INJECTIVITY/FALL-OFF TEST REPORT #1351

Copy 2 of 2

HOME PIERSON 10-08-02-29W1
SPEARFISH (1023-24.5,1026-27,1028-30,1031-34 mKB)
TEST DATE: DECEMBER 10- 30, 1999

Prepared for:

ANDERSON EXPLORATION LTD.

Prepared by:

PETRO MANAGEMENT GROUP LTD.

JANUARY 2000

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Petro Management Group Ltd.

January 17, 2000

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

Attn.: Mr. Larry Sopko

HOME PIERSON 10-08-02-29W1
SPEARFISH (1023 -24.5, 1026 - 27, 1028 - 30, 1031.5 - 34 mKB)
INJECTIVITY/FALL-OFF TEST
TEST DATE: DECEMBER 10- 30, 1999

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

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Summary of Test Data & Results

Case Name : Finite Conductivity Fracture #1

Home Pierson 10-08-02-29W1	Fall-off Test
Spreafish (1023-24.5,1026-27,1028-30,1031-34)	December 10 - 30, 1999

Model Parameters

Water Permeability (k_w)	0.051 mD	Fracture Half Length (x_f)	25.70 m
Total Mobility $(k/\mu)_t$	0.08 mD/mPa.s	Fracture Flow Capacity ($k_f w$)	166.809 mD.m
Total Transmissivity $(kh/\mu)_t$	0.54 mDm/mPa.s	Fracture Face Skin (sf)	0.197
Wellbore Storage Constant Dim. (C_D)	39.47	Skin Equivalent to Xf	-4.932
		Exterior Radius (r_e)	450.00 m

Formation Parameters

Net Pay (h)	6.70 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)	4.674e-6 kPa^{-1}

Fluid Properties

Water Compressibility (c_w)	4.29138e-7 kPa^{-1}
Oil Compressibility (c_o)	1.26916e-5 kPa^{-1}
Gas Compressibility (c_g)	6.10782e-5 kPa^{-1}
Water Formation Volume Factor (B_w)	1.000
Water Viscosity (μ_w)	0.628 mPa.s
Gas Viscosity (μ_g)	17.861 µPa.s
Solution Gas Ratio (R_{sw})	0 m^3/m^3
Specific Gravity (G)	1.000
PVT Reference Pressure (p_{PVT})	16252.94 kPa

Production and Pressure

$Q_t B_t$	-1.500 m^3/d
Final Water Rate	-1.500 m^3/d
Final Gas Rate	0.000 $10^3 m^3/d$
Final Flowing Pressure (p_{wfo})	16352.94 kPa
Final Measured Pressure	11113.33 kPa
Initial Pressure (p_i)	16252.94 kPa

Synthesis Results

Average Error	-0.01 %
Synthetic Initial Pressure (p_i)	5369.99 kPa
Extrapolated Pressure at Specified Time	6910.12 kPa
Pressure Drop Due To Skin (Δp_s)	1570.25 kPa
Flow Efficiency (FE)	0.834
Damage Ratio (DR)	1.199

Forecasts

Specified Flowing Pressure (p_{wfs})	16352.94 kPa
3 - Month Constant Rate	-1.738 m^3/d
6 - Month Constant Rate	-1.472 m^3/d
Specified Forecast Time	12.00 month
Forecast Constant Rate @ Current Skin	-1.266 m^3/d
PI / II (Actual)	1.57e-4 $m^3/d/kPa$
Forecast Constant Rate @ Skin=0	-1.473 m^3/d
PI / II (Ideal)	1.88e-4 $m^3/d/kPa$

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SUMMARY OF RESULTS

SUMMARY OF RESULTS

1. The average reservoir pressure (P_R) is 6 910 kPa.

2. The effective permeability to water of the Spearfish formation is 0.05 mD.

3. The apparent wellbore skin factor of -4.9 and the fracture half length of 25.7 m confirm the effectiveness of the fracture treatment. The fracture face skin (S_f) of 0.2 indicates that the effectiveness of the fracture has been reduced, possibly due to fine plugging from the injected water.

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

5. The injectivity index (I.I.) is 1.57E-4 $m^3/d/kPa$

6. Radius of investigation is approximately 34 m.

TEST ANALYSIS

DISCUSSION

1. Test Overview:

The Home Pierson 10-08-02-29W1 is completed in the Spearfish formation at 1023 -24.5, 1026 - 27, 1028 - 30, 1031.5 - 34 mKB and is equipped with a 60.3 mm tubing (landed at 1019.22 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 20 hours at a wellhead injection pressure 1 900 kPa. Subsequently, the well was shutin for a 456 hour fall-off period.

2. Data Validation:

During the injection/fall-off test, tandem electronic pressure recorders were set at 1014.4 mCF & 1015.4 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 major pressure anomalies after 3.0 hours of shutin, possibly due to wellbore storage effects. 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.

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 16 353 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. Radial flow was not reached since the pressure derivative did not flatten during the late time data.

Radial flow analysis was performed to determine the reservoir parameters using the semi-log straight line drawn through the late time pressure data, since radial flow was not reached, as shown in the Horner plot (Figure 6). The extrapolation of the last data points yielded a P^* of 7 034 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 7 180 856 kPa. The results of the Horner plot and the pressure derivative are summarized below:

	Horner	Derivative
Effective Permeability, mD	0.09	0.05
Reservoir Pressure, kPa	7 180	n/a
Apparent Skin Factor	-3.7	-5.2

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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 29.0 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	6 910	kPa
Effective Permeability, k	0.05	mD
Fracture conductivity, $K_f.w$	166.8	mD.m
Fracture Half Length, X_f	25.7	m
Six-Month Stabilized Rate, q_s	1.5	$10^3m^3/d$

3. Well Injectivity:

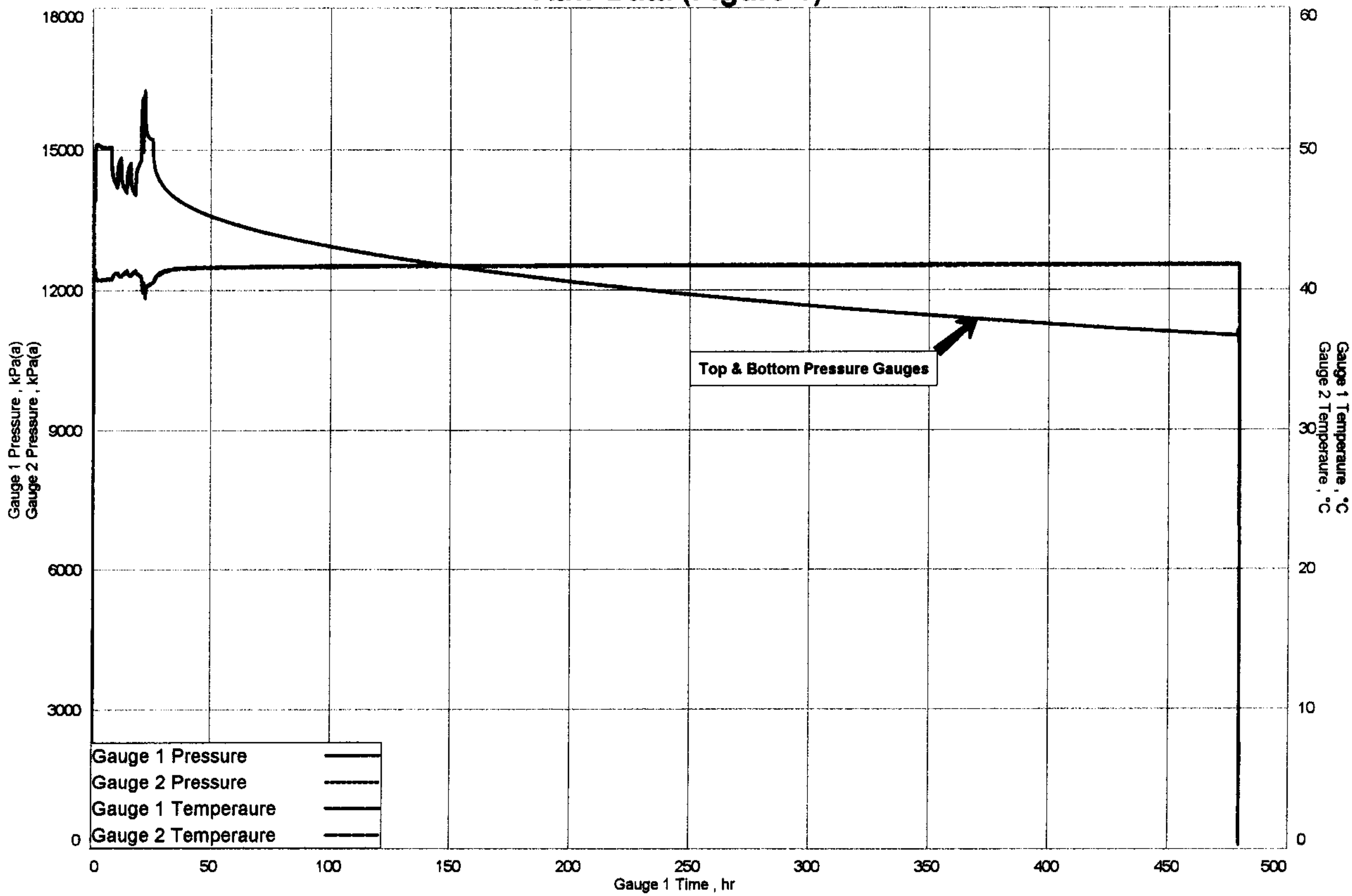
The well stabilized injection rate of 1.5 m3/d and the injectivity index (I.I.) Of 1.57E-4 $m^3/d/kPa$ were obtained from the test history match at the current wellbore skin of -4.9.

