Universitetet i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

FINAL EXAM: PET 670 Formation Evaluation and Well Testing

DATE: December 9, 2015

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 an 8 days buildup period following 30 days production at a rate of 12500 STB/D were recorded in a new fractured oil well. 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 visible or indicated in the data, and indicate the range of each (start and end).

b) By using Fig. 1 as reference, carry out a standard semi-log analysis of the buildup data by choosing representative data points from Table 2 to compute *m*, *kh*, *k*, Δp_{1hr} , *S* and Δp_S.

c) Based on the derivative data in Fig. 1, how many boundaries appear to affect the buildup data? Determine the distance to these boundaries.

d) Fig. 2 shows a semi-log plot of the buildup data with superposition time $\log[\Delta t/(t+\Delta t)]$ on the horizontal axis. In view of the flow regimes identified from Fig. 1, how many straight-line segments should be evident in Fig. 2? Identify these by type and duration (start and end) based on values on the horizontal axis. Also give a best possible estimate of the reservoir pressure based on the buildup data.

e) Fig. 3 shows a square-root-of-time plot of early buildup data with horizontal axis $\sqrt{t+\Delta t}-\sqrt{\Delta t}$. By choosing representative data points from Table 2, use this "tandem square root of time" expression to determine the linear slope m' of early data and the fracture half-length x_f. Relative to the skin value *S* from b), what fracture type is most likely?

f) By assuming the well to be located between parallel boundaries, use results from b) and c) to determine what the linear slope m' of late buildup data should be. Use this slope to estimate the reservoir pressure by extrapolating from the last buildup value to infinite shut-in based on the "tandem square root of time" expression $\sqrt{t+\Delta t}-\sqrt{\Delta t}$.

Table 1 – Input parameters for Problem 1

Formation thickness, h	=	110	ft
Porosity, ϕ	=	0.08	
Viscosity, μ	=	1.8	cp
Total compressibility, c_t	=	$1.3\text{x}10^{-5}$	psi^{-1}
Volume factor, B	=	1.21	RB/STB
Wellbore radius, r_w	=	0.5	ft
Pressure at shut-in, $p_{wf,s}$	=	2811.889	psia

Table 2 – Buildup data

Buildup Time (hrs)	Pressure (psia)	Buildup Time (hrs)	Pressure (psia)
0.0011	2831.851	0.9132	3189.091
0.0014	2834.946	1.4473	3235.239
0.0022	2840.138	2.2937	3285.947
0.0029	2844.515	3.6353	3342.624
0.0036	2848.549	9.1316	3473.277
0.0046	2853.028	14.3387	3542.699
0.0058	2858.051	20.0987	3595.308
0.0073	2863.687	25.8587	3634.633
0.0091	2870.011	37.3787	3692.741
0.0115	2877.106	48.8987	3736.521
0.0145	2885.065	66.1787	3788.562
0.0182	2893.987	74.8187	3810.747
0.0229	2903.962	84.8987	3834.338
0.0289	2915.065	96.4187	3858.881
0.0364	2927.345	107.9387	3881.331
0.0458	2940.812	119.4587	3902.046
0.0576	2955.439	130.9787	3921.291
0.0725	2971.168	142.4987	3939.270
0.0913	2987.910	154.0187	3956.142
0.1447	3023.998	168.4187	3975.873
0.2294	3062.823	182.8187	3994.280
0.3635	3103.557	188.5787	4001.311
0.5762	3145.613	192.0000	4005.403

Problem 2

Wire-line formation testers record data with flow to a point on the surface of a wellbore. If effects of the wellbore are ignored, then one can use a general solution of the type

$$p_{wf}(t) = p_i - \left(\frac{a}{\sqrt{t}} + b \right) \qquad (1)$$

to analyze flow data with constant rate.

a) Use Eq. 1 to derive a general expression that can be used to analyze buildup data $p_{ws}(\Delta t)$ following a period of duration t of flow.

