INJECTIVITY/FALL-OFF TEST REPORT

#1604
Copy 2 of 2

HOME PIERSON 02-17-02-29W1
SPEARFISH (1024 - 1030 mKB)
TEST DATE: DECEMBER 11 - 31, 1999

Prepared for:

ANDERSON EXPLORATION LTD.

Prepared by:

PETRO MANAGEMENT GROUP LTD.

JANUARY 2000

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January 17, 2000

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

Attn.: Mr. Larry Sopko

HOME PIERSON 02-17-02-29W1
SPEARFISH (1024 - 1030 mKB)
INJECTIVITY/FALL-OFF TEST
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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, if available. 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 02-17-02-29W1

Spearfish (1024 - 1030 mKB)

Fall-off Test

Test Date: Dec. 11 - 31, 1999

Model Parameters

Water Permeability (k_w)	0.315 mD	Fracture Half Length (x_f)	2.03 m
Total Mobility ($(k/\mu)_t$)	0.50 mD/mPa.s	Fracture Flow Capacity (k_fw)	188116.090 mD.m
Total Transmissivity ($(kh/\mu)_t$)	1.90 mDm/mPa.s	Fracture Face Skin (sf)	1.870e-7
Wellbore Storage Constant Dim. (C_D)	1745.21	Skin Equivalent to Xf	-2.405
		Exterior Radius (r_e)	450.00 m

Formation Parameters

Net Pay (h)	3.80 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)	4.603e-6 kPa^{-1}

Fluid Properties

Water Compressibility (c_w)	4.28820e-7 kPa^{-1}
Oil Compressibility (c_o)	1.24551e-5 kPa^{-1}
Gas Compressibility (c_g)	6.01975e-5 kPa^{-1}
Water Formation Volume Factor (B_w)	1.000
Water Viscosity (μ_w)	0.628 mPa.s
Gas Viscosity (μ_g)	17.966 μPa.s
Solution Gas Ratio (R_{sw})	0 m^3/m^3
Specific Gravity (G)	1.000
PVT Reference Pressure (p_{PVT})	16415.98 kPa

Production and Pressure

Q_tB_t	-1.500 m^3/d
Final Water Rate	-1.500 m^3/d
Final Gas Rate	0.000 $10^3m^3/d$
Final Flowing Pressure (p_{wfo})	16485.98 kPa
Final Measured Pressure	11014.20 kPa
Initial Pressure (p_i)	16415.98 kPa

Synthesis Results

Average Error	0.14 %
Synthetic Initial Pressure (p_i)	8808.83 kPa
Extrapolated Pressure at Specified Time	9288.85 kPa
Pressure Drop Due To Skin (Δp_s)	kPa
Flow Efficiency (FE)	1.000
Damage Ratio (DR)	1.000

Forecasts

Specified Flowing Pressure (p_{wfs})	16485.98 kPa
3 - Month Constant Rate	-1.606 m^3/d
6 - Month Constant Rate	-1.492 m^3/d
Specified Forecast Time	12.00 month
Forecast Constant Rate @ Current Skin	-1.394 m^3/d
PI / II (Actual)	2.08e-4 $m^3/d/kPa$
Forecast Constant Rate @ Skin=0	-1.394 m^3/d
PI / II (Ideal)	2.08e-4 $m^3/d/kPa$

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SUMMARY OF RESULTS

SUMMARY OF RESULTS

1. The average reservoir pressure (P_R) is 9 289 kPa.

2. The effective permeability to water of the Spearfish formation is 0.32 mD.

3. The apparent wellbore skin factor of -2.4 and the fracture half length of 2.0 m confirm that the well was stimulated.

4. The stabilized water injection rate is 1.5 m^3/d

5. The injectivity index (I.I.) is 2.08E-4 $m^3/d/kPa$.

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TEST ANALYSIS

DISCUSSION

1. Test Overview:

The Home Pierson 02-17-02-29W1 is completed in the Spearfish formation at 1024 - 1030 mKB and is equipped with a 60.3 mm tubing (landed at 1019.11 mKB). The well was fractured during the initial completion to improve productivity.

During the test, water was injected at 1.5 m^3/d for 25 hours at a wellhead injection pressure 2 200 kPa. Subsequently, the well was shutin for a 449 hour fall-off period.

2. Data Validation:

During the injection/fall-off test, tandem electronic pressure recorders were set at 1009.7 mCF & 1010.7 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. There is an abrupt deflection in the pressure data at a BHP of 11 000 kPa, during the fall-off period. The phenomenal has been observed in two other tests. The formation fracture pressure is calculated also at 11 000 kPa. There is a very unusual similarity between the observed pressure anomaly and the estimated formation fracture pressure. This similarity confirms that water has been injected over the formation fracture pressure. As the BHP declines close the fracture pressure of 11 000 kPa, the fracture closes (heals) causing the pressure anomaly. The three wells that exhibited this phenomena are 04-17, 02-09 and 02-17.

The primary pressure derivative (PPD) plot was constructed for the bottom pressure recorder (Figure 3). The PPD showed no pressure anomalies. 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.

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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 1.5 m^3/d at a sandface flowing pressure of 16 486 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". As discussed in the data validation section most of the buildup data was distorted due to the fracture closure (healing) at approximately a BHP of 11 000 kPa.

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 7 825 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 8 086 kPa. The results of the Horner plot are summarized below:

	Horner
Effective Permeability, mD	0.22
Ave. Reservoir Pressure, kPa	8 086
Apparent Skin Factor	-3.4

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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 (Figure 7), in the section "Pressure History Match". The parameters used to achieve the history match are as follows:

	History Match	
Reservoir Pressure, P_r	9 289	kPa
Effective Permeability, k	0.32	mD
Fracture conductivity, $K_f.w$	188116	mD.m
Fracture Half Length, X_f	2.0	m
Six-Month Stabilized Rate, q_s	1.5	$10^3m^3/d$

3. Well Injectivity:

The well stabilized injection rate of 1.5 m3/d and the injectivity index (I.I.) is 2.08E-4 m^3/d/kPa were obtained from the test history match at the current wellbore skin of -2.4.

