4.10.3 Formation Pressure Measurements

A Dresser Atlas Formation Multitester (FMT) was used to obtain pressure measurements and fluid samples.

Pressure measurements are plotted and listed in fig. 4.8. The plot indicates a gas/oil contact and water/oil contact at 1568.5 m RKB and 1579.5 m RKB respectively.

The formation pressure was found to be 158.38 bar at 1522 m RKB with a pressure gradient of 0.010 bar/m in the gas zone, 0,079 bar/m in the oil zone and 0.101 bar/m in the water zone.

Three seregated samples were taken. The content was as follows:

	1563 m RKB	450 Sm^3 of gas
*	1575 m RKB	1.8 l of oil at 135 bar
*	1581 m RKB	1.8 l of oil at 90 bar

* Volumes of water/mudfiltrate are not available since the fluid was transferred to storage bottles offshore.

4.10.4 Testing

Three production tests were performed in the Sognefjord Formation.

The test intervals were: (all depths refer to the CNL-CDL log of October 26, 1983, run No. 5C).

DST No. 1 1577 - 1581 m RKB (oil zone).
DST No. 2 1574 - 1576 m RKB (oil zone).
DST No. 3 1546.5 - 1554.5 m RKB (gas zone).

The objectives of the tests were to:

- Sample reservoir fluids
- Estimate reservoir pressure and temperature
- Evaluate reservoir properties
- Obtain formation productivity
- Evaluate the effect of gravelpacking.
- Obtain water/gas coning behavior (DST No. 1 and No. 2)
- Estimate the influence of barriers (DST No. 1 and No. 2)
- Estimate skin and turbulence effects
- Measure the pressure drop in straight 5" tubing (DST No. 3)

The perforating string had the following design (from the bottom):

- 6" Baker locating seal assembly
- Geovann perforating assembly
- F-nipple for gauges
- Dowell DST-assembly (perforated joint, positrieve packer, safety joint)
- Sperry Sun gauge carrier
- Dowell DST-assembly (HRT, PCT testervalve, SSARV circulating valve, MORV circulating valve and slipjoints)
- Flopetrol subsea assembly and flowhead

The test string had the following design (from the bottom):

- Muleshoe with Baker 2 3/8" indicating collett
- F-nipple and DST-hanger
- Geovann baractuated pressure vent
- Baker seal assembly
- Dowell safety joint
- Sperry Sun gauge carrier
- Dowel DST-assembly, hydraulic jar, HRT, PCT tester valve, SSARV-circulating valve, MORV circulating valve, slipjoints)
- 5" TAC tubing
- Flopetrol subsea assembly and flowhead

The perforation intervals were gravelpacked and the following gravelpack equipment was present during the test:

- sump packer
- tell tail screen
- production screen
- blank pipe section
- upper and lower gravelpack extension
- SC-1 packer

In DST No. 3 additional Sperry Sun gauge-carriers were used above the slipjoints and above the subsea test tree to observe pressure losses in tubing.

DST No. 1

The interval 1577 - 1581 m RKB was perforated tubing conveyed with approx. 28 bar underbalance. The well was backsurged approx. 106 m^3 during a 4 hours flowperiod followed by a 5 hours build-up period.

The perforating string was pulled and the well was gravelpacked with 12-20 mesh sand.

The post gravelpack test started with a cleanout flow followed by an acid treatment. The acid cleanout flow had to be interrupted due to emulsion problems. The emulsion problems were temporarily solved and the sampling program was commenced. One 9 hours surface sampling flow followed by two 8 hours bottom hole sampling flows were carried out.

The coning flow period was interrupted three times due to emulsion problems.
The longest continuous flow lasted cumulatively 55 hours and reached a maximum fluid rate of 1000 m^3/d. The water cut increased to 62%. The GOR was constant at 53 Sm^3/m^3 at separator conditions of 10.3 bar and 60°C. The test was terminated because the surface equipment could not handle the water production.

The test results are presented in table 4.12.
The main flow results are listed in table 4.13.
The flowrates and bottomhole pressures are presented in fig. 4.9.
The pressure build up data are listed in table 4.14.

The produced oil had a gravity of 0.896 g/cc and the gas gravity was 0.66 (air = 1). The produced water had a salinity of 32.500 ppm and a pH of 6.5.

