INJECTIVITY/FALL-OFF TEST REPORT #1344

Copy 2 of 2

HOME PIERSON 02-08-02-29W1
SPEARFISH (1028.4 - 1035.5 mKB)
TEST DATE: DECEMBER 17- JANUARY 3, 2000

Prepared for:

ANDERSON EXPLORATION LTD.

Prepared by:

PETRO MANAGEMENT GROUP LTD.

JANUARY 2000

#401, 100 - 4th Avenue S.W.
Calgary, Alberta, Canada T2P 3N2
Email: pmg@petromgt.com
Bus: (403) 216-5100
Fax: (403) 216-5109
PMG

January 17, 2000

ANDERSON EXPLORATION LTD.
1600, 324 - 8th Ave. S.W.
Calgary, Alta., T2P 2Z5

<u>Attn.: Mr. Larry Sopko</u>

HOME PIERSON 02-08-02-29W1
SPEARFISH (1028.4 - 1035.5 mKB)
INJECTIVITY/FALL-OFF TEST
TEST DATE: DECEMBER 17- JANUARY 3, 2000

As requested, an injectivity/fall-off test analysis was performed on the subject well. A summary of the test data and the analysis results is attached. The report marked ORIGINAL contains the test data on a diskette. Three copies of the report are attached.

Should you have any questions, please feel free to contact me at (403) 216-5101.

Yours truly,
Petro Management Group Ltd.

COPY (Original Signed) S. IBRAHIM

Saad Ibrahim, P. Eng.
Principal Engineer

Summary of Test Data & Results

Case Name : Finite Conductivity Fracture #1

Home Pierson 02-08-02-29W1

Spearfish (1028.4 - 1035.5 mKB)

Fall-off Test

Test Date: Dec 17 - Jan. 3, 2000

Model Parameters

Water Permeability (k_w)	0.306 mD	Fracture Half Length (x_f)	22.77 m
Total Mobility ($(k/\mu)_t$)	0.49 mD/mPa.s	Fracture Flow Capacity ($k_f w$)	150.238 mD.m
Total Transmissivity ($(kh/\mu)_t$)	1.95 mDm/mPa.s	Fracture Face Skin (sf)	0.358
Wellbore Storage Constant Dim. (C_D)	12.19	Skin Equivalent to Xf	-4.734
		Exterior Radius (r_e)	450.00 m

Formation Parameters

Net Pay (h)	4.00 m
Total Porosity (ϕ_t)	17.00 %
Water Saturation (S_w)	70.00 %
Oil Saturation (S_o)	30.00 %
Gas Saturation (S_g)	0.00 %
Wellbore Radius (r_w)	0.091 m
Formation Temperature (T)	42.0 °C
Formation Compressibility (c_f)	5.658e-7 kPa^{-1}
Total Compressibility (c_t)	4.545e-6 kPa^{-1}

Fluid Properties

Water Compressibility (c_w)	4.28557e-7 kPa^{-1}
Oil Compressibility (c_o)	1.22637e-5 kPa^{-1}
Gas Compressibility (c_g)	5.94719e-5 kPa^{-1}
Water Formation Volume Factor (B_w)	1.000
Water Viscosity (μ_w)	0.628 mPa.s
Gas Viscosity (μ_g)	18.052 μPa.s
Solution Gas Ratio (R_{sw})	0 m^3/m^3
Specific Gravity (G)	1.000
PVT Reference Pressure (p_{PVT})	16550.32 kPa

Production and Pressure

$Q_t B_t$	-3.000 m^3/d
Final Water Rate	-3.000 m^3/d
Final Gas Rate	0.000 $10^3 m^3/d$
Final Flowing Pressure (p_{wfo})	14692.17 kPa
Final Measured Pressure	8999.05 kPa
Initial Pressure (p_i)	16550.32 kPa

Synthesis Results

Average Error	-0.17 %
Synthetic Initial Pressure (p_i)	4870.57 kPa
Extrapolated Pressure at Specified Time	5791.92 kPa
Pressure Drop Due To Skin (Δp_s)	1593.18 kPa
Flow Efficiency (FE)	0.821
Damage Ratio (DR)	1.218

Forecasts

Specified Flowing Pressure (p_{wfs})	14692.17 kPa
3 - Month Constant Rate	-3.321 m^3/d
6 - Month Constant Rate	-2.971 m^3/d
Specified Forecast Time	12.00 month
Forecast Constant Rate @ Current Skin	-2.685 m^3/d
PI / II (Actual)	3.35e-4 $m^3/d/kPa$
Forecast Constant Rate @ Skin=0	-3.197 m^3/d
PI / II (Ideal)	4.07e-4 $m^3/d/kPa$

P M G

TABLE OF CONTENTS

#401, 100 - 4th Avenue S.W.
Calgary, Alberta, Canada T2P 3N2

Email: pmg@petromgt.com

Bus: (403) 216-5100
Fax: (403) 216-5109

P M G

SUMMARY OF RESULTS

1. The average reservoir pressure (P_R) is 5 792 kPa.

2. The effective permeability to water of the Spearfish formation is 0.31 mD.

3. The apparent wellbore skin factor of -4.7 and the fracture half length of 22.8 m confirm that the well was stimulated. The fracture face skin (S_f) of 0.36 indicates that the effectiveness of the fracture has been reduced possibly due to fine plugging from in the injected water.

4. The stabilized water injection rate is 3.0 m^3/d

5. The injectivity index (I.I.) is 3.35E-4 $m^3/d/kPa$.

6. Radius of investigation is approximately 62 m.

#401, 100 - 4th Avenue S.W.
Calgary, Alberta, Canada T2P 3N2
Email: pmg@petromgt.com
Bus: (403) 216-5100
Fax: (403) 216-5109
PMG

TEST ANALYSIS

DISCUSSION

1. Test Overview:

The Home Pierson 02-08-02-29W1 is completed in the Spearfish formation at 1028.4 - 1035.5 mKB and is equipped with a 60.3 mm tubing (landed at 1019.2 mKB). The well was fractured during the initial completion to improve productivity.

During the test, water was injected at 3.0 m^3/d for 24 hours at a wellhead injection pressure 3 892 kPa. Subsequently, the well was shutin for a 371 hour fall-off period.

2. Data Validation:

During the injection/fall-off test, tandem electronic pressure recorders were set at 1014.3 mCF & 1015.3 mCF. The pressure and temperature profiles of the two recorders tracked closely through out the test, as shown on the Raw Data plot (Figure 1), in the Section "Test Data Quality". The difference in pressures, measured by the two recorders, was fairly constant during the buildup period (Figure 2), indicating good quality of the pressure data.

The primary pressure derivative (PPD) plot was constructed for the bottom pressure recorder (Figure 3). The PPD showed only minor pressure anomalies after 34.2 hours of shutin. The PPD plot should be monotonically decreasing with time for valid buildup data. The bottom recorder was used in the test analysis.

The pressure data was reported in absolute. Depth correction was made to adjust the recorded pressures from the recorder run depth to the MPP, using a water gradient of 10.0 kPa/m.

#401, 100 - 4th Avenue S.W.
Calgary, Alberta, Canada T2P 3N2
Email: pmg@petromgt.com
Bus: (403) 216-5100
Fax: (403) 216-5109
P M G

TEST INTERPRETATION

1. Pressure Fall-off Analysis:

Pressure fall-off analysis was performed on the shut-in period. The reservoir parameters were provided by Anderson Exploration Ltd., as shown in the attached form "Summary of Test Data and Results". The final water injection rate prior to shutting in the well was 3.0 m^3/d at a sandface flowing pressure of 14 692 kPa, as shown in the Strip Chart (Figure 4) in the section "Pressure Transient Analysis".

Both the Horner Plot and the pressure derivative analysis were used in the analysis, as discussed below, and results were later fine tuned using the pressure history match techniques of the test pressure data.

Wellbore storage regime was identified by the unit slope straight of the pressure derivative as shown in the Diagnostic Derivative Analysis plot (Figure 5) in the section "Pressure Transient Analysis". Linear flow regime, which is used to evaluate the effectiveness of fracture treatment, was identified by the 1/2 slope straight line of the pressure derivative. The flattening of the pressure derivative plot confirms that radial flow was reached.

Radial flow analysis was performed to determine the reservoir parameters using the semi-log straight line drawn through the late time pressure data, as shown in the Horner plot (Figure 6). The extrapolation of the last data points yielded a P^* of 5 350 kPa. The (P^*) was corrected for the shape, areal extent of the reservoir and the location of the well to determine the average reservoir pressure of 5 856 kPa. The results of the Horner plot and the pressure derivative are summarized below:

	Horner	Derivative
Effective Permeability, mD	0.37	0.36
Ave. Reservoir Pressure, kPa	5 856	n/a
Apparent Skin Factor	-3.8	-4.8

#401, 100 - 4th Avenue S.W.
Calgary, Alberta, Canada T2P 3N2
Email: pmg@petromgt.com
Bus: (403) 216-5100
Fax: (403) 216-5109
PMG

Linear flow analysis, using the Tandem Root plot, was performed to evaluate the effectiveness of the hydraulic fracture treatment (Figure 6a). The straight line drawn through the pressure data during linear flow regime, concluded a fracture half length (X_f) of 21.1 m.

