USING THE MFI MULTIPHASE METER FOR WELL TESTING AT GULLFAKS B

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SUMMARY

Results from offshore testing of a multiphase meter is reported. The objective of the test was to investigate the multiphase meter's ability to perform well testing in a more time efficent manner than with a test separator. The results show that it is possible to test all the wells at Gullfaks B within 2 hours with very satisfactory results.
The paper presents a sequence where five wells are tested within 20 minutes. Testing the same wells using the conventional procedure for well testing takes some 20 hours. By optimizing the multiphase meter against the test separator it is possible to obtain an accuracy on the oil rate within 5 % compared to the reference oil rate. This accuracy is based on a 3 minutes logging interval for the multiphase meter compared with a four hour conventional welltest. For most of the wells the accuracy is within 4 % for all three phases.

1 INTRODUCTION

1.1 Background

Some years ago the main discussion in multiphase metering focused on the possibility to succeed in developing a reliable and accurate multiphase meter. Today there exist several commercially available first generation meters. In the last two years many oil companies have gained experience with different meters from field applications and tests. The main issue now is to investigate the performance of the various meters in terms of accuracy and reliability, and finding "the application envelope" with respect to flowrates, composition and flowregimes. The oil industry is about to enter the application phase of multiphase meters using them both topside on existing platforms and subsea on satellite fields on a permanent basis.

If we consider various multiphase meter applications we can divide these into two groups:

* WELL TESTING - By this we mean testing of a well's performance over a period of time. The information is used for reservoir management and well operation purposes.

* ALLOCATION - This refers to "fiscal" metering where the multiphase meter measurement is used to calculate taxation or to apportion production between partners in a field, multiphase pipeline network or for satellite tie-ins to a process platform.

The experience gained from working with different multiphase meters at Gullfaks B (GFB), has taught us that these meters are very efficient for well testing. The time necessary to perform one well test is reduced to the well change-over interval and a short test time.

1.2 Previous work

The first tests with multiphase meters on GFB, the Fluenta MPFM 1900 and the Multi-Fluid International (MFI) LP-Meter, took place in December 1992 and in March 1993, respectively.

The results from these tests have been published earlier [1,2,3].

To summarize the experience with these two electromagnetic meters, they both measure the composition of the oil-continuous wells at GFB with a satisfactory accuracy. The LP-meter can also be used to measure flow rates. From a user's viewpoint these tests indicate that the time is approaching when qualified multiphase meters can be implemented.

In July 1993 new tests on the same two meters took place and showed the same conclusions on overall accuracy and performance. The results presented in this paper showing the MFI LP-meter's ability to perform time-efficient well tests and are from these second experiments.

2 THE GULLFAKS B MULTIPHASE METER TEST RIG

Presently about 20 wells on GFB are producing a total of 30.000 Sm3/d of oil through two identical first stage separators and the test separator. The test separator is normally used for several purposes. Its main activity is the well test programme. But, it is also used in well maintenance programs and for drilling purposes. Upstream of the inlet to the test separator a 4" bypass loop has been connected to the test line. The test section in the bypass loop is shaped like a vertical "U". The multiphase instruments can be placed in both vertical legs and in the horizontal leg.

Figure 1 shows a picture of the MFI LP meter in the test rig. In the background it is possible to observe the test separator and the 8" testline. For information on the test rig, details can be found in [3].

3 TEST PROCEDURES FOR WELL TESTING

Each well on GFB is tested sequentially in a test programme. The X-mas trees at GFB are situated on the platform deck, and there is a very short distance between the manifolds and the separators. The different wells are routed into the test separator or into two identical first stage production separators via a manifold system controlled from the central control room. This means that the time required to change a well from the production separator to the test separator is short.

The stability time for a well is solely dependent on the separator. It normally takes half an hour after change-over before a log can be started. During this time the test separator control system will stabilize the single phase flows rates for the new well. The control room operator is responsible for running well tests and for changing between wells by remotely operating the manifold valves on each well. An offical well test has a duration of four hours. To ensure correct gas measurement, orifice plates of four different borings are used. The test separator readings are totalized at 30 minutes intervals to give volume production rates for oil, water and gas.
Analysis of several well tests show that it is possible to reduce the test duration. Including preparation and stability time, each well test using the test separator could be reduced to approximately 3 hours.

Figure 2 is showing a sequence where well B21 has been tested and the operator wants to test next well, B10.

4 THE MFI LP- MULTIPHASE METER

The MFI LP meter is a compact, full-bore meter for direct measurement of wellstream from live oil and gas wells. The meter is only applicable to oil-continuous flow. Multiphase flow rates are calculated by measuring the composition of the flow mixture (oil, water and gas volume or mass fractions) and the velocity at which the multi-phase mixture is flowing through the meter. These readings are processed to provide flow rates of oil, water and gas at actual conditions.