DST No. 2

The interval 1574 - 1576 m RKB was perforated with 30 bar under-balance. The perforations were backsurged and a pre-gravelpack flow of 4 hours was carried out followed by a 5 hours build up period.

The interval was gravelpacked with 12-20 mesh sand.

The well was flowed to clean out the gravel pack fluids. Then the well was acidized and two gaues were run in hole on wireline. Accidentally the wire broke and 1200m of wire was left in the hole. The well was opened several times to release the fish, but no success was obtained. The well was killed with a $CaCo_3$ pill and the string was pulled and rerun.

The coning flow lasted for 234 hours. Water started being produced after approx. 50 hours of flow and the water cut increased to 34% during the flow period. The maximum fluid rate obtained was 1290 m^3/d. The GOR was constant at 53 Sm^3/m^3 at separator conditions of 3.8 bar and 29°C.
Nitrogen was injected through coiled tubing to lift the fluid.

The main results are presented in table 4.15.
The flow data are listed in table 4.16.
Data from the pressure build up are listed in table 4.17.

Flow rates and bottom hole data are presented in fig. 4.10.

The oil and gas gravities were 0.89 g/cc and 0.66 (air = 1) respectively. The water salinity was 32.500 ppm, and the pH was 6.5.

DST No. 3

The zone 1546.5 - 1554.5 m RKB was perforated with approx. 28 bar underbalance. The perforations were backsurged, and a pre-gravelpack flow of 2 hours was carried out followed by a 1 hour shutin period.

The interval was gravel packed with 12-20 mesh sand. The first attempt to gravel pack failed due to equipment failure.

The main test started with a post-gravelpack flow and a pressure build up-period. The well was acidized and a high rate clean out flow was performed. A multirate gas test was carried out. The well was flowed at 4 different rates each for 4 hours followed by a 4 hours pressure build up period. The highest rate was 1.2×10^6 Sm^3 of gas at a wellhead pressure of 70 bars.

Finally the well was opened for commencing the sampling program. Samples were collected by the Thornton sampling manifold at the wellhead and normal recombination samples were collected from the separator. The separator liquid ratio was 24×10^{-6} m^3/Sm^3 at separator conditions of 32 bar and 12°C.

The main results are presented in table 4.18.
The main flow results are listed in table 4.19.
Data from the main pressure build up period are listed in table 4.20.
Flowrates and bottom hole data are presented in fig. 4.11.

The condensate and gas gravity was 0.78 g/cc and 0.61 (air = 1) respectively.

4.10.5 Fluid Analyses

Oil

Two FMT chambers containing pressurized oil samples were collected. These fluid samples were transfered to storage bottles and checked for validity. Two bottles from the FMT chamber sampled at 1575 m RKB, were selected for further PVT-analyses.

Three bottom hole samplers were run during the test of the oil zone. Quality check showed two of them to be representative with bubble point pressures equal to the measured reservoir pressure at the oil-gas contact. These two samples were selected for extended PVT-analyses. All results, except true boiling point destillation, have been reported.

It is a good agreement between the PVT-data reported on the fluid from the BH samples and those reported on the fluid from the FMT samples. Fig. 4.12 shows viscosity versus pressure at reservoir temperature and 40°C, and fig. 4.13 bubble point pressure versus temperature. Tables 4.21 to 4.23 contain additional PVT-data on fluid from the BH sample.
There is a variation in the wellstream composition reported on fluid from the BH sample and fluid from the FMT samples. This is especially seen in carbon numbers C_6 to C_9, and can be due to both the analysing and the sampling methods. Table 4.24 contains wellstream composition reported on the fluid from the BH sample.

Oil formation volume factor corrected for a four stage separator test (table 4.22) was 1.160 m^3/Sm^3. Bubble point pressure, in this reservoir equal to the reservoir pressure, was 158.5 bar.
A corrected solution gas oil ratio was calculated to 59.10 Sm^3/Sm^3. Dead oil density on fluid from a single stage flash to 15°C and 1 bar was measured to 895.4 kg/m^3. Viscosity was 1.79 mPa s at reservoir conditions.

