INJECTIVITY/FALL-OFF TEST REPORT

#1606
Copy 2 of 2

HOME PIERSON 04-17-02-29W1
SPEARFISH (1025 - 1031 mKB)
TEST DATE: DECEMBER 11 - 31, 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 04-17-02-29W1
SPEARFISH (1025 - 1031 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

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Summary of Test Data & Results

Case Name : Finite Conductivity Fracture #1

Home Pierson 04-17-02-29W1 | Fall-off Test

Spearfish (1025 - 1031 mKB) | Test Date: Dec. 11 - 31, 1999

Model Parameters

Water Permeability (k_w)	0.271 mD	Fracture Half Length (x_f)	3.81 m
Total Mobility ($(k/\mu)_t$)	0.43 mD/mPa.s	Fracture Flow Capacity ($k_f w$)	40769.502 mD.m
Total Transmissivity ($(kh/\mu)_t$)	1.85 mDm/mPa.s	Fracture Face Skin (sf)	0.810
Wellbore Storage Constant Dim. (C_D)	1.91	Skin Equivalent to Xf	-3.037
		Exterior Radius (r_e)	450.00 m

Formation Parameters

Net Pay (h)	4.30 m
Total Porosity (ϕ_t)	16.50 %
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)	5.729e-7 kPa^{-1}
Total Compressibility (c_t)	4.624e-6 kPa^{-1}

Fluid Properties

Water Compressibility (c_w)	4.28887e-7 kPa^{-1}
Oil Compressibility (c_o)	1.25045e-5 kPa^{-1}
Gas Compressibility (c_g)	6.03832e-5 kPa^{-1}
Water Formation Volume Factor (B_w)	1.000
Water Viscosity (μ_w)	0.628 mPa.s
Gas Viscosity (μ_g)	17.944 μPa.s
Solution Gas Ratio (R_{sw})	0 m^3/m^3
Specific Gravity (G)	1.000
PVT Reference Pressure (p_{PVT})	16381.61 kPa

Production and Pressure

$Q_t B_t$	-1.000 m^3/d
Final Water Rate	-1.000 m^3/d
Final Gas Rate	0.000 $10^3 m^3/d$
Final Flowing Pressure (p_{wfo})	14781.80 kPa
Final Measured Pressure	10545.17 kPa
Initial Pressure (p_i)	16381.61 kPa

Synthesis Results

Average Error	0.22 %
Synthetic Initial Pressure (p_i)	9077.46 kPa
Extrapolated Pressure at Specified Time	9401.98 kPa
Pressure Drop Due To Skin (Δp_s)	1248.06 kPa
Flow Efficiency (FE)	0.768
Damage Ratio (DR)	1.302

Forecasts

Specified Flowing Pressure (p_{wfs})	14781.80 kPa
3 - Month Constant Rate	-1.056 m^3/d
6 - Month Constant Rate	-0.990 m^3/d
Specified Forecast Time	12.00 month
Forecast Constant Rate @ Current Skin	-0.931 m^3/d
PI / II (Actual)	1.84e-4 $m^3/d/kPa$
Forecast Constant Rate @ Skin=0	-1.187 m^3/d
PI / II (Ideal)	2.39e-4 $m^3/d/kPa$

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SUMMARY OF RESULTS

SUMMARY OF RESULTS

1. The average reservoir pressure (P_R) is 9 402 kPa.

2. The effective permeability to water of the Spearfish formation is 0.27 mD.

3. The apparent wellbore skin factor of -3.0 and the fracture half length of 3.81 m confirm that the well was stimulated. The fracture face skin (S_f) of 0.81 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 1.0 m^3/d

5. The injectivity index (I.I.) is 1.84E-4 m^3/d/kPa.

TEST ANALYSIS

DISCUSSION

1. Test Overview:

The Home Pierson 04-17-02-29W1 is completed in the Spearfish formation at 1025 - 1031 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 1.0 m^3/d for 25 hours at a wellhead injection pressure 2 800 kPa. Subsequently, the well was shutin for a 432 hour fall-off period.

2. Data Validation:

During the injection/fall-off test, tandem electronic pressure recorders were set at 1014.49 mCF & 1015.49 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.

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 1.0 m^3/d at a sandface flowing pressure of 14 782 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 a BHP approximately 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 9 248 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 9 406 kPa. The results of the Horner plot are summarized below:

	Horner
Effective Permeability, mD	0.31
Ave. Reservoir Pressure, kPa	9 406
Apparent Skin Factor	-1.3

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	9 402	kPa
Effective Permeability, k	0.27	mD
Fracture conductivity, $K_f.w$	40769.5	mD.m
Fracture Half Length, X_f	3.81	m
Six-Month Stabilized Rate, q_s	1.0	$10^3m^3/d$

3. Well Injectivity:

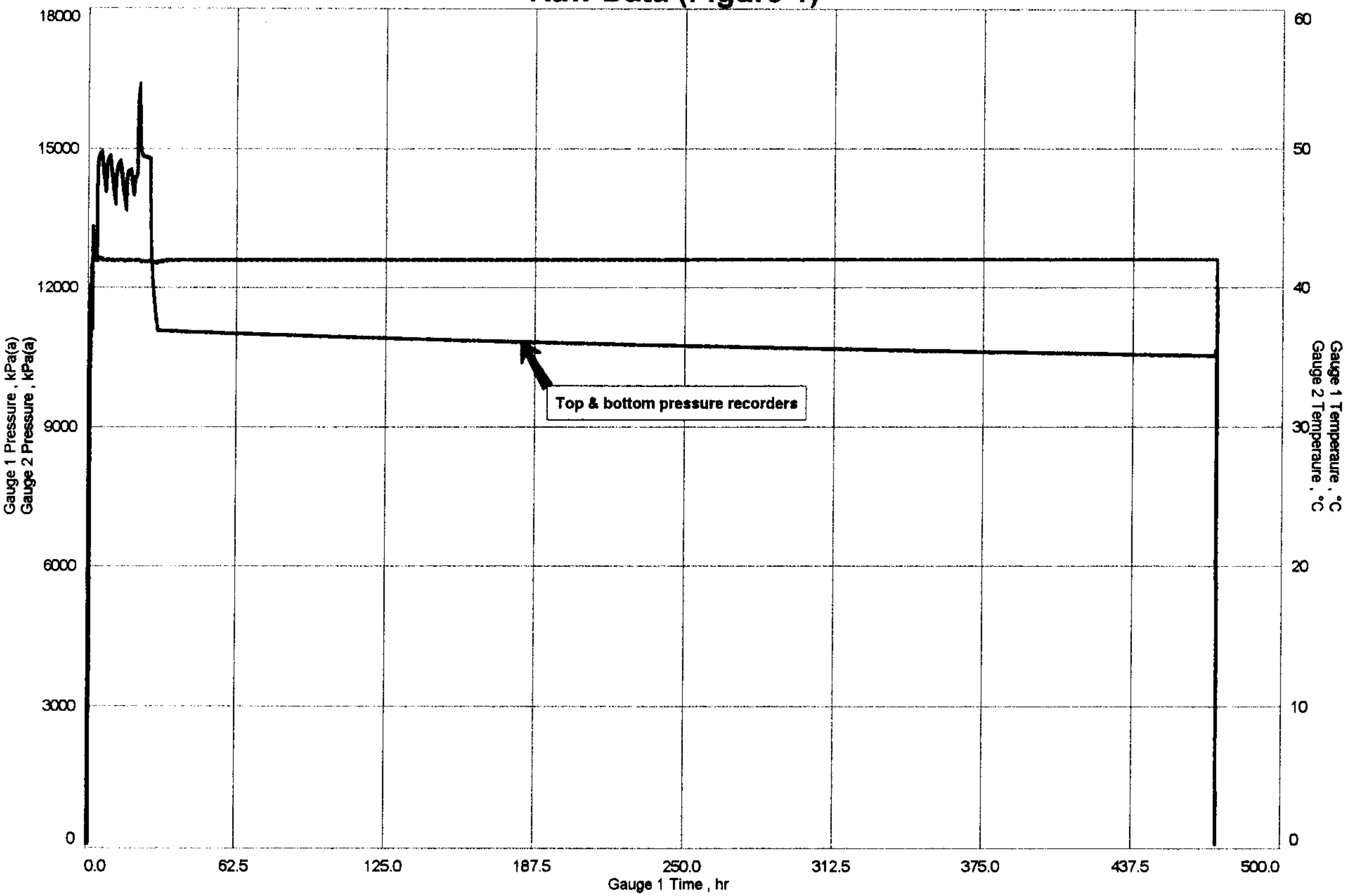
The well stabilized injection rate of 1.0 m3/d and the injectivity index (I.I.) is 1.84E-4 $m^3/d/kPa$ were obtained from the test history match at the current wellbore skin of -3.0.

