Universitetet i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

FINAL EXAM: MPE 760 Formation Evaluation and Well Testing

DATE: December 9, 2013

DURATION: 4 hours

"TOOLS" ALLOWED: Standard simple calculator (HP30S, Casio FX-82, TI-30 or Citizen SR-270X)

THE SET CONSISTS OF: 3 problems on 9 pages (total)

Problem 1

A drawdown test lasting 24 hours was run in a fractured oil well close to an assumed sealing boundary with a constant flow rate of 3300 STB/D. Use parameters from Table 1, drawdown data from Table 2 (reduced), and plots on the last three pages to answer the questions and carry out the analyses below.

a) Fig. 1 shows a log-log plot of the drawdown data. Identify flow regimes evident in the data, and indicate the range of each (start and end).

b) Fig. 2 shows a semi-log of the drawdown data. Use information from the previous point along with representative data points from Table 2 to determine the true semi-log slope *m*, the flow capacity *kh*, and the permeability *k*.

c) Fig. 3 shows a square-root-of-time plot of early drawdown data. Use representative data points from Table 2 and information from the previous point to determine the slope of early data, the initial pressure p_i and the fracture half-length x_f.

d) Use information from Fig. 3 and available properties to estimate the distance to the nearest boundary. In addition, determine the radius of investigation at the end of the data.

e) Use information above and the assumption that linear-flow data (half-slope data) ends at $t_{Dxf} = \dfrac{0.000264kt}{\varphi \mu c_t x_w^2} = 0.016$ for a fracture with infinite conductivity and at $t_{Dxf} = 0.16$ for a fracture with uniform flux to determine the fracture type in the tested well.

Table 1 – Input parameters for Problem 1

Formation thickness, h	=	59	ft
Porosity, ϕ	=	0.09	
Viscosity, μ	=	1.15	cp
Total compressibility, c_t	=	$2.6\text{x}10^{-5}$	psi^{-1}
Volume factor, B	=	1.23	RB/STB
Wellbore radius, r_w	=	0.35	ft

Table 2 – Drawdown data

Elapsed Time (hrs)	Pressure (psia)	Elapsed Time (hrs)	Pressure (psia)
0.003	6298.5	2.145	6249.4
0.006	6297.8	3.029	6241.8
0.009	6297.3	4.049	6235.2
0.015	6296.5	5.069	6230.0
0.021	6295.9	6.089	6225.7
0.027	6295.3	7.109	6222.0
0.034	6294.7	8.129	6218.8
0.043	6294.1	9.149	6216.0
0.054	6293.3	10.169	6213.4
0.068	6292.5	11.189	6211.1
0.085	6291.6	12.209	6209.0
0.107	6290.4	13.229	6207.1
0.135	6289.1	14.249	6205.3
0.170	6287.6	15.269	6203.6
0.214	6285.8	16.289	6202.0
0.270	6283.6	17.309	6200.5
0.340	6281.1	18.329	6199.1
0.428	6278.3	19.349	6197.8
0.539	6275.1	20.369	6196.6
0.678	6271.5	21.389	6195.4
0.854	6267.6	22.409	6194.2
1.075	6263.4	23.429	6193.1
1.518	6256.6	24.000	6192.5

Problem 2

As part of test design study to determine the benefit of stimulation by fracturing, consider a formation with the properties listed below.

Thickness, h	=	36	m
Permeability, k	=	9.5	md
Porosity, ϕ	=	0.21	
Viscosity, μ	=	0.74	cp
Total compressibility, c_t	=	1.74×10^{-4}	bar^{-1}
Volume factor, B	=	1.27	Rm^3/Sm^3
Wellbore radius, r_w	=	0.108	m
Initial pressure, p_i	=	495	bar

a) Assuming only infinite-acting data, what will the bottom-hole pressure be after 300 hours of flow at a constant rate of 500 Sm^3/d if the well has a skin value of 6?

b) If the well is stimulated with an infinite-conductivity fracture of half-length 130 m, what will the bottom-hole pressure be after the same length of flow at the same rate?

