[illegible]
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Question no. 2

Parameters:

$q_L = 500\ bbl/d$

$Gas = 1000\ scf/bbl$

$\sigma_L = 30\ dyne/cm$

$T = 120°F = 580°R$

$P = 1000\ psia$

$Z = f\left(580/395, \frac{1000}{667}\right) = 0.85$

$\gamma_o = 32° API$

$\gamma_g = 0.71$

$D = 2\ inch$

$\mu_L = 2\ cp$

$T_{pc} = 395°R$

$P_{pc} = 667\ psia$

$\rho_g = ?$

$\rho_L = ?$

$\mu_g = 0.0131$

Baker's Correlation

$A = (\pi/4)(2/12)^2$

$A = 0.02182\ ft^2$

$\rho_g = \frac{28.97\gamma_g P}{ZRT} = \frac{28.97 \times 0.71 \times 1000}{0.85 \times 10.73 \times 580} = 3.89\ lbm/ft^3$

$\gamma_o = \frac{141.5}{32 + 131.5} = 0.865$

$\rho_o = 0.865 \times 62.4 = 54\ lbm/ft^3$

$u_{sL} = \frac{q_L}{A} = \frac{500 \times 5.615}{86400 \times 0.02182} = 1.4892\ ft/s$

$u_{sg} = \frac{4}{\pi D^2} \times q \times Z \times \left(\frac{T}{T_{sc}}\right) \times \left(\frac{P_{sc}}{P}\right)$

$u_{sg} = \frac{4}{\pi (2/12)^2} \times \frac{500000}{86400} \times 0.85 \times \frac{580}{520} \times \frac{14.7}{1000}$

$u_{sg} = 3.697\ ft/s$

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

$$\lambda = \left[\left(\frac{3.89}{0.075}\right)\left(\frac{54}{62.4}\right)\right]^{1/2}$$

$$\lambda = 6.6996$$

$$\phi = \frac{73}{\sigma_L}\left[\mu_L\left(\frac{62.4}{\rho_L}\right)^2\right]^{1/3}$$

$$= \frac{73}{20}\left[2\left(\frac{62.4}{54}\right)^2\right]^{1/3}$$

$$\phi = 5.064$$

$$Q_g = u_{sg} \times \rho_g$$

$$= 3.697 \times 3.89 \times 3600 = 5.1773 \times 10^4$$

$$Q_L = u_{sL} \times \rho_L$$

$$= 1.4892 \times 54 \times 3600 = 2.895 \times 10^5$$

$$\frac{Q_g}{\lambda} = \frac{5.1773 \times 10^4}{6.6996} = 7.728 \times 10^3$$

$$\frac{Q_L \lambda \phi}{Q_g} = \frac{2.895 \times 10^5 \times 6.6996 \times 5.064}{5.1773 \times 10^4}$$

$$= 189.71$$

Slug flow (i.e. flow is a function of $\frac{Q_g}{\lambda}$, $\frac{Q_L \lambda \phi}{Q_g}$) (Baker's map).

Mandhane

Flow = (u_{sL}, u_{sg})

u_{sL} = 1.4892 ft/s

u_{sg} = 3.697 ft/s

Flow Mandhane flow map

Flow regime = slug flow

Beggs & Brills

Flow = f(N_{FR}, λ_L)

$$N_{FR} = \frac{u_m^2}{gD}$$

[illegible]

$1.4892 + 3.697 = 5.1862$ [illegible]

[illegible]

[illegible]

$N_{...} = \frac{5.1862^2}{32.17 \times ^3/_{12}} = 5.0165$

$\lambda_L = \frac{u_{sL}}{u_{sL} + u_{sg}} = \frac{1.4892}{1.4892 + 3.697}$

$\lambda_L = 0.287$

flow regime = Intermittent

QUESTION 3

Parameters

$q_o = 4000\,bbl/d$

$GOR = 500\,scf/bbl$

$D = 3\,inches$

$\varepsilon = 0.001$

$T = 150°F = 610°R$

$P = 200\,psia$

$\sigma_L = 20\,dynes/cm$

$\gamma_o = 32°API$

$\gamma_g = 0.71$

$\mu_L = 2cP$

$\mu_g = 0.0131cP$

$T_{pc} = 395°R$

$P_{pc} = 667\,psi$

Derived parameters

$Z = f\left(\frac{610}{395}, \frac{200}{667}\right) = 0.97$

$A = (\pi/4)(3/12)^2 = 0.0491\,ft^2$

$\gamma_o = \frac{141.5}{32 + 131.5} = 0.865$

$\rho_L = 0.865 \times 62.4 = 54\,lbm/ft^3$

$\rho_g = \frac{28.97 \gamma_g P}{ZRT} = \frac{28.97 \times 0.71 \times 200}{0.97 \times 10.73 \times 610} = 0.648\,lbm/ft^3$

