Universitetet i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

FINAL EXAM: MPE 760 Formation Evaluation and Well Testing

DATE: December 7, 2012

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 long buildup test of 48 hours was run in an exploration well after 16 hours of oil production at 3300 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). Each period (flow regime) has a key parameter associated with it. What are these parameters for this buildup? Using the plot for guidance, choose representative data points from Table 2 and determine the key 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. What would the pressure at shut-in have been if there had been no damage, i.e., if the skin value had been 0?

c) Continuing with the Horner plot in Fig. 2, estimate the distance to the nearest boundary and the minimal distance to the next possible boundary. Finally, by using representative data points from Table 2, estimate the formation pressure.

d) 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. In addition, use C to estimate the wellbore volume if the compressibility of the wellbore fluid is assumed to be 4.2E-5 1/psi.

Table 1 – Input parameters for Problem 1

Formation thickness, h	=	106	ft
Porosity, ϕ	=	0.16	
Viscosity, μ	=	0.35	cp
Total compressibility, c_t	=	$3.3\text{x}10^{-5}$	psi^{-1}
Volume factor, B	=	1.4	RB/STB
Wellbore radius, r_w	=	0.25	ft
Pressure at shut-in, $p_{wf,s}$	=	7260.87	psia

Table 2 – Buildup data

Buildup Time (hrs)	Pressure (psia)	Buildup Time (hrs)	Pressure (psia)
0.0001	7262.45	3.1860	7380.07
0.0002	7263.98	4.5460	7382.99
0.0003	7265.47	5.9060	7385.08
0.0005	7268.35	7.2660	7386.66
0.0008	7272.41	8.6260	7387.92
0.0013	7278.24	9.9860	7388.94
0.0020	7286.32	11.3460	7389.80
0.0032	7296.83	12.7060	7390.52
0.0051	7309.26	14.0660	7391.15
0.0080	7322.08	15.4260	7391.69
0.0127	7333.25	18.1460	7392.60
0.0201	7341.49	20.8660	7393.32
0.0319	7347.07	23.5860	7393.91
0.0506	7351.10	26.3060	7394.41
0.0802	7354.46	29.0260	7394.82
0.1271	7357.54	31.7460	7395.18
0.2015	7360.46	34.4660	7395.50
0.3193	7363.30	37.1860	7395.77
0.5061	7366.19	39.9060	7396.01
0.8021	7369.27	42.6260	7396.23
1.2713	7372.64	45.3460	7396.42
2.0148	7376.29	48.0000	7396.59

Problem 2

Data from an extended flow test of an oil well with key test parameters listed below showed that the bottom-hole pressure had dropped from 371.6 to 370.4 bar during three weeks of production at a stable oil rate of 800 Sm^3/d.

Thickness, h	=	36	m
Permeability, k	=	9.5	md
Porosity, ϕ	=	0.21	
Viscosity, μ	=	0.74	cp
Total compressibility, c_t	=	1.74×10^{-4}	bar^{-1}
Volume factor, B	=	1.27	Rm^3/Sm^3
Wellbore radius, r_w	=	0.108	m
Reservoir pressure, p_{res}	=	382.4	bar

a) Assuming that the pressure decline represented pseudo-steady state data, what is the drainage area?

b) If the rate has been constant from the start, what is the minimum possible length of the production at the start of the three-week test period if the drainage area is circular?

Problem 3

The following data have been taken from a flow-after-flow test of a gas well with low static pressure at 2103.1 psia.

q_{sc} (Mscf/d)	p_{wf} (psia)
5250	2018.9
6790	1972.5
8330	1914.3
9540	1860.8

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)

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

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)