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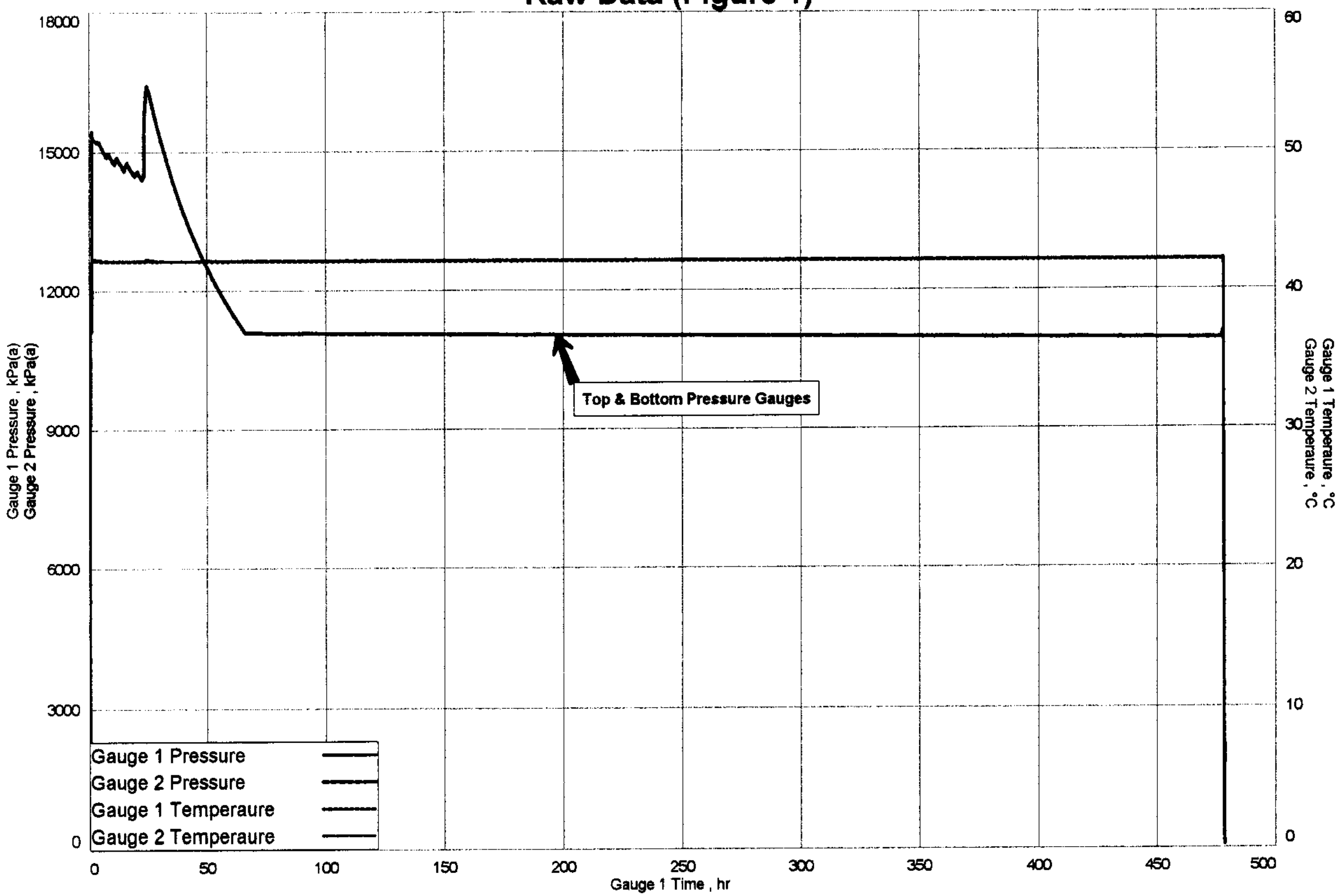
100/02-17-002-29W1/0

Home Pierson
Formation: Spearfish

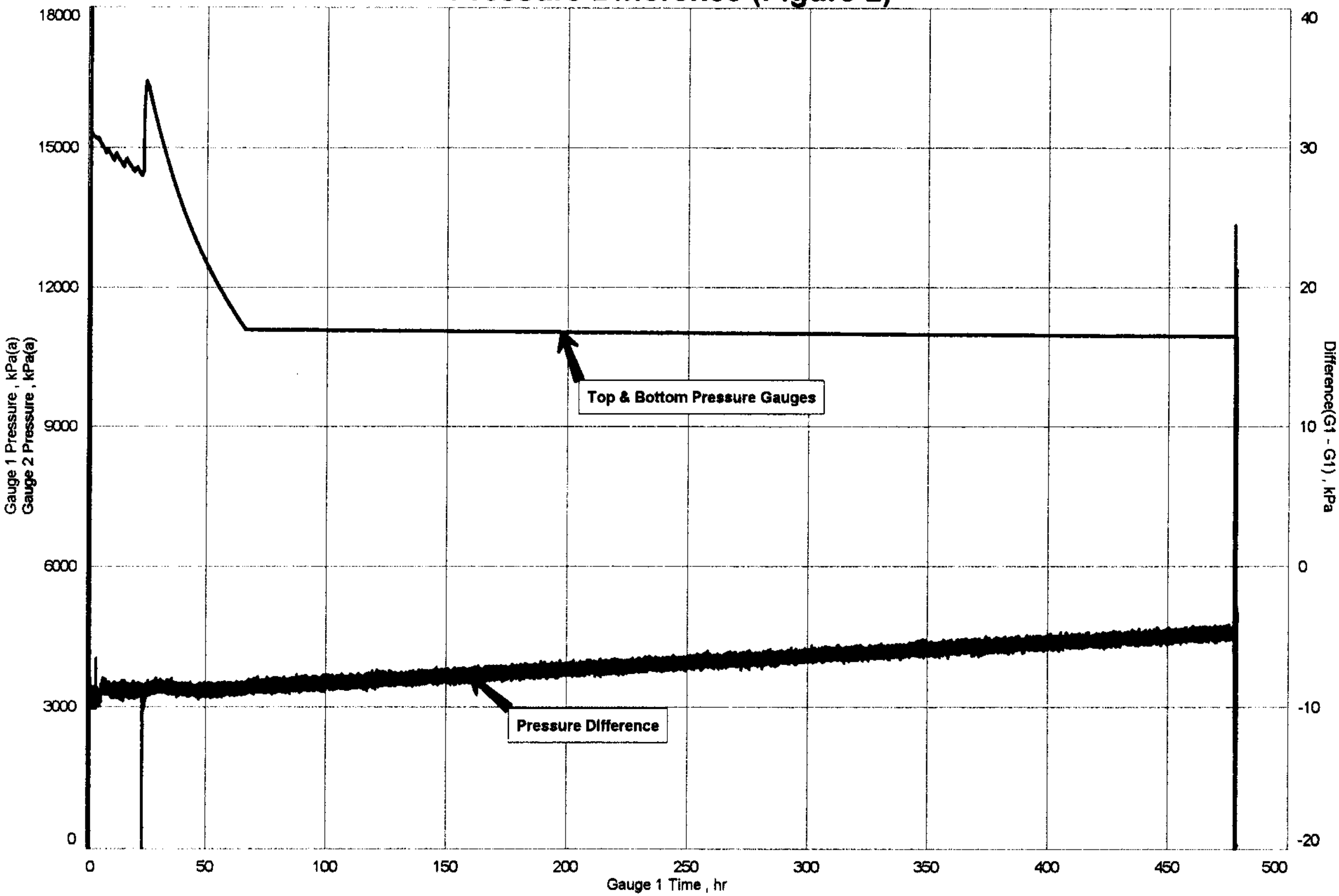
Raw Data (Figure 1)



