WELL 31/2-3

## WIRELINE FORMATION TESTS

### Objectives

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

1. Confirm formation fluid pressures, pressure gradients and fluid contacts obtained from RFT's in Wells 31/2-1 and 31/2-2
2. Obtain preliminary fluid samples at selected depths to confirm reservoir contents, and for PVT analysis.

### Summary and Results

A total of 10 RFT runs were made. The first run indicated pressure gradients very similar to those obtained in Wells 31/2-1 and 31/2-2 (see Fig.I/9.1)It was, however, impossible to confirm the 12 meter oil gradient indicated by RFT's in Well 31/2-2.

Sampling attempts in the water zone failed as only mud filtrate was recovered. In the suspected oil zone, no samples were obtained in spite of numerous attempts, as the tool probe always plugged in the relatively tight and poorly consolidated formation. Only two gas samples were obtained, one in the so called clean sand at the top of the formation and the other in the micaceous sand below (See Figs. I/9.1 & I/9.2).

### Operational Aspects

One major point of interest was whether RFT pressures and samples could confirm or invalidate the presence of an oil column between the gas and the water at about 1570 - 1590 meters BDF. Cores recovered from this depth and also somewhat deeper had been bleeding oil. Also the logs indicated high oil saturation. In well 31/2-2 an oil sample had been recovered with the RFT and RFT pressure readings indicated an oil column of approximately 12 meters (1579 - 1591 m BDF in 31/2-2 corresponding to 1571 - 1583 m BDF in 31/2-3) .

In the first run, RFT 1, fifteen pressure readings were taken from 1387 to 1750.5 meters BDF. The formation fluid pressure gradients resulting from these pressure readings basically confirmed the gradients obtained from RFT's in wells 31/2-1 and 31/2-2. However, due to few pressure readings and one abnormally high reading, the presence of an oil gradient could neither be positively confirmed nor excluded (See Fig. I/9.1. A sampling attempt at 1592.7 m BDF resulted in recovery of a segregation sample only, which was determined by resistivity measurement to be pure mud filtrate.

In the remaining runs RFT 2 through 10 the objective was to obtain samples from the gas and water bearing parts of the formation and in particular to obtain samples in and around the potentially oil bearing part. The aim was to bracket the top and bottom of the potential oil column. However, the success was limited as no sample could be obtained in the oil zone, in spite of numerous attempts. Only two successful gas samples were obtained, one in the upper part of the gas zone (1458 m BDF) and the other one at 1568.5 m BDF which is immediately above the top of the oil estimated at about 1571 BDF. Below the oil a sample of mud filtrate was obtained at 1593 m BDF (See Figs. I/9.1 & I/9.2).

The problems experienced in attempting to obtain a sample in the oil zone are felt to be due to the relatively tight and rather unconsolidated formation. Every time the sample chamber was opened a large drawdown was created and the probe would plug instantaneously probably with mica platelets from the formation. Attempts were made with different probe lengths, different probe filters, different choke sizes and even with another RFT tool. However, no improvement was obtained.

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, the relatively tight micaceous sand gas zone and the highly permeable clean sand gas zone.

3. To investigate sand influx problems and efficiency of the gravel pack used for the clean sand gas test.

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

5. To obtain accurate on site measurements of liquid yields and trace elements in the two gas tests.

Summary and General Results

A total of four intervals were tested. A drill stem test was performed in the water zone at 1600.5 - 1605 m BDF. Tests with regular production strings and perforated completions were carried out in the oil zone at 1577.5 - 1582.5 m BDF and in the micaceous part of the gas bearing section at 1520 - 1535 m BDF. The top clean part of the gas section was tested with a production string and an internal gravel pack completion at 1435 - 1460 m BDF (See Fig. I/9.3).

After the bottom hole test valve was opened for the DST in the water zone, the well flowed for 17 minutes until it died. Some 87.5 liters of formation water (70,000 ppm NaCl equivalent) were recovered.

In the test on the oil zone the well came in at a low rate and flowed at about 30 - 40 B/D for four days. The oil was about 24$^{o}$ API and the GOR around 200 SCF/B. A buildup towards the end of the test indicated a formation permeability of some 20 md and no skin (See Figs. I/9.8, I/9.9 and Table I/9.5).

The micaceous gas zone test stabilized at a rate of about 5 MMSCF/D on 28/64" choke during the clean up period. The tubing head pressure was about 1200 psig. A sequential rate test followed with an extended maximum rate of about 6 MMSCF/D. However, analysis of the bottom hole pressures indicated that the well inflow performance was improving gradually during the sequential test. Thus the rate-dependent skin or turbulence could not be determined. The build-up following the last rate of this sequential test indicated a kh value of about 765 mdft corresponding to a permeability of 16 md. The skin factor (including turbulence) was estimated at 25 (76% of drawdown) (Refer to Figs I/9.12, I/9.13 and Table I/9.10).

When the well was beaned up after the shut-in it became obvious that the inflow performance continued to improve and finally a rate of 30 MMScf/D was achieved with a tubing head pressure of about 700 psig. A buildup following this rate indicates a kh of about 12000 mdft which is 16 times the value from the first buildup. (See Fig. I/9.14 and Table I/9.12) The skin factor (including turbulence) was estimated at 116 or 95% of drawdown. The explanation for the increased kh could be that a channel developed behind the casing creating communication with the better sand some 10 meters above the top of the perforations.

Evaluation of the variable rate test following the buildup indicates that some 78% of the drawdown prior to the buildup was caused by turbulence. The Darcy skin factor was estimated at 23.5 (See I/9.15 and Table I/9.13).

The results from the third and last pressure buildup were essentially equivalent to those obtained in the second buildup.

The clean sand gas test which was performed with a gravel pack completion, was dominated by severe turbulence effects. After the initial clean up at 13 - 17 MMSCF/D flow rate, the well produced at maximum rate of about 40 MMScf/D. Restrictions through surface facilities maintained the tubing head pressure at 800 psig. In the first buildup the pressure stabilized in 3 minutes, indicating a very high transmissibility together with high turbulence and skin effects. It is not possible to derive a value for kh from the buildup. The second and third buildups were similar.

The variable flow period following the second buildup provided valuable quantitative information. The drawdown is essentially caused by turbulence as illustrated in Fig. 35. Assuming no Darcy skin (which is unlikely) the smallest possible permeability value was estimated at 1.7 D. It is, however, reasonable to assume same Darcy skin factor and thus a permeability which is much higher than the indicated minimum value. The fourth and last buildup (See Fig. I/9.23 and Table I/9.19) indicated that the permeability might be in order of 8D.

The test interpretations can be summarized as follows:

| Zone | Rate MMSCF/D (B/D) | kh mdft | Perm. md | Total Skin Incl. Turb. Factor | Total Skin Incl. Turb. % of Drawd. | Darcy Skin Factor | Darcy Skin % of Drawd. |
|---|---|---|---|---|---|---|---|
| Oil Zone | (32) | 334 | 20 | 0 | 0 | 0 | 0 |
| Mic. Gas Zone | | | | | | | |
| First BU | 6.0 | 765 | 16 | 25 | 76 | N.A. | N.A. |
| Second BU | 32.6 | 12177 | N.A. | 116 | 95 | 23.5 | 17 |
| Clean Gas Zone | | | | | | | |
| Min Case | 38.1 | 144500 | 1700 | 632 | 99 | 0 | 0 |
| Possible Case | 38.1 | 635000 | 7700 | 2800 | > 99 | 24 | < 1 |

## 31/2-3 DRILL STEM TEST

A drill stem test was performed on the interval 1600.5 - 1605 m. From logs, the interval was thought to be water productive, but have approximately 15% oil saturation. The object of the test was to obtain a formation water sample and to determine whether any oil was producible.

The assembly was run as shown, (Fig. I/9.3) with 1250 m of fresh water cushion providing 500 psi drawdown on the formation. The RTTS packer was set at 1574 m, and after opening the APR-N valve indications of inflow was observed for 17 minutes. The level of the water cushion rose 275 m to 49 m BDF before the well was dead.