2. Pressure History Match:

The preliminary results from the Horner analysis were used as starting parameters for pressure history matching of the test data. The best match of the test data was obtained, using the Finite Conductivity Fracture Model. The overlay of simulated analysis results on the real test data is presented in the cartesian, semi-log and log-log plots (Figures 7,8 and 9), in the section "Pressure History Match". The parameters used to achieve the history match are as follows:

	History Match	
Reservoir Pressure, P_r	5 792	kPa
Effective Permeability, k	0.31	mD
Fracture conductivity, $K_f.w$	150.2	mD.m
Fracture Half Length, X_f	22.8	m
Six-Month Stabilized Rate, q_s	3.0	$10^3m^3/d$

3. Well Injectivity:

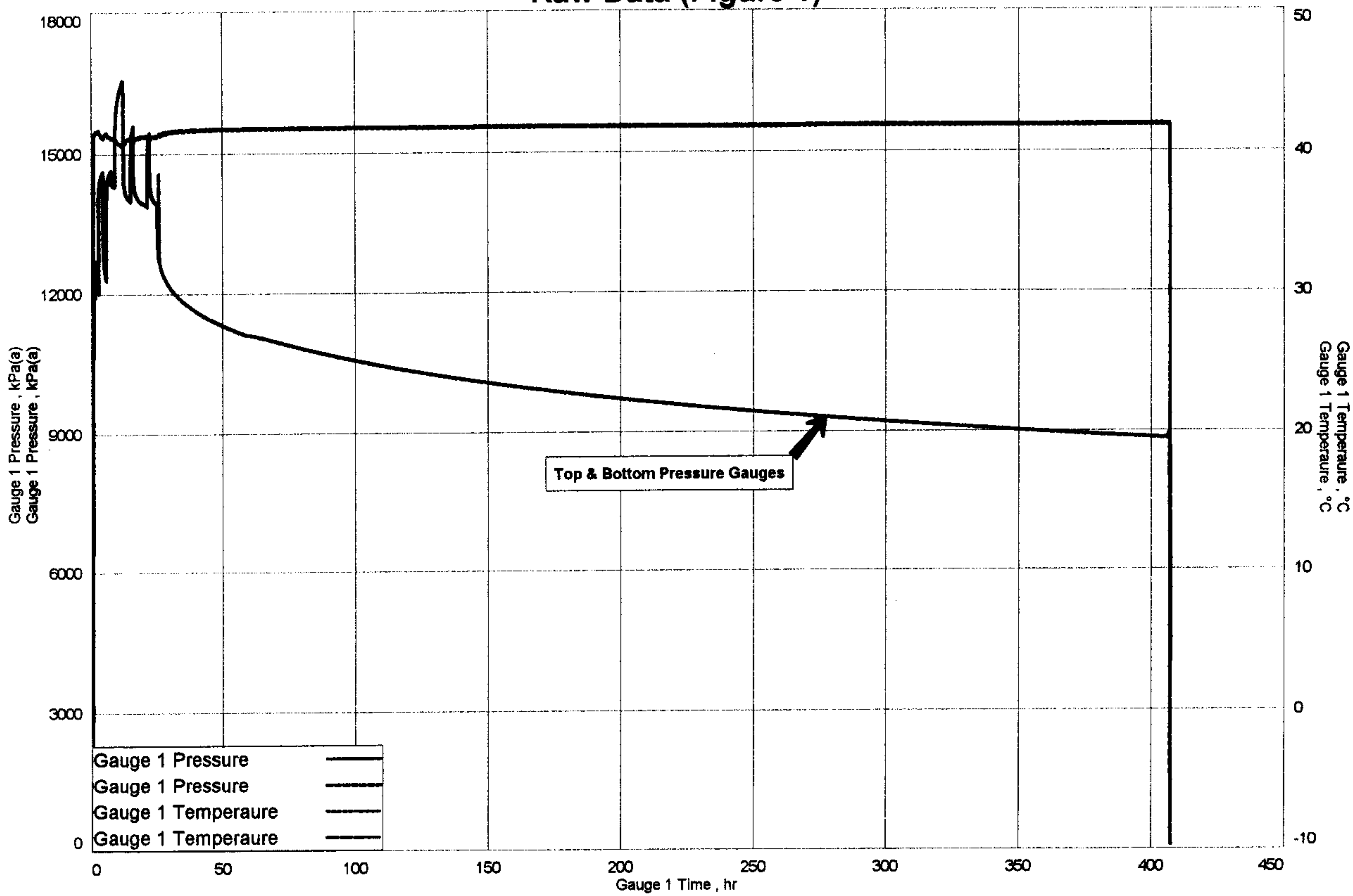
The well stabilized injection rate of 3.0 m3/d and the injectivity index (I.I.) is 3.35E-4 $m^3/d/kPa$ were obtained from the test history match at the current wellbore skin of -4.7.

TEST DATA QUALITY

100/02-08-002-29W1/0

Home Pierson
Formation: Speafish

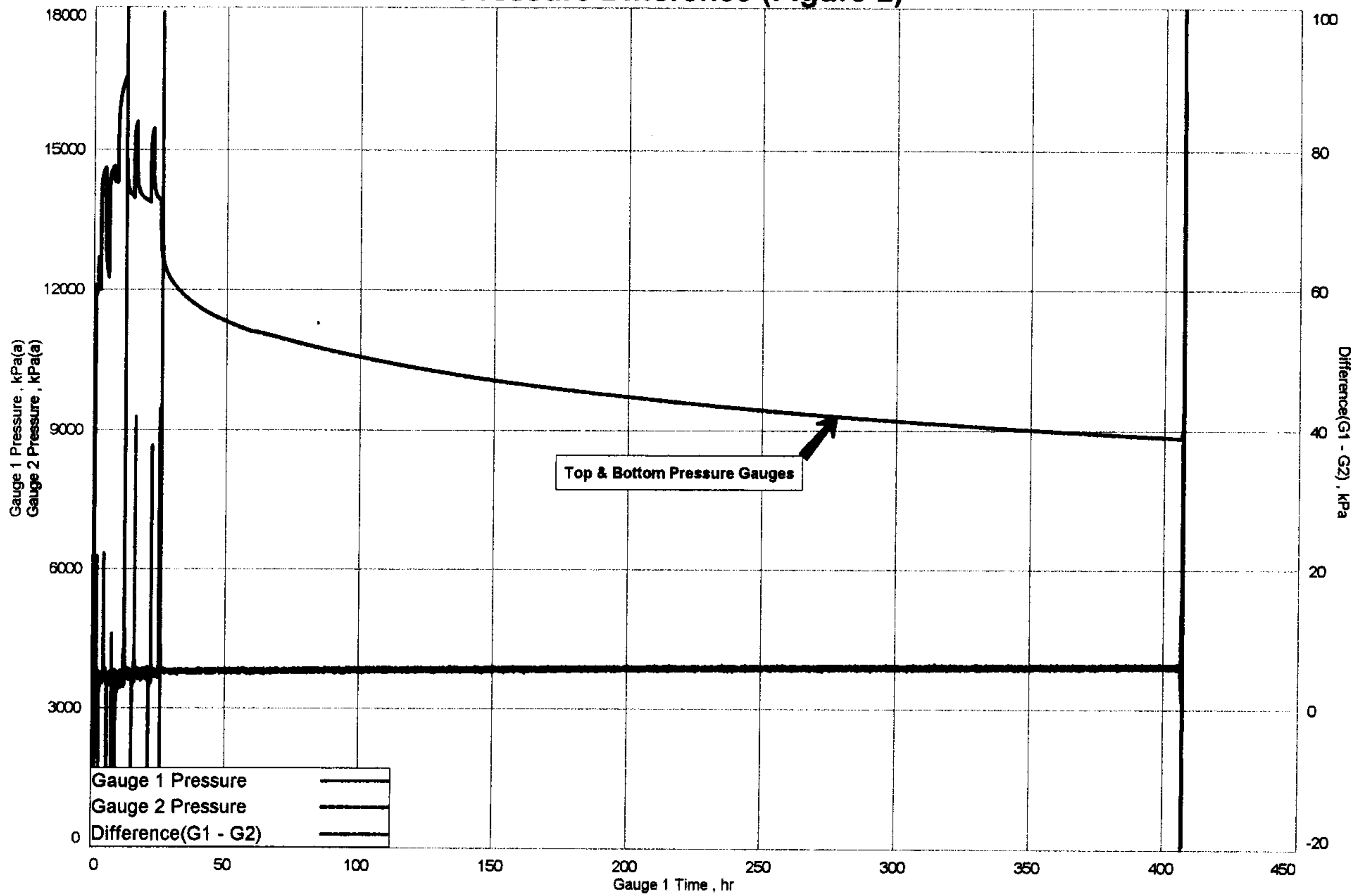
Raw Data (Figure 1)



100/02-08-002-29W1/0

Home Pierson
Formation: Speafish

Pressure Difference (Figure 2)