The composition meter consists of a microwave sensor element for measuring mixture dielectric properties and a gamma densitometer for measuring mixture density. The dielectric properties of the multiphase flow are most sensitive to water and the density reading is sensitive to the gas-liquid ratio. These complementary properties are measured very accurately by the MFI LP Meter to give precise information about the composition of multiphase flows. In the meter, the dielectric measurements, adjusted according to the temperature and pressure conditions, are combined with the density measurements to yield the instantaneous ratios of oil, water and gas.

MFI's way of measuring velocity is based on dielectric measurements from two cross-sections that are analysed with cross-correlation routines to determine the average time it takes the oil, water and gas mixture to flow from the first to the second section. The distance between the two measurement sections is known, and the production rates of the components can be found.

Physically, the MFI meter consists of a short spool-piece with microwave, density, temperature and pressure sensors, and a box housing the electronics system. The electronics comprises a system generating and processing microwave signals and a computer that does the data processing.
The meter calculates flowrates, compositions every second. To reduce the amount of data the programme average 10 samples such that data recording is taken every tenth second.

Later this autumn, MFI and Statoil, are planning a test at Gullfaks B on a new MFI Full-Range meter, which can also be used in water-continous flow. This development has been sponsored by the oil-companies BP, Elf, Philips, Saga, Total and Statoil.

5 CALIBRATION OF THE MULTIPHASE METER

After the installation of the MFI LP meter a calibration is required. This was performed in December 1992 on the gamma densitometer in air at atmosphere condition, and the whole procedure was finished after about 10 minutes. There has been no further calibration of the meter since this first calibration.

It is also necessary to enter available data about the process fluids into the flowcomputer. The necessary data consists of densities at process conditions and water conductivity.
No attempts have been made to discriminate between the oil, water and gas in the different wells tested.

Based on results from earlier tests of the meter [1, 2] some efforts were made to improve the accuracy. The results from the composition metering were very satisfactory showing accuracies within +/- 2 % absolute deviation on all three phases. For most tests the velocity readings were systematically high by 8 - 12 %. It was therefore decided to introduce a velocity calibration factor. In this way the meter could be tuned to Gullfaks B conditions aiming for an overall accuracy within 5%.

6 RESULTS USING THE MULTIPHASE METER FOR WELL TESTING

6.1 Objectives

The main objective of the test was to show that by introducing a multiphase meter after the test manifold, it is possible to perform testing of all the wells at GFB in 2 hours.

A second objective was to show that it is possible to tune a multiphase meter to give an accuracy in well testing better than +/- 5 % of actual rates for all three phases. If this accuracy can be achieved it can open up for using multiphase meters for "allocation" purposes.

6.2 The test sequence

The test programme consists of several test series where two different wells are tested sequencially. The period of change-over are logged on data files. A full well test on the test separator is run for each well to obtain accurate reference production data for comparison.
In this presentation the data from three test series are used to illustrate the performance of the meter:

* Well test: B21 - B10
* Well test: B9 - B25
* Well test: B25 - B9

To show the overall accuracy of the meter and the possibilities a reliable multiphase meter offers, emphasis has been given to the flowdata from the MFI LP-meter taken from the change-over period between the testing of two wells.
In this test set-up the results from the multiphase meter are based on only a few minutes test interval with stable flow. The reference measurements are offical well tests over a four hour period.

6.3 Change -over from well B21 to B10

The figures 3a,b,c give detailed information from the tests on well B21 and well B10 in three different ways.

Figure 3a shows the production rates using a 10 second sampling interval. Looking into the details it can be observed that there is natural variations in the production rates. The flow variations seem to follow a cyclic behaviour. If the flow data from the multiphase meter is studied, it can be observed that the phase fractions are stable over one cycle period. The flow velocity on the other hand is following a cyclic pattern and therefore will create the same pattern for the flowrates.

In figure 3b a sliding window of 100 seconds has been used. Comparing the two figures it can be seen that the latter gives the necessary flowrate information without disturbances from the smaller fluctuations in the velocity. By increasing the average sampling time local periodical flow variations can be dampened.

In figure 3c the results are averaged from the beginning of the test. In this figure it can be observed that B10 is stable four minutes after start of the change-over. The change-over period can be separated into two parts which not easily can be discriminated. The first part contains the time it takes the operator to operate the 4 valves to route a new well from the production separator into the test separator and vice versa. The second period is the time needed to stabilize the flow from the new well after the valve operations are finished. In the B21-B10 change-over it can be observed that the time needed is 4.5 minutes. In this situation the operator used quite a long time in the operation of the valves compared with later similar operations. Other similar change-overs indicate that this operation can be reduced to approximately two minutes.

