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

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

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

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

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

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

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

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

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

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

Then calculate for x, S, f_{tp}

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

$$S = \frac{\ln(x)}{[-0.0523 + 3.182\ln(x) - 0.8725[\ln(x)]^2 + 0.01853[\ln(x)]^4}$$

$$S = \frac{0.92}{[-0.0523 + 3.182(0.92) - 0.8725(0.92)^2 + 0.01853(0.92)^4}$$

$$S = 0.4279.$$

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

Step 5 → Calculate $(dp/dz)_f$

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

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

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

$$dp/dz = 0.22282/ft$$

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

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

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

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

$$\frac{ft^3}{day} = \frac{1000}{0.002} = \underline{\underline{500,000}}$$ [Flowrate of gas].

* Since Z was not given.
Use the Z-Factor Chart.

$$\frac{T}{T_{pc}} = \frac{580}{395} = 1.47, \quad \frac{P}{P_{pc}} = \frac{1000}{667} = \underline{\underline{1.5}}$$

From the Chart.

$Z = \cancel{0.935}\ 0.85$

Therefore.

$$U_{sg} = \frac{4}{\pi \times (2/12)^2 ft^2} \times \left(\frac{500,000 \times 0.850}{86400}\right)\left(\frac{580}{520}\right)\left(\frac{14.7}{1000}\right)$$

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

$$U_{sg} = \frac{14,494,200,000}{3,920,417,280} = \cancel{4.0668\ ft/sec}$$

$$= \underline{\underline{3.697\ ft/sec}}$$

Question 8

$$\frac{F}{F_n} = 1 - \frac{\ln(0.12)}{0.2665 + 1.9780\,0.8959 + 0.16971}$$

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

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

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

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

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

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

$$F = 0.023$$

Pressure gradient

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

$$\left(dp/dx\right)_F \simeq 16.2185 = 0.113\ \text{psi/ft}$$

To get G_L and G_g

$G_L = u_{sL} \rho_L$ --- (*)

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

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

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

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

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

To get λ and ϕ

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

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

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

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

$$\phi = \frac{73}{20}\left[\cancel{1.57}\,2\left(\frac{62.4}{53.96}\right)^2\right]^{\frac{1}{3}}$$

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

To get Beggs Brill reading, use the Formular

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

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

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

Therefore the reading is

~~DeMarket~~

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

Recall that.

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

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

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

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

$L_1 = 316(0.12)^{0.302} = 166.57$

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

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

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

The flow regime transition is distributed flow because

$\lambda_L < 0.4$ and $N_{FR} \geq L_1$

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

Beggs and Brills map is predicted to be Intermittent

Question Two.

Given data

$q_o = 4000 bbl/day$

$q_g = ?$

$D = 3 inches$

$\sigma = 20 dynes/cm$

$Temp = 150°F + 460 = 610°R$

$Pressure = 200 psia.$

$GOR = 500 scf/bbl.$

Step 1 → Calculate the Area

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

Step 2 → Calculate U_{SL}, U_{Sg}, U_m

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

$$U_{Sg} = \frac{q_g}{A} = \frac{4}{\pi D^2}[qZ]\left[\frac{T}{T_{sc}}\right]\left[\frac{P_{sc}}{P}\right]$$

To calculate the gas Flowrate

Mandhane et al (1979)
Beggs and Brill's Correlation.

Froude number against liquid fraction
- Taitel and Duckler (1976): A theoretical model used to generate flow regime maps for particular fluid & pipe size.

4) Restricted flow refers to flow of fluid under a choke used to control flow due to many factors such as prevention of the causes of sand production.
Fluid flowing through a restriction may be accelerated to reach some velocity in the throat of the choke. This is the critical condition. As downstream pressure of choke do affect the flowrate.
For single phase liquid flow through choke. It is rare for this case, the flowing pressure is below bubble point
But in case it happens.
Flowrate is related to pressure drop across choke by

$$q = CA\sqrt{\frac{2g_c}{\rho}} \quad (1)$$

C = Co-efficient of the choke

$A = C.S, \quad q = 22000C(D_2)^2\sqrt{\frac{\Delta P}{\rho}}$

D in choke is diameter in inches

Question One.

* Horizontal multi-phase Flow Regimes

multiphase Flow in horizontal pipes different from that in vertical pipes.

Due to the Potential Energy Constant in horizontal Flow, the Flow regime has no significant effect and pressure drop on horizontal Flow. However Certain Correlations Consider Flow regime.

