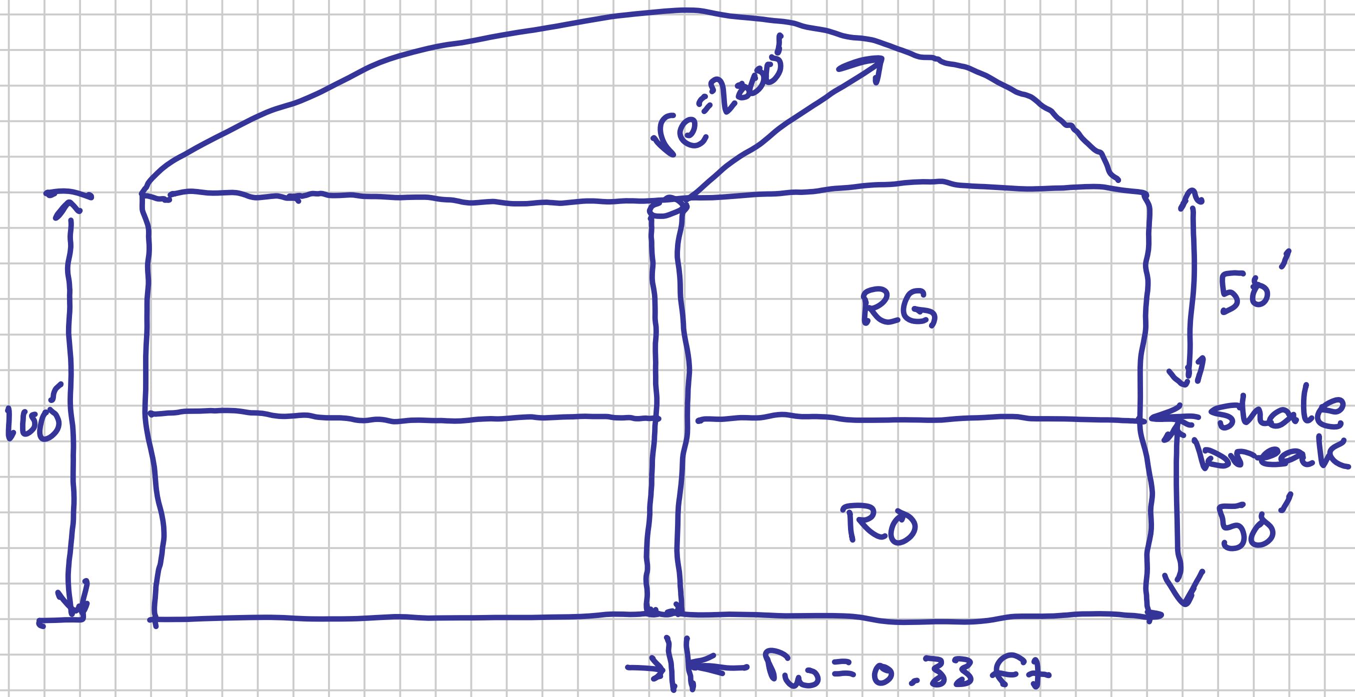
TPG 4125 PVT & FLOW EXAM
SOLUTION (2005)



Q: IFIP relate to
(a) single well
(b) Field (project)

