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THE PORSGRUNN 2 TEST PROGRAMME OF MULTIPAHSE METERS

GENERAL RESULTS AND EXAMPLES OF DIFFERENT METER PERFORMANCE

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Porsgrunn

Main Index

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1. The Summary

Use of multiphase meters has a large economical potential, especially in development of satellite fields. During the last 10 years several development projects of multiphase flow meters are supported by the oil industry and multiphase meter experience is gained through different testing and field trial programs. Among these are tests in the Multiphase Flow Loop at the Hydro Research Centre in Porsgrunn, Norway.

This presentation gives examples of observations made during the "Porsgrunn 2" test programme carried out in 1996.

This test programme was carried out on meters from Fluenta a.s, Framo Engineering A.S, ISA Controls Ltd., Kværner Process Systems A.S and Multi-Fluid International A.S. Sponsoring oil companies were: BP Exploration, Conoco, Elf, Esso, Phillips, Shell, Saga, Statoil and Hydro.

The Porsgrunn test programs are carried out in The Multiphase Flow Loop (MPFL) at Norsk Hydro, Research Centre Porsgrunn. The MPFL is a circulating test loop for hydrocarbon liquid (crude oil or condensates), hydrocarbon gas and formation water operating up to 110 bar and 140 °C. The flow loop has a length of 120 meter and a diameter of 3 inch (77.9 mm).

The test programme consisted of pressure levels from 30 to 90 bar, of watercuts from 0 to 90 % and of gas volume fractions up to 98 %. Fluids were: Formation water, hydrocarbon gas and crude oil, all recombined to Oseberg oil field specifications

Results are presented as examples of performance of two meters, one operating on the basis of cross-correlation only and one with only venturi based velocity measurements.

The results show that the accuracy and the distribution of liquid and gas flowrates of a multiphase flow meter having velocity calculations based on cross-correlation only are well up to the level of the venturi based meter tested.

Studying flow regimes and fluid continuity as possible factors for making influence on multiphase meter performance we found that even if the test programme covered several flow regimes, non of these were found to have any influence on the accuracy of the two specific multiphase meters. Watercut was, however, found to be a parameter that made significant influence on the composision measurement of one of the two meters.

2. The acknowledgement

Acknowledgement is given to the following oil companies which attended as clients to the "Porsgrunn 2" test programme. The authors would like to express their gratitude for the interest and support given by the clients during the test programme and for the permission to use test program results as a basis for this presentation.

BP Exploration, Sunbury
Norske Conoco AS
Elf Petroleum Norge AS
Esso Norge AS
Phillips Petroleum Norge AS

Saga Petroleum AS
A/S Norske Shell
Statoil
Hydro

3. The multiphase flow meters included

The following multiphase meters were installed in parts of, or in the complete, test programme:

Fluenta MPFM 1900VI
Framo Multiphase Meter
ISA Multistream Meter
Kvaerner Process Systems Meter
MFI MultiPhase Meter

4. The test facility

4.1 General

The Multiphase Flow Loop (MPFL) at Norsk Hydro, Research Centre Porsgrunn is a circulating test loop for hydrocarbon liquid (crude oil or condensates), hydrocarbon gas and formation water operating up to 110 bar and 140 °C.
The fluids used are recombined to specified composition.
The pressure in the loop is controlled by a gas accumulator. The flow rates of the individual phases are measured by flow meters and controlled by variable capacity pumps. The circulation capacity of liquid is maximum 60 m^3/h, while the maximum gas capacity is 205 Am^3/h.
The temperature of the fluids are controlled prior to mixing of liquid and gas. All equipment, including all pipes, have electric heat tracing ensuring stable temperature. A simplified flow diagram is enclosed in the appendix.
After establishing three phase flow the fluids enter the test loop. The loop has a length of 2 x 60 meter with a pipe having a internal diameter of 77.9 mm. At the end of each of the two loop lengths there are test sections. At the end of the first length is the test section used for the multiphase flow meter test and at the end of the second length a test section area equipped with several types of instrumentation adapted for multiphase technology measurements. Downstream the instrumentation area the fluids enter the separator before being recirculated.