Fig 3d shows the time needed to perform similar well tests with the test separator. The total operation lasted 9 hours. It is possible to reduce this time to a total duration of 3 - 4 hours for two wells. Included is the time for manual work like changing orifice plates, taking samples etc.

A question of major importance when new equipment is introduced concerns performance, i.e. accuracy and reliability. In figure 3c the test separator readings are superimposed and the reference flowrates shown in frames. Table 1 (B21, B10) shows the accuracy using the two different methods.

It is not straight forward to evaluate the performance of multiphase meters. If one of the phases contributes only a few percent of the total flow it is not very meaningfull to refer the accuracy for that phase to the reference measurement of the single phase. The accuracy data are therefore presented in two different ways. The first method compares each individual phase with the reference phase, while the second method compares the phase readings with the total flow. The results from the two wells are measured very satisfactory within +/- 1.5 % compared with total flow and within 3 % for the oil and gas rates compared with reference single phase flowrates.
Well no. B21 has a very low watercut and can be used as a good example that clearly illustrates the problem in defining accuracy figures for multiphase meters.
The deviation on water is quite large (40 %) using the single phase flowrates as a reference and nearly negligible when refered to total flow (0.6 %). This is because the water content in the well is only 1.5 % (volumetric). From fiscal metering it is well-known that the a 4" reference turbine meter is not very accurate for such low water flowrates.

6.4 Testing five wells in 20 minutes

Since the instrument is excellent for trending of a well performance, the special sequence, " Testing five wells in 20 minutes", was set up to show that the LP-meter has ability to test many different wells in a short period of time. Figure 4a shows a 20 minutes test sequence with 5 different wells. Superimposed in the figure are readings from the test separator for each well.

In figure 4b the same test using the test separator is shown. Using this method 20 hours of testing was needed to complete the programme. The test programme was started when B21 was tested. After a 4-hour test was finished, next well B10 was routed into the test separator for a complete test. The first test of B9 was abrupted when the multiphase meter gave no readings, indicating water continuous flow and the official well test was abrupted. B25 was the next well for test, followed by a new test of B9.

B9 was tested twice in this sequence to illustrate an important limitation Statoil has experienced using electromagnetic multiphase meters in oilwells having a watercut between 30 - 50 % and injection of production chemicals.
B9 has a watercut around 30 %. When 10 PPM of a corrosion inhibitor was injected the multiphase meter stopped to function indicating water continuos flow. Stopping the injection pump caused the well immediately to become oil-continuously, and the meter started to measure the flowrates again. Investigations later has shown that this chemical has an unwanted effect on the surface active properties of the emulsion.
In our case we have concluded that the transition point between oil-continuous emulsion and water-continuous emulsion has been moved down on the watercut scale.

Table 1 shows the accuracy for each well. The overall accuracy are essentially within +/- 5 % using each phase as a reference and within +/- 4 % using total flow as a reference. B25 has been divided into two parts. The results shown in table B25a is referring to the output from the multiphase meter during the beginning of the test, while table B25b is referring to the last minutes of the test before a new well was replacing B25. The gas fraction at actual condition referring to the test section for the various wells at GFB, varies from 30 - 50 volumetric percent. The flow regime is most likely bubble-flow in the testsection. The difference in the flowrates seen by the multiphase meter for B25 might be caused by slip flow. B25 is produced from a different reservoir and has a higher gas-content than the other wells. Comparing test results also show that the results for this well is worse than the results from the others. For the other wells the accuracy are far better than the requirement on +/- 5 %.

This experiment shows that during 20 minutes five well tests of different wells can be performed. That gives an average of about four minutes for each well. Comparing the two different methods for well testing we can conclude that significant improvements can be obtained by starting to use multiphase meters.

7 CONCLUSION

Statoil has gained experience in multiphase meters using the MFI LP meter on Gullfaks B from December 1992 to March 1994. For Gullfaks B flow condition, the meter is qualified for use in well testing. Compared to the conventional method using the flow readings from the test separator it is possible to optimize the time needed for well testing and thereby releasing the test separator for other purposes. The change-over period needed before steady production rates for a new well is achived is less then 4 minutes for the majority of the wells. After the valve operation period is finished it takes 1 - 2 minutes before the meter has obtained stable production rate readings for the new well routed into the test line.The stability time needed between two well tests is dominated by the time needed for the valve operation. This will be very different on a satellite field having a dedicated test line from the subsea template. Here the stability time will be dominated by the multiphase flow transport phenomena. Of course this could be eliminated if the multiphase meters were installed subsea.

Five wells are tested within 20 minutes with the meter compared with 20 hours needed using the test separator. This indicates the possibility of testing all the wells on Gullfaks B within 2 hours. Adequate data from prior testing has been used to formulate a correction factor which gives results with an acceptable accuracy. In this way the performance of the multiphase meter has been optimized to give 5 % maximum deviation on flowrates used on Gullfaks B.

