Universitetet i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

FINAL EXAM: MPE 350 Well Test Analysis

DATE: December 11, 2009

DURATION: 4 hours

"TOOLS" ALLOWED: Standard calculator

THE SET CONSISTS OF: 3 problems on 10 pages (total)

Problem 1

A vertical well was tested with 3 days (72 hrs) flow at 2800 STB/D followed by a ten days shut-in period to determine formation properties and possible nearby boundaries. Use the input parameters in Table 1 and the reduced set of buildup data in Table 2 together with the plots on the last four pages to answer the questions and carry out the analyses below.

a) Fig. 1 shows a loglog diagnostic plot of the buildup data with 3 lines fit to segments of derivatives. What flow regimes are these lines likely to represent? If the last flow regime had been fully developed, what would the ratio between derivatives at lines 2 and 3 be?

b) Based on the data shown in Fig. 1, select representative data points from Table 2 and determine C and C_D. Use a similar approach to determine kh and k.

c) The superposition plot in Fig. 2 is a Horner plot with $\log(\Delta t/(t+\Delta t))$ on the horizontal axis. By selecting representative data points from Table 2, determine the semilog slope m, p_{1hr}, kh, k, S and Δp_S.

d) The plot in Fig. 3 shows in more detail the last part of the data from the Horner plot in Fig. 2. Determine the time corresponding to the intersection of the two straight lines. Use distance-to-fault analysis to determine the distance to the nearest boundary based on parameters from the analysis above. If the data only shows effect of one boundary, use the radius of investigation r_{inv} to determine how close to the well additional boundaries can be located without affecting the buildup.

e) Based on the data from Fig. 3, estimate the formation pressure after the flow period. If the buildup period had lasted just 20 hrs, would it then be possible to obtain a good estimate of the formation pressure if it the presence of a nearby sealing boundary was reasonably certain? Indicate how such knowledge could have been used for a short buildup.

f) Fig. 4 shows a linear (Cartesian) plot of the first 10 minutes of buildup data. By selecting representative data points from Table 2, determine C and C_D. Moreover, determine if the listed shut-in pressure from Table 2 is consistent with the estimate of C.

Table 1 – Input parameters for Problem 1

Formation thickness, h	=	63	ft
Porosity, ϕ	=	0.22	
Viscosity, μ	=	1.03	cp
Total compressibility, c_t	=	$3.2\text{x}10^{-5}$	psi^{-1}
Volume factor, B	=	1.26	RB/STB
Wellbore radius, r_w	=	0.354	ft

Table 2 – Data from the buildup period

Buildup time (hrs)	Pressure (psia)	Buildup time (hrs)	Pressure (psia)
0	3570.68	4.3521	4848.16
0.0022	3601.91	6.1475	4860.47
0.0043	3632.16	8.6835	4872.93
0.0065	3661.49	11.903	4884.67
0.0086	3689.95	15.143	4893.90
0.0108	3717.56	22.703	4909.79
0.0151	3770.41	31.343	4922.45
0.0194	3820.25	41.063	4932.76
0.0245	3874.83	51.863	4941.26
0.0308	3938.60	63.743	4948.34
0.0435	4051.71	76.703	4954.29
0.0548	4137.60	89.663	4958.98
0.0690	4229.57	104.78	4963.34
0.1376	4503.31	120.98	4967.08
0.2746	4686.54	138.26	4970.30
0.5479	4761.27	156.62	4973.08
0.7739	4779.96	176.06	4975.51
1.0932	4795.23	196.58	4977.64
2.1812	4822.76	218.18	4979.51
3.0810	4835.68	240.00	4981.10

Problem 2

Consider a land-based oil field with identical, rectangular drainage areas where all wells are fractured to compensate for poor formation properties.

a) If we have the option of either doubling the number of wells or doubling the length of the fractures without changing the shape of the well pattern, which option is likely to have the greatest impact on the field productivity? (Can use a case study with chosen fracture and drainage area dimensions.)

Problem 3

The following data have been taken from a flow-after-flow (FAF) test of a gas well with static pressure 520 bar.

q_{sc} (Sm^3/d)	p_{wf} (bar)
330000	448.72
495000	396.75
620000	350.12
740000	299.48

a) Determine the deliverability and AOF potential of the well by using LIT analysis, simple pressure formulation and direct computations without plotting (assume that the data set is consistent such that any two points can be used in the computations).

b) Determine the deliverability and AOF potential of the well by using simple back-pressure analysis (loglog) based on a simple pressure formulation and direct computations without plotting (assume that the data set is consistent such that any two points can be used in the computations).

