Universitetet i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

FINAL EXAM: MPE 760 Formation Evaluation and Well Testing

DATE: December 6, 2011

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 short buildup test was run in an oil well after 10 days of production at 1100 STB/D. Use parameters from Table 1, buildup 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 loglog plot of the buildup data with only the wellbore storage period fully developed. Based on the plotted data, give an estimate of the derivative value representing radial flow, and use this value to estimate the flow capacity *kh* and permeability *k*.

b) Fig. 2 shows a Horner plot of the buildup data with $\log(\Delta t/(t + \Delta t))$ on the horizontal axis. Assume that the formation pressure was 5000 psia at the start of the production, and use this information along with data from the tables below and an assumption of a large drainage area to estimate the semilog slope *m* and determine *kh*, *k*, *S* and Δp_S based on this estimate.

c) Fig. 3 shows a simple Cartesian plot of the buildup data. Use representative data points from Table 2 to determine the wellbore storage constant *C*.

d) Based on results from the Horner analysis, what is the radius of investigation at the end of the buildup period? Determine if a sealing fault 500 ft from the well would affect data prior to shut-in.

e) If the skin value of the well could be reduced to 0, what would the pressure be at shut-in?

f) If the well had been flowed for just 6 minutes prior to shut-in, could radial flow still have been reached with realistic semilog slope during a long buildup? Explain!

Table 1 – Input parameters for Problem 1

Formation thickness, h	=	200	ft
Porosity, ϕ	=	0.24	
Viscosity, μ	=	0.85	cp
Total compressibility, c_t	=	$4\text{x}10^{-5}$	psi^{-1}
Volume factor, B	=	1.23	RB/STB
Wellbore radius, r_w	=	0.354	ft
Pressure at shut-in, $p_{wf,s}$	=	2809.15	psia

Table 2 – Buildup data

Buildup Time (hrs)	Pressure (psia)	Buildup Time (hrs)	Pressure (psia)
0.0010	2810.57	0.101	2945.94
0.0013	2810.93	0.128	2979.55
0.0018	2811.64	0.161	3020.87
0.0020	2811.99	0.202	3071.38
0.0025	2812.73	0.254	3132.67
0.0029	2813.17	0.320	3206.38
0.0036	2814.21	0.403	3294.05
0.0040	2814.83	0.508	3396.86
0.0051	2816.29	0.639	3515.35
0.0057	2817.16	0.805	3648.95
0.0072	2819.23	1.013	3795.50
0.0080	2820.45	1.275	3950.85
0.0101	2823.36	1.606	4108.77
0.0128	2827.02	2.021	4261.41
0.0161	2831.62	2.545	4400.55
0.0202	2837.38	3.204	4519.34
0.0254	2844.61	4.033	4613.99
0.0320	2853.67	5.077	4684.57
0.0403	2865.00	6.392	4734.52
0.0508	2879.15	8.047	4769.11
0.0639	2896.79	10.131	4793.76
0.0805	2918.74	12.000	4808.09

Problem 2

Consider a fractured gas well in a low-permeability reservoir with formation and PVT parameters

Thickness, h	=	86	ft
Permeability, k	=	0.015	md
Porosity, ϕ	=	0.06	

Viscosity, μ	=	0.024	cp
Total compressibility, c_t	=	9.2×10^{-5}	psi^{-1}
Volume factor, B_g	=	0.0052	rcf/scf
Z factor	=	1.008	
Wellbore radius, r_w	=	0.354	ft
Reservoir temperature, T_{res}	=	302	^{o}F
Reservoir pressure, p_{res}	=	4317	psia

Assume that analysis of an extended period with linear-flow data implied a fracture half-length of 470 ft.

a) If it turns out that the formation and fracture height is only 38 ft, how must the length be changed if the permeability is not changed? If the flow capacity remains unchanged at 1.29 md·ft with the new thickness, what must the half-length then be?

b) If it turns out that the height is correct at 86 ft, but the porosity should have been set equal to 0.12, how would that affect the computed fracture half-length?

c) If the duration of the data used in the analysis was 72 hrs, how large area would then have affected the data?

