Universitetet i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

FINAL EXAM: PET 670 Formation Evaluation and Well Testing

DATE: December 9, 2014

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

Data from a long shut-in period of more than 3 months have been recorded in a new oil-producing well following 10 days production at a stable rate of 11200 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 log-log plot of the buildup data. Identify flow regimes evident in the data, and indicate the range of each (start and end). Using the plot for guidance, choose representative data points from Table 2 and determine key well and formation parameters.

b) Fig. 2 shows a Horner plot of the buildup data with $\log(\Delta t/(t + \Delta t))$ on the horizontal axis. Choose representative data points from Table 2 and carry out a standard semi-log analysis of the buildup data and determine the semi-log slope m, kh, k, Δp_{1hr} , S and Δp_S.

c) Both Fig. 1 and Fig. 2 indicate the presence of a nearby boundary. Use any standard method to determine the distance to this boundary.

d) Assume that the end of the data from Fig. 1 indicates a bounded system and estimate the distance to the outer boundary.

e) Use information from Fig. 1 and Fig. 2 to estimate the reservoir pressure after the flow period.

f) Based on results above, estimate the initial reservoir pressure prior to the 10 days long flow period.

g) Fig. 3 shows a simple Cartesian plot of early buildup data. Use representative data points from Table 2 to determine the wellbore storage constants C and C_D.

Table 1 – Input parameters for Problem 1

Formation thickness, h	=	102	ft
Porosity, ϕ	=	0.13	
Viscosity, μ	=	0.78	cp
Total compressibility, c_t	=	2.9×10^{-5}	psi^{-1}
Volume factor, B	=	1.53	RB/STB
Wellbore radius, r_w	=	0.354	ft
Pressure at shut-in, $p_{wf,s}$	=	4273.03	psia

Table 2 – Buildup data

Buildup Time (hrs)	Pressure (psia)	Buildup Time (hrs)	Pressure (psia)
0.0012	4363.49	2.1549	6090.68
0.0024	4446.75	3.8320	6147.56
0.0036	4523.97	6.8143	6208.52
0.0048	4595.75	12.118	6277.30
0.0060	4662.54	21.549	6354.31
0.0072	4724.74	38.320	6436.27
0.0084	4782.66	76.458	6533.51
0.0096	4836.62	160.78	6626.31
0.0108	4886.92	253.18	6672.92
0.0121	4938.26	358.78	6702.11
0.0136	4991.42	543.58	6728.24
0.0171	5101.45	635.98	6735.54
0.0215	5212.99	820.78	6744.53
0.0271	5321.44	913.18	6747.33
0.0342	5422.42	1097.98	6751.03
0.0541	5589.94	1190.38	6752.25
0.0765	5682.51	1375.18	6753.95
0.1080	5751.75	1467.58	6754.54
0.1526	5805.36	1652.38	6755.38
0.2155	5850.00	1837.18	6755.93
0.3832	5915.22	2021.98	6756.30
0.6814	5975.69	2206.78	6756.55
1.2118	6033.96	2391.58	6756.73

Problem 2

Consider two oil producers a distance 230 m apart in a large reservoir with the following flow properties:

Thickness, h	=	12	m
Permeability, k	=	7.3	md
Porosity, ϕ	=	0.08	
Viscosity, μ	=	1.14	cp
Total compressibility, c_t	=	$1.98\text{x}10^{-4}$	bar^{-1}
Volume factor, B	=	1.47	Rm^3/Sm^3
Wellbore radius, r_w	=	0.108	m
Reservoir pressure, p_{res}	=	767.1	bar

Assume Well 1 to be produced at a rate of 150 Sm^3/d and Well 2 at a rate of 65 m^3/d, and that they start producing at the same time.

a) Considering Well 1, what is the expected semi-log slope for this well prior to the onset interference from Well 2.

b) How long will it take before the onset of interference between the two wells?

c) If the pressure data from Well 1 reach a second semi-log straight line, what will the expected slope of this line be?