Using electromagnetic multiphase flowmeters, that only function in oil continuous conditions, it is important to know that corrossion inhibitors or other chemicals may have an unwanted effect on the multiphase flow. By injecting small quantities of some chemicals in wells having a watercut around 30 - 40 %, the flow can become water-continuous causing the meter to malfunction.

The results of this test demonstrate the usefullness of multiphase meters in one application, using multiphase meters in line with test separators or replacing test separators for well testing. This makes it possible to use existing test separators as production separators of hydrocarbons.

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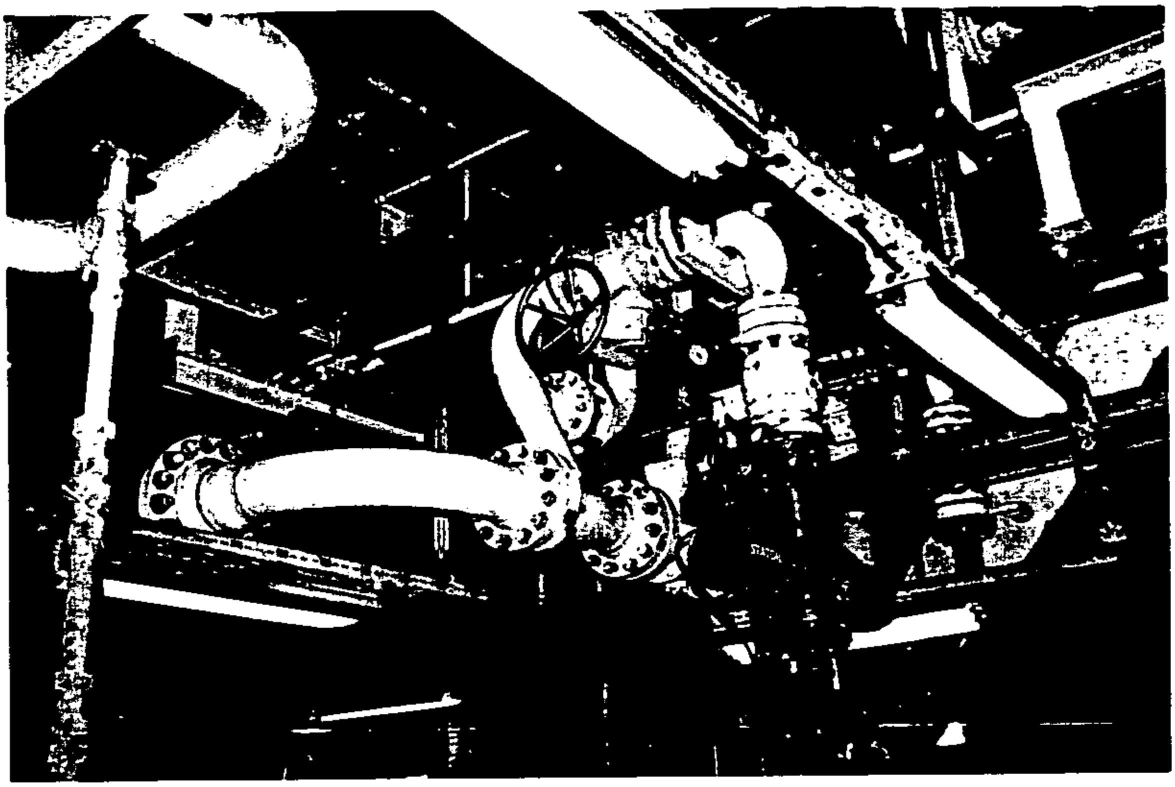

