Universitetet
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FACULTY OF SCIENCE AND TECHNOLOGY

RE-SIT EXAM: PET 670 Formation Evaluation and Well Testing

DATE: March 3, 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 a drawdown period of 30 days at a stable rate of 3190 STB/D have been recorded in a new oil-producing well. 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). Using the plot for guidance, choose representative data points from Table 2 and determine the wellbore storage constants C and C_D.

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

c) Both Fig. 1 and Fig. 2 show effects of at least two boundaries in the drawdown data. Determine the distance to these boundaries.

d) Assume the drainage area to be rectangular and use the radius of investigation and results from the previous point to estimate the minimal area consistent with the drawdown data.

e) Fig. 3 shows a simple Cartesian plot of early drawdown data. Use representative data points from Table 2 to verify that the initial pressure from Table 1 is consistent with early drawdown data and to determine the wellbore storage constants C and C_D.

Table 1 – Input parameters for Problem 1

Formation thickness, h	=	78	ft
Porosity, ϕ	=	0.18	
Viscosity, μ	=	3.4	cp
Total compressibility, c_t	=	$1.2\text{x}10^{-5}$	psi^{-1}
Volume factor, B	=	1.17	RB/STB
Wellbore radius, r_w	=	0.354	ft
Initial pressure, p_i	=	8300	psia

Table 2 – Drawdown data

Drawdown Time (hrs)	Pressure (psia)	Drawdown Time (hrs)	Pressure (psia)
0.00020	8272.65	5.0731	7340.91
0.00040	8246.75	8.0403	7308.56
0.00060	8222.11	12.743	7273.85
0.00100	8176.16	20.196	7237.38
0.00140	8134.23	32.009	7199.69
0.00180	8095.94	46.409	7168.69
0.00227	8055.45	60.809	7145.93
0.00285	8010.14	75.209	7127.97
0.00359	7960.85	89.609	7113.13
0.00452	7909.04	104.01	7100.48
0.00639	7830.90	118.41	7089.42
0.00902	7758.77	132.81	7079.56
0.01274	7698.38	147.21	7070.64
0.01800	7651.78	165.21	7060.50
0.02543	7617.29	194.01	7046.05
0.03591	7591.33	222.81	7033.18
0.05073	7570.40	251.61	7021.46
0.08040	7546.32	280.41	7010.62
0.12743	7524.15	309.21	7000.47
0.20196	7502.84	348.81	6987.41
0.32009	7482.01	392.01	6974.10
0.50731	7461.55	435.21	6961.58
0.80403	7441.08	492.81	6945.89
1.27430	7419.77	564.81	6927.58
2.01963	7396.49	636.81	6910.42
3.20090	7370.31	708.81	6894.22

Problem 2
Consider a long horizontal well producing from a large oil reservoir with the following well and formation properties:

Thickness, h	=	14	m
Horizontal permeability, k	=	9.2	md
Vertical permeability, k_V	=	0.92	md
Well location, z_w	=	7	m
Well length, L_w	=	1100	m
Porosity, ϕ	=	0.09	
Viscosity, μ	=	1.11	cp
Total compressibility, c_t	=	2.3×10^{-4}	bar^{-1}
Volume factor, B	=	1.23	Rm^3/Sm^3
Wellbore radius, r_w	=	0.108	m
Reservoir pressure, p_{res}	=	689	bar

Assume the well to be produced at a constant rate of 850 Sm^3/d and answer the questions below.

a) How long can the period of early radial flow data be assumed to last?

b) Assuming a similarity with the behavior of fractured wells, what will the slope of the linear flow period be in a square-root of time plot?

