FRAMO MULTIPHASE FLOW METER - FIELD TESTING EXPERIENCE FROM STATOIL GULLFAKS A AN PLATFORMS AND TEXACO HUMBLE TEST FACILITIES

5.3

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SUMMARY AND CONCLUSIONS

The tests performed at the Gullfaks A and B platform and Texaco's test facilities at Humble have given impor experience with the FRAMO Multiphase Flow Meter system at field conditions.

At the Gullfaks B platform, the meter was installed in series with a test separator system. Phase flow rates fro wells were measured with the multiphase flow meter with the test separator as reference.

The scope of work for the test at Gullfaks A is to verify the operational stability of the meter over at least a months period at an offshore installation.

In the tests at Texaco's Humble test site, a test matrix was followed and the objective was to investigate the meter behaviour at varying gas fractions, water cuts, flow rates and flow conditions.

The tests has shown that we are able to reproduce the good accuracy and repeatability obtained with the FRA multiphase flow meter in previous multiphase flow loop tests.

The tests performed at the Gullfaks A and B platform and Texaco's test facilities at Humble have given impor experience with the FRAMO Multiphase Flow Meter system at field conditions.

1.0 ABBREVIATIONS

GVF	=	Gas Volume Fraction	%
OVF	=	Oil Volume Fraction	%
WVF	=	Water Volume Fraction	%
Q_{tot}	=	Total flow rate	m^3/h
Q_{oil}	=	Oil flow rate	m^3/h
Q_{gas}	=	Gas flow rate	m^3/h
Q_{water}	=	Water flow rate	m^3/h
MPFM	=	Multiphase Flow Meter	

2.0 INTRODUCTION

This document includes a summary of the test experience gained from three extensive field test programmes u the Framo Multiphase Flow Meter.

The main objectives of the field testing were as follows:

- To operate the flow meter in actual well environments.
- Investigate meter performance in dynamic operating conditions and under various upstream flow regim
- Investigate the influence of various fluid compositions.
- Verify the test results gained from in-house testing.
- Establish meter turn-down capabilities.
- Establish the repeatability and stability performance.

The following test sites were used:

Site	Customer	Period
Gullfaks B	Statoil	March - April 1994
Humble test facilities	Texaco	March - May 1994
Gullfaks A	Statoil	May 1994 -

For reference purposes a full technical description of the Framo flow meter concept as well as test results from the in-house testing have been included in Appendix.

3.0 STATOIL GULLFAKS B TEST

3.1 Test conditions and programme

The flow meter was tested on well fluids from six different wells on Gullfaks B . All wells produces by the use of water injection. One of the wells produces with zero water cut while the rest have water break through and, hence, produce at different water cuts.

The flow meter was installed downstream a test manifold in a by-pass loop located upstream the test separator as shown in Figure 9. The test separator was equipped with dedicated instrumentation for the measurements of the individual flow rates of oil, water and gas.

The test was sponsored by Statoil, Shell, Conoco, BP, Elf and Norsk Hydro.

The following basic design conditions apply for the test meter used at Gullfaks B:

Parameter	Unit	Design	Range
Pressure	(bar)	300	5-300
Temperature	(°C)	90	15-90
Gas Volume Fraction	(%)	20-60	0-100
Water Cut	(%)	5-90	0-100
Total vol. flow rate	(m^3/h)	200	20-300

Table 1: Design parameters for the MPFM used in the Gullfaks B test

Selected wells were routed through the meter into the test separator with flow conditions as given in the table below:

Well ID	Q_{tot} (m^3/h)	GVF (%)	OVF (%)	WVF (%)	WC (%)
Well 1	200	43	57	0	0
Well 2	95	20	17	63	79
Well 3	100	25	30	45	60
Well 4	100-140	26-30	40-43	23-25	41
Well 5	140	34	56	10	15
Well 6	55-60	28	44	28	39

Table 2: Test matrix at Gullfaks B

Average flow measurements from the test separator were carried out in intervals of approximately ten minutes and, hence, the same intervals apply for flow meter measurements.

3.2 Test results

A comparison of flow rate measurements taken from the Framo meter and the test separator are shown in the figures 1 through 6. Figures 1 through 3 show individual component volumetric flow rate compared to test separator while figures 4 through 6 show the same test points, but now presented together with the test separator measurements for the individual wells, all as function of time.

The straight line represents the test separator measurements. This has been done for presentation purposes even though it would have been more correct to use a band to visualise the inaccuracy in the test separator system.

Looking at the individual wells, the scatter around the mean value is small, thus the repeatability is good. Assuming the reference data are correct, some deviation in the average error can be anticipated due to using the same set of calibration values for all wells.

A variation in water salinity from well to well was discovered during the tests. Although salt content will affect the attenuation coefficient for water, these variations were not adjusted for during the test. The same set of calibration constants were used for all wells. The sensitivity to water salinity appeared less than expected.

3.3 Discussion of results.

The Gullfaks B field test has shown that the Framo multiphase flow meter operates satisfactory at field proc conditions and the meter performance, as established in previous flow loop tests, has been re-produced.