TEST DATA
QUALITY

100/10-08-002-29W1/0

Home Pierson
Formation: Spearfish

Raw Data (Figure 1)



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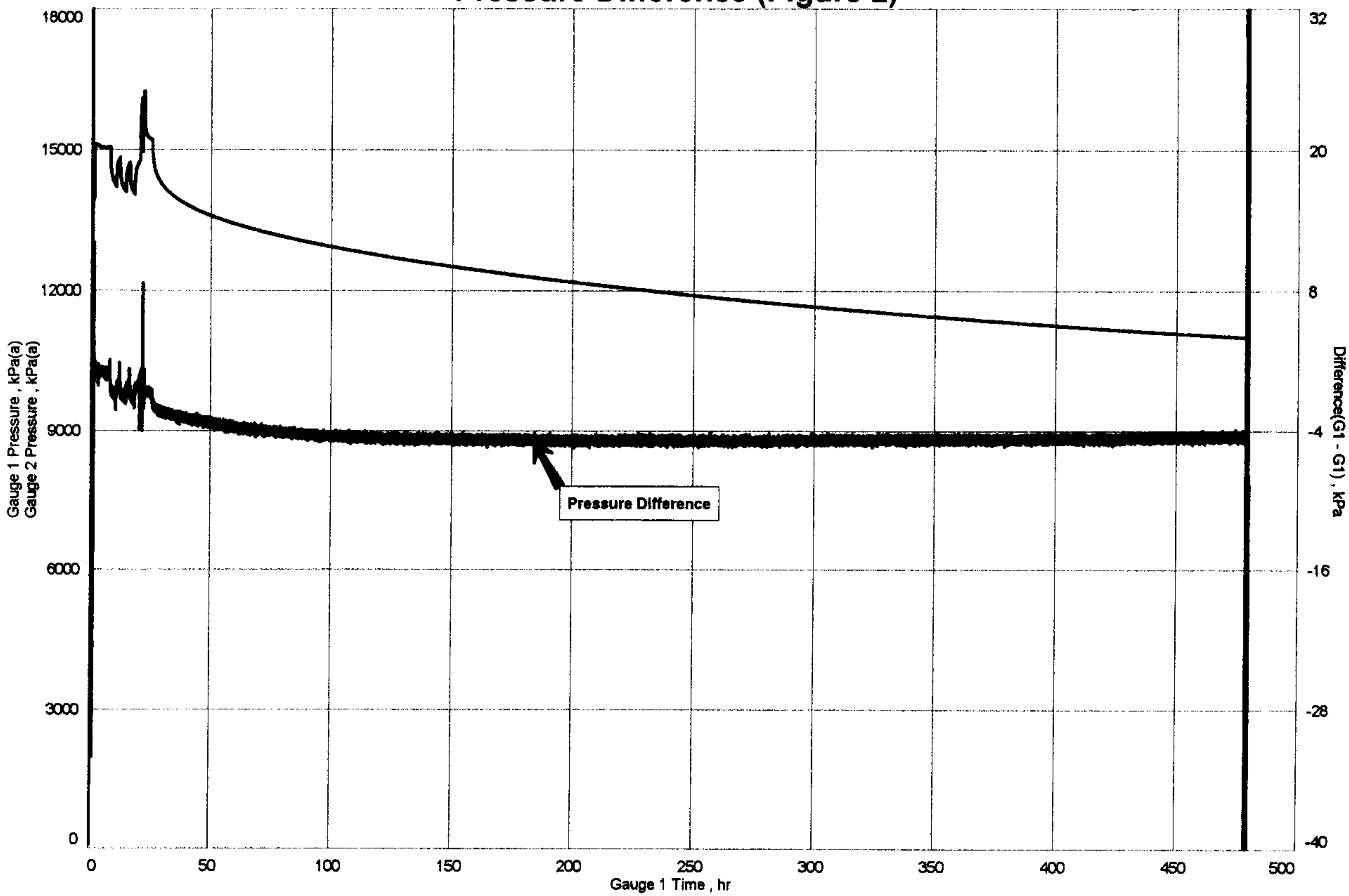
Home Pierson
Formation: Spearfish

Pressure Difference (Figure 2)



Home Pierson 10-08-02-29W1
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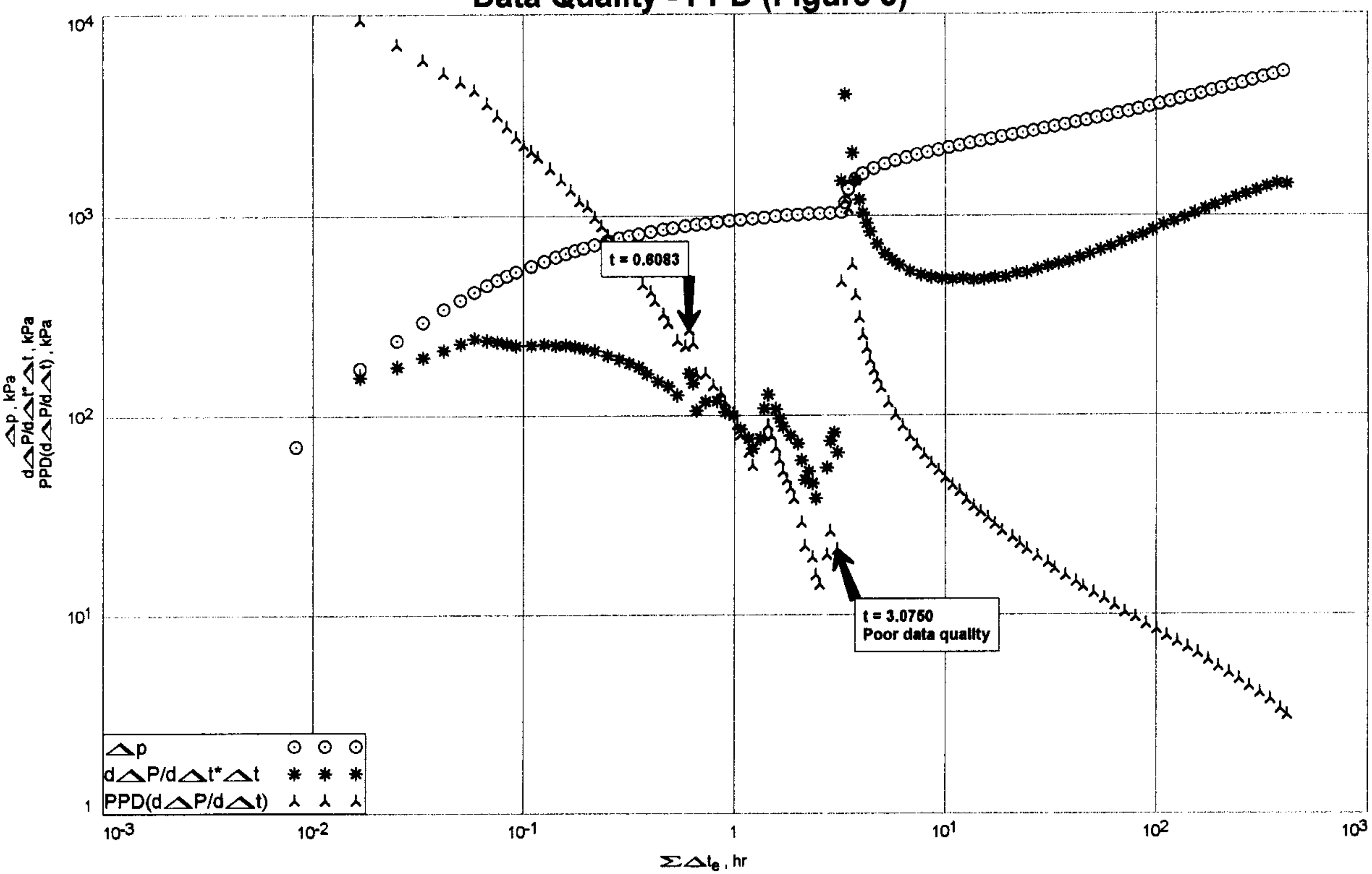
Data Quality - PPD (Figure 3)