$q_g = GOR \times q_L$

$q_g = 500 \times 4000 = 2 \times 10^6\,ft^3/d$

Beggs & Brill method

Flow regime calculation

$U_{sL} = \frac{q_L}{A} = \frac{[illegible] \times 5.61}{86400 \times 0.0491} = 5.29446 \text{ ft/s}$

$U_{sg} = \frac{4}{\pi D^2} \times q_g \times 0.0283 \times \left(\frac{T}{T_{sc}}\right) \times \left(\frac{P_{sc}}{P}\right)$

$= \frac{4}{\pi\left(\frac{3}{12}\right)^2} \times \frac{2 \times 10^6}{86400} \times 0.0283 \times \frac{610}{520} \times \frac{14.7}{200}$

$U_{sg} = 39.4395 \text{ ft/s}$

$U_m = U_{sL} + U_{sg} = 39.4395 + 5.2944 = 44.7339$

$\lambda_L = \frac{5.2944}{44.7339} = 0.11835$

$N_{FR} = \frac{U_m^2}{gD} = \frac{44.7339^2}{32.17 \times 3/12} = 248.818$

$L_1 = 316 \times (0.11835)^{0.302} = 165.876$

$L_2 = 0.0009252(0.11835)^{-2.4684} = 0.1795$

$L_3 = 0.1(0.11835)^{-1.4516} = 2.2151$

$L_4 = 0.5(0.11835)^{-5.738} = 104023.273$

Flow is distributive since $\lambda_L < 0.4$ & $N_{FR} \geq L_1$

Hold-up calculation

$y_L = y_{L0}\psi$

$y_{L0} = \frac{a\lambda_L^b}{N_{FR}^c}$

$y_{L0} = \frac{1.065 \times (0.11835)^{0.5824}}{248.818^{0.0609}}$

$y_{L0} = \frac{0.3073}{1.3993} = 0.21961$

$\rho_m = \rho_L\lambda_L + \rho_g\lambda_g$ Note: $\lambda_g = 1 - \lambda_L$

$\rho_m = 54 \times 0.11835 + 0.648 \times 0.88165$

$\rho_m = 6.962216 \text{ lbm/ft}^3$

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

$= 7 \times 0.11835 + 0.0131 \times 0.88165$

$= 0.84825$

$N_{Rem} = \frac{\rho_m U_m d}{\mu_m} = \frac{6.9672 \times 14.47344 \times 3/12}{6.72 \times 10^{-4} \times 0.846875}$

$N_{Rem} = \frac{9.3462291}{2.002 \times 10^{-5}}$

$N_{Rem} = 466,726.96$

$\simeq 4.7 \times 10^5$

$F_n = 0.006$

Calculating x, S, f_{tp}

$x = \frac{\lambda_L}{y_{L\theta}^2} = \frac{0.11835}{0.21961^2} = 2.454$

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

$S = \frac{0.89772}{2.8042 - 0.7031 + 0.012}$

$S = \frac{0.89772}{2.1131} = 0.4248$

$f_{tp} = f_n e^S$

$f_{tp} = 0.006 \times e^{0.4248}$

$f_{tp} = 9.1757 \times 10^{-3}$

$= 0.009176$

Frictional Pressure gradient calculation

$\left(\frac{dp}{dz}\right)_F = \frac{2 f_{tp} \rho_m U_m^2}{g_c d}$

$\frac{\Delta P}{\Delta Z}$ = [illegible]

$\frac{\Delta P}{\Delta Z}$ = [illegible] lb/ft^3

$\frac{\Delta P}{\Delta Z}$ = [illegible] $\times$ [illegible]