4.2 The test section

48 meters (approximately 600 pipe diameters) downstream of the mixing point of the three fluids, the test section used for the test of multiphase flow meters was connected as a parallel flow line. A photo showing the flow loop including the test section is shown in the appendix.
In the test section which have the same diameter as the flow loop the multiphase flow meters were installed, three in series, two in parallel. Each meter installation was thoroughly discussed with the suppliers before making the test set-up.

In separate meetings with each vendor prior to the testing, installation arrangement and assistance, meter documentation's and calibration procedures were thoroughly discussed and settled.

4.3 The reference flow meters

The reference meters were calibrated with representative fluids at operating conditions. Calibrations are traceable to national or international standards and are carried out by accredited laboratories.

Oil flowmeter :2" PD meter Kral & L/M OMX68.01147, 0.6 - 42 am3/h,
Water flowmeter :2" turbine meter Daniel 2"-1406-1P, 2 - 51 am3/h,
Gas flowmeter :80 mm turbine meter Instromet SM-RI-G160-80-150-G, 5 - 250 am3/h

Water concentration in crude oil leaving the separator was continuously determined by a MFI Water Cut Meter. Also regularly manual sampling and analysis were carried out on both liquid phases leaving the separator.
Net liquid flow rates were calculated on the basis of fluid concentrations.

5. The test fluid

The MPFL was filled with fluids according to Oseberg oil field specifications. (90 bar data: Oil density: approx. 800 kg/m^3, gas density: approx. 70 kg/m^3 and water density: approx.1000 kg/m^3). Crude oil was taken from the Oseberg A test separator and brought to Porsgrunn without any air contamination. Pentane, butane, propane, ethane and methane were used to recombine the crude to Oseberg specifications and to make the correct hydrocarbon gas composition. The water phase was artificially made formation water, also according the Oseberg specification.

6. The test program

The test program consisted of three test periods and was organizied to provide information from both installation and operation. Between the first and second test period the vendors were alowed to make meter adjustments.
The test temperature was kept at 60 °C and the pressure changed between 30, 60 and 90 bar.
Gas superficial velocities were from 0 to 12 m/s and liquid superficial velocities from 0.1 to 2.5 m/s implying watercuts from 0 to 90 % and GVFs from 0 to 99 %.
The data presented in this paper are mainly taken from the third test period.

7. The test results

As a basis for this presentation we have focused on two different types of multiphase meter outputs; one with only venturi measurements as basis for velocity calculations and one with the velocity calculations only based on cross-correlation. In addition to the presentation of examples of results and observations from testing of these two

types of meters we also present some observations made on reproducibilty of a multiphase meter.
General knowledge of multiphase meters point out fluid continuity (oil- or water continouos fluid) and flow regime to be factors that most probably make influence on multiphase meter performance. This presentation is focused on possible differences between the two types of multiphase measurement caused by these operating conditions.
Figure 1 and figure 2 give an ordinary presentation of meter performance; a graph showing multiphase meter reading versus reference meter reading.

