statoil

THE INTERPRETATION OF DRILL STEM
TEST CONDUCTED IN WELL 34/10-16

L.P. DAKE 1984

Testanalyser

Den norske stats oljeselskap a.s

Testrapport 34/10-16

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1. INTRODUCTION: Two tests were conducted in 34/10-16, one in the Brent oil column and the other in the Upper Brent gas-condensate accumulation. The tests are of particular interest because during the production periods of each, the bottom-hole flowing pressure stabilized after just a few hours of flow. This behaviour, while not unusual in testing North Sea wells, has been largely overlooked in the literature on the subject of Pressure Analysis. Therefore, prior to analysing the tests (sections 3 and 4) an outline of the basic theory is presented together with a sound interpretation method for analysing pressure buildups following a period of steady-state flow

2. BASIC THEORY OF BUILDUP ANALYSIS: The basic equation describing the pressure response at the wellbore during a pressure buildup is:

$$\alpha (p_i - p_{ws}) = p_D(t_D' + \Delta t_D) - p_D(\Delta t_D) \qquad (1)$$

where, in this text α is defined in field units as:

$$\alpha = 7.08 \times 10^{-3} \frac{kh}{q\mu B_o} \qquad (2)$$

for oilwell testing and

$$\alpha = \frac{kh}{1422\,QT} \tag{3}$$

for gas well testing.

The dimensionless pressure function, p_D, is defined by the pressure response during the flowing period as:

$$\alpha\,(p_i - p_{wf}) = p_D\,(t_D) + S \tag{4}$$

The dimensionless time is defined as:

$$t_D = \frac{.000264\,kt\ (hrs)}{\phi\,\mu\,c\,r_w^2} \tag{5}$$

for any value of the flowing time. (Note that in equation (1), t_D' is the explicit value of the flowing time at well closure and is, therefore, a constant.

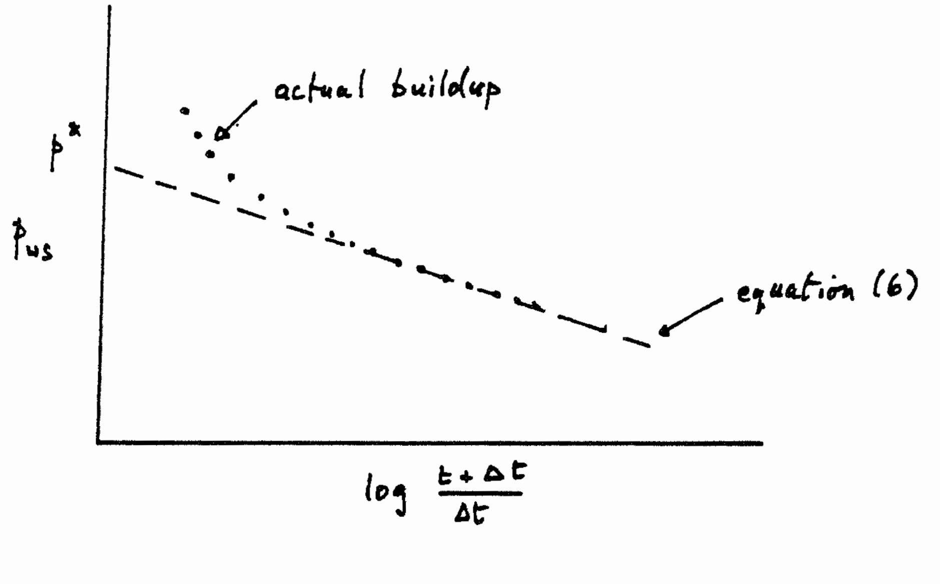
It has been shown in references (1) and (2) that by adding and subtracting $\frac{1}{2}\ln(t_D + \Delta t_D)$ to the right hand side of equation (1), the equation of the straight line intersecting the Horner buildup plot during the period of trancient pressure responce after well closure may be expressed as:

$$\alpha\,(p_i - p_{ws(LIN)}) = 1.151 \log \frac{t' + \Delta t}{\Delta t} + p_D(t_D') - \frac{1}{2} \ln \frac{4 t_D'}{\gamma} \qquad (6)$$

where $p_D(t_D')$ is the dimensionless pressure evaluated at the time of closure, and is therefore a constant. So too is the final term on the right hand side of equation (6), which represents the purely transient p_D function at the time of closure.

The general nature of the above equation is shown schematically below.

(i)



Equation (6) is derived in such a manner that where it parallels the actual buildup data defines the transient part of the buildup, for small Δt, from which the formation characteristics kh and S may be obtained. Other than that, equation (6) merely represents the equation of the straight line for all values of the closed-in time. It's extrapolation to infinite closed-in time yields a value of $p_{ws} = p^*$ which has <u>no physical meaning</u> apart from the unique case of testing an infinite acting reservoir when $p^* = p_i$.

In the case of such an infinite acting reservoir

$$p_D(t_D') = \frac{1}{2} \ln \frac{4t_D'}{\gamma} \qquad (7)$$

in equation (6) and the equation is reduced to the simple form

$$\alpha(p_i - p_{ws(LIN)}) = 1.151 \log \frac{t + \Delta t}{\Delta t} \qquad (8)$$

which is the original equation of Horner.

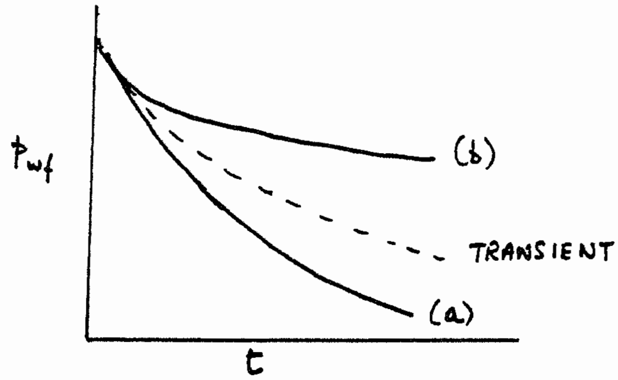
Two other more practical cases may be considered

a) when $p_D(\Delta t_D') > \frac{1}{2} \ln \frac{4t_D'}{\gamma}$

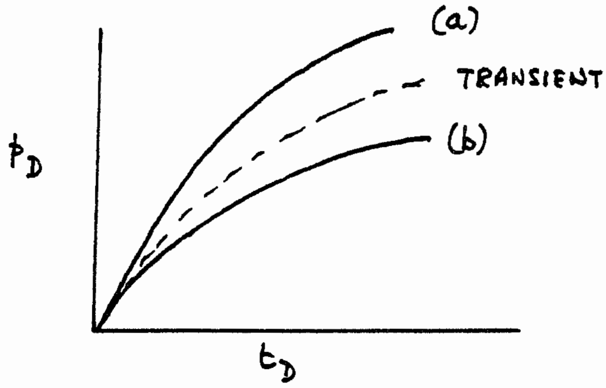
b) when $p_D(\Delta t_D') < \frac{1}{2} \ln \frac{4t_D'}{\gamma}$

The former occurs when the drawdown is greater than for the infinite reservoir case and the latter when the drawdown is less, as shown in the schematic below.

(ii)

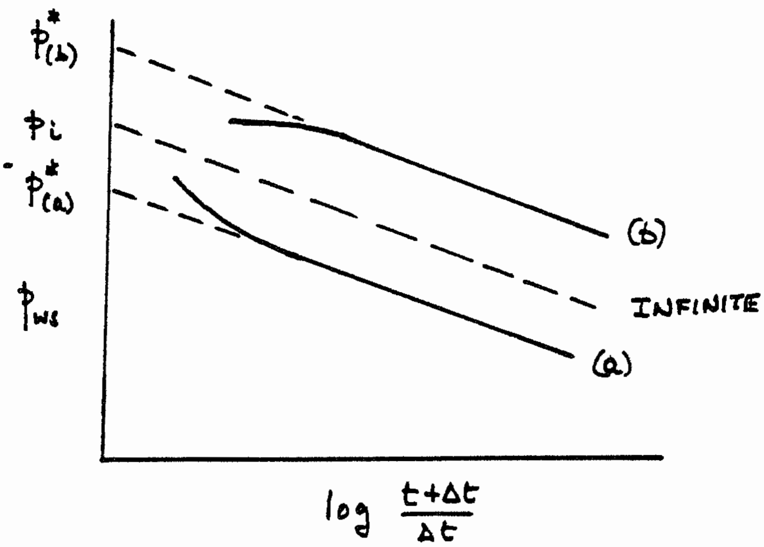


(iii)



Performing a buildup for such p_D functions yields the following:

iv)

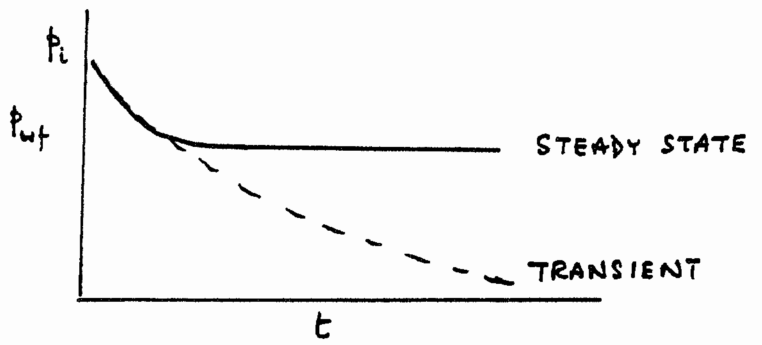


These plots follow from inspection of equation (6).

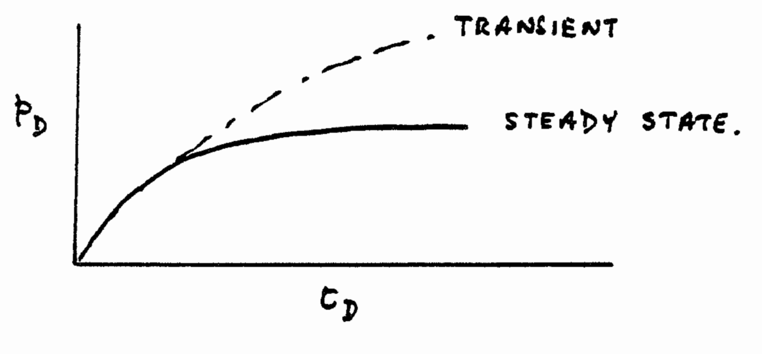
Case (a), which is commonly described in the literature occurs, for instance, when there is an additional drawdown during flow caused by the presence of a fault system.