TEST DATA
QUALITY

100/04-17-002-29W1/0

Home Pierson
Formation: Spearfish

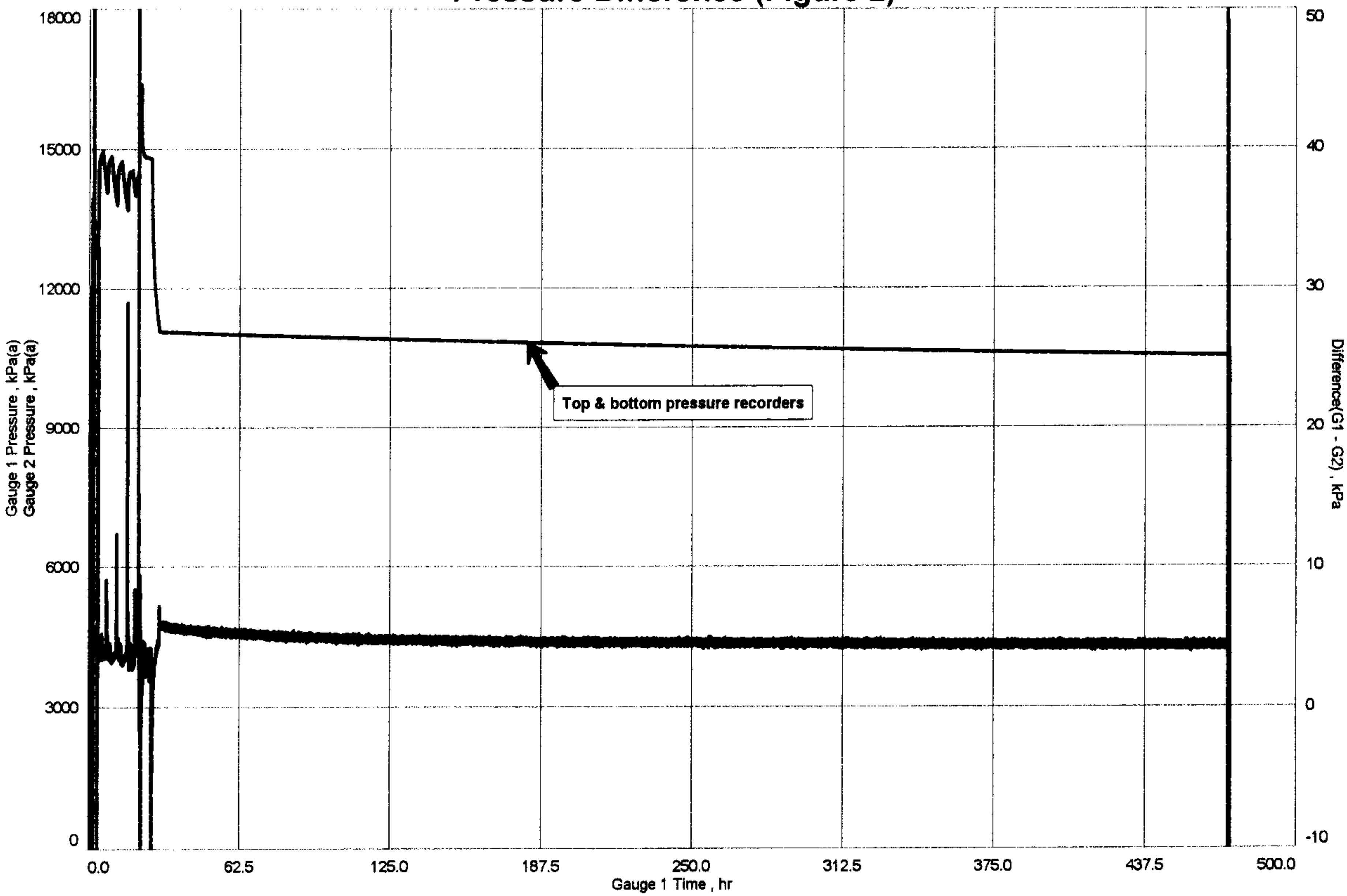
Raw Data (Figure 1)



100/04-17-002-29W1/0

Home Pierson
Formation: Spearfish

Pressure Difference (Figure 2)