Flow regime Can be Classified Into Segregated Flow (two phases are for the most part separate). Intermittent Flow (gas & liquid are alternating). Distributed Flow in which one phase is dispersed in the other phase.

* Segregated is Futher divided into Stratified smooth, stratified wavy (ripple Flow) or annular, stratified smooth Flow consists of liquid Flow along the bottom of the gas.

* Intermittent is divided into Slug: High liquid slugs and high velocity gas bubbles plug.

* Distributed Flow bubble, mist, dispersed bubble Flow

* Flow regime are predicted.

fig - Baker (1953) modified to scott (1963, [$\frac{\rho g}{\lambda}$ and $\frac{G_L \lambda \phi}{\rho_g}$]

Question 4 297.6032

Choke Performance Curves 188.706

Assume GLR to be 500scf/bbl

Choke sizes 8/14, 12/64, 16/64

Using $P_L = \frac{A q_L (GLR)^B}{D_{64}^C}$

$A = 10, \ B = 0.546, \ C = 1.89$

Using the Gilbert Correlation.

$P_{Lf} = \frac{A q_L (GLR)^B}{D_{64}^C}$

For 8/64 choke size.

$P_{Lf} = \frac{10 \times q_L (500)^{0.546}}{(8)^{1.89}} = \frac{297.6032 q_L}{50.914}$

$P_{Lf} = \underline{5.84 q_L}$

For 16/64 choke size.

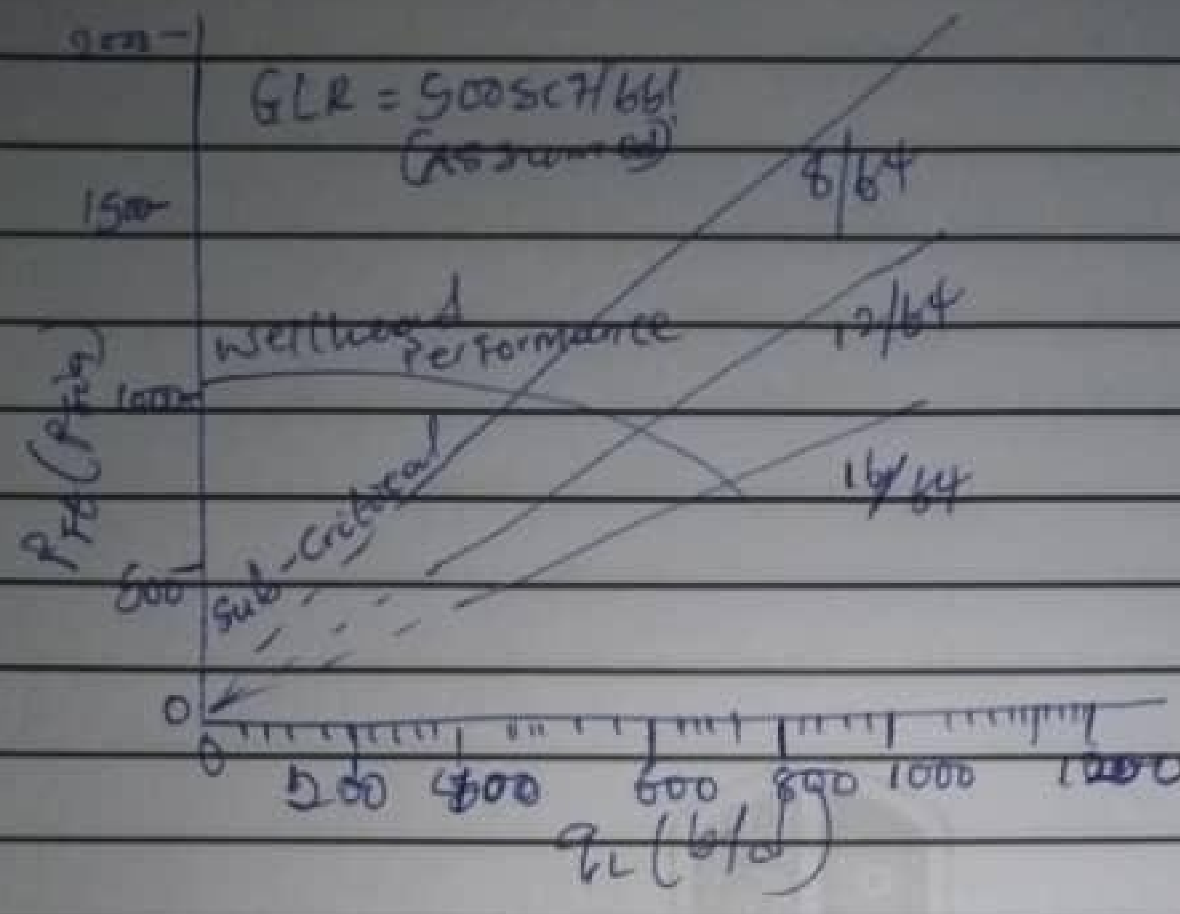
$P_{Lf} = \frac{10 \times q_L \times (500)^{0.546}}{(16)^{1.89}} = \frac{297.603 q_L}{188.706}$