100/02-17-002-29W1/0

Home Pierson
Formation: Spearfish

Pressure Difference (Figure 2)



Home Pierson 02-17-02-29W1
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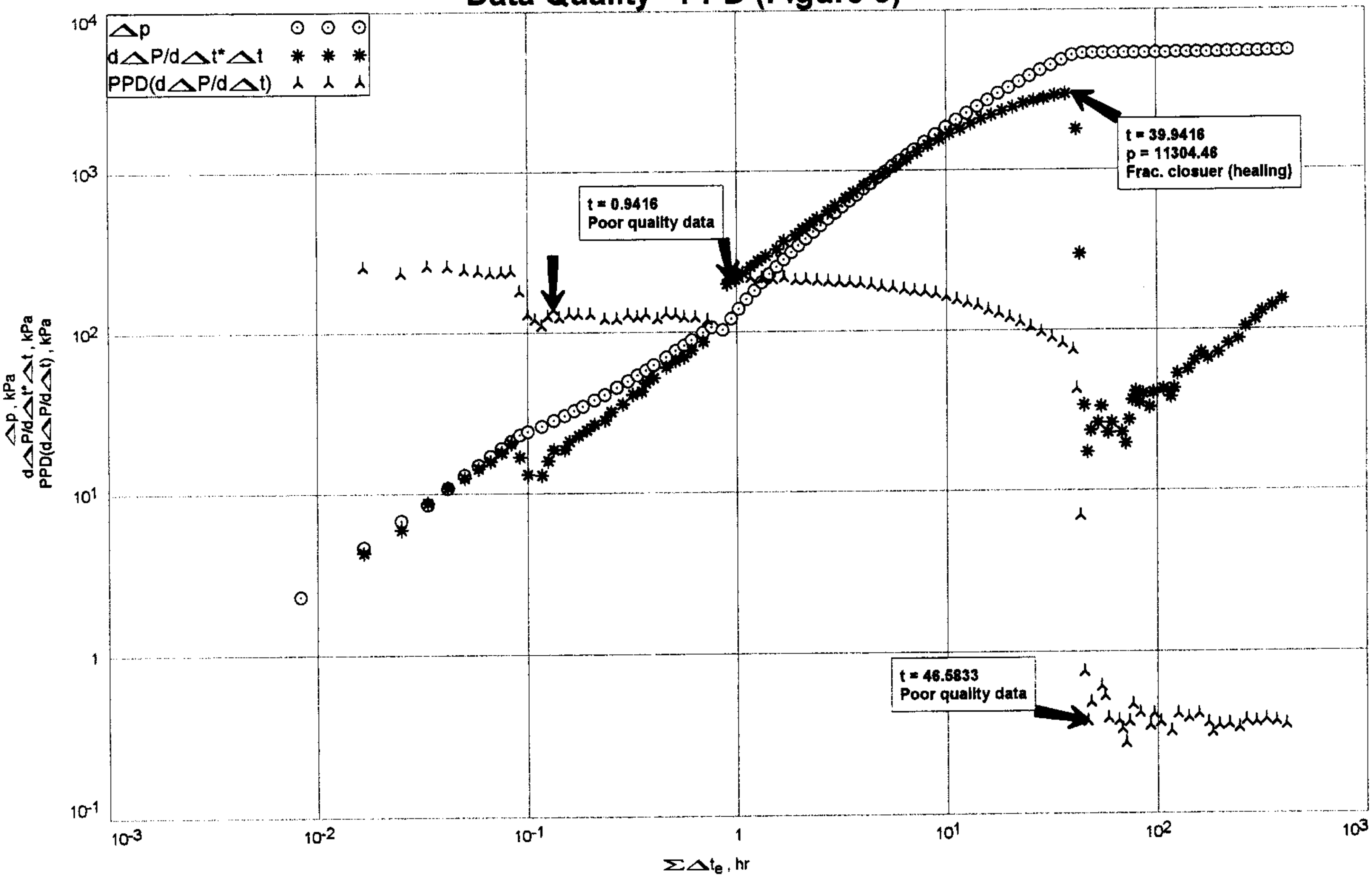
Data Quality - PPD (Figure 3)