Problem 3

The following data have been taken from an isochronal test of a gas well with low static pressure at 1998.5 psia, with the first three data points taken from transient flow periods.

q_{sc} (Mscf/d)	p_{wf} (psia)	
4800	1943.9	trans
6700	1897.5	trans
8600	1839.3	trans
9540	1765.8	stabilized

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

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:

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

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

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

Fig. 1

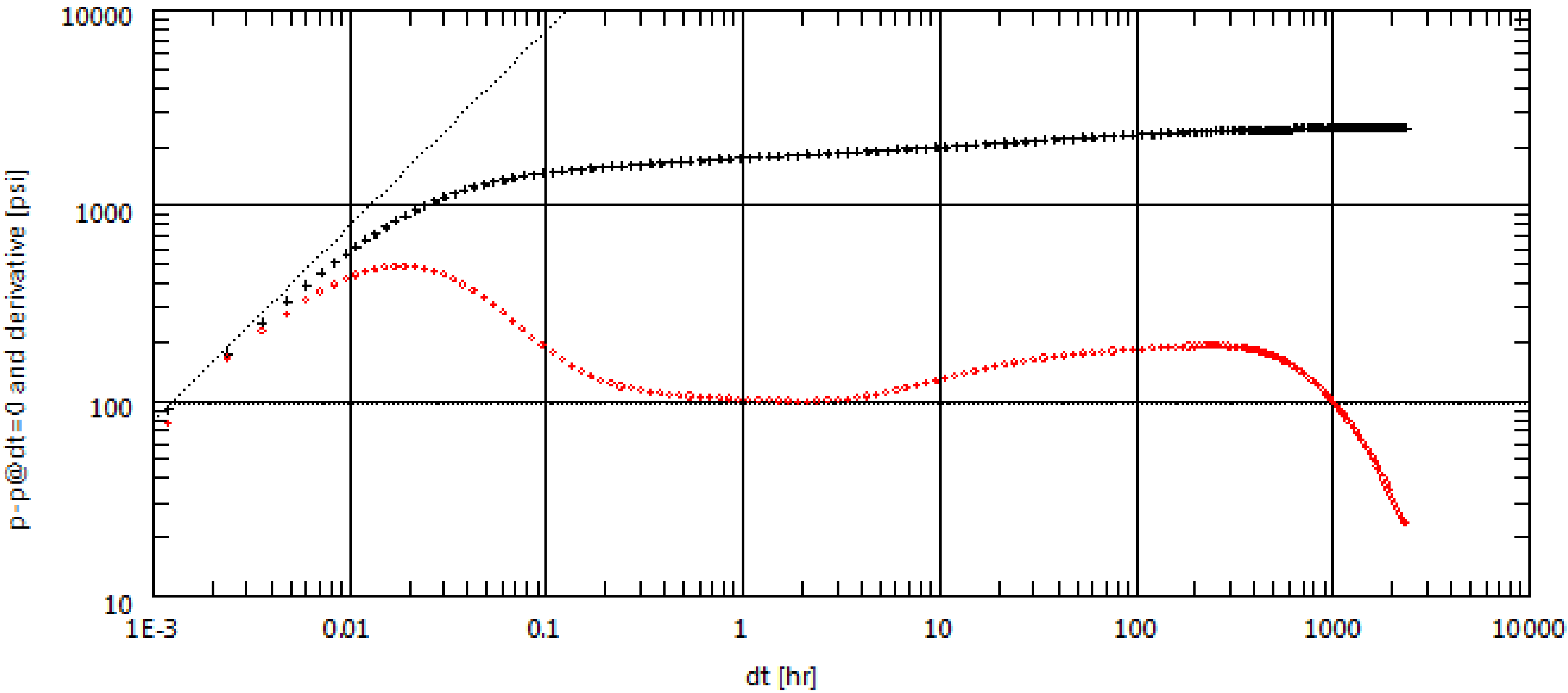
10000
1000
100
10
p-p@dt=0 and derivative [psi]
1E-3
0.01
0.1
1
10
100
1000
10000
dt [hr]

