Question One.

Given data.

q_o = 500bbl/day

D = 2inches

Temp = 120°F + 460 = 580°R

Pressure : 1000psia.

q_L = ?

GOR = 1000scf/bbl

Area = ?

Step 1 → Calculate Area.

using $A = \frac{\pi d^2}{4} = \frac{3.143 \times (2/12)^2}{4} = 0.02182 ft^2$

Step 2 → Calculate U_{sL}, U_{sg}, U_m.

where $U_{sL} = \frac{q_L}{A}$

$U_{sL} = \frac{\frac{500 \times 5.614 ft^3}{86400 sec}}{0.02182} = 1.48 ft/s$

$U_{sg} = \frac{q_g}{A} = \frac{4}{\pi d^2}\left[q_g \times Z\right]\left[\frac{T}{T_{sc}}\right] \times \left[\frac{P_{sc}}{P}\right]$

To calculate flowrate of gas when GOR and flowrate of oil is given.

$GOR = 1000 scf/bbl = \frac{ft^3}{bbl} = 1000$

$\frac{ft^3}{day} = 1000$

To get G_L and G_g.

$G_L = U_{SL} \rho_L$ --- (*)

$G_g = U_{sg} \rho_g$ --- (*)

$$G_L = \left(1.48\frac{ft}{s}\right)\left(53.96\frac{lbm}{ft^3}\right)\left(3600\frac{sec}{hr}\right)$$

$$G_L = \underline{287498.88\, lbm/hr\text{-}ft^2}.$$

$$G_g = \left(3.69\frac{ft}{s}\right)\left(3.88\frac{lbm}{ft^3}\right)\left(3600\frac{sec}{hr}\right)$$

$$G_g = \underline{51,541.92\, lbm/hr\text{-}ft^2}.$$

To get λ and ϕ

$$\lambda = \left[\left(\frac{\rho_g}{0.075}\right)\left(\frac{\rho_L}{62.4}\right)\right]^{\frac{1}{2}} \text{ --- } (*)$$

$$\phi = \frac{73}{\sigma}\left[\mu_L\left(\frac{62.4}{\rho_L}\right)^2\right]^{\frac{1}{3}} \text{ --- } (*)$$

$$\lambda = \left[\left(\frac{3.88}{0.075}\right)\left(\frac{53.96}{62.4}\right)\right]^{\frac{1}{2}}.$$

$$\lambda = \sqrt{(44.7360)} = \underline{6.688}$$

$$\phi = \frac{73}{20}\left[2\left(\frac{62.4}{53.96}\right)^2\right]^{\frac{1}{3}}.$$

$$\phi = \frac{73}{20}\left(2.67457\right)^{\frac{1}{3}} = \underline{5.1}$$

$$\frac{ft^3}{day} \times \frac{day}{bbl} = 1000$$

$$\frac{ft^3}{day} \times \frac{1}{\frac{bbl}{day}} = 1000$$

$$\frac{ft^3}{day} \times \frac{1}{500} = 1000$$

$$\frac{ft^3}{day} \times 0.002 = 1000$$

$$\frac{ft^3}{day} = \frac{1000}{0.002} = \underline{\underline{500,000}}$$. (Flowrate

82 ft^2

* Since Z was not given.

Use the Z-Factor Chart.

$$\frac{T}{T_{pc}} = \frac{580}{395} = 1.47, \quad \frac{P}{P_{pc}} = \frac{1000}{667}$$

From the Chart.

$Z = \cancel{0.935}$ 0.85

Therefore.

$$U_{sg} = \frac{4}{\pi \times \left(\frac{2}{12}\right)^2 ft^2} \times \left(\frac{500,000 \times 0.850}{86400}\right)\left(\frac{580}{520}\right)\left(\frac{1}{1}\right.$$