PRESSURE
TRANSIENT
ANALYSIS

Finite Conductivity Fracture Water Well Model

Case Name : Finite Conductivity Fracture #1

Home Pierson 10-08-02-29W1

Spreafish (1023-24.5,1026-27,1028-30,1031-34)

Fall-off Test

December 1999

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Formation Temperature (T)	42.0 °C
Formation Compressibility (c_f)	5.658e-7 kPa^{-1}
Total Compressibility (c_t)	4.674e-6 kPa^{-1}

Production and Pressure

$Q_t B_t$	-1.500 m^3/d
Final Water Rate	-1.500 m^3/d
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Final Flowing Pressure (p_{wfo})	16252.94 kPa
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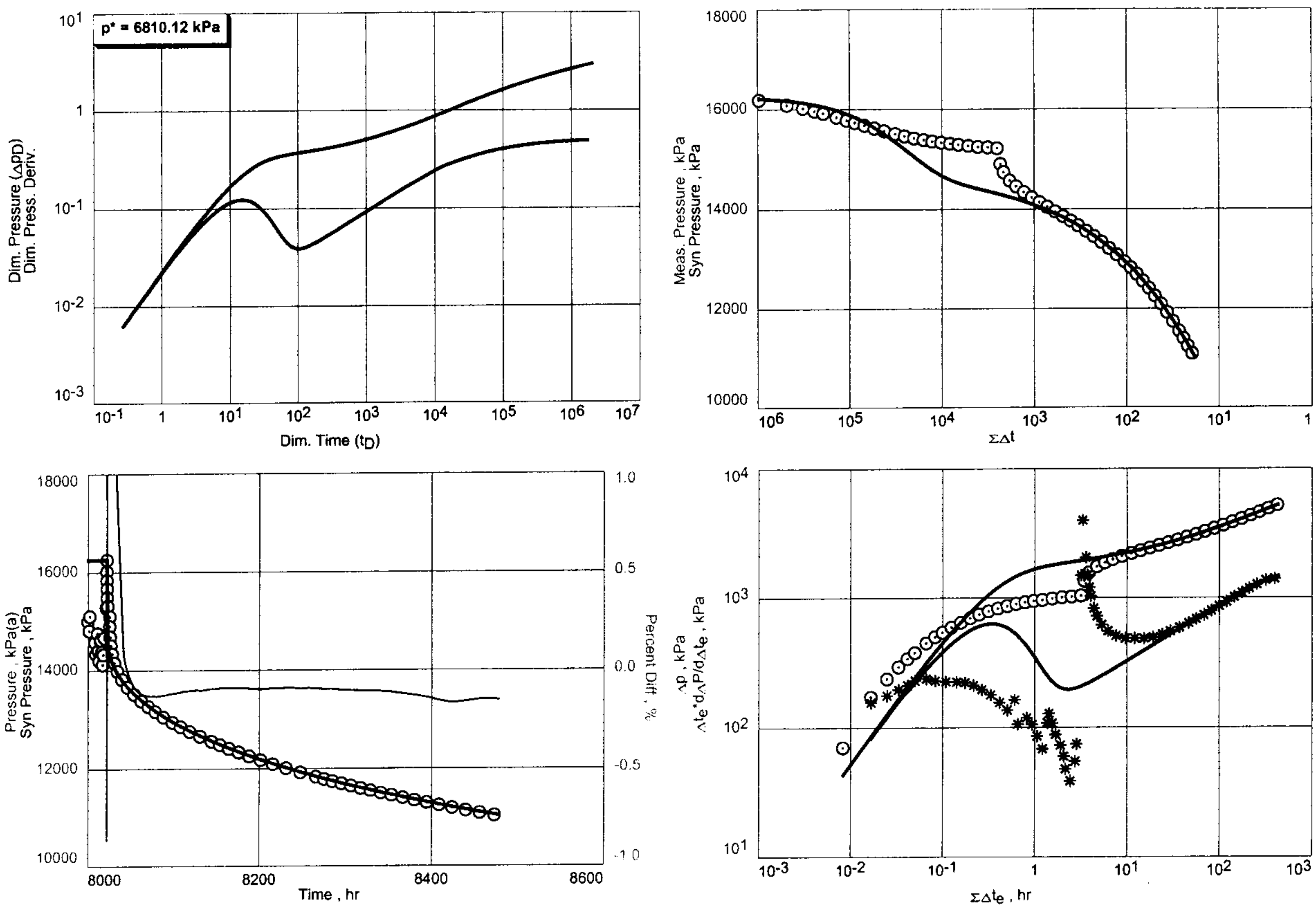
Finite Conductivity Fracture #1



Home Pierson 10-08-02-29W1
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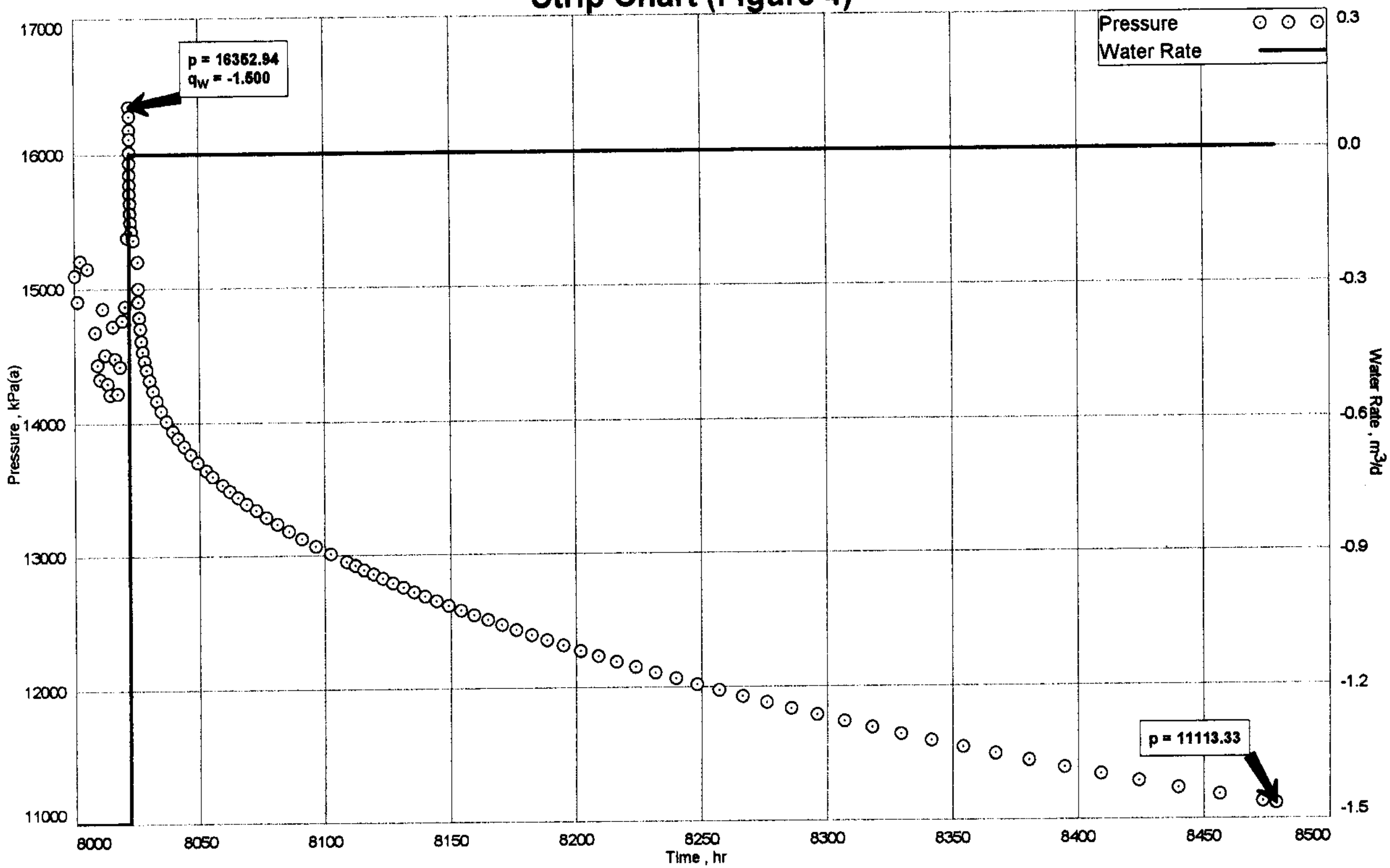
Strip Chart (Figure 4)



Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
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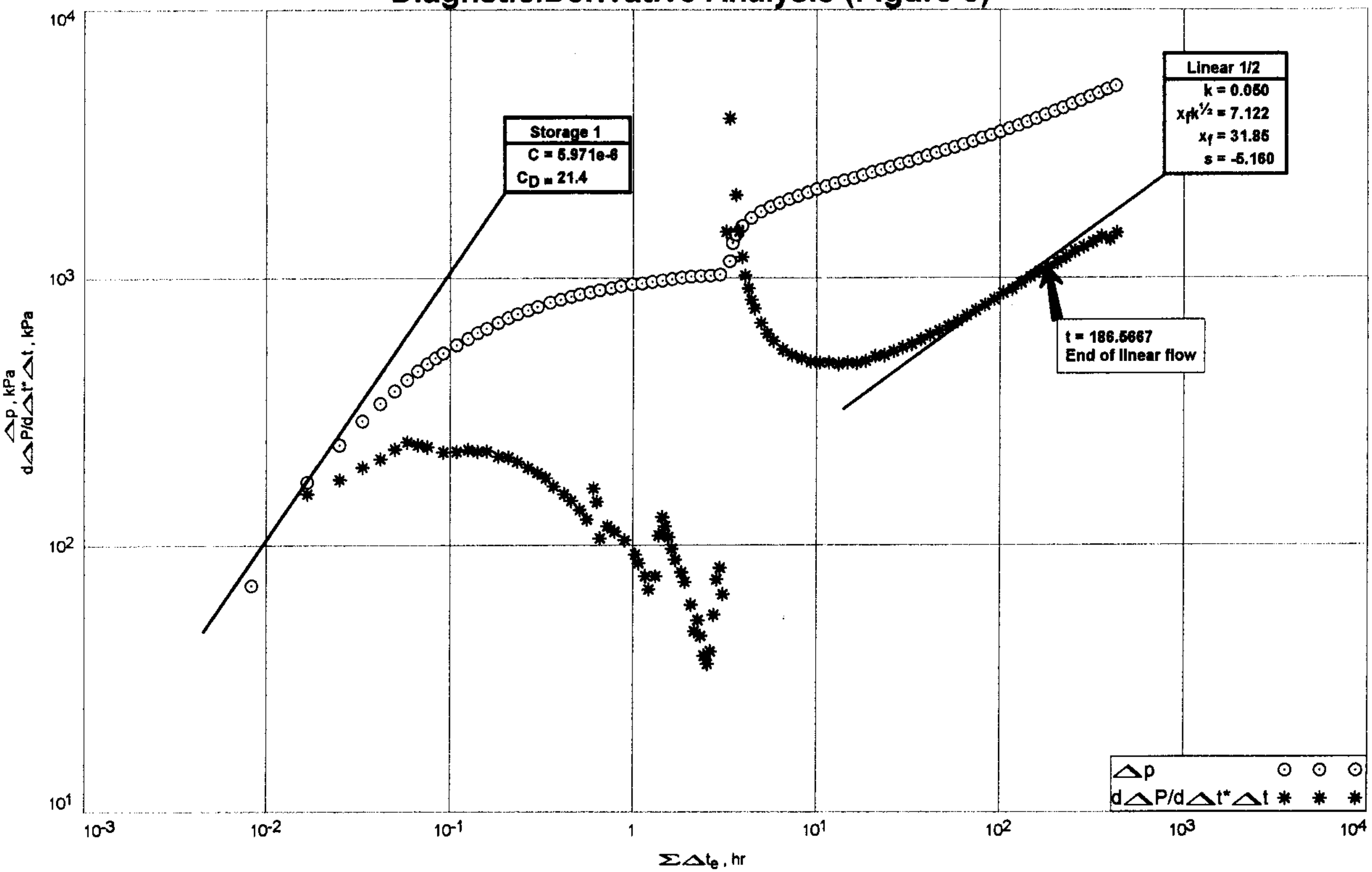
Diagnstic.Derivative Analysis (Figure 5)



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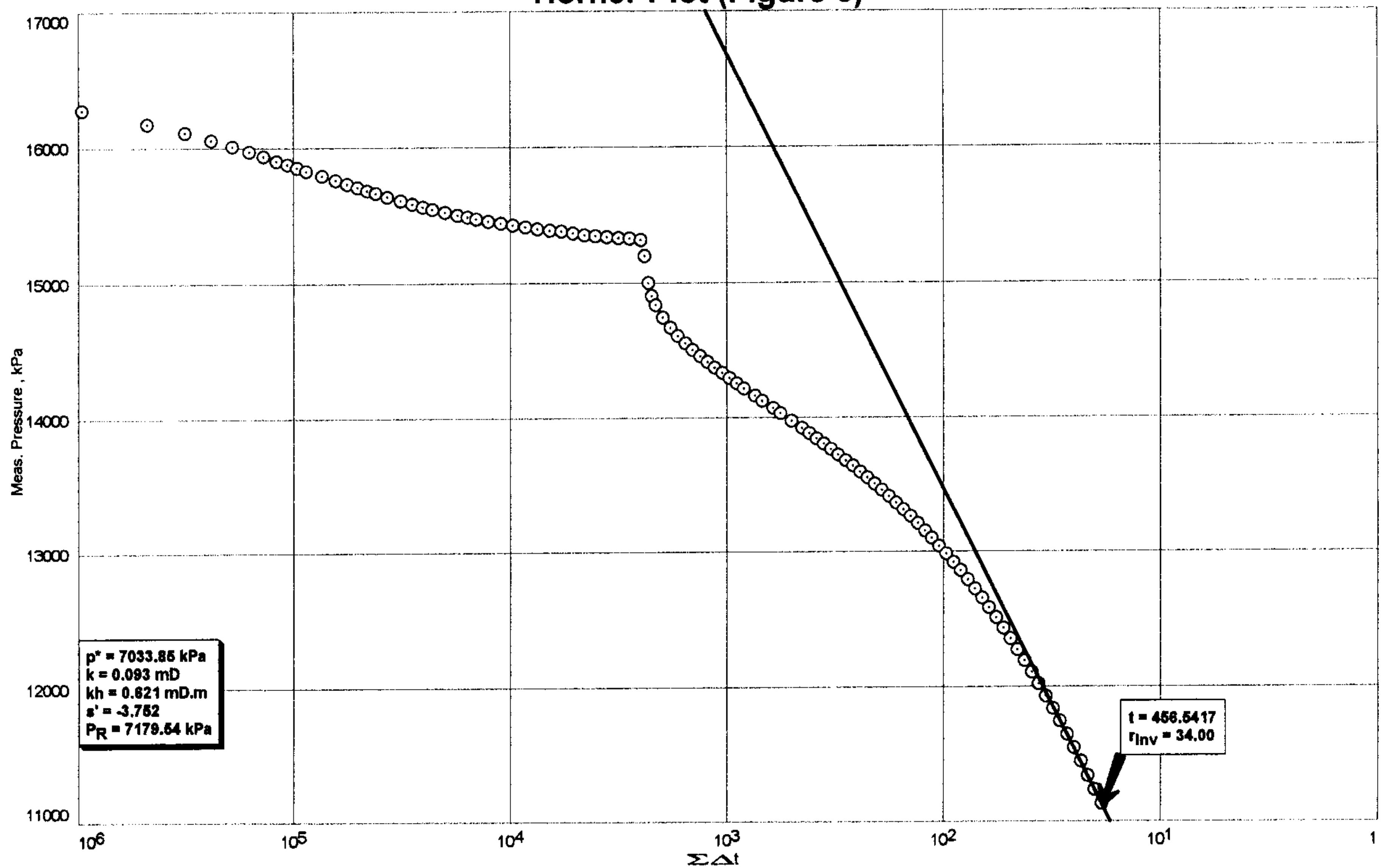
Horner Plot (Figure 6)



Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
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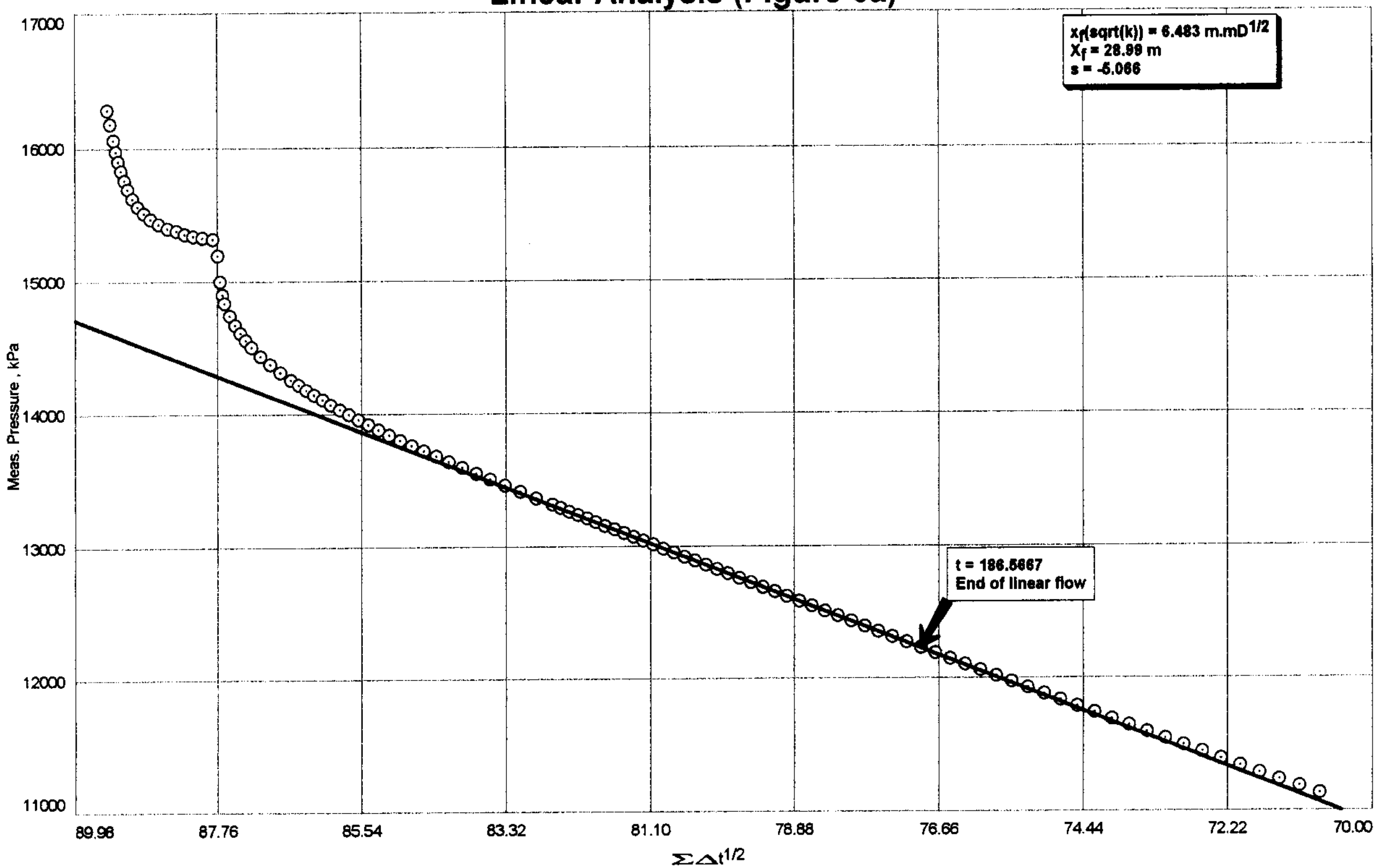
Linear Analysis (Figure 6a)



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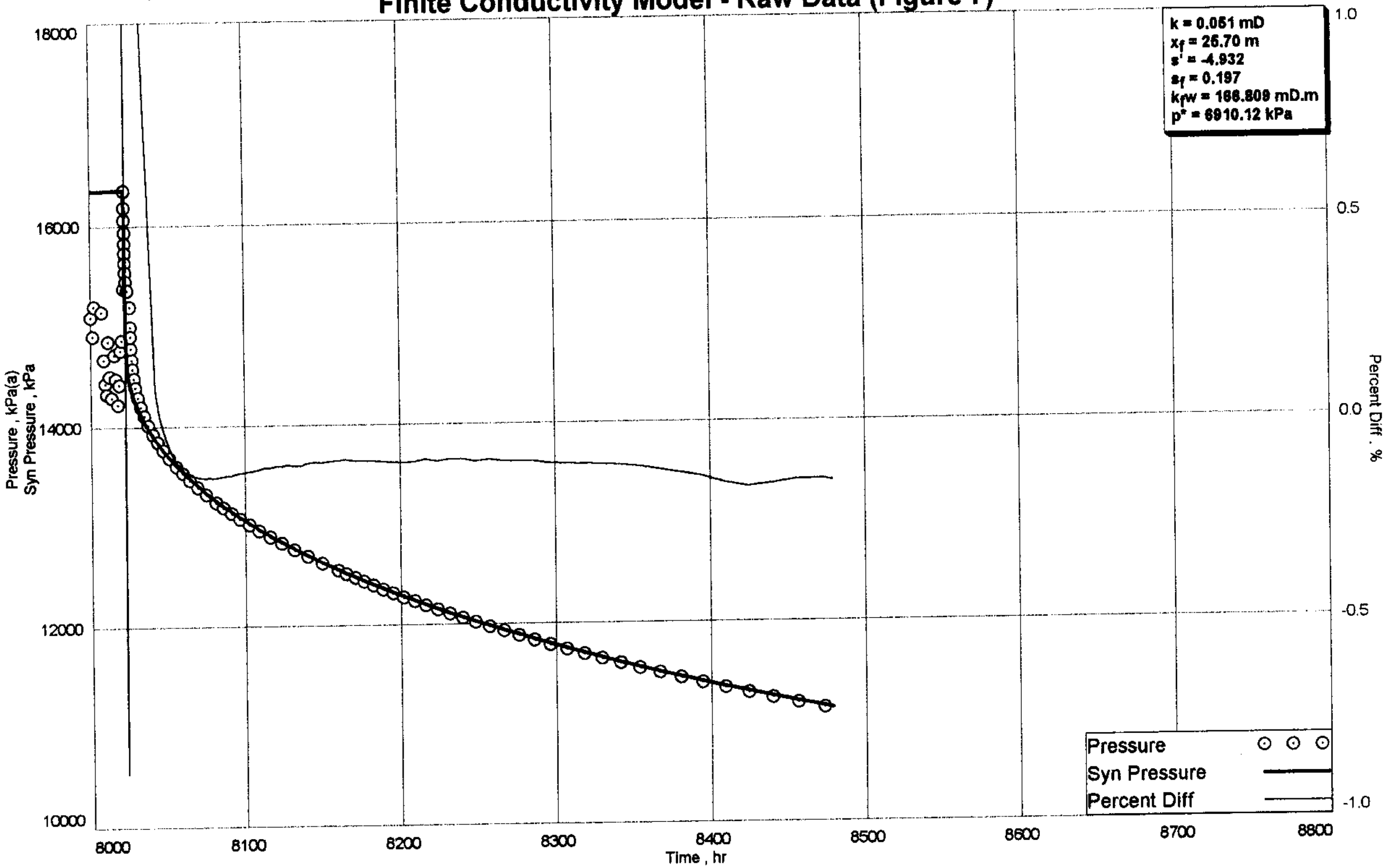
PRESSURE
HISTORY
MATCHING

Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
Fall-off Test
December 10 - 30, 1999

Finite Conductivity Model - Raw Data (Figure 7)