Gas

One FMT sample was collected from the gas zone. Quality check and analysis showed the gas sample not to be representative.
During the drill stem test of the gas zone, Thornton Test Manifold and Minilab was used. The analytical results from Nautilus Ventures are presented in table 4.25.
Fluid samples from Thornton Minilab will be analysed by another service laboratory. These analyses will contain PNA distribution, measured molecular weight and density for carbon numbers larger than C_6. The analyses are not yet finished.

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TAB. 4.12 MAIN RESULTS DST # 1
1577.2-1581.2M RKB

WELL: 31/5-2

	K (md)	S	ΔP skin (bar)	PI final m^3/day/bar	Remarks
BU 1	3608	3.3	0.2	127	Pre gravel pack
BU 2	N/A	N/A		84	Acid clean out flow
BU 3	N/A	N/A		101	Surface sampling flow
BU 4	3194	7.4	5.7	87	Coning flow

Reservoir pressure at 1579.2 m RKB : 158.8 bar

Highest measured temperature: 68.3°C

Ideal PI = 168 m^3/day/bar

DATE 14.2.85	AUTH. ThS
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REF	

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TAB. 4.13 FLOW RESULTS OF DST # 1
1577.2-1581.2M RKB

WELL: 31/5-2

	max rate m^3/day	final rate m^3/day	max fw %	WHP bar	GOR Sm^3/m^3	sep. press. bar	sep. temp. °C	dur. flow hrs. min.	dur. build up hrs. min.	PI m^3/day/bar
Pre gravel pack flow	65	65	-	33	-	-	-	3.58	5.0	127
Pre acid post gravel pack flow	190	72	-	14	-	-	-	1.29	3.16	84
Acid clean out flow	196	196	25	25	-	-	-	8.35	9.52	83
Sampling flow	254	223	58	26	55.2	12	53	33.0	8.16	101
Coning flow	1030	1000	63	20	54.7	10	60	55.17	3.16	87

Pi ideal = 168 m^3/day/bar

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REF	

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TAB. 4.15 MAIN RESULTS DST # 2
1574-1576M RKB

WELL: 31/5-2

	K (md)	S	P skin (bar)	PI final m^3/day/bar	Remarks
BU 1	5346	14.5	0.3	101	Pre gravel pack
BU 2	6064	43	5.4	38	* Acid clean out
BU 3	7470	43	6.0	57	* Sampling flow
BU 4	7450	43	9.5	59	* Fishing flow
BU 5					
BU 6	5820	96	21.9	22	Coning flow **

* The results are obtained by Gringarten type curve interpretation

** The initial PI was 56 m^3/day/bar

( ) The m-factor was evaluated from the log/log-interpretation
Reservoir pressure at 1585m RKB was 158.6 bar
Highest measured temperature was 73.8°C

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TAB. 4.16 FLOW RESULTS OF DST # 2
1574-1576M RKB

WELL: 31/5-2

	max rate m^3/day	final rate m^3/day	max fw %	WHP bar	GOR scf/bbl Sm^3/m^3	sep. press. bar	sep. temp. °C	dur. flow hr. min.	dur. build up hr. min.	PI m^3/day/bar
Perf. flow	60	49	-	37	-	-	-	4.0	6.0	101
Gravel pack clean out flow	443	278	-	27	-	-	-	9.20	4.35	8.5
Acid clean up flow	291	291	-	35	-	-	-	1.55	3.30	38
Sampling flow	401	401	-	41	46.3	11	21	9.50	10.1	57
Flow during fishing	644	644	-	35	-	-	-	1.51	12.54	59
Flow to detect pollution		636	-	35	-	-	-	1.20	4.28	-
Coning flow	1296	533	34	18	52.5	3.8	29	233.32	11.39	22 *

* Initial producticity index of coning flow was 56 m^3/day/bar.