The test has also verified that the mass attenuation coefficient for oil seems to be independent of actual oil (crude, dead crude, diesel, Exsol D80) and furthermore, the mass attenuation coefficient for natural gas is equa oil. Another interesting finding is that the Barium spectre contains information which can be utilised for determir the salinity of water. These findings will contribute to simplify the calibration requirements of the meter in future.

No sensitivity to flow regimes, sand, chemicals have been observed during the test.

The deviation around the mean value for single wells indicates excellent repeatability.

4.0 TEXACO HUMBLE TEST

4.1 Test conditions and programme

The Framo Multiphase flow meter was tested by Texaco at the Humble test facility in Texas, USA in April and M 1994 as part of a project sponsored by Statoil, Svenska Petroleum, and the Norwegian KAPOF programme.

The Humble test facility allows multiphase testing with live fluids - natural gas/oil/water and the ability to measur field typical flow regimes. The test rig flow schematic is shown in figure 10.

Flow loop specifications:

Oil/crude flow rate:	0-20.000 bbl/d (0-133 Sm^3/h)
Water flow rate:	0-20.000 bbl/d (0-133 Sm^3/h)
Gas flow rate: (nitrogen/natural gas)	0-13 nmscf/d (0-15340 Sm^3/h)
System pressure:	50-1500 psi (3,4 - 103,4 bar)
Slug length:	Field typical

The objective with the test was to investigate the meter performance at the following conditions:

- Variable water cut
- Variable gas volume fractions
- Variable flow rates (flow turn-down test)
- Field typical flow regimes

The test matrix was as follows:

Water cut:	50%, 60%, 70%, 80%, 90%
Gas volume fractions (GVF):	60%, 80%, 90%, 96%
Flow rates:	4 from low to high limit of meter (50 to 300 m^3/h)

The multiphase flow meter used in the test is a topside version of the Framo meter with a 2" venturi section.

The following design conditions apply for the meter used at Humble:

	Unit	Design	Range
Flow line pressure, P	bar	10,3	3,4 - 250
Production temperature T	^oC	25	15 - 70
Gas Volume Fraction (GVF)	-	60 - 96	0 - 100
Water Cut	%	5 - 90	0 - 100
Total flowrate (all phases) Q_{tot}	m^3/hour	150	50 - 400

4.2 Test results

The main difference between the GULLFAKS B test and the test at Humble was the flow regimes and the Gas Volume Fraction (GVF). At Gullfaks B the GVF was below 50% while at Humble they consentrated on 50% and higher with severe slugging included as part of the test.

The meters capability to measure water cut was tested by varying the GVF from 50% to 90% and at each step, vary the water cut from 5% to 90%. The total volumetric flow rate was kept constant during this test. The results are shown in figure 7 (measured water cut vs. reference water cut).

In the tests at Humble, three different configurations were used to prepare the inlet flow conditions for the multiphase flow meter. Homogeneous flow was created by mixing the three components just upstream the meter. Short slugs were generated by mixing in a 100 meter riser, and long slugs by mixing in a 100 meter riser followed by a 600 meter terrain pipeline upstream the meter. Although the meter interfaces to a 4" pipeline, the dominating pipe diameter in the loop is 6".

The data presented in figure 8 represent the results from tests on different GVFs comparing reference oil flow rate to metered oil flow rate under homogeneous and slugging conditions.

4.3 Discussion of results

Results from the three-phase oil, water and gas tests at Humble show that phase flow rates are predicted with good accuracy over the whole range tested. The error in oil and water flow rates relative to the actual total flow rate are within +/- 5% which are comparable to the GULLFAKS B results. This is also true for the gas flow rates less than about 70%.

As in the GULLFAKS B test and in inhouse testing the meter has a tendency to measure lower gas flow rates than the reference system at high gas volume fractions (70 to 100% gas). This trend was foreseen and is systematic.

Due to the built-in flow mixer which always provides homogenous flow to the measuring section, the meter seems to measure with good repeatability over the whole test range, even at extreme slugging conditions.

5.0 GULLFAKS A TEST

5.1 Test Conditions and Programme

The Framo Multiphase Flow Meter was installed on Gullfaks A as part of the Poseidon multiphase pump skid in May 1994. As for the test at Humble, this test was sponsored by Statoil, Svenska Petroleum, and KAPOF.

The objective of this test was to get long term experience with the meter under real offshore conditions and to enable online monitoring of the pump performance.

The meter was hence located downstream the pump where the conditions are as follows:

Total flow	:	120 - 140 m3/hr
GVF	:	30 - 35%
WC	:	50%
Pressure	:	70 bar
Temperature	:	70 - 80_C

Only one well is being boosted by the multiphase pump.

5.2 Test Results

So far we have received a limited number of test points which has been compared to the test separator.

The results we have got are, however, within the specified accuracy of the meter which is ± 5% of actual total flow.

The meter has been in operation for about 1200 hours so far. Further testing will continue throughout the rest of 1994 and possibly into 1995.