R

$$U_{sg} = \frac{4}{0.08726} \times \left(\frac{425000}{86400}\right)\left(\frac{580}{520}\right)\left(\frac{14.7}{1000}\right)$$

$$U_{sg} = \frac{14,494,200,000}{3,920,417,280} = \underline{\underline{4.06}}$$

= 2.19

$$N_{Rem} = \frac{\rho_m U_m D}{\mu_m} = \frac{7.05084 \times 44.33 \times 3/12}{0.252 \times 6.72 \times 10^{-4}}$$

$$N_{Rem} = 461,433.14377$$

Then Calculate for x, S, f_{tp}

$$x = \frac{\lambda_L}{Y_{L0}^2} = \frac{0.12}{(0.221)^2} = 2.5$$

$$S = \frac{\ln(x)}{[-0.0523 + 3.182\ln(x) - 0.8725[\ln(x)]^2 + 0.01853[\ln$$

$$S = \frac{0.92}{[-0.0523 + 3.182(0.92) - 0.8725(0.92)^2 + 0.01853(0}$$

$$S = 0.4279.$$

$$f_{tp} = f_n e^S = 0.006 \times e^{0.4279} = 0.009176$$

Step 5 → Calculate $(dp/dz)_f$

$$\frac{dp}{dz} = \frac{2 f_{tp} \rho_m U_m^2}{g_c D}.$$

$$dp/dz = \frac{2 \times 0.009176 \times 7.05084 \times (44.33}{32.17 \times (3/12)}$$

$$dp/dz = 32.0116) ft^3 = \frac{32.0116}{ft^3} \times \frac{1}{144} \frac{ft^2}{in}$$

$$dp/dz = 0.2228 psi/ft$$

From fig 10.6

$$f\left(\frac{m_L}{m_m}\right)^{0.1} = 0.02$$

$$f = \frac{0.02}{\left(\frac{14.03}{15.283}\right)^{0.1}} = \underline{\underline{0.0201}}$$

$$\left(\frac{dp}{dx}\right)_f = \frac{f \rho_m U_m^2}{2 g_c D}$$ [Pressure gradient]

$$= \frac{0.0201 \times 7.050 \times (44.83)^2}{2 \times 32.17 \times 0.25}$$

$$= \frac{17.0167}{144} \; lbf/ft^2 \times \frac{1 ft^2}{144 in^2}$$

$$= \underline{\underline{0.12 \, psi/ft}}$$

For Dukler Correlation

Step 1 → Assume $Y_L = \lambda_L$, $\rho_n = \rho_m$,

$N_{Ren} = N_{Rem}$

$Y_L = \lambda_L = 0.15$

$\rho_n = \rho_m =$

$$\rho_n = \frac{\rho_L \lambda_L^2}{Y_L} + \frac{\rho_g \lambda_g^2}{Y_g}$$

$$Y_g = 1 - Y_L$$

Question 8

$$F/F_n = 1 - \frac{\ln(0.12)}{0.2665 + 1.9780 \cdot 0.8959 + 0.16936}$$

$$F/F_n = -\frac{2.12}{1.51836}$$

$$\frac{F}{F_n} = 1 - \left(-\frac{2.12}{1.51836}\right)$$

$$F = \frac{-2.12 \times 0.00630}{1.51836}$$

$$\frac{F}{F_n} = \frac{1}{1} + \frac{2.12}{1.51836}$$

$$F/F_n = \frac{1.51836 + 2.12}{1.51836}$$

$$1.51836F = (1.51836 + 2.12)\,0.00630$$

$$F = 0.023.$$

Pressure gradient

$$\left(dP/dx\right)_F = \frac{F \rho_K U_m^2}{2 g_c D} = \frac{0.023 \times 5.77 \times 44.33}{2 \times 32.17 \times 0.25}$$

$$\left(dP/dx\right)_F \simeq 16.2135 \quad 0.113\ Psi/ft$$

$Y_L = 0.15$ $\qquad \lambda_g = \frac{U_{sg}}{U_m} =$

$$\rho_K = \frac{53.93 \times 0.12^2}{0.15} + \frac{0.654 \times 0.8805^2}{(1 - 0.15)}$$

$$\rho_K = 5.1773 + 0.5965 = \underline{5.7791 lbm/ft^3}$$

Next. Calculate N_{Rek}.

