①

(a) $\gamma_{\bar{g}} = 0.7 \qquad \gamma_{API} = 35 \qquad \gamma_{\bar{o}} = \dfrac{141.5}{131.5 + \gamma_{API}} = 0.8498$

$\rho_{\bar{g}} = \rho_{air,sc} \cdot \gamma_{\bar{g}} = (1.223)(0.7)$

$\underset{\sim\sim\sim}{\rho_{\bar{g}} = 0.856 \text{ kg/m}^3}$

$\rho_{\bar{o}} = \gamma_{\bar{o}}\, \rho_{\bar{w}}$

$= (0.8498)(999)$

$\underset{\sim\sim\sim}{\rho_{\bar{o}} = 849 \text{ kg/m}^3}$

(b) At $p = p_b = 275$ bara

$B_o = 1.42 \text{ m}^3/\text{Sm}^3$

$R_s = 150 \text{ Sm}^3/\text{Sm}^3$

$r_s = 3 \cdot 10^{-5} \text{ Sm}^3/\text{Sm}^3$

$b_{gd} = 210 \text{ Sm}^3/\text{m}^3 \Rightarrow B_{gd} = 0.00476 \text{ m}^3/\text{Sm}^3$

(c) $\rho_o = \dfrac{\rho_{\bar{o}} + \rho_{\bar{g}} R_s}{B_o}$

$= \dfrac{849 + 0.856(150)}{1.42}$

$\underset{\sim\sim\sim}{\rho_o = 688 \text{ kg/m}^3}$

$\rho_g = \dfrac{\rho_{\bar{g}} + \rho_{\bar{o}} r_s}{B_{gd}}$

$= \dfrac{0.856 + 849(3 \cdot 10^{-5})}{0.00476}$

$\underset{\sim\sim\sim}{\rho_g = 185 \text{ kg/m}^3}$

(d) $p_o(D_{WOC}) = p_o(D_{GOC}) + \rho_o g (D_{WOC} - D_{GOC})$

$= 275 + \underbrace{688(9.8)(500)}_{Pa} \cdot \underset{\text{bar/Pa}}{10^{-5}}$

$p_o(D_{WOC}) = 308.7$ bara

$p_g(D_{TOP}) = p_g(D_{GOC}) + \rho_g\, g\, (D_{TOP} - D_{GOC})$

$= 275 + 185(9.8)(-200) \cdot 10^{-5}$

$\underset{\sim\sim\sim}{p_g(D_{TOP}) = 271.4 \text{ bara}}$

(e) B_o @ $p = 309$ bara $> p_b$ (undersaturated)

$\underline{B_o = 1.405 \text{ m}^3/\text{Sm}^3}$ graphically (linearly) extrapolated

(f) $N_o = HCPV_o \,/\, \bar{B}_{oi}$

$= 2.5 \cdot 10^8 / 1.4125$

$\bar{B}_{oi} = \frac{1}{2}(1.42 + 1.405) = 1.4125 \text{ m}^3/\text{Sm}^3$

$\underline{N_o = 1.77 \cdot 10^8 \text{ Sm}^3}$

$G_o = N_o \cdot \bar{R}_{si}$

$= (1.77 \cdot 10^8)(150)$

$\underline{G_o = 2.655 \cdot 10^{10} \text{ Sm}^3}$

$G_g = HCPV_g \,/\, \bar{B}_{gdi}$

$= 10^8 / 0.00476$

$\underline{G_g = 2.1 \cdot 10^{10} \text{ Sm}^3}$

$N_g = G_g \, \bar{r}_{si}$

$= (2.1 \cdot 10^{10})(3 \cdot 10^{-5})$

$\underline{N_g = 6.30 \cdot 10^5 \text{ Sm}^3}$

$\underline{IOIP = 1.776 \cdot 10^8 \text{ Sm}^3}$

$\underline{IGIP = 4.755 \cdot 10^{10} \text{ Sm}^3}$

(g) $M_{\bar{g}} = M_{air} \cdot \gamma_{\bar{g}}$

$= 28.97\,(0.7)$

$\underline{M_{\bar{g}} = 20.28}$

$$M_{\bar{o}} = \frac{6084}{\gamma_{API} - 5.9}$$

$\underline{M_{\bar{o}} = 209}$

(h)

