8. PRODUCTION TESTS

WIRELINE FORMATION TESTS

Objectives

Prior to the full scale production test programme, a series of runs were made with the Schlumberger Repeat Formation Tester (RFT). The objectives were as follows:

1. Confirm formation fluid pressures, pressure gradients and fluid contacts obtained from RFT's in Well 31/2-1.

2. Obtain preliminary fluid samples at selected depths to confirm reservoir contents and for PVT analysis. Particular interest was related to the possible existence of a thin oil column indicated by the logs between the gas and water.

Summary and Results

A total of eight runs were made. The first run (see Fig. I/8.1) established pressure gradients in the water leg and the possible oil column (1579-1591 m BDF). In the gas bearing section the results are obscured because of too low pressures at the three top readings, probably because of temperature effects in the gauge. The remaining seven runs, of which runs nos 2,3 and 7 were misruns, were fluid sampling attempts. Gas samples were obtained at 1548 and 1571 m BDF and oil samples at 1587.5 and 1590 m BDF. The recovery of oil samples confirmed the existence of movable oil in the reservoir, probably between 1579 and 1591 m BDF as indicated by logs and RFT pressure gradients.

Operational Aspects

The most interesting aspect to test with the RFT was the pressure of a possible oil column between the gas and the water at about 1579-1591 m BDF.

In the first run, which was a pretest run to obtain formation pressures, twelve pressure readings were taken from 1545.5 - 1800.5 m BDF (see Fig. I/8.1). Above the water a possible oil gradient was observed from about 1571-1583 m BDF. In the gas bearing section the results are not as reliable since the three uppermost pressure readings are obviously too low. The reason is believed to be that the pressure gauge was not given time to heat up prior to the start of pressure measurements.

Runs 2 through 8 were made to obtain fluid samples to confirm reservoir contents and for preliminary PVT analysis. Particular interest was related to the possible oil column interval. In runs 2 and 3 unsuccessful sampling attempts were made above and in the potential oil bearing section. The probe plugged and the tool had to be pulled for service. Run 4 resulted in a successful gas sample at 1548 m BDF. An oil sample was obtained at 1587.5 m BDF in run 5. This sample was transferred with some problems into four 600 cc Otis bottles at the site. Apparently the transfer was not properly done because two of the 600 cc bottles have been found to contain essentially gas and the two others oil with bubble points that are 475 psi apart. In run 6 a gas sample was recovered from 1571 m BDF. Run 7 was a misrun because of probe plugging, but in run 8 an oil sample was obtained at 1590 m BDF. This sample was transported to the PVT lab in the RFT sample chamber for controlled transfer.

After having obtained the two oil samples in runs 5 and 8 it became apparent that a thin column of movable oil did exist between the gas and the water. Considering the results of the RFT reservoir pressure gradient survey and the logs this column is believed to have a thickness of about 12 meters from 1579-1591 m BDF.

At the time of writing no results have been received from PVT analyses of the RFT samples.

PRODUCTION TESTS

Objectives

The objectives of the full scale production tests were as follows:

1. To obtain positive evidence of the type of reservoir fluid at various depths.

2. To assess well inflow performance, including permeability, skin and turbulence in the oil zone and in the micaceous and clean gas zones.

3. To investigate sand influx problems and efficiency of the gravel packs used for the oil zone and clean gas zone tests.

4. To obtain PVT samples to be used for compositional and phase behaviour analyses.

5. To obtain accurate on site measurements of liquid yield and trace elements in the clean sand gas test.

General Test Results (Fig. I/8.4)

Three intervals were tested (see Fig. I/8.2). The interval 1586.5-1588.5 m BDF was tested using an internal gravel pack completion and a regular production string. Logs and RFT's had indicated this interval to be oil bearing. The micaceous gas zone was tested with a perforated completion in the interval 1570-1575 m BDF. Finally a test was carried out in the clean sand gas zone at 1553-1562 m BDF applying an internal gravel pack completion.

A total of some 42 days were spent on the oil zone test as it was realized that the productivity of the oil was of extreme importance to any future development plans.

After completion the well came in on 22.6.80 at a rate of about 96 B/D which gradually declined. The GOR was about 180 SCF/B. A buildup on 27.6.80 indicated a permeability of 917 mD, and a high skin factor of 62 (91% of drawdown). The damage was thought to be the result of viscous brine that was lost into the formation during the completion, and therefore it was decided to acidize the well. This stimulation increased the rate to 170 B/D which declined slowly. After reaching a minimum of 119 B/D the rate started increasing again accompanied by an increase in producing GOR. On 4.7.80 381 B/D at a GOR of 300 SCF/B was obtained. A build-up indicated that the increased rate could be attributed to improved lifting efficiency caused by the higher GOR.

In the meantime plans had been made for lifting the oil with gas from the micaceous zone (see Fig. I/8.5). These plans had been discussed with partners and were approved by the Norwegian Petroleum Directorate (NPD) on 4.7.80. However, because of improved lift, the installation of this gas lift was postponed. Instead another acid/deemulisifier job was performed on 6.7.80. The well responded strongly with the rate reaching a maximum of 830 B/D which was sustained for about 24 hours. Then the decline pattern observed after the previous stimulation started. A third stimulation job on 10.7.80 had essentially no effect, and the decline continued. No further action was taken as industrial action among the rig personnel was imminent, and when the well was shut in on 13.7.80 prior to the strike the rate was down to 420 B/D. The buildup was monitored and indicated a permeability of 831 mD and a skin factor of 29 (82% of drawdown).

When work was resumed after the strike, the gas lift hook-up was installed (see Fig. I/8.5) and the well was acidized. After this the well came in at a rate of 1400 B/D with a producing GOR (including lift gas) of about 1300 SCF/B. As before the well started to decline immediately. It was apparent that the acid/demulsifier treatment resulted in no permanent improvement.

Wax had been found on top of the bomb hanger when retrieving pressure bombs. It was thought that this could perhaps be contributing to the formation plugging and on 24.8.80 Shell Sol 'A' was injected to dissolve the wax. This made the rate return to 1400 B/D followed by the gradual decline.

As apparently it made no difference which fluid was pumped into the formation to achieve a production increase, the plugging could be interpreted as moving formation fines that were flushed back into the formation every time some fluid was injected. These fines would then slowly return when the well was produced again. As a result a "Clay Acid" treatment was carried out on 26.8.80 to dissolve the fines. The well responded strongly and came back at some 2500 B/D including 25% BS&W, but the rate declined along the same pattern as before. On 28.8.80 the rate was down to 1350 B/D including 5% BS&W. At this point in time the skin factor was estimated at 5.8 (45% of drawdown). An estimate indicates that the well was probably skin free during the period it was making 2500 B/D.