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TAB. 4.18 MAIN RESULTS DST # 3
1546.5-1554.5M RKB

WELL: 31/5-2

	K (md)	S total	S turbulence	$\Delta\Phi$ skin (bar^2/cp) x 10^3	$\Delta\Phi$ drawdown (bar^2/cp) x 10^3	E %
BU 1		2.3		0.35	1.4	75
BU 2	6525	1174	1135	927	932	0.5
BU 3	5854	212	173	2420	2540	4.7

Completion skin: s = 39

Reservoir pressure at middle perforations, 1550.5 m RKB: 157.8 bar

Highest measured temperature: 68.3°C

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TAB. 4.19 FLOW RESULTS OF DST # 3
1546.5-1554.5M RKB

WELL: 31/5-2

	Rate gas 10^6 Sm^3/day	Rate cond. m^3/day	WHT °C	WHP bar	Duration flow hrs. min.	PI 10^6 Sm^3/day/bar
Pre gravel pack flow	0.23	N/A	13	126	2.0	3360
Gravelpack clean out flow	0.92	N/A	13	56	6.45	19
Acid clean out flow	1.21	16	12	64	11.25	65
Multirate flow	0.37		12	134	4.05	237
	0.51	8	16	129	4.00	193
	0.87	14	14	110	4.01	131
	1.23	16	24	70	3.54	102
Sampling flow	0.527	13.4	12	129	15.53	189

The most reliable condensate rate was obtained during the sampling flow. The LGR was 24 x 10^{-6} m^3/Sm^3 with separator conditions at 32 bar and 12°C.
The glycon injection rate was 0.4 m^3/day.

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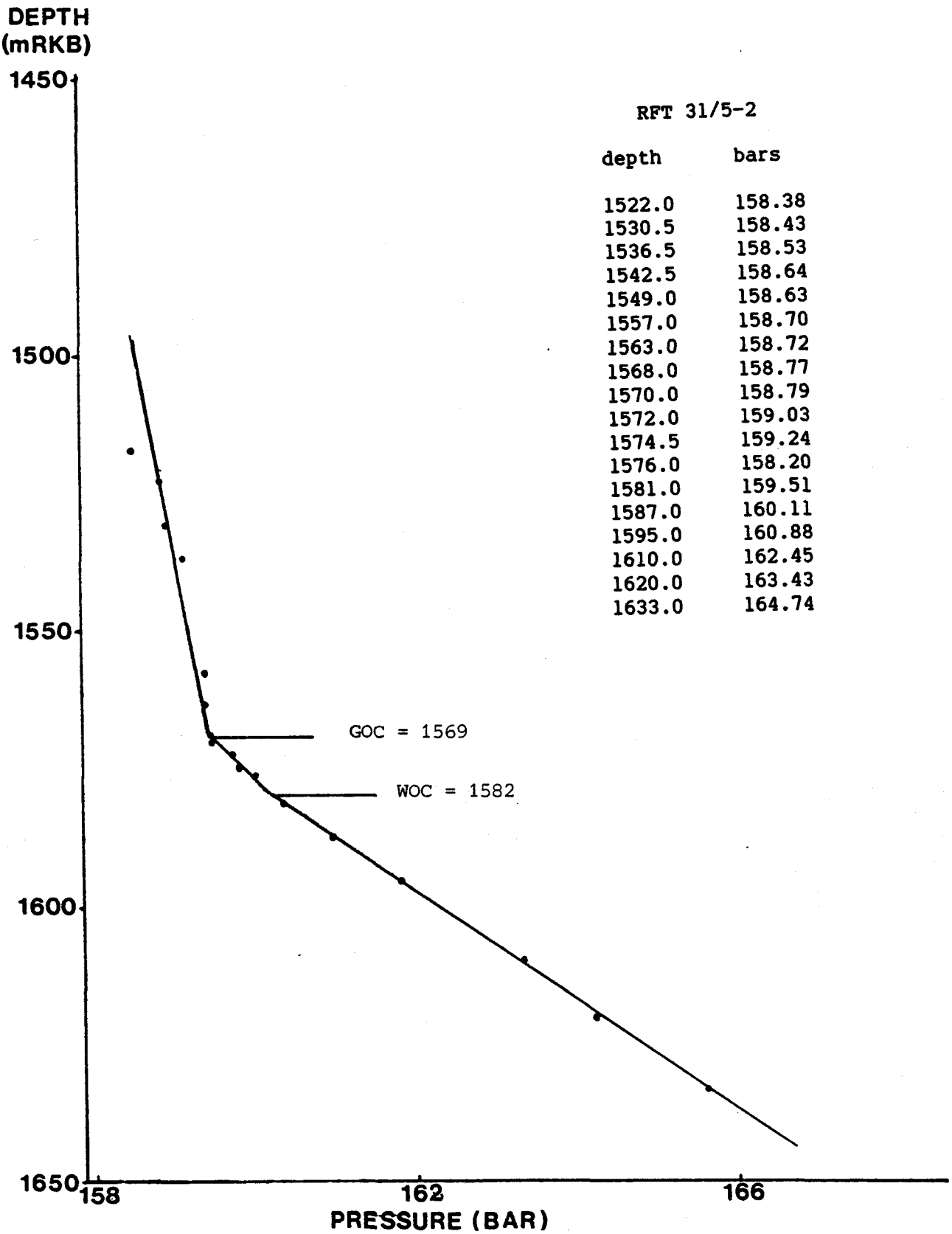
FIG. 4.8 FORMATION PRESSURE VS. DEPTH