Appendix 1 - Framo multiphase flow meter description and test results

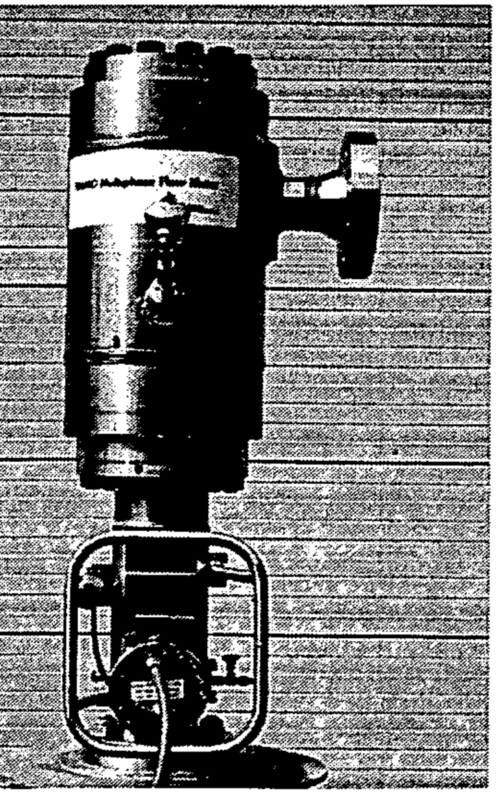
FRAMO ENGINEERING AS

FRAMO Multiphase Flow Meter

A considerable amount of research effort lies behind the development of reliable, flexible and accurate multiphase flow meters. This is now available from Framo Engineering AS for both topside and subsea applications.

The multiphase flow meters offer the following advantages compared to conventional methods of well testing:

- On-line well monitoring
- Improved well control
- Optimized production control
- Improved allocation methods
- Reduced OPEX and CAPEX
- Reduced space and weight requirement for topside installations



The FRAMO multiphase flow meter is capable of measuring all combinations of oil, water and gas in a well stream.

The system consists of a multi-energy level gamma fraction meter and a venturi momentum meter in combination with an in-line static mixing unit.

Flow mixer

The mixing unit makes the metering system completely independent of upstream flow regimes and provides a homogeneous flow to the metering section.

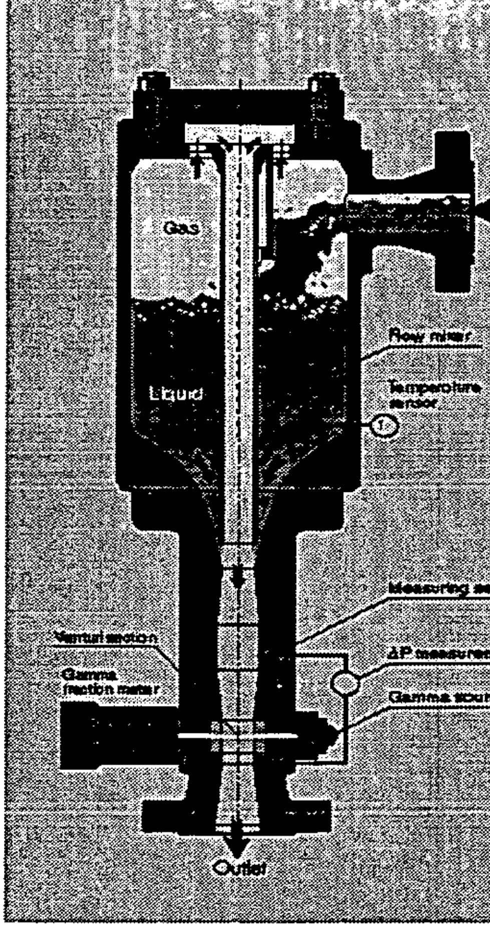
The flow mixer is a purely static device. The most dense part of the fluid is drained from the bottom of the mixer via an ejector, while the lightest fraction is drained from the top and directed via a pipe back to the ejector, where it is mixed with the dense fluid, according to the ejector ratio.

Multi-energy gamma meter

The multi-energy gamma meter determines the fractions of oil, water and gas in the well stream. The gamma meter is located immediately downstream the flow mixer, and these fractions can be treated as volume fractions.

Calculation of the oil, water and gas fractions is based on the relative attenuation of different gamma energy levels. The gamma meter consists of a gamma isotope and a ruggedized detector.

Topside Multiphase Flow M



The combination of two different energy levels is sufficient to determine three fractions, since the third fraction can be deducted by subtracting the first two from 100%.

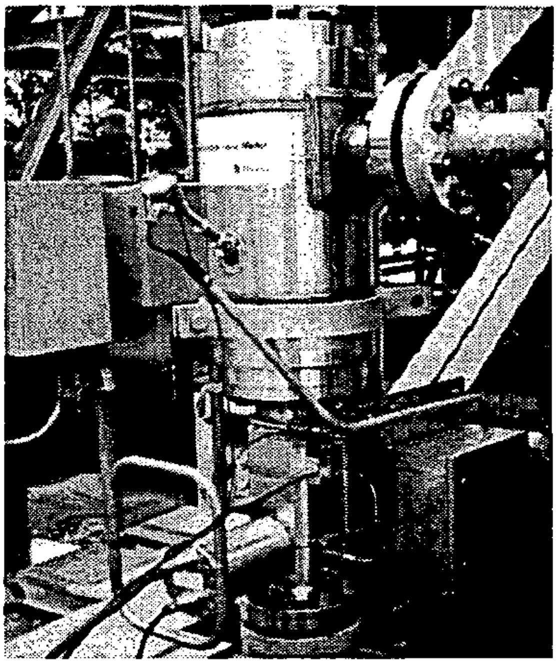
Venturi meter

A venturi meter is used in combination with the gamma fraction meter to obtain the flow rates of oil, water and gas. This can be done since the venturi meter is located immediately downstream the flow mixer. Multiphase mixtures have the same properties as single phase mixtures of similar density, and the single-phase venturi relation can therefore be utilized.