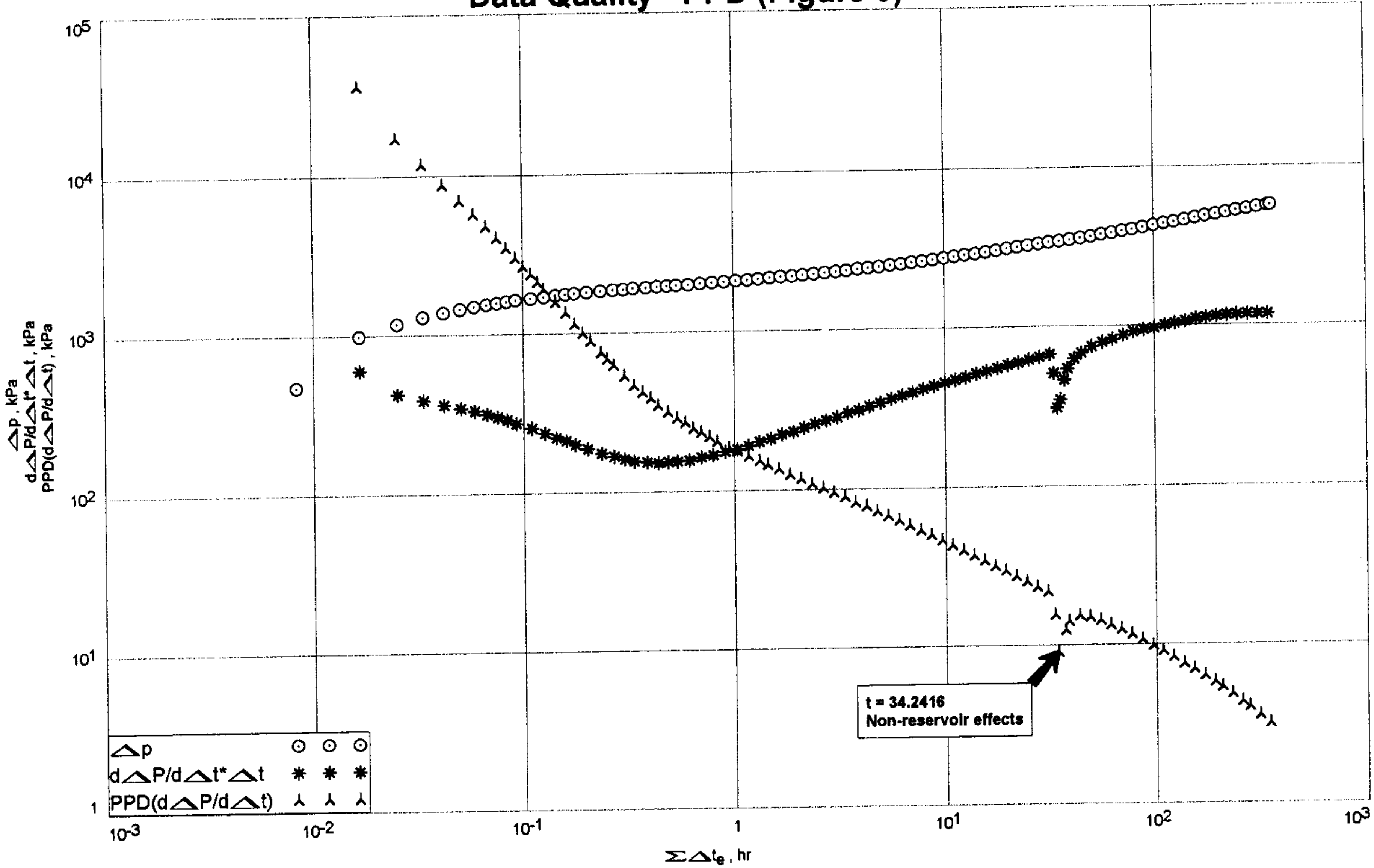


C:\Data\WellTest\anderson\Pierson\and2-8 05-Jan-00 Ver 2.305

PMG

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

Data Quality - PPD (Figure 3)



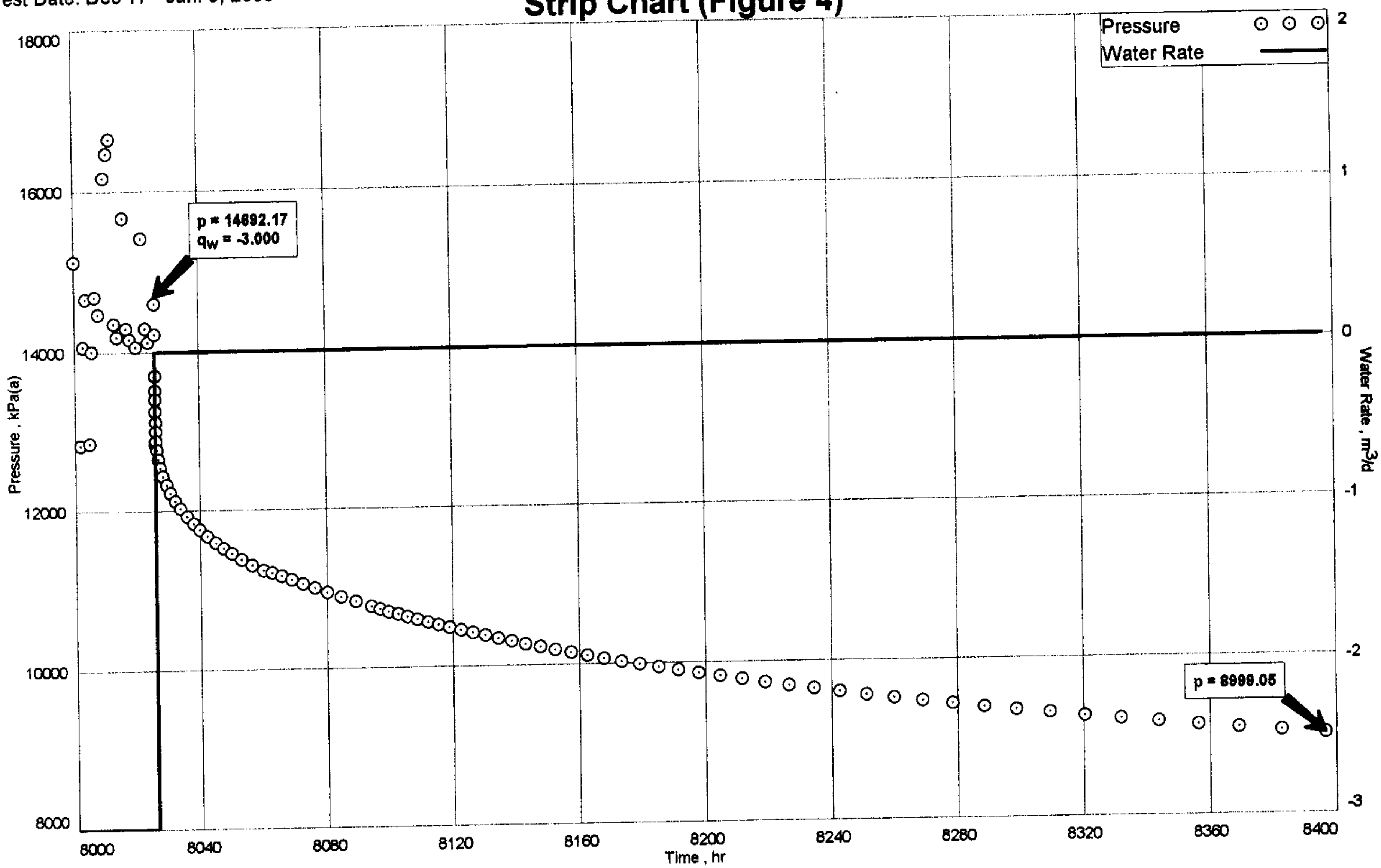
P M G

C:\Data\WellTest\anderson\Pierson\020802.FKT 07-Jan-00 Ver 2.305

PRESSURE TRANSIENT ANALYSIS

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

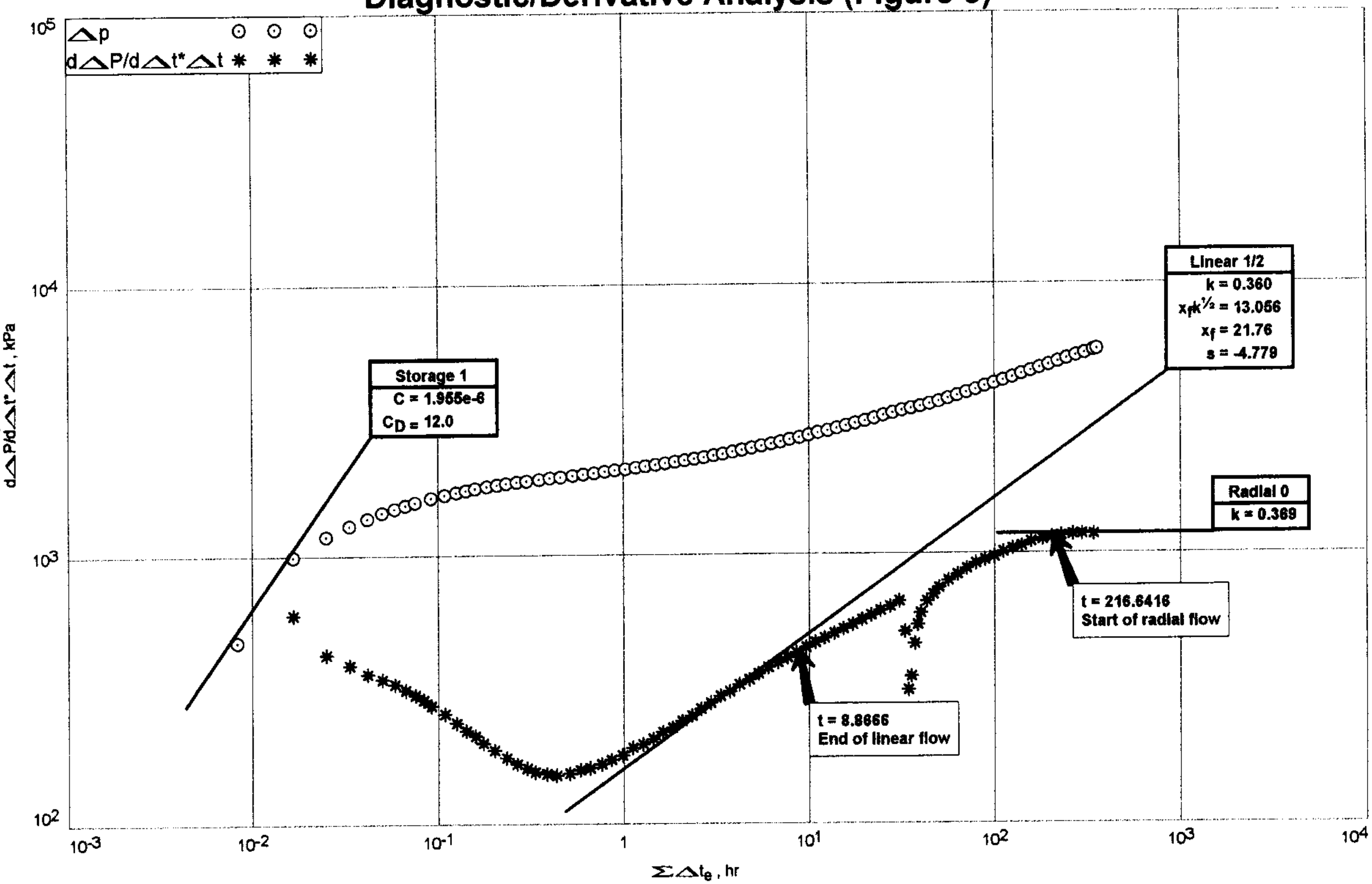
Strip Chart (Figure 4)