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PRESSURE TRANSIENT ANALYSIS

Home Pierson 02-17-02-29W1
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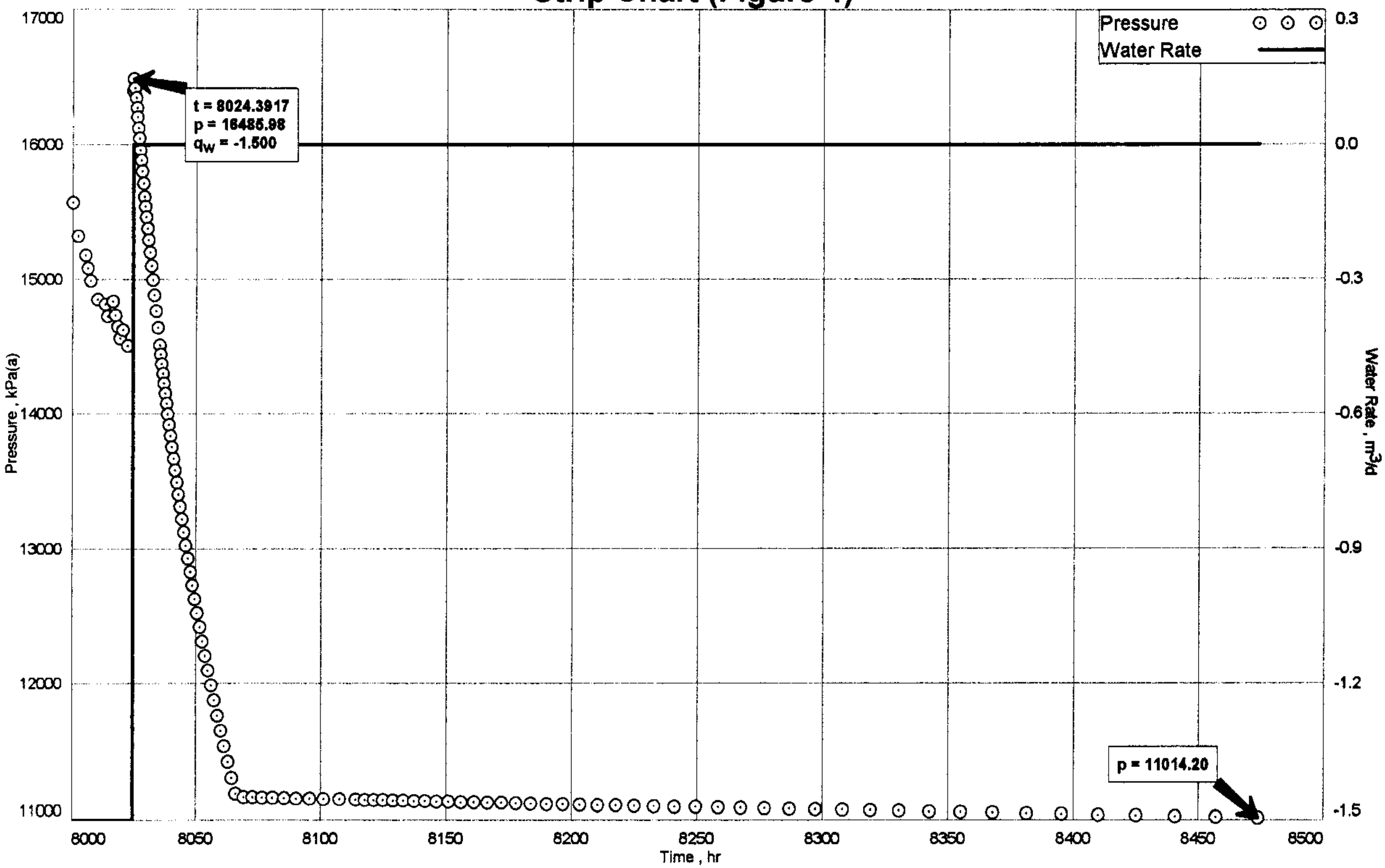
Strip Chart (Figure 4)



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Home Pierson 02-17-02-29W1
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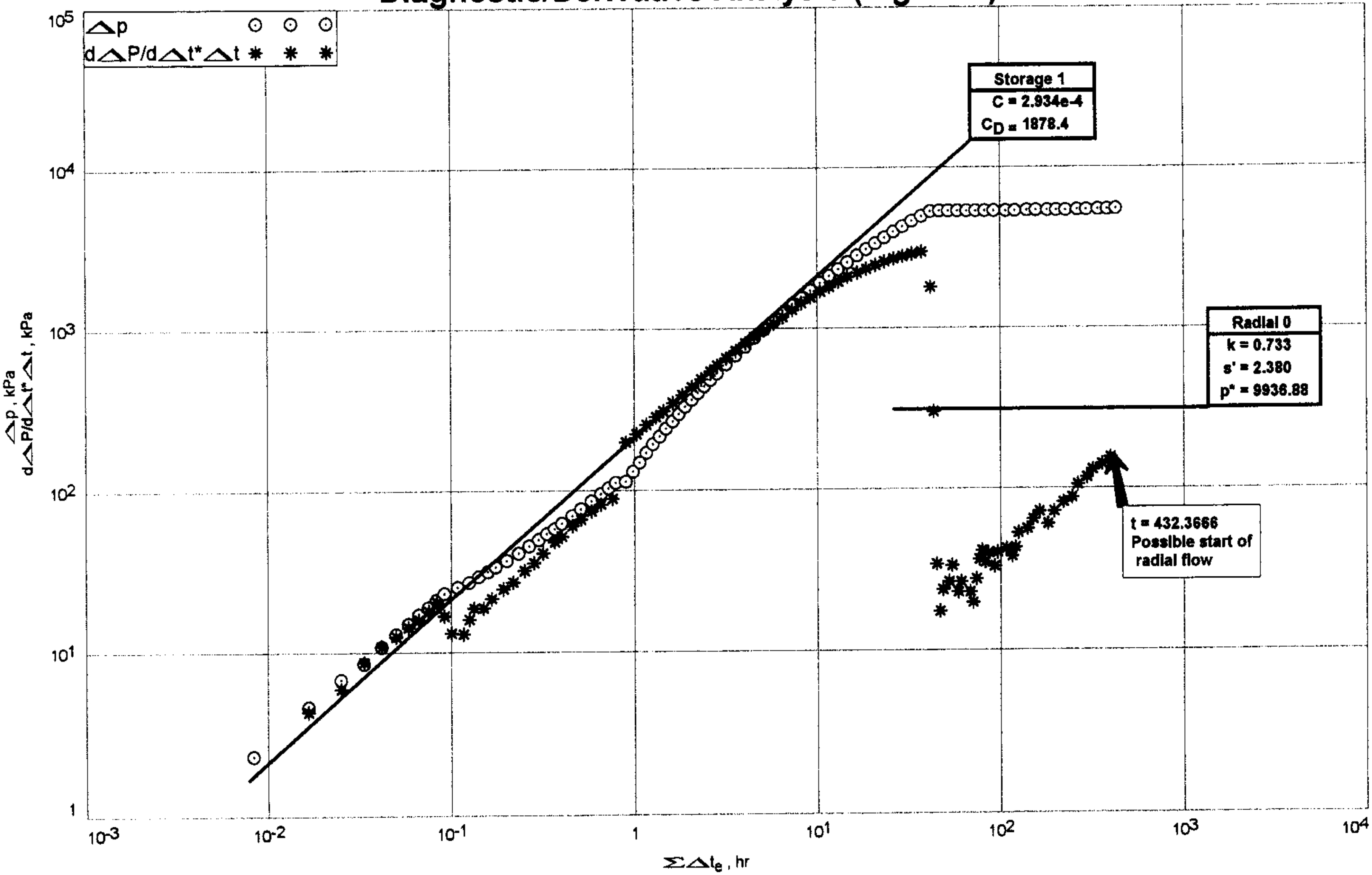
Diagnostic/Derivative Analysis (Figure 5)