87.5 litres of formation water were recovered from the sample chamber, in four samples. The resistivities of the samples were measured, and are given below together with calculated salinities.

| Sample no | Volume(litres) | Resistivity(Ohm, m) at 11$^{o}$ C | Salinity (ppm NaCl) calculated |
|---|---|---|---|
| 1 (bottom of chamber) | 25 | 0.155 | 67,000 |
| 2 | 25 | 0.152 | 68,000 |
| 3 | 25 | 0.153 | 68,000 |
| 4 (top of chamber) | 12.5 | 0.145 | 69.000 |

N.B. Brine resistivity 0.0606 ohm m at 14.5$^{o}$ C +/- 200,000 ppm
Water resistivity 3.340 ohm m at 14.5$^{o}$ C +/- 2100 ppm

Thus samples are considered representative of formation water as a salinity of some 70,000 ppm was predicted from logs.

From the pressure gauges, a formation pressure of 2307 psig was calculated. This corresponds well with the RFT data. (See Fig. I/9.1).

## OIL ZONE PRODUCTION TEST

### Objectives

The oil zone production test was carried out on the interval 1577.5 - 1582.5 m, which logs had indicated to be oil bearing. The objectives were as follows:

a) to test the presence of movable oil
b) to ascertain at what rate this oil might be produced
c) to evaluate well inflow performance and possible water and/or gas coning effects
d) to obtain PVT samples

### Test Description

The production test string having been run (see Fig. I/9.4), the surface equipment was installed (as Fig. I/9.5), except that for the oil test the sand trap, sand detection equipment and the Thornton sampling equipment were not required. The tubing was displaced to diesel through the XA-SSD, and the zone was perforated. The test sequence is shown in Fig. I/9.6.

After the well was perforated, it was cleaned up at a rate less that 100 B/D on a 4/64" choke. One Sperry Sun, and one Amerada pressure gauge were run, and the well was then flowed on an 8/64" choke, still unloading diesel. The flowrate dropped almost to zero for 3 hours with some gas being produced. A sample of this gas was taken, and Geoservice found it to be 100% methane. The flowrate began to climb again, the well was then flowed for a further 55-1/2 hours. The pressure gauges, when recovered, indicated that the well was flowing stably after about 24 hours. A certain amount of the fluctuation in the flowrate was due to the method of measurement (based on stock tank level). The well was flowing approximately 30 B/D crude oil, 24$^{o}$ API, with approximately 5 MSCF/D gas, gravity 0.691. Traces of sand and water were seen. Surface samples of oil were taken, then Flopetrol took their bottom hole samples on 6.7.80 after the well had produced 80 bbls; the tubing contents + rathole were 58.9 bbls. The first sample taken was discovered to contain brine. A second sample was recovered from 1438 m, then a third together with a Sperry Sun gauge to establish fluid gradients in the tubing. The results of this survey which Sperry Sun characterized as a misrun, because of the unreasonably high pressure gradients at top and bottom of the surveyd interval, are seen on Fig.I/9.7.The second and third samples were found to have good opening pressures and bubble points (opening pressures 1240 and 1470 psig, and bubble points 1500 and 1460 psig at 64$^{o}$ F respectively). In view of the results of the gradient survey, a tandem sampler was run to 1460 m which was considered to the lowest safe sampling point. Two further oil samples were obtained.

New Sperry Sun and Amerada pressure bombs were run, and the well was shut in for a build up survey of 18 hours. The Sperry Sun gauge failed, but the Amerada was successful and gave a stabilized bottom hole pressure of 2248 psig at 1561 m BDF. Analysis of the pressure build up indicated a formation permeability of 20 md and no skin (see Figs. I/9.8, I/9.9 and Table I/9.5). The first attempt to retrieve to bombs failed due to being unable to latch into the bombs. The well was flowed briefly to clear away sand suspected, to be on the fishing neck and F nipple. The bombs were then retrieved successfully, new bombs were run, and the well was opened on an 8/64" choke. It was flowed for 5 hours, after stabilising, with a rate slowly increasing to 43 B/D. The oil gravity (with emulsion) dropped to 15$^{o}$ API, and some water was produced, with the BSW rising to a peak of 24%.

The choke was increased to 16/64", and the well flowed at approximately 60 B/D. The oil gravity returned to 22° API, and the maximum BSW was 9.5%. The well was then flowed for 27.5 hours on a 1/2" choke. The flow did not stabilize, the average production over the period was 86 bpd, and on average, the production rate did not change significantly during this period, however, the bottom hole flowing pressure dropped from an initial average of 1825 psi to 1650 psi at the end. There was no evidence of water coning the BSW was generally +/- 1% with occasional peaks of 5%. Unfortunately, due to the higher rate of gas production, the meter on the surge tank could not function, and in this last flow period, the gas flow rate could not be monitored.

The well was beaned to 8/64" to recover the gauges. These has worked successfully, and the well was closed in and the test concluded.

Measurements

During flowing periods the following data were read every 15 mins (Refer Fig. I/9.5).

| | |
|---|---|
| Well head Pressure | From dead weight tester (DWT) and Foxborough chart recorder measured at the data header |
| Well head temperature | From mercury thermometer in the choke manifold and Foxborough charter recorder |
| Annulus Pressure | From the kill line |
| Liquid Flow rate (B/D) | Calculated from measurements of the surge tank level |
| Gas Flow rate (SCF/D) | Measured with precision gas meter installed in the surge tank vent. |

The latter two parameters were measured unconventionally as the very low flow rates and pressures pecluded the use of the separator.

Produced fluid densities were measured. The gas was monitored for $H_2S$ and $CO_2$ content with Dräger tubes, and was also analysed on site with the Geoservice chromatograph.

During pressure build-up surveys, wellhead pressures was read

i) every 5 minutes during initial lubricator calibration stop

ii) every 15 minutes during the flow period

iii) after closing in, every 5 minutes for the first hour, then every half hour

iv) every 5 minutes during gradient stops while pulling the bombs

v) every 5 minutes during the final lubricator calibration stop

Downhole pressures were measured by Sperry Sun MRPG gauges and Ameradas. The MRPG's also recorded temperature.

Test Sequence

The test sequence may be summarized as follows:

Test Sequence

(Refer to Fig. I/9.6)

| PHASE | PERIOD hrs | date | DURATION hrs | CHOKE 1/64 Ins | FLOW RATE BPD Initial | FLOW RATE BPD Final | CUM Prod. bbls | WHP psig Init. | WHP psig Final | BHP psig Init. | BHP psig Final |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PERFORATED | 1452 | 4.6.80 | | 4 | - | 38 | - | 20 | 36 | - | - |
| CLEAN UP | 1744-2305 | 4.66.80 | 5.35 | 8 | 45 | 156 | - | 14 | 110 | - | - |
| | 2305-0515 | 5.6.80 | 6.17 | 4 | 9 | 72 | 25.8 | 134 | 125 | - | - |
| | 0515-0930 | 5.6.80 | 4.25 | | | | | | | | |
| | 0930- | 5.6.80 | | | | | | | | | |
| | 1700 | 7.6.80 | 55.50 | 8 | 72 | 58 | 105.9 | 125 | 92 | - | - |
| BUILD UP | 1700- | 7.6.80 | | | | | | | | | |
| | 1100 | 8.6.80 | 18.00 | - | - | - | - | 92 | 216 | 1032 | 2248 |

Flowed well for 1.40 hrs (3.1 bbls) to assist in latching on to pressure

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MAIN FLOW | 2330-0610 | 8.9.80 | 6.67 | 8 | 35 | 43 | 119.1 | 82 | 79 | 2055 | 2042 |
| | 0610-1100 | 9.6.80 | 4.83 | 16 | 69 | 61 | 132.8 | 33 | 19 | 1893 | 1913 |
| | 1100- | 9.6.80 | | | | | | | | | |
| | 1430 | 10.6.80 | 27.5 | 32 | av. | 80 [illegible] | 228.7 | | | | |

Table I/9.1

## MICACEOUS SAND GAS TEST

### Objectives

This test was performed on the interval 1520 - 1535 m BDF, in the highly micaceous sand of lower permeability below the main, clean, section of the gas bearing reservoir. The objectives were:

a) to assess well inflow performance; permeability, skin and turbulence

b) to obtain PVT samples at separator conditions for subsequent analysis

c) to obtain atmospheric condition condensate samples

d) to obtain accurate well head composition, and liquid gas ratios using the Thornton "Minilab".

e) to obtain impurity and trace element measurements using KSLA equipment (Hydrogen sulphide, mercury, radon and water)

### Test Description

A production string was run as shown in Fig.I/9.10,and the tubing was displaced to diesel through the XA-SSD prior to perforation. The surface equipment was installed as in Fig.I/9.5, the Baker sandtrap was installed during the test when it became available. The test sequence is shown in Fig. I/9.11.