Home Pierson 04-17-02-29W1
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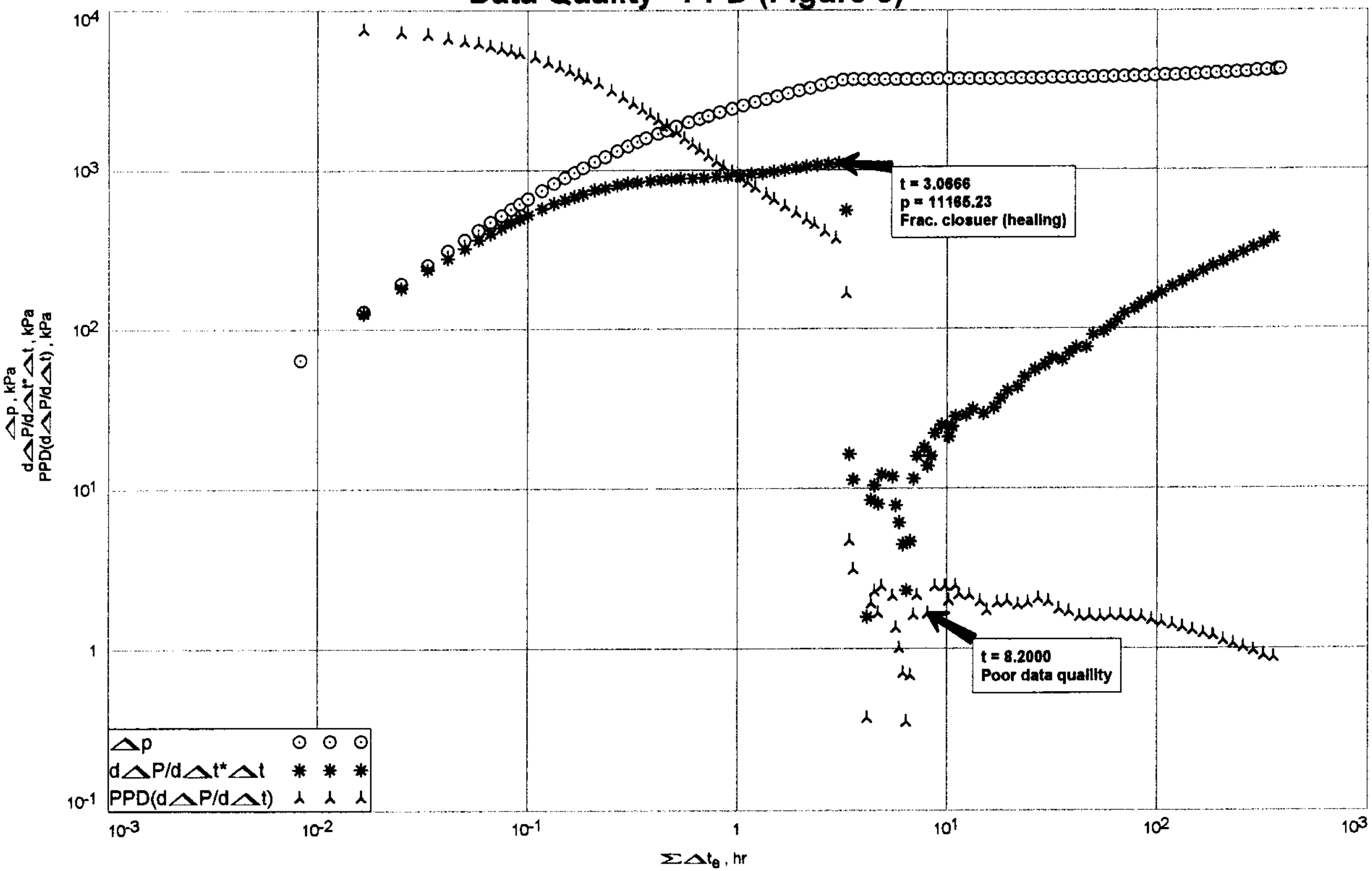
Data Quality - PPD (Figure 3)



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PRESSURE
TRANSIENT
ANALYSIS

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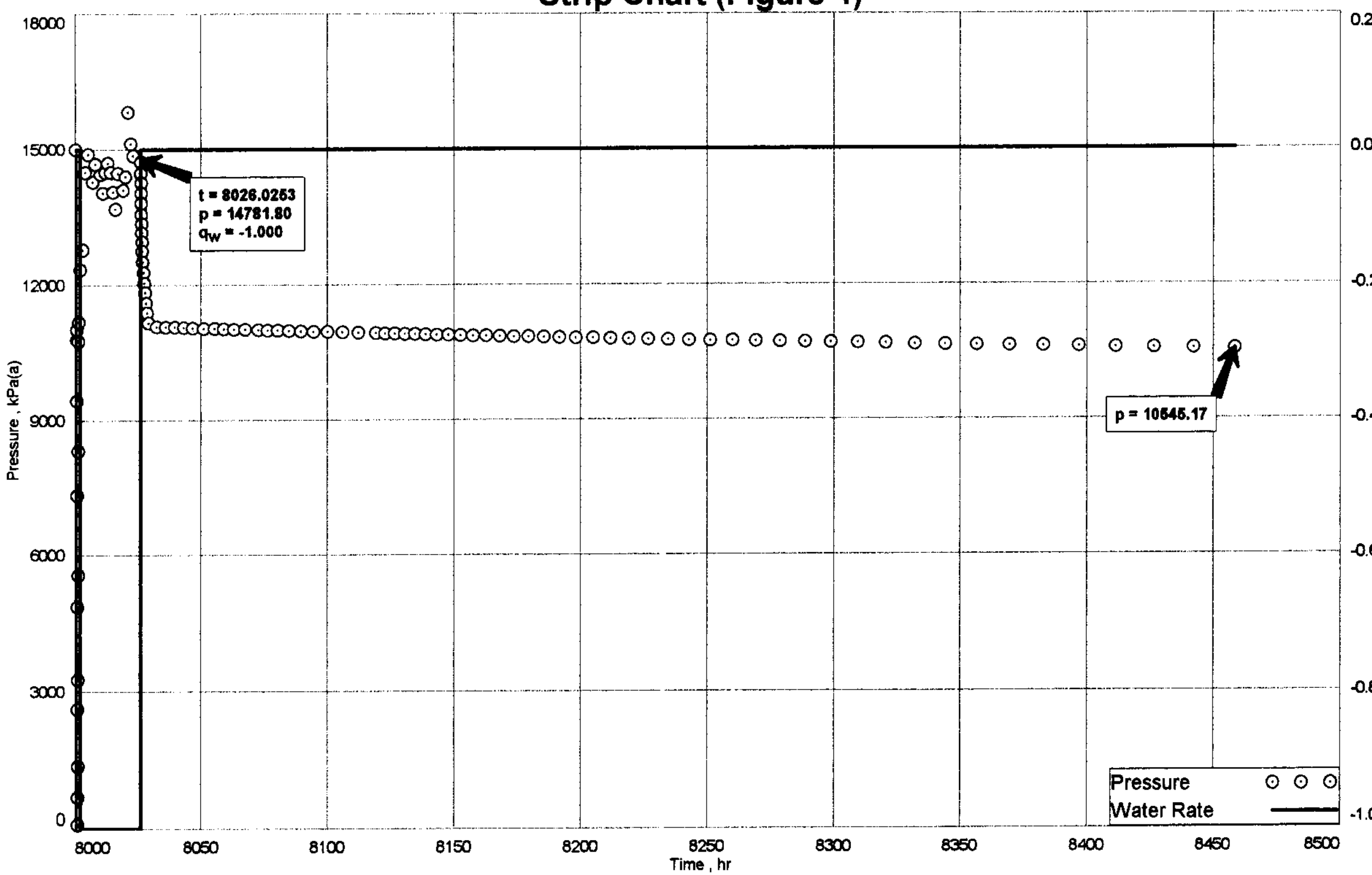
Strip Chart (Figure 4)