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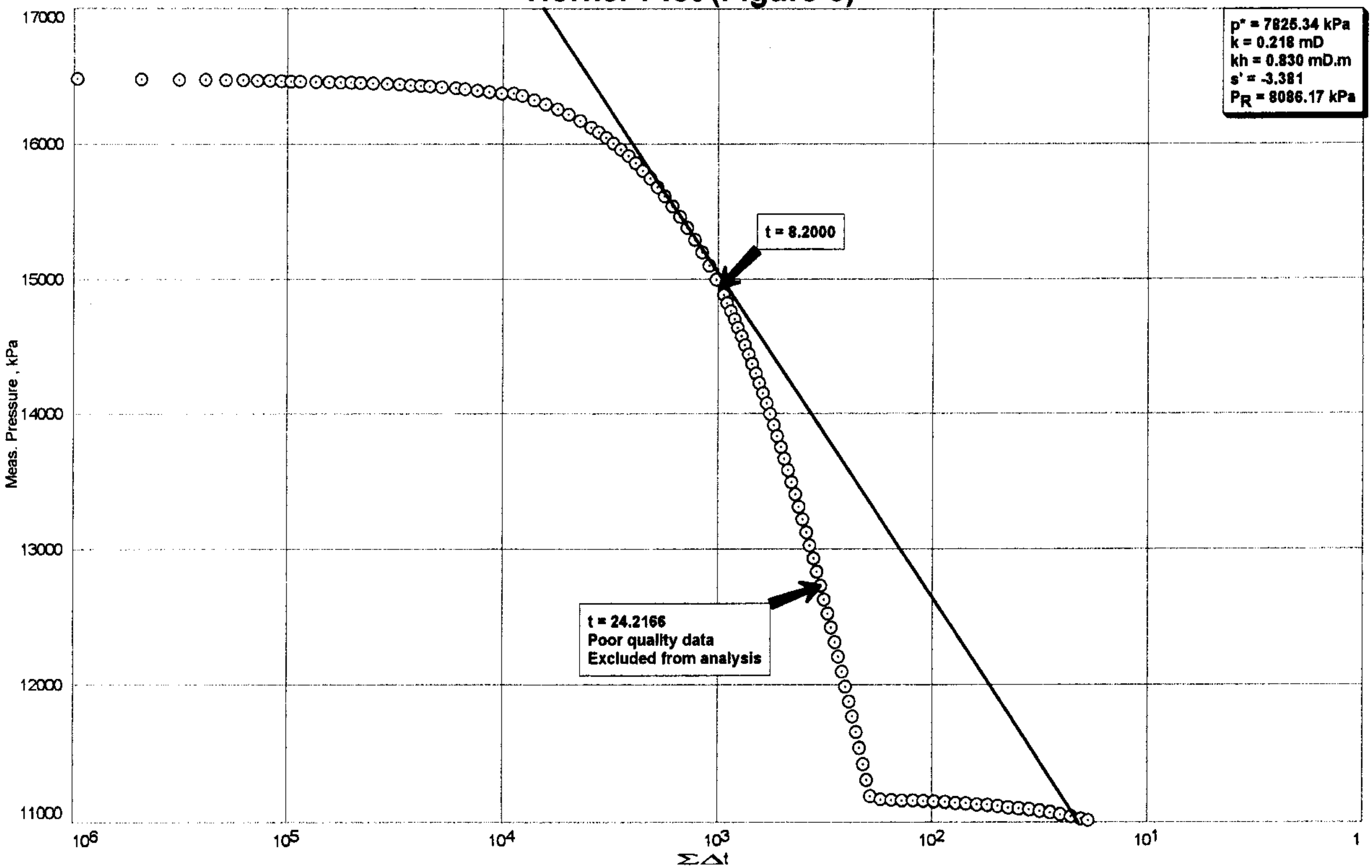
Horner Plot (Figure 6)



