Universitetet i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

RE-SIT EXAM: PET670 Formation Evaluation and Well Testing

DATE: February 26, 2016

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 10 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 hydraulically fractured oil well. Use parameters from Table 1, drawdown data from Table 2 (reduced), and plots on the last four 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 plot of the drawdown data with log(t) 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) Based on Fig. 1, how many boundaries are evident in the data? Estimate the distance to these?

d) Fig. 3 shows a square-root of time plot of part of the data. Choose representative data points from Table 2 and determine the fracture half-length x_f. Based on the half-length and results above, determine which fracture type is most likely.

e) Choose representative data points from Table 2 and use linear-flow analysis relative to Fig. 3 to determine the width of the drainage area.

f) Fig. 4 shows a Cartesian plot of the entire drawdown data set. Choose representative data points from Table 2 and carry out a reservoir-limit analysis to determine the drainage area A and shape factor C_A.

Table 1 – Input parameters for Problem 1

Formation thickness, h	=	47	ft
Porosity, ϕ	=	0.21	
Viscosity, μ	=	1.8	cp
Total compressibility, c_t	=	$1.08\text{x}10^{-5}$	psi^{-1}
Volume factor, B	=	1.29	RB/STB
Wellbore radius, r_w	=	0.354	ft
Initial pressure, p_i	=	4850	psia

Table 2 – Drawdown data

Drawdown Time (hrs)	Pressure (psia)	Drawdown Time (hrs)	Pressure (psia)
0.0012	4846.729	114.809	4602.667
0.0020	4845.757	132.809	4591.837
0.0032	4844.658	150.809	4581.707
0.0051	4843.275	168.809	4572.131
0.0080	4841.533	186.809	4562.997
0.0127	4839.341	222.809	4545.728
0.0202	4836.581	244.409	4535.839
0.0320	4833.107	266.009	4526.210
0.0507	4828.734	287.609	4516.784
0.0804	4823.243	309.209	4507.516
0.1274	4816.439	330.809	4498.374
0.2020	4808.247	352.409	4489.330
0.3201	4798.757	374.009	4480.365
0.5073	4788.185	395.609	4471.461
0.8040	4776.786	420.809	4461.136
1.2743	4764.798	446.009	4450.862
2.0196	4752.404	471.209	4440.629
3.2009	4739.744	496.409	4430.427
5.0731	4726.908	521.609	4420.249
8.0403	4713.967	546.809	4410.091
12.743	4700.818	572.009	4399.947
20.196	4686.806	597.209	4389.814
32.009	4670.643	622.409	4379.691
46.409	4655.031	647.609	4369.575
60.809	4641.778	672.809	4359.464
78.809	4627.285	698.009	4349.358
96.809	4614.391	720.000	4340.541

Problem 2
Consider a rectangular drainage area A that is 1000 m wide and 2000 m long. Under stabilized production at constant rate the identity

$$\bar{p} - p_{wf} = \frac{18.66 q B \mu}{kh} \left(\frac{1}{2} \ln \frac{4A}{e^{\gamma} C_A r_w^2} + S \right)$$

can be used to determine the drawdown in metric units, where $e^{\gamma} = 1.781$ and C_A is the shape factor, which depends on the drainage shape and well location. Solve the problems below with the following reservoir properties:

Thickness, h	=	18	m
Permeability, k	=	73	md
Viscosity, μ	=	2.3	cp
Volume factor, B	=	1.23	Rm^3/Sm^3
Wellbore radius, r_w	=	0.108	m

a) If the reservoir is produced at the rate 200 m^3/d at a centered well with an infinite-conductivity fracture with half-length 30 m, what will the drawdown be if $C_A = 21.84$?

b) If the reservoir is instead produced with one non-fractured well at the center of each half of the area, what will the drawdown be if each well is produced at 100 m^3/d and the shape factor changes to $C_A = 30.88$?