Case (b) is of greater interest in this note particularly when considering the tests in 34/10-16. In these, the flowing pressure and p_D function are as shown below:

(v)



(vi)



There is a complete stabilization of pressure in both tests, demonstrating the steady-state condition $\left(\frac{dp}{dt} = 0\right)$.

There is a lack of uniqueness in analysing such tests which arises from the following analysis:

Subtracting equation (1) from (2) yields.

$$\alpha\,(p_{ws} - p'_{wf}) = p_D(t'_D) - p_D(t'_D + \Delta t_D) + p_D(\Delta t_D) + S \qquad (9)$$

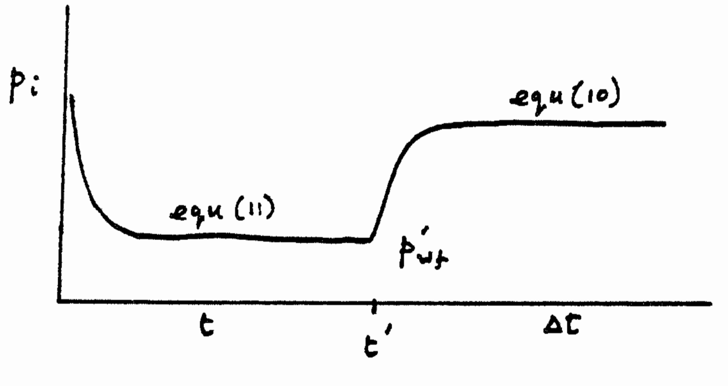
but, for steady state flow, $p_D(t'_D) = p_D(t'_D + \Delta t_D)$
and equation (9) becomes: (p'_{wf} = final flowing pressure = constant)

$$\alpha\,(p_{ws} - p'_{wf}) = p_D(\Delta t_D) + S \qquad (10)$$

This, should be solved in conjunction with equation (2)

$$\alpha\,(p_i - p_{wf}) = p_D(t_D) + S \qquad (11)$$

(vii)



These simultaneous equations, which are minor images of one another represent the drawdown (11) and buildup (10), respectively. Unfortunately, there are three unknowns ($\alpha(kh)$, p_D and S) which means that there is no unique solution. It can be shown that joining any two points on the buildup will yield values of k and S which will provide solutions to equations (10) and (11). Interpretation of pressure buildup tests therefore becomes highly subjective since often there are several linear sections. It is imperative to determine the one which represents the purely transcient response from which k and S can be uniquely determined.

For steady-state (or near steady state flow), the following method is suggested.

For steady state conditions $p_D(t_D' + \Delta t_D) = p_D(t_D')$ = constant (C) and equation (1) may be expressed as

$$\alpha(p_i - p_{ws}) = C - p_D(\Delta t_D) \tag{12}$$

and IMPOSING the condition of transcience for which:

$$p_D(\Delta t_D) = \frac{1}{2}\ln\frac{4\Delta t_D}{\gamma} \tag{13}$$

gives

$$\alpha(p_i - p_{ws}) = C - \frac{1}{2}\ln\frac{4\Delta t_D}{\gamma} \tag{14}$$

or

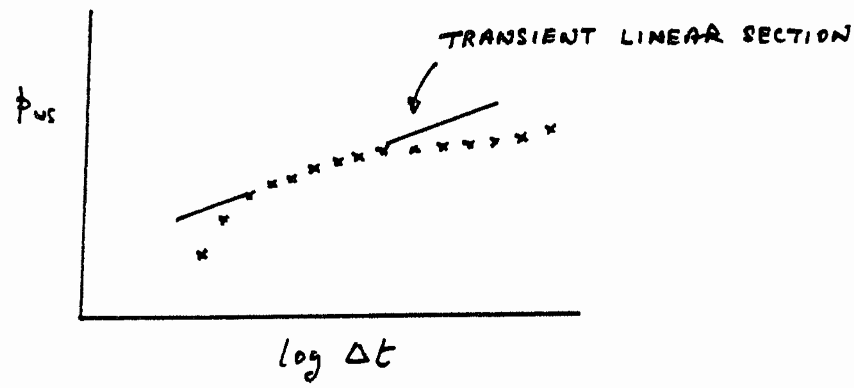
$$\alpha(p_i - p_{ws}) = C' - 1.151\log\Delta t \tag{15}$$

where
$$C' = C\,\frac{1}{2}\ln\frac{4\times .000264k}{\gamma\phi\mu c r_w^2} = \text{constant} \tag{16}$$

Consequently, a plot of:

$$p_{ws} \quad vs. \quad \log \Delta t \tag{17}$$

should be linear, provided transient conditions prevail (ie condition (13) is satisfied).



This is the Miller, Dyes, Hutchinson method (1950) for depleted wells which is now being revived, on a sounder theoretical basis. It has the advantages over the Hornér plot that:

- The assumptions implicit in deriving the MDH plot (viz: $p_D(t_D + \Delta t_D)$ = constant) is sounder and simpler than for determining the transient linear section of the Horner plot (references 1 and 2).

- The MDH plot gives a <u>shorter</u> but better defined transient linear section than the Horner plot. Ramey (reference 1) universally recommends the use of Horner rather than MDH because it gives a "longer" straight line. For steady state tests, however, the Horner straight line is "longer and more confusing" and it is advised to use the MDH method in preference for such tests.

There are also other complications in analysing steady-state tests one of these being - "the radius of investigation". The normal formula for calculating how far the test "sees" into the reservoir during the flowing time t' is:

$$r_e = 0 \cdot 03 \sqrt{\frac{kt'}{\phi \mu c}} \tag{17}$$

It must be realised, however, that this formula is only relevant provided the pressure continuously falls during the production period. If it doesn't then the radius of investigation may be calculated as:

$$\alpha \left(p_i - p_{wf} \right) = \ln \frac{r_e}{r_w} + S \tag{18}$$

which is the steady state solution of the diffusivity equation. Generally, in a steady state test r_e is much less than for a test in which the pressure continuously falls.

REFERENCES

1) Ramey, H.J. Jr and Cobb, W.M.: "A General Pressure Buildup Theory for a Well in a Closed Drainage Area" J.P.T. December 1971

2) Dake, L.P: "Fundamentals of Reservoir Engineering" Elsevier, Amsterdam 1978.

3 <u>34/10-16 : DST-1</u> <u>(3397-3407 m KB)</u>

This test was conducted over a 10 metre interval of the Brent sand section, within the 70 metre oil column discovered in the well. The perforated zone is shown in figure-1 and appears to be an isolated thin sand thus removing any complications with partial penetration effects from the analysis.

a) <u>FLOWING PERIOD</u> The well was produced at an oil rate which averaged 6029 stb/d when the flow was switched through the test separator. The total duration of the flow period was 10·83 hours and rate and pressure data are listed in table-1 and plotted in figure-2. As can be seen, after approximately four hours of production the pressure stabilized at about 4420 psia, even showing a slight tendency to rise towards the end of the flowing period.

b) <u>PRESSURE BUILDUP</u> The well was closed-in both down-hole and at the choke manifold for a buildup of 10·90 hours. The closed-in times and corresponding pressure data are listed in table 2. From the conventional plot of log Δp vs log Δt (figure 3), it appears that a hard down-hole closure was achieved. This is misleading, however, since during the first 30 minutes of closure the static wellhead pressure rose by about 1650 psia indicating that the down-hole LPR-N valve was leaking.

c) <u>BUILDUP ANALYSIS</u> Data required to analyse the test are listed below:

q : 6029 stb/d (average rate)
μ : 0.506 cp
B_o : 1.585 rb/stb
h : 10 metres (32.8 ft)
ϕ : 0.18 PV
c : 15×10^{-6} / psi
r_w : 0.35 ft
p_i : 6654 psia

The conventional Horner buildup plot is shown as figure 4. It is considered that the first 30 minutes of this are dominated by afterflow effects caused by leakage of the LPR-N valve. Thereafter, there appears to be an extremely well defined "Horner straight line". Basing the analysis on this linear section would yield values of formation parameters of $k = 180$ mD and $S = 11.3$. This linear portion of the buildup is, however, suspect, since extrapolation of the linear trend to $\Delta t = \infty$ intersects the ordinate at $p_{ws} = p_i$ = 6654 psia, whereas, as described in section 2, the extrapolated pressure following a period of steady state flow should lie above the initial pressure.

As suggested in section 2, the best way to define the transcient, linear portion of a buildup, particularly following stabilized flow is to plot the data in the MDH manner, p_{ws} vs $\log \Delta t$. Such a plot is shown as figure 5.

This plot has the effect of shortening, and so better defining the linear part of the buildup which extends between $\Delta t = 0.6$ and 1.4 hours. The slope of this linear section is $m = 150$ psia/log cycle. Therefore:

$$kh = 162.6 \frac{q_o \mu B_o}{m} = \frac{162.6 \times 6029 \times .506 \times 1.585}{150}$$

i.e. $\quad kh = 5241$ mD.ft and $k = 160$ mD

and $\quad S = 1.151 \left[\frac{(p_{ws(1hr)} - p_{wf})}{m} - \log \frac{k}{\phi \mu c r_w^2} + 3.23 \right]$

$$= 1.151 \left[\frac{(6509 - 4421)}{150} - \log \frac{160}{.18 \times .506 \times 15 \times 10^{-6} \times .35^2} + 3.23 \right]$$

$$S = 9.4$$

Admittedly, choice of the correct "straight-line" does not alter the permeability or skin very much in this particular test.

The linear section defined by the MDH plot is defined in the Horner buildup, as shown in figure 6 and demonstrates all the features described in theory in section 2. That is, the extrapolated pressure, p^*, is greater than the initial pressure, p_i, and the linear trend is parallel to the infinite reservoir case but lies above the latter.