PMG

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

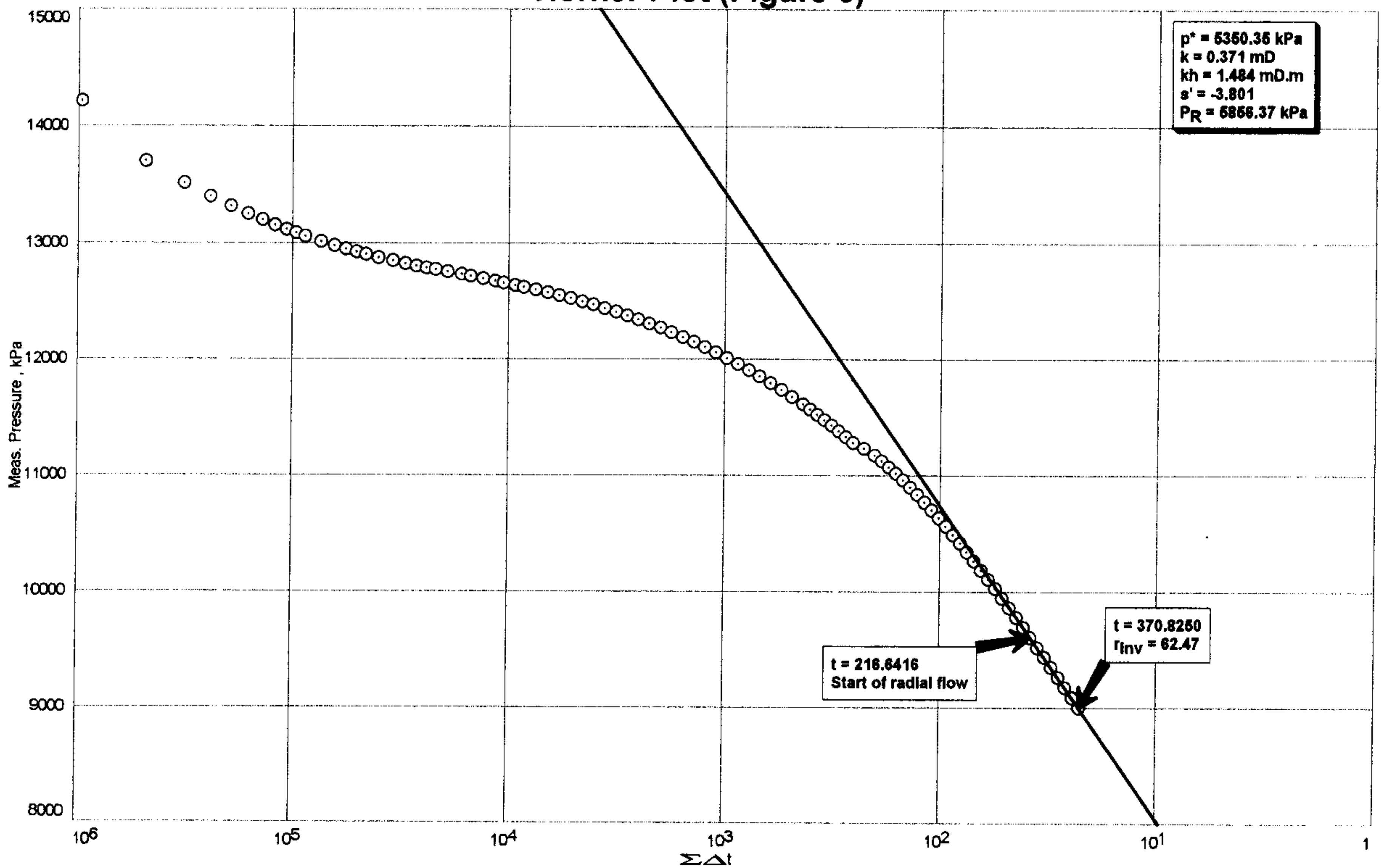
Diagnostic/Derivative Analysis (Figure 5)



P M G

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

Horner Plot (Figure 6)

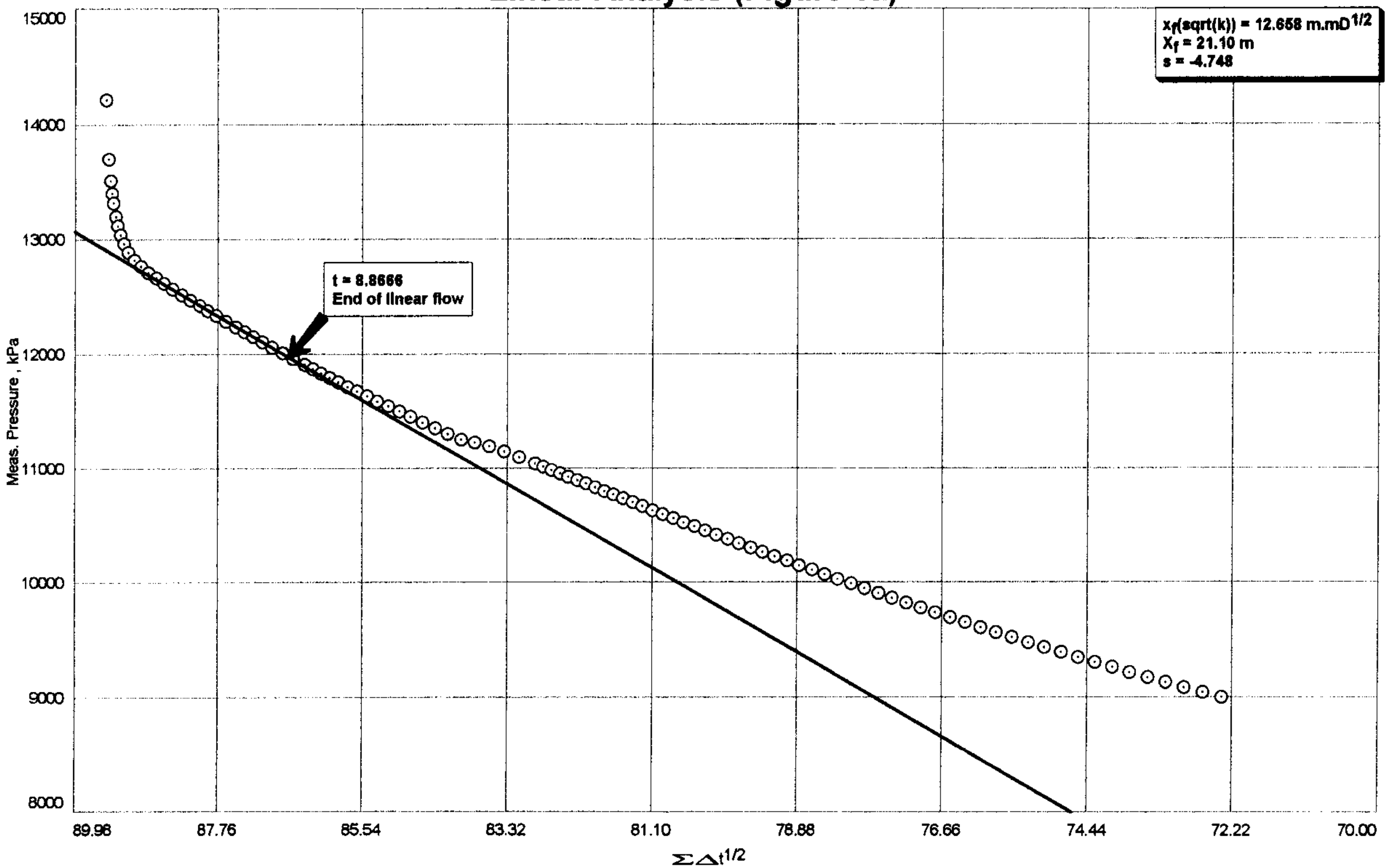


C:\Data\WellTest\anderson\Pierson\020802.FKT 18-Jan-00 Ver 2.305

PMG

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

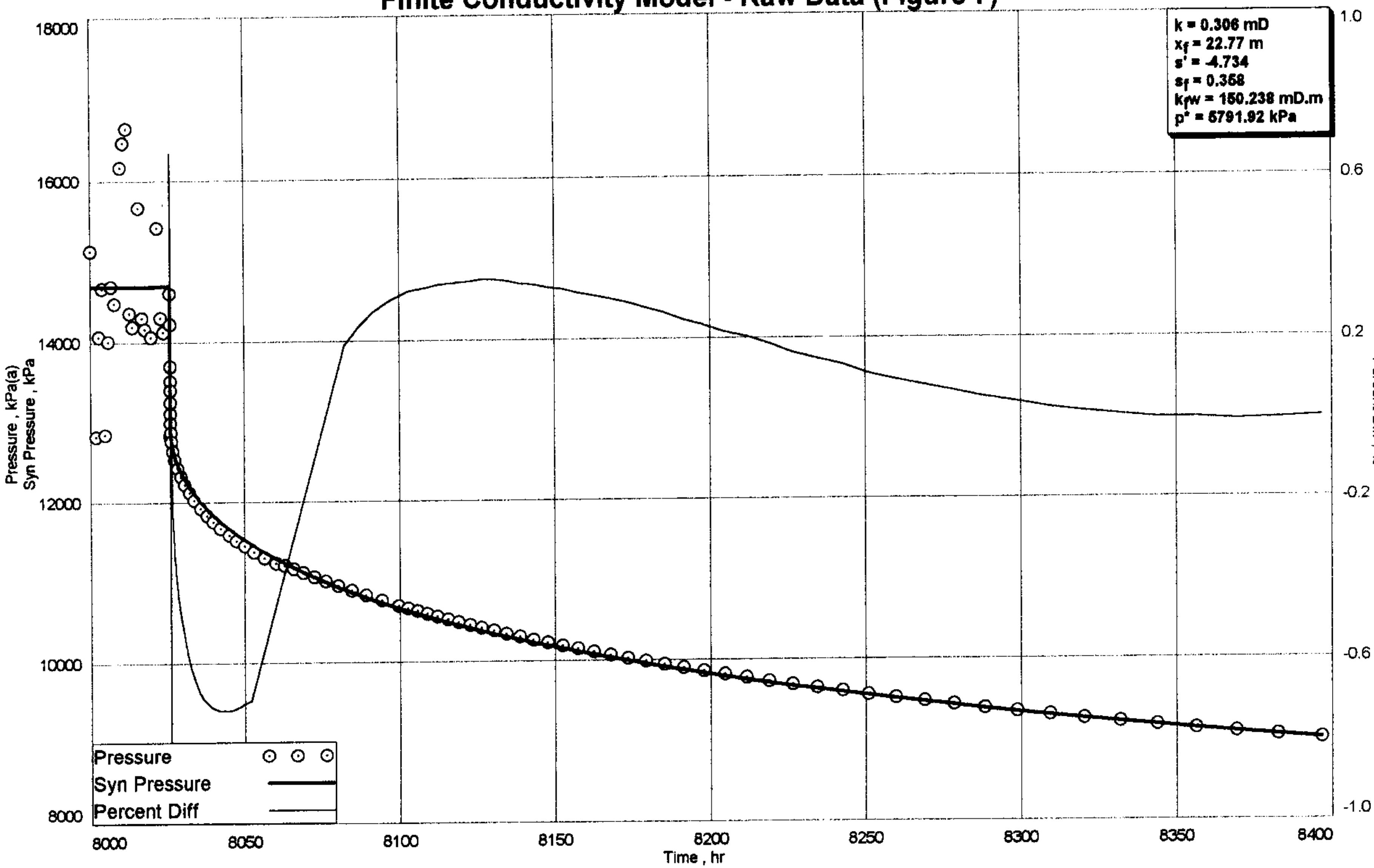
Linear Analysis (Figure 6a)