Problem 3

The following data have been taken from an isochronal test of a gas well with high static pressure at 8765 psia, with the first three data points taken from transient flow periods.

q_{sc} (Mscf/d)	p_{wf} (psia)	
10300	8370	trans
17000	7960	trans
21000	7650	trans
19500	7100	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)

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

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

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

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

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

*) Field units: replace 3.098 by 3.23.

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

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

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

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

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

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

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

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

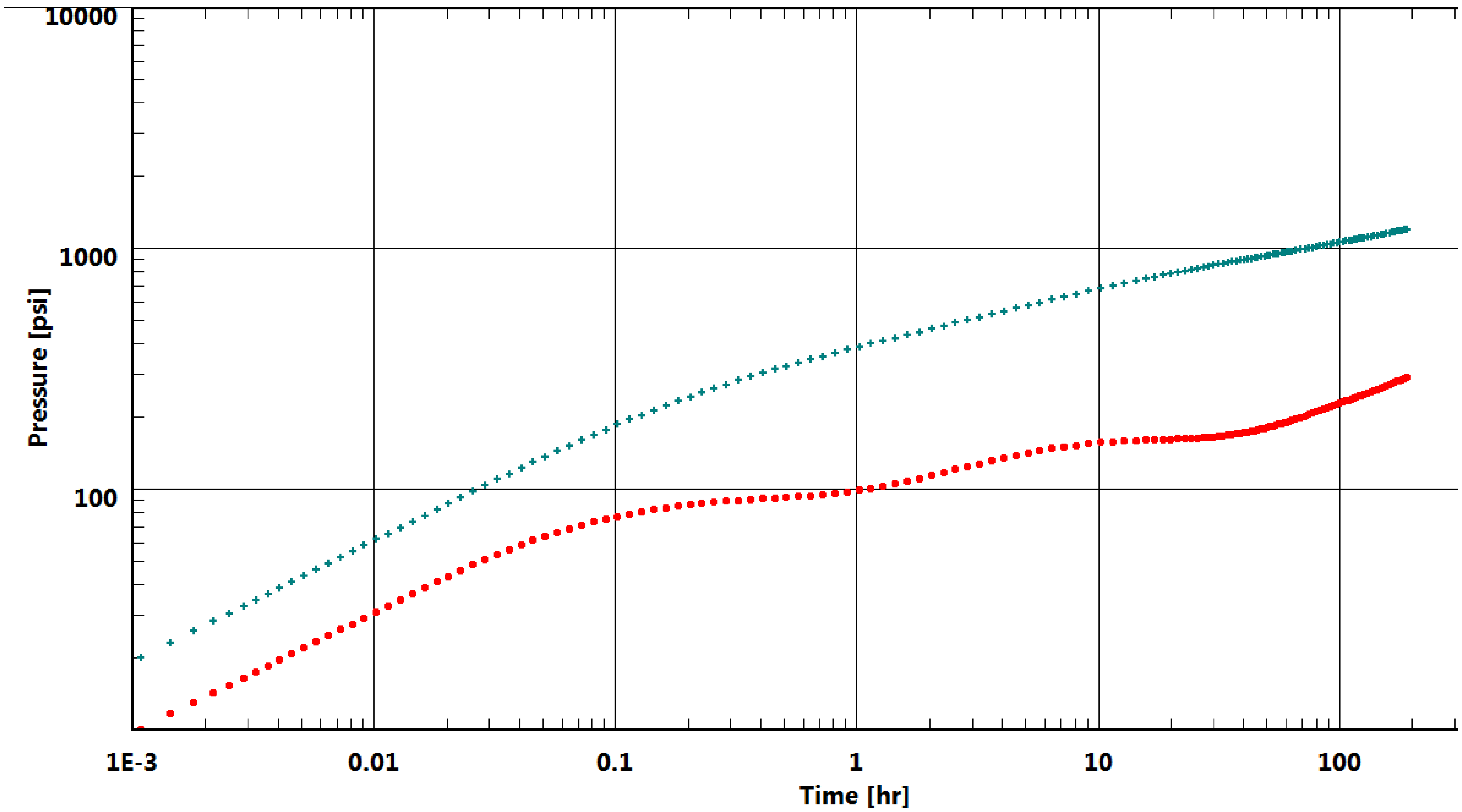
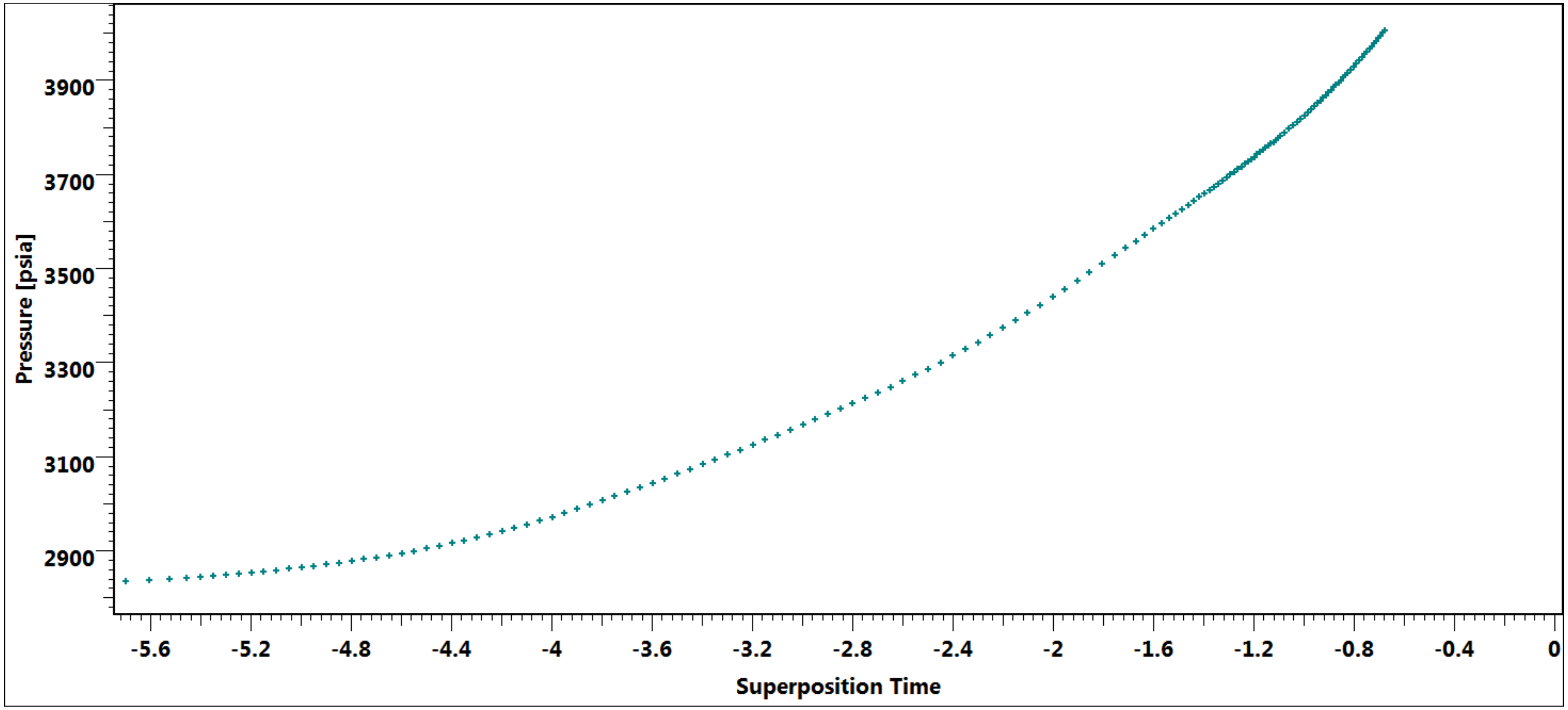
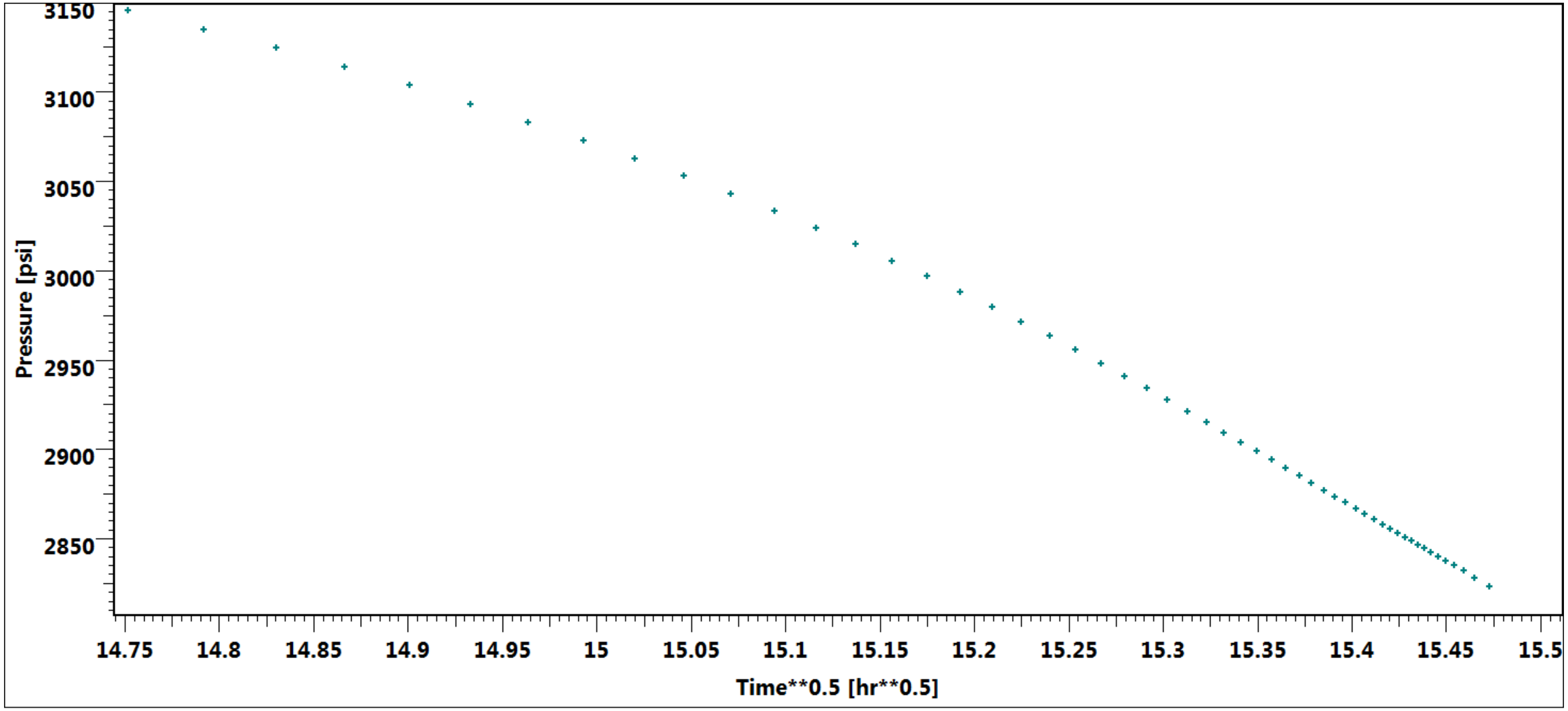


Fig. 2



Pressure [psia]
3900
3700
3500
3300
3100
2900
-5.6
-5.2
-4.8
-4.4
-4
-3.6
-3.2
-2.8
-2.4
-2
-1.6
-1.2
-0.8
-0.4
0
Superposition Time

Fig. 3



3150
3100
3050
3000
2950
2900
2850
Pressure [psi]
14.75
14.8
14.85
14.9
14.95
15
15.05
15.1
15.15
15.2
15.25
15.3
15.35
15.4
15.45
15.5
Time**0.5 [hr**0.5]