The radius of investigation for this test may be evaluated using the steady state equation (18), i.e.

$$7.08 \times 10^{-3} \frac{kh}{q\mu B_o} (p_i - p_{wf}) = \ln \frac{r_e}{r_w} + S \qquad (18)$$

$$\frac{7.08 \times 10^{-3} \times 160 \times 32.8}{6029 \times .506 \times 1.585} (6654 - 4421) = \ln \frac{r_e}{.35} + 9.4$$

$$r_e = 820 \text{ ft}$$

TABLE 1

34/10-16 DST-1 : FLOWING PERIOD

Gauge MK 3 0076 at 3386·63 m KB (3361·63 m.ss)

TIME (HRS)	FLOWING PRESSURE p_{wf} (psia)	OIL RATE q (stb/d)
0	6654 (p_i)	
·033	4999	
·100	4867	
·200	4707	
·300	4566	
·400	4450	
·500	4375	
·700	4235	
·900	4231	
1·000	4238	
1·500	4339	
2·000	4357	
2·500	4414	
3·000	4384	
4·000	4367	
5·000	4379	6005
6·000	4388	6025
7·000	4391	6031
8·000	4396	6025
9·000	4407	6030
10·000	4410	6054
10·833	4421	6031

TABLE 2

34/10-16, DST-1 : PRESSURE BUILDUP

Δt (hrs)	$\log \Delta t$ (mins)	$\log \frac{t+\Delta t}{\Delta t}$	p_{ws} (psia)	Δt (hrs)	$\log \Delta t$ (mins)	$\log \frac{t+\Delta t}{\Delta t}$	p_{ws} (psia)
0			4421 (p_{wf})				
·033	·297	2·517	5899	·900	1·732	1·115	6502
·067	·604	2·211	5943	1·000	1·778	1·073	6509
·100	·778	2·039	5983	1·133	1·832	1·024	6517
·133	·902	1·916	6022	1·400	1·924	·941	6530
·167	1·001	1·819	6065	2·000	2·079	·807	6549
·200	1·079	1·742	6109	2·500	2·176	·727	6560
·233	1·146	1·677	6159	3·000	2·255	·664	6569
·267	1·205	1·619	6204	3·500	2·322	·612	6576
·300	1·255	1·569	6253	4·000	2·380	·569	6582
·333	1·301	1·525	6299	4·500	2·431	·532	6587
·367	1·343	1·485	6342	5·000	2·477	·501	6592
·400	1·380	1·448	6379	5·500	2·519	·473	6595
·433	1·415	1·415	6409	6·000	2·556	·448	6599
·467	1·447	1·384	6432	6·500	2·591	·426	6602
·500	1·477	1·355	6449	7·000	2·623	·406	6605
·533	1·505	1·329	6460	8·000	2·681	·372	6609
·567	1·532	1·303	6467	9·000	2·732	·343	6614
·600	1·556	1·280	6473	10·000	2·778	·319	6617
·633	1·580	1·258	6478	10·900	2·816	·300	6619
·700	1·623	1·217	6485				
·800	1·681	1·163	6495				

FIGURE 2

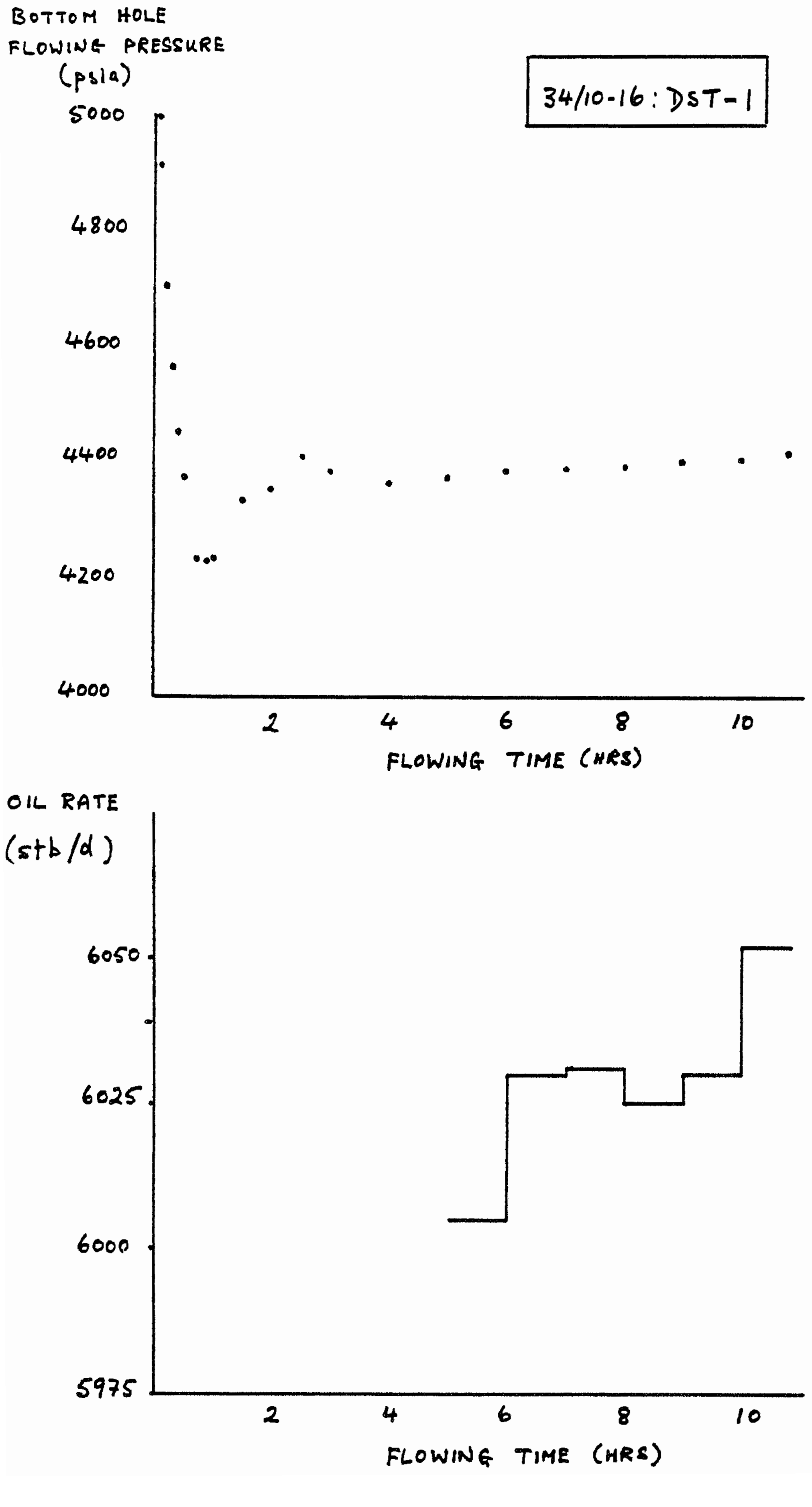
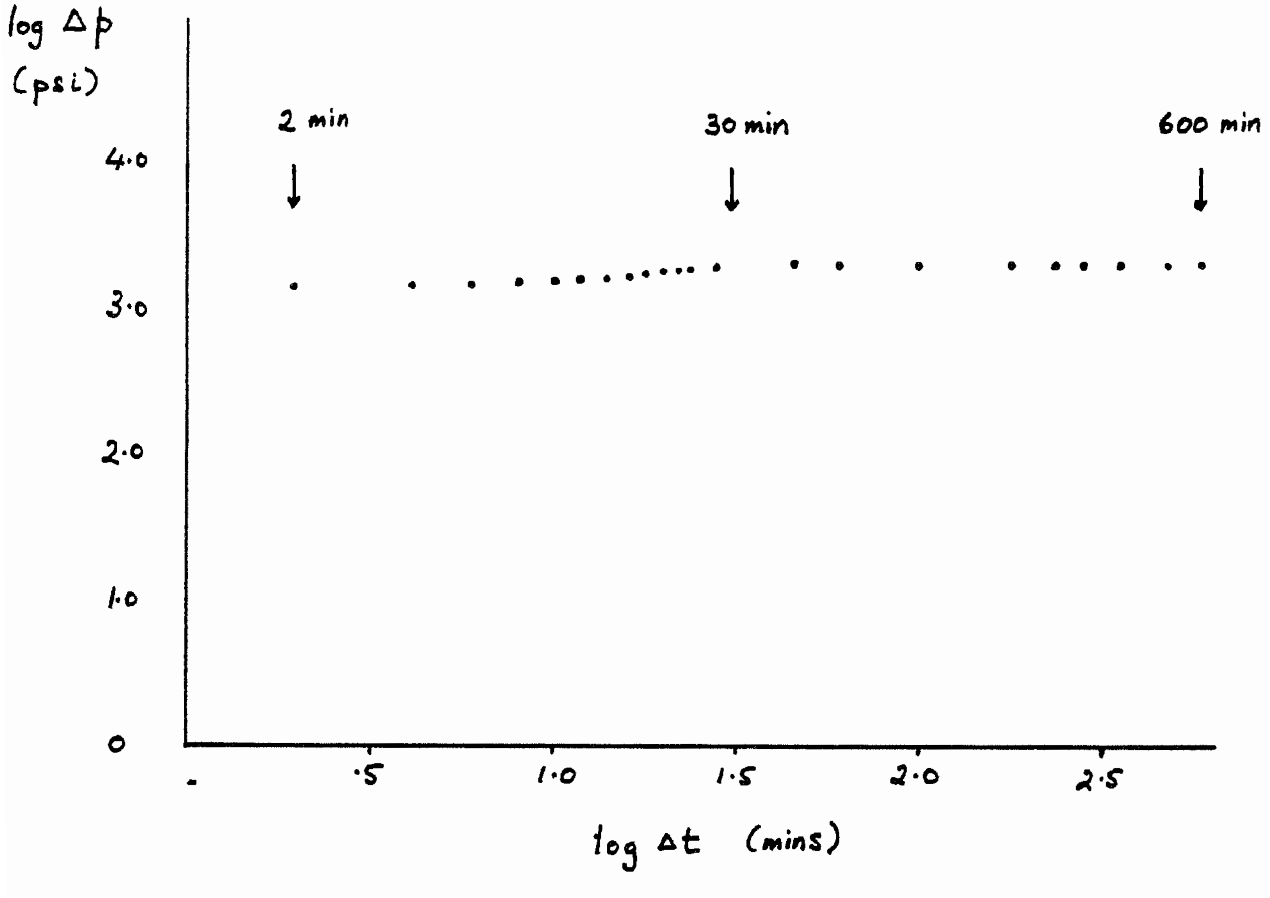
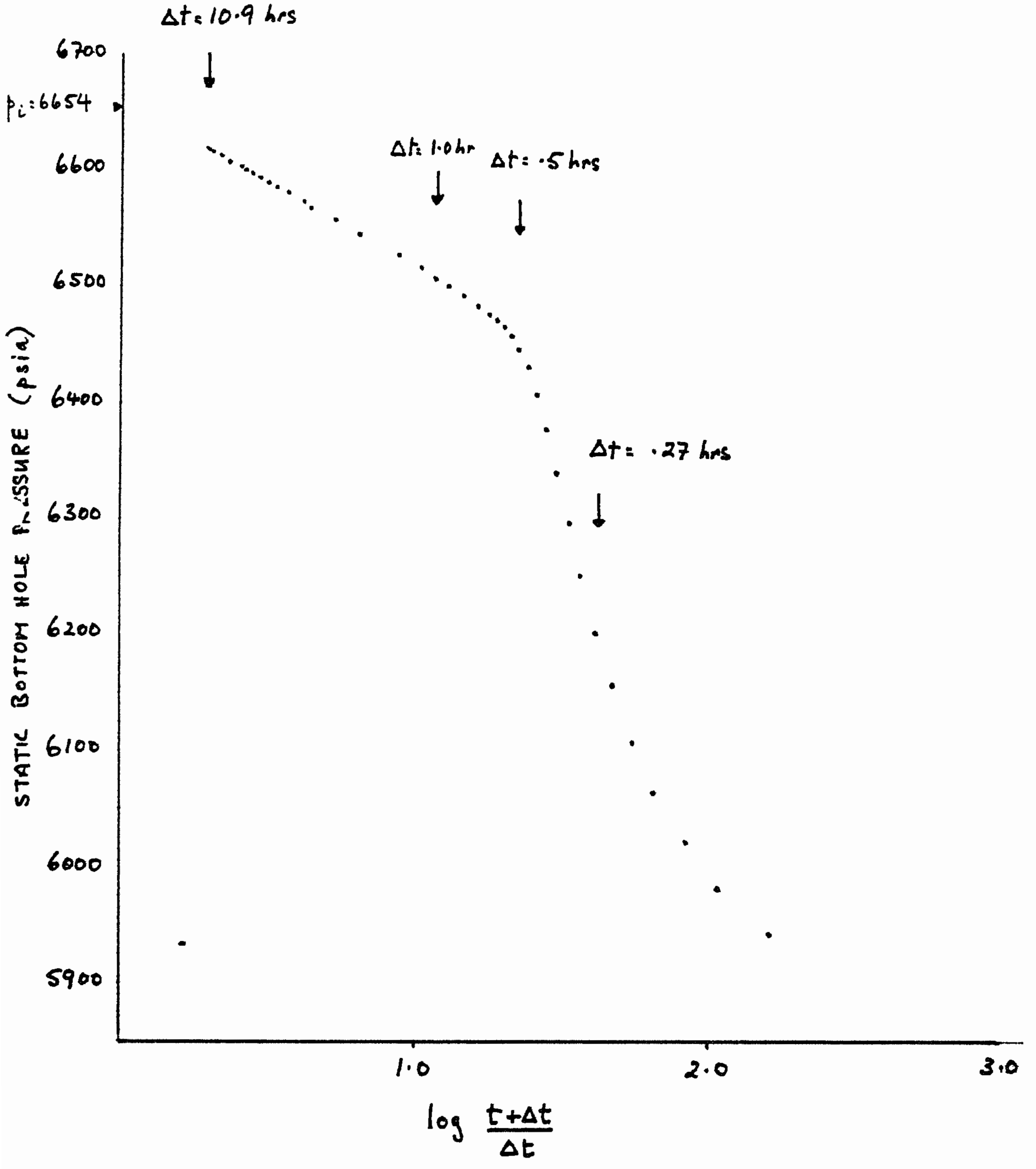