Problem 3

The following data have been taken from a flow-after-flow test of a gas well with high static pressure at 6940 psia.

q_{sc} (Mscf/d)	p_{wf} (psia)
17325	6662
22400	6509
27500	6317
31480	6141

Use the information above to carry out the analyses below. Choose the pressure formulation that is best suited for the given pressure range.

a) Determine the deliverability and AOF potential of the well by using LIT analysis and direct computations without plotting (assume the data to be consistent such that computations can be based on any chosen representative data points).

b) Determine the deliverability and AOF potential of the well by using simple log-log analysis (back-pressure equation) and direct computations without plotting (assume the data to be consistent such that computations can be based on any chosen representative data points).

STANDARD EQUATIONS

$$p_D = \frac{kh}{18.66 qB\mu}\Delta p$$ (SI units, oil)

$$p_D = \frac{kh}{141.2 qB\mu}\Delta p$$ (field units, oil)

$$p_D = \frac{p_r kh}{0.06563 q_{sc} Z_r \mu_r T_r}\Delta p$$ (SI units, gas at high pressure)

$$p_D = \frac{p_r kh}{711 q_{sc} Z_r \mu_r T_r}\Delta p$$ (field units, gas at high pressure)

$$t_D = \frac{0.000355 kt}{\phi\mu c_t r_w^2}$$ (SI units, oil and gas)

$$t_D = \frac{0.000264 kt}{\phi\mu c_t r_w^2}$$ (field units, oil and gas)

$$C_D = \frac{C}{2\pi\phi h c_t r_w^2}$$ (SI units, oil and gas)

$$C_D = \frac{5.615C}{2\pi\phi h c_t r_w^2}$$ (field units, oil and gas)

$$\frac{t_D}{C_D} = \frac{0.002232 kht}{\mu C}$$ (SI units, oil and gas)

$$\frac{t_D}{C_D} = \frac{0.0002951 kht}{\mu C}$$ (field units, oil and gas)

$$C = \frac{qB}{24}\frac{t}{\Delta p} = c_{wb}V_{wb}$$

$$\Delta p = m't = \frac{qB}{24C}t$$

STANDARD EQUATIONS (Contin.)

$$m = \frac{21.49 qB\mu}{kh} \qquad \text{(SI units)}$$

$$m = \frac{162.6 qB\mu}{kh} \qquad \text{(field units)}$$

$$S = 1.151\left(\frac{p_i - p_{1hr}}{m} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.098\right) \qquad \text{(SI units, drawdown data)*}$$

$$S = 1.151\left(\frac{p_{1hr} - p_{wf,s}}{m} - \log\frac{t}{t+1} - \log\frac{k}{\phi\mu c_t r_w^2} + 3.098\right) \qquad \text{(SI units, buildup data)*}$$

*) Field units: replace 3.098 by 3.23.

$$\Delta p_S = \frac{m}{1.151} S$$

$$r_{inv} = 0.0286\sqrt{\frac{kt}{\phi\mu c_t}} \qquad \text{(SI units)}$$

$$r_{inv} = 0.0246\sqrt{\frac{kt}{\phi\mu c_t}} \qquad \text{(field units)}$$

$$d = 0.01412\sqrt{\frac{kt}{\phi\mu c_t}} \qquad \text{(SI units)}$$

$$d = 0.01217\sqrt{\frac{kt}{\phi\mu c_t}} \qquad \text{(field units)}$$

$$p_i - \bar{p} = \frac{m}{1.151} 2\pi t_{DA}$$

$$p_{ws}(\Delta t) = \bar{p} \quad \text{when} \quad \Delta t_e = \frac{\phi\mu c_t A}{0.000355 k C_A} \qquad \text{(SI units)}$$

$$p_{ws}(\Delta t) = \bar{p} \quad \text{when} \quad \Delta t_e = \frac{\phi\mu c_t A}{0.000264 k C_A} \qquad \text{(field units)}$$

STANDARD EQUATIONS (Contin.)

