac{T(K)}{p(bara)}$

$\left[\dfrac{m^3}{Sm^3}\right]$ $\quad 0.0117$

$b_g = 85.6 \dfrac{Sm^3}{m^3}$

Field: (psia, °F)

$\dfrac{p_{sc}}{T_{sc}} = \dfrac{14.696}{60 + 459.67} = 0.02828$

$B_g = 0.02828 \dfrac{T(°R)}{p(psia)}$

$\left[\dfrac{ft^3}{scf}\right]$ $\quad 0.0117$

$b_g = 85.6 \dfrac{scf}{ft^3}$

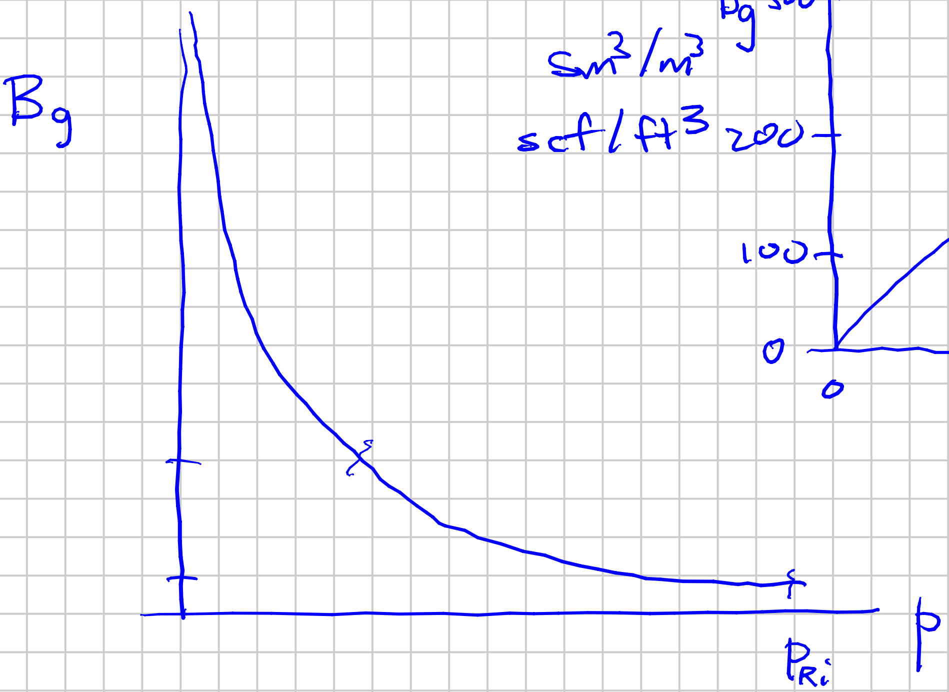
$b_g \gg 1$

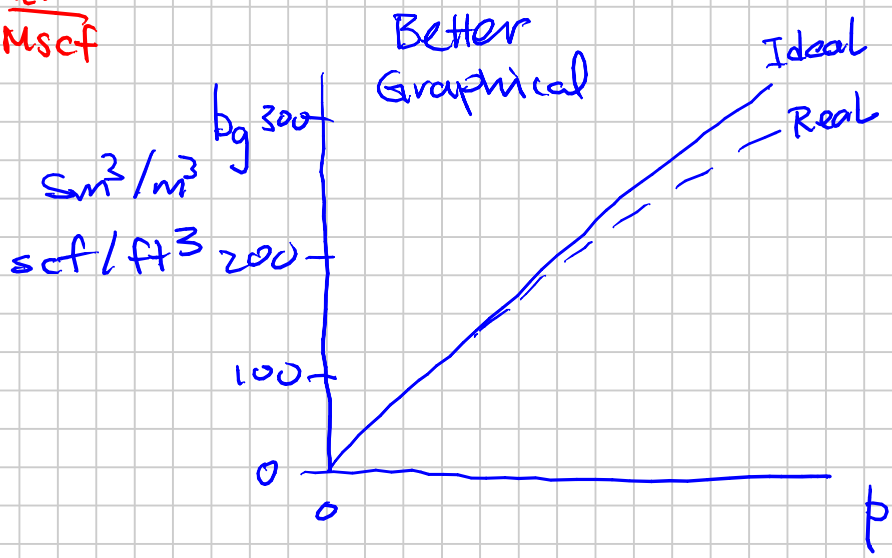
$\sim 100 - 300$ (N.S.)