The basic venturi meter configuration is equipped with high-precision pressure sensors for both venturi differential pressure and absolute pressure.

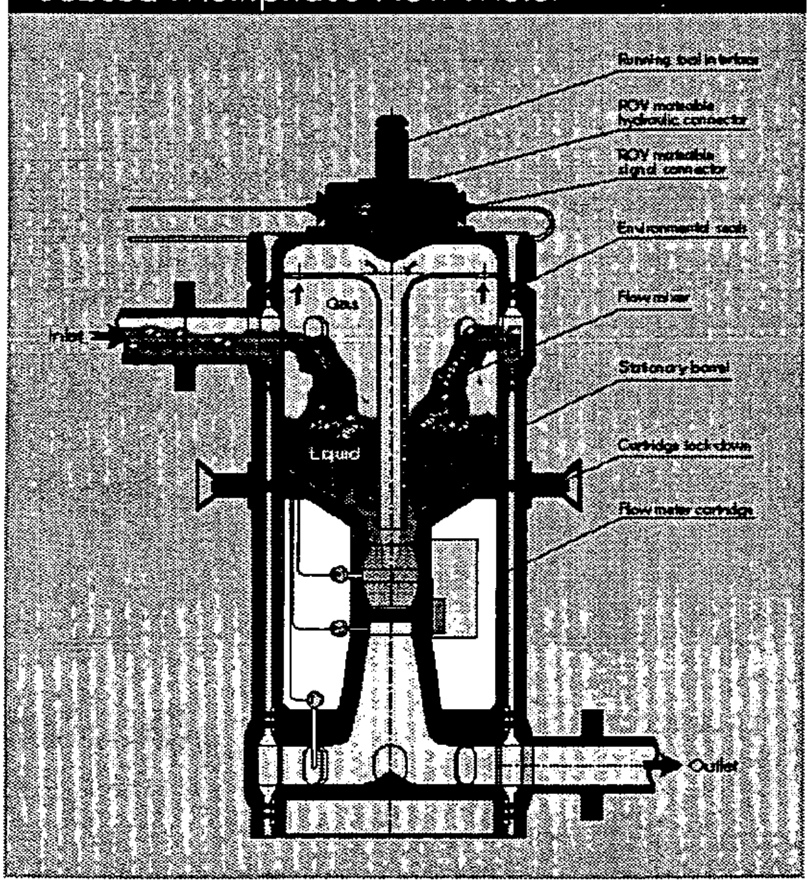
Design parameters:

- Accommodates any flow regime
- 0 - 100% Water Cut
- 0 - 100% GVF
- Subsea and topside designs available

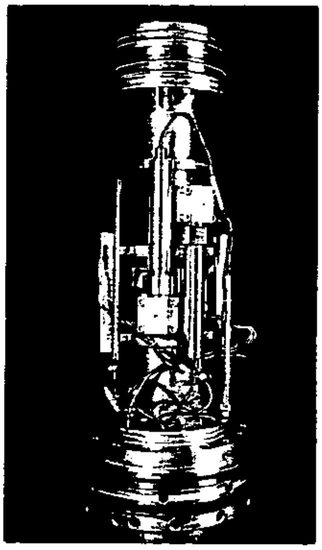


FRAMO topside multiphase flow meter successfully tested at Humble field in Texas

Subsea Multiphase Flow Meter



Measuring section of the subsea meter



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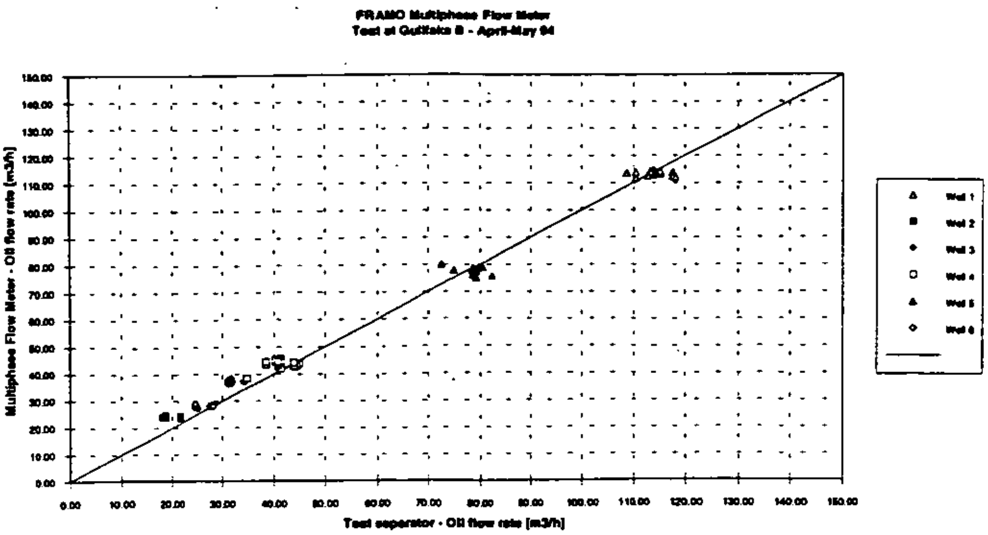