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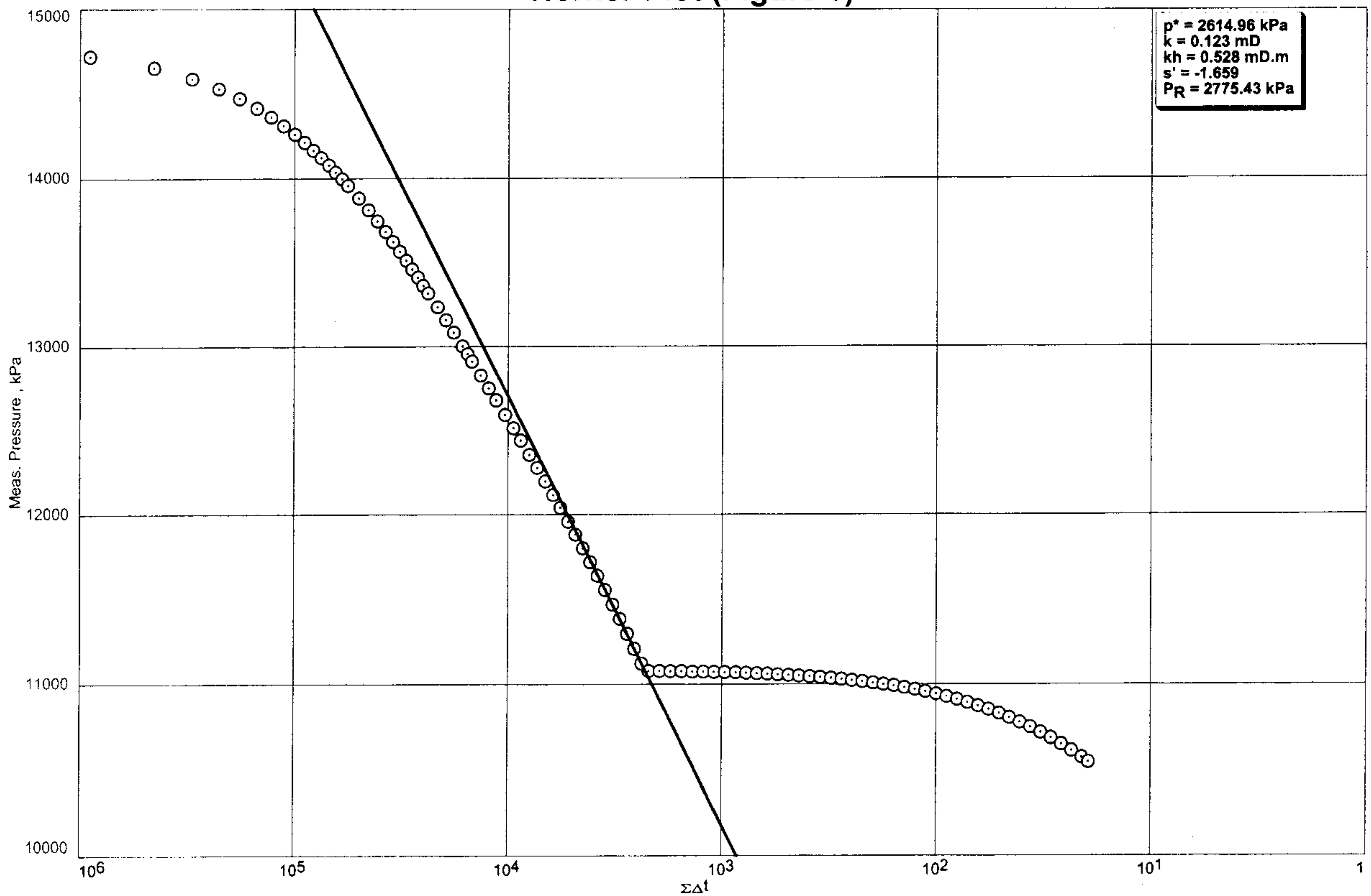
Horner Plot (Figure 6)



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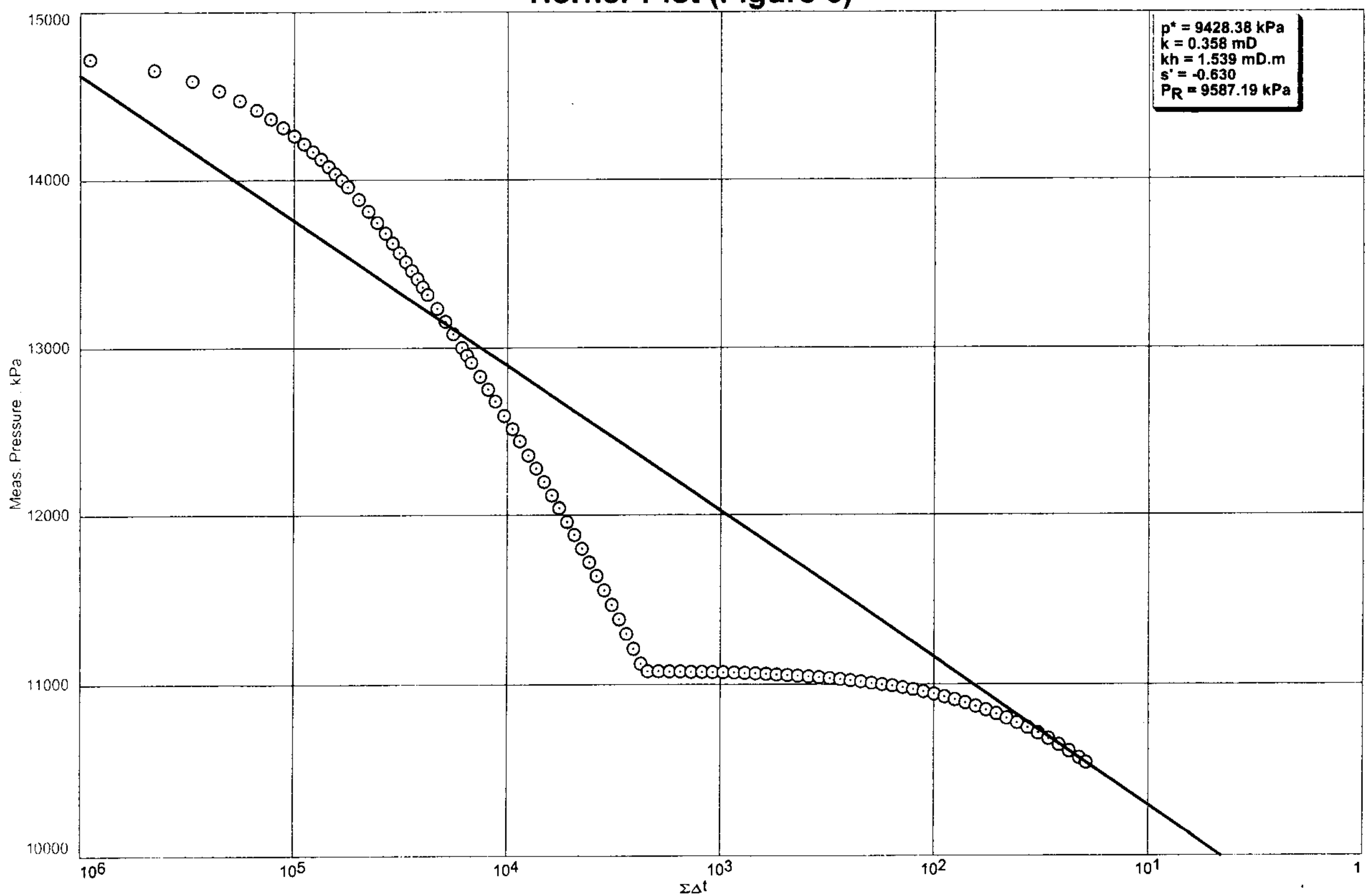
Horner Plot (Figure 6)