PRESSURE
HISTORY
MATCHING

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

Finite Conductivity Model - Raw Data (Figure 7)

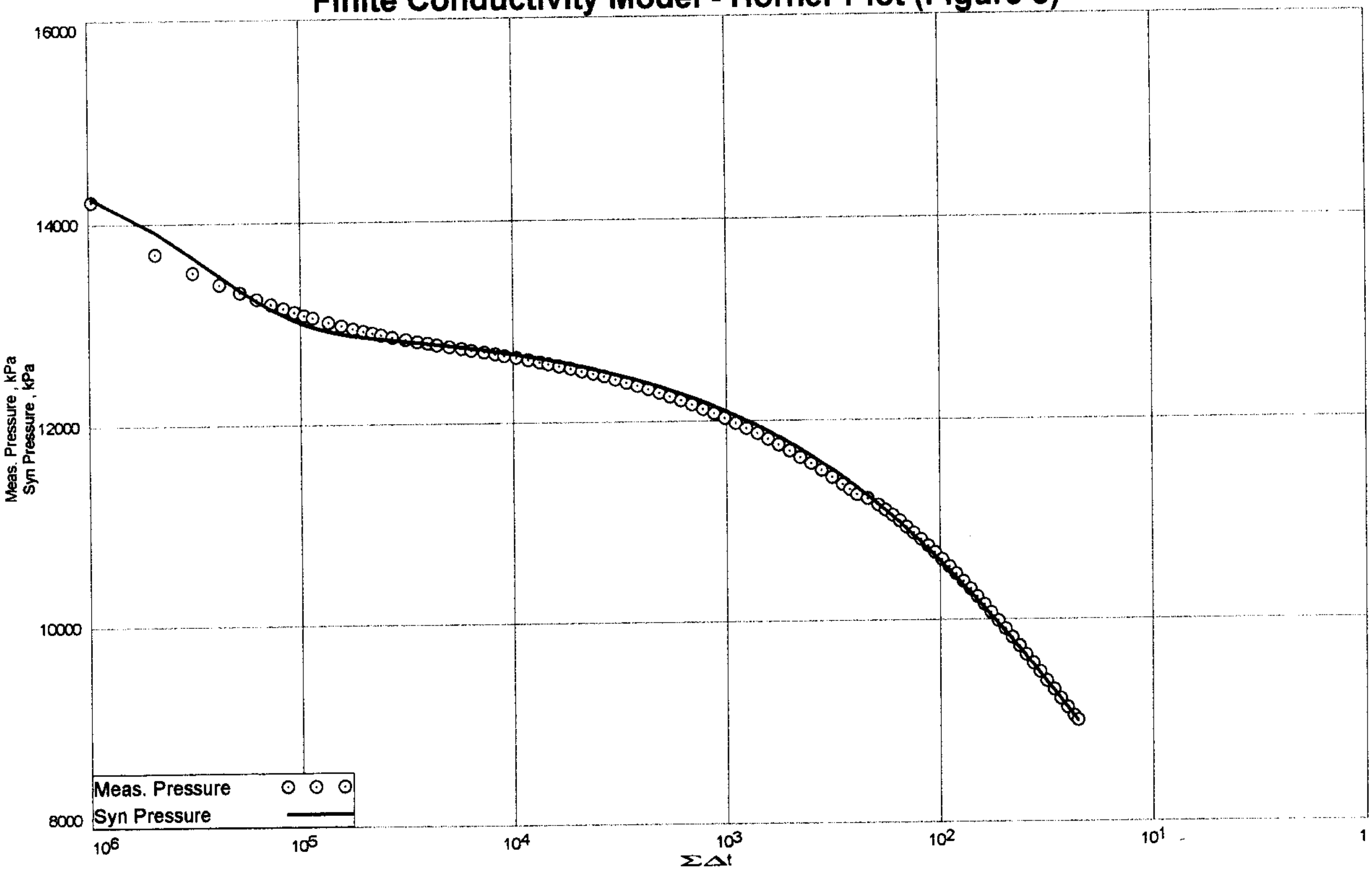


PMG

ast C:\Data\WellTest\anderson\Pierson\020802.FKT 07-Jan-00 Ver 2.305

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

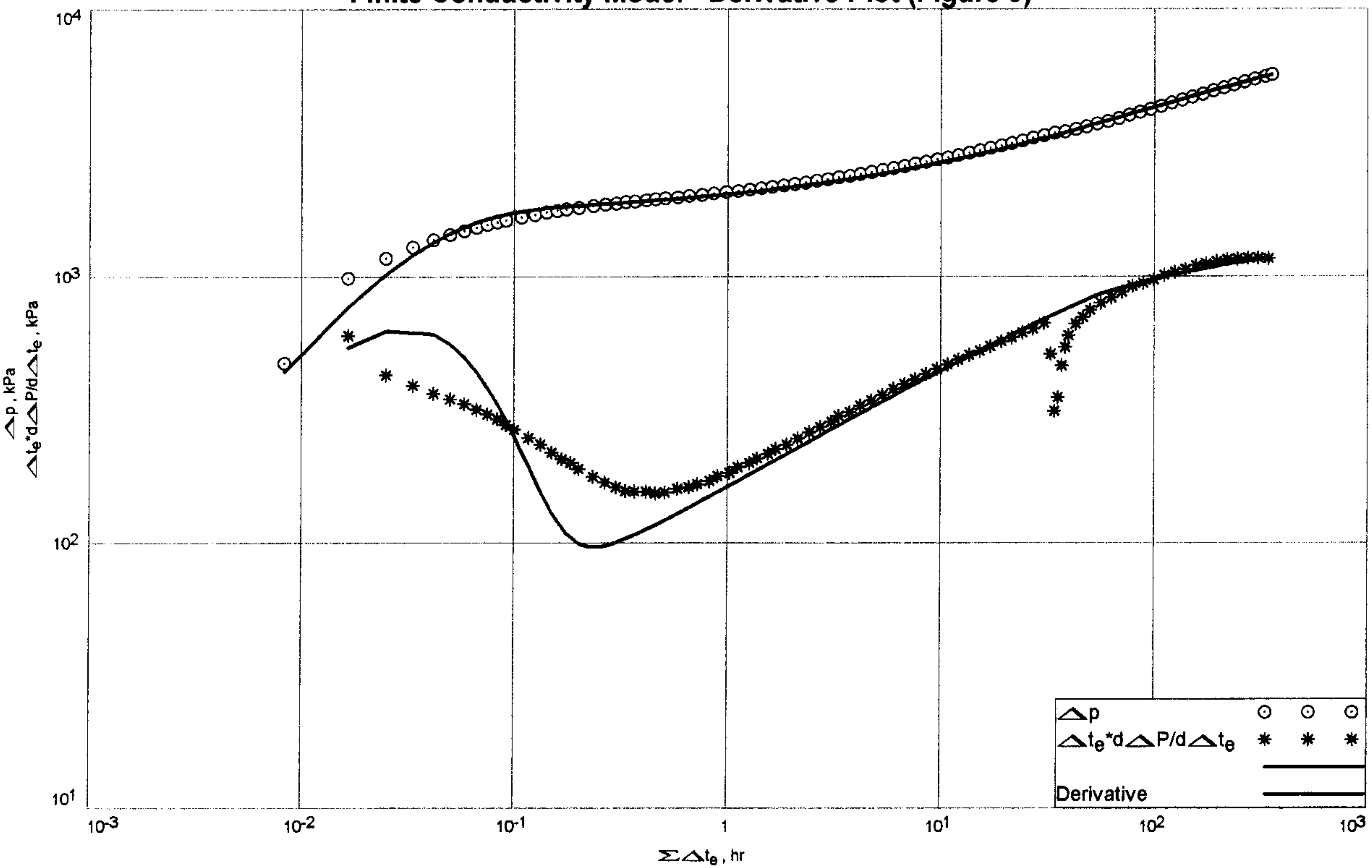
Finite Conductivity Model - Horner Plot (Figure 8)



P M G

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

Finite Conductivity Model - Derivative Plot (Figure 9)