$$N_{Rek} = \frac{\rho_K U_m D}{\mu_m} = 0.724 \times 44.33 \times 0.25$$

$$N_{Rek} = \frac{N_{Rem} U_m}{\mu_m} =$$

$$461483.1437 \times \left[\frac{44.33}{0.0250}\right]$$

$$N_{Rek} = \underline{818213250.4088}$$

Next Calculate. f_n.

$$f_n = 0.0056 + 0.5 (N_{Rek})^{-0.32}$$

$$= 0.0056 + 0.5 \left[818213250.4088\right]^{-0.32}$$

$$f_n = \underline{0.00680}$$

$$\frac{f}{f_n} = 1 - \frac{\ln(\lambda_L)}{1.281 + 0.478 \ln(\lambda_L) + 0.444 [\ln(\lambda_L)]^2 + 0.094 [\ln(\lambda_L)]^3 + 0.00843 [\ln(\lambda_L)]^4}$$

To get Beggs Brill Reading, Use the Formular

$N_{Fr} = \frac{U_m^2}{gD}$, $\lambda_L = \frac{U_{sL}}{U_m}$

$N_{Fr} = \frac{(44.33)^2}{32.17 \times (3/12)} = \frac{1965.1489}{8.0425} = \underline{244.3}$

$\lambda_L = \frac{U_{sL}}{U_m} = \frac{5.30}{44.33} = \underline{0.12}$

Therefore the Reading is

~~to get~~

Step 3 → Calculate the holdup for horizontal Flow. Using the Formular

Recall that.

Seagr $L_1 = 316\lambda_L^{0.302}$

$L_2 = 0.0009252\lambda_L^{-2.4684}$

$L_3 = 0.10\lambda_L^{-1.4516}$

$L_4 = 0.5\lambda_L^{-6.738}$

$L_1 = 316(0.02)^{0.302} = \underline{166.57}$

$L_2 = 0.0009252 \times (0.12)^{-2.4684} = \underline{0.17345}$

$L_3 = 0.10 \times (0.12)^{-1.4516} = \underline{2.171}$

$L_4 = 0.5 \times (0.12)^{-6.738} = \underline{800,657.48}$

The flow regime transition is ~~a~~

[illegible] flow because

So therefore, from the holdup constants table

$a = 1.065$, $b = 0.5824$, $c = 0.0609$.

$$Y_{L0} = \frac{a \lambda_L^b}{N_{FR}^c} = \frac{1.065 \times (0.12)^{0.5824}}{(244.34)^{0.0609}}$$

$$Y_{L0} = \frac{0.30978812}{1.39775} = \underline{\underline{0.22163}}$$

Step 4 → Calculate the no-slip friction factor based on the mixture reynold number

$\rho_m = \rho_L \lambda_L + \rho_g \lambda_g$.

$\lambda_L = 0.12$, $\lambda_g = \frac{U_{sg}}{U_m} = \frac{39.033}{44.33} = \underline{\underline{0.8805}}$

$\rho_L = 53.96\, lbm/ft^3$

$$\rho_g = \frac{2.7 \times \gamma_g \times P}{Z \times T} = \frac{2.7 \times 0.71 \times 200}{0.96 \times 610}$$

$\rho_g = 0.654\, lbm/ft^3$

$\rho_m = 53.96 \times 0.12 + 0.654 \times 0.8805$

$\rho_m = 6.475 + 0.5758 = \underline{\underline{7.050847\, lbm/ft^3}}$

* Calculate Reynold number using.

$$N_{Re} = \frac{1648 \cdot 98}{d\, \mu}$$

$\mu_m = \mu_L \lambda_L + \mu_g \lambda_g$

$\mu_m = 2 \times 0.12 + 0.0131 \times 0.8805$

$\mu_m = 0.24 + 0.011534 = \underline{\underline{0.252}}$

$GOR = 500\,scf/bbl$

$$\frac{\frac{ft^3}{day}}{\frac{bbl}{day}} = 500$$

$$\frac{ft^3}{day} \times \frac{1}{\frac{bbl}{day}} = 500$$

$$ft^3/day \times \frac{1}{4000} = 500$$

$$ft^3/day \times 0.00025 = 500$$

$$ft^3/day = 500/0.00025 = 2000,000$$

To get Z-Factor

$$T/T_{pc} = \frac{610}{395} = 1.54 \quad P/P_{pc} = \frac{200}{667} = 0.30$$

From the Chart $Z = \underline{0.96}$.