Fig. 1 MFI LP-meter at Gullfaks B

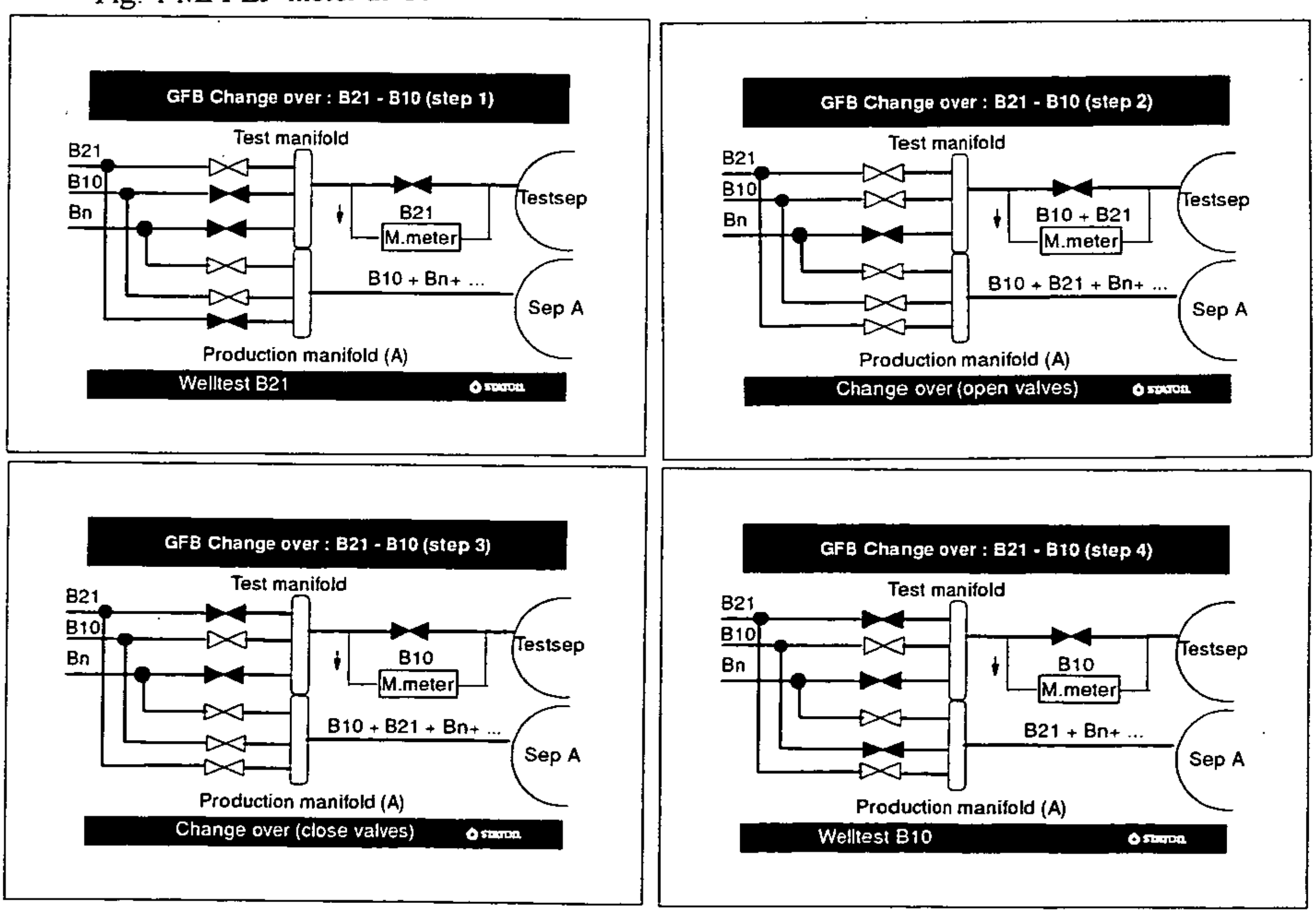

Figure 2. Change sequence B21 - B10

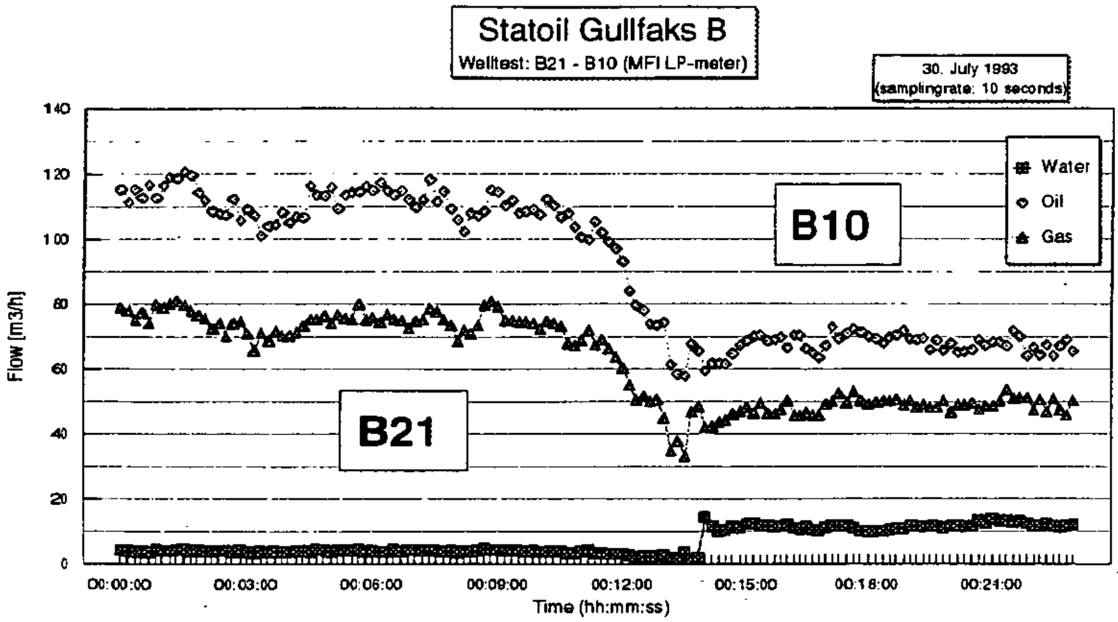

Fig. 3a Inst.flowrates (10 seconds sampling interval)