(a) $HCPV_{RG} = HCPV_{RO}$; $h_g = h_o$

$\phi = 0.15$

$$HCPV = A \cdot h \cdot \phi \cdot (1 - S_w)$$ $S_w = 0.2$

$$A = \pi (r_e^2 - r_w^2)$$

$$\simeq \pi r_e^2 \quad ; \quad r_e >> r_w$$

$$HCPV_{RG} = HCPV_{RO}$$

$$= \pi r_e^2 h \phi (1-S_w)$$

$$= \pi (2000)^2 (50)(0.15)(1-0.2)$$

$$HCPV_{RG} = \underline{7.540 \cdot 10^7} \quad ft^3$$

$$HCPV_{RO} = \underline{1.343 \times 10^7 \quad RB}$$

<u>RG</u>

$$IGIP_{RG} = HCPV_{RG} \cdot \frac{1}{B_{gd,i}}$$

$$IOIP_{RG} = IGIP_{RG} \cdot r_{si}$$

$$B_{gdi} = 0.001 \frac{RB}{scf} \quad @ \ 2800 \text{ psia}$$

$$r_{si} = 16.36 \frac{STB}{MMscf} \quad \text{— " —}$$

$$IGIP_{RG} = 1.343 \cdot 10^7 \ RB \cdot \frac{1}{0.001} \frac{scf}{RB}$$

$$= 1.343 \cdot 10^{10} \ scf$$

$$= 13.43 \quad bcf \ (10^9 \ scf)$$

$$IOIP_{RG} = 13\,430 \ MMscf \times 16.36 \frac{STB}{MMscf}$$

$$= 219\,715 \ STB$$

RO: $HCPV_{RO} = 1.343 \cdot 10^{7}$ RB

$$IOIP_{RO} = HCPV_{RO} \cdot \frac{1}{B_{oi}} \quad @ \ 2800 \text{ psia}$$

$$IGIP_{RO} = IOIP_{RO} \cdot R_{si}$$

$B_{oi} = 1.4699$ RB/STB

$R_{si} = 762$ scf/STB

$IOIP_{RO} = 9.135 \cdot 10^{6}$ STB

$IGIP_{RO} = 6.96 \cdot 10^{9}$ scf

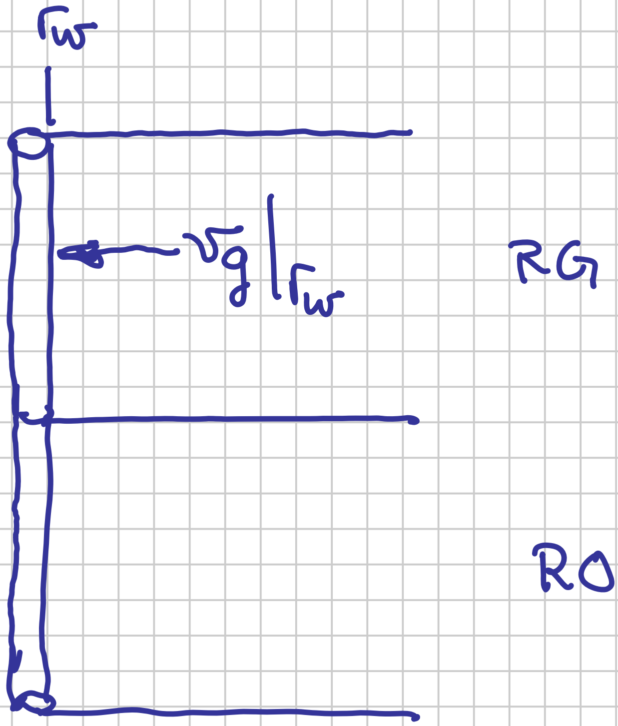
$@\ r_w$

3. After 2000 days, calculate the gas flow velocity (ft/d) in the gas zone at the wellbore.

4. After 2000 days, calculate the gas flow velocity (ft/d) in the oil zone at the wellbore.

5. After 2000 days, calculate the oil flow velocity (ft/d) in the oil zone at the wellbore.

$P_{r_w} = 500$ psia



q_g RG @ 2000 d

$$= \frac{18.365}{\left[1 + (0.173)(0.00188)(2000)\right]^{(1/0.173)}}$$

$$= 1.014 \quad \text{MMscf/D}$$

$$= 1.014 \cdot 10^6 \ \text{scf/D}$$

q_g @ r_w use B_{gd} @ 500 psia

$$B_{gd} = 0.00615 \text{ RB/scf}$$

$$q_{gR} = 6237 \text{ RB/d}$$

$$= 35000 \text{ ft}^3\text{/d}$$

$$= v_g \cdot (2\pi r_w \cdot h)$$

$$v_g = \frac{35000 \text{ ft}^3\text{/d}}{2\pi(0.33)(50)}$$

(3) $\underline{v_g = 338 \text{ ft/D}}$

(4) v_g @ r_w (@ 500 psia) in $\underline{\underline{\text{RO}}}$

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

in solution in flowing oil

free gas flowing

$q_{\bar{o}}$ @ 2000 days

$$= \frac{1605}{e^{0.000728(2000)}}$$

$$= \frac{1605}{\left[1+(0.001)(0.000728)(2000)\right]^{1/0.001}}$$

$$q_{\bar{o}} = 375 \text{ STB/D}$$

Ch. 7 : Eq.