After perforation, the well was opened on an 8/64" choke, to unload the diesel. After five hours it was largely flowing gas, and was passed through a 28/64" choke to the separator. The well was allowed to clean up for a further 27 hours, producing gas of gravity 0.617, and condensate of 50.3$^{o}$ API, with some water (mostly brine), and traces of sediment. The gas contained no detectable $H_2S$ and approximately 0.4% $CO_2$.

During the last 12 hours of the clean-up period, the rate was fairly stable at +/- 5 MMSCF/D, and some preliminary sampling was done. PVT samples nos 1-3 of gas and condensate were recovered from the separator, and Thornton and KSLA did preliminary work (see results in Tables I/9.6&I/9.7).

Difficulties were experienced in running the pressure bombs due to heavy hydrate formation. Methanol was injected, and after a successful drift run the Sperry Sun and Amerada pressure bombs were installed. They remained on bottom for 6 hours recording a stable pressure of 2243 psig, corresponding to a static reservoir pressure of 2265 psia at 1527.5 m BDF.

The bombs were then pulled, and rerun with longer duration (112 hrs) clocks. The first sequential rate test was then performed, with 1-1/4 hours flow periods at rates of 1.3, 2.4, 3.4 and 5.2 MMSCF/D. However, the inflow performance was improving gradually during this test (see Table I/9.8). Thus the Darcy flow and turbulence coefficients could not be determined. The last rate was extended for 24 hours with the rate slowly increasing from 5 to 6 MMSCF/D. The WHP was also increasing. During this period Thornton took samples, (See Table I/9.6), and Geoservice made gas analyses (95% C-1, See Table I/9.9).

The well was closed in for 6 hours, for the first build up period. Analysis of the pressure buildup indicates a formation permeability of 16 md and a skin factor of 25 (76% of drawdown-including turbulence). (See Figs. I/9.12,I/9.13 and Table I/9.10).
since the well was still cleaning up during the first sequential test. The well was flowed for 4 hours at each of the following rates: 1.3, 2.4 and 3.7 MMSCF/D. Gas and condensate recombination samples no 4 were taken at the separator during the last flow rate of this test. However, it was still apparent that the inflow performance was improving during this test.

The well was closed in, and the pressure bombs retrieved. The well was then opened up for a maximum rate test. Flowing for 4-3/4 hours on a 44/64" choke, the flow rate and WHP increased considerably. After increasing the choke to 48/64" the rate and WHP continued to rise.

It had been suspected from the sequential tests, and became apparent with the last test, that the well had not cleaned up completely It was therefore decided to close the well in, and run Sperry Sun and Amerada pressure bombs before beaning the well up, in approx 1 hour stages, to its maximum flowing rate.

Thus the well was opened up and the third sequential rate test was commenced. The well was flowed for approximately 1-1/2 hours at the following rates: 16, 21, 23, 28 and 30 MMSCF/D observing for sand production with the Sand-dec probe. Each time the choke was increased there was a corresponding increase in counts from the probe, but this always returned to a base level close to zero.. At the maximum rate the adjustable choke was reduced from 104 to 92 because it exercised no control over the system at higher settings due to downstream restrictions. After 8-1/2 hours the flow rate stabilized at 32.6 MMSCF/D, and this was maintained for 3 hours. As may be seen in Table I/9.11 the inflow performance continued to improve also during this sequential test with essentially the same bottom hole flowing pressures at 16 and 32 MMSCF/D. Following the last rate the well was shut in for the second build-up period, of 9-1/2 hours.

Analysis of the pressure buildup (see Fig. I/9.14 and Table I/9.12) indicates a kh value of some 1200 mdft which is 16 times the value estimated from the first buildup. The skin factor (including turbulence) was as high as 116 (95% of drawdown). The reason for the increased kh is believed to be development of a channel behind the casing (poor cement bound log) creating communication with the better sand some 10 meters above the top of the perforations. The very high skin/turbulence could support this theory.

During the shut in period, the Baker sand trap was installed. This necessitated closing the flowhead wing valve, so that no WHP readings are available for this time. The sand trap was installed just downstream of the flowhead and sandec spool, in order not only to trap sand but also to calibrate the sandec equipment. Due to its suspected action as a separator, later confirmed, the sand trap was bypassed during Thornton's attempts at sampling. The adjustable choke, and chiksan elbows downstream showed signs of sand erosion and were replaced during the shut in period.

The well was then opened for a fourth, and final, sequential rate test.

The well was flowed:

5 hours at 9.5 MMSCF/D
9 hours at 18.1 MMSCF/D
4½ hours at 27.5 MMSCF/D

Analysis of this sequential test (see Fig.I/9.15 and Table I/9.13) indicates that turbulence effects are very significant. Combined with results from the second buildup it is found that at 32.6 MMSCF/D (rate prior to buildup) some 78% of the total drawdown is caused by turbulence. Out of the total skin factor of 116 seen in the buildup only 23.5 is Darcy skin. The remainder is turbulence. Only 5% of the drawdown corresponds to Darcy flow drawdown on the formation.

The second flow period was extended to allow Thornton to take more samples. However, there were severe hydrate problems. The well had to be closed in suddenly when the line from the separator to the gas flare plugged and the separator pressure rose sharply. This was due, in part, to an inadequate steam supply to the heater, which was improved gradually during the course of the tests. There were further hydrate problems, some of which seemed to emanate from the Thornton manifold itself. Injection of methanol controlled the problem, but can have a deleterious effect on the Thornton sampling procedure.

PVT recombination samples nos 5-8 were taken at the separator during this sequential rate test. Geoservice also analysed gas samples. (see Fig. I/9.9).

The well was then beaned up to its maximum rate, and the flow was stable at 31.2 MMSCF/D for 1-1/2 hours, indicating that no further cleaning up had occurred.

The well was then closed in for a 2 hour build up period (the Sperry Sun gauge reached the end of its clock and the test was concluded. As can be appreciated from Fig .I/9.6 and Table I/9.14 this buildup was essentially identical to the second buildup. The kh was estimated at 11500 mdft and the skin factor (including turbulence) at 112.

## Measurements

During the test, WHP, WHT etc were measured as detailed for the Oil Zone Test. In addition, since flow was passed through the separator, the gas flow rate was measured every 15 minutes with a Daniel orifice meter, and the liquid production rate was calculated by periodically reducing the level of condensate in the separator to a set level, by flowing into the stock tank, and measuring the volume. Sand production was monitored with the sandec probe, (see separate report). Only one probe was used, and gave only qualitiative results, because no correlation between signal and sand production was available. In addition, $H_2S$, $CO_2$ and salinity were monitored during flow periods.