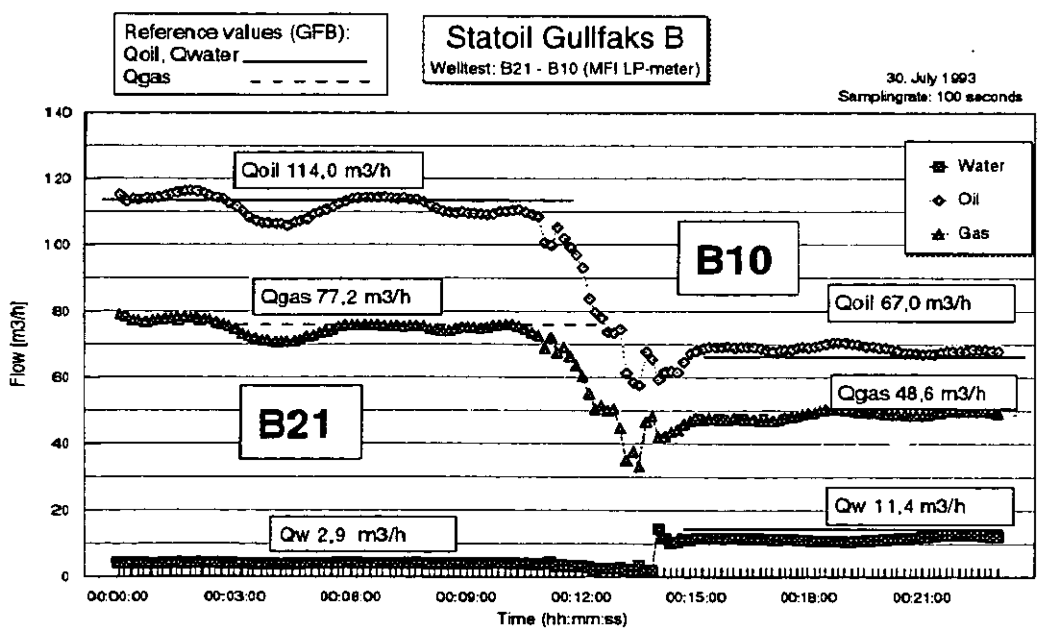

Fig. 3b Inst.flowrates (100 seconds sampling interval)