At this point in time it was felt that little additional information could be obtained by continued testing and the test was terminated at 20.45 hours 28.8.80.

The well was opened for the micaceous sand gas test at 19.52 hours on 1.9.80. The well was cleaned up for some 42 hours, the last half of which at maximum obtainable rate of 46 MMSCF/D (refer test sequence in Fig. I/8.6. The gas gravity was about 0.6 and the condensate yield about 4 B/MMSCF. One accidental (due to failure in rig air supply) and one planned shut in on 1.9.80 both resulted in built up surface pressures in less than one minute, thus indicating a high formation transmissibility. Because of this pressure behaviour no transient data exist from the test.

After having installed the gravel pack for the clean sand gas test (see Fig. I/8.7) the well was opened at 06.00 hours, 18.9.80. The test sequence is shown in Fig. I/8.8. The gas gravity was 0.61. Due to a variety of minor problems, seven unscheduled shut-ins occurred during the clean-up phase. It was noted that the surface pressure built up completely in less than one minute, thus excluding the possibility of obtaining transient pressure data.

3I/2-2 Oil Test

TEST SEQUENCE

PHASE	PERIOD FROM	PERIOD TO	DURATION / HRS	CHOKE 1/64"	FLOWRATE (BPD) INITIAL	FLOWRATE (BPD) FINAL	WHP (psig) INITIAL	WHP (psig) FINAL	BHP (psig) INITIAL	BHP (psig) FINAL
1st Flow (clean up)	013 22/6	0430 23/6	27	5→6→8	48	0	135	0	-	-
	The well killed itself, confirmed by gradient syrvey. Displaced with diesel again.									
2nd Flow	0700 23/6	1700 24/6	34	8	54	36	25	109	-	-
	1700 24/6	0830 25/6	15½	16→8→10	72	48	56	170	-	-
	0830 25/6	2000 27/6	59½	12	108	96	113	138	-	1864
	Schlumberger took 3 bottom hole samples during last flow period.									
1st Build-up	2000 27/6	0630 28/6	10½	shut in	-	-	119	357	1864	2259
3rd Flow	1730 28/6	2400 28/6	6½	12	96	94	129	132	1930	1930
Acidisation No. 1										
4th Flow	1000 29/6	1500 30/6	29	12	192	110	48	302	1943	1945
2nd Build-up	1500 30/6	0500 1/7	14	shut in	-	-	302	531	1945	2267
5th Flow	1300 1/7	0900 2/7	20	11→20→28→36	154	450	284	77	1990	1155
	0900 2/7	1900 4/7	58	32	429	338	84	64	1170	1170
3th Build-up	1900 4/7	1000 5/7	15	shut in	-	-	64	550	1170	2267
6th Flow	1330 5/7	1400 6/7	23½	32	400	410	90	90	-	1084
Acidisation No. 2										
1st Flow	1930 6/7	1400 7/7	18½	32→40	824	967	160	135	1515	1225
	1400 7/7	0200 10/7	60	48	814	416	100	40	1165	1000
	0200 10/7	1630 10/7	14½	40	425	370	60	40	1000	1150
Acidisation No. 3										
8th Flow	2030 10/7	0730 11/7	11	40→20→32	512	53	67	30	1280	1280
	0730 11/7	1600 12/7	32½	24	373	394	104	130	1450	1330
	1600 12/7	1000 13/7	18	32	481	394	90	60	1185	1135
4th Build-up	1000 13/7	1900 13/7	9	shut in	-	-	60	531	1135	2255
	Secured well for strike. Installed new completion with gas lift from micaceous gas zone.									
Acidisation No. 4										
9th Flow	0930 20/8	1300 21/8	27½	32	1277	1143	704	525	-	-
	1300 21/8	1800 21/8	5	48	1309	1098	315	225	-	-
	1800 21/8	0600 22/8	12	shut in	-	-	225	1530	-	-
	0600 22/8	1630 22/8	10½	48	1000	850	215	240	-	-
	Increased injection valve choke isze from 3/16" to 5/16"									
10th Flow	0730 23/8	1600 23/8	8½	48	8450	780	450	430	-	-
	1600 23/8	1800 24/8	26	64	750	630	350	345	-	-
	Well treated for wax deposition with SHELL "SOL A"									
11th FLOW	0030 25/8	1500 25/8	14½	48	1720	840	550	490	-	-
	1500 25/8	0130 26/8	9½	64	975	815	405	390	-	-
Acidisation No. 5	CLAY ACID TREATMENT									
12TH FLOW	1700 26/8	2100 28/8	52	64	2500	1340	560	480	-	-
	Ran a gradient survey.									

TABLE I/8:I

Well 3I/2-2 Micaceous gas zone

Phase	Period	Choke ins	Rate MMSCF/D init.	Rate MMSCF/D final	WHP PSIG init.	WHP PSIG final	WHT °F init.	WHT °F final	BHP PSIG init.	BHP PSIG final	BHT °F init.	BHT °F final	Comments
Cleaning up	1.9.80 1952 3.9.80 1605		10	46		1025		57					Max rate of 51 MMSCF/
Buildup	3.9.80 1605 - 1727				2000	2020	57	54					No BHP available due to bomb failure. WHP buildup in less than one minute.
Seq. rate	3.9.80 1727-1815	28/64	12.2	12.2	1960	1960	55	52					Test stopped due to change in program.
Shut in. Wireline	3.9.80 1815 - 4.9.80 0130												Shut in to pull bomb Immediate WHP buildu Gauges failed at 1200 hrs 2.9.80.
Static press	4.9.80 0130 - 0241								2270	2270 (2269)	148	154	Rerun bombs. Recorde static pressure befo start of seq. rate test.
Sequential rate test 1st rate	4.9.80 0241 - 1030	28/64	14.2	14.8	1797	1913	48	51	2251	2251 (2246)	156	156	Flow rate too low to clean out brine lost into tubing due to SSD opening tool failure. 2 sets of PVT samples taken towards the end of the flow period.
2nd rate	4.9.80 1030 - 1430	34/64	21.3	21.6	1880	1810	52	55	2225	2226 (2225)	156	156	Stable flow, 2 sets of PVT samples taken
3rd rate	4.9.80 1430 - 1630	58/64	32.7	35	1650	1610	57	60	2156	2146 (2146)	156	154	Stable flow.Sperry Sun readings fluctua ting.
4th rate	4.9.80 1630 - 1858	128/64 + 64/64	50.9	53.1	965	1015	48	55		(1993)	154	152	Stable flow.Sperry Sun gauge failed due to vibration.
Buildup	4.9.80 1858 - 5.9.80 0554				1950	2218	67	62	2293	2293 (2294)	155	155	Immediate build-up. Problem to pull bomb due to sand accumulation on top of bombs.