$$U_{sg} = \frac{4}{\pi d^2}\left[q_g Z\right]\left[\frac{T}{T_{sc}}\right]\left[P_{sc}/P\right]$$

$$U_{sg} = \frac{4}{\pi \times (3/12)^2} \times \left[\frac{2\times10^6 \times 0.96}{86400}\right]\left[\frac{610}{520}\right]\left[\frac{14.7}{200}\right]$$

$$U_{sg} = \frac{68,866,560,000}{1,764,318,434.25603} = \underline{39.038\,ft/sec}$$

$U_m = U_{sg} + U_{sl} = 39.03 + 5.30 = $ [illegible]

The Coordinates for the Baker map are

$$\frac{G_g}{\lambda} = \frac{51541.92}{6.688} = 7706.63.$$

$$\frac{G_L \lambda \phi}{G_g} = \frac{287498.88 \times 6.688 \times 5.1}{51541.92} = 190.26$$

*Reading From the Baker map, the Flow regime is Predicted to be Slug Flow

*Reading From the mandhane map using $U_{sL} = 1.48 ft/s.$, $U_{sg} = 3.67 ft/sec.$ is Predicted to be slug Flow.

*Reading From the Beggs and Brill map using the Formular

$$N_{FR} = \frac{U_m^2}{gD}, \quad \lambda_L = \frac{U_{sL}}{U_m}.$$

$$N_{FR} = \frac{(5.176)^2}{32.17 \times \left(\frac{2}{12}\right)}$$

where g is Constant 32.17.

$$N_{FR} = \frac{26.79076}{5.3616} = 4.99.$$

$$\lambda_L = \frac{U_{sl}}{U_m} = \frac{1.48}{5.176} = \underline{0.286}$$

Beggs and Brills map is predicted to be Intermittent

Question Two.

Given data

$q_o = 4000 bbl/day$

$q_g = ?$

$D = 3 inches$

$\sigma = 20 dynes/cm$

$Temp = 150°F + 460 = 610°R$

Pressure = 200Psia.

GOR = 500SCF/bbl.

Step 1 → Calculate the Area

Using $A = \pi d^2/4 = \frac{\pi \times (3/12)^2}{4} = \underline{0.049 ft^2}$

Step 2 → Calculate U_{sL}, U_{sg}, U_m

$$U_{sL} = \frac{q_L}{A} = \frac{\frac{4000 \times 5.614 ft^3}{86400 sec}}{0.049} = \underline{5.30 ft/sec}$$

$$U_{sg} = \frac{q_g}{A} = \frac{4}{\pi d^2}\left[q z\right]\left[\frac{T}{T_{sc}}\right]\left[\frac{P_{sc}}{P}\right]$$

To calculate the gas Flowrate

$U_m = U_{sl} + U_{sg} = 1.48 + 3.698 = 5.174\ ft/sec$

Step 3 → To get the Baker Flow regime
To Calculate density of oil & gas.
given that

$\gamma_o\ (S.G) = 32°API$

$\gamma_g\ (S.G) = 0.71$

For oil (- - - ✱

$$API = \frac{141.5}{s.g} - 131.5$$

$$32 = \frac{141.5}{s.g} - 131.5$$

$$32 + 131.5 = \frac{141.5}{s.g.}$$

$$163.5 \times s.g = 141.5$$

$$s.g = \frac{141.5}{163.5} = \underline{\underline{0.865}}$$

Therefore $\rho_o = 0.865 \times 62.4 = \underline{\underline{53.97\ lbm/ft^3}}$

For Gas - ✱

Use the Formular. Given $\gamma_g = 0.71$

$$\rho_g = \frac{2.7 \times \gamma_g \times P}{Z \times T} = \frac{2.7 \times 0.71 \times 1000}{0.85 \times 580}$$

$$\rho_g = \underline{\underline{3.88\ lbm/ft^3}}$$