BOTTOM HOLE
FLOWING PRESSURE
(psia)
34/10-16: DST-1
5000
4800
4600
4400
4200
4000
2
4
6
8
10
FLOWING TIME (HRS)
OIL RATE
(stb/d)
6050
6025
6000
5975
2
4
6
8
10
FLOWING TIME (HRS)

FIG 3



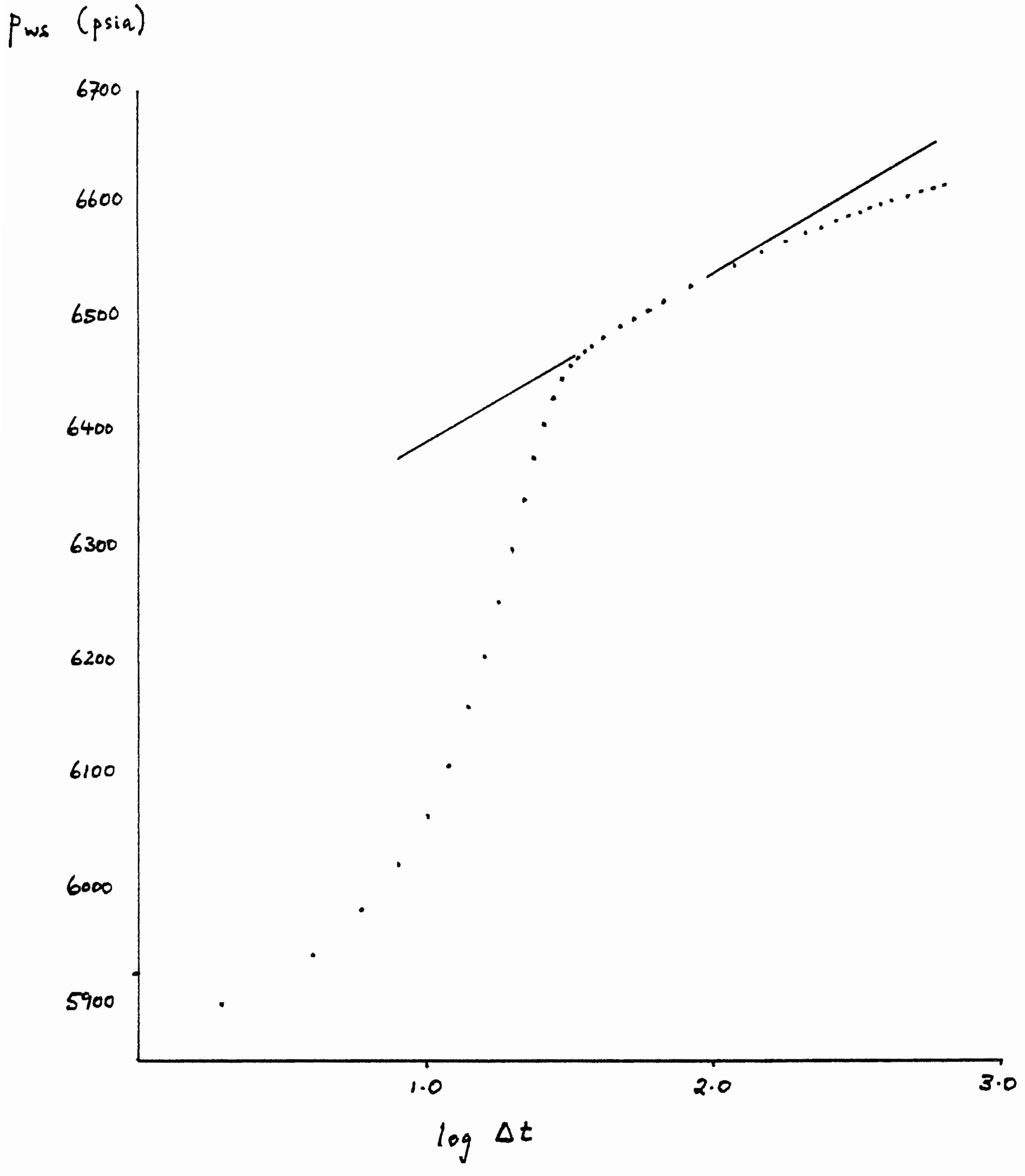
34/10-16 : DST-1: log Δp vs log Δt

FIG 4



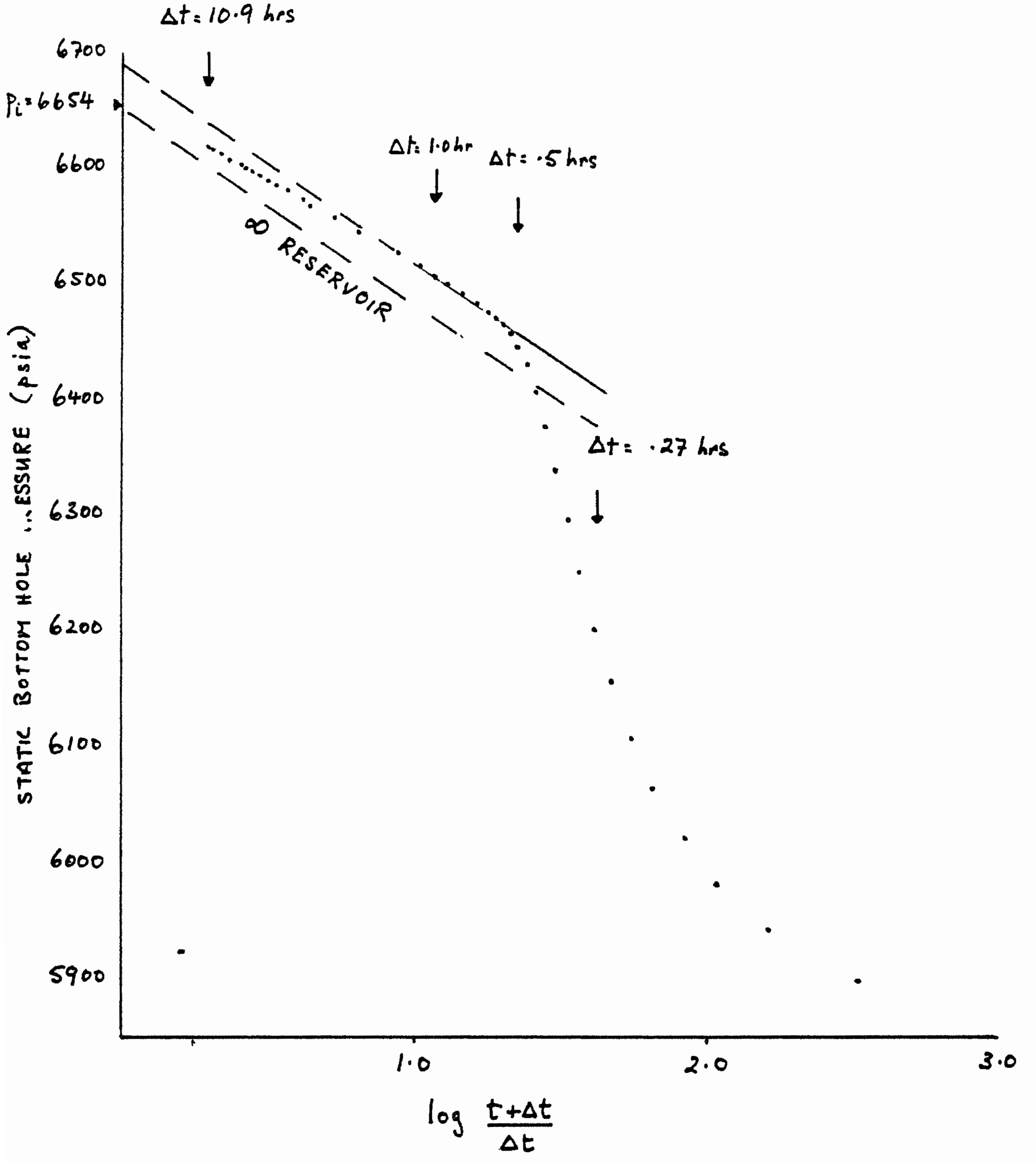
34/10-16: DST-1, PRESSURE BUILDUP (HORNER)

FIG 5



34/10-16 : DST-1 , PRESSURE BUILDUP (MDH-PLOT)

FIG 6



34/10-16 : DST-1 , PRESSURE BUILDUP

3. 34/10-16: DST-2 (

This test was conducted over a 10 metre interval in the Upper Brent sands which were gas-condensate bearing. The test consisted of two flow periods, at different rates, each followed by a pressure buildup. This type of test should permit discrimination between mechanical and rate dependent skin factors.

a) FLOWING PERIODS Data for the two flowing periods are plotted in figures 7 and 8, to which the following statistics apply:

	DRY GAS RATE	FLOWING TIME
FIRST FLOW	45.5 MMscf/d	8.667 hrs
SECOND FLOW	58.0 "	7.017 "

During each flow period, pressure stabilization was rapidly achieved after well clean-up, thus demonstrating the condition of steady-state flow.

The test has been analysed using real gas pseudo pressures which are generated in the following section.

b) GENERATION OF REAL GAS PSEUDO PRESSURE FUNCTION

PVT data required to generate the real gas pseudo pressure function:

$$m(p) = 2\int_{p_b}^{p} \frac{p\,dp}{\mu Z}$$

are taken from the Core Laboratories report (Reservoir Fluid Study for STATOIL, Well 34/10-16, DST-2, April 1984). The m(p) function is evaluated in the following table.

PRESSURE psia	μ cp	Z	$\frac{2p}{\mu Z}$ psia/cp	$\overline{\frac{2p}{\mu Z}}$ psia/cp	Δp psia	m(p) psia^2/cp
715	·0135	·942	112448	61224	715	43·78 x10^6
1314	·0148	·950	186913	149680	599	133·43 "
2115	·0167	·934	271192	229052	801	316·90 "
3015	·0190	·944	336195	303694	900	590·23 "
3914	·0216	·978	370560	353378	899	907·91 "
4715	·0243	1·019	380830	375695	801	1208·85 "
5514	·0275	1·075	373040	376935	799	1510·02 "
6055	·0303	1·121	356530	364785	541	1707·36 "
6507	·0317	1·161	353606	355068	452	1867·86 "

Over the range of pressures of interest in DST-2, the m(p) function displays a linear relationship with pressure as follows: (refer figure 5).

$$m(p) = [0.3702\,p - 541.083] \times 10^6 \quad psia^2/cp$$

which is valid over the range $p = 3900 - 6500$ psi.

c) PRESSURE BUILDUPS The first flow was followed by a buildup of 8.967 hours and the second by a buildup of 7.100 hours. Pressure-Time data for these closed-in periods are presented in tables 3 and 4. On each occasion, surface pressures indicated that a "hard" down-hole closure had been achieved and afterflow effects were minimal.

d) BUILDUP ANALYSES Data required to analyse the tests are listed below:

FIRST BUILDUP	SECOND BUILDUP
Q_g = 45.5 MMscf/d	Q_g = 58.0 MMscf/d
q_o = 1980 stb/d	q_o = 2400 stb/d
Q_1 = 47.0 MMscf/d	Q_2 = 59.75 MMscf/d

The total, effective dry gas rates (Q_1, Q_2) include the liquid condensate expressed as a dry gas equivalent.

μ : 0.032 cp
T : 117 °C : 243 °F : 703 °R
h : 10 metres (32.8 ft)