* Field readings of Amerada chart shown in brackets.

TABLE I/8.2

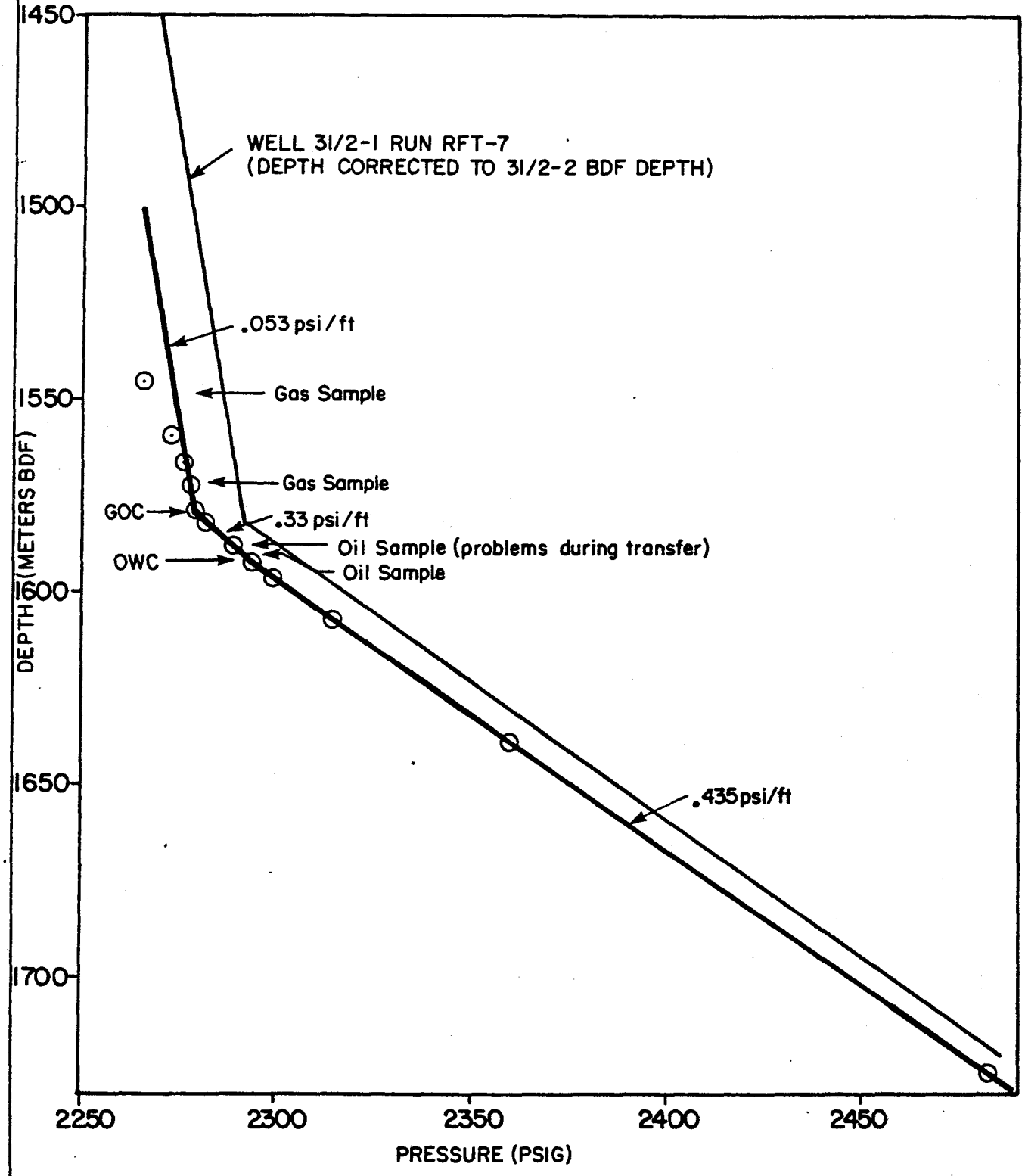
TEST SEQUENCE WELL 31/2-2 CLEAN SAND

Phase	Period	Choke ins	Rate MMSCF/D init	Rate MMSCF/D final	WHP psig init	WHP psig final	WHT °F init	WHT °F final	BHP psig init	BHP psig final	BHT °F init	BHT °F final	Comments
Clean up	18.9.80 0600	40864		19.2		1807		54					No BHP's measured during cleanup. continous sand readi by SANDEC probe
Shut in Run Bombs Record static pressure	20.9.80 2000 21.9.80 0416								2263	2264	147	147	Two Sperry Sun (1 mi mode and 2 min mode) 3 static gradient st
Beaning up 1. rate	21.9.80 0416-0622	24/64	7.6	7.5	1936	1940	52	51	2199	2221	147	154	Well not completely stable.
2. rate	21.9.80 0622-0829	46/64	22.2	22.8	1670	1737	50	57	2110	2113	152	151	
3. rate	21.9.80 0829-1035	64/64	29.3	29.6	1560	1595	57	63	2056	2063	151	150	
Bean back 1. rate	21.9.80 1035-1800	46/64	23.2	23.4	1745	1733	63	61	2127	2132	150	152	Thornton sampling stable flow
Shut in	21.9.80 1800-1930								2262	2262	152	150	Changing surface flo lines
2. rate	21.9.80 1930-2115	64/64	30.9	31.2	1615	1614	57	64	2061	2066	150	150	Beaned up over 15 mi stable flow
Beaning up	21.9.80 2115-2236										150	145	
Maximum rate	21.9.80 2236 22.9.80 0201	128/64+128/64	49.6	49.7	871	865	59	57	1868	1868	145	145	Stable flow
Build up	22.9.80 0204								2261	2263	145	147	Start up shut in wel at 0201 well complet shut in at 0204