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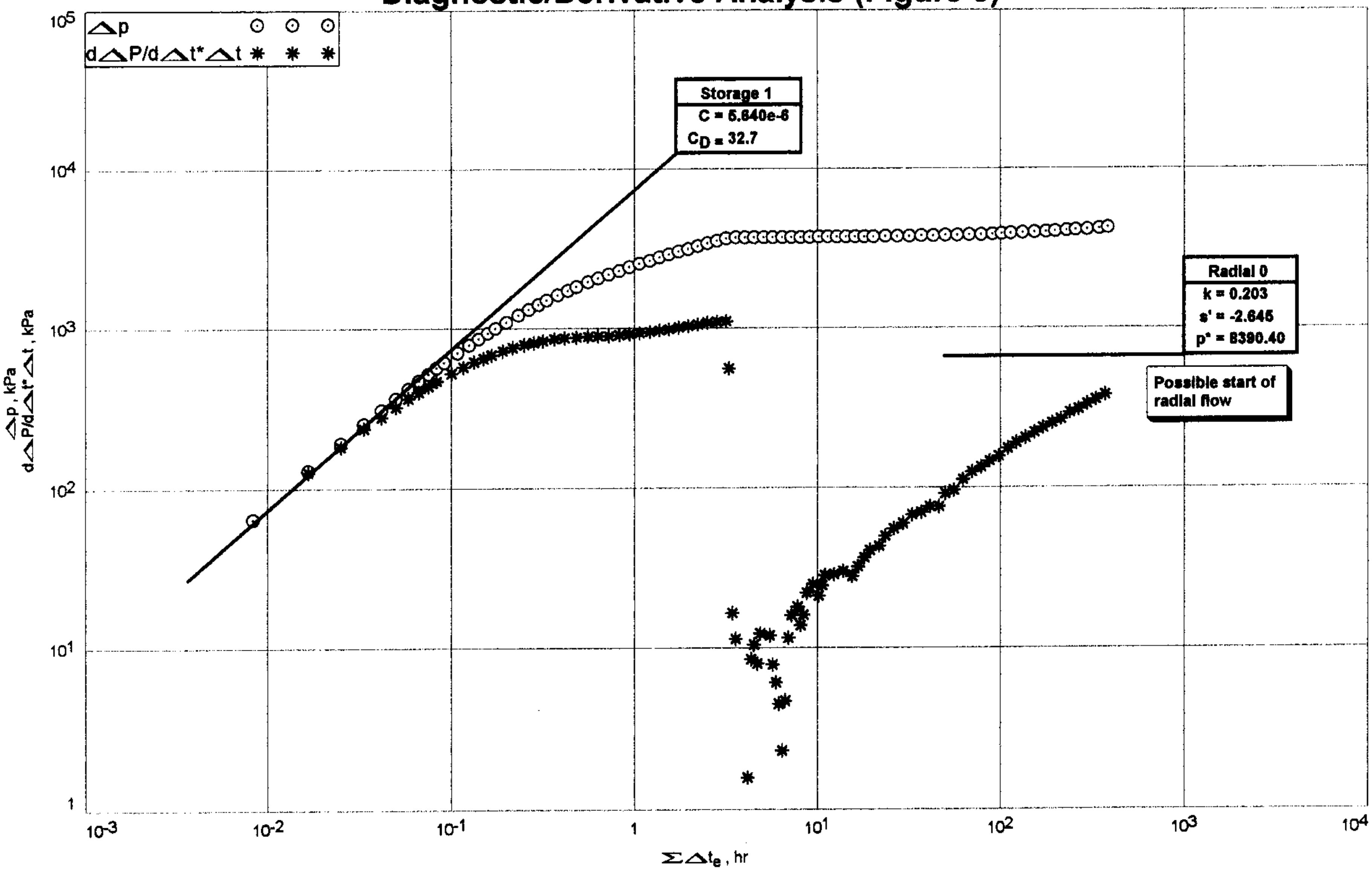
Diagnostic/Derivative Analysis (Figure 5)



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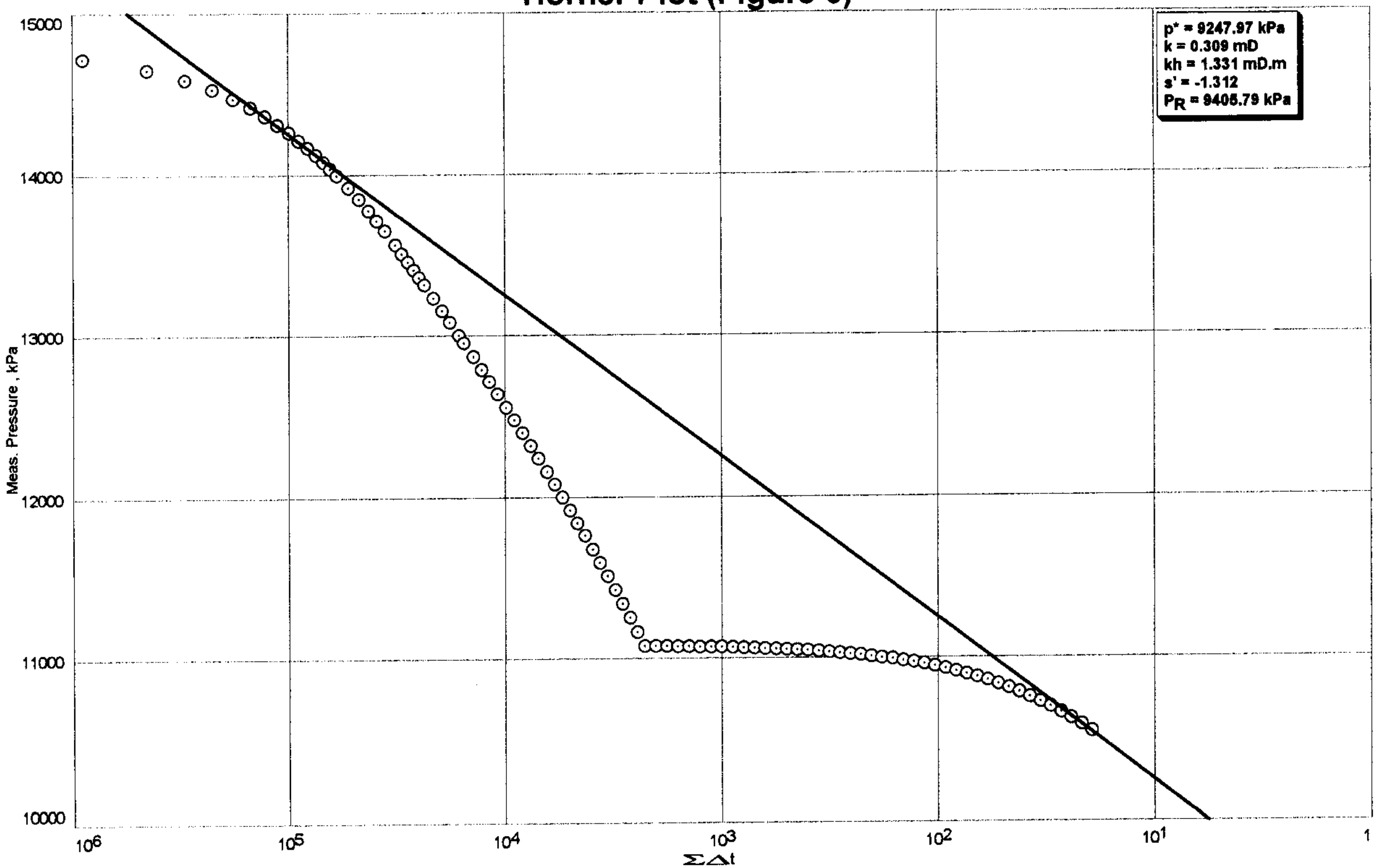
Horner Plot (Figure 6)