ϕ : 0.20 PV
c : 1.537×10^{-4} psi^{-1}
r_w : .35 ft
p_i : 6505.2 psia , $m(p_i)$: 1867.1 psia^2/cp $\times 10^6$
FIRST FLOW p_{wf} : 5869.7 psia , $m(p_{wf})$ = 1631.9 " " "
SECOND FLOW p_{wf} : 5600.8 psia , $m(p_{wf})$ = 1532.3 " " "

Because both buildups were preceded by periods of steady-state flow, MDH plots of $m(p_{ws})$ vs. log Δt have been used to detect the early, transient straight line from which formation characteristics may be obtained. These are plotted for the first and second buildups as figures 10 and 11, respectively.

The linear sections are readily discernable from which the following measurements have been made:

	SLOPE (psia^2/cp/cycle)	$m(p_{ws-1hr})$ (psia^2/cp)
FIRST BUILDUP	5.0×10^6	1863.1×10^6
SECOND BUILDUP	6.5 "	1861.0 "

For gas well testing, using equations expressed in real gas pseudo pressures, the relationships for determining the formation parameters are:

$$kh = \frac{1637\, Q\, T}{m}$$

$$S_T = 1.151 \left[\frac{(m(p_{ws\text{-}1hr}) - m(p_{wf})}{m} - \log \frac{k}{\phi \mu c\, r_w^2} + 3.23 \right]$$

$$\frac{kh}{1422\, QT} \left(m(p_i) - m(p_{wf})\right) = \ln \frac{r_e}{r_w} + S_T$$

where S_T = the total skin = $S + DQ$

S = mechanical skin

DQ = rate dependent skin

In the analysis, two values of S_T are determined which permit the separate evaluation of S and D. Using the input data above the results obtained for the two buildups are as follows:

	FIRST BUILDUP	SECOND BUILDUP
k (mD)	330	323
S_T	46.1	51.1
S	27.7	27.7
D /Mscf/d	3.91×10^{-4}	3.91×10^{-4}
$m(p_i)$ (psia²/cp)	1867.1	1864.5
r_e (ft)	1100	800

It is interesting to note that the calculated radius of investigation under steady state flow conditions (~ 1000 ft) is less than would be calculated if the pressure were continuously dropping during the flowing period, which would be 1600 ft.

Plotting conventional Horner buildup plots (figures 12 and 13) and imposing the correct "straight-line", defined by the MDH plot again illustrates the typical characteristics for buildups following periods of steady-state flow, with the linear trend and its extrapolation lying above that for the infinite reservoir case.

TABLE 3

34/10-16: DST-2, FIRST PRESSURE BUILDUP

FLOWING TIME = 8.667 hours

Δt (hrs)	$\log \Delta t$ (min)	$\log \frac{t+\Delta t}{\Delta t}$	p_{ws} (psia)	$m(p_{ws})$ (psia)^2/cp
0			5869.7 (p_{wf})	1631.9 × 10^6
·033	·297	2.421	6373.4	1818.3 "
·067	·604	2.115	6463.1	1851.6 "
·100	·778	1.943	6479.9	1857.8 "
·133	·902	1.821	6482.2	1858.6 "
·167	1.001	1.723	6483.7	1859.2 "
·200	1.079	1.647	6484.8	1859.6 "
·233	1.146	1.582	6485.6	1859.9 "
·267	1.205	1.525	6486.7	1860.3 "
·300	1.255	1.467	6487.3	1860.5 "
·333	1.301	1.432	6488.0	1860.8 "
·367	1.343	1.391	6488.6	1861.0 "
·400	1.380	1.355	6489.0	1861.1 "
·433	1.415	1.323	6489.2	1861.2 "
·500	1.477	1.263	6490.0	1861.5 "
·700	1.623	1.127	6491.7	1862.1 "
1.000	1.778	·985	6492.7	1862.5 "
1.500	1.954	·831	6494.3	1863.1 "
2.000	2.079	·727	6495.3	1863.5 "
2.500	2.176	·650	6495.8	1863.7 "
3.000	2.255	·590	6496.3	1863.8 "
3.500	2.322	·541	6496.8	1864.0 "
4.000	2.380	·501	6497.1	1864.1 "