"bbl"

$$B_g \left[\frac{RB}{Mscf}\right] = 0.0117 \frac{ft^3}{scf} \times \underbrace{\frac{bbl}{5.6146\ ft^3}}_{\text{"1"}} \times \underbrace{\frac{10^3\ scf}{Mscf}}_{\text{"1"}}$$

$$= 2.08 \frac{RB}{Mscf}$$





$$pV = nRT$$

1. Gas volumes reported and measured and used are MOST often @ STC

   scf Sm^3 std m^3

2. Translation from surface STC gas volumes to moles or vice versa is common in engineering.

   ✓ $379 \frac{scf}{lb\text{-}mole}$ ✓ $23.6x \frac{Sm^3}{kg\text{-}mole}$

✓ 22.4 $\frac{dm^3}{mol}$ $\frac{L}{g\text{-mole}}$ @ $T_{sc} = 0\,°C$

$R = 10.7315$ psia, °R, ft^3, lb-mole

$R = 8314.3$ Pa, K, m^3, kg-mole

@ STC $p_{sc} = 14.696$ psia 1.0135 bar(a)

$T_{sc} = 60\,°F$ (SPE)

(Alt. 20 °C or 25 °C) other Societies

0 °C

Want: Surface Condition Gas "Molar Volume") $v_{\bar{g}}$

$$v_{\bar{g}} \equiv \frac{V_g(p_{sc}, T_{sc})}{n_g} = \frac{R\,T_{sc}}{p_{sc}}$$

Independent of the gas "makeup"

CH_4 CO_2 N_2 ...

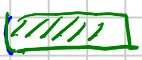
SI:

$$v_{\bar{g}} = \frac{8314.3\,(15.56 + 273.15)}{1.0135 \cdot 10^5} = 23.68 \ \frac{Sm^3}{kg\text{-mole}}$$

Field:

$$v_{\bar{g}} = \frac{10.7315\,(60 + 459.67)}{14.696} = 379.5 \ \frac{scf}{lb\text{-mole}}$$

Gas Equivalent of STO

STO  $V_{\bar{o}}$ / V_{STO} —equivalent as a STG ($\bar{g}$)→ "$V_{\bar{g}}$"

$$n_{\bar{o}} \times \frac{RT_{sc}}{p_{sc}}$$

" $v_{\bar{g}}$ "

$$[Sm^3] \quad V_{\bar{o}} \times \frac{\rho_{\bar{o}}\,[kg/m^3]}{M_{\bar{o}}\left[\frac{kg}{kg\text{-}mole}\right]} \times 23.68$$

$\underbrace{\qquad\qquad}_{kg\text{-}mole}$ $\qquad \frac{Sm^3}{kg\text{-}mole}$

Barrel Oil Equivalent (boe) bbl

$\bar{g}$ & $\bar{o}$ on an "energy" basis

~ (6000 scf) ≃ (1 STB)

	$\bar{g}$	$\bar{o}$	boe
North Field (Qatar)	$900 \cdot 10^{12}$ scf	(900 Tcf)	$150 \cdot 10^{9}$
Troll Gas	$45 \cdot 10^{12}$ scf	(45 Tcf)	$7.5 \cdot 10^{9}$
Ormen Lange	$10 \cdot 10^{12}$ scf	(10 Tcf)	$1.7 \cdot 10^{9}$