Problem 3
The following data have been taken from a flow-after-flow test of a gas well with high static pressure at 8655 psia.

q_{sc} (Mscf/d)	p_{wf} (psia)
8300	8392
15000	7965
19000	7622
22000	7320

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.)

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

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

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

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

*) 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)

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

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)

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

Fig. 1

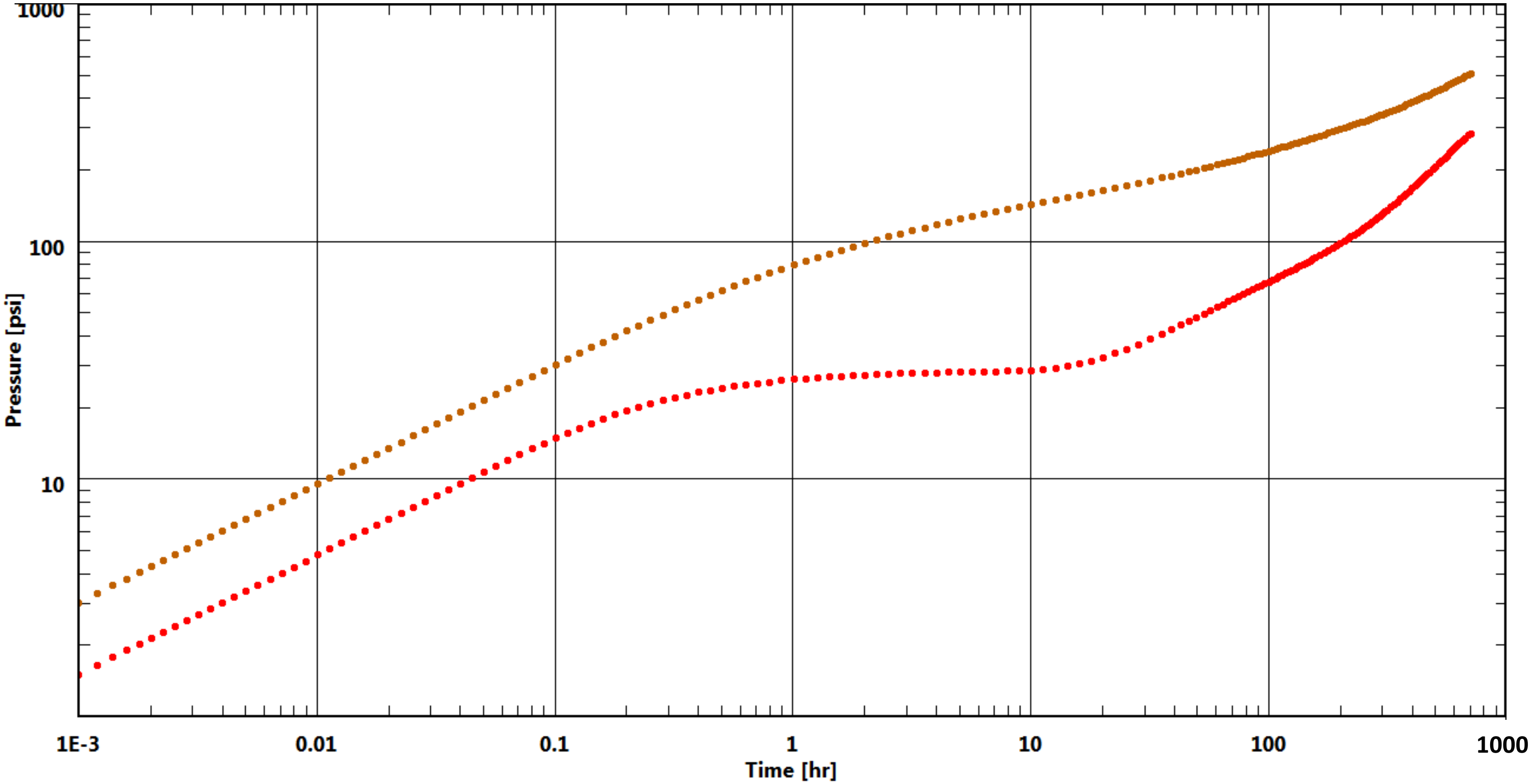


Fig. 2

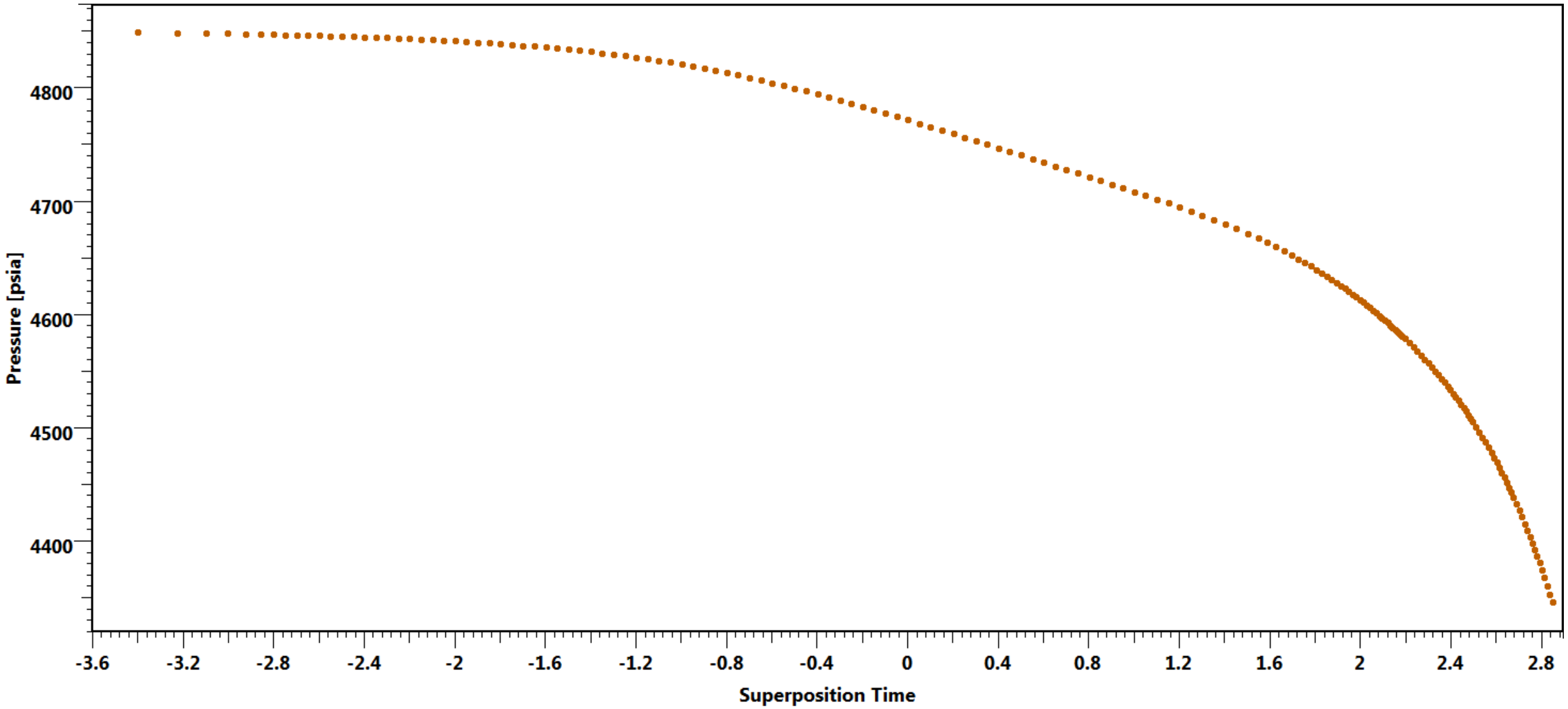

4800
4700
4600
4500
4400
Pressure [psia]
-3.6
-3.2
-2.8
-2.4
-2
-1.6
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
2.4
2.8
Superposition Time