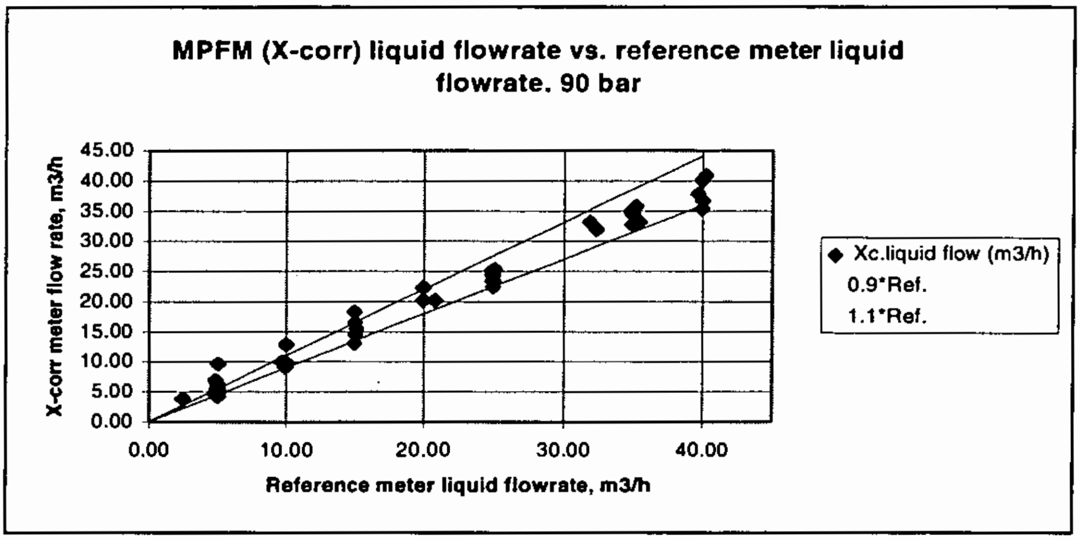


Fig 1. Cross-correlation based liquid flowrate vs. reference flowrate

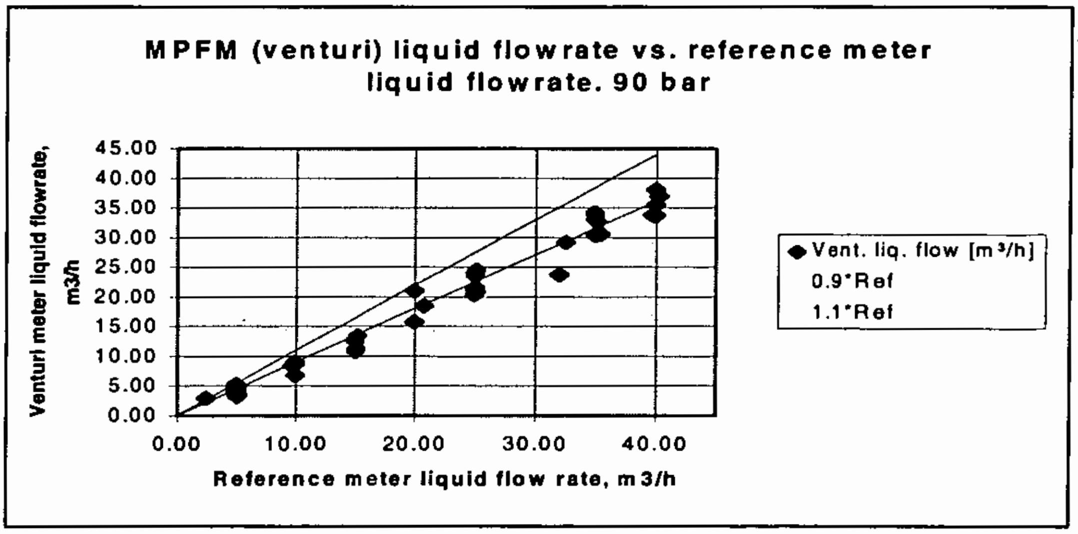


Fig.2 Venturi based liquid flowrate vs. reference flowrate

The main observations made from the graphs presented in figures 1 and 2 are:
- Some under-estimation of the venturi based liquid flow rate.
- The distribution of the different measurements are of the same order of magnitude.

Consequently we can conclude that the liquid velocity measurements of this specific cross-corelation based system is well up to the level of a venturi based system.

The results of gas flowrate measurement are presented in figures 3 and 4.