$$q_{\bar{o}} \simeq q_{\bar{o}o}$$

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

$$= q_{\bar{g}} - q_{\bar{o}o} \cdot R_s$$

R_s @ P_{wf}

Acceptable

$$\simeq q_{\bar{g}} - q_{\bar{o}} R_s$$

$$= \underset{\frac{scf}{D}}{10^6} - \underset{\frac{STB}{D}}{375} \left(118 \frac{scf}{STB}\right)$$

$$= 955000 \text{ scf/D}$$

r_s

$$q_{\bar{o}g} = 0.955 \frac{MMscf}{D} \cdot 1.4 \frac{STB}{MM}$$

$$= 1.4 \text{ STB/D}$$

$$<< 375$$

$$q_{\bar{g}g} \doteq 10^6 \text{ scf/D}$$

$$B_{gd} = 0.00615 \text{ RB/scf}$$

$$q_{gR} = 6237 \text{ RB/d}$$

$$= 35000 \text{ ft}^3/\text{d}$$

$$= v_g \cdot (2\pi r_w \cdot h)$$

$$v_g = \frac{35000 \text{ ft}^3/\text{d}}{2\pi(0.33)(50)}$$

(4) $\underline{v_g \sim 338 \text{ ft/D}}$

(5) $q_{\bar{o}} = 375 \text{ STB/D}$

$$q_{\bar{o}} \simeq q_{\bar{o}o}$$

$$q_{oR} = q_{\bar{o}o} \cdot B_o \leftarrow @\ P_{wf} = 500 \text{ psia}$$

$$= 375 \frac{\text{STB}}{\text{D}} \cdot 1.12 \frac{\text{RB}}{\text{STB}}$$

$$= 420 \text{ RB/D}$$

$$v_o = \frac{q_{oR}}{2\pi r h}$$

$$= \frac{(420)(5.615)}{2\pi(0.33)(50)}$$

(5) $\underline{v_o = 22.7 \text{ ft/D}}$

(6) $\bar{P}_R$ in RG ~ 2000 psia

R_p = producing GOR.

Gas Condensate reservoir

we can assume $q_{\bar{o}o} \sim 0$

Producing GOR $\simeq \frac{1}{r_s}$ (1st order approx)

