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MATRIC no. 15/ENG07/021

1) $q_o = 500\ bbl/day$

I.D = 2"

Temp = 120°F = 580°R

Pressure = 1000 psi

$q_L = ?$

GOR = 1000 scf/bbl

To Calculate Area $= \frac{\pi d^2}{4} = \frac{3.142\,(2/12)^2}{4} = 0.02182\ ft^2$

$U_{sL} = \frac{q_L}{A} = \frac{\frac{500 \times 5.615\ ft^3}{86400}}{0.02182} = 1.48 ft/s$

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

$q_g = 1000 scF/bbl \times 500 bbl/day = 500,000 scf$

using the Z chart, Z = 0.85

Therefore

$U_{sg} = \frac{4}{\pi \times (7/12) ft^2} \times \left(\frac{500,000 \times 0.850}{86400}\right)\left(\frac{580}{520}\right)\left(\frac{14.7}{1000}\right)$

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

$U_{sg} = \frac{14{,}414{,}200{,}000}{3{,}920{,}417{,}280}$

$= ~~4.0~~ \; 3.677 \; ft/sec$

$U_m = U_{sL} + U_{sg} = 1.481 + 3.697 = 5.141 \; ft/sec$

Calculation of Baker flow regime

$\gamma_o = 32°API$

$\gamma_g = 0.71$

$\therefore \gamma_o = \frac{141.5}{S.G} - 131.5$

$\therefore S.G = 0.865$

$\rho_L = 0.865 \times 62.4 = 53.96 \; lbm/ft^3$

For Gas

$\gamma_g = 0.71$

$\therefore \rho_g = \frac{2.7 \times \gamma_g \times P}{ZT} = \frac{2.7 \times 0.71 \times 1000}{0.85 \times 580}$

$\rho_g = 3.88 \; lbm/ft^3$

$G_L = U_{sL} \rho_L$

$G_g = U_{sg} \rho_g$

$G_L = (1.48 \; ft/s)(53.96 \; lbm/ft^3)(3600 \; sec/hr)$

$= 287498.88 \; lbm/hr \cdot ft^2$

$G_g = (3.69 \; ft/s)(3.88 \; lbm/ft^3)(3600 \; sec/hr)$

$= 51{,}541.92 \; lbm/hr \cdot ft^2$

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Also to get λ and ϕ

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

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

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

$$= \left[44.7360\right]^{1/2} = 6.688$$

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

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

The Coordinates for the Baker map are

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

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

The map show SLUG FLOW

From the Mandhane map $U_{SL} = 1.48$ ft/s, $U_{Sg} = 3.67$ ft/sec

— SLUG FLOW

From the Beggs & Brills map

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

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

$= 4.99$

$\lambda_L = \frac{U_{sL}\ 1.48}{5.176} = 0.286$

from the values above the Beggs & Brill Map predict

– INTERMITTENT FLOW

QUESTION 2

$q_o = 4000\ bbl/day$

$q_g = ?$

$D = 3''$

$\sigma = 20\ dynes/cm$

Temp = 150°F = 610°R

Pressure = 200 psig

GOR = 500 scf/bbl

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

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

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

To Calculate the gas flowrate

GOR = 500 scf/bbl

$\therefore q_g = 500\ scf/bbl \times 4000\ bbl/day = 2mmscf/day$

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

$\therefore Z = 0.96$

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

$= 39.033\ ft/sec$

$U_m = 39.033 + 5.30 = 43.33\ ft/sec$

Using the N_{Fr} formula to get beggs & brill pattern

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

$$N_{Fr} = \frac{(43.33)^2}{32.17 \times (3/12)} = 244$$

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

Calculating the hold up

$L_1 = 316 \lambda_L^{0.302}$

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

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

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

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

$L_2 = 0.0009252(0.12)^{-2.4684} = 0.1734$

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

$L_4 = 0.5(0.12)^{-6.738} = 800,657.4$

The flow regime is therefore DISTRIBUTED FLOW

since $\lambda_L < 0.4$ and $N_{FR} > L_1$

From the hold-up constants

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

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

$$= 0.22163$$

The No slip fraction

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

$\lambda_L = 0.12$, $\lambda_g = \frac{u_{sg}}{u_m} = \frac{39.035}{44.33} = 0.8805$