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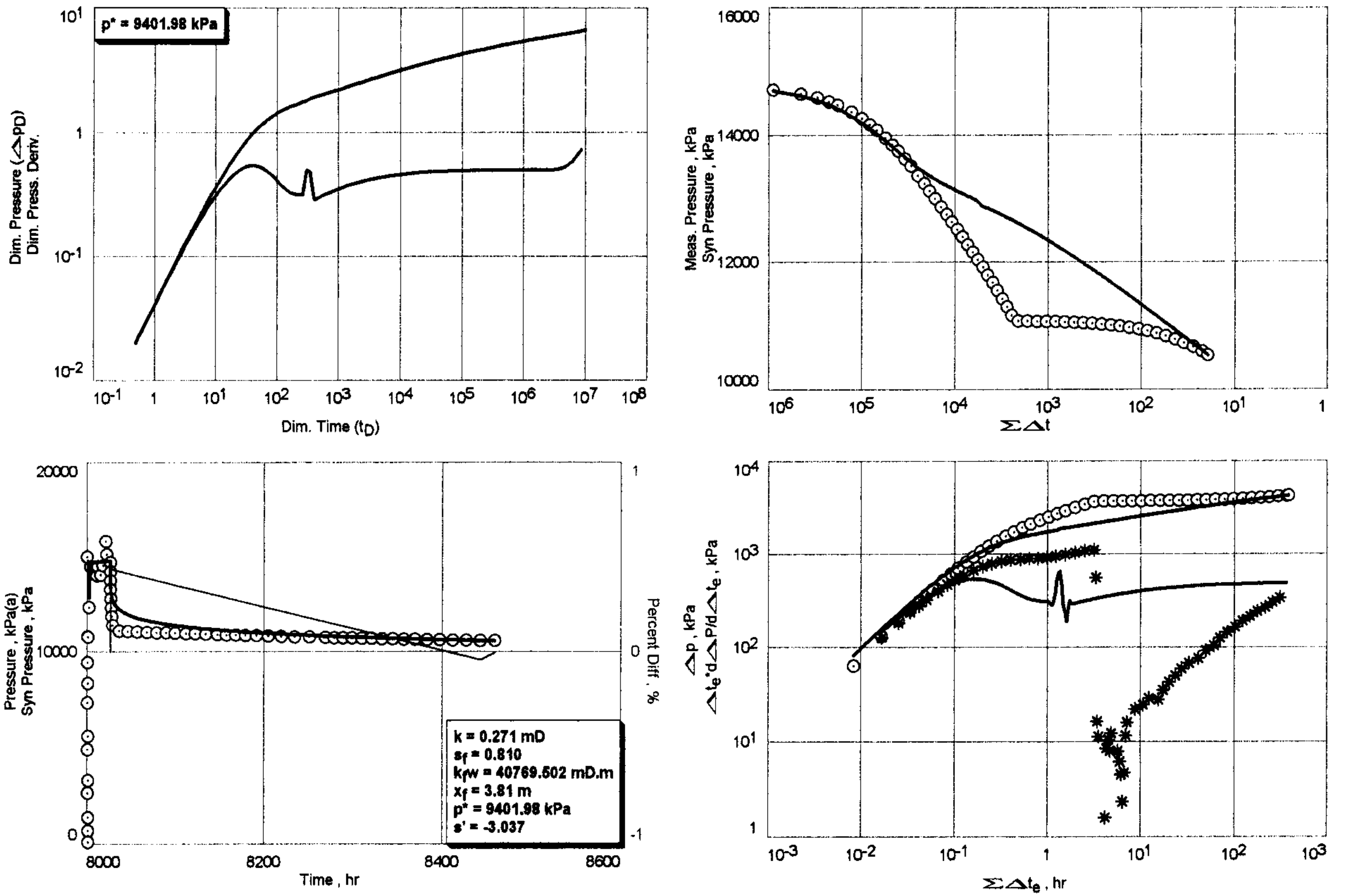
PRESSURE
HISTORY
MATCHING

Finite Conductivity Fracture #1



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SUBSURFACE
PRESSURES

Home Pierson 04-17-02-29W1
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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
1	-8000.0000	8000.0000	15000.00	0.000	0.000	-1.000
2	-0.1000	8000.1000	15000.00	0.000	0.000	-1.000
3	0.5003	8000.5003	10780.28			0.000
4	0.5308	8000.5308	11008.02			
5	0.5642	8000.5642	11178.04			
6	0.6003	8000.6003	11006.73			
7	0.6364	8000.6364	9429.33			
8	0.6753	8000.6753	7323.12			
9	0.7169	8000.7169	4871.58			
10	0.7611	8000.7611	2612.23			
11	0.8083	8000.8083	676.55			
12	0.8583	8000.8583	95.09			
13	0.9111	8000.9111	229.02			
14	0.9667	8000.9667	1347.46			
15	1.0250	8001.0250	3266.82			
16	1.0861	8001.0861	5565.09			
17	1.1528	8001.1528	8321.38			
18	1.2225	8001.2225	10751.17			
19	1.2975	8001.2975	11185.47			
20	1.3753	8001.3753	11206.54			
21	1.4586	8001.4586	11077.62			
22	1.5475	8001.5475	11116.14			
23	1.6392	8001.6392	11149.14			
24	1.7364	8001.7364	11135.07			
25	1.8419	8001.8419	11119.75			
26	1.8781	8001.8781	11150.22			
27	1.8808	8001.8808	12336.43			
28	2.8836	8002.8836	12773.86			-1.000
29	3.8836	8003.8836	14491.16			
30	4.8836	8004.8836	14893.87			
31	5.8836	8005.8836	14739.30			
32	6.8836	8006.8836	14284.24			
33	7.8836	8007.8836	14672.38			
34	8.8919	8008.8919	14834.03			
35	9.8919	8009.8919	14450.30			
36	10.8919	8010.8919	14028.74			
37	11.8919	8011.8919	14493.21			
38	12.8919	8012.8919	14693.83			
39	13.8919	8013.8919	14493.61			
40	14.8919	8014.8919	14054.12			
41	15.8919	8015.8919	13683.39			
42	16.8919	8016.8919	14474.73			

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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	17.8919	8017.8919	14543.15			
44	18.8919	8018.8919	14099.28			
45	19.8919	8019.8919	14394.00			
46	20.8919	8020.8919	15827.42			
47	21.8919	8021.8919	15127.63			
48	22.8919	8022.8919	14859.36			
49	23.8919	8023.8919	14828.23			
50	24.8919	8024.8919	14807.76			
51	25.8919	8025.8919	14793.21			
52	26.0169	8026.0169	14792.04			
53	26.0253	8026.0253	14781.80			-1.000
54	26.0336	8026.0336	14717.86	0.000		0.000
55	26.0419	8026.0419	14651.87			
56	26.0503	8026.0503	14589.10			
57	26.0586	8026.0586	14528.88			
58	26.0669	8026.0669	14471.16			
59	26.0753	8026.0753	14415.76			
60	26.0836	8026.0836	14362.34			
61	26.0919	8026.0919	14310.90			
62	26.1003	8026.1003	14261.34			
63	26.1086	8026.1086	14213.29			
64	26.1169	8026.1169	14167.00			
65	26.1253	8026.1253	14122.38			
66	26.1336	8026.1336	14078.85			
67	26.1419	8026.1419	14036.84			
68	26.1503	8026.1503	13996.48			
69	26.1586	8026.1586	13957.17			
70	26.1669	8026.1669	13919.09			
71	26.1753	8026.1753	13882.17			
72	26.1836	8026.1836	13846.46			
73	26.1919	8026.1919	13811.61			
74	26.2003	8026.2003	13777.73			
75	26.2086	8026.2086	13744.90			
76	26.2169	8026.2169	13712.99			
77	26.2253	8026.2253	13681.88			
78	26.2336	8026.2336	13651.38			
79	26.2419	8026.2419	13621.81			
80	26.2586	8026.2586	13564.90			
81	26.2753	8026.2753	13510.89			
82	26.2919	8026.2919	13459.21			
83	26.3086	8026.3086	13409.96			
84	26.3253	8026.3253	13362.90			

