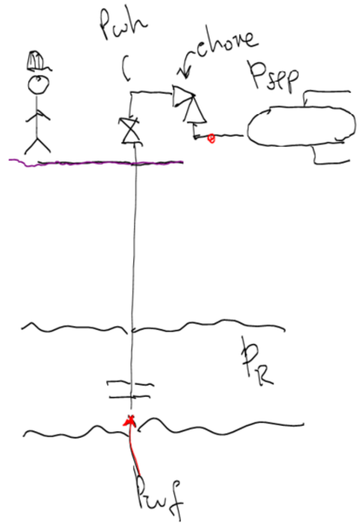
PROBLEM 1 (47 POINTS).

Consider the dry gas production system shown in the figure below:



An excel file is provided with all the information and VBA functions you need to make your calculations. Assume the model used to represent the IPR of the formation is the backpressure equation. Assume that the model used to represent the TPR is the dry gas tubing equation.

Task 1. (10 POINTS) If the well is producing a dry gas rate of 1 E5 Sm^3/d, and wellhead pressure is 80 bara, estimate the backpressure coefficient of the formation. Assume n= 1.

The Excel file provides the behavior of the term $\frac{1}{\mu_g \cdot B_g}$ versus pressure. Assess if using the back-pressure equation is appropriate or not in this case.

Explain your answer.

Task 2. (12 POINTS) Consider that the sensor of the wellhead pressure is damaged and unavailable. The only information available is pressure downstream the choke (40 bara), choke opening (9.4 mm) and rate of 1 E5 Sm^3/d. Is it still possible to estimate the backpressure coefficient of the formation? Is the choke operating in the critical or subcritical regime?

Explain your answer.

Task 3. (13 POINTS) Assume reservoir pressure has changed to 100 bara. Estimate choke adjustment (new value of choke opening) to ensure the dry gas rate remains constant. Use the values of dry gas IPR estimated in task 2. Is the choke operating in the critical or subcritical regime?

Explain your answer.

Task 4 (12 POINTS). At this new reservoir pressure, you are concerned about liquid loading. Check if there could be risk of liquid loading at well bottom, using the Turner equation:

$$v_{gc} = 5.46 \cdot \left(\frac{(\rho_L - \rho_G) \cdot \sigma_{LG}}{\rho_G^2} \right)^{1/4}$$

Assume that liquid density is 1000 kg/m3, and interfacial tension liquid-gas is 0.028 N/m. Assume the tubing inner diameter is 0.07 m.

Explain your answer.

Additional information:

Dry gas low pressure IPR equation (backpressure equation), assuming Darcy flow (n=1):

$$q_{\bar{g}} = C_R \cdot \left(p_R^2 - p_{wf}^2\right)$$

This equation is available as several VBA functions, with names "IPRqg", and "IPRpwf"

Dry gas IPR equation, assuming Darcy flow:

$$q_{\bar{g}} = C_R \cdot \int_{p_{wf}}^{p_R} \frac{1}{\mu_g \cdot B_g} dp$$

Dry gas tubing equation:

$$q_{\bar{g}} = C_T \cdot \left(\frac{p_{wf}^2}{e^S} - p_{wh}^2\right)^{0.5}$$

This equation is available as several VBA functions, with names "Tubingqg", "Tubingp1" and "Tubingp2"

Dry gas choke equation:

$$q_{\bar{g}} = \frac{p_1 \cdot T_{sc} \cdot A_2 \cdot C_d}{p_{sc}} \cdot \sqrt{2 \cdot \frac{R}{Z_1 \cdot T_1 \cdot M_w} \cdot \frac{k}{k-1} \cdot \left(y^{\frac{2}{k}} - y^{\frac{k+1}{k}}\right)}$$

With 1 referring to the inlet, and $y = p_2/p_1$. This equation is available as a VBA function with the name: "Orificerate_metric"