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Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
Fall-off Test
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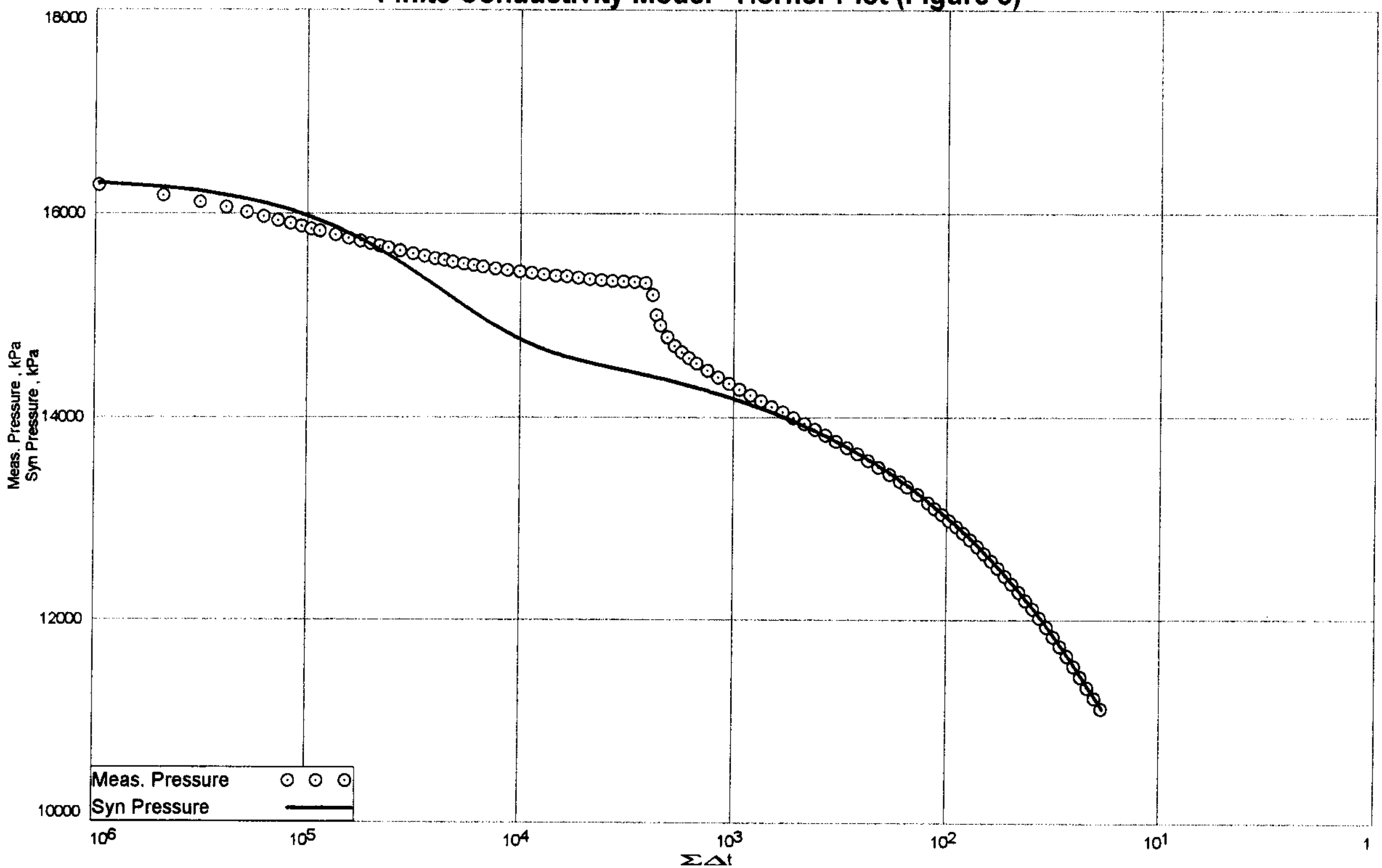
Finite Conductivity Model - Horner Plot (Figure 8)



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Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
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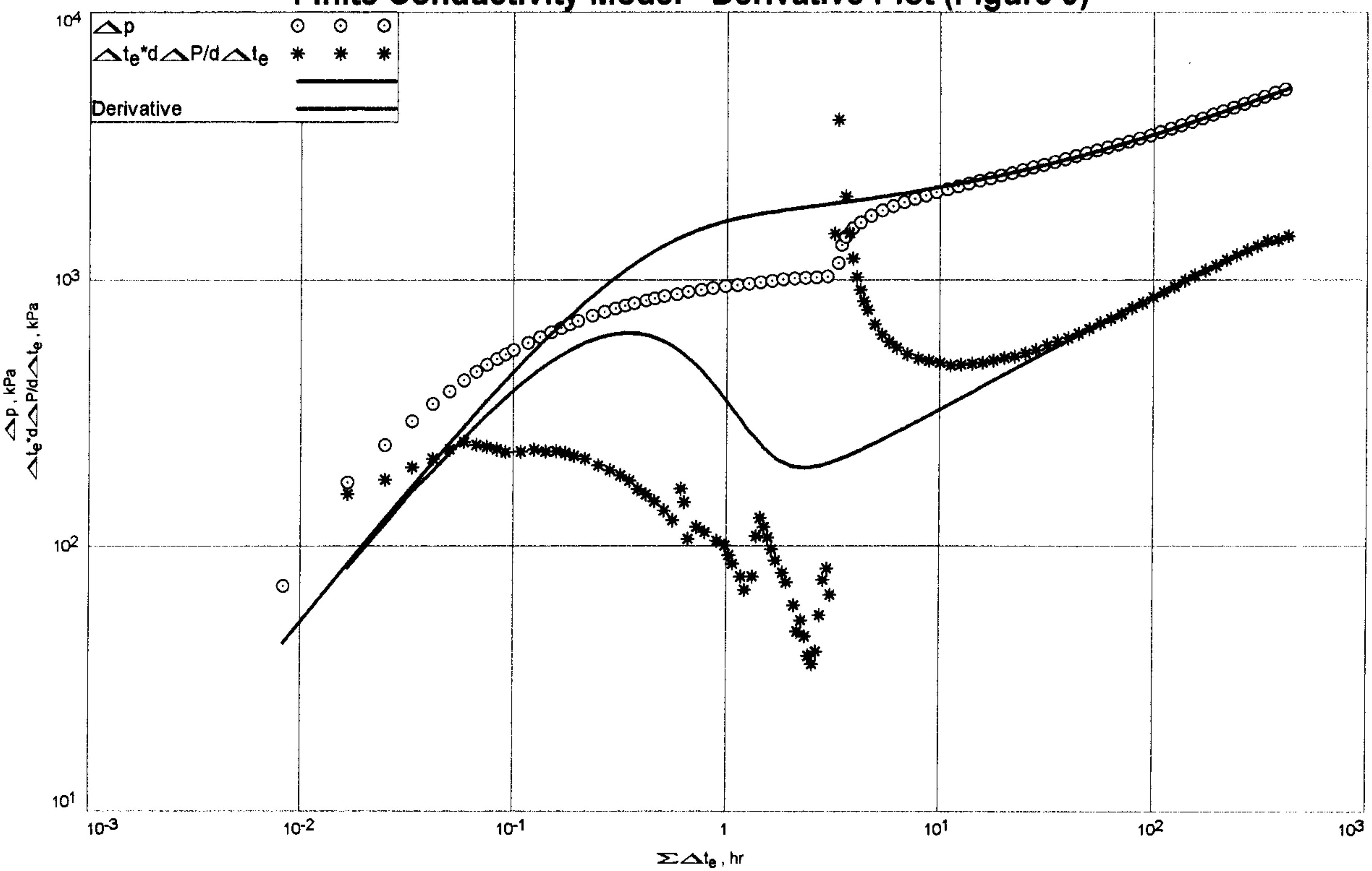
Finite Conductivity Model - Derivative Plot (Figure 9)



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SUBSURFACE
PRESSURES

Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
Fall-off Test
December 10 - 30, 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
1	8000.0000	8000.0000	15100.00	0.000	0.000	-1.500
2	8001.2000	8001.2000	14907.23	0.000	0.000	
3	8002.2000	8002.2000	15205.11	0.000		-1.500
4	8003.2000	8003.2000	15168.47			
5	8004.2000	8004.2000	15157.23			
6	8005.2000	8005.2000	15147.74			
7	8006.2000	8006.2000	15147.71			
8	8007.2000	8007.2000	15150.39			
9	8008.2000	8008.2000	14676.11			
10	8009.2000	8009.2000	14434.91			
11	8010.2000	8010.2000	14325.55			
12	8011.2000	8011.2000	14853.74			
13	8012.2000	8012.2000	14508.19			
14	8013.2000	8013.2000	14294.83			
15	8014.2000	8014.2000	14211.28			
16	8015.2000	8015.2000	14720.10			
17	8016.2000	8016.2000	14479.17			
18	8017.2000	8017.2000	14219.60			
19	8018.2000	8018.2000	14421.32			
20	8019.2000	8019.2000	14763.03			
21	8020.2000	8020.2000	14866.41			
22	8021.2000	8021.2000	15377.56			
23	8022.0667	8022.0667	16348.93			
24	8022.0750	8022.0750	16352.94			
25	8022.0833	8022.0833	16282.56			0.000
26	8022.0917	8022.0917	16180.38			
27	8022.1000	8022.1000	16114.88			
28	8022.1083	8022.1083	16059.58			
29	8022.1167	8022.1167	16012.50			
30	8022.1250	8022.1250	15973.66			
31	8022.1333	8022.1333	15935.46			0.000
32	8022.1417	8022.1417	15902.88			
33	8022.1500	8022.1500	15875.11			
34	8022.1583	8022.1583	15850.46			
35	8022.1667	8022.1667	15828.76			
36	8022.1750	8022.1750	15809.26			
37	8022.1833	8022.1833	15791.32			
38	8022.1917	8022.1917	15774.29			
39	8022.2000	8022.2000	15758.49			
40	8022.2083	8022.2083	15743.75			
41	8022.2167	8022.2167	15729.81			
42	8022.2250	8022.2250	15717.09			