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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	26.3419	8026.3419	13317.79			
86	26.3586	8026.3586	13274.85			
87	26.3753	8026.3753	13233.59			
88	26.3919	8026.3919	13193.91			
89	26.4086	8026.4086	13155.64			
90	26.4253	8026.4253	13118.88			
91	26.4419	8026.4419	13083.41			
92	26.4586	8026.4586	13049.26			
93	26.4836	8026.4836	13000.25			
94	26.5086	8026.5086	12953.55			
95	26.5336	8026.5336	12909.14			
96	26.5586	8026.5586	12866.62			
97	26.5836	8026.5836	12825.97			
98	26.6086	8026.6086	12786.97			
99	26.6336	8026.6336	12749.68			
100	26.6586	8026.6586	12713.74			
101	26.6836	8026.6836	12678.94			
102	26.7169	8026.7169	12634.92			
103	26.7503	8026.7503	12592.57			
104	26.7836	8026.7836	12552.15			
105	26.8169	8026.8169	12513.26			
106	26.8503	8026.8503	12475.94			
107	26.8836	8026.8836	12439.88			
108	26.9253	8026.9253	12396.75			
109	26.9669	8026.9669	12355.23			
110	27.0086	8027.0086	12315.28			
111	27.0503	8027.0503	12277.06			
112	27.0919	8027.0919	12240.09			
113	27.1419	8027.1419	12197.21			
114	27.1919	8027.1919	12156.04			
115	27.2419	8027.2419	12116.24			
116	27.2919	8027.2919	12077.92			
117	27.3419	8027.3419	12041.09			
118	27.4003	8027.4003	11999.25			
119	27.4586	8027.4586	11958.82			
120	27.5169	8027.5169	11920.08			
121	27.5753	8027.5753	11882.38			
122	27.6419	8027.6419	11840.59			
123	27.7086	8027.7086	11800.19			
124	27.7753	8027.7753	11761.07			
125	27.8503	8027.8503	11718.62			
126	27.9253	8027.9253	11677.47			

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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	28.0003	8028.0003	11637.58			
128	28.0836	8028.0836	11594.94			
129	28.1669	8028.1669	11553.22			
130	28.2586	8028.2586	11509.23			
131	28.3503	8028.3503	11466.39			
132	28.4419	8028.4419	11425.15			
133	28.5419	8028.5419	11381.49			
134	28.6419	8028.6419	11339.21			
135	28.7503	8028.7503	11295.13			
136	28.8586	8028.8586	11252.42			
137	28.9753	8028.9753	11208.02			
138	29.0919	8029.0919	11165.23			
139	29.2169	8029.2169	11121.14			
140	29.3419	8029.3419	11078.45			
141	29.4753	8029.4753	11077.99			
142	29.6169	8029.6169	11077.43			
143	29.7586	8029.7586	11077.10			
144	29.9086	8029.9086	11077.69			
145	30.0669	8030.0669	11077.22			
146	30.2253	8030.2253	11077.18			
147	30.3919	8030.3919	11077.10			
148	30.5669	8030.5669	11076.52			
149	30.7503	8030.7503	11076.28			
150	30.9419	8030.9419	11075.89			
151	31.1419	8031.1419	11075.31			
152	31.3503	8031.3503	11074.83			
153	31.5669	8031.5669	11074.31			
154	31.7919	8031.7919	11073.89			
155	32.0253	8032.0253	11073.69			
156	32.2669	8032.2669	11073.41			
157	32.5169	8032.5169	11073.34			
158	32.7753	8032.7753	11073.23			
159	33.0419	8033.0419	11072.98			
160	33.3169	8033.3169	11072.35			
161	33.6086	8033.6086	11071.75			
162	33.9086	8033.9086	11071.10			
163	34.2253	8034.2253	11070.35			
164	34.5503	8034.5503	11070.03			
165	34.8919	8034.8919	11069.11			
166	35.2419	8035.2419	11068.33			
167	35.6086	8035.6086	11067.48			
168	35.9836	8035.9836	11066.42			

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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	36.3753	8036.3753	11065.59			
170	36.7836	8036.7836	11064.81			
171	37.2086	8037.2086	11063.72			
172	37.6503	8037.6503	11062.65			
173	38.1086	8038.1086	11061.74			
174	38.5836	8038.5836	11060.55			
175	39.0753	8039.0753	11059.56			
176	39.5919	8039.5919	11058.37			
177	40.1253	8040.1253	11057.17			
178	40.6836	8040.6836	11056.07			
179	41.2586	8041.2586	11054.92			
180	41.8586	8041.8586	11053.84			
181	42.4836	8042.4836	11052.80			
182	43.1336	8043.1336	11051.59			
183	43.8086	8043.8086	11050.37			
184	44.5086	8044.5086	11048.92			
185	45.2336	8045.2336	11047.61			
186	45.9919	8045.9919	11045.98			
187	46.7753	8046.7753	11044.53			
188	47.5919	8047.5919	11042.75			
189	48.4419	8048.4419	11041.21			
190	49.3253	8049.3253	11039.48			
191	50.2419	8050.2419	11037.59			
192	51.1919	8051.1919	11035.72			
193	52.1836	8052.1836	11033.82			
194	53.2086	8053.2086	11031.92			
195	54.2753	8054.2753	11029.65			
196	55.3836	8055.3836	11027.42			
197	56.5336	8056.5336	11025.25			
198	57.7336	8057.7336	11022.91			
199	58.9753	8058.9753	11020.41			
200	60.2669	8060.2669	11018.01			
201	61.6086	8061.6086	11015.30			
202	63.0086	8063.0086	11013.14			
203	64.4586	8064.4586	11010.52			
204	65.9669	8065.9669	11007.85			
205	67.5336	8067.5336	11005.24			
206	69.1586	8069.1586	11002.35			
207	70.8503	8070.8503	10999.51			
208	72.6086	8072.6086	10996.85			
209	74.4336	8074.4336	10994.08			
210	76.3336	8076.3336	10991.10			

Print Filter Used: Nth Line = 1.000

Home Pierson 04-17-02-29W1
Spearfish (1025 - 1031 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	78.3086	8078.3086	10987.84			
212	80.3586	8080.3586	10984.19			
213	82.4919	8082.4919	10980.70			
214	84.7086	8084.7086	10977.29			
215	87.0086	8087.0086	10973.47			
216	89.4003	8089.4003	10969.72			
217	91.8836	8091.8836	10965.60			
218	94.4669	8094.4669	10961.29			
219	97.1503	8097.1503	10956.99			
220	99.9336	8099.9336	10952.47			
221	102.8253	8102.8253	10947.56			
222	105.8336	8105.8336	10942.74			
223	108.9586	8108.9586	10937.80			
224	112.2086	8112.2086	10932.69			
225	115.5836	8115.5836	10927.17			
226	119.0919	8119.0919	10921.79			
227	122.7336	8122.7336	10916.24			
228	126.5253	8126.5253	10910.27			
229	130.4586	8130.4586	10904.49			
230	134.5503	8134.5503	10898.44			
231	138.8003	8138.8003	10892.12			
232	143.2169	8143.2169	10885.70			
233	147.8086	8147.8086	10878.98			
234	152.5753	8152.5753	10872.17			
235	157.5336	8157.5336	10865.13			
236	162.6836	8162.6836	10857.92			
237	168.0336	8168.0336	10850.47			
238	173.5919	8173.5919	10843.02			
239	179.3670	8179.3670	10835.22			
240	185.3670	8185.3670	10827.28			
241	191.6086	8191.6086	10819.23			
242	198.0919	8198.0919	10810.78			
243	204.8253	8204.8253	10802.25			
244	211.8253	8211.8253	10793.53			
245	219.1003	8219.1003	10784.66			
246	226.6586	8226.6586	10775.43			
247	234.5086	8234.5086	10766.03			
248	242.6669	8242.6669	10756.61			
249	251.1503	8251.1503	10746.87			
250	259.9586	8259.9586	10737.01			
251	269.1169	8269.1169	10726.95			
252	278.6336	8278.6336	10716.56			