$$B_{gd} = B_{gw}(1 + C_{\bar{o}g} r_s) \qquad \text{Eq. 7.12}$$

$$C_{\bar{o}g} = 133\,000 \frac{\gamma_{\bar{o}g}}{M_{\bar{o}g}} = 133000 \frac{0.8498}{209} = 541 \text{ scf/STB}$$

$$= 96.3 \text{ Sm}^3/\text{Sm}^3$$

$$B_{gw} = \frac{p_{sc}}{T_{sc}} \frac{T_R Z_g}{p_{Ri}}$$

Solve for Z_g given $B_{gd} = 0.00476 \text{ m}^3/\text{Sm}^3$

$$Z_g = \frac{B_{gd}}{(1 + C_{\bar{o}g} r_s)} \cdot \left(\frac{T_{sc}}{T_R} \cdot \frac{p_{Ri}}{p_{sc}}\right)$$

$$= \frac{0.00476}{1 + (96.3)(3 \cdot 10^{-5})} \left(\frac{15.56 + 273}{100 + 273}\right)\left(\frac{275}{\cancel{1.01325}\ 1.0135}\right)$$

$$\underline{Z_g = 0.996}$$

Standing-Katz Chart Method

$$\gamma_w = \gamma_{gR} = \gamma_g = \frac{\gamma_{\bar{g}} + 4580\, r_p \gamma_{\bar{o}}}{1 + 133000\, r_p \left(\frac{\gamma_{\bar{o}}}{M_{\bar{o}}}\right)} \qquad \text{Eq. 3.55} \quad r_p \text{ [STB/scf]}$$

$$r_p = r_s = 3 \cdot 10^{-5} \frac{1}{5.615}$$

$$= 5.3 \cdot 10^{-6} \text{ STB/scf}$$

$$\gamma_g = \frac{0.7 + 4580(5.3 \cdot 10^{-6})(0.8498)}{1 + 133000(5.3 \cdot 10^{-6})\left(\frac{0.8498}{209}\right)}$$

$$\gamma_g = 0.718 \sim 0.72$$

Fig. 3.7 "Condensate Fluid" Curves

$$p_{pc} = 665 \text{ psia} = 45.85 \text{ bara}$$

$$T_{pc} = 385\ °R = 214 \text{ K}$$

$$p_{pr} = 275/45.85 = 6$$

$$T_{pr} = (100 + 273)/214 = 1.75$$

$$\underline{(Z_g)_{chart} = 0.935}$$

(i) $B_{od,b} > (B_{od})_{SEP\ Test}$

because the DLE Process is at $T = T_R$ which leads to higher K_i for heavier (C_{7+}) components and thus more vaporization of the reservoir oil. That shrinks the final oil @ p_{sc} relative to a multistage flash process at lower temperatures.

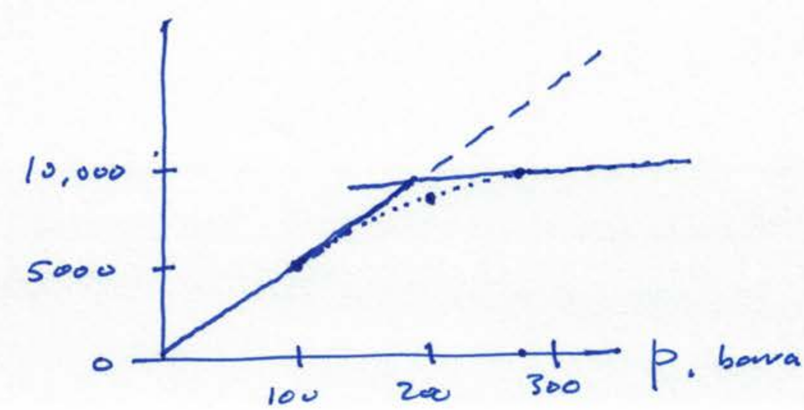
(j) μ_o ($p > p_b$) increases at lower pressures because
(1) gas is coming out of solution, increasing μ_o
(2) oil density increases, increasing μ_o
These two reasons are inter-related, so decreasing R_s is really the main reason.