Figure 1 Measured oil flow rate vs. test separator oil flow rate, Gullfaks B

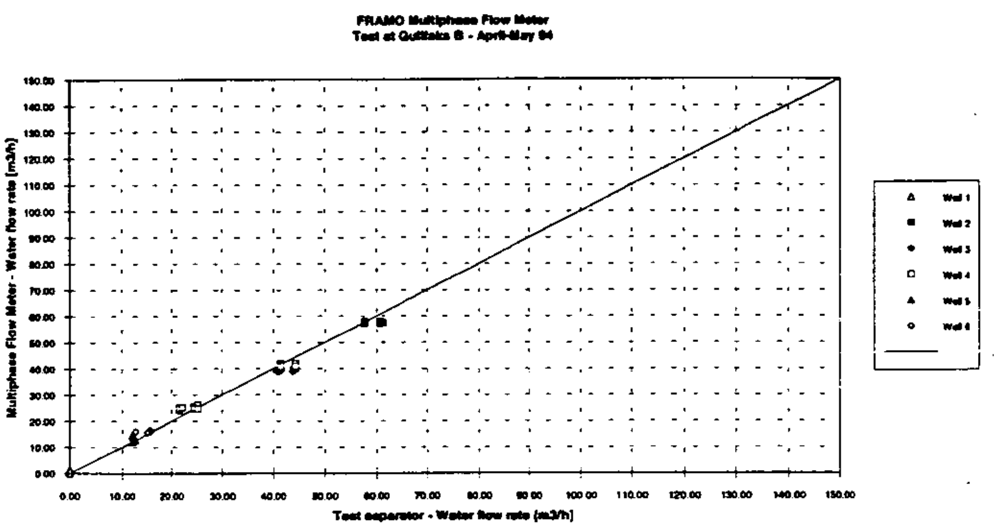


Figure 2 Measured water flow rate vs. test separator water flow rate, Gullfaks B

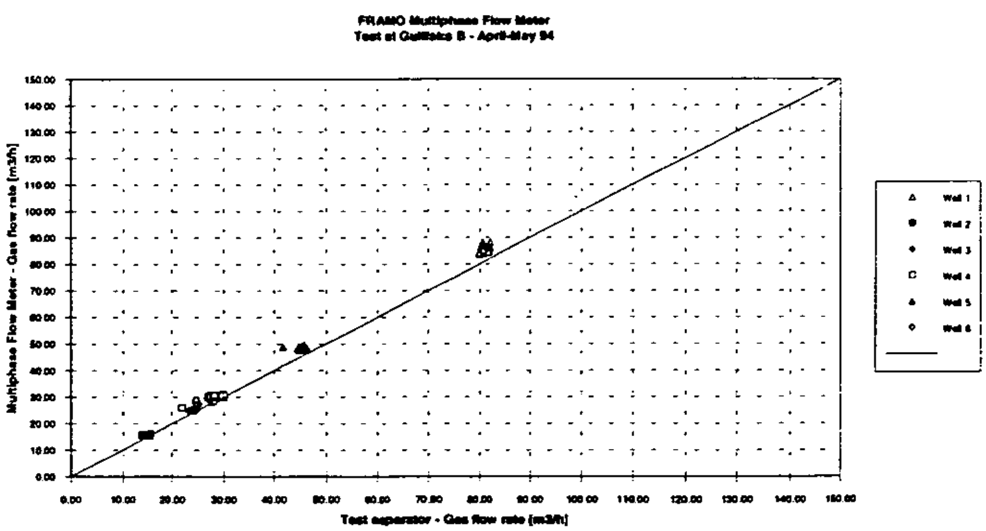


Figure 3 Measured gas flow rate vs. test separator gas flow rate, Gullfaks B

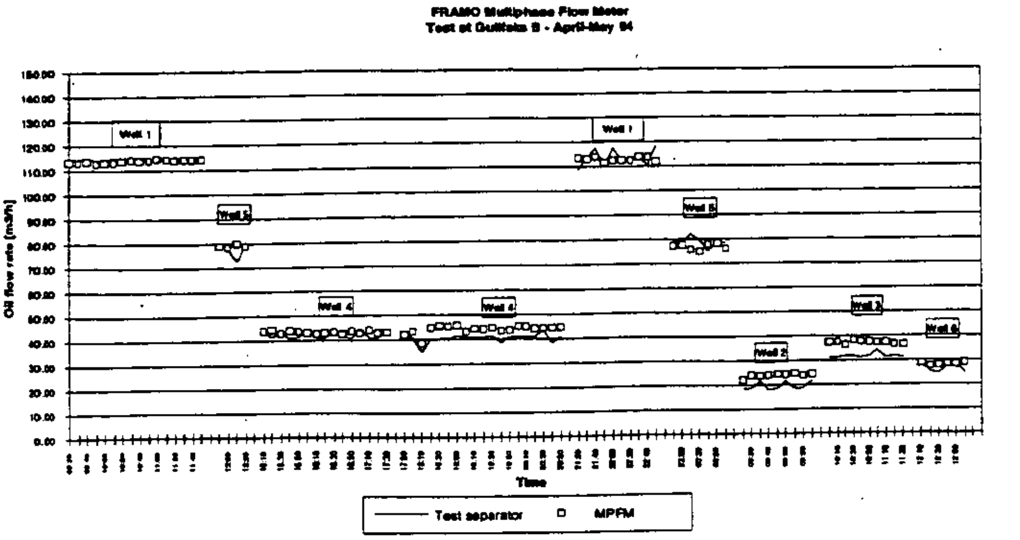


Figure 4 Multiphase flow meter and test separator oil flow rate vs. time, Gullfaks B.