Print Filter Used: Nth Line = 1.000

	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
253	288.5169	8288.5169	10705.98			
254	298.7920	8298.7920	10694.80			
255	309.4669	8309.4669	10683.88			
256	320.5586	8320.5586	10672.51			
257	332.0836	8332.0836	10661.04			
258	344.0586	8344.0586	10649.06			
259	356.5086	8356.5086	10637.12			
260	369.4419	8369.4419	10624.57			
261	382.8836	8382.8836	10612.12			
262	396.8503	8396.8503	10599.51			
263	411.3586	8411.3586	10586.19			
264	426.4419	8426.4419	10572.71			
265	442.1086	8442.1086	10558.95			
266	458.3919	8458.3919	10545.17			

Print Filter Used: Nth Line = 1.000

EQUATIONS

and

NOMENCLATURE

(METRIC UNITS)

BASIC TIME FUNCTIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Channel width

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

Skin Factor

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

BI-LINEAR ANALYSIS

Fracture Conductivity

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

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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)	$10^3m^3/d$	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_fw	fracture conductivity	mD.m	md.ft
kh	flow capacity	mD.m	md.ft
k/μ	mobility	-	-
kh/μ	transmissivity	-	-

PMG

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 - 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

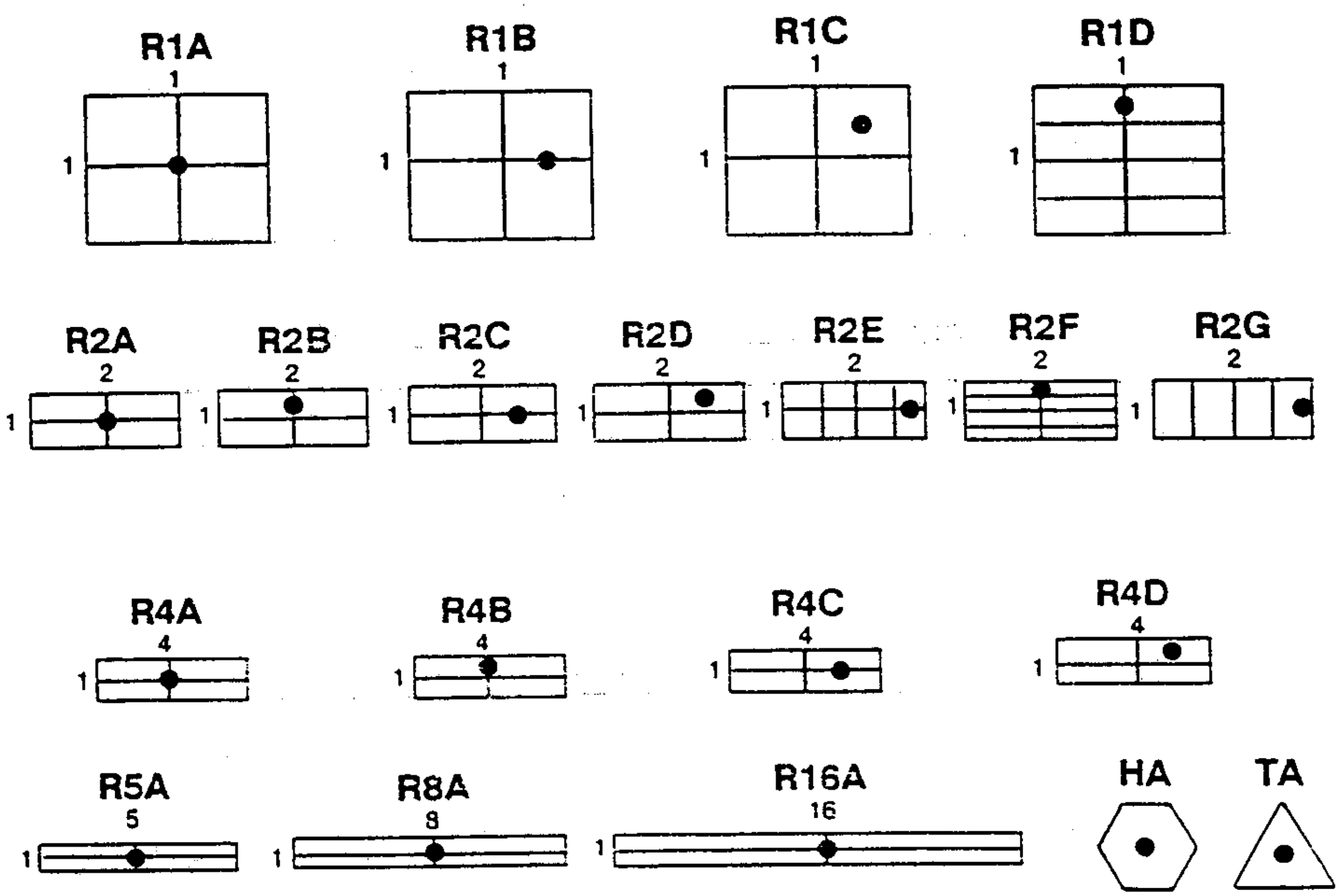
Superscripts

-	average

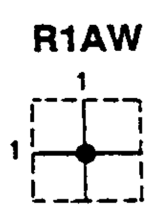
DIETZ SHAPE CODES

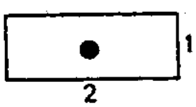
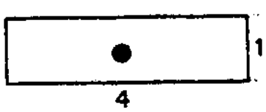
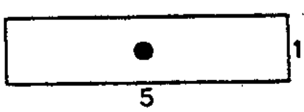
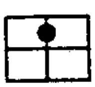
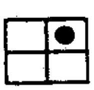
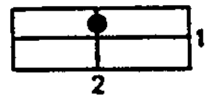
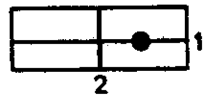
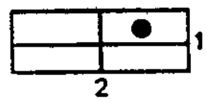
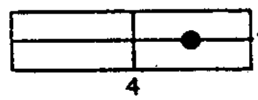
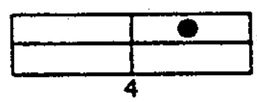
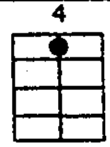
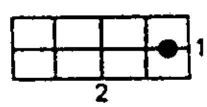
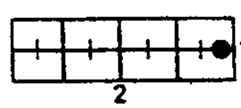
AVERAGE RESERVOIR PRESSURE - MBH CORRECTIONS

NO FLOW OUTER BOUNDARY



CONSTANT PRESSURE OUTER BOUNDARY



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
$10^3 m^3/d$	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