TABLE I/8.3

WELL 31/2-2

RFT PRESSURES VS DEPTH



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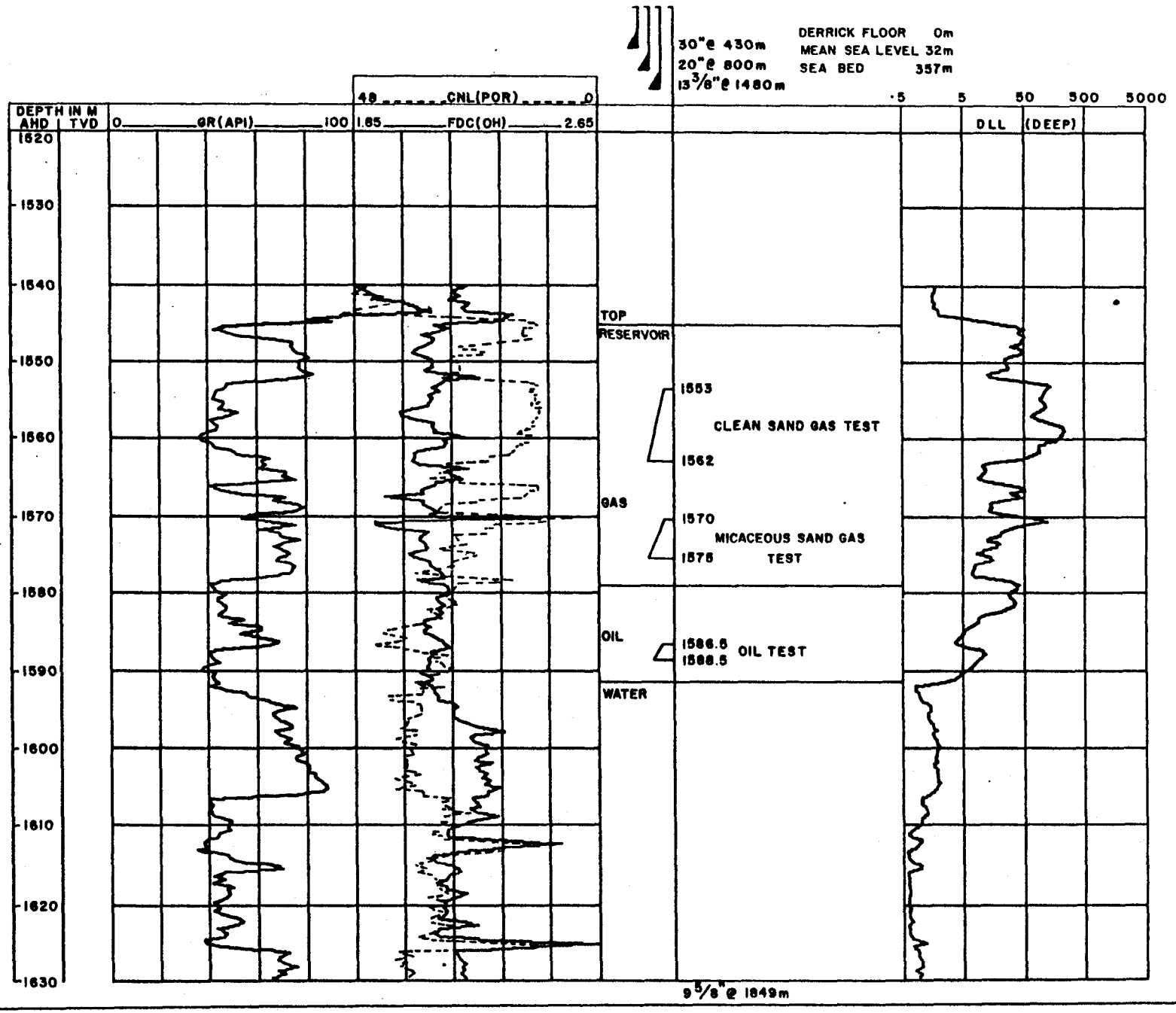
EXPLORATION & PRODUCTION FORUS

31/2-2
EXPLORATION WELL RESUMÉ
RFT PRESSURES VS DEPTH

AUTHOR EPPP/22	FIG. I/8.1	DATE NOV. 1980
REPORT NO NSEP/92		DRAW NO 711/5

31/2-2 TEST INTERVALS



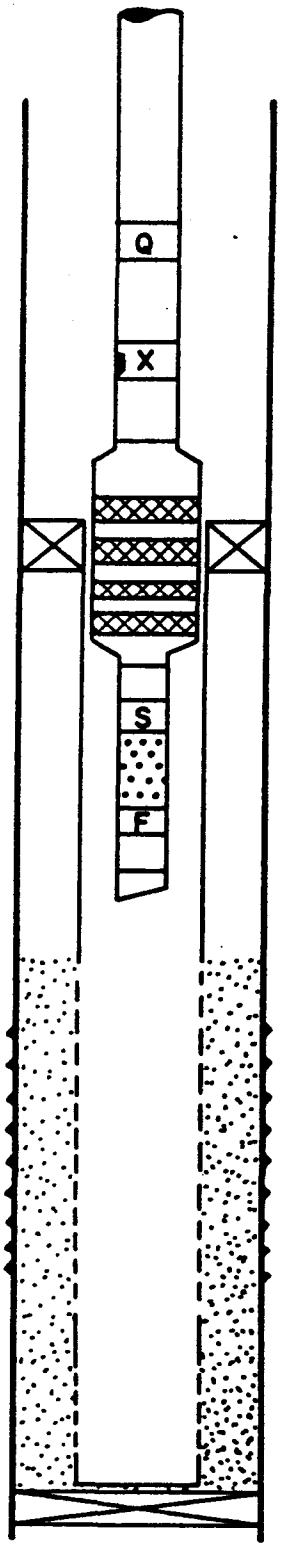
B·S Norske Shell
EXPLORATION & PRODUCTION FORUS

31/2-2
EXPLORATION WELL RESERVE
PRODUCTION TEST
TEST INTERVALS

AUTHOR. EPFF/21 | DATE. NOV. 80
REPORT NO. NSD/82 | FIG. 31/2-2
DRAWING NO. 711/8

31/2-2

OIL ZONE FIRST COMPLETION
PRE GAS LIFT PHASE



	DEPTH m BDF
3½" 10.2 lbs/ft TUBING TO SSTT	
Q NIPPLE	1535.1
XA SLIDING SIDE DOOR	1540.7
G-22 LOCATOR SEAL ASSY.	
BAKER SC-1 PACKER.	1550
S NIPPLE	1555.8
PERFORATED JOINT	
F NIPPLE	1559.2
HALF MULE SHOE	1569.0
TOP WWS.	1582.2
TOP PERFORATIONS	1584.5
PERFS: 8spf 2½" HYPER DOME SCALLOP 12-20 GRAVEL.	
BOTTOM PERFORATIONS	1586.5
BOTTOM WWS	1587