## Test Sequence

The test sequence can be tabulated as follows:

Table I/9.2

MICACEOUS SAND GAS TEST

<u>Test Sequence</u> (see fig. I/9.13)

| Phase | Period | Duration hrs | Choke 1/64 ins | Flowrate MMSCF/D Initial | Flowrate MMSCF/D Final | Cumulative Production MMSCFw | WHP psig Initial | WHP psig Final | BHP psig Initial | BHP psig Final | Separator Pressure psig |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CLEAN UP | 0845-1400 15.6.80 | 5.25 | +/-16 | - | - | - | 50 | 900 | | | |
| | 1400-1700 15-16/6.80 | 27.0 | 28 | 1.82 | 5.03 | +/-4.8 | 588 | 1162 | | | |

Hydrates formed in the tubing prevented running pressure bombs (lost 10 hours)

| Phase | Period | Duration hrs | Choke 1/64 ins | Flowrate MMSCF/D Initial | Flowrate MMSCF/D Final | Cumulative Production MMSCFw | WHP psig Initial | WHP psig Final | BHP psig Initial | BHP psig Final | Separator Pressure psig |
|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIC PRESSURE MEASUREMENT | 0712-1300 17.6.80 | 5.8 | - | - | - | - | 1949 | 1948 | 2241 | 2243 | |
| SEQUENTIAL RATE TEST 1 | 0345-0500 18.6.80 | 1.25 | 12 | 1.27 | 1.30 | | 1859 | 1699 | 2162 | 2028 | 190 |
| | 0500-0615 | 1.25 | 18 | 2.37 | 2.33 | | 1514 | 1370 | 1841 | 1776 | 450 |
| | 0615-0730 | 1.25 | 23 | 3.48 | 3.36 | | 1134 | 1200 | 1453 | 1525 | 455 |
| | 0730-0730 18/19-6.80 | 24.0 | 28 | 5.00 | 6.11 | 10.7 | 1040 | 1254 | 1268 | 1459 | 475 |
| 1st BUILD UP | 0730-1330 19.6.80 | 6.0 | - | - | - | | 1254 | 1988 | 1459 | 2264 | |
| SEQUENTIAL RATE TEST 2 | 1330-1530 | 2 | 12 | 1.32 | 1.32 | | 1885 | 1882 | 2150 | 2145 | 185 |
| | CLOSED IN FOR HELICOPTER | | | | | | | | | | |
| | 1600-1800 | 2 | 12 | 1.23 | 1.29 | | 1885 | 1882 | 2156 | 2145 | 185 |
| | 1800-2200 | 4 | 18 | 2.36 | 2.38 | | 1732 | 1738 | 1982 | 2011 | 450 |
| | 2200-0200 20.6.80 | 4 | 20 | 3.68 | 3.73 | | 1540 | 1555 | 1795 | 1828 | 465 |
| MAX FLOW RATE TEST | 0845-1330 | 4.75 | 44 | 10.87 | 12.63 | | 999 | 1112 | - | - | 425 |
| | 1530-1745 | 4.25 | 48 | 15.63 | 15.85 | | 1010 | 1040 | - | - | 430 |
| SEQUENTIAL RATE TEST 3 | 0430-0600 21.6.80 | 1.50 | 48 | 15.86 | 16.01 | | 1014 | 1022 | 1281 | 1283 | 430 |
| | 0630-0730 | 1.00 | 60 | 20.32 | 20.98 | | 829 | 1179 | 1179 | 1174 | 490 |
| | 0800-1000 | 2.00 | 72 | 23.00 | 23.01 | | 754 | 754 | 1069 | 1110 | 440 |
| INCREASED TO MAX FLOW RATE | 1000-1130 | 1.50 | 78 | 26.15 | 26.27 | | 647 | 637 | 1092 | 1079 | 320 |
| | 1200-1330 | 1.50 | 90 | 26.66 | 29.46 | | 597 | 632 | 1036 | 1118 | 285 |
| | 1330-1500 | 1.50 | 104 | 28.38 | 28.64 | | 600 | 614 | 1079 | 1067 | 260 |
| | 1500-0230 22.6.80 | 11.50 | 92 | 27.57 | 32.62 | 40.16 | 594 | 689 | 1098 | 1250 | 250 |
| 2nd BUILD UP | 0230-1200 | 9.50 | - | - | - | | 689 | 1987 | 1250 | 2254 | - |
| SEQUENTIAL RATE TEST 4 | 1300-1815 | 5.25 | 28 | 9.51 | 9.53 | | 1847 | 1845 | 2120 | 2119 | 440 |
| | 1912 Closed well in when hydrates plugged flare line | | | | | | | | | | |
| | 2100-0600 23.6.80 | 9.00 | 40 | 18.51 | 18.1 | | 1610 | 1602 | 1909 | 1904 | 480 |
| | 0715-1245 | 4.50 | 64 | 27.24 | 27.50 | | 1105 | 1095 | 1576 | 1515 | 440 |
| INCREASED TO MAX FLOW RATE | 1415-1515 | 1.00 | 96 | 31.29 | 31.23 | | 679 | 680 | 1244 | 1245 | 300 |
| | 1630-1800 | 1.50 | 128 | 32.14 | 31.22 | 57.5 | 632 | 629 | 1277 | 1233 | 230 |
| 3rd BUILD UP | 1800-2000 | 2.00 | - | - | - | | 629 | 1989 | 1233 | 2257 | - |

## CLEAN SAND GAS TEST

### Objectives

This test was carried out on the interval 1435-1460 m BDF, in the so-called "clean" sand, a zone of unconsolidated gas-bearing sand, containing little mica and having a very high permeability. The objectives of the test were:

a) to evaluate well inflow performance; skin and turbulence
b) to assess sand influx, and gravel pack efficiency
c) to obtain PVT recombination samples at separator conditions
d) to obtain atmospheric condensate samples
e) to allow Thornton to measure accurate well head compositions and liquid/gas ratios
f) to allow KSLA to perform trace element analyses.

### Test Description

After the micaceous sand zone was squeeze cemented, the clean sand was perforated in viscous brine, to prevent losses. The perforations were then backsurged. Mechanical difficulties were encountered, and after the final attempt 84 bbls of viscous brine were lost to the formation. The wire wrapped screen liner was then run and gravel packed with + 6000 lbs of 20-40 mesh gravel in a "Water-Pack" slurry. The production string was run (see Fig. I/9.17), but due to a delay in the "breaking" of the "Water-Pack" carrier fluid, it was decided to acidize the well prior to production. This was performed as part of the operation of displacing the tubing string to diesel, 20 bbls of 15% and hydrochloric acid were pumped into the formation.

The well was then opened and the test commenced. The test sequence is illustrated in Fig. I/9.18.

The choke size was slowly increased to unload the well. After 3/4 of an hour 48 Bbls of diesel had been produced back and gas broke through. The well was then flowed on a 33/64" choke for 17 hours. The pH of the liquids produced was monitored, and remained low as the acid returned. The well was beaned up as to 40/64" and the clean up continued for another 11 hours. At the end of this period, liquid produced by the well was still 60% acid/brine. The gas had the same composistion as the previous test (95% C-1, see Fig. I/9.15) and no H2S was detected with the Dräger tubes.

The well was then flowed at 23 MMSCF/D for 4 hours. The flow was fairly stable, but acid and brine were still being produced. The well was then beaned up in stages until fully open. A maximum rate of nearly 40 MMSCF/D was achieved for about 11 hours, giving a total of about 48 hours clean up. By that time 75% of the liquid produced was condensate, but some acid was still being produced.

KSLA performed some preliminary sampling, but the well stream was still contaminated.

The well was closed in, and Sperry Sun and Amerada pressure bombs were run. Due to the threat of impending industrial action, the test programme was condensed at this point, to enable it to be completed before 10th July. The well was beaned up to its maximum rate and flowed for 4 hours at 41 MMSCF/D. Atmospheric pressure samples of condensate were recovered from the separator. The well was then closed in for the first pressure build up survey. It was observed that the pressure built up very rapidly, stabilising after about five minutes. Although 1 minute mode Sperry Sun gauges were used the buildup was too quick to quantitively determine the value of kh (see Fig.I/9.19) It is, however, obvious, in view of the extremely quick buildup of the 640 psi drawdown, that the values of kh and skin/turbulence were both very high.

The well was then flowed again at its maximum rate, 40 MMSCF/D, for 5 ½ hours. Flow was passed through the Thornton mainifold, causing a noticeable drop in production rate, and Thornton took samples.

The well was closed in for the second pressure build up of 1 ½ hours. Since the Sperry Sun gauges were on a 2 minute mode, this provided insufficient resolution for interpretation of the very rapid build up.

New 1 minute mode Sperry Sun gauges were run, and the sequential rate test was performed.

The well was flowed:

1 1/4 hrs at 9.6 MMSCF/D
6 hrs at 21.0 MMSCF/D
1 1/4 hrs at 30.6 MMSCF/D
1 1/2 hrs at + 38 MMSCF/D (maximum rate)

The second flow period was extended to allow Thornton and KSLA to take samples (See Tables I/9.16&I/9.17 for results). PVT recombination samples nos. 1 through 8 of gas and condensate were taken at the separator.

After maximum flowrate period , the well was shut in for the third pressure build-up. The bombs were recovered, and it was found that both Sperry Sun gauges had failed, and only the Amerada gauge had worked. This did not have sufficient time and pressure resolution to draw conclusions from this buildup data.