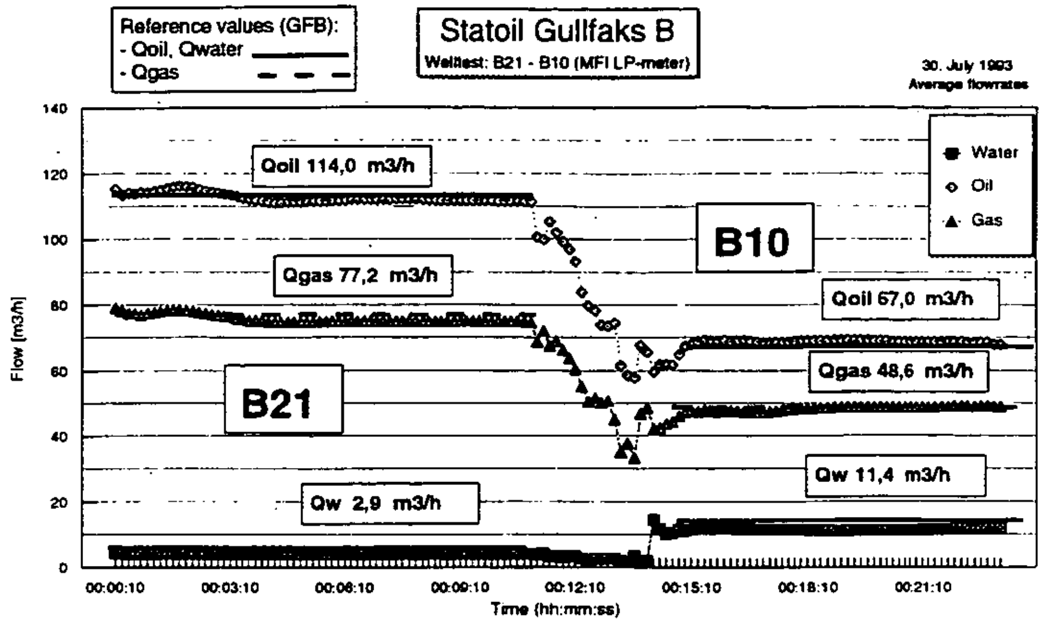

Fig. 3C Average values B21-B10

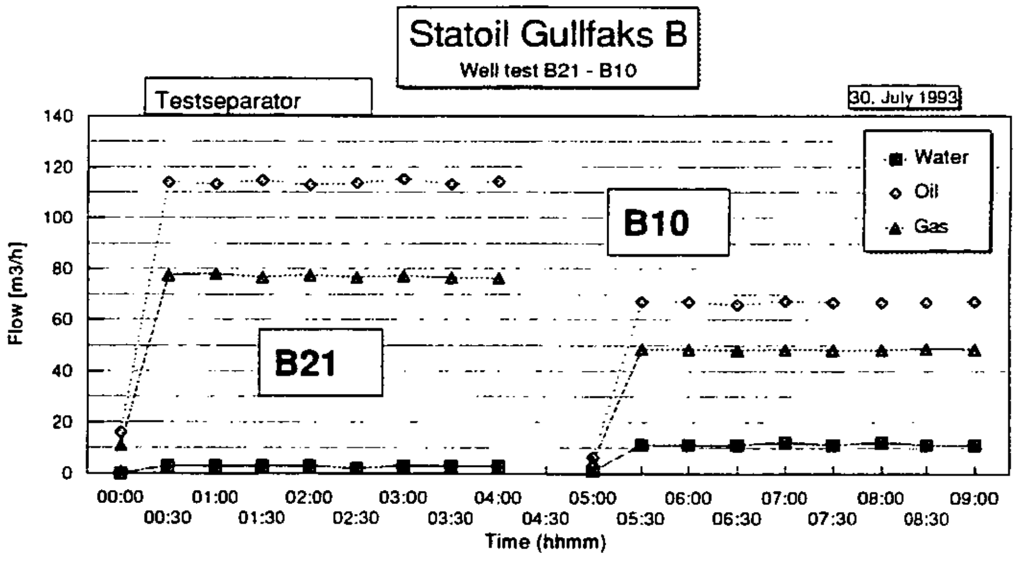

Fig. 3d Well: B21 - B10 Testseparator

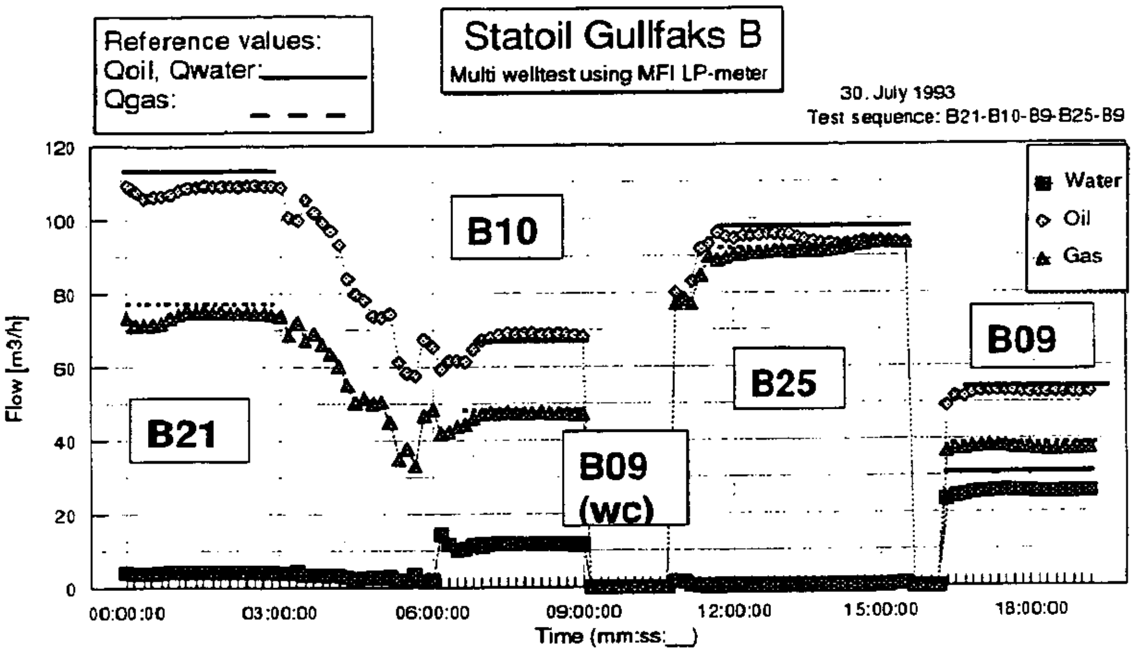

Fig. 4A Testsequence 5 wells

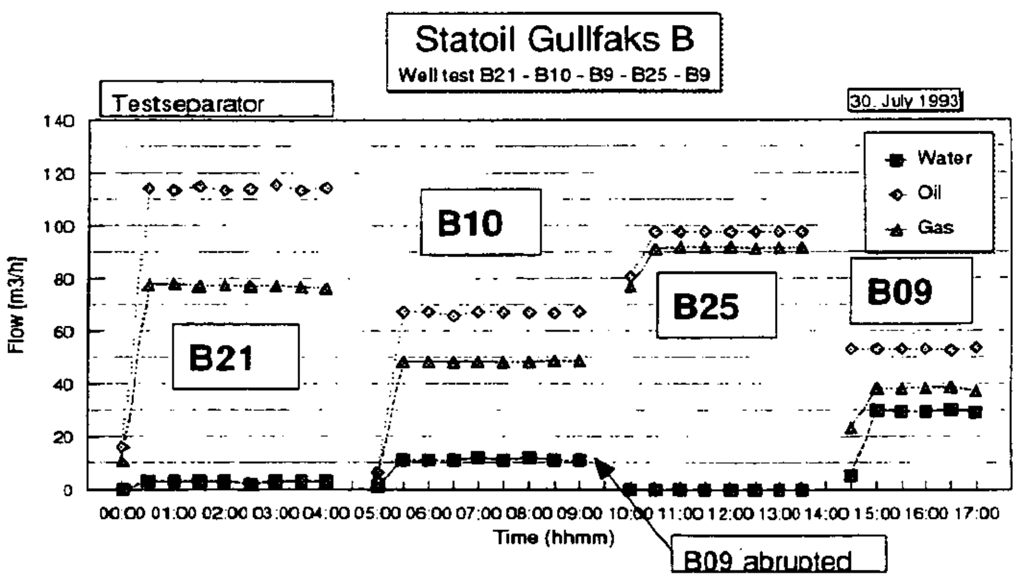

Fig. 4B welltesting using testseparator

Using the MFI LP meter for well testing Test 30. July 1993

Accuracy MFI LPmeter - GFB reference Well B21 - B10 - B25 - B09

B21

	Qoil [m3/h]	Qgas [m3/h]	Qwater [m3/h]	% Oil	% Gas	% Water
				Fractions (absolute)		
MFI B21	111,54	75,06	4,10	58,49	39,36	2,15
GFB B21	114,05	77,20	2,92	58,74	39,76	1,50
Accuracy (Ref Qtot)	-1,29	-1,10	0,61	-0,25	-0,40	0,65
Accuracy (Ref Qphase)	-2,20	-2,77	40,41			

B10

	Qoil [m3/h]	Qgas [m3/h]	Qwater [m3/h]	% Oil	% Gas	% Water
				Fractions (absolute)		
MFI B10	67,70	48,57	11,53	52,97	38,00	9,02
GFB B10	66,95	48,52	11,36	52,79	38,26	8,96
Accuracy (Ref Qtot)	0,59	0,04	0,13	0,19	-0,25	0,07