Problem 3

The following data have been taken from an isochronal test of a gas well with low static pressure at 131.21 bar and the last flow period stabilized.

q_{sc} (m^3/d)	p_{wf} (bar)
424750	125.41
549350	122.21
673940	118.20
771630	114.51
652420	112.61

Use the information above to carry out the analyses below.

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 loglog 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)

$$C_D = \frac{5.615 C}{2\pi\phi h c_t r_w^2}$$ (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.

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

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

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

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

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

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

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

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

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)

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

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

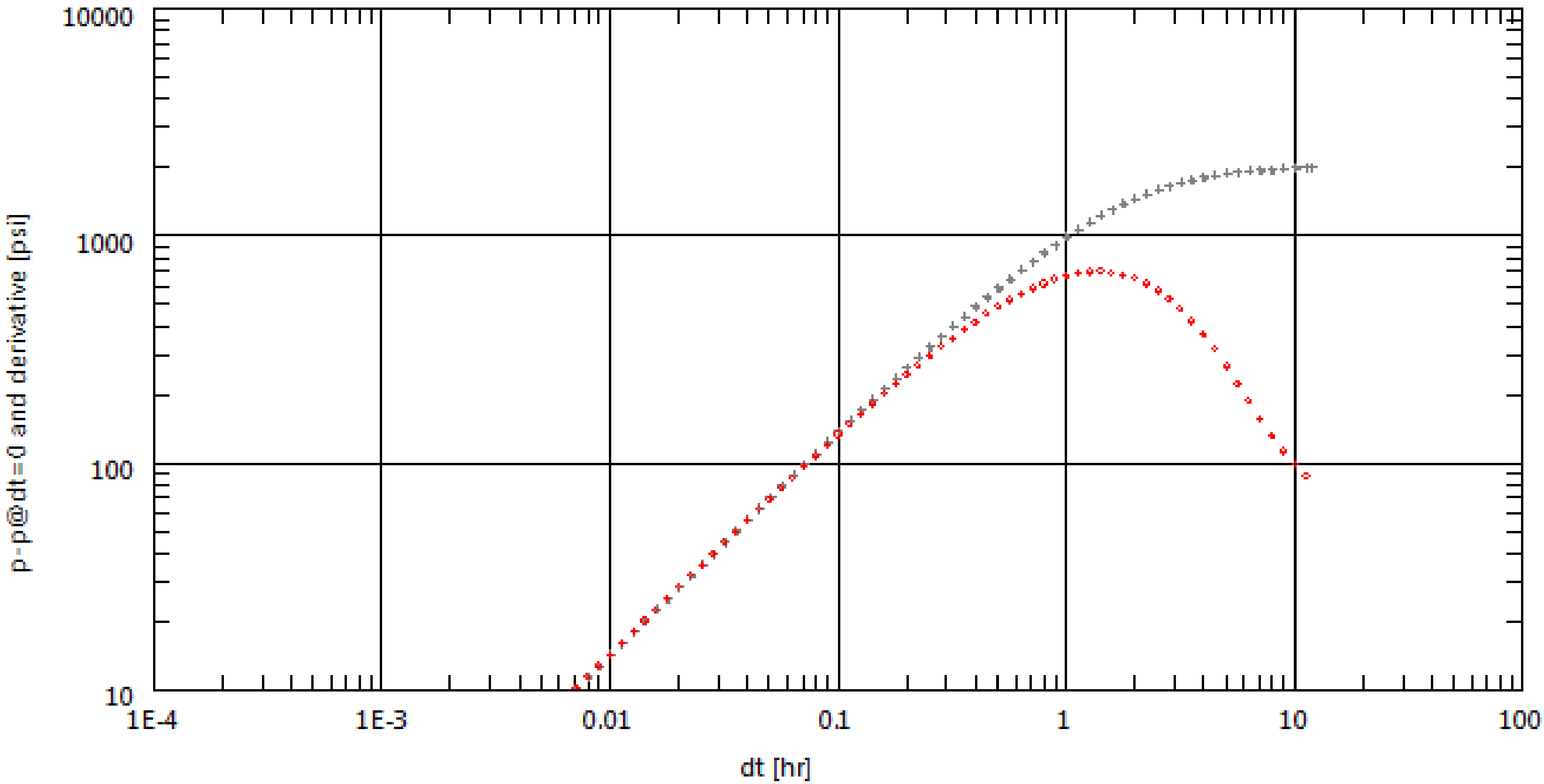
10000
1000
100
10
1E-4
1E-3
0.01
0.1
1
10
100
dt [hr]
p-p@dt=0 and derivative [psi]