However, the Amerada pressures provided useful information for interpreting the variable rate test. (See Fig. I/9.20 and Table I/9.18).As may be appreciated from th resulting inflow performance relationship in Fig. I/9.21, almost 100% of the drawdown is used to overcome the severe turbulence. Assuming no Darcy skin the minimum value of the formation permeability was estimated at 1.7D. However, with the very high turbulence, it is reasonable also to assume a high Darcy skin factor and thus a much higher permeability.

The maximum flow rate achieved, of ca. 40 MMSCF/D, was considerably less than had been expected. With the severe turbulence it was suspected that, despite the backsurging and acidisation some of the perforations might be plugged. A PCT was run, consisting of a flow meter, high resolution thermometer and casing collar locator. After two misruns, in which the CFS, continuous flow-meter sonde, failed, the full bore spinner was run and functioned successfully. With the well flowing at 24.4 MMSCF/D, the flow meter indicated a flow profile as illustrated in Fig. I/9.22. The results can be tabulated as follows:

| Interval (m BDF) | % of total flow | Rock Properties |
|---|---|---|
| 1436-1442 | ca. 50 | clean, highly permeable sand |
| 1442-1450 | ca. 10 | deteriorating permeability, highly micaceous in parts |
| 1450-1457 | ca. 35 | top 5m: deteriorating permeability some limestone streaks bottom 2m: good, highly permeable sand |
| 1457-1460 | ca. 5 | good highly permeable sand |

Thus, the perforations were found to be not producing equally, with half of the flow coming from the top 6m. This profile does not correspond closely with the lithological differences seen, and appears to indicate plugging of the perforations at the bottom of the interval.

The HRT shows an anomalous temperature gradient in the interval, and yields no useful information.

In order to gain better build up information, two Sperry Sun gauges were run, one in a 15 second mode, the other in a 30 second mode. The well was then flowed for:

1 hour at 20.7 MMSCF/D
1 hour at ± 39 MMSCF/D

This was followed by a 3 hour pressure build up survey, and the gauges were recovered. The 15 second mode gauge had failed, but the other functioned.

The two rate test gave similar BHFP's to those obtained in the previous four rate test. The buildup was extremely fast (essentially fully built up in 3 minutes). A McKinley type curve plot of the buildup is shown in Fig. I/9.23 However, there is no type curve of high enough transmissibility to fit the data. As explained in Table I/9.19, however, it is believed that the formation permeability may be as high as 8 Darcies.

The test was then concluded prior to the outset of industrial action.

## Measurements

Measurement during the test were as described under the Micaceous Sand Gas Test.

## Test Sequence

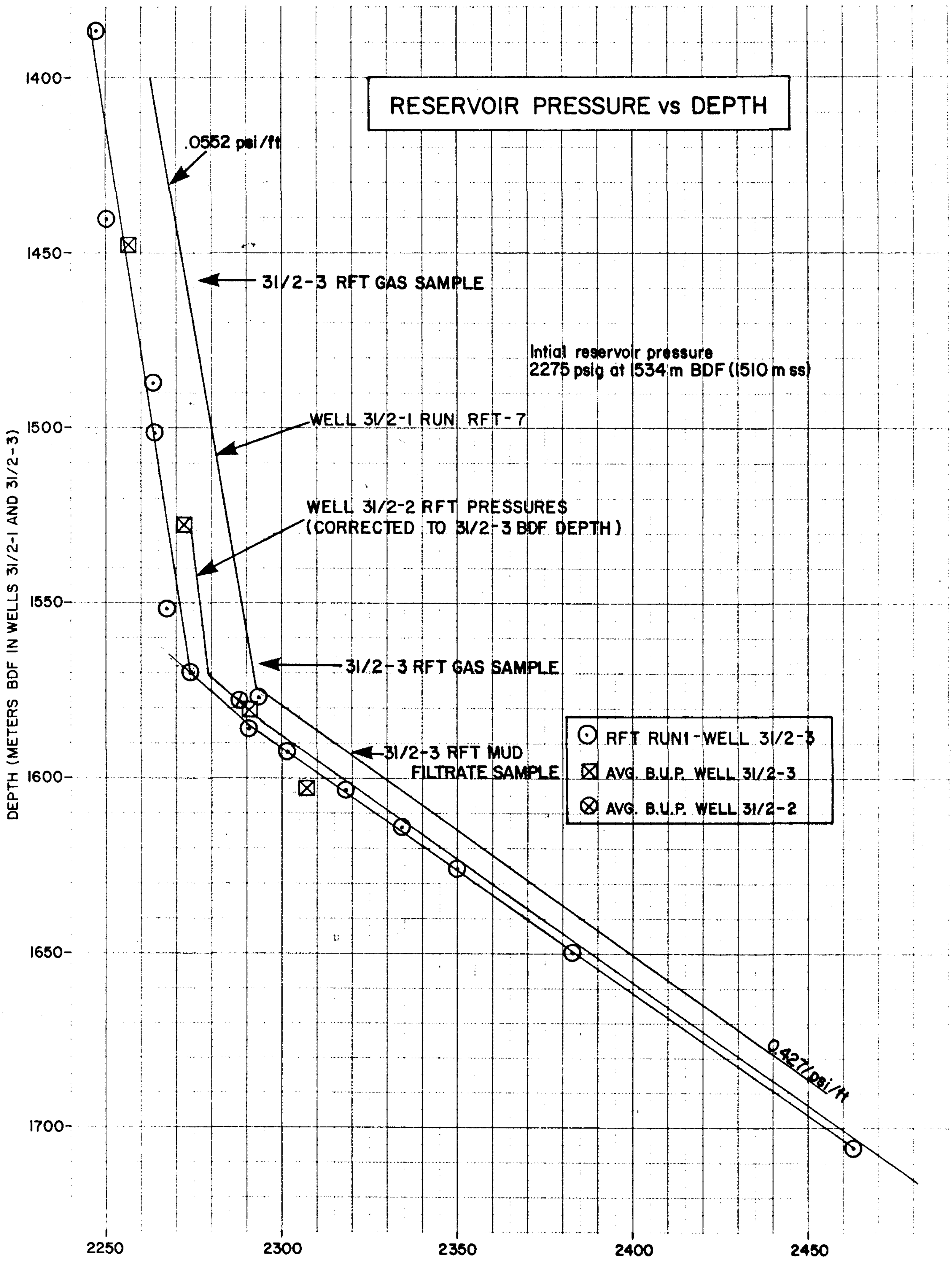
The Test sequence can be tabulated as follows:

# CLEAN SAND GAS TEST SEQUENCE

| PHASE | PERIOD | | TIME HRS | CHOKE INSX1/64 | FLOWRATE MMSCF/D | | CUM PROD MMSCF | WHP psig | | BHP psig | | SEPARATE PRESSURE psig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Init. | Final | | Init. | Final | Init. | Final | |
| CLEAN UP | 0800 | 4.7.80 | 16 | 32 | 11.99 | 11.61 | | 1829 | 1879 | - | - | 290 |
| | 0400- | 5.7.80 | | | | | | | | | | |
| | 0400-1500 | | 11 | 40 | 16.93 | 17.07 | | 1789 | 1783 | - | - | 300 |
| | 1500-2000 | | 5 | 48 | 23.07 | 22.9 | | 1652 | 1652 | - | - | 440 |
| | 2000-2200 | | 2 | 56 | 27.96 | 28.74 | | 1477 | 1480 | - | - | 440 |
| | 2200-0100 | 6.7.80 | 3 | 96 | 38.10 | 38.10 | | 977 | 990 | - | - | 370 |
| | 0100-1230 | | 11.5 | MAX | 39.92 | 39.52 | | 732 | 782 | - | - | 345 |
| MAX FLOW RATE | 1750-2220 | | 4.5 | MAX | 40.82 | 40.70 | 54.5 | 780 | 790 | 1655 | 1612 | 350 |
| 1st BUILD UP | 2220-0400 | 7.7.80 | 5.67 | - | - | - | | 790 | 1997 | 1612 | 2254 | - |
| MAX FLOW RATE | 1000-1530 | | 5.5 | MAX | 41.42 | 39.12 | 63.7 | 794 | 770 | 1693 | 1681 | 350 |
| 2nd BUILD UP | 1530-1700 | | 1.5 | - | - | - | - | 770 | 2002 | 1681 | 2254 | - |
| SEQUENTIAL FLOW | 2200-2315 | | 1.25 | 32 | 9.65 | 9.67 | | 1954 | 1952 | 2227 | 2226 | 315 |
| RATES TEST 1 | 2315-0515 | 8.7.80 | 6.0 | 46 | 21.19 | 20.69 | | 1760 | 1757 | 2121 | 2109 | 330 |
| | 0515-0630 | | 1.25 | 60 | 30.62 | 30.62 | | 1484 | 1484 | 1967 | 1961 | 340 |
| | 0630-0800 | | 1.5 | MAX | 39.61 | 35.85 | 73.3 | 889 | 800 | 1719 | 1748 | 360 |
| 3rd BUILD UP | 0800-1100 | | 3.0 | - | - | - | | 800 | 2001 | 1748 | 2256 | - |