WELL: 31/5-2



RFT 31/5-2

depth	bars
1522.0	158.38
1530.5	158.43
1536.5	158.53
1542.5	158.64
1549.0	158.63
1557.0	158.70
1563.0	158.72
1568.0	158.77
1570.0	158.79
1572.0	159.03
1574.5	159.24
1576.0	158.20
1581.0	159.51
1587.0	160.11
1595.0	160.88
1610.0	162.45
1620.0	163.43
1633.0	164.74

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REF	

5.2.1. Mud Properties,Daily Report

Well no: 31/5-2

Saga Petroleum a.s.

DATE	HOLE SIZE INCHES	DEPTH METERS	MUD WEIGHT ppg	P.V.	Y.P.	GEL STRENGHT	n	K	WATER LOSS	pH	ALKALINITY Pf/Mf	Ca+ ppM	CL- ppM	SAND %	SOLIDS %	COMMENTS
4.10.																prepare spud in
5.10.	36	418	8.7	28	56	20/40	.41	6.5	21	10.5	.2/.3	80	1100		3	spud in
6.10.	17 ½	580	8.7	25	50	16/36	.41	5.8	21	10.4	.2/.3	80	1100		3	run 30" csg.
7.10.	26	655	8.7	25	50	17/36	.41	5.8	21	10.4	.2/.3	80	1100		3	drl. 26" hole
8.10.	26	860	8.7	25	50	17/36	.41	5.8	21	10.4	.2/.3	80	1100		3	run 20" csg.
9.10.	17 ½	848	9.1	17	31	8/19	.44	3.1	17	8.3	.0/.2	0	60000		–	run BOP
10.10.	17 ½	848	9.1	17	24	5/13	.50	1.8	17	8.0	.0/.1	0	63000		–	– " –
11.10.	17 ½	848	9.1	18	22	6/9	.53	1.5	17	8.0	.0/.1	40	63000		–	– " –
12.10.	17 ½	894	9.2	17	19	5/9	.56	1.1	10	9.5	.1/.3	260	55000	1	3	drl.
13.10.	17 ½	1277	11.2	20	20	5/9	.58	1.1	12	8.3	.0/.1	520	60000	1	12	drl.
14.10.	17 ½	1430	11.2	23	21	5/11	.61	1.0	13	8.3	.0/.1	880	61000	1	12	drl., log
15.10.	17 ½	1430	11.6	19	15	5/10	.64	.63	13	8.3	.0/.1	880	58000	1	12	logging
16.10.	17 ½	1415	11.6	22	15	5/10	.67	.56	13	8.6	.0/.1	960	53000	1	12	casing 13 3/8"
17.10.	12 1/4	1435	10.5	16	19	6/12	.54	1.2	12	10	.1/.3	360	47000	.5	9	drl. 12 1/4"
18.10.	12 1/4	1505	10.5	19	22	7/13	.55	1.3	7	9.9	.1/.3	300	52000	.75	10	drl.
19.10.	12 1/4	1511	10.5	19	22	5/14	.55	1.3	7	9.7	.1/.3	400	54000	1	10	coring
20.10.	12 1/4	1543	10.5	18	22	5/13	.54	1.3	8	9.5	.1/.3	400	55000	1	10	– " –
21.10.	12 1/4	1589	10.5	19	24	7/15	.53	1.58	7.5	9.3	.1/.3	400	52000	1	10	– " –
22.10.	12 1/4	1617	10.5	20	23	8/15	.55	1.39	7.0	9.3	.1/.3	400	55000	1	10	– " –
23,10.	12 1/4	1831	10.5	19	22	7/16	.55	1.33	7.5	9.4	.1/.3	360	52000	.75	10	drl. 12 1/4" H.
24.10.	12 1/4	1923	10.5	17	17	6/14	.59	.86	7.0	9.5	.1/.3	300	54000	.25	10	– " –
25.10.	12 1/4	1965	10.5	17	18	6/14	.55	1.1	7.0	9.5	.1/.3	300	54000	.25	10	logging
26.10.	12 1/4	1965	10.5	16	17	7/15	.57	.94	8.0	9.1	.1/.3	200	57000	.25	10	– " –
27.10.	12 1/4	1965	10.5	15	17	7/16	.55	1.0	8.0	9.1	.1/.3	160	58000	.25	10	– " –
28.10.	12 1/4	1965	10.5	17	16	7/15	.6	.79	10.5	9.0	.1/.3	240	59000	.25	10	RIH.circ.logging
29.10.	12 1/4	1965	10.5	17	16	7/15	.6	.79	10.5	9.0	.1/.3	320	59000	.25	10	run 9 5/8". cmt.
30.10.	12 1/4	1965	10.5	16	16	7/15	.58	.84	10.5	9.0	.1/.3	320	59000	.25	10	RIH.Fishing.WOW
31.10.	12 1/4	1965	10.5	16	16	7/15	.58	.84	10.5	9.0	.1/.3	320	59000	.25	10	WOW.Fishing
1.11.	12 1/4	1965	10.5	15	15	7/15	.58	.78	11	9.0	.1/.3	320	59000	.25	10	Fishing.WOW.Fish.
2.11.	12 1/4	1965	10.5	15	20	7/15	.51	1.41	6	9.0	.1/.3	240	59000	.25	10	WOW.Fishing
3.11.	12 1/4	1965	10.5	14	16	5/14	.55	1,0	8	9.0	.1/.3	240	59000	.25	10	Fishing
4.11.	8 ½	2008	10.3	13	16	6/14	.53	1.1	15	10.3	.3/.8	440	55000	.5	10	drl.