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PRESSURE HISTORY MATCHING

Finite Conductivity Fracture #1

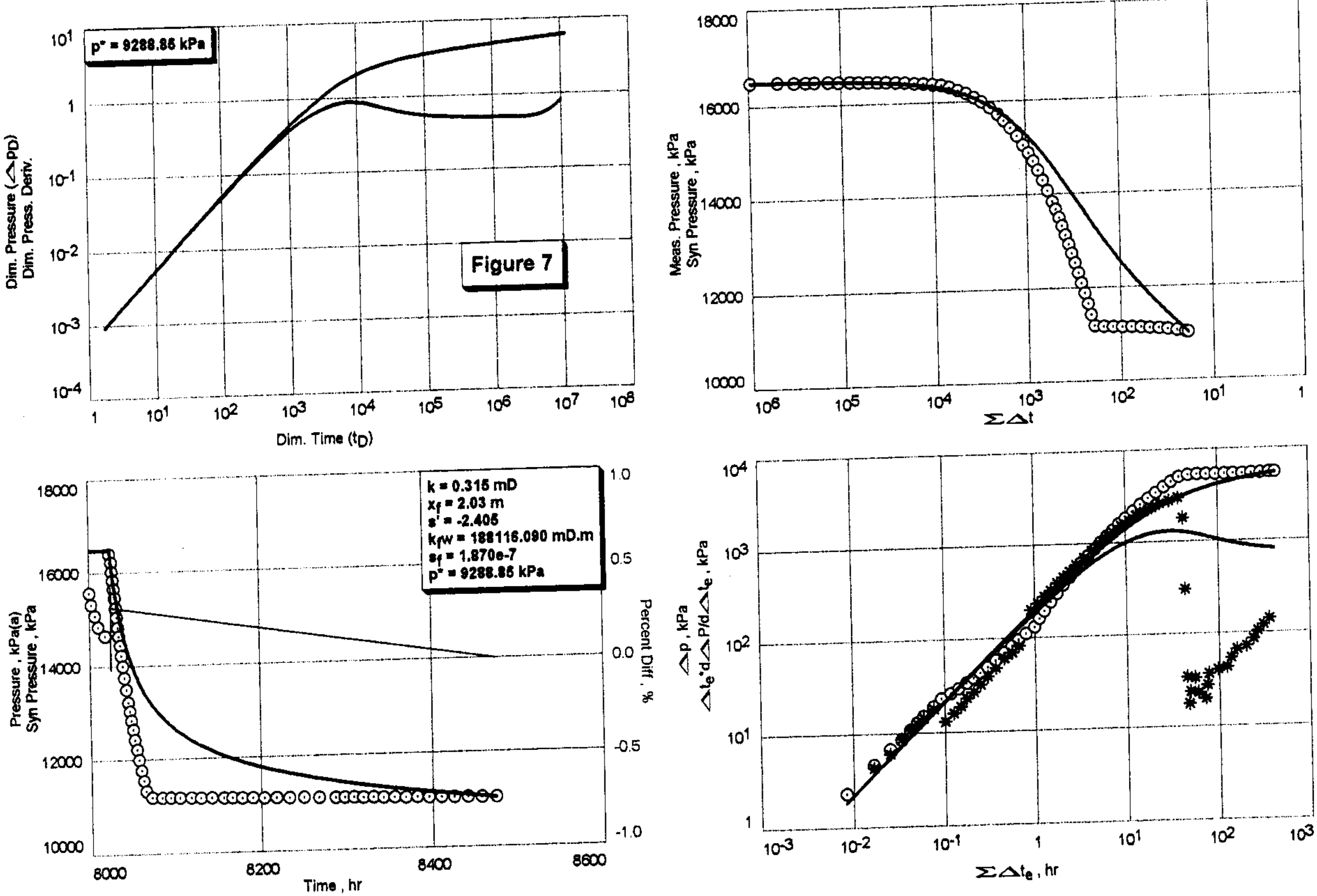

Figure 7

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SUBSURFACE
PRESSURES

Home Pierson 02-17-02-29W1
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	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
1	-8000.0000	8000.0000	15570.00	0.000	0.000	-1.500
2	-0.1000	8000.1000	15570.00	0.000	0.000	
3	2.1806	8002.1806	15318.85			-1.500
4	3.1806	8003.1806	15287.53			
5	4.1806	8004.1806	15284.79			
6	5.1806	8005.1806	15178.81			
7	6.1833	8006.1833	15081.93			
8	7.1833	8007.1833	14987.39			
9	8.1917	8008.1917	15044.77			
10	9.1917	8009.1917	14939.31			
11	10.1917	8010.1917	14849.34			
12	11.1917	8011.1917	14884.44			
13	12.1917	8012.1917	14899.85			
14	13.1917	8013.1917	14811.92			
15	14.1917	8014.1917	14725.23			
16	15.1917	8015.1917	14736.70			
17	16.1917	8016.1917	14833.49			
18	17.1917	8017.1917	14730.28			
19	18.1917	8018.1917	14643.64			
20	19.1917	8019.1917	14556.88			
21	20.1917	8020.1917	14619.78			
22	21.1917	8021.1917	14582.26			
23	22.1917	8022.1917	14500.65			
24	23.1917	8023.1917	14558.40			
25	24.1917	8024.1917	16396.84			
26	24.3833	8024.3833	16484.78			
27	24.3917	8024.3917	16485.98			-1.500
28	24.4000	8024.4000	16483.68			0.000
29	24.4083	8024.4083	16481.36			
30	24.4167	8024.4167	16479.20			
31	24.4250	8024.4250	16477.45			
32	24.4333	8024.4333	16475.24			
33	24.4417	8024.4417	16473.05			
34	24.4500	8024.4500	16471.05			
35	24.4583	8024.4583	16468.97			
36	24.4667	8024.4667	16467.07			
37	24.4750	8024.4750	16464.98			
38	24.4833	8024.4833	16462.96			
39	24.4917	8024.4917	16461.90			
40	24.5000	8024.5000	16460.76			
41	24.5083	8024.5083	16459.88			
42	24.5167	8024.5167	16458.91			

Print Filter Used: Nth Line = 1.000

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	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	24.5250	8024.5250	16457.75			
44	24.5333	8024.5333	16456.57			
45	24.5417	8024.5417	16455.66			
46	24.5500	8024.5500	16454.49			
47	24.5583	8024.5583	16453.46			
48	24.5667	8024.5667	16452.34			
49	24.5750	8024.5750	16451.27			
50	24.5833	8024.5833	16450.32			
51	24.5917	8024.5917	16449.12			
52	24.6000	8024.6000	16448.13			
53	24.6083	8024.6083	16446.98			
54	24.6250	8024.6250	16445.01			
55	24.6417	8024.6417	16442.89			
56	24.6583	8024.6583	16440.74			
57	24.6750	8024.6750	16438.80			
58	24.6917	8024.6917	16436.51			
59	24.7083	8024.7083	16434.46			
60	24.7250	8024.7250	16432.17			
61	24.7417	8024.7417	16430.26			
62	24.7583	8024.7583	16428.09			
63	24.7750	8024.7750	16425.89			
64	24.7917	8024.7917	16423.75			
65	24.8083	8024.8083	16421.56			
66	24.8250	8024.8250	16419.68			
67	24.8500	8024.8500	16416.42			
68	24.8750	8024.8750	16413.06			
69	24.9000	8024.9000	16409.55			
70	24.9250	8024.9250	16406.52			
71	24.9500	8024.9500	16403.52			
72	24.9750	8024.9750	16400.26			
73	25.0000	8025.0000	16397.12			
74	25.0250	8025.0250	16393.92			
75	25.0500	8025.0500	16390.86			
76	25.0833	8025.0833	16386.68			
77	25.1167	8025.1167	16382.44			
78	25.1500	8025.1500	16378.68			
79	25.1833	8025.1833	16374.62			
80	25.2167	8025.2167	16384.34			
81	25.2500	8025.2500	16382.76			
82	25.2917	8025.2917	16373.43			
83	25.3333	8025.3333	16364.25			
84	25.3750	8025.3750	16355.04			

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	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
85	25.4167	8025.4167	16346.01			
86	25.4583	8025.4583	16336.66			
87	25.5083	8025.5083	16325.88			
88	25.5583	8025.5583	16314.95			
89	25.6083	8025.6083	16303.83			
90	25.6583	8025.6583	16292.90			
91	25.7083	8025.7083	16281.86			
92	25.7667	8025.7667	16269.34			
93	25.8250	8025.8250	16256.57			
94	25.8833	8025.8833	16244.00			
95	25.9417	8025.9417	16231.61			
96	26.0083	8026.0083	16217.43			
97	26.0750	8026.0750	16202.77			
98	26.1417	8026.1417	16188.11			
99	26.2167	8026.2167	16171.96			
100	26.2917	8026.2917	16156.01			
101	26.3667	8026.3667	16140.20			
102	26.4500	8026.4500	16122.29			
103	26.5333	8026.5333	16104.73			
104	26.6250	8026.6250	16085.14			
105	26.7167	8026.7167	16065.93			
106	26.8083	8026.8083	16046.67			
107	26.9083	8026.9083	16025.77			
108	27.0083	8027.0083	16004.94			
109	27.1167	8027.1167	15982.45			
110	27.2250	8027.2250	15960.08			
111	27.3417	8027.3417	15935.54			
112	27.4583	8027.4583	15911.54			
113	27.5833	8027.5833	15885.71			
114	27.7083	8027.7083	15860.08			
115	27.8417	8027.8417	15832.70			
116	27.9833	8027.9833	15803.86			
117	28.1250	8028.1250	15774.96			
118	28.2750	8028.2750	15744.71			
119	28.4333	8028.4333	15712.91			
120	28.5917	8028.5917	15681.02			
121	28.7583	8028.7583	15647.98			
122	28.9333	8028.9333	15613.42			
123	29.1167	8029.1167	15577.53			
124	29.3083	8029.3083	15540.69			
125	29.5083	8029.5083	15502.16			
126	29.7167	8029.7167	15462.37			