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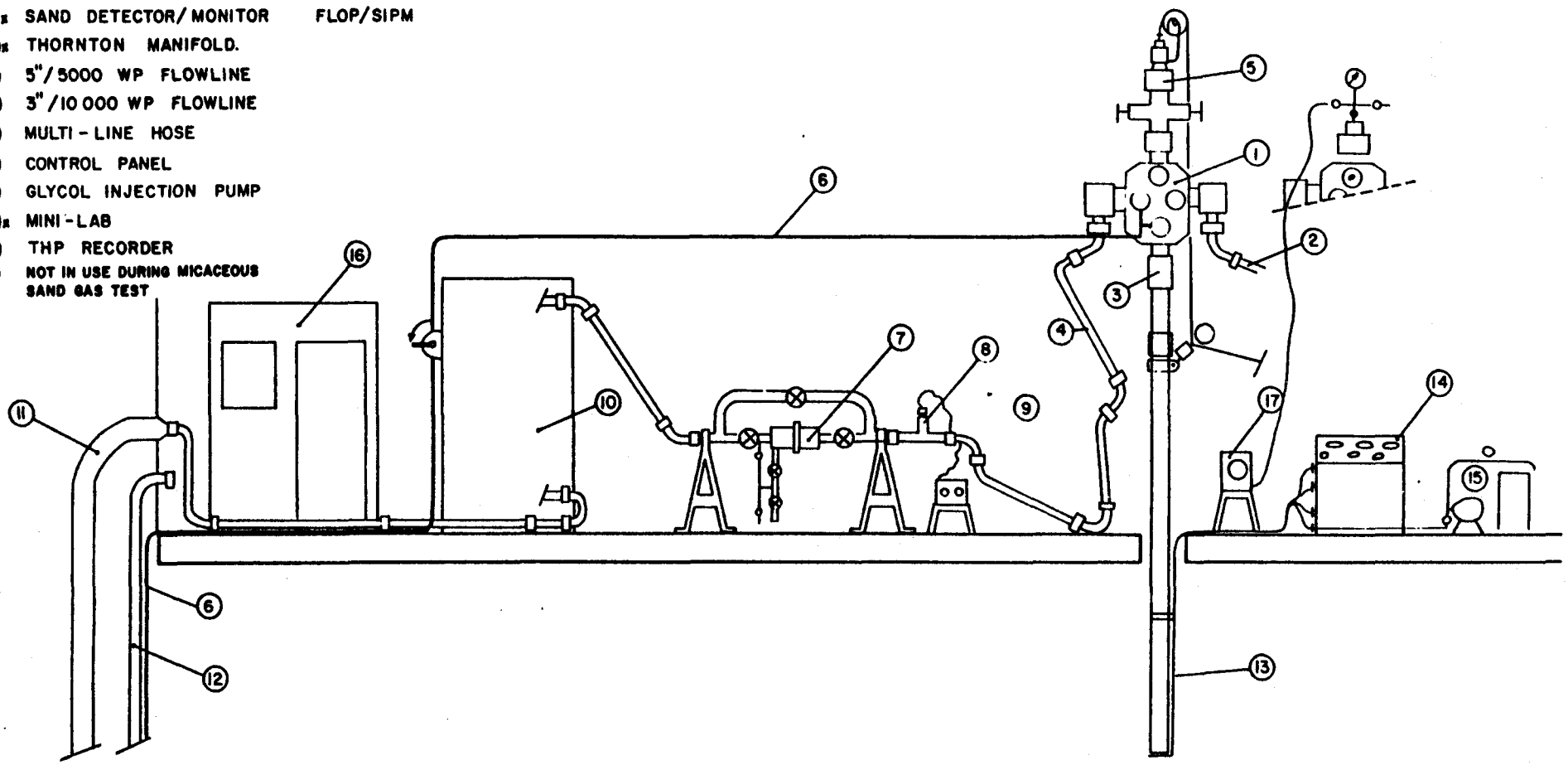
31/2-2
EXPLORATION WELL RESUME
OIL ZONE COMPLETION
PRE GAS LIFT PHASE

AUTHOR EPPO/3	FIG.	DATE NOV. 80
REPORT NO NSEP/82	1/8.3	DRAW NO 711/7

WELL 31/2-2
WELL TEST ARRANGEMENT ON DRILLFLOOR
(WEST VENTURE)

1) OTIS WELL HD + AUT M.G. AND W.V.
2) KILL LINE COMPLETE WITH B.P.V.
3) SWIVEL
4) 3"/1502 CHICKSAN LOOPS
5) 4" BOP + STUFFINGBOX
6) SHUT DOWN LINE TO W.V. AND M.G., OPERATIONAL AT 3 POINTS
7) BAKER KNOCK OUT SAND FILTER + BY-PASS + DRAIN.
8) x SAND PROBE + HOUSING
9) x SAND DETECTOR/MONITOR FLOP/SIPM
10) x THORNTON MANIFOLD.
11) 5"/5000 WP FLOWLINE
12) 3"/10 000 WP FLOWLINE
13) MULTI-LINE HOSE
14) CONTROL PANEL
15) GLYCOL INJECTION PUMP
16) x MINI-LAB
17) THP RECORDER