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)

$$C = \frac{qB}{24}\frac{t}{\Delta p} = c_{wb} V_{wb}$$

$$\Delta p = m' t = \frac{qB}{24 C} t$$

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.

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

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

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

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

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

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

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

$$p_{ws}(\Delta t) = \overline{p} \quad \text{when} \quad \Delta t_e = \frac{\phi\mu c_t A}{0.000264 C_A} \qquad \text{(field units)}$$

STANDARD EQUATIONS (Contin.)

Fractured wells:

$$m' = \frac{0.6236 qB}{h x_f} \sqrt{\frac{\mu}{k \phi c_t}}$$ (SI units)

$$m' = \frac{4.064 qB}{h x_f} \sqrt{\frac{\mu}{k \phi c_t}}$$ (field units)

$$S = \ln \frac{2 r_w}{x_f}$$ (fracture with infinite conductivity)

$$S = \ln \frac{e r_w}{x_f} = \ln \frac{2.718 r_w}{x_f}$$ (fracture with uniform flux)

Reservoir limit analysis:

$$m' = \frac{0.04167 qB}{\phi c_t A h}$$ (SI units)

$$m' = \frac{0.2339 qB}{\phi c_t A h}$$ (field units)

$$p_0 = p_i - \frac{18.66 qB\mu}{kh} \left(\frac{1}{2} \ln \frac{4A}{e^{\gamma} C_A r_w^2} + S \right)$$ (SI units)

$$p_0 = p_i - \frac{141.2 qB\mu}{kh} \left(\frac{1}{2} \ln \frac{4A}{e^{\gamma} C_A r_w^2} + S \right)$$ (field units)

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

Gas tests:

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

$$\bar{p}^2 - p_{wf}^2 = a q_{sc} + b q_{sc}^2$$ (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