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

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

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

$$\rho_m = 53.96(0.12) + 0.654(0.8805)$$

$$= 7.050847\ lbm/ft^3$$

The Reynolds number

$$N_{Re} = \frac{1.488 \rho}{D \mu}$$

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

$$= 2(0.12) + 0.0131(0.8805)$$

$$= 0.252$$

$$N_{Re\,m} = \frac{\rho_m u_m D}{\mu_m} = \frac{7.05084 \times 44.33 \times (3/12)}{0.252 \times 6.72 \times 10^{-4}} = 461,433.14$$

To Calculate x, S, F_{tp}

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

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

$S = \frac{0.92}{|-0.0523 + 3.182(0.92) - 0.8725(0.92)^2 + 0.01853(0.12)|}$

$= 0.4271$

$F_{tp} = F_n e^S = 0.006 \times e^{0.4271} = 0.009176$

Calculating $(dP/dz)_f$

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

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

$= 32.01\, lbm/ft^3 \Rightarrow \frac{32.01}{144} = 0.22\, Psi/ft$

From Fig 10.6

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

$F = \frac{0.02}{\left(\frac{14.03}{15.283}\right)} = 0.0201$

$\left(\frac{dP}{dz}\right)_f = \frac{F \rho_m U_m^2}{2 g_c D} \Rightarrow$ pressure gradient

$= \frac{0.0201 \times 7.050 \times (44.33)^2}{2 \times 32.17 \times 0.25}$

$= \frac{~~17.0767~~\ 17.016\ lb/ft^3}{144\ ft^3}$

$= 0.12\ psi/ft$

For Duckler Correlation

assuming $Y_L = \lambda_L$, $\rho_o = \rho_m$

$N_{Rem} = N_{Rom}$

$Y_L = \lambda_L = 0.15$

$\rho_K = \rho_m$

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

$Y_g = 1 - Y_L$

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

$$\rho_K = \frac{53.93 \times 0.12^2}{0.15} + \frac{0.654 \times 0.8605^2}{(1-0.15)}$$

$= 5.774\ lbm/ft^3$

$\therefore N_{ReK} = \frac{~~\rho_K U_m D~~}{~~\mu_m~~}\ \frac{N_{Rem}\ U_m}{\mu_m}$

$= 461433.1437 \times \left(\frac{44.33}{0.0250}\right)$

$= 818213250.4088$

To Calculate F_n

$F_n = 0.0056 + 0.5\,(N_{ReK})^{-0.32}$

$= 0.0056 + 0.5\,(818213250.4088)^{-0.32}$

$= 0.00630$

$$\frac{F}{F_n} = 1 - \frac{\ln(\lambda_L)}{1.281 + 0.478\ln(\lambda_L) + 0.444(\ln(\lambda_L))^2 + 0.094(\ln(\lambda_L))^3 + 0.00843(\ln(\lambda_L))^4}$$

$$= 1 - \frac{\ln(0.12)}{0.2665 + 1.9730 - 0.3959 + 0.1636}$$

recall, $F_n = 0.00630$

$1.51836F = (1.51836 + 2.12)0.00630$

$F = 0.023$

Pressure gradient

$$\left(\frac{dP}{dz}\right)_F = \frac{F \rho_k U_m^2}{2 g_c D} = \frac{0.023 \times 8.77 \times 44.33}{2 \times 32.17 \times 0.25}$$

$= 16.2135\ lbm/ft^3$

$= 0.113\ psi/ft$

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4.) Restricted flow refers to the flow of fluid through a choke used to control flow due to many factors such as prevention of causes of sand production. Fluid flowing through a choke may be accelerated to reach sonic velocity in the of the choke. This is the critical condition. As downstream pressure of choke does affect the flowrate

For single phase liquid flow through the choke, it is rare and the flowing pressure is below bubble point. However, in the event that it happens, the pressure drop is given by

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

C = Coefficient of choke

A = Cross sectional area

$$q = 22000\,C(D_2)^2\left(\frac{\Delta P}{\rho}\right)$$

D = Diameter

HORIZONTAL MULTIPHASE FLOW

The flow in horizontal pipes is different from vertical in multiphase flow. The P.E is constant in horizontal flow, so it has no effect

~~FLOW Regime~~

SEGREGATED FLOW - In this type of flow the two phases are seperate for the most part. It is also divided into two

* Stratified smooth - liquid flow along the bottom of the gas
* Stratified wavy - also known as annular

Intermittent - Gas & Liquid are alternating. It is divided into High Liquid slugs and high velocity gas bubbles plug

Distributed flow - In this flow, one phase is dispersed in the othe