Δt (hrs)	log Δt (min)	log $\frac{t+\Delta t}{\Delta t}$	p_{ws} (psia)	$m(p_{ws})$ (psia^2/cp)
4.500	2.431	.466	6497.4	1864.3
5.000	2.477	.437	6497.6	1864.3
6.000	2.556	.388	6497.9	1864.4
7.000	2.623	.350	6498.2	1864.6
8.000	2.681	.319	6498.5	1864.7
8.967	2.731	.294	6498.1	1864.5

TABLE 4

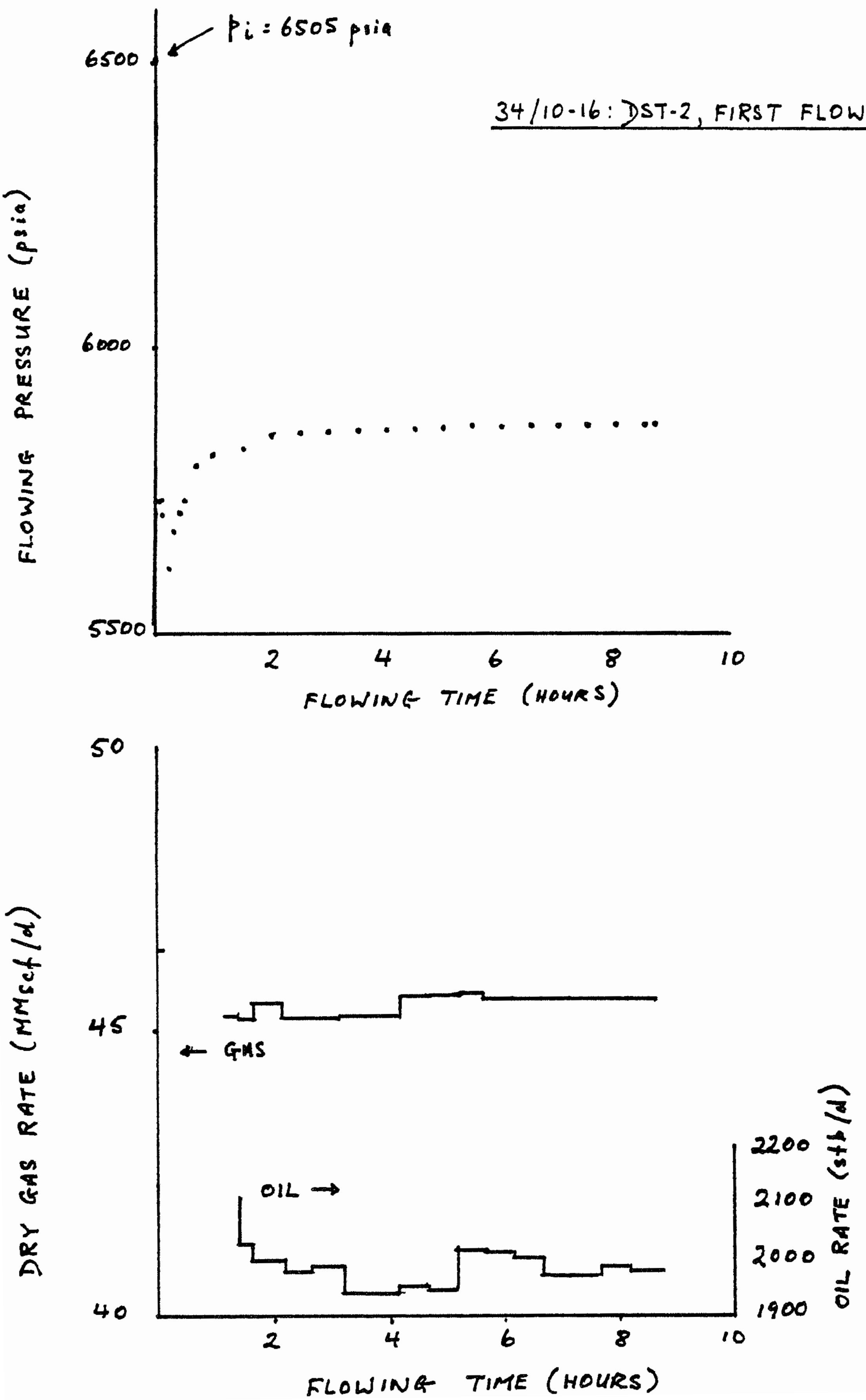
34/10-16 : DST-2 , SECOND PRESSURE BUILDUP

FLOWING TIME = 7.017 hrs.

Δt (hrs)	log Δt (min)	log $\frac{t+\Delta t}{\Delta t}$	p_{ws} (psia)	$m(p_{ws})$ (psia^2/cp)
0			5600.8 (p_{wf})	1532.3
·033	·297	2·330	6277·1	1782·7
·067	·604	2·024	6451·0	1847·1
·100	·778	1·852	6470·5	1854·3
·133	·902	1·730	6473·4	1855·4
·167	1·001	1·634	6475·3	1856·1
·200	1·079	1·557	6476·7	1856·6
·233	1·146	1·493	6478·0	1857·1
·267	1·205	1·436	6479·0	1857·4
·300	1·255	1·387	6479·7	1857·7
·333	1·301	1·344	6480·4	1858·0
·367	1·343	1·304	6481·0	1858·2
·400	1·380	1·268	6481·4	1858·3
·433	1·415	1·236	6481·9	1858·5
·467	1·447	1·205	6482·5	1858·7
·500	1·477	1·177	6482·7	1858·8
·700	1·623	1·042	6484·5	1859·5
1·000	1·778	·904	6486·3	1860·1
1·533	1·964	·746	6489·3	1861·3
2·000	2·079	·654	6488·8	1861·1
2·500	2·167	·581	6489·8	1861·4
3·000	2·255	·524	6490·7	1861·8
3·500	2·322	·478	6490·9	1861·8

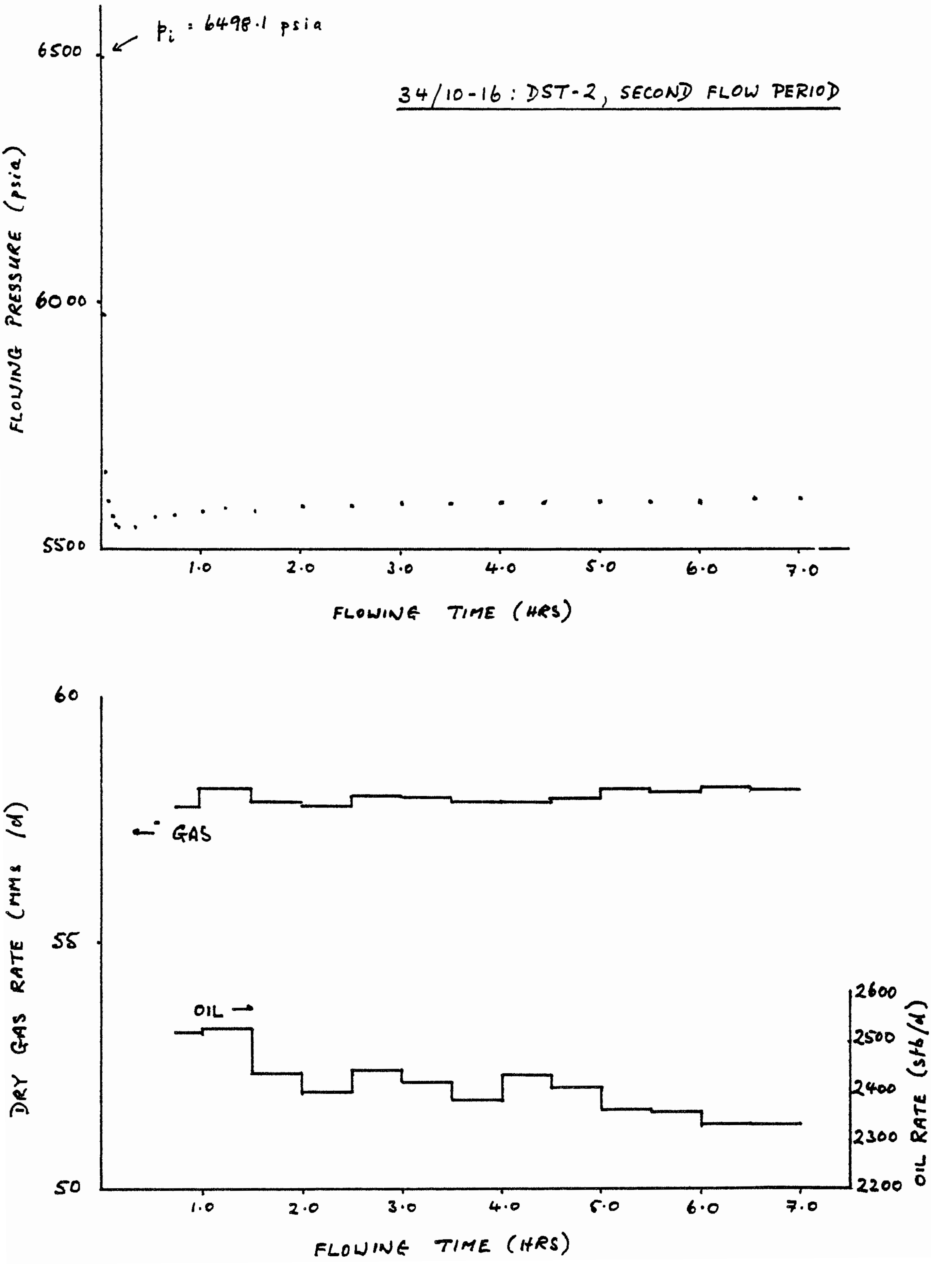
Δt (hrs)	$\log \Delta t$ (mins)	$\log \frac{t+\Delta t}{\Delta t}$	p_{ws} (psia)	$m(p_{ws})$ (psia^2/cp)
4.000	2.380	.440	6491.4	1862.0
4.500	2.431	.408	6491.7	1862.1
5.000	2.477	.381	6491.7	1862.1
5.500	2.514	.357	6492.5	1862.4
6.000	2.556	.336	6492.5	1862.4
6.500	2.591	.318	6492.6	1862.5
7.000	2.623	.302	6493.2	1862.7
7.100	2.629	.298	6493.2	1862.7