5.2.1. Mud Properties,Daily Report

Well no: 31/5-2

Saga Petroleum a.s.

DATE	HOLE SIZE INCHES	DEPTH METERS	MUD WEIGHT ppg	P.V.	Y.P.	GEL STRENGHT	n	K	WATER LOSS	pH	ALKALINITY Pf/Mf	Ca+ ppM	CL- ppM	SAND %	SOLIDS %	COMMENTS
5.11.	8 ½	2088	10.1	14	16	6/10	.55	1.0	9	10.5	.3/.7	380	55000	.25	11	drl.
6.11.	8 ½	2350	9.8	13	16	6/10	.53	1.1	12	10.5	.2/.6	320	39000	.75	9	drl.
7.11.	8 ½	2467	10.0	11	11	6/10	.58	.6	13	10.1	.1/.4	360	37000	.25	10	drl.
8.11.	8 ½	2500	10.0	12	12	6/11	.58	.6	13	10.1	.1/.4	340	36000	.25	10	drl. logging

5.2.2. Mud Materials used

Well no: 31/5-2

Saga Petroleum a.s.

MATERIAL	UNIT	36" HOLE	26" HOLE	17 1/2" HOLE	12 1/4" HOLE	8 1/2" HOLE	5 7/8" HOLE	TOTAL
BENTONITE	50 kg	314	370		19			703
CAUSTIC	25 kg	11	11	4	14			40
SODA ASH	50 kg	2	3	1	5			11
WO 21	25 kg	1						1
PRO DEFOAM	25 l	1		9	3	2		15
BARITE	MT	7		152	74	16		249
LIME	40 kg		1					1
KCL	50 kg			1434	951	42		2427
MILPOL 302	25 kg			89	107	43		239
MILPOL 352 L	25 kg			66				66
PERMALOSE	25 kg			72				72
UNICAL	25 kg			17				17
DRISPAC REG	50 LB			42	21	29		92
PERMA LOSE	25 kg				229	47		276
BICARB	50 kg				24	9		33