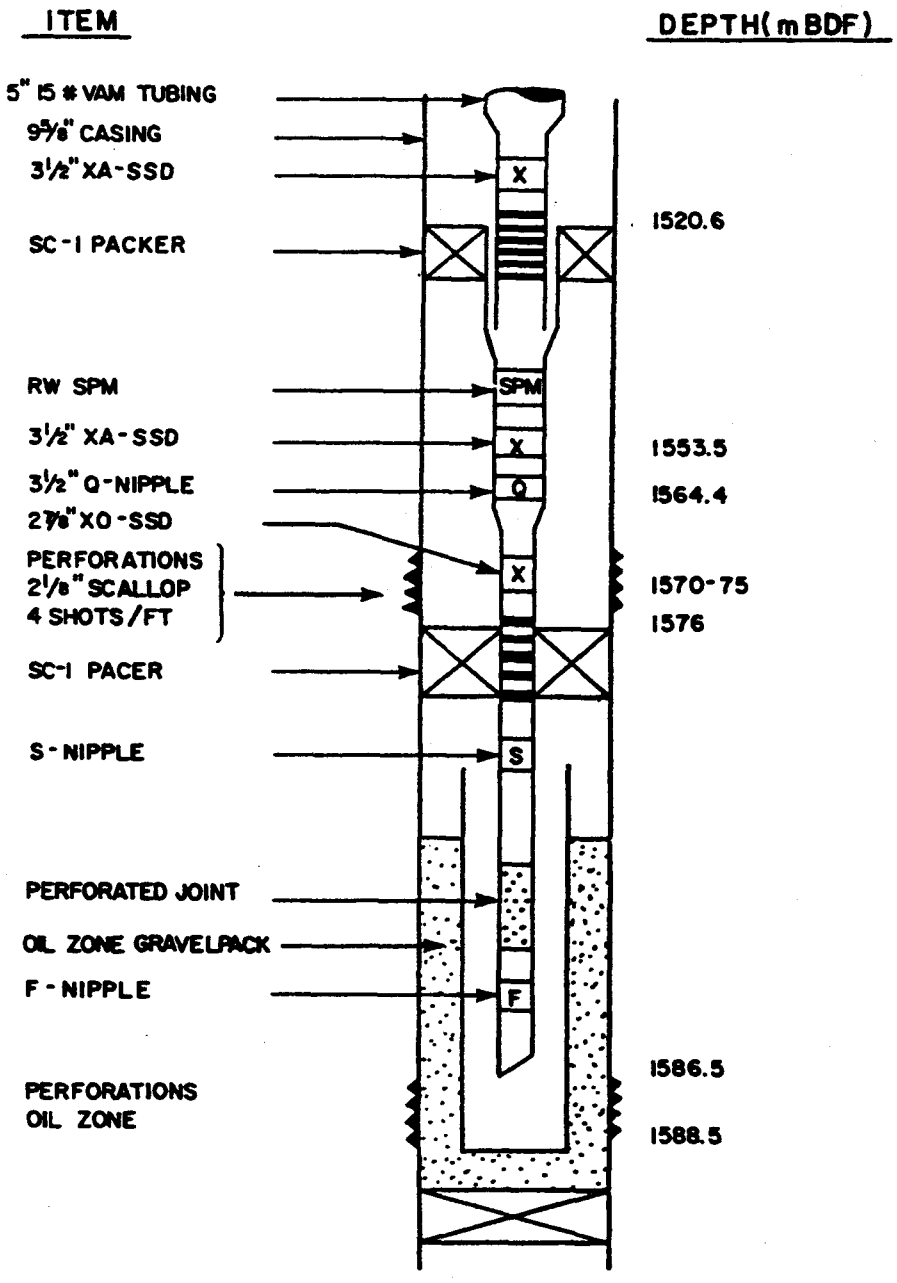
x) NOT IN USE DURING MICACEOUS SAND GAS TEST



A/S Norske Shell EXPLORATION & PRODUCTION NORWAY	
31/2-2 EXPLORATION WELL RESUME TEST EQUIPMENT ARRANGEMENT	
AUTHOR: EPPP/21	DRG.
REPORT NO.: RESERVE 1/84	DATE: NOV. 80
	DRAWING NO.: TW/1