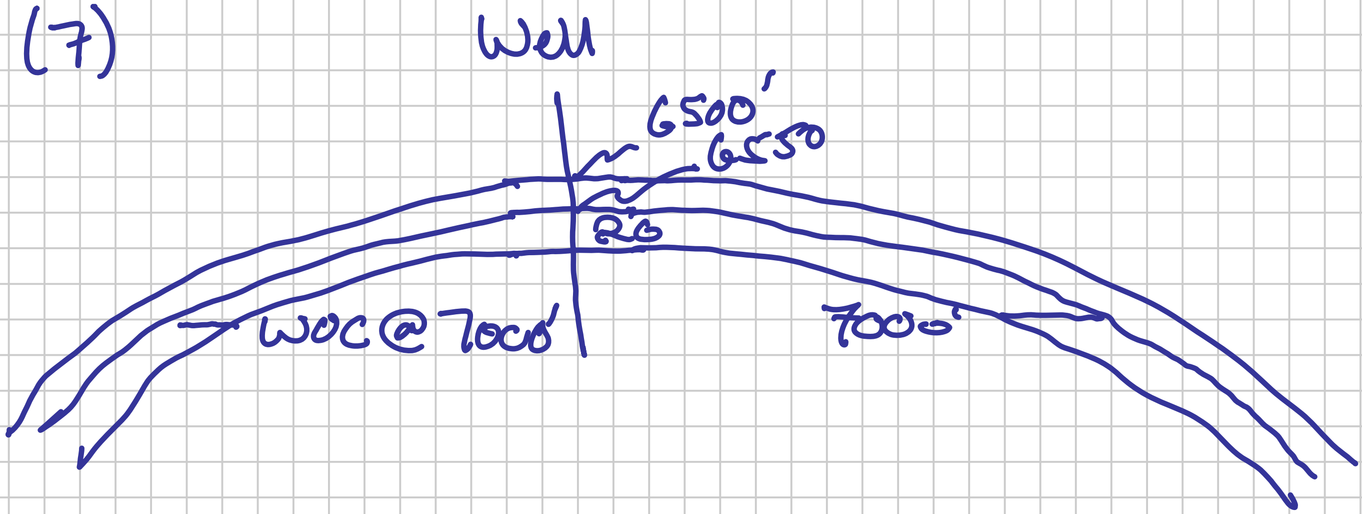
r_s @ 2000 psia

$= 6.6$ STB/MMscf

$$R_p = \frac{1}{r_s} = \frac{10^6 \text{ scf/MMscf}}{6.6 \text{ STB/MMscf}} =$$

$\underline{R_p = 150000 \text{ scf/STB}}$

(7)



p@ 6550 ft = 2800 psia

Oil pressure gradient down to 7000 ft.

$$\boxed{P_{7000} = P_{6550} + \underbrace{\rho_o \frac{1}{144}}_{psi/ft} (7000-6550)}$$

$$\bar{\rho}_o \simeq \rho_o \text{ at } 6550 \text{ ft depth}$$

$$\rho_o = \frac{\rho_{\bar{o}} + \rho_{\bar{g}} R_s}{B_o}$$

$$\rho_{\bar{o}} = 29.975 \text{ lb/ft}^3$$

$$\rho_{\bar{g}} = 0.073 \text{ lb/ft}^3$$

$$R_s = 762 \text{ scf/STB} = 136 \text{ ft}^3/\text{ft}^3$$

$$B_o = 1.47 \text{ RB/STB} \quad (\text{ft}^3/\text{ft}^3)$$

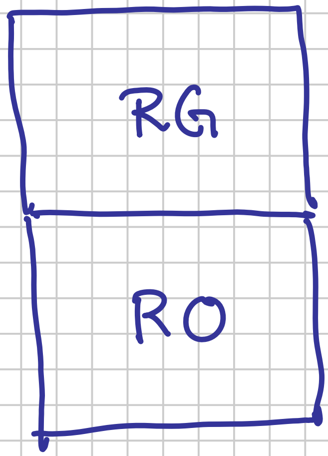
$$\rho_o = \frac{29.925 + 0.073(136)}{1.47}$$

$$= 27.14 \text{ lb/ft}^3$$

$$p_{7000} = 2800 + \frac{27.14}{144}(7000 - 6550)$$

$$\underline{p_{7000'} = 2884 \quad @ \text{ WOC}}$$

8.



Pressure decline rate is related to 2 factors:

(1) Volumetric rate of withdrawl $\sim q_i \sim$ PSS initial rate

(2) Compressibility of the volume being drained × Volume (HCPV)

$$DR_{RG} \sim \frac{q_{i\,RG}}{\bar{c}_{RG}}$$

$$\bar{c}_{RG} \gg \bar{c}_{RO}$$

$$DR_{RO} \sim \frac{q_{i\,RO}}{\bar{c}_{RO}}$$

For similar q_{iRG} & q_{iRO}

RO would deplete faster because of its lower $\bar{c}_{RO}$

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q_{iRG} vs q_{iRO}

$$v_{iRG} \cong \frac{k}{\mu_g}\left(\frac{dp}{dr}\right)_{RG} ; v_{iRO} \cong \frac{k}{\mu_o}\left(\frac{dp}{dr}\right)_{RO}$$

$$\left(\frac{dp}{dr}\right)_{RG} \sim \left(\frac{dp}{dr}\right)_{RO}$$

$$\mu_g < \mu_o$$

$$\mu_g = \frac{1}{10}\mu_o$$

RG $c_g \uparrow$ $q_{iRG} \uparrow$ vs RO $c_o \downarrow$ $q_{iRO} \downarrow$

?