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Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
Fall-off Test
December 10 - 30, 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
43	8022.2333	8022.2333	15704.77			
44	8022.2417	8022.2417	15693.10			
45	8022.2500	8022.2500	15682.35			
46	8022.2583	8022.2583	15671.88			
47	8022.2667	8022.2667	15662.61			
48	8022.2750	8022.2750	15652.90			
49	8022.2833	8022.2833	15644.14			
50	8022.2917	8022.2917	15635.64			
51	8022.3083	8022.3083	15620.17			
52	8022.3250	8022.3250	15606.05			
53	8022.3417	8022.3417	15593.37			
54	8022.3583	8022.3583	15581.45			
55	8022.3750	8022.3750	15570.72			
56	8022.3917	8022.3917	15560.58			
57	8022.4083	8022.4083	15551.40			
58	8022.4250	8022.4250	15542.67			
59	8022.4417	8022.4417	15534.64			
60	8022.4583	8022.4583	15527.53			
61	8022.4750	8022.4750	15520.46			
62	8022.4917	8022.4917	15513.63			
63	8022.5083	8022.5083	15507.99			
64	8022.5333	8022.5333	15499.54			
65	8022.5583	8022.5583	15491.93			
66	8022.5833	8022.5833	15484.95			
67	8022.6083	8022.6083	15478.54			
68	8022.6333	8022.6333	15473.01			
69	8022.6583	8022.6583	15467.33			
70	8022.6833	8022.6833	15461.86			
71	8022.7083	8022.7083	15453.88			
72	8022.7333	8022.7333	15450.36			
73	8022.7667	8022.7667	15444.85			
74	8022.8000	8022.8000	15439.71			
75	8022.8333	8022.8333	15434.04			
76	8022.8667	8022.8667	15429.41			
77	8022.9000	8022.9000	15424.55			
78	8022.9333	8022.9333	15419.82			
79	8022.9750	8022.9750	15414.87			
80	8023.0167	8023.0167	15410.10			
81	8023.0583	8023.0583	15405.52			
82	8023.1000	8023.1000	15401.59			
83	8023.1417	8023.1417	15398.01			
84	8023.1917	8023.1917	15394.27			

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
85	8023.2417	8023.2417	15390.39			
86	8023.2917	8023.2917	15387.70			
87	8023.3417	8023.3417	15384.77			
88	8023.3917	8023.3917	15382.25			
89	8023.4500	8023.4500	15378.48			
90	8023.5083	8023.5083	15373.05			
91	8023.5667	8023.5667	15368.10			
92	8023.6333	8023.6333	15363.23			
93	8023.7000	8023.7000	15358.87			
94	8023.7667	8023.7667	15355.26			
95	8023.8333	8023.8333	15351.92			
96	8023.9083	8023.9083	15348.56			
97	8023.9833	8023.9833	15345.43			
98	8024.0583	8024.0583	15342.83			
99	8024.1417	8024.1417	15339.64			
100	8024.2250	8024.2250	15338.00			
101	8024.3167	8024.3167	15335.80			
102	8024.4083	8024.4083	15333.73			
103	8024.5000	8024.5000	15332.22			
104	8024.6000	8024.6000	15330.70			
105	8024.7000	8024.7000	15329.38			
106	8024.8083	8024.8083	15327.54			
107	8024.9167	8024.9167	15325.05			
108	8025.0333	8025.0333	15321.64			
109	8025.1500	8025.1500	15318.59			
110	8025.2750	8025.2750	15316.51			
111	8025.4083	8025.4083	15197.41			
112	8025.5417	8025.5417	14999.62			
113	8025.6833	8025.6833	14901.51			
114	8025.8250	8025.8250	14836.49			
115	8025.9750	8025.9750	14784.86			
116	8026.1333	8026.1333	14741.42			
117	8026.3000	8026.3000	14702.62			
118	8026.4667	8026.4667	14669.00			
119	8026.6417	8026.6417	14638.06			
120	8026.8250	8026.8250	14608.54			
121	8027.0167	8027.0167	14581.06			
122	8027.2167	8027.2167	14554.67			
123	8027.4250	8027.4250	14529.59			
124	8027.6417	8027.6417	14505.43			
125	8027.8667	8027.8667	14481.90			
126	8028.1000	8028.1000	14459.31			

Print Filter Used: Nth Line = 1.000

Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
Fall-off Test
December 10 - 30, 1999

	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
127	8028.3417	8028.3417	14437.31			
128	8028.5917	8028.5917	14415.78			
129	8028.8500	8028.8500	14395.12			
130	8029.1167	8029.1167	14374.57			
131	8029.4000	8029.4000	14354.21			
132	8029.6917	8029.6917	14334.06			
133	8029.9917	8029.9917	14314.79			
134	8030.3083	8030.3083	14294.85			
135	8030.6333	8030.6333	14275.55			
136	8030.9750	8030.9750	14256.43			
137	8031.3250	8031.3250	14237.09			
138	8031.6917	8031.6917	14218.55			
139	8032.0750	8032.0750	14199.16			
140	8032.4667	8032.4667	14180.93			
141	8032.8750	8032.8750	14161.97			
142	8033.3000	8033.3000	14143.80			
143	8033.7417	8033.7417	14125.31			
144	8034.2000	8034.2000	14106.54			
145	8034.6750	8034.6750	14088.02			
146	8035.1750	8035.1750	14069.64			
147	8035.6917	8035.6917	14050.96			
148	8036.2250	8036.2250	14032.91			
149	8036.7833	8036.7833	14013.80			
150	8037.3667	8037.3667	13995.29			
151	8037.9667	8037.9667	13976.45			
152	8038.5917	8038.5917	13957.87			
153	8039.2417	8039.2417	13939.22			
154	8039.9167	8039.9167	13920.12			
155	8040.6167	8040.6167	13901.03			
156	8041.3500	8041.3500	13882.29			
157	8042.1083	8042.1083	13862.84			
158	8042.9000	8042.9000	13843.20			
159	8043.7167	8043.7167	13823.44			
160	8044.5667	8044.5667	13803.64			
161	8045.4500	8045.4500	13783.92			
162	8046.3667	8046.3667	13764.07			
163	8047.3250	8047.3250	13743.91			
164	8048.3167	8048.3167	13723.44			
165	8049.3500	8049.3500	13702.84			
166	8050.4250	8050.4250	13681.85			
167	8051.5417	8051.5417	13660.91			
168	8052.7000	8052.7000	13639.49			

Print Filter Used: Nth Line = 1.000

Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
Fall-off Test
December 10 - 30, 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
169	8053.9000	8053.9000	13617.78			
170	8055.1500	8055.1500	13595.98			
171	8056.4500	8056.4500	13574.21			
172	8057.8000	8057.8000	13551.62			
173	8059.2000	8059.2000	13529.25			
174	8060.6583	8060.6583	13506.47			
175	8062.1750	8062.1750	13483.76			
176	8063.7500	8063.7500	13460.23			
177	8065.3833	8065.3833	13436.66			
178	8067.0833	8067.0833	13412.86			
179	8068.8500	8068.8500	13388.68			
180	8070.6833	8070.6833	13364.07			
181	8072.5917	8072.5917	13339.29			
182	8074.5750	8074.5750	13314.05			
183	8076.6333	8076.6333	13288.79			
184	8078.7750	8078.7750	13262.51			
185	8081.0000	8081.0000	13236.28			
186	8083.3083	8083.3083	13209.83			
187	8085.7083	8085.7083	13182.78			
188	8088.2000	8088.2000	13155.40			
189	8090.7917	8090.7917	13127.46			
190	8093.4833	8093.4833	13099.37			
191	8096.2833	8096.2833	13070.78			
192	8099.1917	8099.1917	13041.69			
193	8102.2167	8102.2167	13011.96			
194	8105.3583	8105.3583	12982.04			
195	8108.6167	8108.6167	12951.51			
196	8112.0083	8112.0083	12920.99			
197	8115.5333	8115.5333	12889.28			
198	8119.1917	8119.1917	12857.54			
199	8122.9917	8122.9917	12824.92			
200	8126.9417	8126.9417	12792.09			
201	8131.0500	8131.0500	12758.13			
202	8135.3167	8135.3167	12724.10			
203	8139.7500	8139.7500	12690.07			
204	8144.3583	8144.3583	12655.15			
205	8149.1500	8149.1500	12619.37			
206	8154.1250	8154.1250	12583.60			
207	8159.2917	8159.2917	12546.91			
208	8164.6667	8164.6667	12509.91			
209	8170.2500	8170.2500	12471.74			
210	8176.0500	8176.0500	12433.41			