Fig. 3

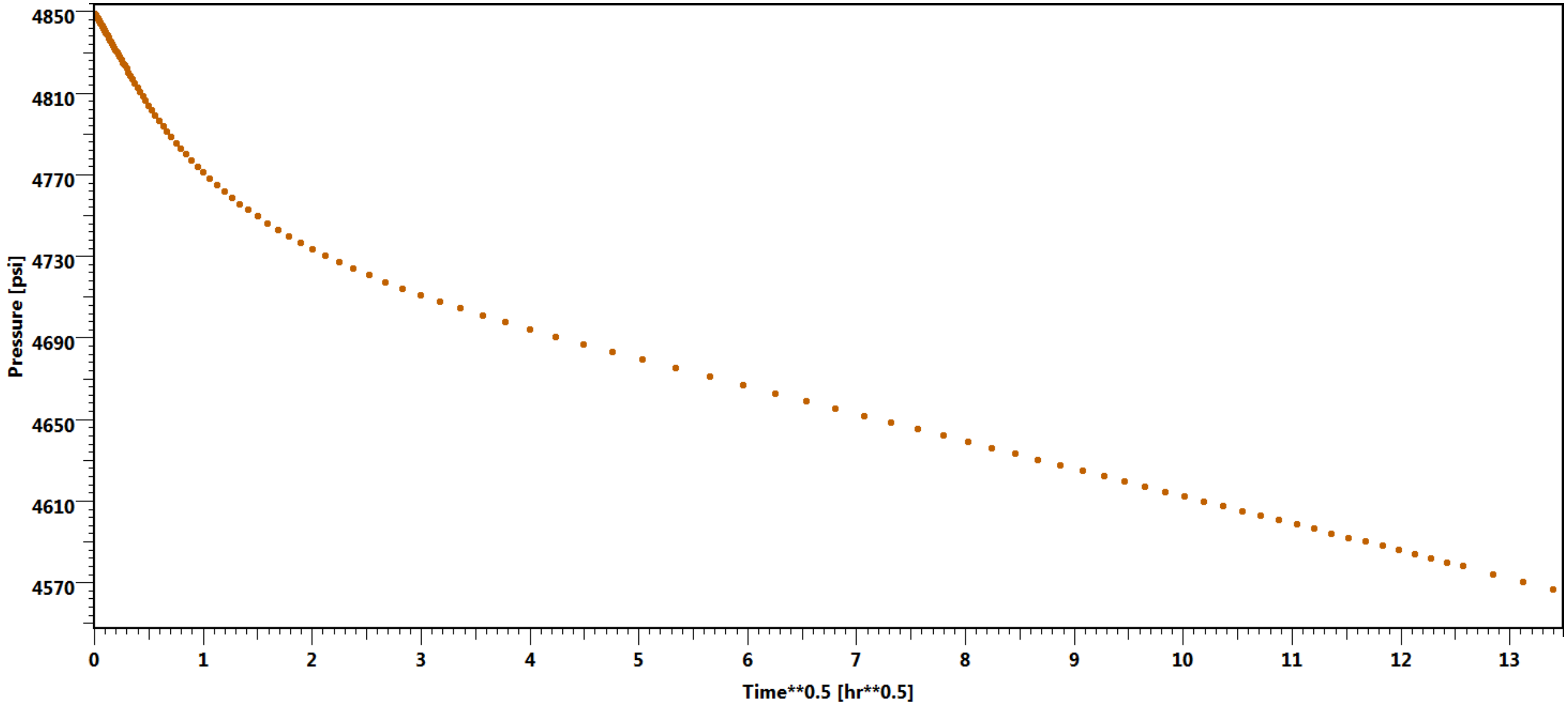
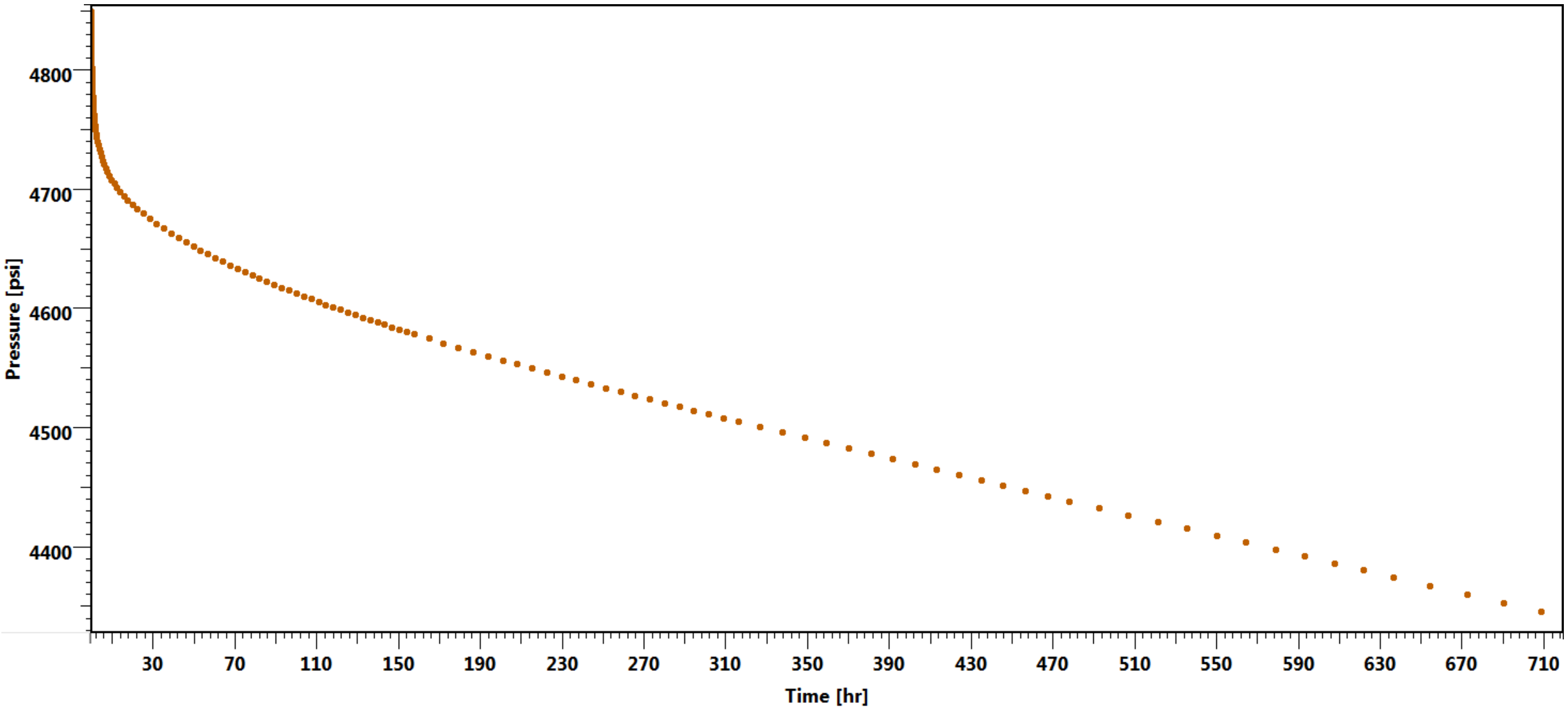

4850
4810
4770
4730
4690
4650
4610
4570
Pressure [psi]
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Time**0.5 [hr**0.5]

Fig. 4


4800
4700
4600
4500
4400
Pressure [psi]
30
70
110
150
190
230
270
310
350
390
430
470
510
550
590
630
670
710
Time [hr]