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	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	29.9333	8029.9333	15421.11			
128	30.1583	8030.1583	15378.73			
129	30.3917	8030.3917	15335.03			
130	30.6333	8030.6333	15290.35			
131	30.8833	8030.8833	15244.50			
132	31.1417	8031.1417	15197.70			
133	31.4083	8031.4083	15149.52			
134	31.6833	8031.6833	15100.04			
135	31.9750	8031.9750	15047.69			
136	32.2750	8032.2750	14994.20			
137	32.5917	8032.5917	14937.94			
138	32.9167	8032.9167	14881.07			
139	33.2583	8033.2583	14821.49			
140	33.6083	8033.6083	14761.57			
141	33.9750	8033.9750	14699.42			
142	34.3500	8034.3500	14636.70			
143	34.7417	8034.7417	14571.87			
144	35.1500	8035.1500	14504.84			
145	35.5750	8035.5750	14437.06			
146	36.0167	8036.0167	14367.85			
147	36.4750	8036.4750	14296.46			
148	36.9500	8036.9500	14223.81			
149	37.4417	8037.4417	14149.68			
150	37.9583	8037.9583	14073.17			
151	38.4917	8038.4917	13995.00			
152	39.0500	8039.0500	13914.32			
153	39.6250	8039.6250	13833.32			
154	40.2250	8040.2250	13751.04			
155	40.8500	8040.8500	13666.33			
156	41.5000	8041.5000	13579.90			
157	42.1750	8042.1750	13491.64			
158	42.8750	8042.8750	13402.06			
159	43.6000	8043.6000	13311.03			
160	44.3583	8044.3583	13217.91			
161	45.1417	8045.1417	13123.32			
162	45.9583	8045.9583	13027.00			
163	46.8083	8046.8083	12928.90			
164	47.6917	8047.6917	12829.50			
165	48.6083	8048.6083	12728.05			
166	49.5583	8049.5583	12625.84			
167	50.5500	8050.5500	12521.93			
168	51.5750	8051.5750	12417.23			

Print Filter Used: Nth Line = 1.000

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	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	52.6417	8052.6417	12311.11			
170	53.7500	8053.7500	12204.33			
171	54.9000	8054.9000	12095.89			
172	56.1000	8056.1000	11985.91			
173	57.3417	8057.3417	11875.16			
174	58.6333	8058.6333	11762.71			
175	59.9750	8059.9750	11649.68			
176	61.3750	8061.3750	11535.17			
177	62.8250	8062.8250	11420.25			
178	64.3333	8064.3333	11304.46			
179	65.9000	8065.9000	11187.83			
180	67.5250	8067.5250	11166.83			
181	69.2167	8069.2167	11164.69			
182	70.9750	8070.9750	11164.21			
183	72.8000	8072.8000	11163.36			
184	74.7000	8074.7000	11162.40			
185	76.6750	8076.6750	11161.61			
186	78.7250	8078.7250	11160.38			
187	80.8583	8080.8583	11159.05			
188	83.0750	8083.0750	11158.07			
189	85.3750	8085.3750	11157.30			
190	87.7667	8087.7667	11156.05			
191	90.2500	8090.2500	11155.33			
192	92.8333	8092.8333	11154.16			
193	95.5167	8095.5167	11153.58			
194	98.3000	8098.3000	11152.66			
195	101.1917	8101.1917	11151.48			
196	104.2000	8104.2000	11149.88			
197	107.3250	8107.3250	11148.32			
198	110.5750	8110.5750	11147.21			
199	113.9500	8113.9500	11145.27			
200	117.4583	8117.4583	11144.26			
201	121.1000	8121.1000	11142.77			
202	124.8917	8124.8917	11141.19			
203	128.8250	8128.8250	11139.78			
204	132.9167	8132.9167	11138.25			
205	137.1667	8137.1667	11136.55			
206	141.5833	8141.5833	11134.84			
207	146.1750	8146.1750	11133.66			
208	150.9417	8150.9417	11131.58			
209	155.9000	8155.9000	11129.64			
210	161.0500	8161.0500	11127.68			

Print Filter Used: Nth Line = 1.000

Home Pierson 02-17-02-29W1
Spearfish (1024 - 1030 mKB)
Fall-off Test
Test Date: Dec. 11 - 31, 1999

	Time hr	Cum Time hr	Pressure kPa(a)	Gas Rate $10^3m^3/d$	Oil Rate m^3/d	Water Rate m^3/d
211	166.4000	8166.4000	11125.53			
212	171.9583	8171.9583	11123.43			
213	177.7333	8177.7333	11120.87			
214	183.7333	8183.7333	11118.57			
215	189.9750	8189.9750	11115.85			
216	196.4583	8196.4583	11113.14			
217	203.1917	8203.1917	11110.62			
218	210.1917	8210.1917	11108.16			
219	217.4667	8217.4667	11106.10			
220	225.0250	8225.0250	11103.50			
221	232.8750	8232.8750	11100.71			
222	241.0333	8241.0333	11098.15			
223	249.5167	8249.5167	11095.10			
224	258.3250	8258.3250	11092.03			
225	267.4833	8267.4833	11088.94			
226	277.0000	8277.0000	11085.58			
227	286.8833	8286.8833	11082.39			
228	297.1583	8297.1583	11078.65			
229	307.8333	8307.8333	11074.57			
230	318.9250	8318.9250	11071.07			
231	330.4500	8330.4500	11066.66			
232	342.4250	8342.4250	11062.44			
233	354.8750	8354.8750	11057.62			
234	367.8083	8367.8083	11052.82			
235	381.2500	8381.2500	11047.61			
236	395.2167	8395.2167	11042.55			
237	409.7250	8409.7250	11037.21			
238	424.8083	8424.8083	11031.63			
239	440.4750	8440.4750	11026.10			
240	456.7583	8456.7583	11020.22			
241	473.6750	8473.6750	11014.20			