FIG 7



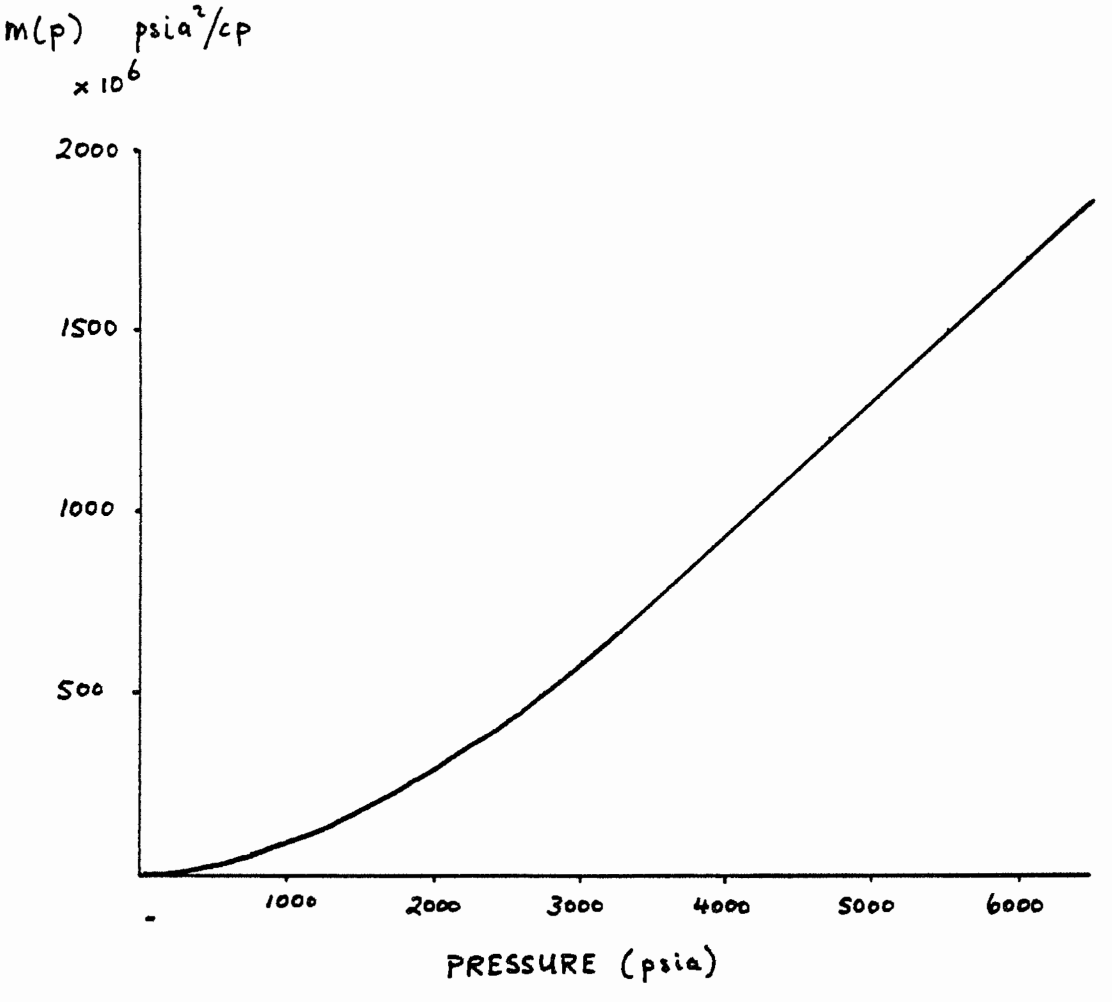
pi = 6505 psia
6500
6000
5500
34/10-16: DST-2, FIRST FLOW PERIOD
FLOWING PRESSURE (psia)
2
4
6
8
10
FLOWING TIME (HOURS)
50
45
40
← GAS
OIL →
DRY GAS RATE (MMscf/d)
2200
2100
2000
1900
OIL RATE (stb/d)
2
4
6
8
10
FLOWING TIME (HOURS)

FIG 8



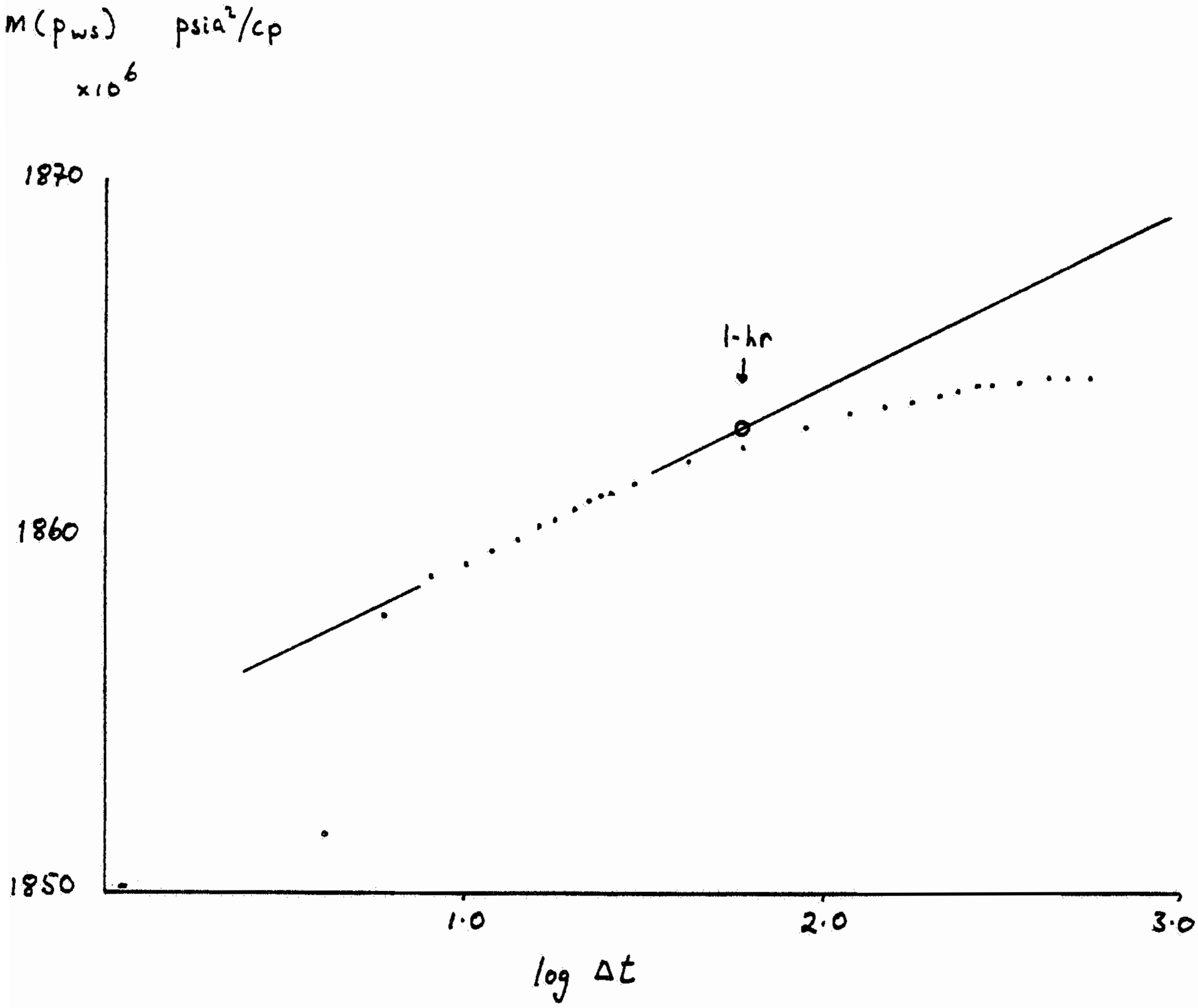
p_i = 6498.1 psia
34/10-16 : DST-2, SECOND FLOW PERIOD
FLOWING PRESSURE (psia)
6500
6000
5500
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOWING TIME (HRS)
GAS
OIL
DRY GAS RATE (MMs /d)
60
55
50
OIL RATE (stb/d)
2600
2500
2400
2300
2200
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOWING TIME (HRS)