PMG

C:\Data\WellTest\anderson\Pierson\020802.FKT 07-Jan-00 Ver 2.305

SUBSURFACE PRESSURES

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

	Time hr	Cum Time hr	Pressure kPa(a)	Gas Rate $10^3m^3/d$	Oil Rate m^3/d	Water Rate m^3/d
1	-8000.0000	8000.0000	15132.00	0.000	0.000	-3.000
2	-0.1000	8000.1000	15132.00	0.000	0.000	-3.000
3	1.6667	8001.6667	12831.29			
4	1.6750	8001.6750	12819.90			
5	2.6750	8002.6750	14067.84			-3.000
6	3.6750	8003.6750	14666.31			
7	4.6750	8004.6750	12854.15			
8	5.6750	8005.6750	14007.25			
9	6.6750	8006.6750	14688.15			
10	7.6750	8007.6750	14476.73			
11	8.6750	8008.6750	14436.03			
12	9.6750	8009.6750	16166.46			
13	10.6750	8010.6750	16470.16			
14	11.6750	8011.6750	16650.14			
15	12.6750	8012.6750	14356.70			
16	13.6750	8013.6750	14185.90			
17	14.6750	8014.6750	14131.96			
18	15.6750	8015.6750	15663.64			
19	16.6750	8016.6750	14296.88			
20	17.6750	8017.6750	14159.25			
21	18.6750	8018.6750	14101.21			
22	19.6750	8019.6750	14061.46			
23	20.6750	8020.6750	14030.07			
24	21.6750	8021.6750	15414.70			
25	22.6750	8022.6750	14295.07			
26	23.6750	8023.6750	14122.78			
27	24.6750	8024.6750	14059.28			
28	25.6750	8025.6750	12836.67			
29	25.7333	8025.7333	14601.39			
30	25.7417	8025.7417	14692.17	0.000		-3.000
31	25.7500	8025.7500	14215.67			0.000
32	25.7583	8025.7583	13701.32			
33	25.7667	8025.7667	13514.39			
34	25.7750	8025.7750	13399.50			
35	25.7833	8025.7833	13315.89			
36	25.7917	8025.7917	13250.80			
37	25.8000	8025.8000	13198.30			
38	25.8083	8025.8083	13154.99			
39	25.8167	8025.8167	13118.23			
40	25.8250	8025.8250	13086.77			
41	25.8333	8025.8333	13059.67			
42	25.8417	8025.8417	13035.95			

Print Filter Used: Nth Line = 1.000

PMG

Fast C:\Data\WellTest\anderson\Pierson\020802.FKT 07-Jan-00 Ver 2.305

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

	Time hr	Cum Time hr	Pressure kPa(a)	Gas Rate $10^3m^3/d$	Oil Rate m^3/d	Water Rate m^3/d
43	25.8500	8025.8500	13014.97			
44	25.8583	8025.8583	12996.09			
45	25.8667	8025.8667	12979.37			
46	25.8750	8025.8750	12963.95			
47	25.8833	8025.8833	12950.07			
48	25.8917	8025.8917	12937.46			
49	25.9000	8025.9000	12925.67			
50	25.9083	8025.9083	12914.92			
51	25.9167	8025.9167	12904.98			
52	25.9250	8025.9250	12895.70			
53	25.9333	8025.9333	12886.87			
54	25.9417	8025.9417	12878.79			
55	25.9500	8025.9500	12871.03			
56	25.9583	8025.9583	12863.88			
57	25.9750	8025.9750	12850.64			
58	25.9917	8025.9917	12838.50			
59	26.0083	8026.0083	12827.64			
60	26.0250	8026.0250	12817.48			
61	26.0417	8026.0417	12808.19			
62	26.0583	8026.0583	12799.51			
63	26.0750	8026.0750	12791.40			
64	26.0917	8026.0917	12783.84			
65	26.1083	8026.1083	12776.55			
66	26.1250	8026.1250	12769.70			
67	26.1417	8026.1417	12763.13			
68	26.1583	8026.1583	12756.71			
69	26.1750	8026.1750	12750.70			
70	26.2000	8026.2000	12742.25			
71	26.2250	8026.2250	12734.02			
72	26.2500	8026.2500	12726.31			
73	26.2750	8026.2750	12718.80			
74	26.3000	8026.3000	12711.79			
75	26.3250	8026.3250	12704.82			
76	26.3500	8026.3500	12698.12			
77	26.3750	8026.3750	12691.85			
78	26.4000	8026.4000	12685.64			
79	26.4333	8026.4333	12677.60			
80	26.4667	8026.4667	12669.82			
81	26.5000	8026.5000	12662.36			
82	26.5333	8026.5333	12655.13			
83	26.5667	8026.5667	12648.11			
84	26.6000	8026.6000	12641.36			

Print Filter Used: Nth Line = 1.000

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

	Time hr	Cum Time hr	Pressure kPa(a)	Gas Rate $10^3m^3/d$	Oil Rate m^3/d	Water Rate m^3/d
85	26.6417	8026.6417	12632.98			
86	26.6833	8026.6833	12624.93			
87	26.7250	8026.7250	12617.39			
88	26.7667	8026.7667	12609.64			
89	26.8083	8026.8083	12602.53			
90	26.8583	8026.8583	12593.64			
91	26.9083	8026.9083	12585.30			
92	26.9583	8026.9583	12577.17			
93	27.0083	8027.0083	12569.13			
94	27.0583	8027.0583	12561.49			
95	27.1167	8027.1167	12552.49			
96	27.1750	8027.1750	12543.91			
97	27.2333	8027.2333	12535.62			
98	27.2917	8027.2917	12527.37			
99	27.3583	8027.3583	12518.25			
100	27.4250	8027.4250	12509.21			
101	27.4917	8027.4917	12500.41			
102	27.5667	8027.5667	12491.00			
103	27.6417	8027.6417	12481.63			
104	27.7167	8027.7167	12472.52			
105	27.8000	8027.8000	12462.50			
106	27.8833	8027.8833	12452.91			
107	27.9750	8027.9750	12442.42			
108	28.0667	8028.0667	12432.30			
109	28.1583	8028.1583	12422.42			
110	28.2583	8028.2583	12411.69			
111	28.3583	8028.3583	12401.30			
112	28.4667	8028.4667	12390.32			
113	28.5750	8028.5750	12379.62			
114	28.6917	8028.6917	12368.40			
115	28.8083	8028.8083	12357.33			
116	28.9333	8028.9333	12345.92			
117	29.0583	8029.0583	12334.62			
118	29.1917	8029.1917	12322.64			
119	29.3333	8029.3333	12310.51			
120	29.4750	8029.4750	12298.48			
121	29.6250	8029.6250	12286.32			
122	29.7833	8029.7833	12273.51			
123	29.9417	8029.9417	12261.04			
124	30.1083	8030.1083	12248.14			
125	30.2833	8030.2833	12235.05			
126	30.4667	8030.4667	12221.59			

Print Filter Used: Nth Line = 1.000

PMG

Fast C:\Data\WellTest\anderson\Pierson\020802.FKT 07-Jan-00 Ver 2.305

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

	Time hr	Cum Time hr	Pressure kPa(a)	Gas Rate $10^3m^3/d$	Oil Rate m^3/d	Water Rate m^3/d
127	30.6583	8030.6583	12207.86			
128	30.8583	8030.8583	12193.80			
129	31.0667	8031.0667	12179.62			
130	31.2833	8031.2833	12165.10			
131	31.5083	8031.5083	12150.33			
132	31.7417	8031.7417	12135.52			
133	31.9833	8031.9833	12120.27			
134	32.2333	8032.2333	12105.40			
135	32.4917	8032.4917	12089.97			
136	32.7583	8032.7583	12074.67			
137	33.0333	8033.0333	12059.04			
138	33.3250	8033.3250	12042.90			
139	33.6250	8033.6250	12026.90			
140	33.9417	8033.9417	12010.17			
141	34.2667	8034.2667	11993.54			
142	34.6083	8034.6083	11976.52			
143	34.9583	8034.9583	11959.49			
144	35.3250	8035.3250	11941.84			
145	35.7000	8035.7000	11924.60			
146	36.0917	8036.0917	11906.89			
147	36.5000	8036.5000	11888.88			
148	36.9250	8036.9250	11870.65			
149	37.3667	8037.3667	11852.22			
150	37.8250	8037.8250	11833.51			
151	38.3000	8038.3000	11814.60			
152	38.7917	8038.7917	11795.57			
153	39.3083	8039.3083	11776.04			
154	39.8417	8039.8417	11756.27			
155	40.4000	8040.4000	11736.21			
156	40.9750	8040.9750	11716.08			
157	41.5750	8041.5750	11695.60			
158	42.2000	8042.2000	11674.84			
159	42.8500	8042.8500	11653.75			
160	43.5250	8043.5250	11632.46			
161	44.2250	8044.2250	11610.72			
162	44.9500	8044.9500	11588.98			
163	45.7083	8045.7083	11566.72			
164	46.4917	8046.4917	11544.35			
165	47.3083	8047.3083	11521.79			
166	48.1583	8048.1583	11498.72			
167	49.0417	8049.0417	11475.45			
168	49.9583	8049.9583	11452.03			

Print Filter Used: Nth Line = 1.000

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

	Time hr	Cum Time hr	Pressure kPa(a)	Gas Rate $10^3m^3/d$	Oil Rate m^3/d	Water Rate m^3/d
169	50.9083	8050.9083	11428.08			
170	51.9000	8051.9000	11403.82			
171	52.9250	8052.9250	11379.68			
172	53.9917	8053.9917	11354.88			
173	55.1000	8055.1000	11329.97			
174	56.2500	8056.2500	11304.47			
175	57.4500	8057.4500	11278.63			
176	58.6917	8058.6917	11252.65			
177	59.9833	8059.9833	11239.25			
178	61.3250	8061.3250	11228.71			
179	62.7250	8062.7250	11212.29			
180	64.1750	8064.1750	11193.11			
181	65.6833	8065.6833	11170.61			
182	67.2500	8067.2500	11146.99			
183	68.8750	8068.8750	11122.20			
184	70.5667	8070.5667	11096.22			
185	72.3250	8072.3250	11069.91			
186	74.1500	8074.1500	11042.40			
187	76.0500	8076.0500	11014.10			
188	78.0250	8078.0250	10985.19			
189	80.0750	8080.0750	10955.75			
190	82.2083	8082.2083	10925.56			
191	84.4250	8084.4250	10894.85			
192	86.7250	8086.7250	10863.85			
193	89.1167	8089.1167	10832.16			
194	91.6000	8091.6000	10800.22			
195	94.1833	8094.1833	10767.52			
196	96.8667	8096.8667	10734.32			
197	99.6500	8099.6500	10700.71			
198	102.5417	8102.5417	10666.99			
199	105.5500	8105.5500	10632.15			
200	108.6750	8108.6750	10597.01			
201	111.9250	8111.9250	10561.65			
202	115.3000	8115.3000	10525.85			
203	118.8083	8118.8083	10489.70			
204	122.4500	8122.4500	10453.29			
205	126.2417	8126.2417	10416.72			
206	130.1750	8130.1750	10379.59			
207	134.2667	8134.2667	10341.65			
208	138.5167	8138.5167	10303.27			
209	142.9333	8142.9333	10264.96			
210	147.5250	8147.5250	10226.03			