μ_o ($p > p_b$) increases at higher pressures because ρ_o increases.

(k)

p	B_g	μ_g	$1/\mu_g B_g$
275	222	0.0208	10673
200	158	0.0177	8926
100	80	0.0153	5229

$\frac{1}{\mu_g B_g}$



(l) $n_{\bar{g}g} = G_g / (RT_{sc}/p_{sc})$

$n_{\bar{g}o} = G_o / (RT_{sc}/p_{sc})$

$n_{\bar{o}g} = N_g \left(\frac{\rho_{\bar{o}}}{M_{\bar{o}}}\right)$

$n_{\bar{o}o} = N_o \left(\frac{\rho_{\bar{o}}}{M_{\bar{o}}}\right)$

$RT_{sc}/p_{sc} = 23.68$ Sm³/kg-mole

$\rho_{\bar{o}} = 849$ kg/m³

$M_{\bar{o}} = 209$ kg/Kg-mole

$\left(\frac{\rho_{\bar{o}}}{M_{\bar{o}}}\right) = 4.06$ kg-mole/Sm³

$n_{\bar{g}g} = (2.1\cdot10^{10})/(23.68) = 8.87\cdot10^{8}$ kg-mole

$n_{\bar{g}o} = (2.655\cdot10^{10})/(23.68) = 1.121\cdot10^{9}$ kg-mole

$n_{\bar{o}g} = (6.30\cdot10^{5})(4.06) = 2.558\cdot10^{6}$ kg-mole

$n_{\bar{o}o} = (1.77\cdot10^{8})(4.06) = 7.186\cdot10^{8}$ kg-mole

$$y_{\bar{g}} = \frac{n_{\bar{g}g}}{n_{\bar{g}g}+n_{\bar{o}g}} = \underline{0.9971 = y_{\bar{g}}}$$

$$y_{\bar{o}} = 1 - y_{\bar{g}} = \underline{0.0029 = y_{\bar{o}}}$$

$$x_{\bar{g}} = \frac{n_{\bar{g}o}}{n_{\bar{g}o}+n_{\bar{o}o}} = \underline{0.6094 = x_{\bar{g}}}$$

$$x_{\bar{o}} = 1 - x_{\bar{g}} = \underline{0.3906 = x_{\bar{o}}}$$

$$K_{\bar{g}} = \frac{y_{\bar{g}}}{x_{\bar{g}}} = \underline{1.636 = K_{\bar{g}}}$$

$$K_{\bar{o}} = \frac{y_{\bar{o}}}{x_{\bar{o}}} = \underline{0.0074 = K_{\bar{o}}}$$

$$z_{\bar{g}} = \frac{n_{\bar{g}g}+n_{\bar{g}o}}{(n_{\bar{g}g}+n_{\bar{g}o})+(n_{\bar{o}g}+n_{\bar{o}o})} = \underline{0.7358 = z_{\bar{g}}}$$

$$z_{\bar{o}} = 1 - z_{\bar{g}} = \underline{0.2642 = z_{\bar{o}}}$$

(2)

(a) p^2 can be used when $p_R \lesssim 150$-200 bara where $p/\mu Z \sim$ linear with zero intercept.

p_p should be used when $p_R \gtrsim 200^+$ bara

$$p_p \equiv 2 \int_{p_o}^{p} \frac{p}{\mu Z}\, dp \qquad \text{or} \qquad \tilde{p}_p \equiv \int \frac{1}{\mu_g B_g}\, dp$$