Fig. 2

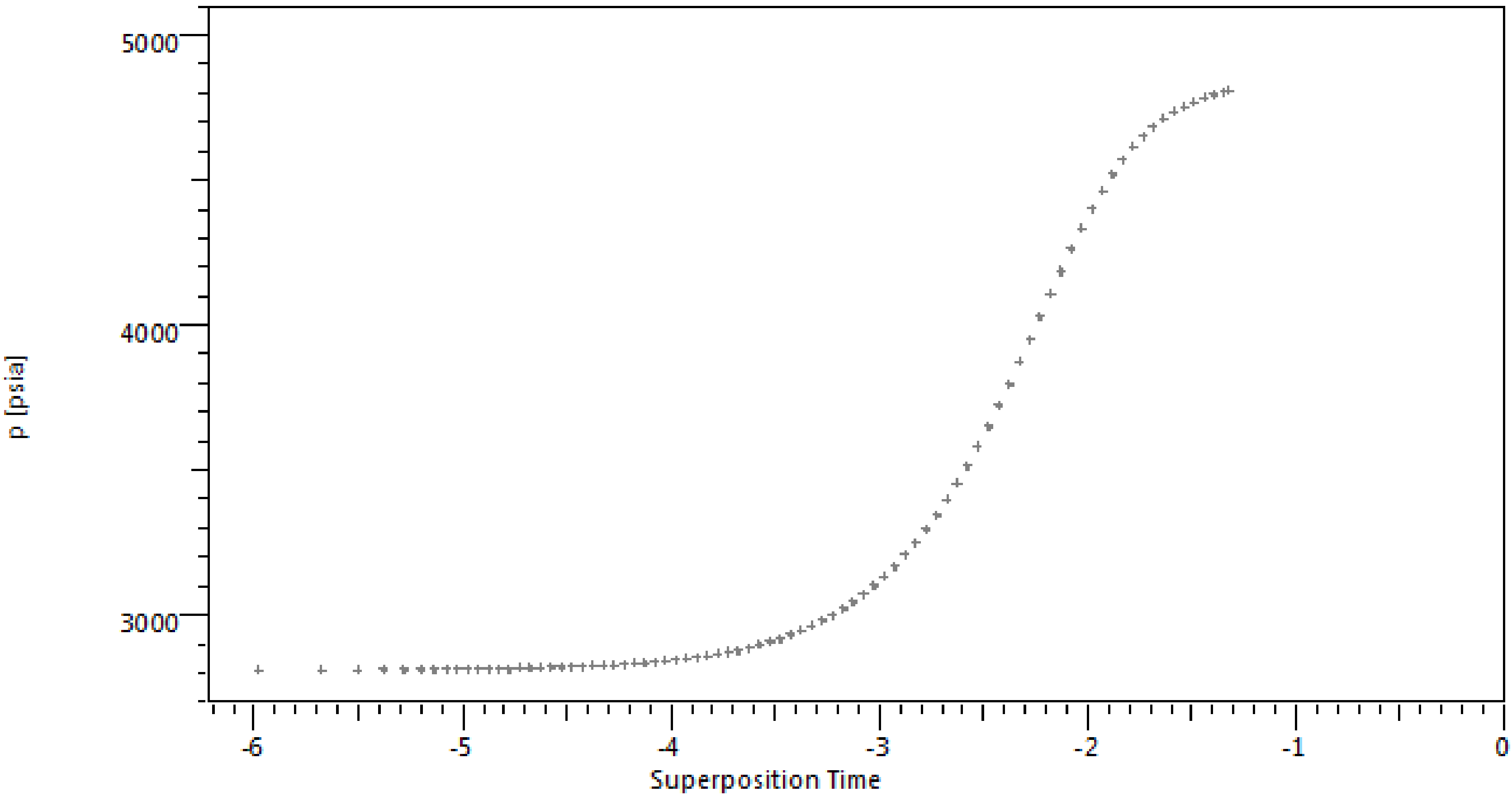

Fig. 3