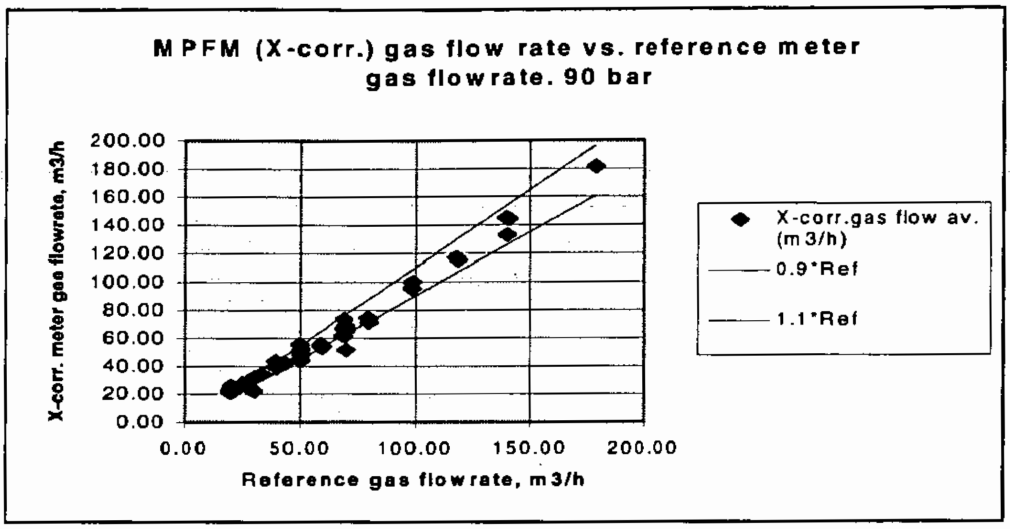


Fig. 3 Cross-correlation based gas flowrate vs. reference gas flowrate

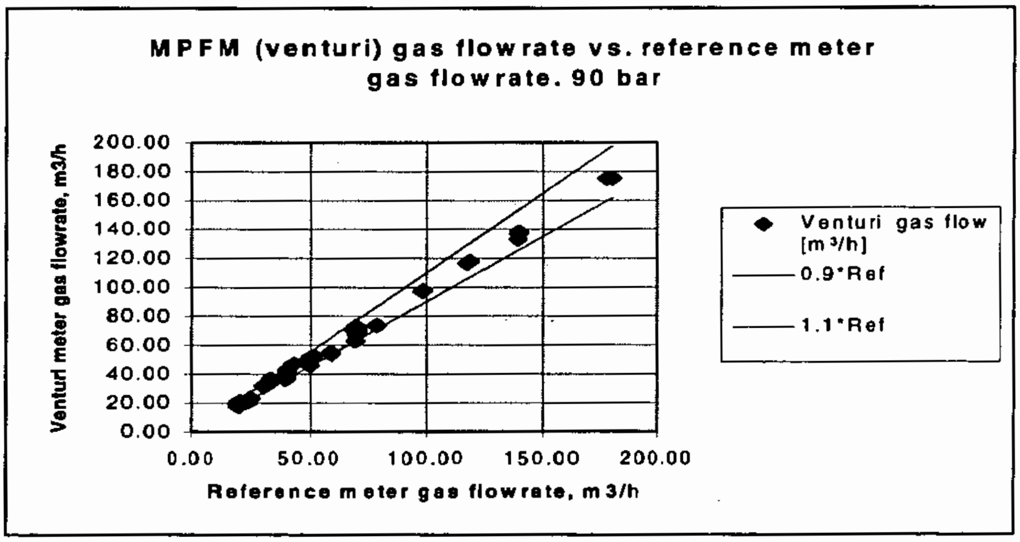


Fig. 4 Venturi based gas flowrate vs. reference gas flowrate

Nor for the gas flowrate are we able to observe any significant difference between the two types of velocity measurements.

To look for other possible differences in the performance of the two types of meters we will look into the composition measurements, here presented as outputs of meter oil rate versus reference oil rate.