Schlumberger ran a Production Combination Tool : flowmeter and high resolution thermometer. Due to troubles with the flowmeter it was rerun twice.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PCT RUN | 0008-0130 | 9.7.80 | 1. | 48 | 24.18 | 24.18 | | 1694 | 1670 | - | - | |
| 2 RATE | 0600-0700 | | 1. | 46 | 20.68 | 20.65 | | 1772 | 1774 | 2144 | 2139 | 315 |
| FLOW TEST | 0700-0800 | | 1 | MAX | 40.85 | 38.09 | 76.8 | 800 | 727 | 1774 | 1789 | 330 |
| 4th BUILD UP | 0800-1100 | | 3 | - | - | - | | 727 | 2002 | 1789 | 2254 | - |




a·s Norske Shell
EXPLORATION & PRODUCTION FORUS
31/2-3
EXPLORATION WELL RESUMÉ
RESERVOIR PRESSURE VS DEPTH

| | | |
|---|---|---|
| AUTHOR EPPP/22 | FIG: I/9.1 | DATE |
| REPORT NO | | DRAW NO |

WELL 31/2-3

SAMPLES OBTAINED FROM RFT TESTS

| Test No. | Depth m-BDF | Recovery | Remarks |
|---|---|---|---|
| 4.1 | 1458 | Gas | 2-3/4 gal chamber sent to laboratory for conventional gas PVT analysis with composition to C20+ |
| 6.11 | 1568.5 | Gas | As for test No. 4.1 |
| 10.1 | 1584.5 | Mud Filtr. + Sand | Piston in sample chamber jammed because of sand influx |
| 1.2 | 1592.7 | Mud Filtr. | Resistivity measurement indicates mud filtrate |
| 9.11 | 1593 | Mud Filtr. | As for test No. 1.2 |

Table I/9.4

MICACEOUS SAND GAS TEST

INTERPRETATION OF FIRST PRESSURE BUILDUP 19.6.80

PARAMETERS

| | | |
|---|---|---|
| Well bore radius | $r_w$ | = 0.51 ft |
| Thickness (perforated length) | $h$ | = 49 ft |
| Porosity | $\phi$ | = 0.30 |
| Reservoir pressure | $p$ | = 2279 psia at 1484 m BDF |
| FBHP before shut in | $p_{wf}$ | = 1478 psia at 1484 m BDF |
| Gas rate before shut in | $q_g$ | = 6000 MSCF/D |
| Cumulative production | $G_p$ | = 6.1 MMSCF |
| Reservoir Temperature | $t$ | = $144^o$ F |
| Gas viscosity at p | $\mu_g$ | = 0.017 cp |
| Compressibility at p | $c_t$ | = $450 \times 10^{-6}$/psi |

HORNER PLOT

The plot shows that no reliable straight line portion can be found and hence no analysis is possible.

MCKINLEY TYPE CURVES

Early time fit for $\mathcal{T}/F$ = 15,000

Late time fit for $\mathcal{T}/F$ =150,000

Match point on early time curve $\Delta$ m(p) = $100 \times 10^6$
for $(F' \Delta m(p)/q_g) = 1.3 \times 10^{-2}$ where F' is
wellbore storage in MMSCF/(psi$^2$/cp)

$$F' = ((F' \Delta m(p)/q_g) \times \frac{q_g}{m(p)} = 1.3 \times 10^{-2} \times \frac{6000}{100 \times 10^6} = 0.78 \times 10^{-6}$$

It can be shown that the wellbore storage, F, expressed in Bbl/psi at reservoir conditions

$$F = 10 \left(\frac{T}{\mu}\right)_{wf} \times F' = 10 \frac{604}{0.014} \times 0.78 \times 10^{-6} = 0.34$$

Wellbore transmissibility : $\mathcal{T}_w = (\mathcal{T}/F) \times F = 15000 \times 0.34 = 5100$ mdft/cp

Permeability thickness : $kh = \mathcal{T}f \times \mu_{avg} = 51000 \times 0.015 = 765$ mdft

Permeability : $K = \frac{kh}{h} = \frac{765}{49} = 15.6$ md

SKIN CALCULATION

At the intersection of two type curves the following reading can be made for the late time curve:

$F' \Delta m(p) / q_g = 3.8 \times 10^{-3}$

which gives the pseudo pressure build-up corresponding to this curve

$$m(p)_{150,000} = (F' \Delta m(p)/q_g) \times \frac{q_g}{F'} = 3.8 \times 10^{-3} \times \frac{6000}{0.78 \times 10^{-6}} = 29.2 \times 10^{-6}$$

The real pseudo pressure buildup at the intersection

$\Delta m(p)_{15000} = 200 \times 10^6$

Pseudo pressure drop due to skin

$$\Delta m(p)_s = \Delta m(p)_{15000} - \Delta m(p)_{150000} = (200 - 29) \times 10^6 = 171 \times 10^6 \text{ psi}^2/\text{cp}$$

$$\text{Skin factor } S = \frac{\Delta m(p)_s \times kh}{1422 q_g T} = \frac{171 \times 10^6 \times 765}{1422 \times 6000 \times 604} = 25.4$$

Flowing pseudo pressure excluding skin

m (p) wf, no skin = m (p) wf + m(p) skin = $(199.1 + 171) \times 10^6 = 370.1 \times 10^6$ psi$^2$/cp

which gives pwf, no skin = 2086 psia

$\Delta p_s$ = pwf, no skin - pwf = 2086 - 1478 = 608 psi

$$\% \text{ of drawdown } \frac{\Delta p_s}{\Delta p} \times 100\% = \frac{608}{2279-1478} \times 100\% = 76\%$$

Table I/9.10

## MICACEOUS SAND GAS TEST

## PRESSURE BUILDUP ANALYSIS SECOND BUILDUP 22.6.80

### PARAMETERS

| | | |
|---|---|---|
| Well bore radius | $r_w$ | = 0.51 ft |
| Thickness (perforated length) | h | = 49 ft |
| Porosity | Ø | = 0.30 |
| Reservoir pressure | $\bar{p}$ | = 2279 psia at 1484 m BDF |
| BHFP before shut in | $p_{wf}$ | = 1262 psia at 1484 m BDF |
| Gas production rate | $q_g$ | = 32600 MSCF/D |
| Cumulative production | Gp | = 25.9 MMSCF |
| Reservoir temperature | t | = 144$^{o}$ F |
| Gas viscosity at $\bar{p}$ | $\mu_g$ | = 0.017 cp |
| Compressibility at $\bar{p}$ | $C_t$ | = 450 x $10^{-6}$/psi |

### HORNER ANALYSIS

| | | |
|---|---|---|
| Straight line slope | m | = 2.63 x $10^{6}$ (psi$^{2}$/cp)/cycle |
| Permeability thickness | kh | = 12177 mdft |
| Permeability (h= perf. length) | k | = 248.5 md |
| Extrapolated pressure | p* | = 2283 psia |
| Pressure after 1 hr shut in | $P_{1hr}$ | = 2273 psia |
| Skin factor (including turbulence) | S' | = 116 |
| Pressure drop due to skin | $\Delta ps$ | = 965 psi |
| Skin - % of drawdown | 95% | |