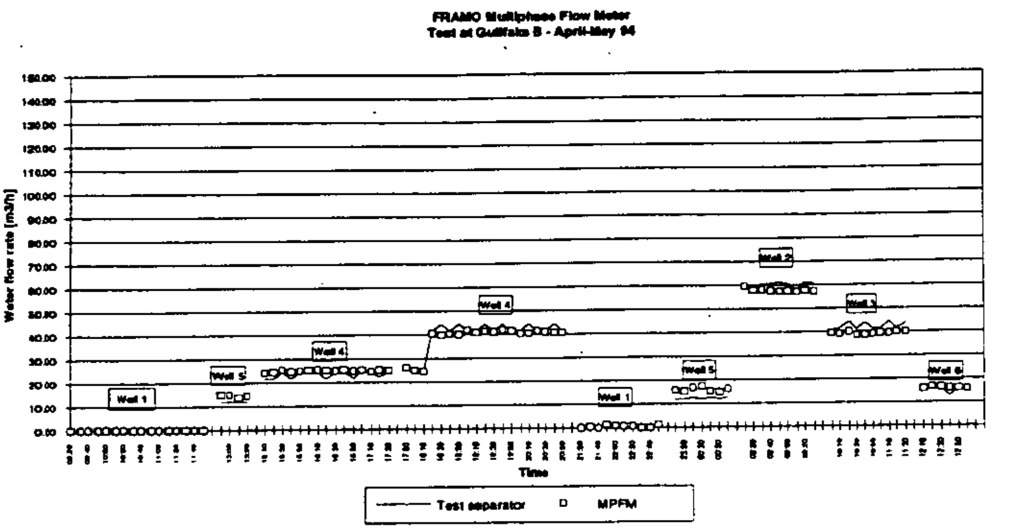


Figure 5 Multiphase flow meter and test separator water flow rate vs. time, Gullfaks B.

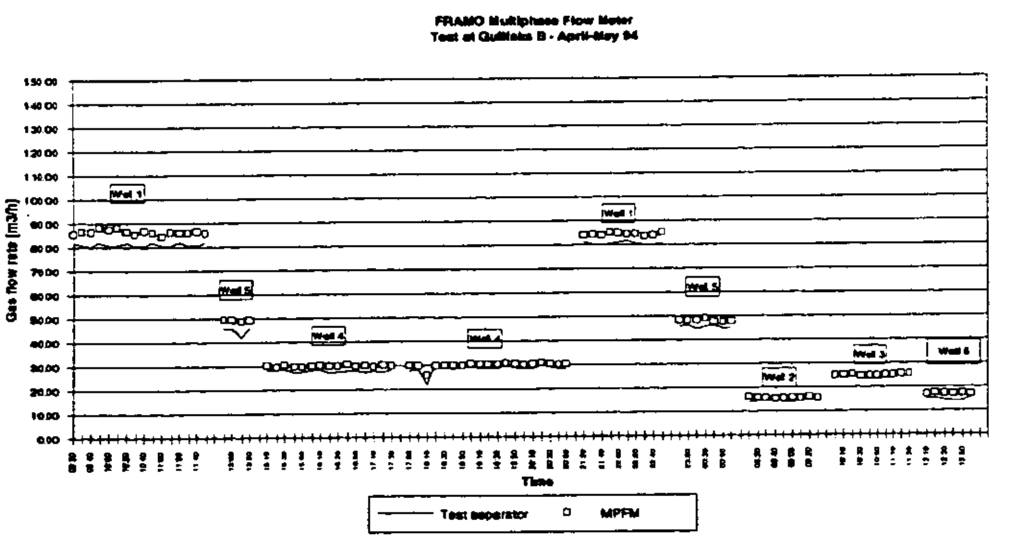


Figure 7 Multiphase flow meter and test separator gas flow rate vs. time, Gullfaks B.