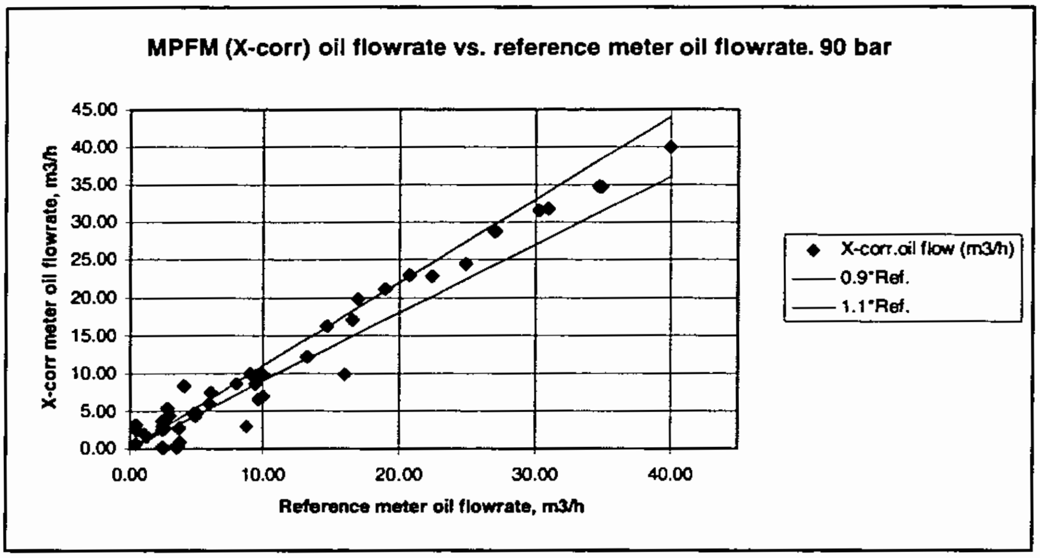


Fig. 5 Cross-correlation based oil flowrate vs. reference flowrate

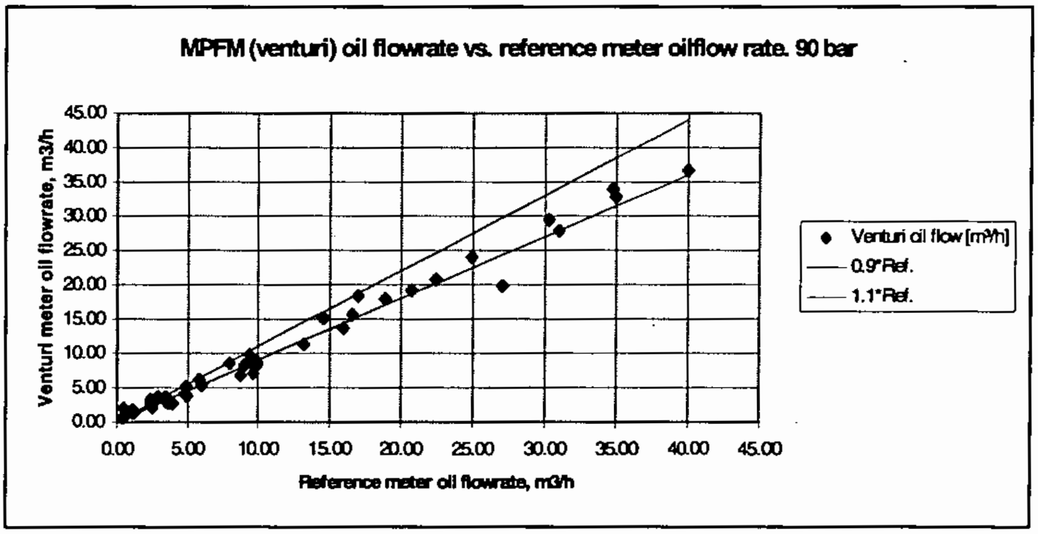


Fig. 6 Venturi based oil flowrate vs. reference flowrate

For the venturi based meter we find some under-estimating of rate. However, for the cross-correlation based meter we find a significant wider distribution of the readings of low flowrates of oil.