Fig. 2

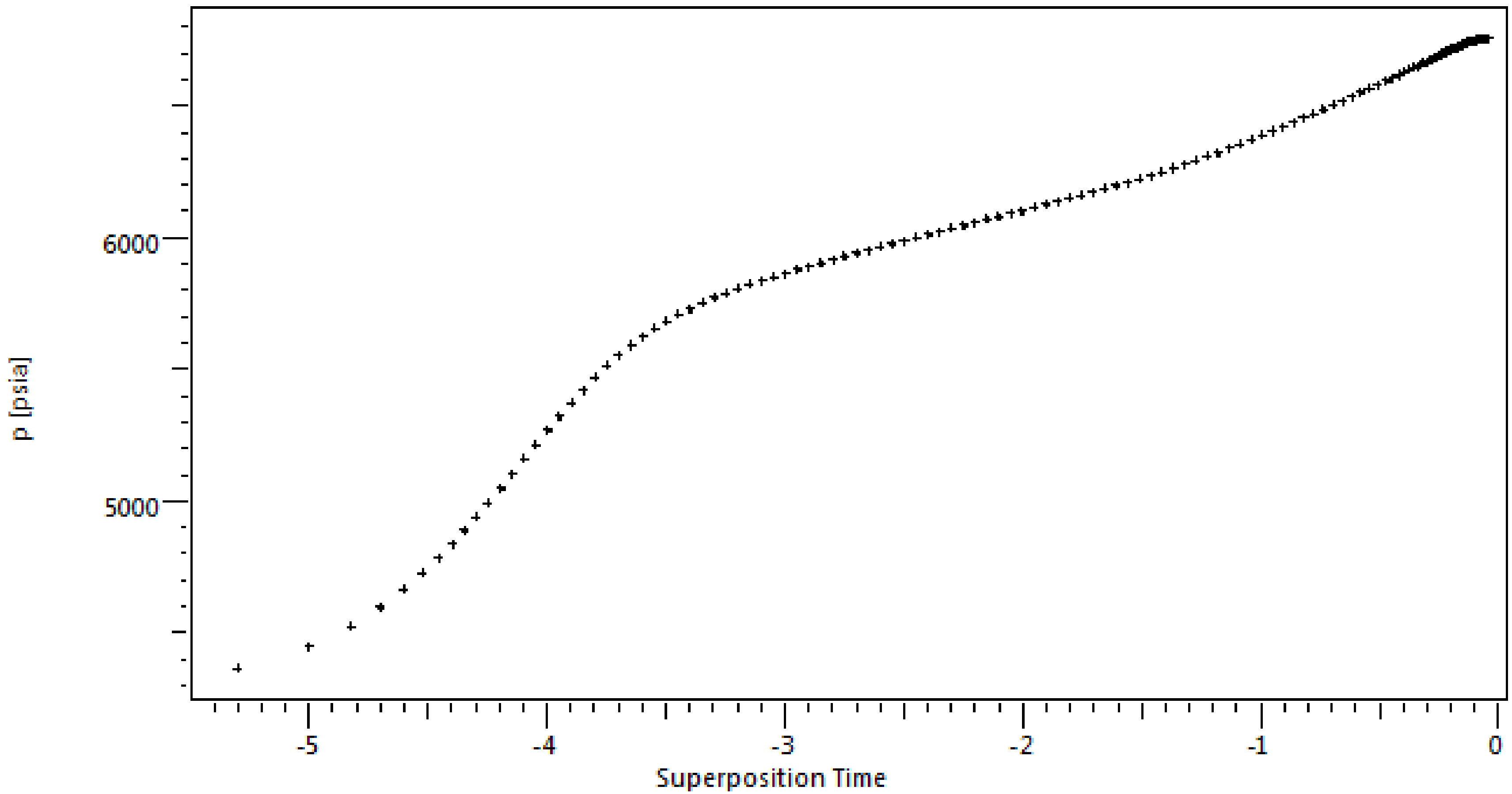

Fig. 3