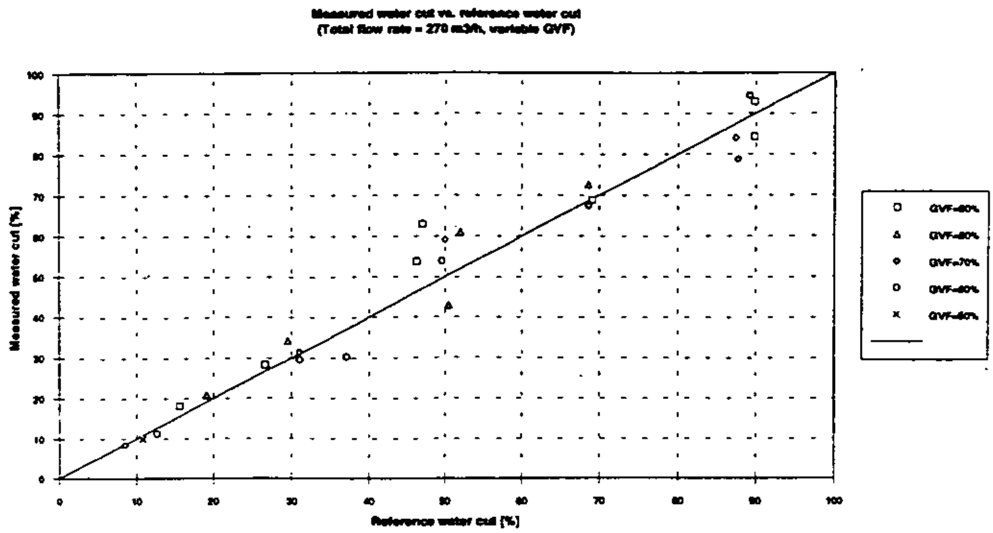


Figure 7 Measured water cut vs. reference water cut, Humble.

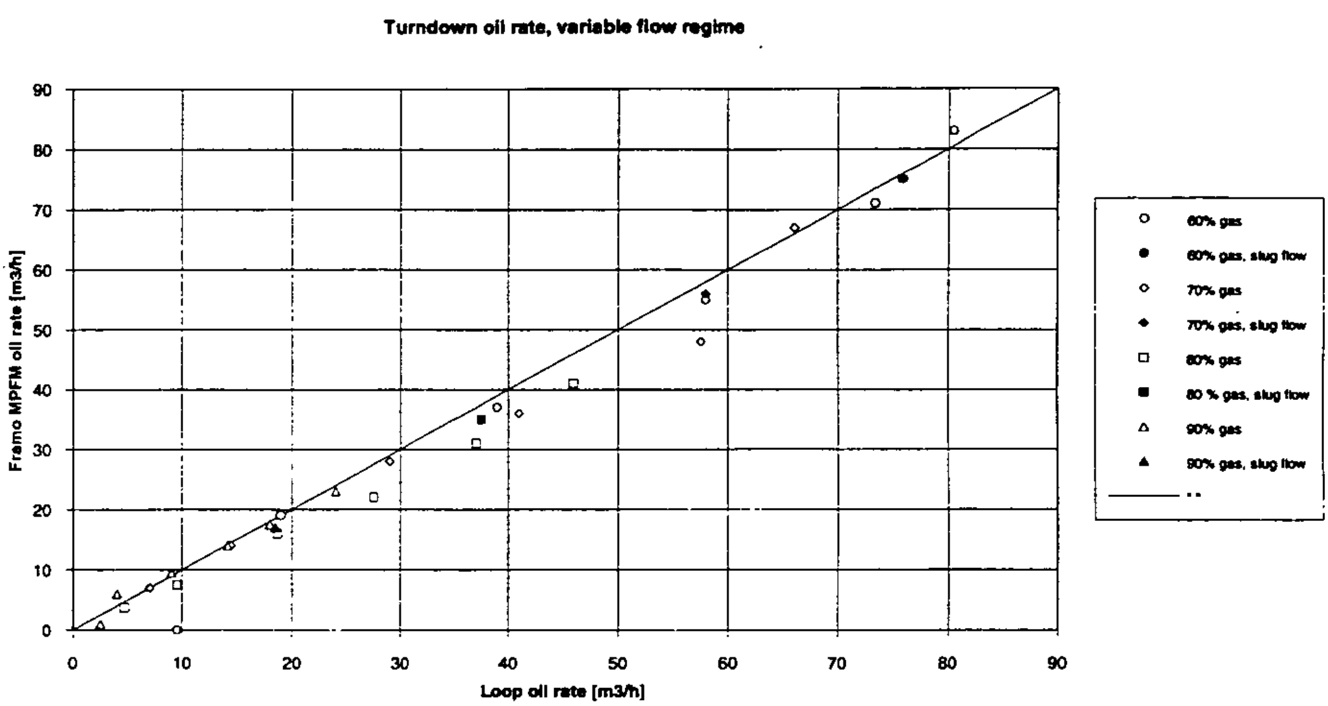


Figure 8 Measured oil rate vs. reference oil rate at variable flow regimes, Humble.