$\frac{\Delta P}{\Delta Z}$ = [illegible] psi/ft //

Gaston Correlation

Calculation of mass flow rate

$\bar{m}_L = q_L \rho_L$

$q_L = 4000 \frac{bbl}{d} \times \frac{5.615 ft^3}{86400} = 0.26 ft^3/s$

$\bar{m}_L = 0.26 ft^3/s \times 54 lbm/ft^3 = 14.035 lbm/s$

$\bar{m}_g = q_g \rho_g$

$q_g = A \times U_{sg} = 0.0491 \times 39.2 [illegible] = 1.936$

$\bar{m}_g = q_g \rho_g = 1.936 \times 0.648 = 1.255 lbm/s$

$\bar{m}_m = \bar{m}_L + \bar{m}_g = 14.035 + 1.255$

$\bar{m}_m = 15.293 lbm/s$

Gas Viscosity (μ_g)

$\mu_g = 0.0131 \times 6.72 \times 10^{-4}$

$= 8.8 \times 10^{-6} lbm/ft\text{-}sec$

Calculating F

$\frac{(0.057)(\bar{m}_g \bar{m}_m)^{0.5}}{\mu_g D^{2.25}}$

$\frac{0.057 \times (1.255 \times 15.293)^{0.5}}{8.8 \times 10^{-6} (3/12)^{2.25}}$

$= 6.42 \times 10^5$

as from fig 10.6 $f \left(\frac{\bar{m}_L}{\bar{m}_g}\right)^{0.5} = 0.02$

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$f = \frac{0.25}{\left(\frac{14.035}{15.293}\right)^{0.1}} = 0.0202$

$\left(\frac{\partial p}{\partial x}\right)_f = \frac{f \rho_m u_m^2}{2 g_c D}$

$= \frac{0.0202 \times 6.9622 \times 44.2234^2}{2 \times 32.17 \times (3/12)}$

$= 17.6014\ lf/ft^3$

$= 0.122\ psi/ft$

Duckler Correlation

$\frac{dp}{dx} = \left(\frac{\partial p}{\partial x}\right)_f + \left(\frac{\partial p}{\partial x}\right)_{KE}$

Frictional Pressure drop

$\left(\frac{dp}{dx}\right)_F = \frac{f \rho_K u_m^2}{2 g_c D}$

$\rho_K = \frac{\rho_L \lambda_L^2}{y_L} + \frac{\rho_g \lambda_g^2}{y_g}$

& $N_{ReK} = \frac{\rho_K u_m D}{\mu_m} = N_{Rem}\left(\frac{\rho_K}{\rho_m}\right)$

Assuming $\lambda_L = y_L$

$\rho_K = \rho_m$

$N_{Rem} = N_{ReK}$

$\lambda_L = y_L = 0.11835$

$\rho_K = \frac{54 \times 0.11835^2}{0.11835} + \frac{0.648 \times 0.88165}{0.88165}$

$\rho_K = 6.9621\ lbm/ft^3$

$N_{ReK} = 4.7 \times 10^5 \left(\frac{6.962}{6.9622}\right) = 4.7 \times 10^5$

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

$= 0.0056 + 0.5 (4.7 \times 10^5)^{-0.32}$

$= 0.013$

$$\frac{f}{f_n} = 1 - \left([illegible] \right)$$

$$\frac{f}{f_n} = 1 \left(\frac{[illegible]}{[illegible]} \right)$$

$$\frac{f}{f_n} = 1-(-1.3818) = 2.3818$$

$f = f_n \times 2.3818$

$f = 0.013 \times 2.3818$

$f = 0.31$

$$\left(\frac{\partial P}{\partial x}\right)_f = \frac{f \rho_m U_m^2}{2 g_c D}$$

$$= \frac{0.013 \times 6.962 \times 44.7329^2}{2 \times 32.17 \times 0.25}$$

$= 11.261 \, lbf/ft^2 = 0.078 \, psi/ft$ //

QUESTION 1

* 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 correlation Consider flow regime. flow regime can be classified into Segregated flow (the Phases are for the most Part separated). Intermittent flow (Gas & Liquid are alternating). Distributed flow in which one Phase is dispersed in the other phase.

QUESTION 4

Restricted flow refers to flow of fluid under a choke used to control flow due to many factors such as Prevention of the chances of Sand Production. 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. flow rate is related to pressure drop across choke by $q = CA\sqrt{\frac{2g_c \Delta P}{\rho}}$ where C = flow coefficient of the choke & A = cross-sectional Area of the choke.