$\mu = \mu_g$
$Z = Z_g$
p_o = arbitrary reference (low) pressure

(b) $$\frac{1}{\mu_g B_g} \sim \frac{p}{\mu_g Z_g}$$

$$B_g = \frac{p_{sc}}{T_{sc}} \frac{T_R Z_g}{p}$$

$$\frac{1}{\mu_g B_g} = \underbrace{\left(\frac{T_{sc}}{p_{sc} T_R}\right)}_{\text{constant}} \left(\frac{p}{\mu_g Z_g}\right)$$

(c) If C_R = constant $\Rightarrow$ Darcy eq.

i.e. not Dq_g term in C_R

(d) Friction
Gravity (e^s terms)

~~[illegible]~~

(e)

$$q_g = C_R (p_R^2 - p_{wf}^2) \qquad q_g = C_T (p_w^2 - p_t^2)^{0.5}$$

$$p_R^2 = e^S p_c^2$$

$$p_{wf}^2 = e^s p_w^2$$

$$q_g = C_R e^S (p_c^2 - p_w^2)$$

$$q_g = C_R' (p_c^2 - p_w^2)$$

$$(p_c^2 - p_w^2) = \frac{1}{C_R'} q_g \qquad (1')$$

$$(p_w^2 - p_t^2) = \frac{1}{C_T^2} q_g^2 \qquad (2')$$

$$(p_c^2 - p_t^2) = B q_g^2 + A q_g \Rightarrow \boxed{B q_g^2 + A q_g - (p_c^2 - p_t^2) = 0}$$

$$B = 1/C_T^2 \qquad A = 1/C_R' = \frac{1}{e^S C_R}$$

$$q_g = \frac{-A + \left[A^2 + 4 B \Delta p^2\right]^{1/2}}{2B} \qquad \text{Question 1}$$

$$p_t = \left[p_c^2 - \left(B q_g^2 + A q_g\right)\right]^{1/2} \qquad \text{Question 2}$$

$$A = \frac{1}{1.3(10^{-3})} = 769 \sim 770 \qquad p_c^2 = 1200^2/1.3$$

$$B = \frac{1}{4^2} = \frac{1}{16} = 0.0625 \qquad p_c^2 = 1.108 \cdot 10^6 \text{ psia}^2$$

$$q_g = \frac{-770 + \left[(770)^2 + 4(0.0625)\left((1200)^2/1.3 - 200^2\right)\right]^{1/2}}{2(0.0625)}$$

$$\underline{q_g = 1258 \text{ Mscf/D}}$$

$$p_t = \left[(1200)^2/1.3 - \left((0.0625)(200)^2 + 770(200)\right)\right]^{1/2}$$

$$\underline{p_t = 975 \text{ psia}}$$

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(f) $d_T' = 2 d_T \Rightarrow C_T' = C_T \left(\frac{d_T'}{d_T}\right)^{2.6} = 4(2)^{2.6} = 24$

$(kh)' = 2(kh) \Rightarrow C_R' = 2 C_R$

$$A' = \frac{1}{1.3\, C_R'} = \frac{1}{1.3(10^{-3})2} = 385 \qquad (\text{vs } 770)$$

$$B' = \frac{1}{C_T'^2} = \frac{1}{24^2} = 0.00174 \qquad (\text{vs } 0.0625)$$

$$q_g = \frac{-385 + \left[(385)^2 + 4(0.00174)\left((1200)^2/1.3 - 200^2\right)\right]^{1/2}}{2(0.00174)}$$

$$\underline{\underline{q_g = 2740 \text{ Mscf/D}}}$$

$$p_t = \left[(1200)^2/1.3 - \left((0.00174)(200)^2 + 385(200)\right)\right]^{1/2}$$

$$\underline{\underline{p_t = 1015 \text{ psia}}}$$