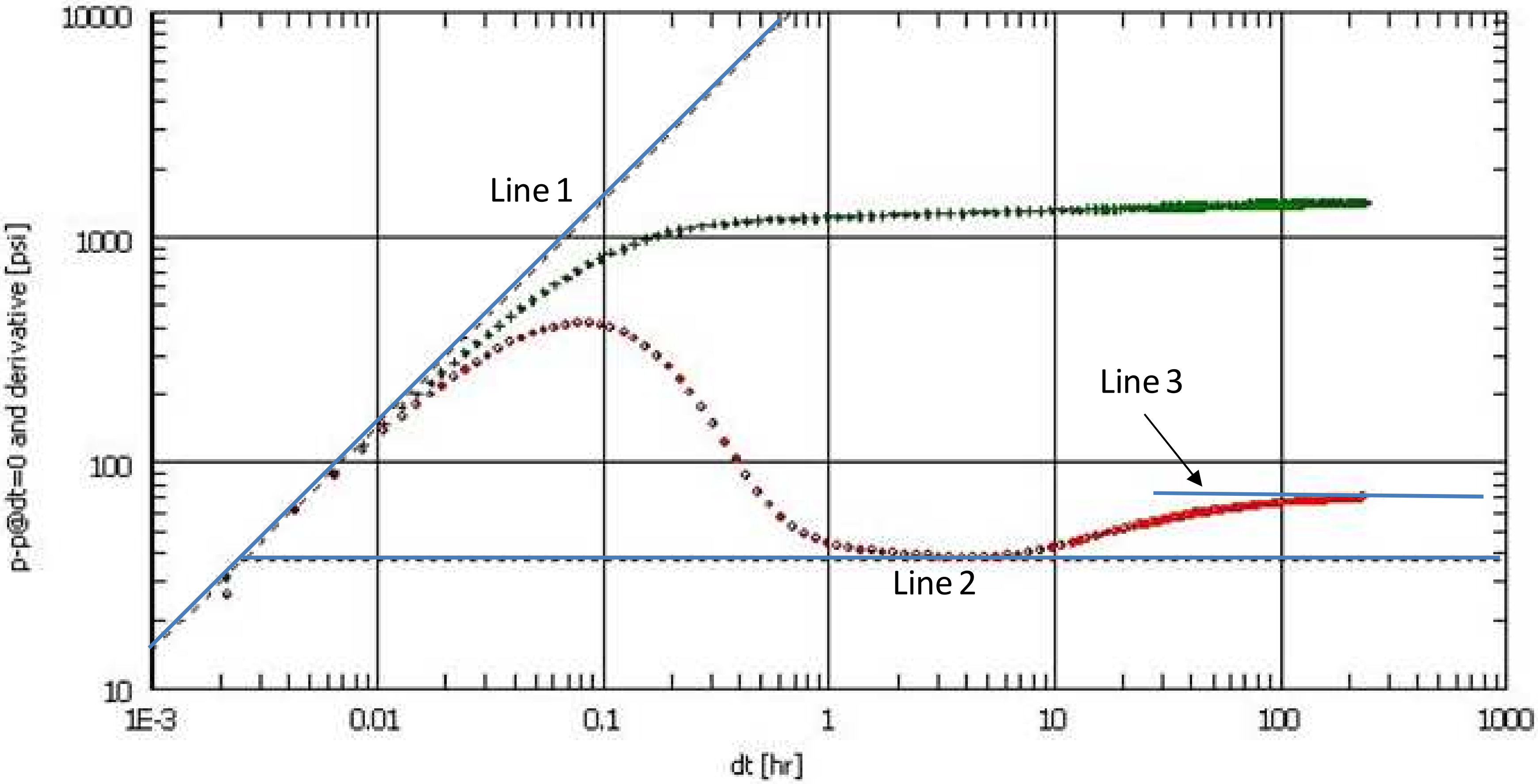

10000
1000
100
10
1E-3
0.01
0.1
1
10
100
1000
dt [hr]
p-p@dt=0 and derivative [psi]
Line 1
Line 2
Line 3