Accuracy (Ref Qphase)	1,12	0,10	1,50			

B09 (WC)

Corrision inhibitor -> Well B09 water cont.

B25-a

	Qoil [m3/h]	Qgas [m3/h]	Qwater [m3/h]	% Oil	% Gas	% Water
				Fractions (absolute)		
MFI B25	93,46	92,11	0,00	50,36	49,64	0,00
GFB B25	97,49	91,59	0,00	51,56	48,44	0,00
Accuracy (Ref Qtot)	-2,13	0,28	0,00	-1,20	1,20	0,00
Accuracy (Ref Qphase)	-4,13	0,57	0,00			

B25-b

	Qoil [m3/h]	Qgas [m3/h]	Qwater [m3/h]	% Oil	% Gas	% Water
				Fractions (absolute)		
MFI B25	90,33	94,59	0,00	48,85	51,15	0,00
GFB B25	97,49	91,59	0,00	51,56	48,44	0,00
Accuracy (Ref Qtot)	-3,79	1,59	0,00	-2,71	2,71	0,00
Accuracy (Ref Qphase)	-7,34	3,28	0,00			

B09

	Qoil [m3/h]	Qgas [m3/h]	Qwater [m3/h]	% Oil	% Gas	% Water
				Fractions (absolute)		
MFI B09	53,52	37,31	25,84	45,87	31,98	22,15
GFB B09	53,24	38,30	29,84	43,86	31,55	24,58
Accuracy (Ref Qtot)	0,23	-0,82	-3,30	2,01	0,43	-2,44
Accuracy (Ref Qphase)	0,53	-2,58	-13,40			

Table 1 - Accuracy MFI LP meter versus test separator Gullfaks B