Print Filter Used: Nth Line = 1.000

Home Pierson 10-08-02-29W1
Spreafish (1023-24.5,1026-27,1028-30,1031-34)
Fall-off Test
December 10 - 30, 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	8182.0750	8182.0750	12394.45			
212	8188.3417	8188.3417	12354.71			
213	8194.8500	8194.8500	12314.50			
214	8201.6167	8201.6167	12273.70			
215	8208.6417	8208.6417	12232.70			
216	8215.9417	8215.9417	12191.77			
217	8223.5333	8223.5333	12148.92			
218	8231.4167	8231.4167	12106.68			
219	8239.6083	8239.6083	12063.19			
220	8248.1250	8248.1250	12018.45			
221	8256.9750	8256.9750	11974.33			
222	8266.1667	8266.1667	11928.74			
223	8275.7167	8275.7167	11882.70			
224	8285.6417	8285.6417	11836.33			
225	8295.9583	8295.9583	11788.70			
226	8306.6750	8306.6750	11741.26			
227	8317.8167	8317.8167	11692.87			
228	8329.3917	8329.3917	11644.12			
229	8341.4167	8341.4167	11594.67			
230	8353.9167	8353.9167	11544.75			
231	8366.9000	8366.9000	11493.86			
232	8380.3917	8380.3917	11442.61			
233	8394.4167	8394.4167	11390.68			
234	8408.9917	8408.9917	11337.71			
235	8424.1333	8424.1333	11284.96			
236	8439.8667	8439.8667	11233.99			
237	8456.2167	8456.2167	11182.69			
238	8473.2083	8473.2083	11130.07			
239	8478.6083	8478.6083	11113.12			
240	8478.6167	8478.6167	11113.33			

Print Filter Used: Nth Line = 1.000

EQUATIONS

and

NOMENCLATURE

(METRIC UNITS)

PM

BASIC TIME FUNCTIONS

Flow Time t

Shut-In Time Δt

Horner Time $\dfrac{t + \Delta t}{\Delta t}$

Superposition Time $t_n = \sum_{j=1}^{n} \dfrac{q_j - q_{j-1}}{q_n} \log(t - t_{j-1})$

$$\Delta t_n = \sum_{j=1}^{n} \frac{q_j}{q_n} \log \frac{t_n + \Delta t - t_{j-1}}{t_n + \Delta t - t_j}$$

Equivalent Time $\Delta t_e = \dfrac{t \cdot \Delta t}{t + \Delta t}$

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

TYPECURVES - DIMENSIONLESS VARIABLES

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

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

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

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

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

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

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

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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

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

Pressure Drop Skin

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

Flow Efficiency

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

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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

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

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

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

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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

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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

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Symbol	Description	Metric (SI)	Field
α	wellbore storage/unloading constant	m^3/kPa	bbl/psi
μ	viscosity - gas - liquid	μPa.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

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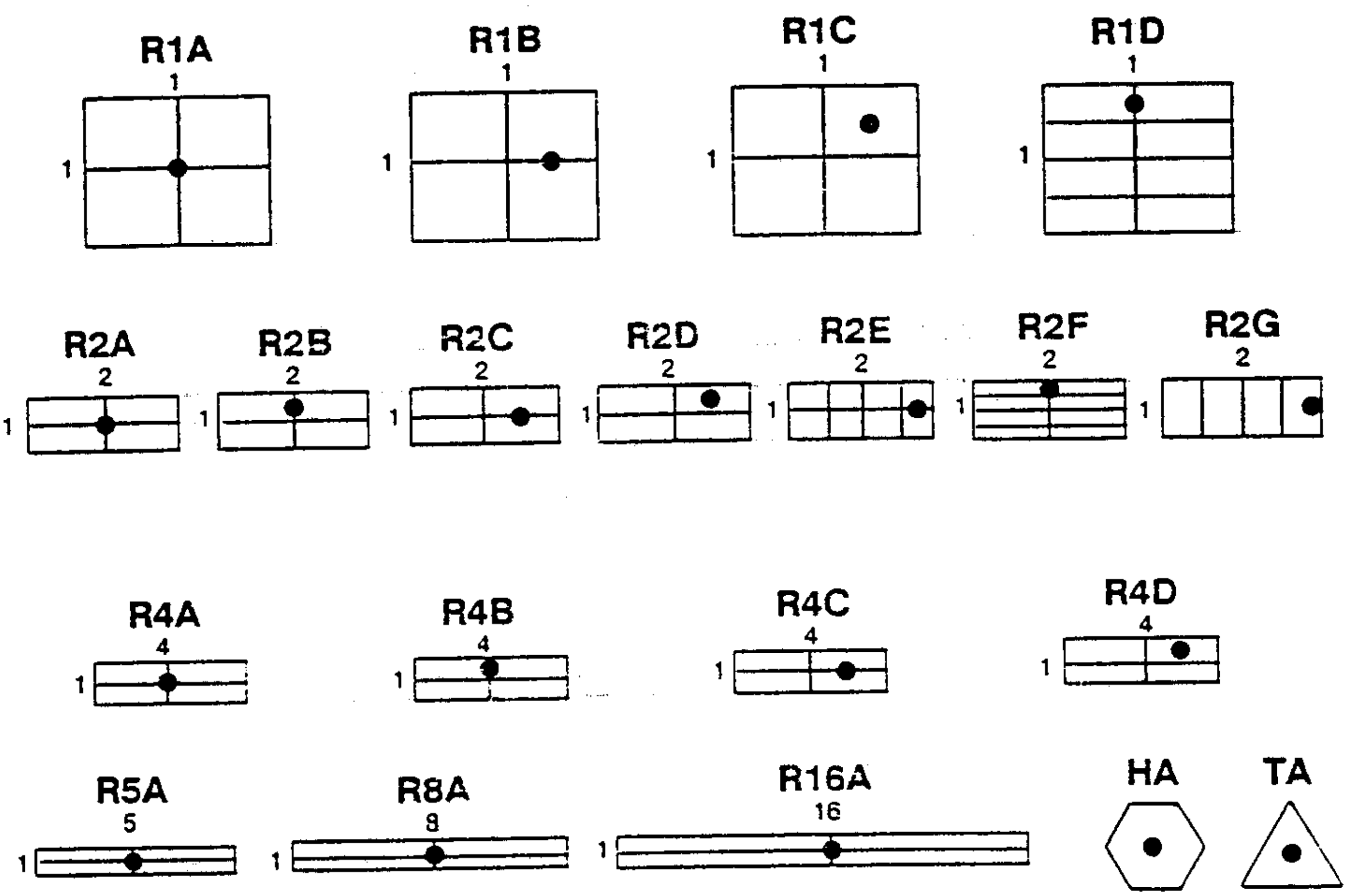
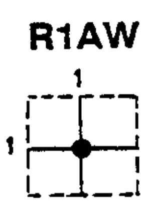
DIETZ SHAPE CODES

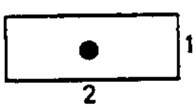
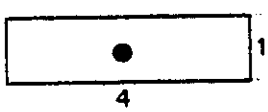
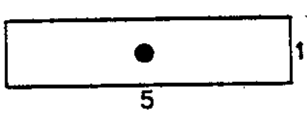
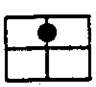
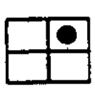
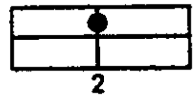
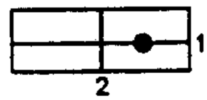
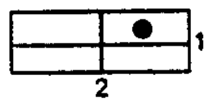
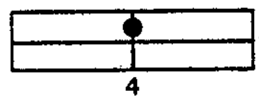
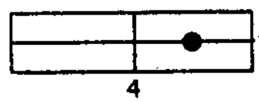
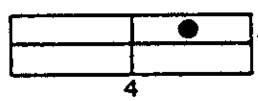
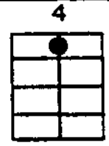
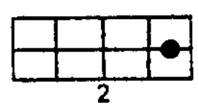
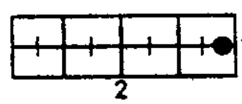
AVERAGE RESERVOIR PRESSURE - MBH CORRECTIONS

NO FLOW OUTER BOUNDARY



CONSTANT PRESSURE OUTER BOUNDARY



Reservoir shape	$\ln C_A$	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)

PMG

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