FIG 9



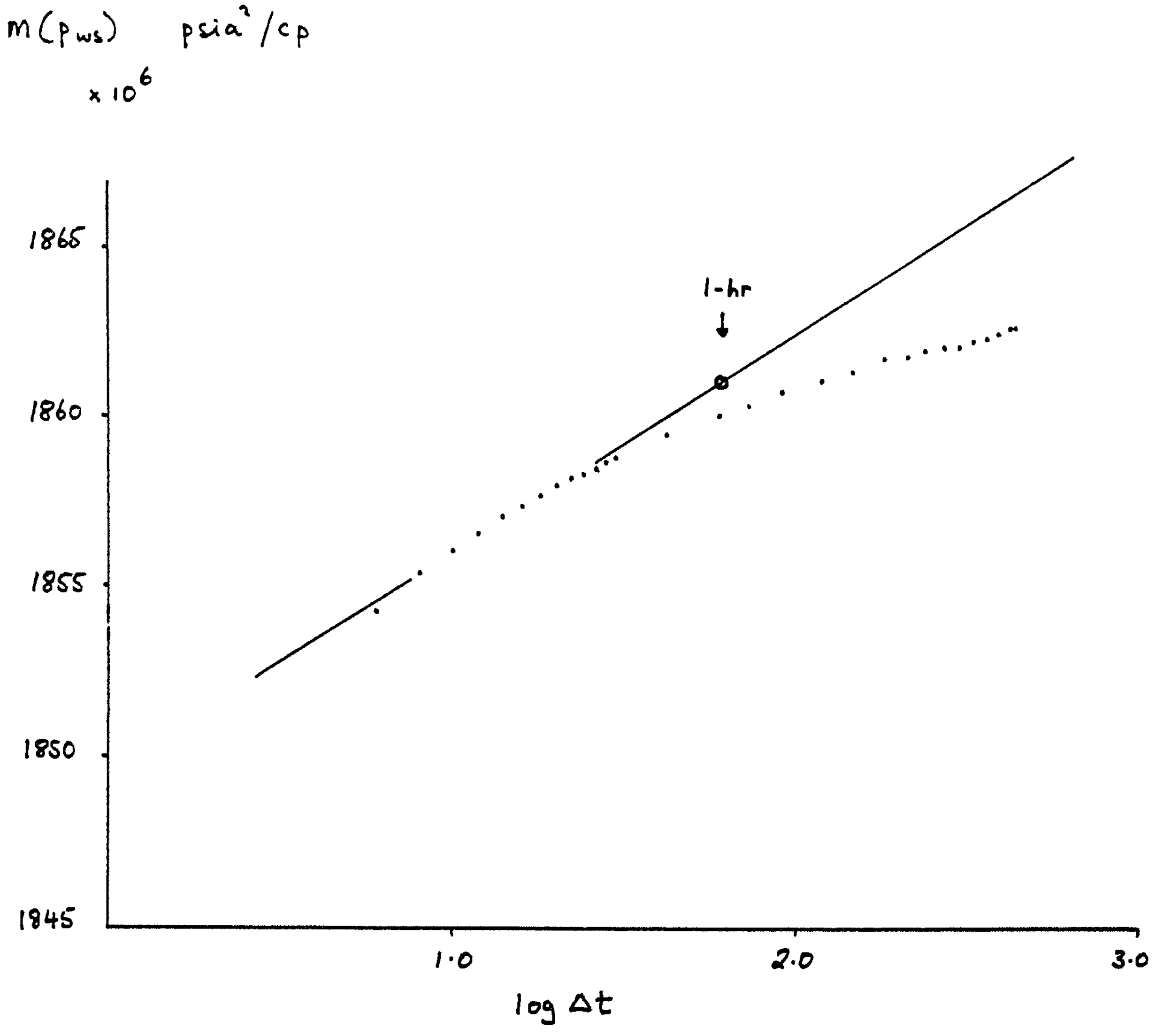
34/10-16 : DST-2, REAL GAS PSEUDO PRESSURE

FIG 10



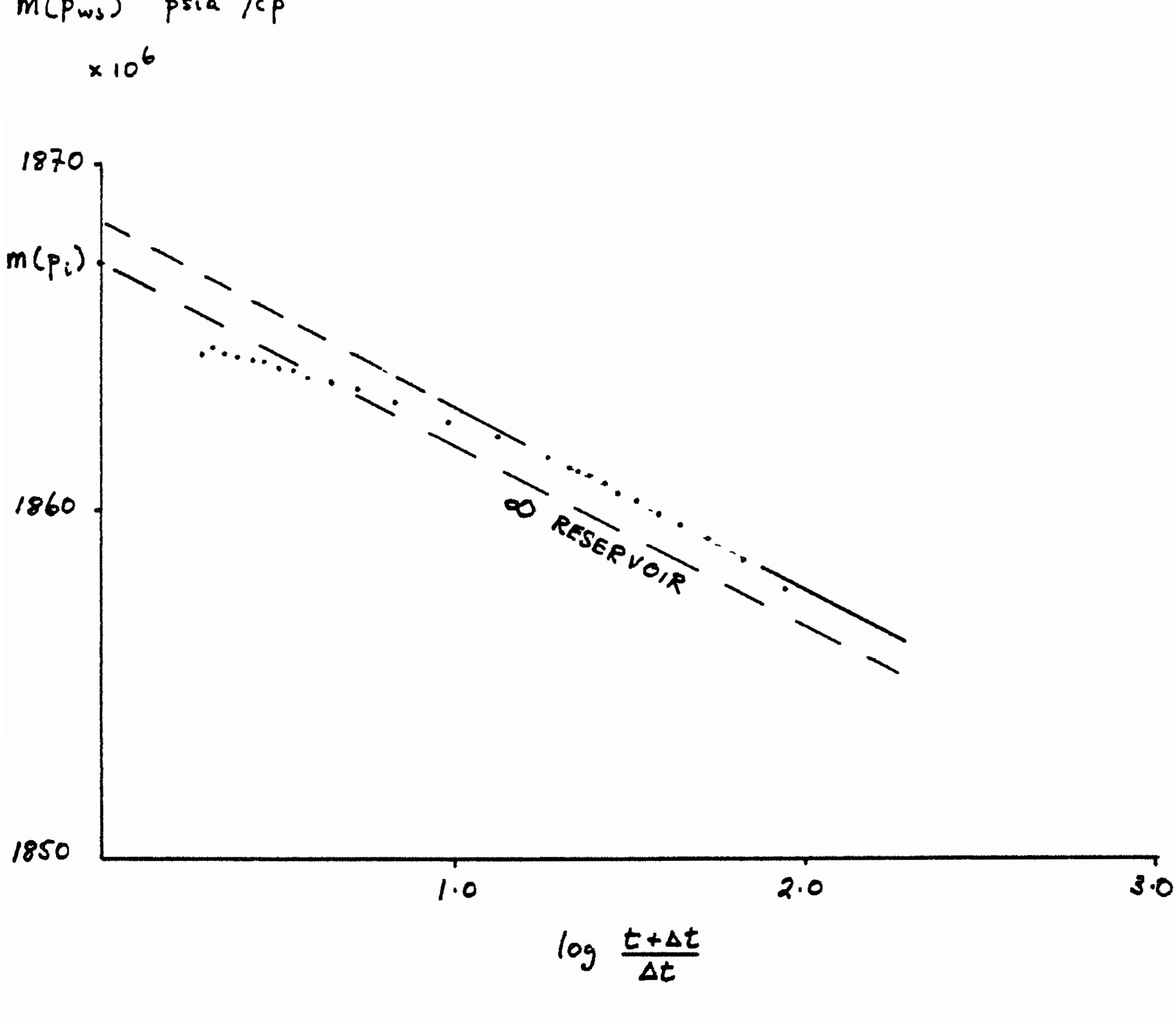
34/10-16: DST-2, FIRST BUILDUP, MDH PLOT

FIG 11



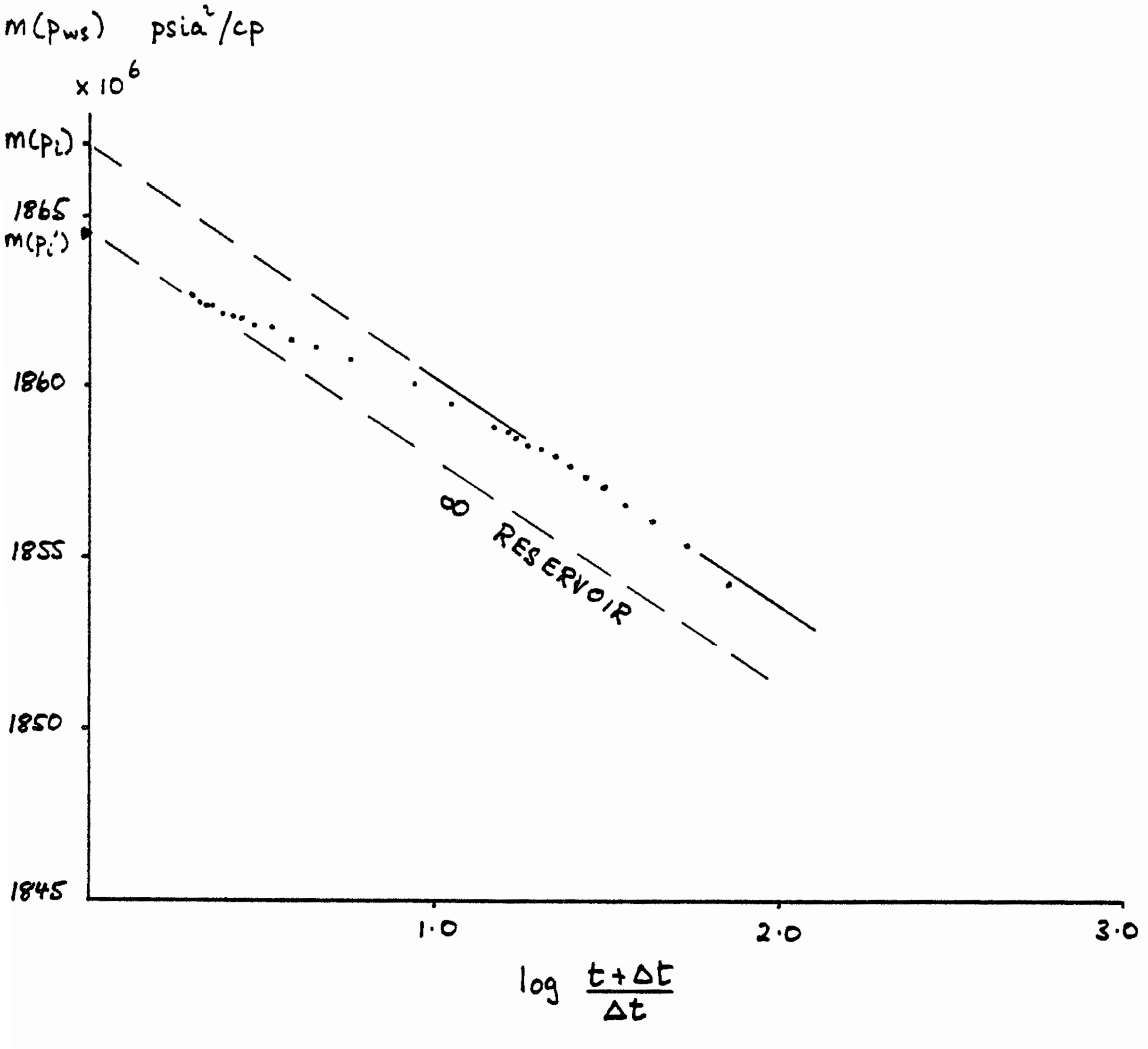
34/10-16 : DST-2, SECOND BUILDUP, MDH PLOT

FIG 12



34/10-16 : DST-2, FIRST BUILDUP, HORNER PLOT

FIG 13



34/10-16 : DST-2, SECOND BUILDUP, HORNER PLOT

$m(p_i')$ = MAXIMUM PRESSURE AFTER FIRST BUILDUP