EXAMINATION 2017

Fundamentals of Oil and Gas Engineering

Politecnico di Milano

3rd July 2017, 14:15-17:15

Answer any THREE questions

1. Material balance for a gas field *(50 marks total)*

(i) Draw phase diagrams of a dry gas, wet gas, gas condensate, near-critical oil and a black oil field with the same reservoir and surface conditions. Explain briefly the behaviour of these reservoirs as the pressure drops, and list the likely composition of the hydrocarbon in the different reservoirs. *(20 marks)*

(ii) You have the following production data for a gas field that might be produced by a natural water drive.

G_p (10^6 scf)	Pressure (MPa)	B_g (rb/scf)
0	40	0.000456
150	39	0.000481
450	38	0.00055
630	37	0.000598
800	36	0.000657

The initial water saturation is 0.21 and the residual gas saturation, from laboratory measurements, is 0.34.

The material balance equation is:

$$G_p = G\left(1 - \frac{B_{gi}}{B_g}\right) + \frac{W_e}{B_g}$$

Assuming a simple aquifer model, make an approximate estimate of the original gas in place and the value of the aquifer size times the aquifer compressibility. You may neglect the compressibility of the connate water and rock in the gas field itself. *(18 marks)*

(iii) What is the recovery factor now? What is the average gas saturation in the field? What is the pressure drop necessary for water influx to invade the whole field? Comment on these answers carefully: how should the field be managed? *(12 marks)*

2. You measure the following from appraisal wells in an oilfield: *(50 marks total)*

Depth (m)	Pressure (MPa)	Fluid and density (kg.m^{-3})
2,500	34.51	Gas, 360
2,620	35.08	Oil, 634
2,857	37.21	Water, 1,067

The acceleration due to gravity = 9.81 ms^{-2}. Depths are measured from the surface.

(i) Is the reservoir normally pressured, over pressured or under pressured? Explain your answer. *(4 marks)*

(ii) Find the depths of the free oil and free water levels. Hence find the height of the oil column. *(18 marks)*

(iii) Log measurements in the field suggest the presence of water between 2,590 m and 2,610 m, and below 2,695 m. How can you reconcile this with the results in part (ii)? *(14 marks)*

(iv) The average cross-sectional area of the field is 10 km^2, while the average porosity and water saturation in the hydrocarbon-bearing zones is 0.21 and 0.32 respectively. The oil formation volume factor is 1.5. Estimate the original oil in place and explain your working clearly. *(14 marks)*

3. Buckley-Leverett analysis. *(50 marks total)*

(i) Does Buckley-Leverett analysis quantify sweep efficiency or local displacement efficiency? Explain your answer while defining both these terms. *(11 marks)*

(ii) Explain how you can use the results of Buckley-Leverett analysis combined with field production data to estimate sweep efficiency. Use a diagram to explain your reasoning and list what other information is needed. *(12 marks)*

(iii) Plot the relative permeability curves shown below, as well as the corresponding fractional flow. *(12 marks)*

$$k_{rw} = 5(S_w - 0.25)^3$$

$$k_{ro} = 3(S_o - 0.2)^2$$

μ_o = 0.002 Pa.s

μ_w = 0.001 Pa.s

(iv) Calculate the saturation as a function of dimensionless velocity and the pore volumes produced as a function of pore volumes injected. Plot your answers on a graph. *(15 marks)*

contd.

4. Material balance for an oilfield. You are given the following data for an oilfield that is being produced under primary production. *(50 marks total)*

N_p (MMstb)	G_p (MMscf)	P (MPa)	R_s (scf/stb)	B_o (rb/stb)	B_g (rb/scf)
0	0	32	400	1.356	0.000187
1.41	480	30	400	1.361	0.000199
1.98	1568	28	370	1.355	0.000213
3.41	3016	26	345	1.349	0.000251
5.78	6890	24	295	1.335	0.000302

(i) In this field, are we producing above or below the bubble point and why? *(4 marks)*

(ii) Define R, R_s and R_p. *(6 marks)*

(iii) From the material balance equation below, find the size of the oilfield and the relative size of the gas cap (if any). You may assume that there is no active aquifer and can ignore the compressibility for the formation. *(18 marks)*

$$N_p\left(B_o+\left(R_p-R_s\right)B_g\right)=$$
$$NB_{oi}\left[\frac{\left(B_o-B_{oi}\right)+\left(R_{si}-R_s\right)B_g}{B_{oi}}+ m\left(\frac{B_g}{B_{gi}}-1\right)+(1+m)\left(\frac{c_wS_{wc}+c_f}{1-S_{wc}}\right)|\Delta P|\right]$$
$$+\left(W_e-W_pB_w\right)$$

(iv) Compare the expansion of oil to the expansion of gas (for the final set of data), to quantify relatively how much recovery is contributed by gas expansion and how much from oil expansion. *(7 marks)*

(v) What options are there for dealing with the produced gas? *(5 marks)*

(vi) What is the recovery factor now? Is this as good as a typical ultimate recovery factor for this type of field? Comment on the relative pressure decline in the field. What further development options would you consider? *(10 marks)*

5. Spontaneous imbibition and relative permeability. *(50 marks total)*

(i) Write down the multiphase extension of Darcy's law, explain all the terms with units. What does relative permeability mean physically? *(7 marks)*

The figure below shows field data of relative permeability from a Middle Eastern carbonate core. The solid line labelled "kr-dr-22" is the primary drainage relative permeability (22 is the name of the sample); this is before wettability alteration and the core is water-wet. The dashed line "kr-Imb-22" is the waterflood relative permeability after wettability alteration. The red square is the final waterfllod relative permeability after flooding at a high flow rate (a so-called bump flood).

(ii) Explain the likely wettability of the core during waterflooding. Describe your answer carefully. *(18 marks)*

(iii) In the legend the waterflood curves are referred to as "imb" for imbibition. Is this correct? Explain using your answer to parts (i) and (ii). *(10 marks)*

(iv) For this set of relative permeabilities discuss the difference in likely local displacement efficiency for waterflooding and spontaneous imbibition. *(15 marks)*