Print Filter Used: Nth Line = 1.000

Home Pierson 02-08-02-29W1
Spearfish (1028.4 - 1035.5 mKB)
Fall-off Test
Test Date: Dec 17 - Jan. 3, 2000

	Time hr	Cum Time hr	Pressure kPa(a)	Gas Rate $10^3 m^3/d$	Oil Rate m^3/d	Water Rate m^3/d
211	152.2917	8152.2917	10187.12			
212	157.2500	8157.2500	10147.44			
213	162.4000	8162.4000	10107.57			
214	167.7500	8167.7500	10067.71			
215	173.3083	8173.3083	10027.31			
216	179.0833	8179.0833	9986.44			
217	185.0833	8185.0833	9945.20			
218	191.3250	8191.3250	9903.48			
219	197.8083	8197.8083	9861.93			
220	204.5417	8204.5417	9819.87			
221	211.5417	8211.5417	9777.97			
222	218.8167	8218.8167	9735.39			
223	226.3750	8226.3750	9692.27			
224	234.2250	8234.2250	9649.65			
225	242.3833	8242.3833	9606.70			
226	250.8667	8250.8667	9563.06			
227	259.6750	8259.6750	9519.84			
228	268.8333	8268.8333	9476.50			
229	278.3500	8278.3500	9433.09			
230	288.2333	8288.2333	9389.48			
231	298.5083	8298.5083	9346.09			
232	309.1833	8309.1833	9302.42			
233	320.2750	8320.2750	9258.84			
234	331.8000	8331.8000	9215.36			
235	343.7750	8343.7750	9171.80			
236	356.2250	8356.2250	9128.58			
237	369.1583	8369.1583	9084.89			
238	382.6000	8382.6000	9041.96			
239	396.5667	8396.5667	8999.05			

Print Filter Used: Nth Line = 1.000

EQUATIONS

and

NOMENCLATURE

(METRIC UNITS)

BASIC TIME FUNCTIONS

Flow Time	t
Shut-In Time	Δt
Horner Time	$\frac{t + \Delta t}{\Delta t}$
Superposition Time	$t_n = \sum_{j=1}^{n} \frac{q_j - q_{j-1}}{q_n} \log(t - t_{j-1})$
	$\Delta t_n = \sum_{j=1}^{n} \frac{q_j}{q_n} \log \frac{t_n + \Delta t - t_{j-1}}{t_n + \Delta t - t_j}$
Equivalent Time	$\Delta t_e = \frac{t \cdot \Delta t}{t + \Delta t}$
Root Time	$\sqrt{t}$
	$\sqrt{\Delta t}$
Tandem Root Time	$\sqrt{t + \Delta t} - \sqrt{\Delta t}$

BASIC TIME FUNCTIONS (cont'd)

Quad Root Time $\sqrt[4]{t}$

$\sqrt[4]{\Delta t}$

Tandem Quad Root Time $\sqrt[4]{t+\Delta t} - \sqrt[4]{\Delta t}$

TYPECURVES - DIMENSIONLESS VARIABLES

$$\Delta p_D = \frac{(kh/\mu)_t \, \Delta p}{141.2 \; q_t \, B_t}$$

$$t_D = \frac{2.637E{-}4 (k/\mu)_t \, t}{\phi c r_w^2}$$

$$\frac{t_D}{C_D} = 0.000295 \; (\frac{kh}{\mu})_t \frac{t}{C}$$

$$C_D e^{2s} = \frac{0.8936 \; C \; e^{2s}}{\phi c h r_w^2}$$

$$t_{DA} = \frac{2.637E{-}4 \; (k/\mu)_t \, t}{\phi c A}$$

$$t_{Dxf} = \frac{2.637E{-}4 \; (k/\mu)_t \, t}{\phi c x_f^2}$$

$$(k_f w)_D = \frac{k_f w}{k x_f}$$

PMG

McKINLEY ANALYSIS

Wellbore Capacity

$$F = \left(\frac{\Delta p\ F}{qB}\right)\left(\frac{qB}{\Delta p}\right)$$

Alpha

$$\alpha = \frac{F}{5.615}$$

Note: Alpha is the same as C

Wellbore Storage Constant
Compressible Fluid

$$C = c_{ws} V_{ws}$$

Wellbore Storage Constant
Changing Liquid Level

$$C = \frac{cross-sectional\ area}{5.615\ liquid\ gradient}$$

Transmissivity

$$\frac{kh}{\mu} = \left(\frac{T}{F}\right) F$$

Pressure Drop Skin

$$\Delta p_s = \left[1 - \frac{kh_{(wellbore)}}{kh_{(formation)}}\right] \Delta p_{(departure)}$$

Flow Efficiency

$$FE = \frac{p^* - p_{wf} - \Delta p_s}{p^* - p_{wf}}$$

PMG

SEMILOG ANALYSIS

Transmissivity

$$\left(\frac{kh}{\mu}\right)_t = \frac{162.6\ q_t\ B_t}{m}$$

Permeability

$$k = \frac{162.6\ q_o\ B_o\ \mu_o}{mh}$$

Skin Factor

$$s' = 1.151\left[\frac{p_{ws} - p_{wfo}}{m} - \log\frac{t\Delta t}{t+\Delta t} - \log\left(\frac{(k/\mu)_t}{\phi_t c_t r_w^2}\right) + 3.23\right]$$

Pressure Drop
due to Skin

$$\Delta p_s = 0.869\ ms'$$

Flow Efficiency

$$FE = \frac{\bar{p}_R - p_{wfo} - 0.869\ ms'}{\bar{p}_R - p_{wfo}}$$

Damage Ratio

$$DR = \frac{1}{FE}$$

Radius of Investigation

$$r_{inv} = \sqrt{\frac{(k/\mu_t)\ t}{948\phi_t c_t}}$$

Time to Stabilization

$$t_s = \frac{\phi\ c\ A}{2.637E\text{-}4\ (k/\mu)_t}(t_{DA})_{pss}$$

SEMILOG ANALYSIS (cont"d)

Stabilized Rate

$$q_s = \frac{p_i - p_{wfo}}{\frac{162.6\ B_o}{(k/\mu)_o\ h}\left(\log\left(\frac{4A}{1.781\ r_w^2 C_A}\right) + \frac{4\pi(t_{DA})_{pss}}{2.303} + \frac{2s'}{2.303}\right)}$$

Productivity Index

$$P\ I = \frac{q}{\bar{p}_R - p_{wfo}}$$

MBH Average Pressure

$$\bar{p}_R = p^* - \frac{m}{2.303}(MBH\ function)$$

DIETZ Average Pressure

$$(\Delta t)_{\bar{p}_R} = \frac{\phi\ c_t\ A}{2.637E{-4}\ C_A(k/\mu)_t}$$

LINEAR ANALYSIS

Fracture half-length

$$x_f = \frac{4.064\ q_t\ B_t}{mh(\phi c k/\mu)_t^{1/2}}$$

Channel width

$$W = \frac{8.128\ q_t\ B_t}{mh(\phi c k/\mu)_t^{1/2}}$$

Skin Factor

$$s = \ln\frac{2\ r_w}{x_f}$$

BI-LINEAR ANALYSIS

Fracture Conductivity

$$k_f w = \left[\frac{44.1\ qB\mu}{mh(\phi\mu c k)^{1/4}}\right]^2$$

PMG

NOMENCLATURE

Symbol	Description	Metric (SI)	Field
a	LIT flow equation coefficient	-	-
A	drainage area	m^2	ft^2
AOF	absolute open flow potential (gas)	$10^3 m^3/d$	MMcfd
b	LIT flow equation coefficient	-	-
B	formation volume factor	-	-
c	compressibility	kpa^{-1}	psi^{-1}
c_{ws}	compressibility of wellbore fluids	kpa^{-1}	psi^{-1}
C	wellbore storage/unloading constant	m^3/kPa	bbl/psi
C	simplified flow equation coefficient	-	-
C_A	shape factor	-	-
C_{aD}	apparent wellbore storage constant	-	-
C_D	dimensionless wellbore storage constant	-	-
C_{pD}	storage pressure parameter	-	-
DR	damage ratio	-	-
F	wellbore capacity (McKinley)	m^3/kPa	ft^3/psi
FE	flow efficiency	-	-
G	relative density (gas)	-	-
GOR	gas-oil ratio	m^3/m^3	ft^3/bbl
h	net pay	m	ft
k	permeability	mD	md
$k_{(x,y,z)}$	permeability in the x,y,z direction	mD	md
k_f	fracture permeability	mD	md
$k_f w$	fracture conductivity	mD.m	md.ft
kh	flow capacity	mD.m	md.ft
k/μ	mobility	-	-
kh/μ	transmissivity	-	-

Symbol	Description	Metric (SI)	Field
L	length of horizontal well	m	ft
L_e	effective length of horizontal well	m	ft
m	slope of transient plots	-	-
n	simplified flow equation coefficient	-	-
p	pressure	kPa	psia
p_{bp}	bubble point pressure	kPa	psia
p_c	gas pseudo-critical pressure	kPa	psia
p_i	initial pressure	kPa	psia
p_R	average reservoir pressure	kPa	psia
p_{tf}	flowing wellhead pressure	kPa	psia
p_{ts}	shut-in wellhead pressure	kPa	psia
p_{wf}	flowing sandface pressure	kPa	psia
P_{wfo}	final flowing pressure	kPa	psia
p_{ws}	shut-in sandface pressure	kPa	psia
p^*	extrapolated pressure	kPa	psia
Δp_D	dimensionless pressure	-	-
Δp	pressure drop	kPa	psi
PI	productivity index	$m^3/d/kPa$	bbl/d/psi
q	flow rate - gas - liquid	$10^3 m^3/d$ m^3/d	MMcf/d bbl/d
q_j	j^{th} flow rate	m^3/d	bbl/d
q_n	n^{th} flow rate	m^3/d	bbl/d
q_s	stabilized rate - gas - liquid	$10^3 m^3/d$ m^3/d	MMcf/d bbl/d
r_e	external radius	m	ft
r_{inv}	radius of investigation	m	ft
r_w	wellbore radius	m	ft
R_s	solution gas ratio	m^3/m^3	ft^3/bbl