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

Fig. 1

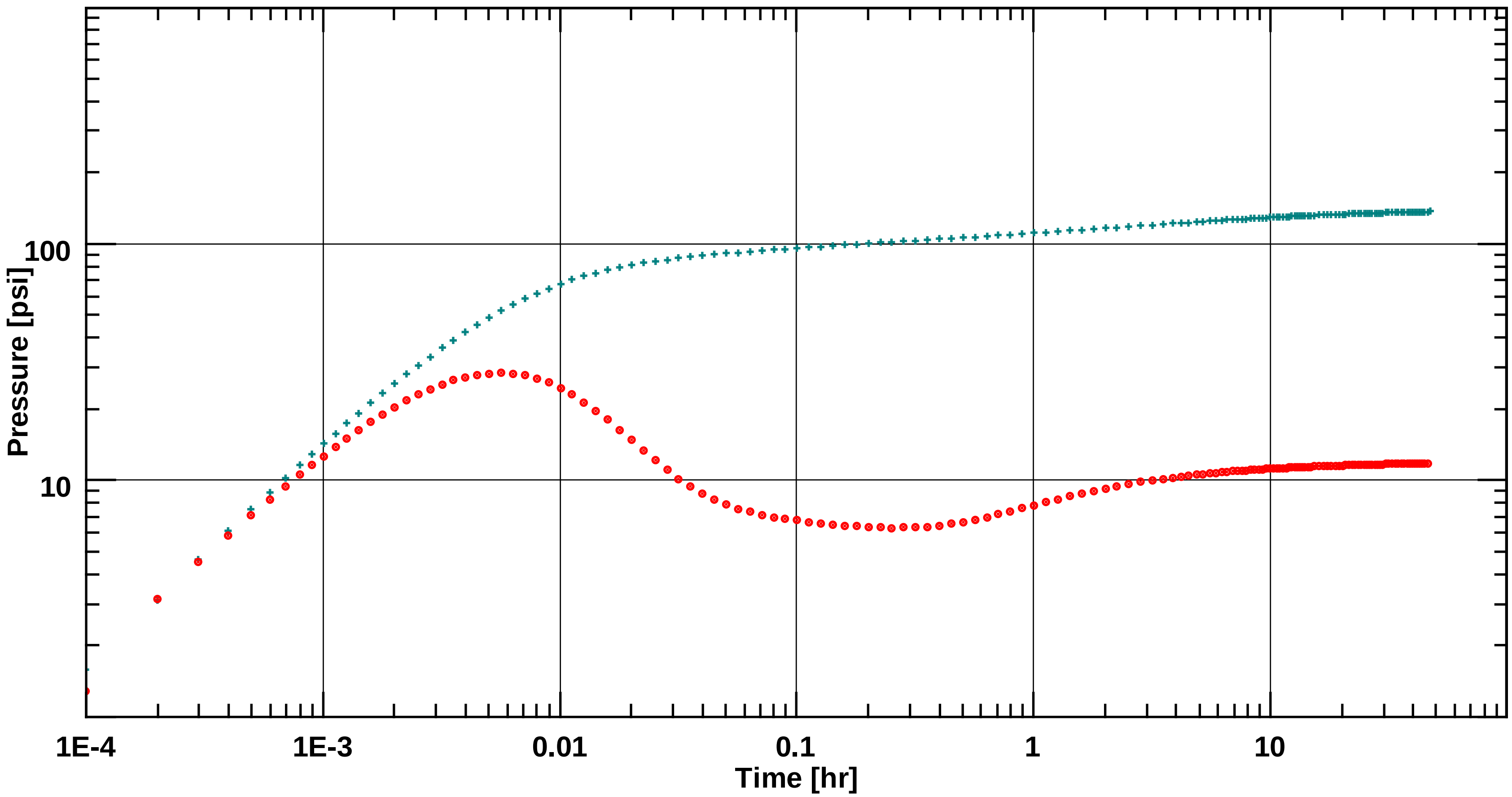
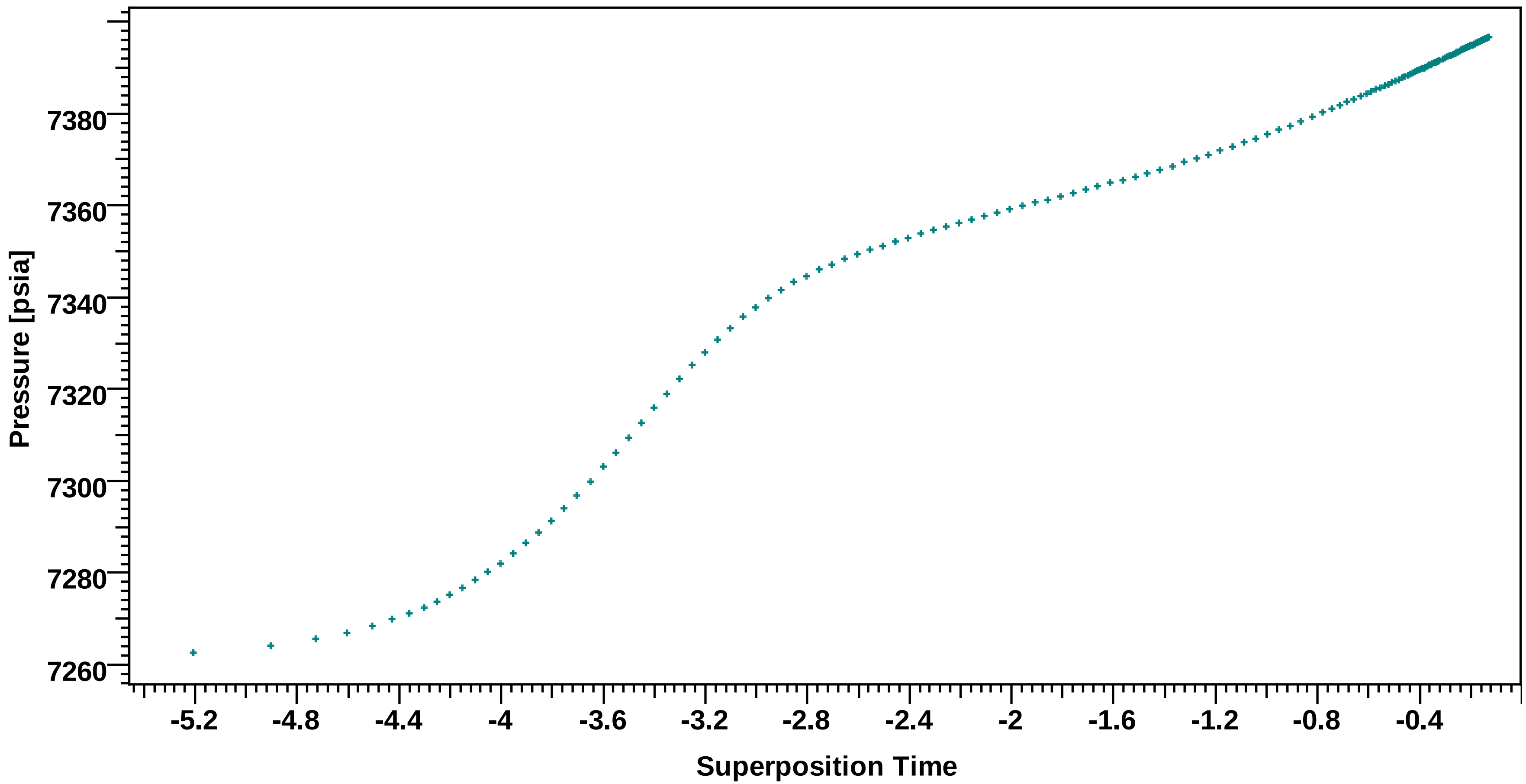