We will look into the possible effects of operating conditions to search for relationships that would explain the difference of the oil flow measurement.

7.1 The flow regimes

One parameter most probably making influence on the meter performance is the type of flow regime. Figure 7 shows meter performance presented as error of liquid flow measurement vs. flow regimes (as indentified in a horizontal pipe).

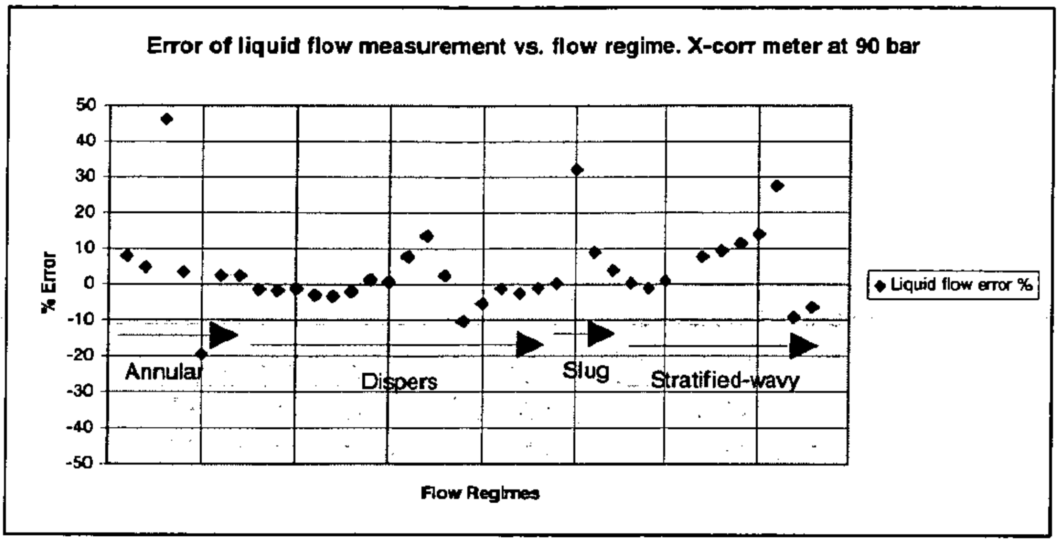


Fig. 7 Cross-correlation based liquid flowrate vs. flow regime

The data presented in figure 7 confirm the conclusion drawn on the basis of results presented in graph no. 1; it is not possible to observe any effect of flow regime on the quality of the liquid flowrate readings.
The same presentation made on oil flowrate is showed in figure 8.