Fractured wells:

$$m' = \frac{0.6236qB}{hx_f}\sqrt{\frac{\mu}{k\phi c_t}}$$ (SI units)

$$m' = \frac{4.064qB}{hx_f}\sqrt{\frac{\mu}{k\phi c_t}}$$ (field units)

$$S = \ln\frac{2r_w}{x_f}$$ (fracture with infinite conductivity)

$$S = \ln\frac{er_w}{x_f} = \ln\frac{2.718r_w}{x_f}$$ (fracture with uniform flux)

Reservoir limit analysis:

$$m' = \frac{0.04167qB}{\phi c_t Ah}$$ (SI units)

$$m' = \frac{0.2339qB}{\phi c_t Ah}$$ (field units)

$$p_0 = p_i - \frac{18.66qB\mu}{kh}\left(\frac{1}{2}\ln\frac{4A}{e^{\gamma}C_A r_w^2} + S\right)$$ (SI units)

$$p_0 = p_i - \frac{141.2qB\mu}{kh}\left(\frac{1}{2}\ln\frac{4A}{e^{\gamma}C_A r_w^2} + S\right)$$ (field units)

$$e^{\gamma} = e^{0.57721..} = 1.781\ldots$$

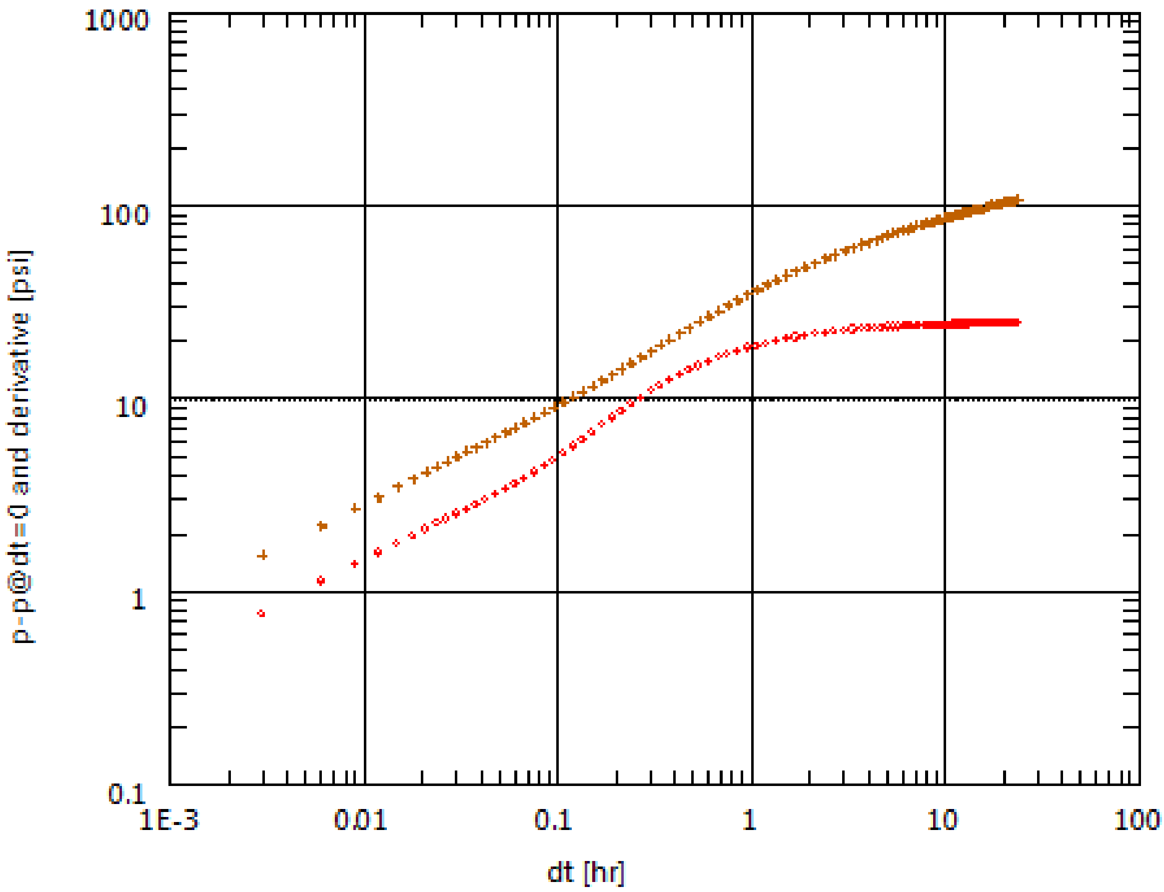
Gas tests:

$$q_{sc} = C(\overline{p}^2 - p_{wf}^2)^n$$ (simplified deliverability, p^2 formulation)

$$\overline{p}^2 - p_{wf}^2 = aq_{sc} + bq_{sc}^2$$ (LIT based deliverability, p^2 formulation)

$$\text{AOF} = \frac{1}{2b}\left(-a + \sqrt{a^2 + 4b\overline{p}^2}\right)$$ (LIT based AOF, p^2 formulation)