31/2-2

TEST STRING FOR OIL ZONE GAS LIFT AND MICACEOUS SAND GAS TEST



NOTE: m BDF = mSS + 33m
TOP RESERVOIR AT 1544.5 m BDF

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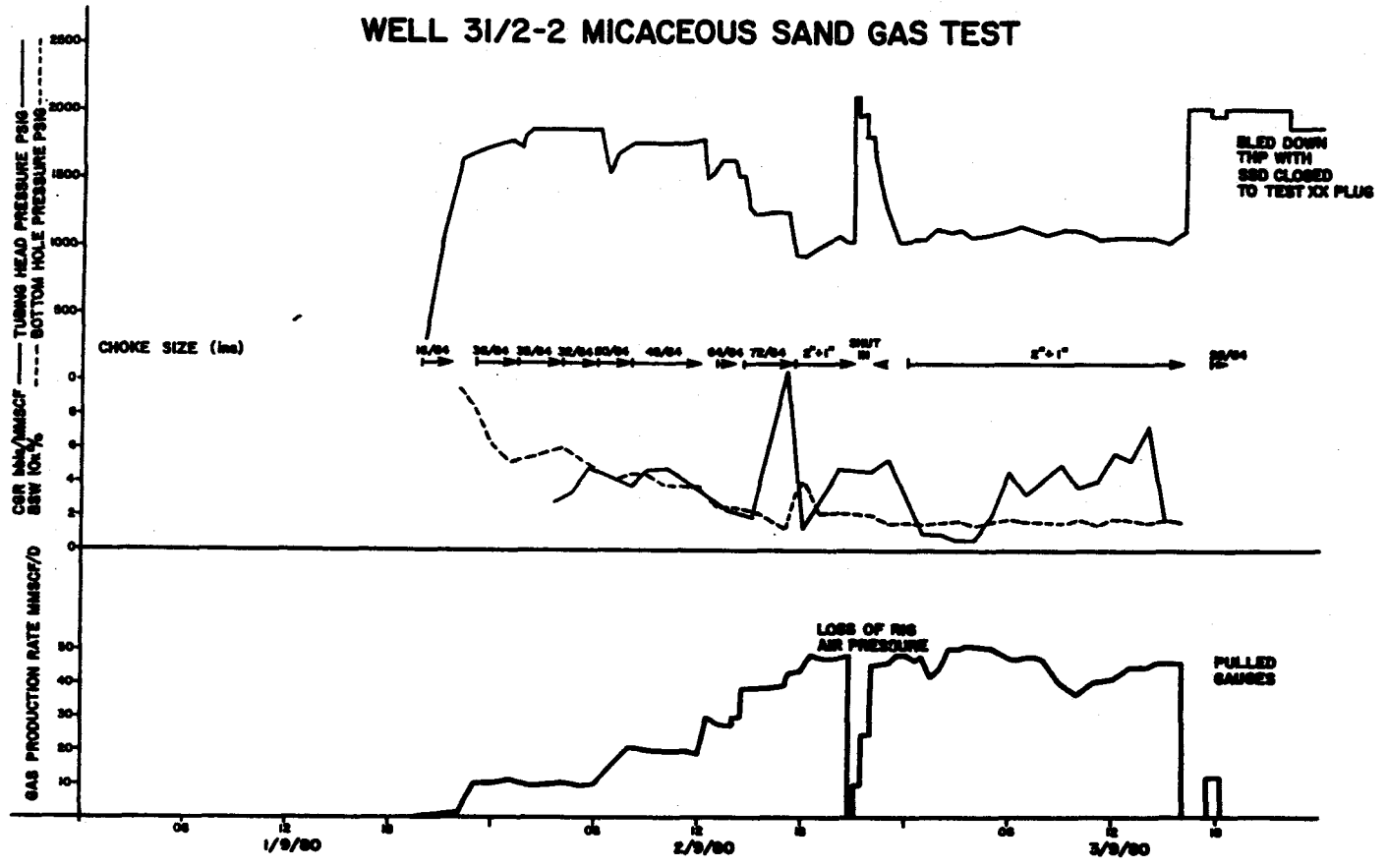
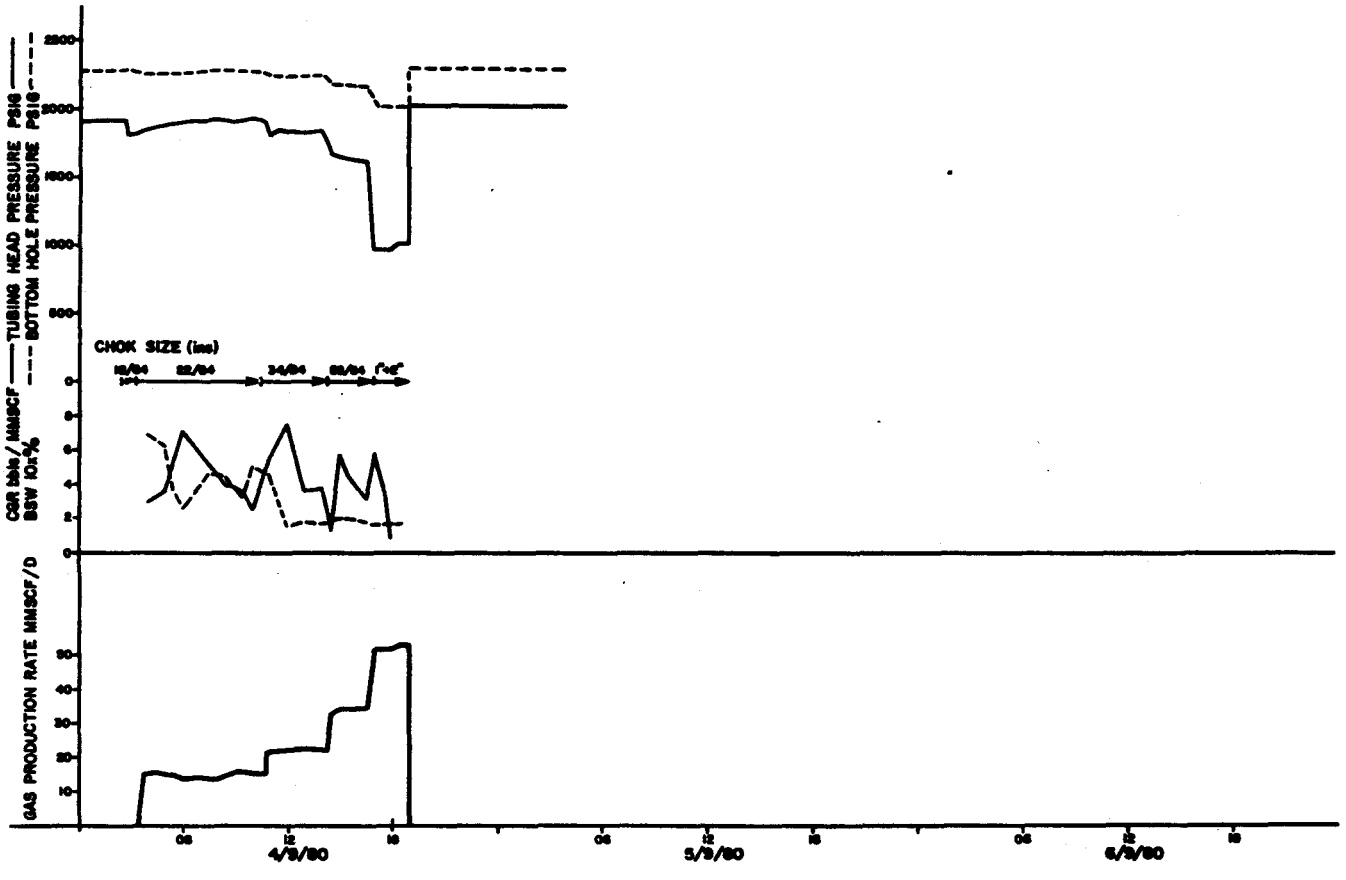
EXPLORATION & PRODUCTION FORUS

