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

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

Then calculate for x, S, F_{tp}

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

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

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

$S = 0.4279.$

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

Step 5 → Calculate $(dp/dz)_F$

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

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

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

$dp/dz = 0.22282 / ft$

Question 4

$$f/f_n = 1 - \frac{\ln(0.12)}{0.2665 + 1.9780 - 0.8959 + 0.16936}$$

$$f/f_n = -\frac{2.12}{1.51836}$$

$$\frac{f}{f_n} = 1\left(-\frac{2.12}{1.51836}\right)$$

$$f = -\frac{2.12 \times 0.00680}{1.51836}$$

$$\frac{f}{f_n} = 1 + \frac{2.12}{1.51836}$$

$$f/f_n = \frac{1.51836 + 2.12}{1.51836}$$

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

$$f = 0.023$$

Pressure gradient

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

$$\left(dP/dx\right)_f = 16.2185 \qquad 0.113 \, Pa/ft$$

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

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

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

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

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

$Z = \cancel{0.835}\ 0.85$

Therefore.

$$U_{sg} = \frac{4}{\pi \times \left(\frac{3}{12}\right)^2 ft^2} \times \left(\frac{500,000 \times 0.850}{86400}\right)\left(\frac{580}{520}\right)\left(\frac{14.7}{1000}\right)$$

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

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

$$= 3.697\ ft/sec$$

To get Beggs Brill reading, use the formular

$$N_{Fr} = \frac{U_m^2}{g D} , \quad \lambda_L = \frac{U_{sL}}{U_m}$$

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

$$\lambda_L = \frac{U_{sL}}{U_m} = \frac{5.30}{44.32} = \underline{0.12}$$

Therefore the reading is

~~Horizontal~~

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

Recall that.

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

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

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

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

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

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

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

$$L_4 = 0.5 \times (0.12)^{-6.738} = 800,657.42$$

The flow regime transition is ~~a~~ ~~distributed~~ flow because

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

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

$$\rho_k = \frac{55.93 \times 0.12^2}{0.15} + \frac{0.654 \times 0.2805^2}{(1 - 0.15)}$$

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

Next. Calculate N_{Rek}.

$$N_{Reh} = \frac{\rho_k U_m D}{\mu_m} = \cancel{0.774 \times 44.33 \times 0.25}$$

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

$$461433.1437 \times \boxed{\frac{44.33}{0.0250}}$$

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

Next Calculate. f_n.

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

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

$$f_n = \underline{\underline{0.00680}}$$

$$\ln(\lambda_L)$$

$$f_n \;\; 1.281 - 0.478 \ln(\lambda_L) + 0.444 [\ln(\lambda_L)]^2 + 0.094 [\ln(\lambda_L)]^3$$
$$+ 0.00843 [\ln(\lambda_L)]^4$$

Question - 4

297.6032

Choke Performance Curves 188.706

Assume GLR to be 500scf/bbl

Choke Sizes 8/64, 12/64, 16/64

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

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

Using the Gilbert Correlation.

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

For 8/64 Choke size.

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

$$P_{LF} = 5.84 q_L$$

For 16/64 Choke size.

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

$$P_{LF} = 1.577 q_L$$

For 12/64 Choke size

$$P_{LF} = \frac{10 \times q_L \times (500)^{0.546}}{(12)^{1.89}} = \frac{297.6032 q_L}{104.56}$$

$$P_{LF} = 2.718 q_L$$

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 further 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
by Baker (1953) modified to Scott (1913,
[illegible] and [illegible]

GOR = 500 scf/bbl

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

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

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

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

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

To get z-Factor

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

From the Chart $z = 0.96$.

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

$$U_{sg} = \frac{4}{\pi\times(3/12)^2}\times\left[\frac{2\times10^6\times0.96}{86400}\right]\left[\frac{610}{520}\right]\left[\frac{14.7}{200}\right]$$

$$U_{sg} = \frac{68,866,560,000}{1,764,318,434.25103} = 39.038\ ft/sec$$

[illegible] $= 39.03 + 5.30 = 44.33\ ft/sec$

Mandhane et al (1974)
Beggs and Brill Correlation.

Froude number against liquid fraction
- Taitel and Dukler (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

$$q = CA\sqrt{\frac{2g_c \Delta P}{\rho}}$$

C = Co-efficient of the choke

$$A = C.6, \quad q = 22000C(D_2)^2\sqrt{\frac{\Delta P}{\rho}}$$

Choke is diameter in inches