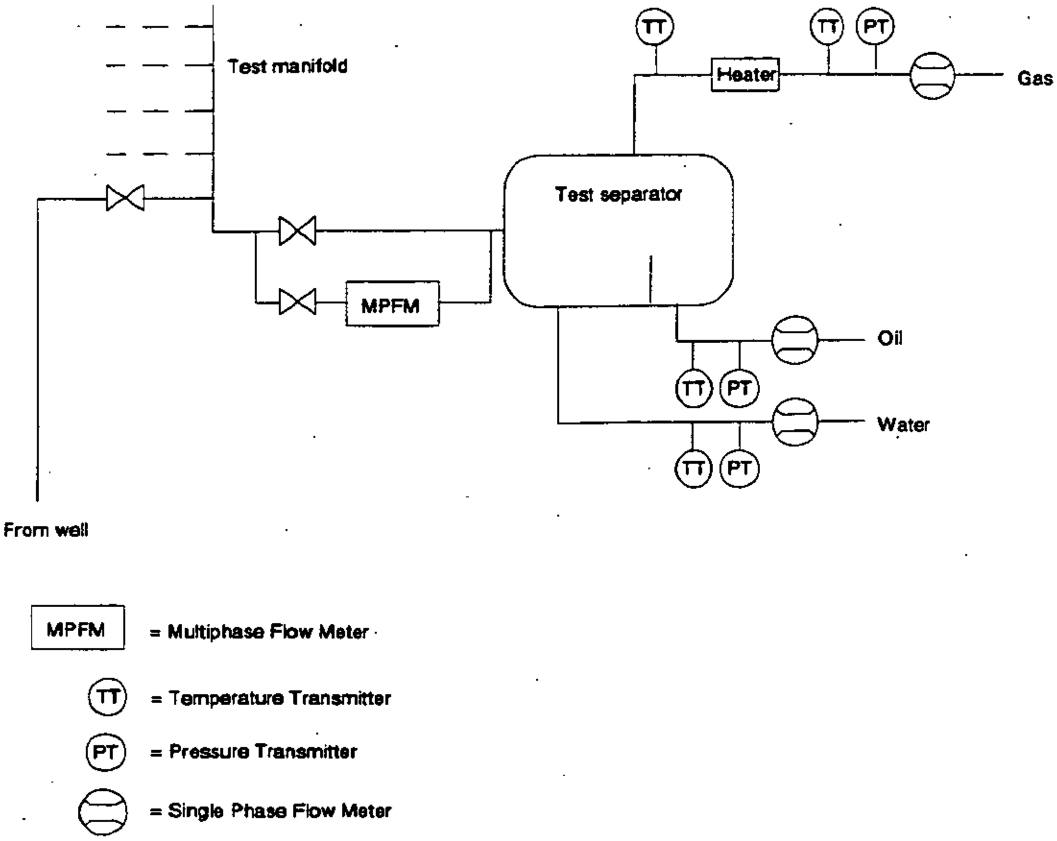
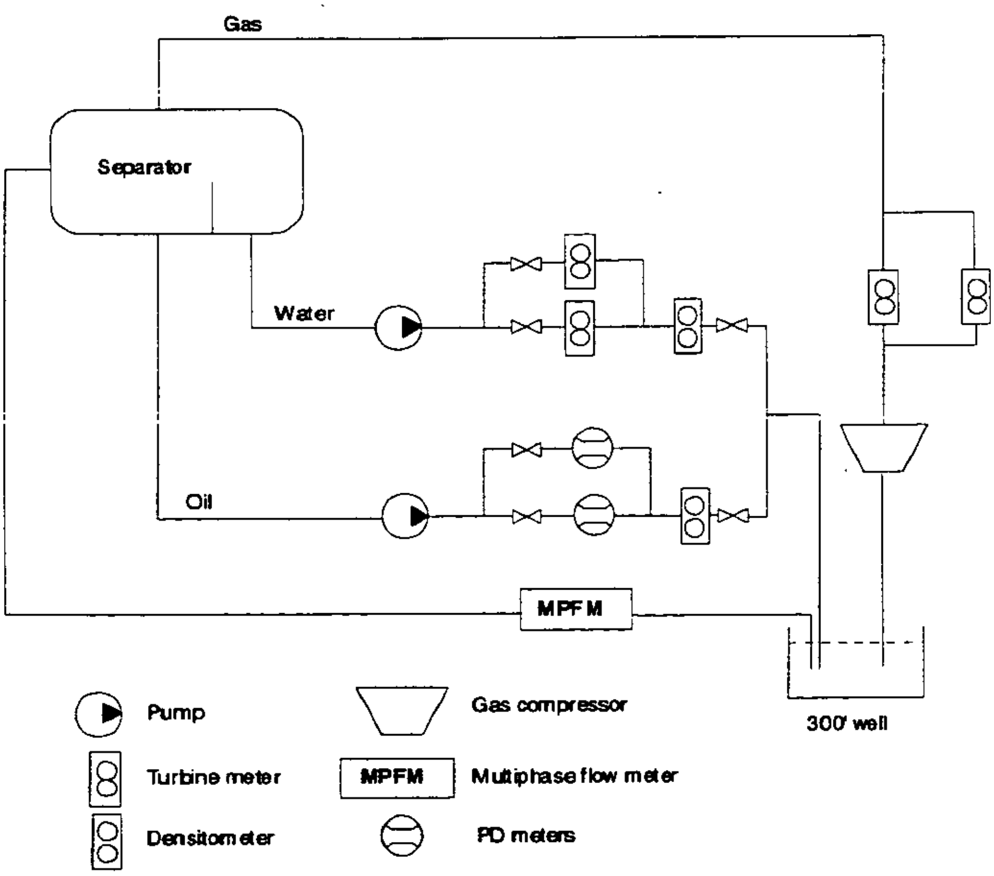


Figure 9. Test set-up at Gullfaks B.



igure 10 Multiphase test loop at Humble test site.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.