31/2-2
EXPLORATION WELL RESUMÉ
OIL ZONE AND MICACEOUS
SAND TEST STRING

AUTHOR EPPP/21 | FIG. I/8.5 | DATE NOV. 90
REPORT NO NSEP/92 | DRAW NO 711/10

WELL 31/2-2 MICACEOUS SAND GAS TEST

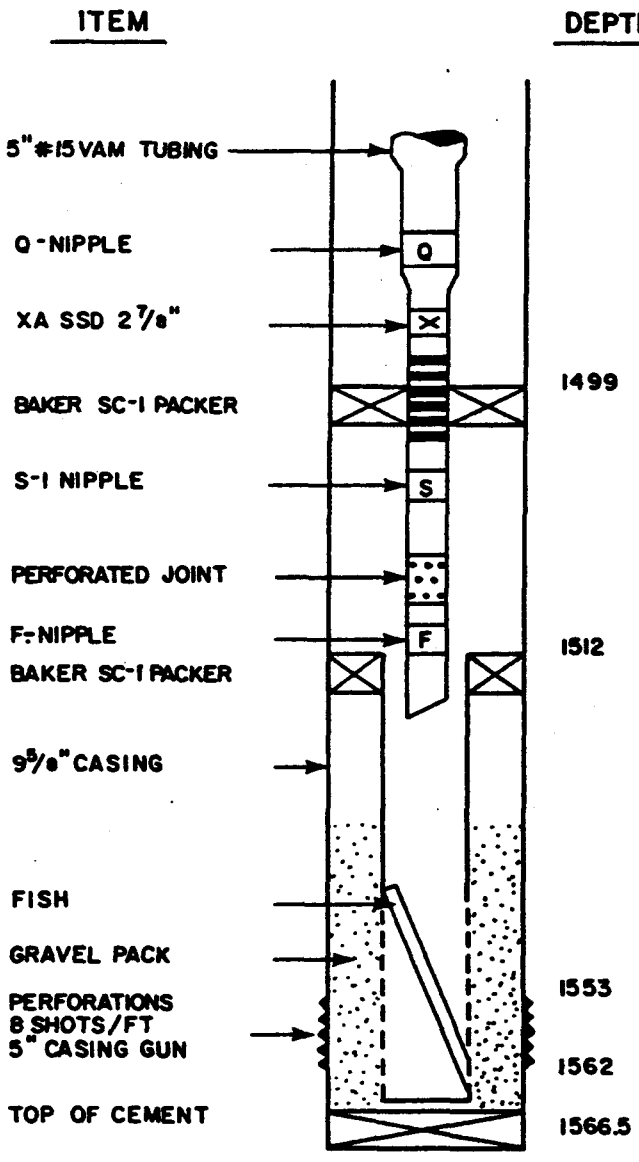




a·s Norske Shell EXPLORATION & PRODUCTION FORUS		
31/2-2 **EXPLORATION WELL RESUMÉ** MICACEOUS SAND GAS TEST		
AUTHOR: EPPP/21	FIG.	DATE: NOV. 1980
REPORT NO.: NSEP/92	I/8.6	DRAW.NO.: 711/12

31/2-2

CLEAN SAND
GAS TEST STRING



NOTE: mBDF = mSS + 33m
TOP RESERVOIR AT 1544.5 mBDF

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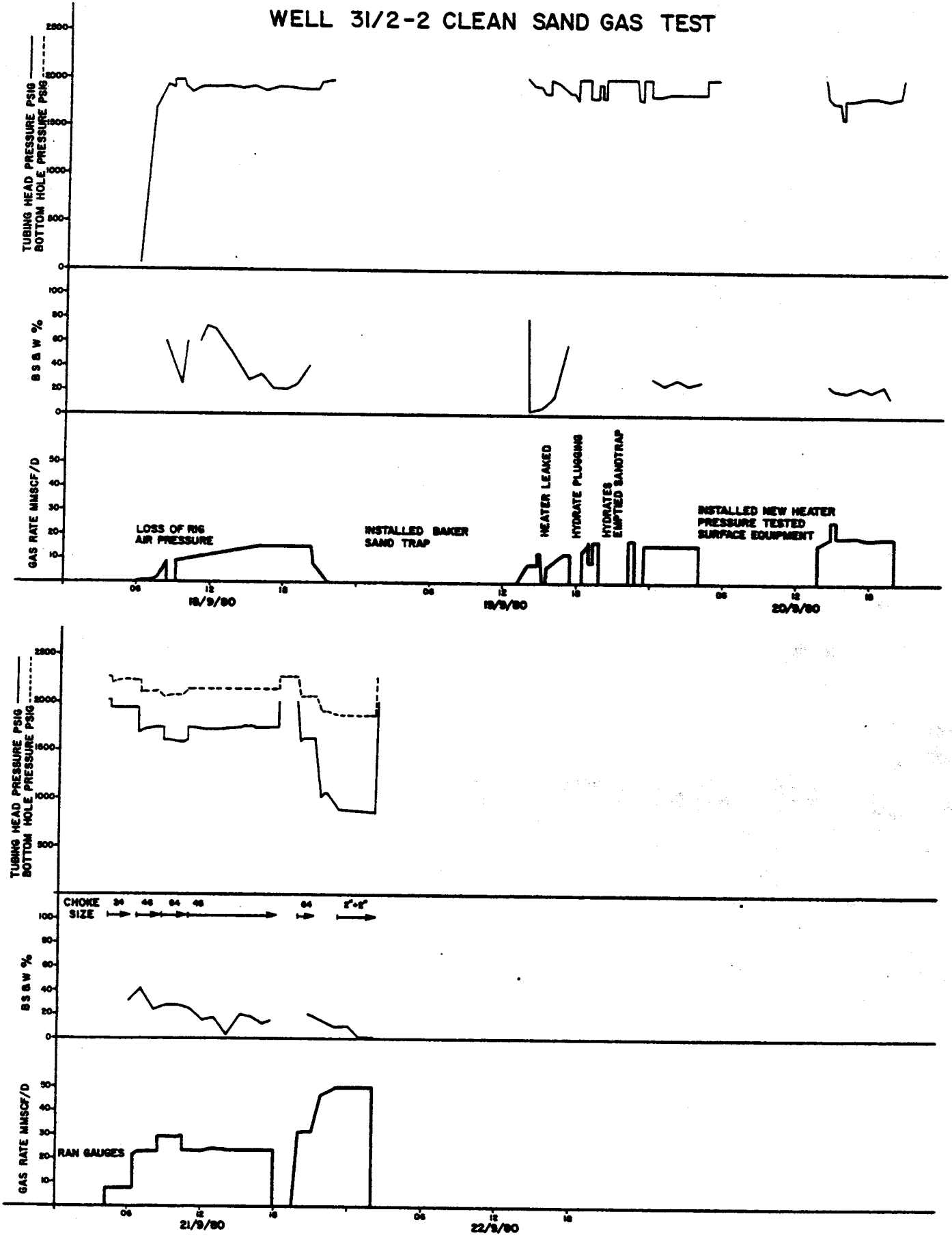
EXPLORATION & PRODUCTION FORUS

31/2-2
EXPLORATION WELL RESUMÉ
CLEAN SAND GAS TEST STRING

AUTHOR EPPP/21	FIG.	DATE NOV. 90
REPORT NO NSEP/92	1/87	DRAW NO 711/15

WELL 31/2-2 CLEAN SAND GAS TEST



a·s Norske Shell EXPLORATION & PRODUCTION FORUS		
31/2-2 EXPLORATION WELL RESUMÉ CLEAN SAND GAS TEST		
AUTHOR: EPPP/21	FIG. I/8.8	DATE: NOV. 1980
REPORT NO.: NBEP/92		DRAW. NO.: 711/14