Gas depletes faster than oil

9.

$$q_i = \frac{kh}{\left[\ln\left(\frac{r_e}{r_w}\right) + s\right]} \int_{P_{wf}}^{P_{Ri}} \lambda \, dp$$

$$q = \frac{q_i}{\left[1 + bDt\right]^{1/b}}$$

$$D = \frac{1}{1-b} \cdot \frac{q_i}{Q_{ult}}$$

Q_{ult} = ultimate cum. production when $q \to 0$

b same

Q_{ult} same

q_i (skin change)

D changes because q_i changes

$$q_i^{s=-4} = q_i^{s=0} \cdot \frac{\ln\frac{r_e}{r_w} + 0}{\ln\frac{r_e}{r_w} - 4}$$

RG:

$$q_i^{s=-4} = \underbrace{18.365 \ \frac{\text{MMscf}}{D}}_{q_i^{s=0}} \cdot \frac{\ln\left(\frac{2000}{0.33}\right)}{\ln\left(\frac{2000}{0.33}\right) - 4}$$

$$q_i^{s=-4} = 34 \ \text{MMscf/D}$$

$$Q_{ult} = \frac{1}{1-b} \cdot \frac{q_i}{D}$$

$$= \frac{1}{1-0.173} \cdot \frac{18.365 \ \text{MM}}{0.00188}$$

$$= 11\,812 \ \text{MMscf}$$

$$= 11.8 \cdot 10^9 \ \text{scf}$$

$$D_{RG} = \frac{1}{1-b} \cdot \frac{q_i^{s=-4}}{Q_{ult}}$$

$$= \frac{1}{1-0.173} \cdot \frac{34 \ \text{MM}}{11\,812 \ \text{MM}}$$

$$D_{RG} = 0.00348 \quad 1/d$$

RO:

$$q_i^{s=-1} = 1605 \ \frac{STB}{D} \cdot \frac{\ln \frac{2000}{0.33}}{\ln\left(\frac{2000}{0.33}\right) - 4}$$

$$= 3000 \ \frac{STB}{D}$$

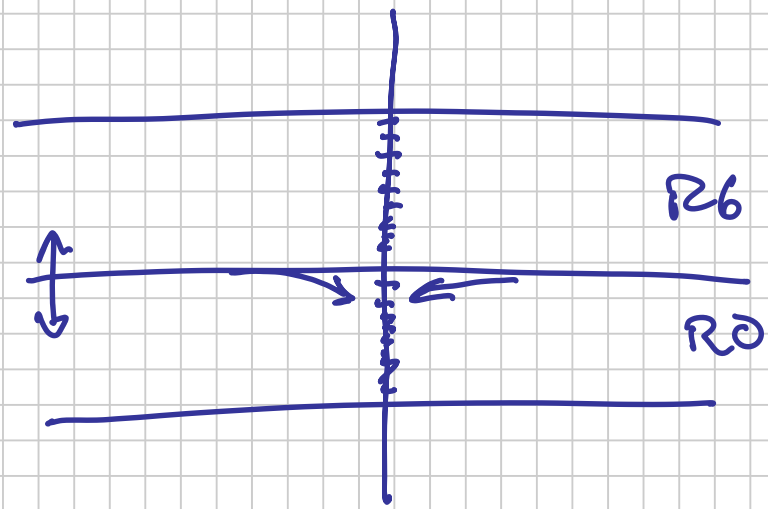
$$Q_{ult} = \frac{1}{1-0} \cdot \frac{1605}{0.000728}$$

$$= 2.204 \cdot 10^6 \ STB$$

$$D_{RO} = \frac{1}{1-0} \cdot \frac{3000}{2.204 \cdot 10^6}$$

$$\underline{\underline{D_{RO} = 0.00136 \ 1/d}}$$

10.



(a) Expect some gas entering from the RG zone into the RO perforations. $\lambda_g > \lambda_o$

(b) p_{RG} depletes slower than p_{RO}, $p_{RG}(t) > p_{RO}(t)$ then gas coning (a) would worsen

$\downarrow$ RG $\quad \downarrow \quad \downarrow$

Opposite would lessen the coning effect.

RG

$\uparrow \quad \uparrow \quad \uparrow$

p_{RO}

(c) Less coning of RG into RO increases ultimate oil RF in RO zone.

(d) Higher ultimat oil recovery (RO zone) will a sealing shale barrier. That is, without shale barrier, lower oil RF.