Print Filter Used: Nth Line = 1.000

EQUATIONS

and

NOMENCLATURE

(METRIC UNITS)

PMG

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 $\sqrt{t+\Delta t} - \sqrt{\Delta t}$

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BASIC TIME FUNCTIONS (cont'd)

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

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TYPECURVES - DIMENSIONLESS VARIABLES

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

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

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

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

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

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

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

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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

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

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SEMILOG ANALYSIS (cont"d)

Stabilized Rate

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

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

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

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	-	-

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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

PMC

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	m^3	ft^3
	- liquid	m^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	μPa.s	cp
	- liquid	mPa.s	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

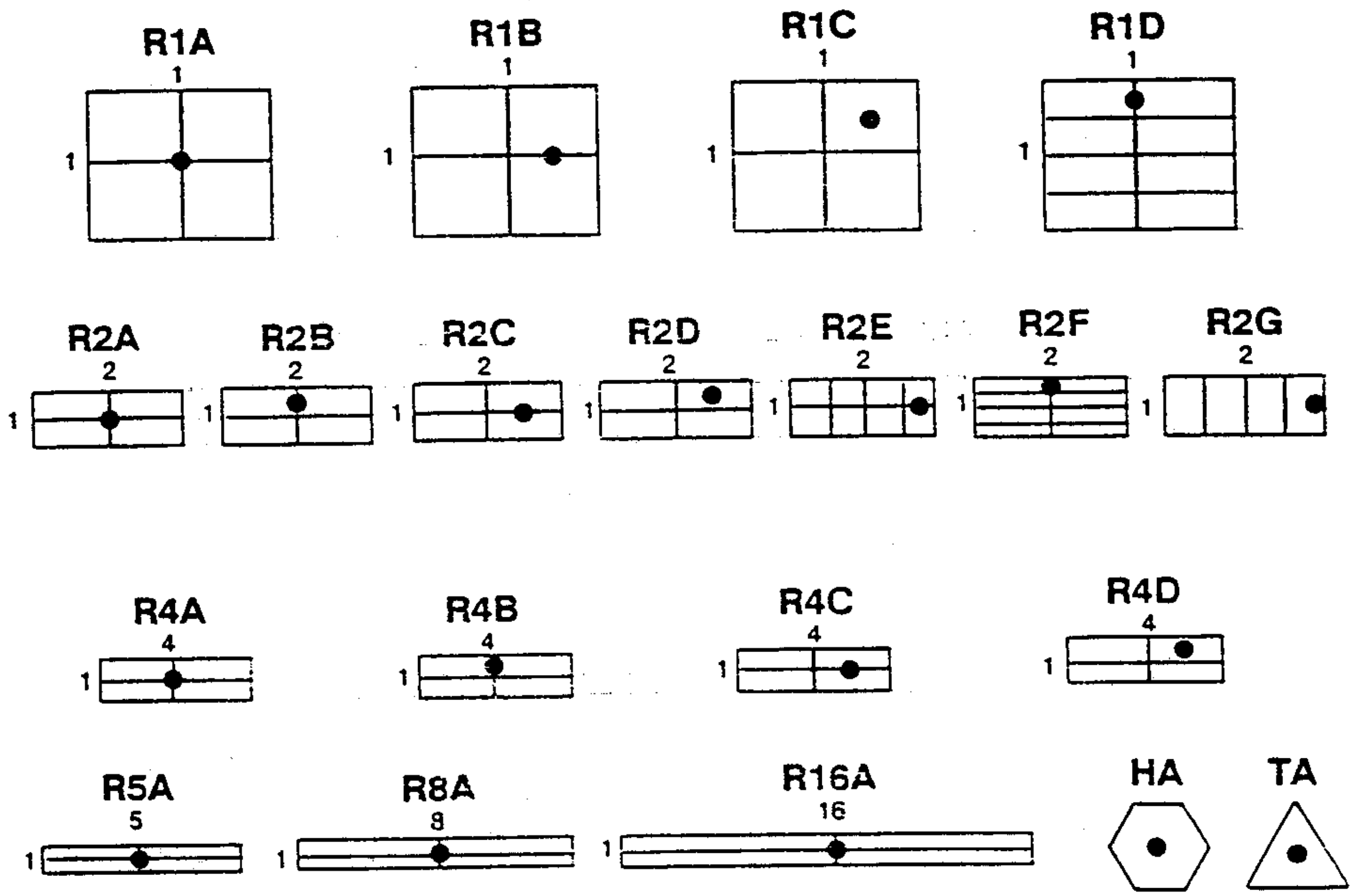
Superscripts

-	average

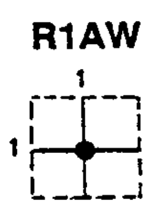
DIETZ SHAPE CODES

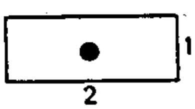
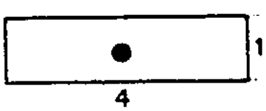
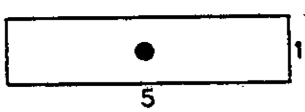
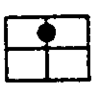
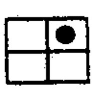
AVERAGE RESERVOIR PRESSURE - MBH CORRECTIONS

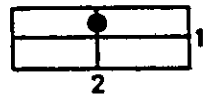
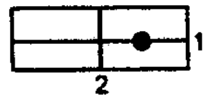
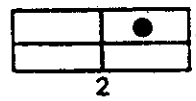
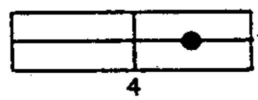
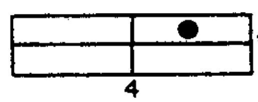
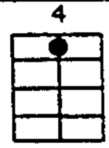
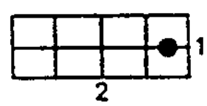
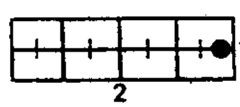
NO FLOW OUTER BOUNDARY



CONSTANT PRESSURE OUTER BOUNDARY



	$\ln C_A$	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

	$\ln C_A$	C_A	STABILIZED CONDITIONS FOR t_{DA} >
	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)

PMG

UNITS CONVERSION AND PREFIXES

METRIC (SI) UNIT	FIELD UNIT	DIVIDED BY
$10^3 m^3/d$	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
$m^3/10^3 m^3$	bbl/MMcf	5.643 052 E-03

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