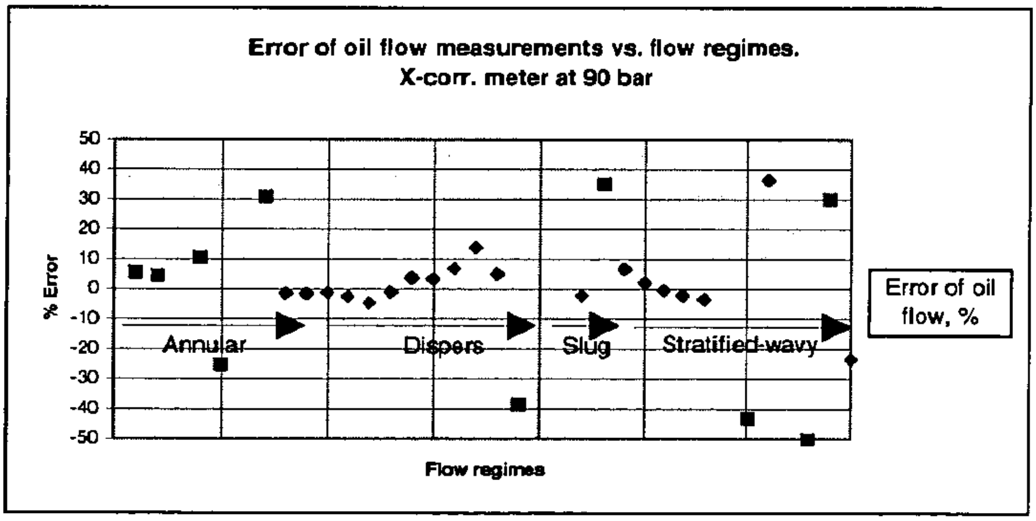


Fig. 8 Cross-correlation based oil flowrate vs. flow regime

In figure no. 8 all data points representing low oil flow (< 7 m³/h) are showed as squares , all other datapoints as diamonds. It is observed that the low flow data points represent the measurements having the far greatest error. However, nor for these low flowrate data points there can be observed any relationship between flow regime and error of measurement.

Venturi based measurements:

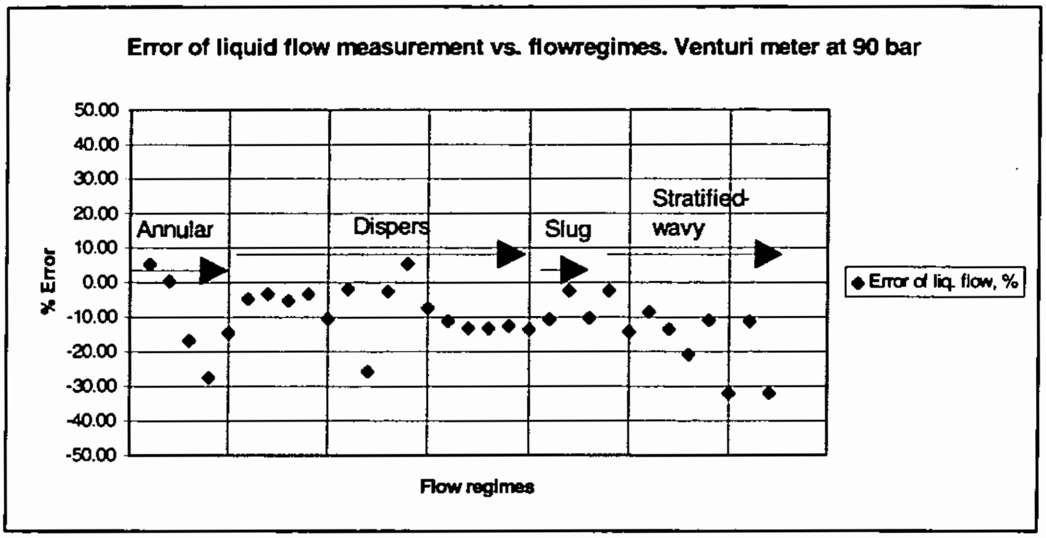


Fig. 9 Venturi based liquid flowrate vs. flow regime

Nor for the venturi based measurement we observe any significant relationship between error of liquid flow measurement and flow regimes. We only observe the same under-estimate of liquid flow as presented earlier.

From these graphs we can conclude that none of these two specific meters are influenced by flow regimes. For the venturi meter we find the under-estimated liquid flowrates as observed in the basic data in figure 2, the under-estimation can, however, not be linked to any specific flow regime.

7.2 The continuity (I.e. The watercut)

General knowledge of multiphase flow meters will also indicate water concentration as a parameter that will make influence on meter offsets.
A presentation (figure 10 and 11) showing the error of liquid rate measurement vs. continuity shows that the composition measurement of the cross-correlation based meter definitily is affected by the liquid continuity. The error of liquid rate measurement is significant higher in a water continouos fluid.
For the venturi meter, however, the conclusion is not that clear, but some influence from the watercut is observed.