Problem 3
The following data have been taken from an isochronal test of a gas well with high static pressure at 5034.5 psia, with the first three data points taken from transient flow periods.

q_{sc} (Mscf/d)	p_{wf} (psia)	
8200	4927.4	trans
13000	4802.3	trans
18700	4598.3	trans
16100	4582.6	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

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

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

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

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

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

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

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

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

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

$$\frac{t_D}{C_D} = \frac{0.0002951kht}{\mu C}$$ (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)

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

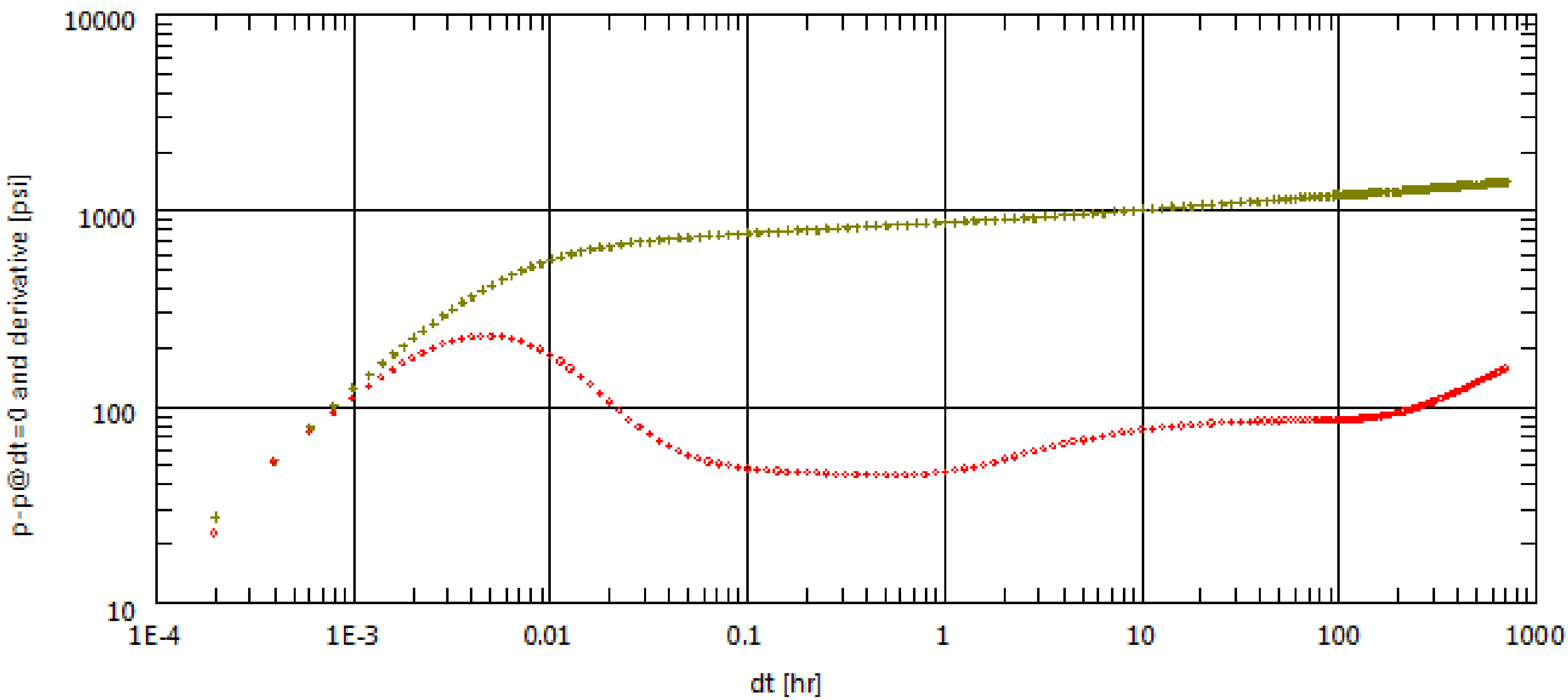
Gas tests:

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

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

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

Fig. 1



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

Fig. 2

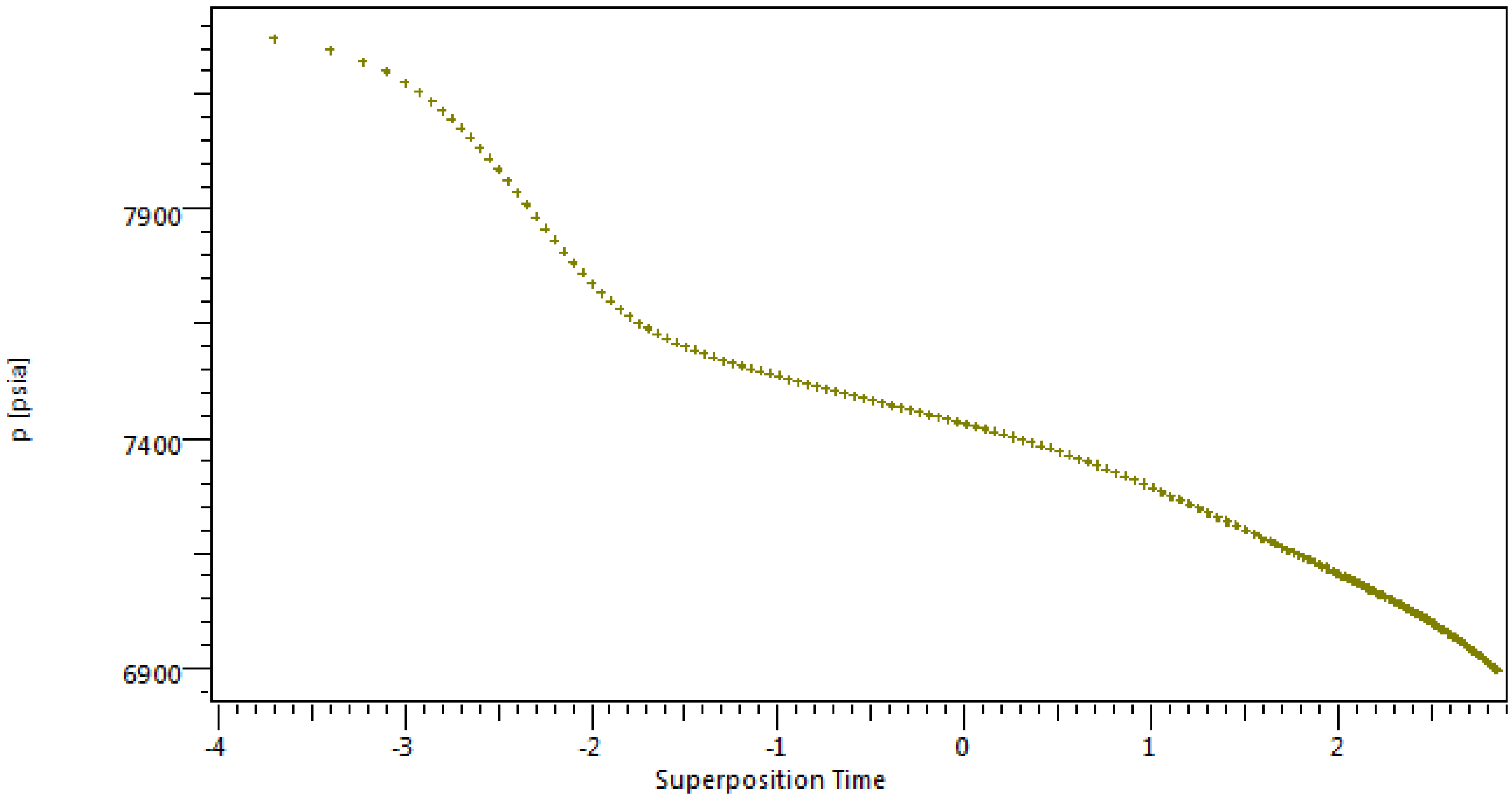


Fig. 3