Table I/9.12

## MICACEOUS SAND GAS TEST

## PRESSURE BUILDUP ANALYSIS THIRD BUILDUP 23.6.80

### PARAMETERS

| | | |
|---|---|---|
| Well bore radius | rw | = 0.51 ft |
| Thickness (perforated length) | h | = 49 ft |
| Porosity | Ø | = 0.30 |
| Reservoir pressure | p | = 2279 psia at 1484 m BDF |
| BHFP before shut in | pwf | = 1262 psia at 1484 m BDF |
| Gas production rate | $q_g$ | = 31700 MSCF/D |
| Cumulative production | Gp | = 25.3 MMSCF |
| Reservoir temperature | t | = $144^0$ F |
| Gas viscosity at p | $\mu_g$ | = 0.017 cp |
| Compressibility at p | $C_t$ | = $450 \times 10^{-6}$/psi |

### HORNER ANALYSIS

| | | |
|---|---|---|
| Straight line slope | m | = $2.74 \times 10^6$ ($psi^2$/cp)/cycle |
| Permeability thickness | kh | = 11498 mdft |
| Permeability (h= perf. length) | k | = 234.7 md |
| Extrapolat ed pressure | p* | = 2284 psia |
| Pressure after 1 hr shut in | $p_{1hr}$ | = 2273 psia |
| Skin factor (including turbulence) | S′ | = 112 |
| Pressure drop due to skin | $\Delta ps$ | = 972 psi |
| Skin - % of drawdown | 96% | |

Table I/9.14

# 31/2-3 CLEAN SAND GAS TEST
## PRESSURE BUILDUP ANALYSIS FOURTH BUILDUP 9.7.80

PARAMETERS

| | | |
|---|---|---|
| Well bore radius | rw | = 0.51 ft |
| Thickness (perforated length) | h | = 82 ft |
| Porosity | Ø | = 0.30 |
| Reservoir Pressure | p | = 2265 psia at 1404 m BDF |
| BHFP before shut in | pwf | = 1795 psia at 1404 m BDF |
| Gas production rate | qg | = 38100 MSCF/D |
| Cumulative production | Gp | = 2.5 MMSCF |
| Reservoir temperature | t | = $141^0$ F |
| Gas viscosity at p | $\mu g$ | = 0.017 cp |
| Compressibility | Cg | = $450 \times 10^{-6}$/psi |

MCKINLEY TYPE CURVES

Early time. for for $\mathcal{T}/F = 2.5 \times 10^4$
There is no type curve with high enough $\mathcal{T}/F$ to fit the late time data. The curve with the highest $\mathcal{T}/F = 1 \times 10^6$ is shown in Fig. 37. However, based on the late time data and the general change of the type curves with higher values of $\mathcal{T}/F$, it is reasonable to assume that the correct $\mathcal{T}/F$ could be as high as $1 \times 10^8$.

Early time match point : $\Delta m(p) = 50 \times 10^6$ for
$(F'\Delta m(p)/q g) = 1.3 \times 10^{-3}$ where F' is wellbore storage in MSCF/$(psi^2/cp)$

$$F' = (F'\Delta m(p)/q g) \times \frac{q g}{m(p)} = 1.3 \times 10^{-3} \times \frac{38100}{50 \times 10^6} = 0.99 \times 10^{-6}$$

Wellbore storage in $BBL_{res}$/psi

$$F = 10 \left(\frac{T}{\mu}\right)_{wf} \times F' = 10 \times \frac{601}{0.015} \times 0.99 \times 10^{-6} = 0.397$$

Wellbore transmissibility $\mathcal{T}_w = (\mathcal{T}/F)_w \times F = 2.5 \times 10^4 \times 0.397 = 9917$ mdft/cp

Assuming $(\mathcal{T}/F) = 1 \times 10^8$ for the late time data gives the formation transmissibility as

$$\mathcal{T}_f = \mathcal{T}_w \times \frac{(\mathcal{T}/F)f}{(\mathcal{T}/F)w} = 9917 \times \frac{1 \times 10^8}{2.5 \times 10^4} = 39.7 \times 10^6 \text{mdft/cp}$$

which gives for the formation

$$(kh)_f = \mathcal{T}_f \times \mu_{avg} = 39.7 \times 10^6 \times 0.016 = 635 \times 10^3 \text{ mdft}$$

$$kf = \frac{(kh)f}{h} = \frac{635 \times 10^3}{82} = 7.74 \times 10^3 \text{ md} = 7.74 \text{ D}$$

Using the Darcy coefficient from the sequential rate flow test, B, an estimate of Darcy skin factor for this high kh can be made.

$$B = \frac{1422\ T}{kh}\left[\ln (0.47\ re/rw) + S\right]$$ and assuming

ln (0.47 re/rw) = 7 the Darcy skin factor is

$$S = \frac{B \times kh}{1422\ T} - 7 = \frac{41.6 \times 635 \times 10^3}{1422 \times 601} - 7 = 24$$

The non-Darcy flow constant for this kh is

$$D = \frac{Fkh}{1422T} = \frac{0.0979 \times 635000}{1422 \times 601} = 73.3 \times 10^{-3}/\text{(MSCF/D)}$$

The total skin including turbulence at 38100 MScf/D is then:
$S' = S + Dq = 24 + 73.3 \times 10^{-3} \times 38100 = 2800$
which is close to 100% of drawdown when converted into pressure terms.

Table I/9.19

OPERATOR A/S NORSKE SHELL EXPLORATION & PRODUCTION

WELL NO. 31/2-3

ANCHOR DRILLING FLUIDS AS

# MATERIAL CONSUMPTION & COST ANALYSIS

36" HOLE DRILLED TO 450 Meters ~~Feet~~ 30" CASING SET AT 445 Meters ~~Feet~~

ACTUAL AMOUNT OF HOLE DRILLED 93 Meters ~~Feet~~ DAYS ON INTERVAL 2

DRILLING FLUID SYSTEM SPUD MUD

| MATERIAL | UNIT SIZE | PROG. | USED | VARIANCE ± | COST |
|---|---|---|---|---|---|
| BENTONITE | M/T | | 22 | | $ 6.270.00 |
| CAUSTIC SODA | 25/50KG | | 10 | | 224.10 |
| LIME | 25KG | | 18 | | 81.00 |
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|---|---|---|---|
| COST/DAY | $ 3.287.55 | TOTAL COST FOR INTERVAL | $ 6.575.10 |
| COST/Mt. ~~or Ft.~~ | $ 70.70 | PROG. COST FOR INTERVAL | $ 5.398.00 |
| ENGR. COST | $ 700.00 | COST VARIANCE FOR INTERVAL | $ 1.177.10 |

OPERATOR A/S NORSKE SHELL EXPLORATION & PRODUCTION

WELL NO. 31/2-3

ANCHOR DRILLING FLUIDS AS

# MATERIAL CONSUMPTION & COST ANALYSIS

26" HOLE DRILLED TO 814 Meters ~~Feet~~ 20" CASING SET AT 803.5 Meters ~~Feet~~

ACTUAL AMOUNT OF HOLE DRILLED 364 Meters ~~Feet~~ DAYS ON INTERVAL 8

DRILLING FLUID SYSTEM SPUD MUD

| MATERIAL | UNIT SIZE | PROG. | USED | VARIANCE ± | COST |
|---|---|---|---|---|---|
| BARITE | M/T | | 134 | | $ 16.616.00 |
| BENTONITE | M/T | | 23 | | 6.555.00 |
| CAUSTIC SODA | 25/50 KG | | 18 | | 448.20 |
| LIME | 25KG | | 5 | | 22.50 |
| SODA ASH | 50KG | | 12 | | 210.00 |

COST/DAY $ 2.981.46

TOTAL COST FOR INTERVAL $ 23.851.70

COST/Mt. ~~or Ft~~. $ 65.5

PROG. COST FOR INTERVAL $ 12.622.00

ENGR. COST $ 2.800.00

COST VARIANCE FOR INTERVAL — $ 11.229.70

OPERATOR A/S NORSKE SHELL EXPLORATION & PRODUCTION

WELL NO. 31/2-3

ANCHOR DRILLING FLUIDS AS

# MATERIAL CONSUMPTION & COST ANALYSIS

17 1/2" HOLE DRILLED TO 1364 Meters ~~Feet~~ 13 3/8" CASING SET AT 1353 Meters ~~Feet~~