Fig. 2

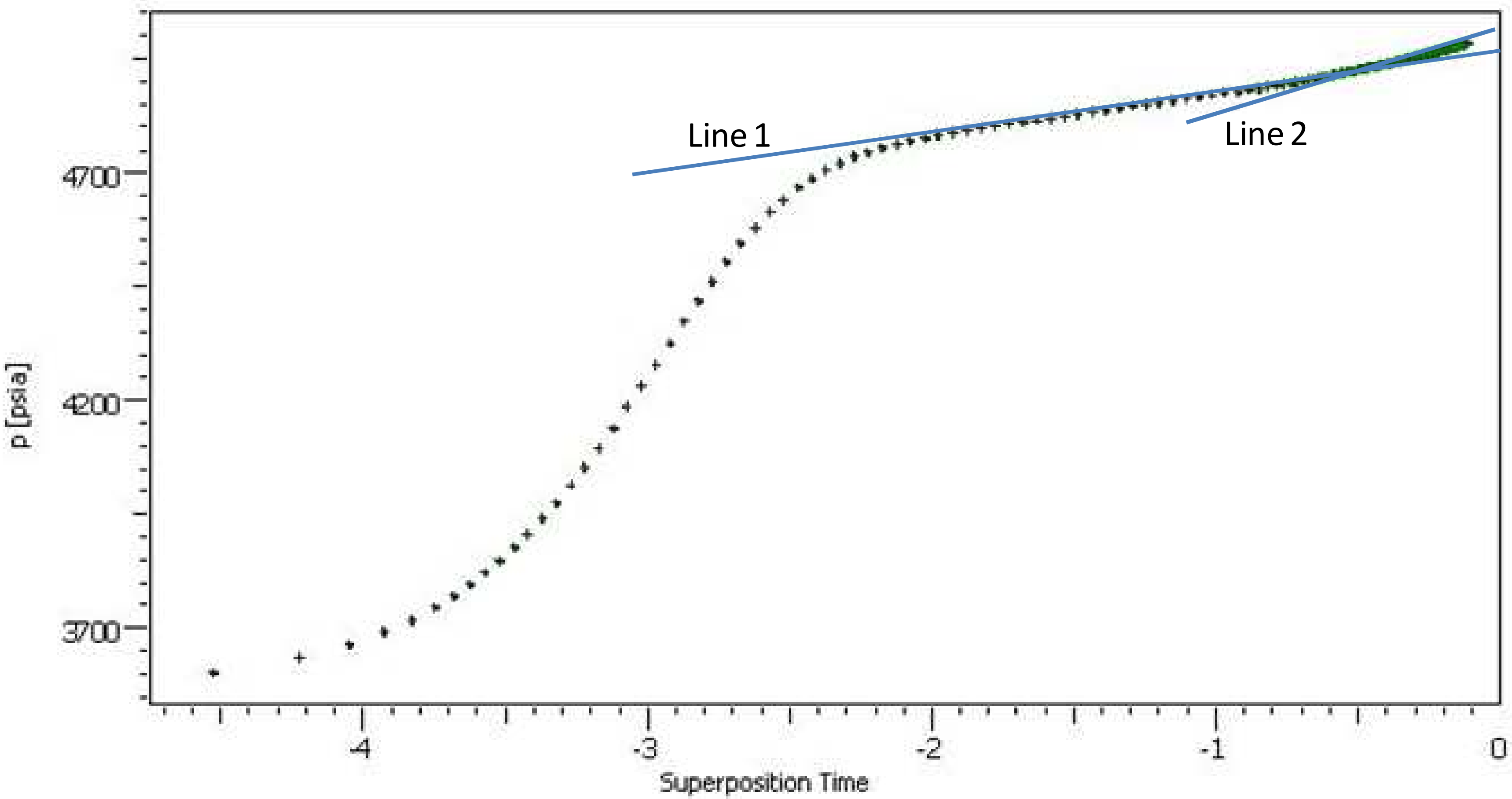


Fig. 3

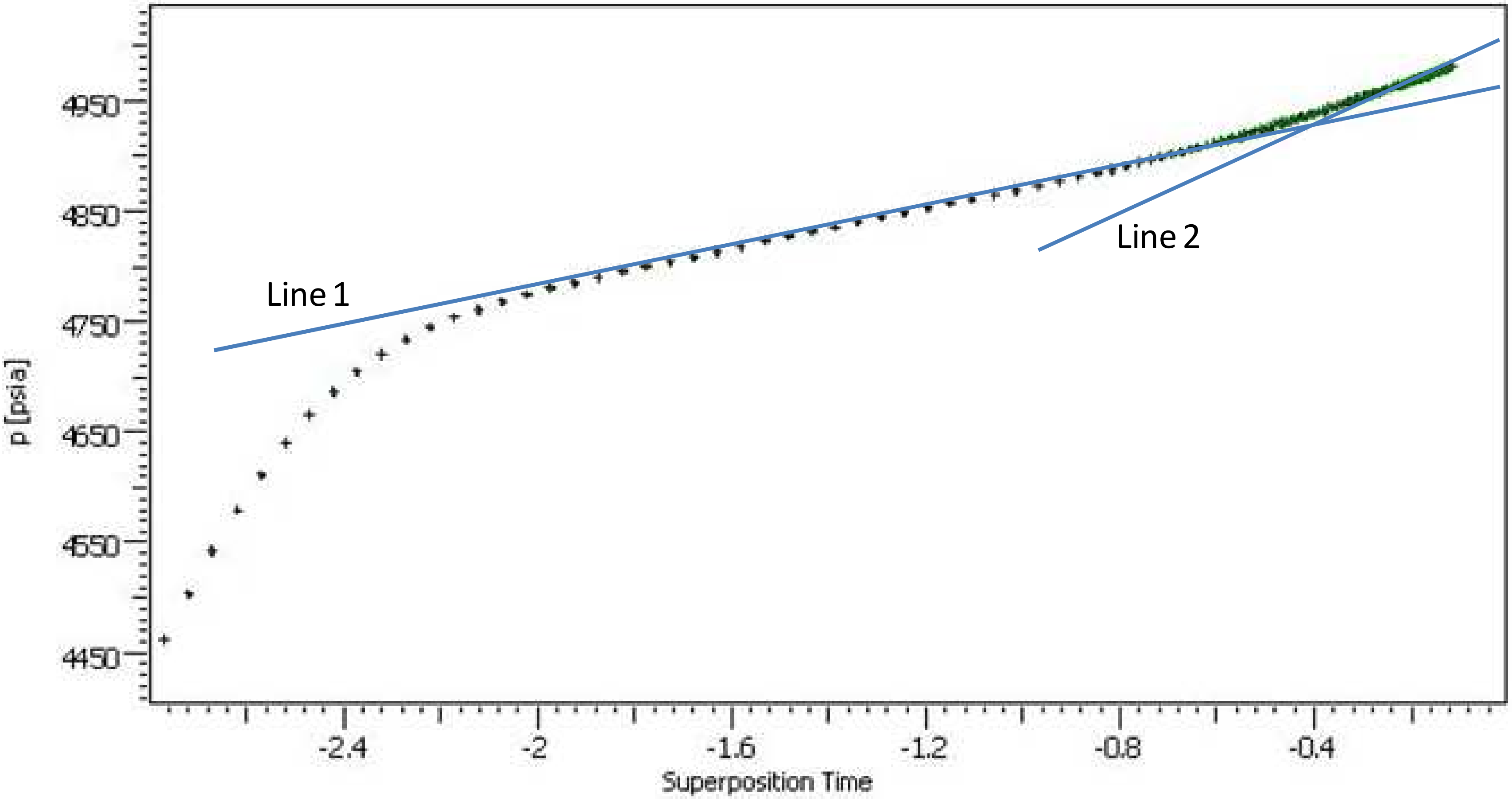
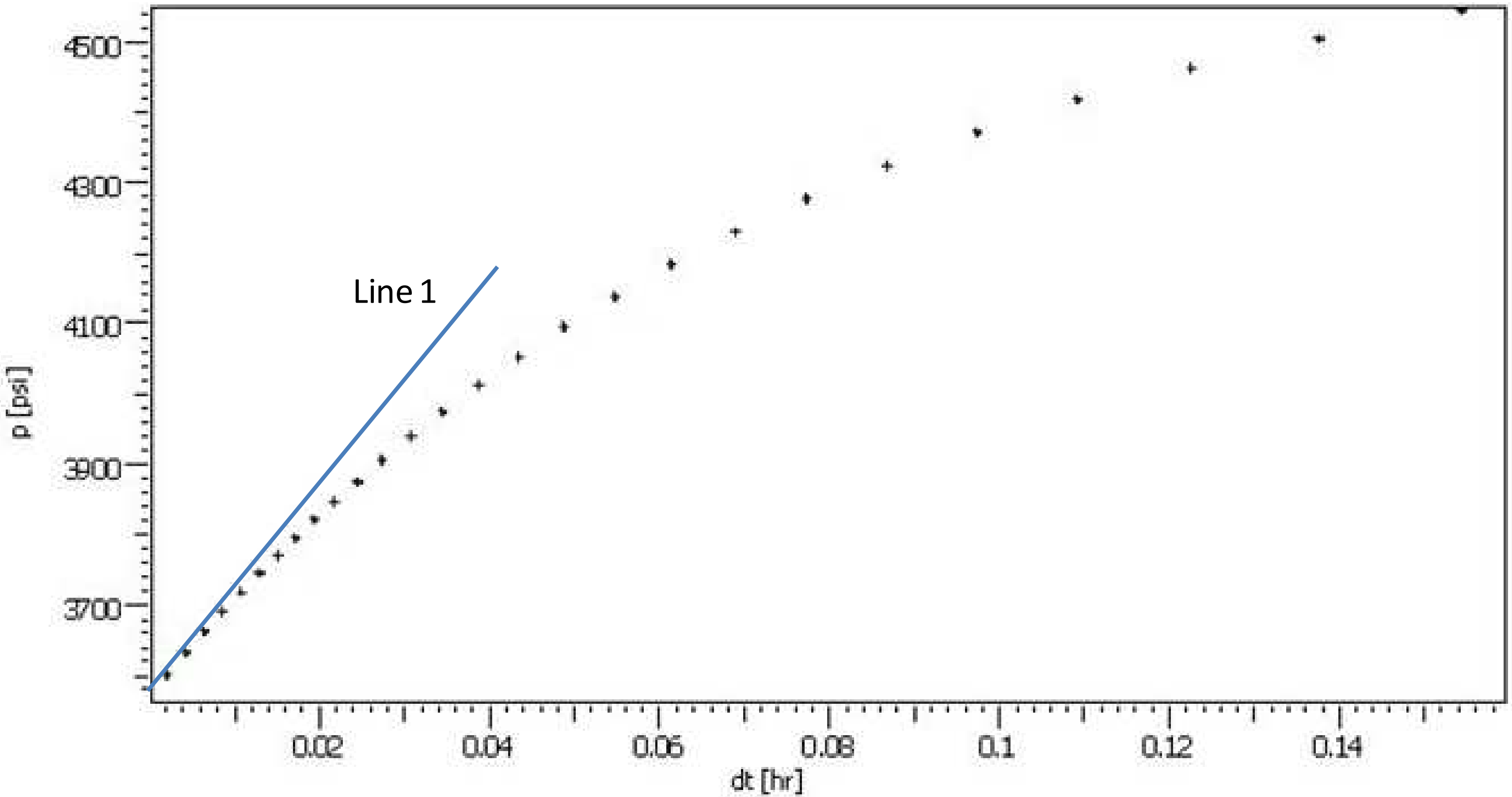

Line 1
Line 2
4950
4850
4750
4650
4550
4450
p [psia]
-2.4
-2
-1.6
-1.2
-0.8
-0.4
Superposition Time

Fig. 4



Line 1
4500
4300
4100
3900
3700
p [psi]
0.02
0.04
0.06
0.08
0.1
0.12
0.14
dt [hr]