Symbol	Description	Metric (SI)	Field
s	skin factor	-	-
s'	apparent skin factor	-	-
S	saturation (oil, gas, water)	-	-
t	time	hr	hr
t_D	dimensionless time	hr	hr
t_a	pseudo-time	hr	hr
t_{DA}	dimensionless time (based on drainage area)	hr	hr
t_{Dxf}	dimensionless time (based on fracture 1/2 length)	hr	hr
t_n	n^{th} flow period, or superposition time	-	-
Δt	shut-in time	hr	hr
Δt_a	shut-in pseudo-time	hr	hr
Δt_e	equivalent time	hr	hr
$(t_{DA})_{pss}$	dimensionless time at pseudo-steady state	-	-
t_s	time to stabilization	hr	hr
T	temperature	K	°R
T_c	gas pseudo-critical temperature	K	°R
V_{ws}	wellbore volume - gas - liquid	m^3 m^3	ft^3 bbl
W	channel width	m	ft
w	fracture width	m	ft
x_e	length of reservoir	m	ft
x_f	fracture half-length	m	ft
x_o	x -location of observation well	m	ft
x_w	x- location of centre of active well	m	ft
y_e	width of reservoir	m	ft
y_o	y- location of observation well	m	ft
y_w	y- location of centre of active well	m	ft
Z	gas compressibility factor	-	-
z_w	z-location of centre of active well	m	ft

Symbol	Description	Metric (SI)	Field
α	wellbore storage/unloading constant	m^3/kPa	bbl/psi
μ	viscosity - gas - liquid	$\mu Pa.s$ mPa.s	cp cp
λ	inter-porosity flow coefficient	-	-
T	transmissivity (McKinley)	mD.m/mPa.s	md.ft/cp
ϕ	porosity	-	-
ψ	pseudo-pressure	$kPa^2/\mu Pa.s$	$psia^2/cp$
ω	storativity ratio	-	-

Subscripts

D	dimensionless
DA	dimensionless based on area
Dxf	dimensionless based on fracture half -length
f	formation or flowing
g	gas
i	initial
o	oil
R	reservoir
s	shut-in, skin, stabilized or storage
t	total, transient, or wellhead (tubing head)
w	water or wellbore (sandface)
ref	evaluated at reference pressure

Superscripts

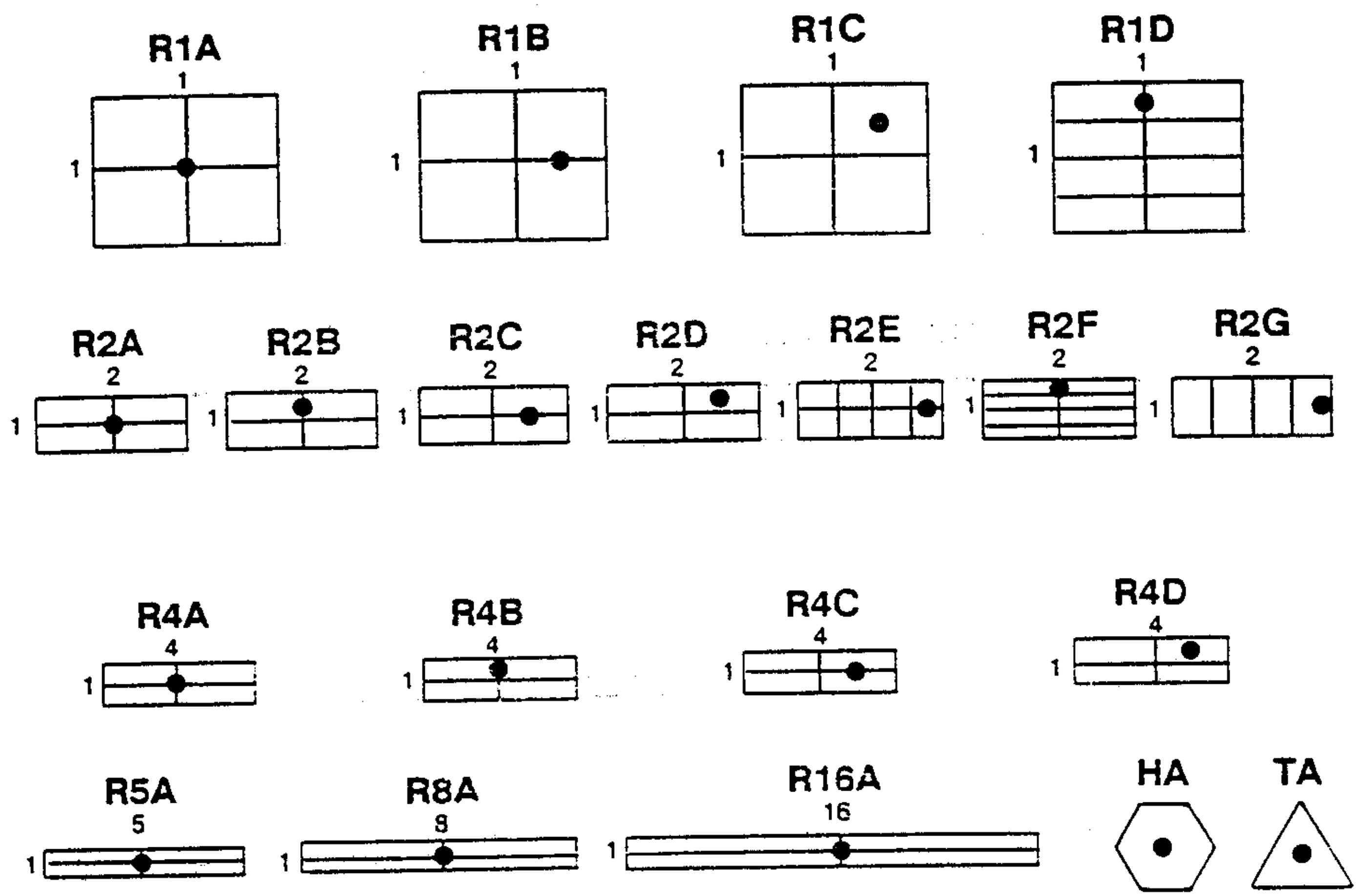
-	average

PMG

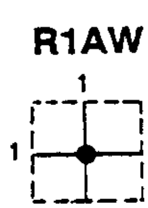
DIETZ SHAPE CODES

AVERAGE RESERVOIR PRESSURE - MBH CORRECTIONS

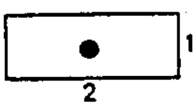
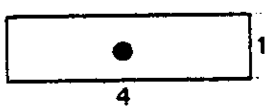
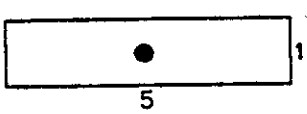
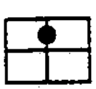
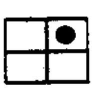
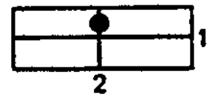
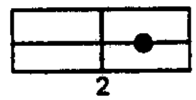
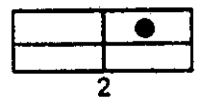
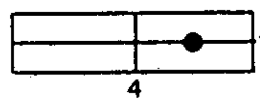
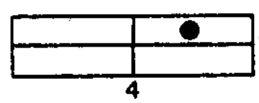
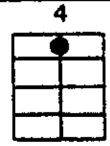
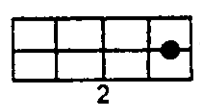
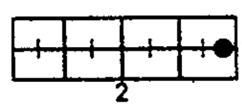
NO FLOW OUTER BOUNDARY



CONSTANT PRESSURE OUTER BOUNDARY



PMG

	$\ln C_A$	C_A	STABILIZED CONDITIONS FOR t_{DA} >
IN BOUNDED RESERVOIRS			
	3.45	31.6	0.1
	3.43	30.9	0.1
	3.45	31.6	0.1
	3.32	27.6	0.2
	3.30	27.1	0.2
	3.09	21.9	0.4
	3.12	22.6	0.2
	1.68	5.38	0.7
	0.86	2.36	0.7
	2.56	12.9	0.6
	1.52	4.57	0.5
	2.38	10.8	0.3
	1.58	4.86	1.0
	0.73	2.07	0.8
	1.00	2.72	0.8
	-1.46	0.232	2.5
	-2.16	0.115	3.0
	1.22	3.39	0.6
	1.14	3.13	0.3
	-0.50	0.607	1.0
	-2.20	0.111	1.2
	-2.32	0.098	0.9
IN WATER DRIVE RESERVOIRS			
	2.95	19.1	0.1
IN RESERVOIRS OF UNKNOWN PRODUCTION CHARACTER			
	3.22	25	0.1

PSEUDO-STEADY STATE SHAPE FACTORS FOR VARIOUS RESERVOIRS

FROM DIETZ (1965)

UNITS CONVERSION AND PREFIXES

METRIC (SI) UNIT	FIELD UNIT	DIVIDED BY
$10^3m^3/d$	MMcfd	2.817 399 E+01
kPa	psia	6.894 757 E+00
mD	md	9.869 233 E-01
mD.m	md.ft	3.008 142 E-01
m	ft	3.048 E-01
m^3	bbl (35 Imp gal) (42 US gal)	1.589 873 E-01
Pa.s	cp	1.0 E+03
°C	°F	(°F-32)5/9 E+00
K	°R	5/9 E+00
m^2	section (640 acres)	2.589 988 E+06
ha	section (640 acres)	2.589 988 E+02
m^3	gallon (Imp)	4.546 09 E-03
m^3	gallon (US)	3.785 412 E-03
$m^3/10^3m^3$	bbl/MMcf	5.643 052 E-03

Standard conditions: Metric (SI) 15°C, 101.325 kPa
Field 60°F, 14.65 psia

PMG