With the critical gas pressure ratio:

$$y_c = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

k is the adiabatic constant. This equation is available as a VBA function with the name: "Criticalratio"

the following VBA functions are provided to estimate dry gas properties:

- ZfacStanding: gas deviation factor
- Bg: gas volume factor
- deng: gas density

SOLUTION:

SEE EXCEL FILE ATTACHED

PROBLEM 2. (40 POINTS)

A pressure survey has been performed in a producing oil well (production rate of 1394 Sm3/d, GOR = 155.1 and water cut of 30%), and pressure and temperature at several depths have been recorded. The values are provided in the Excel file attached. Assume that the water density is constant and equal to 1000 kg/m^3, the water viscosity is constant and equal to 0.6 cP, and the liquid-gas interfacial tension is constant and equal to 0.01 N/m. Assume there is no slip between the oil and water.

Task 1 (25 POINTS). Calculate the following parameters along the well:

- Non-slip gas volume fraction
- Gas void fraction
- Liquid and gas real velocities
- The gas-liquid slip ratio
- The hydrostatic pressure gradient

Task 2 (5 POINTS). Is it important to consider the effect of r_s in your calculations? Can it be neglected?

Task 3. (10 POINTS) Consider that gas lift is applied to the bottom of the well (rate of 300 000 Sm^3/d), and the temperature and pressure is 93 C and 160 bar bara. The oil rate is 1450 Sm3/d. Can the table provided be used to estimate black oil properties for these conditions? If they can, estimate local rates of oil and gas.

Useful information:

- ε is the gas void fraction, equal to:

$$\varepsilon = \frac{A_g}{A_l + A_g}$$

A VBA function named “e_simpson” is provided to calculate the void fraction using the gas density, liquid density, and non-slip gas volume fraction (λ_g).

- The following matrix to convert from standard conditions to local conditions

$$\begin{bmatrix} q_g \\ q_o \\ q_w \end{bmatrix} = \begin{bmatrix} \frac{B_g}{1 - R_s \cdot r_s} & \frac{-R_s \cdot B_g}{1 - R_s \cdot r_s} & 0 \\ \frac{-B_o . r_s}{1 - R_s \cdot r_s} & \frac{B_o}{1 - R_s \cdot r_s} & 0 \\ 0 & 0 & B_w \end{bmatrix}_{(p,T)} \cdot \begin{bmatrix} q_{\bar{g}} \\ q_{\bar{o}} \\ q_{\bar{w}} \end{bmatrix}$$

There are two VBA functions available in the Excel sheet: “qg_local”, to calculate local gas rates from SC oil and gas rates and black oil properties and “qo_local”, to calculate local oil rates from SC oil and gas rates and black oil properties

- A VBA function called "TwoDimInterpol" is provided to find BO properties at any p-T by interpolating on the table provided on the sheet "BO_tables"

SOLUTION:

SEE EXCEL FILE ATTACHED

1. (3 POINTS) What is a coupling?

A short pipe section with two threaded ends that join tubing or casing pipe together.

2. (5 POINTS) what is the casing hanger and what is it's function?

An assembly that is attached to the top of the casing and seats on the bowl of the casing head.

The casing hanger has two main functions: carry the load of the casing string and transfer it to the conductor (via casing head or casing spool) and make a seal between the inside and the outside, to protect the low pressure rating outer casing from high pressures.

True or false:

- (2 POINTS) Well IPR (pwf versus qsc) of gas, saturated oil, and undersaturated oil with significant wellbore pressure drop are non-linear. TRUE
- (2 POINTS) The master valve can be opened half-way to regulate the flow. FALSE
- (1 POINT) IPRs are typically derived assuming boundary dominated flow, constant pressure boundary (steady state regime) or no flow boundary (pseudo steady state regime). The derivation is made departing from Darcy's law and separating variables. When deriving analytically an IPR, the oil or gas volume factor appear in the equation, because Darcy's law applies with local rates, but we often wish to express IPR in terms of standard conditions rate. TRUE