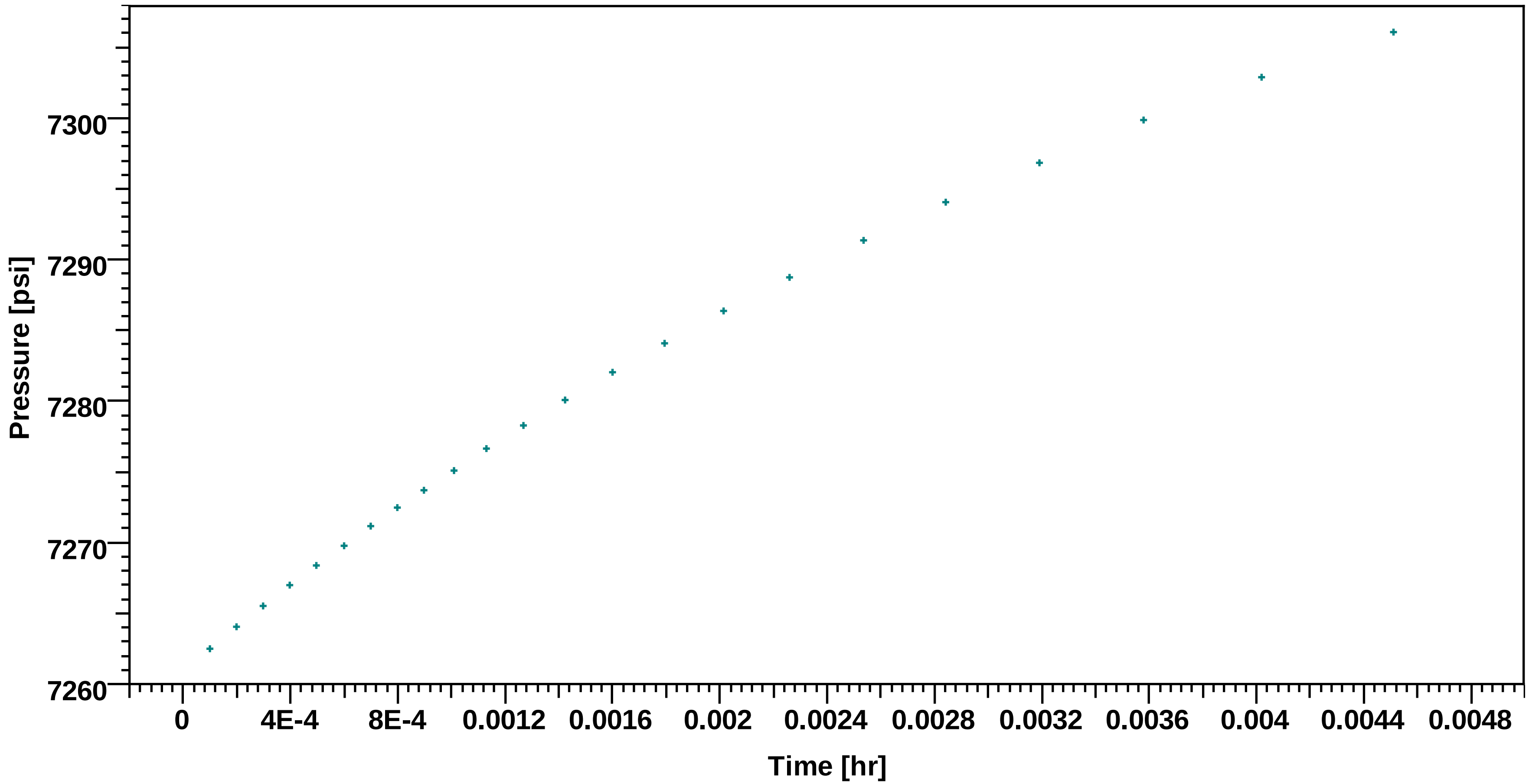


Fig. 2



7380
7360
7340
7320
7300
7280
7260
Pressure [psia]
-5.2
-4.8
-4.4
-4
-3.6
-3.2
-2.8
-2.4
-2
-1.6
-1.2
-0.8
-0.4
Superposition Time

Fig. 3



7300
7290
7280
7270
7260
Pressure [psi]
0
4E-4
8E-4
0.0012
0.0016
0.002
0.0024
0.0028
0.0032
0.0036
0.004
0.0044
0.0048
Time [hr]