ACTUAL AMOUNT OF HOLE DRILLED 550 Meters ~~Feet~~ DAYS ON INTERVAL 10

DRILLING FLUID SYSTEM GYPSUM/LIGNOSULFONATE

| MATERIAL | UNIT SIZE | PROG. | USED | VARIANCE ± | COST |
|---|---|---|---|---|---|
| BARITE | M/T | | 238 | | $ 29.512.00 |
| BENTONITE | 50KG | | 255 | | 3.378.75 |
| CAUSTIC SODA | 25/50KG | | 167 | | 1.710.30 |
| LIGNOSULFONATE | 25KG | | 759 | | 11.916.30 |
| XC-POLYMER | 50LB | | 51 | | 15.402.00 |
| CMC LO VIS | 25KG | | 102 | | 5.406.00 |
| SODA ASH | 50KG | | 32 | | 560.00 |
| GYPSUM | 50KG | | 550 | | 5.445.00 |
| AL. STEARATE | 25KG | | 3 | | 189.00 |
| D. DETERGENT | 200L | | 21 | | 6.195.00 |

COST/DAY $ 7.971.43

TOTAL COST FOR INTERVAL $ 79.714.35

COST/Mt. ~~or Ft.~~ $ 144.93

PROG. COST FOR INTERVAL $ 46.285.00

ENGR. COST $ 3.500.00

COST VARIANCE FOR INTERVAL $ 33.439.35

OPERATOR A/S NORSKE SHELL EXPLORATION & PRODUCTION

WELL NO. 31/2-3

ANCHOR DRILLING FLUIDS AS

# MATERIAL CONSUMPTION & COST ANALYSIS

12 1/4" HOLE DRILLED TO 1827 Meters ~~Feet~~ 9 5/8" CASING SET AT 1816 Meters ~~Feet~~

ACTUAL AMOUNT OF HOLE DRILLED 463 Meters ~~Feet~~ DAYS ON INTERVAL 24

DRILLING FLUID SYSTEM GYPSUM/LIGNOSULFONATE

| MATERIAL | UNIT SIZE | PROG. | USED | VARIANCE ± | COST |
|---|---|---|---|---|---|
| BARITE | M/T | | 91 | | $ 11.284.00 |
| BENTONITE | M/T | | 5 | | 1.425.00 |
| LIGNOSULFONATE | 25KG | | 162 | | 2.543.40 |
| GYPSUM | 50KG | | 80 | | 792.00 |
| CAUSTIC SODA | 25KG | | 82 | | 1.020.90 |
| CMC LO VIS | 25KG | | 76 | | 4.028.00 |
| CMC HI VIS | 25KG | | 89 | | 4.984.00 |
| D. DETERGENT | 200L | | 2 | | 590.00 |
| AL. STEARATE | 25KG | | 1 | | 63.00 |
| SODA ASH | 50KG | | 4 | | 70.00 |
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COST/DAY $ 1.116.68 TOTAL COST FOR INTERVAL $ 26.800.30

COST/Mt. ~~or Ft.~~ $ 57.88 PROG. COST FOR INTERVAL $ 43.612.00

ENGR. COST $ 8.400.00 COST VARIANCE FOR INTERVAL - $ 16.811.70

OPERATOR A/S NORSKE SHELL EXPLORATION & PRODUCTION

WELL NO. 31/2-3

ANCHOR DRILLING FLUIDS AS

# MATERIAL CONSUMPTION & COST ANALYSIS

8 1/2" HOLE DRILLED TO 2601 Meters ~~Feet~~ | - | CASING SET AT - Meters Feet

ACTUAL AMOUNT OF HOLE DRILLED 774 Meters ~~Feet~~ | DAYS ON INTERVAL 12

DRILLING FLUID SYSTEM GYPSUM/LIGNOSULFONATE

| MATERIAL | UNIT SIZE | PROG. | USED | VARIANCE ± | COST |
|---|---|---|---|---|---|
| BARITE | M/T | | 11 | | $ 1.364.00 |
| BENTONITE | 50KG | | 18 | | 238.50 |
| LIGNOSULFONATE | 25KG | | 70 | | 1.099.00 |
| XC-POLYMER | 50LB | | 13 | | 3.926.00 |
| CMC LO VIS | 25KG | | 57 | | 3.021.00 |
| CMC HI VIS | 25KG | | 80 | | 4.480.00 |
| CAUSTIC SODA | 25KG | | 34 | | 423.30 |
| GYPSUM | 50KG | | 77 | | 762.30 |
| AL. STEARATE | 25KG | | 1 | | 63.00 |
| D. DETERGENT | 200L | | 4 | | 1.180.00 |
| BICARBONATE | 50KG | | 10 | | 175.00 |
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| COST/DAY | $ 1.394.34 | TOTAL COST FOR INTERVAL | $ 16.732.10 |
| COST/Mt. ~~or Ft~~ | $ 21.62 | PROG. COST FOR INTERVAL | $ 34.852.00 |
| ENGR. COST | $ 4.200.00 | COST VARIANCE FOR INTERVAL | - $ 18.119.90 |

OPERATOR A/S NORSKE SHELL EXPLORATION & PRODUCTION

WELL NO. 31/2-3

ANCHOR DRILLING FLUIDS AS

# MATERIAL CONSUMPTION & COST ANALYSIS

TESTING

| - | HOLE DRILLED TO | - | Meters Feet | - | CASING SET AT | | Meters Feet |
|---|---|---|---|---|---|---|---|

ACTUAL AMOUNT OF HOLE DRILLED | - | Meters Feet

DAYS ON INTERVAL | - |

DRILLING FLUID SYSTEM | SEAWATER/BRINE |

| MATERIAL | UNIT SIZE | PROG. | USED | VARIANCE ± | COST |
|---|---|---|---|---|---|
| CMC HI VIS | 25KG | | 13 | | $ 728.00 |
| XC-POLYMER | 25KG | | 3 | | 906.00 |

| | | | |
|---|---|---|---|
| COST/DAY | - | TOTAL COST FOR INTERVAL | 1.634.00 |
| COST/Mt. ~~or Ft.~~ | - | PROG. COST FOR INTERVAL | - |
| ENGR. COST | - | COST VARIANCE FOR INTERVAL | - |

OPERATOR A/S NORSKE SHELL EXPLORATION & PRODUCTION

WELL NO. 31/2-3

ANCHOR DRILLING FLUIDS AS

# TOTAL CONSUMPTION & COST ANALYSIS

TOTAL DEPTH: 2601 Meters ~~Feet~~

TOTAL HOLE DRILLED: 2244 Meters ~~Feet~~

TOTAL DAYS: 56

| MATERIAL | UNIT SIZE | PROG. | USED | VARIANCE ± | COST |
|---|---|---|---|---|---|
| BARITE | M/T | | 1474 | | $ 58.776.00 |
| BENTONITE | M/T | | 50 | | 14.250.00 |
| BENTONITE | 50KG | | 273 | | 3.617.25 |
| CAUSTIC SODA | 25/50KG | | 311 | | 3.826.80 |
| LIGNOSULFONATE | 25KG | | 991 | | 15.558.70 |
| LIME | 25KG | | 23 | | 103.50 |
| GYPSUM | 50KG | | 707 | | 6.999.30 |
| CMC HI VIS | 25KG | | 182 | | 10.192.00 |
| CMC LO VIS | 25KG | | 235 | | 12.455.00 |
| XC-POLYMER | 50LB | | 67 | | 20.234.00 |
| SODA ASH | 50KG | | 48 | | 840.00 |
| SODIUM BICARBONATE | 50KG | | 10 | | 175.00 |
| D. DETERGENT | 200L | | 27 | | 7.965.00 |
| AL. STEARATE | 25KG | | 5 | | 315.00 |
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COST/DAY: $ 2.773.35

TOTAL COST ~~FOR INTERVAL~~: $ 155.307.55

COST/Mt.: $ 69.21

PROG. COST ~~FOR INTERVAL~~: $ 142.769.00

ENGR. COST: $ 21.000.00

COST VARIANCE FOR INTERVAL: $ 12.538.55