Fig. 1



1000
100
10
1
0.1
1E-3
0.01
0.1
1
10
100
dt [hr]
p-p@dt=0 and derivative [psi]

Fig. 2

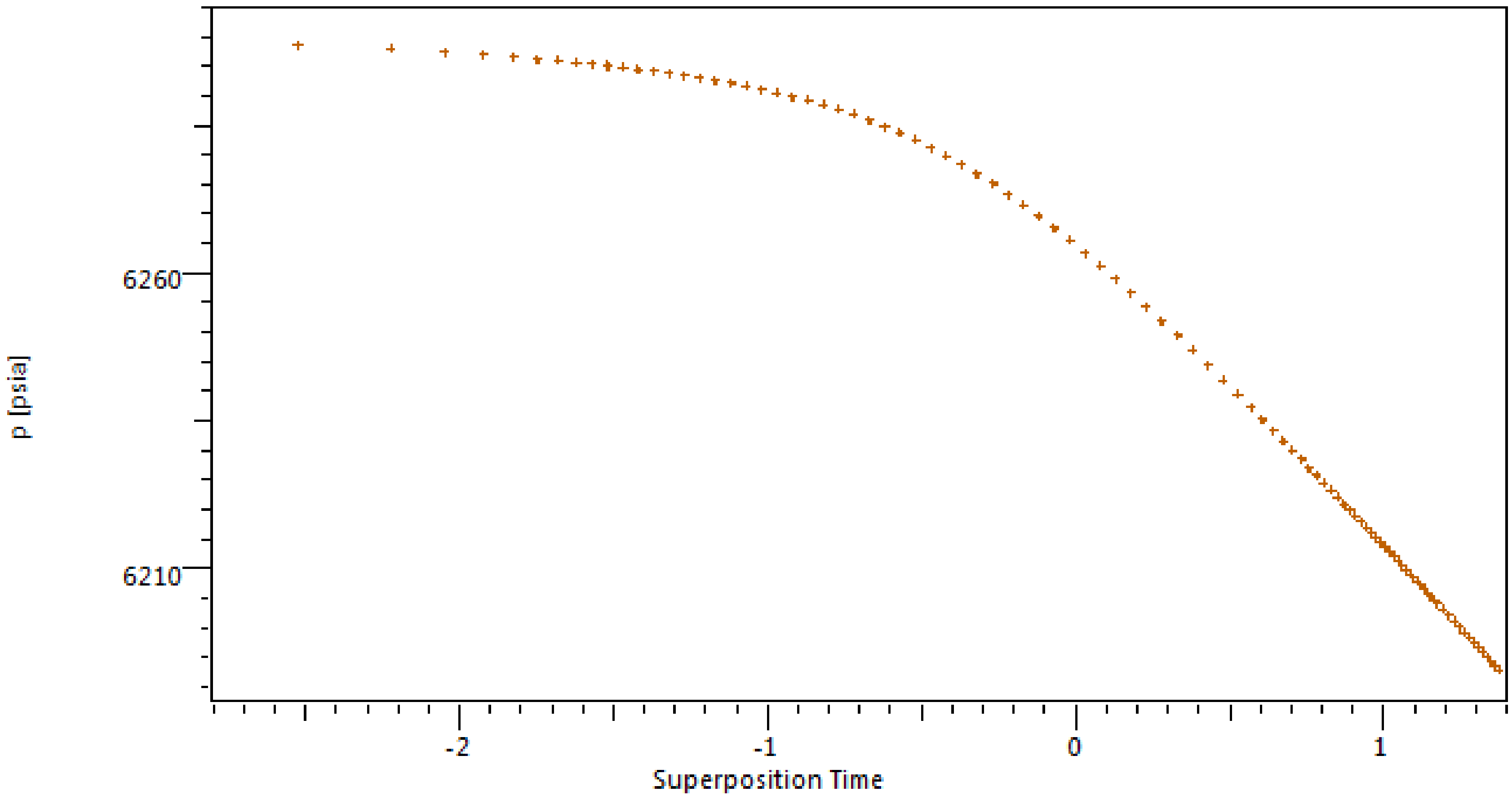


Fig. 3