$P_{Lf} = \underline{1.577 q_L}$

For 12/64 choke size

$P_{Lf} = \frac{10 \times q_L \times (500)^{0.546}}{(12)^{1.89}} = \frac{297.6032 q_L}{109.56}$

$P_{Lf} = \underline{2.7163 q_L}$



~~For~~ Calculate flowrate.

For 8/64.	For 12/64	For 16/64
$P_i = 4350$ psi,	$P_i = 4350$ psi	$P_i = 4350$
$P_{LF} = 5.84\, q_L$	$P_{LF} = 2.7163\, q_L$	$P_{LF} = 1.577\, q_L$
$\frac{(4350-14.7)}{5.84} = q_L$	$\frac{4350-14.7}{2.7163} = q_L$	$\frac{4350-14.7}{1.577} = q_L$
$q_L = 742.34$	$q_L = 1596.03$	$q_L = 2749.08$
$P_2 = 3000$ psi	$P_2 = 3000$	$P_2 = 3000$
$\frac{(3000-14.7)}{5.84} = q_L$	$\frac{3000-14.7}{2.7163} = q_L$	$\frac{3000-14.7}{1.577} = q_L$
$= 511.181$	$q_L = 1099.03$	$q_L = 1893$
$P_3 = 2000$ psi	$P_3 = 2000$	$P_3 = 2000$
$\frac{(2000-14.7)}{5.84} = q_L$	$\frac{2000-14.7}{2.7163} = q_L$	$\frac{2000-14.7}{1.577} = q_L$
$= 339.94$	$q_L = 730.88$	$q_L = 1258.90$
$P_4 = 1000$ psi	$P_4 = 1000$	$P_4 = 1000$
$\frac{1000-14.7}{5.84} = q_L$	$\frac{1000-14.7}{2.7163} = q_L$	$\frac{1000-14.7}{1.577} = q_L$
$q_L = 168.71$	$q_L = 362.74$	$q_L = 624.8$

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]

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

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

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

For Dukler Correlation

Step 1 → Assume $Y_L = \lambda_L$, $\rho_n = \rho_m$, $N_{Ren} = N_{Rem}$

$Y_L = \lambda_L = 0.15$

$\rho_n = \rho_m =$

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

$Y_g = 1 - Y_L$

$Y_L = 0.15$ $\lambda_g = \frac{U_{sg}}{U_{m}} =$

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

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

Next. Calculate N_{Rek}

$$N_{Rek} = \frac{\rho_k U_m D}{\mu_m} = \cancel{0}.774 \times 44.33 \times 0.25$$

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

$$4604833.1437 \times \left[\frac{44.33}{0.0250}\right]$$

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

Next Calculate. f_n.

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

$$= 0.0056 + 0.5\,(818215250.4088)^{-0.32}$$

$$f_n = \underline{0.00680}$$

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

$GOR = 500 scf/bbl$

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

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

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

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

$$ft^3/day = \frac{500}{0.00025} = 2000,000$$

To get Z-Factor

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

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

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

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

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

$$U_m = U_{sg} + U_{sL} = 39.03 + 5.30 = \underline{44.33\,ft/sec}$$

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

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

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

where g is constant 32.17.

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

$U_m = U_{sL} + U_{sg} = 1.48 + 3.691 = 5.171 \text{ ft/sec}$

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 $\rho_o = 0.865 \times 62.4 = \underline{\underline{53.96 \text{ lbm/ft}^3}}$.

For Gas -

use the Formular. Given $\gamma_g = 0.71$

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

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

So therefore, from the holdup constants table

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

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

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

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

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

$$\lambda_L = 0.12, \quad \lambda_g = \frac{u_{sg}}{u_m} = \frac{39.033}{44.33} = \underline{\underline{0.8805}}$$

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

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

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

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

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

* Calculate Reynold number using.

$$N_{Re} = \frac{1488 \rho \vartheta}{\mu}$$

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

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

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