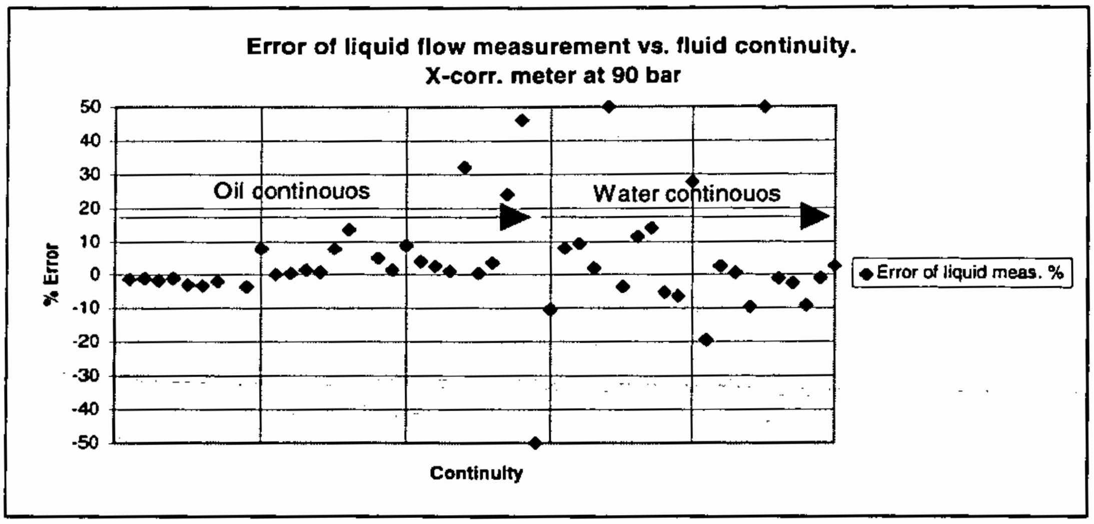


Fig. 10 Cross-correlation based liquid flowrate vs. fluid continuity

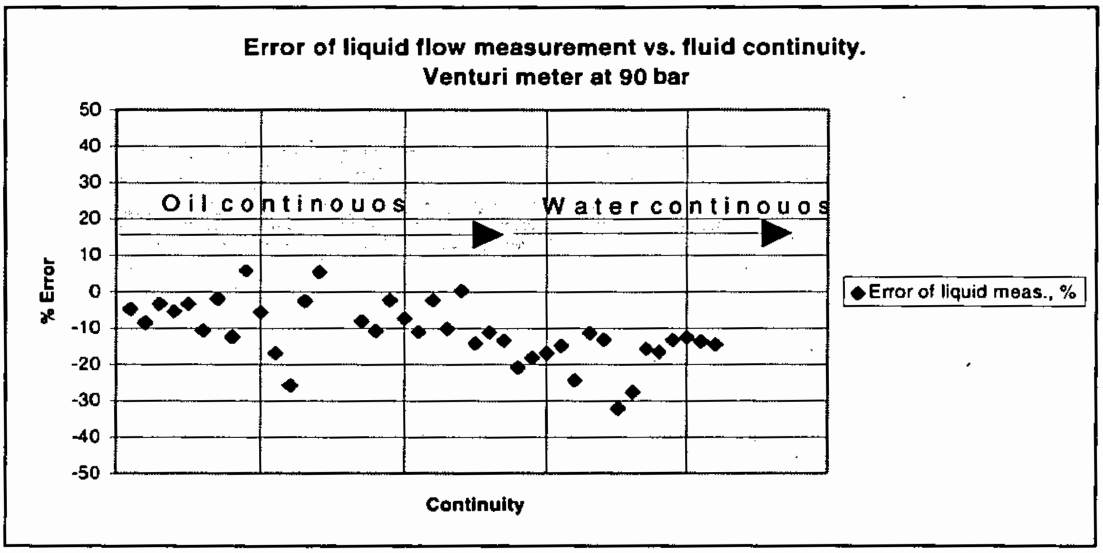


Fig 11 Venturi based liquid flowrate vs. liquid continuity

In order to investigate the effect of presence of water more thourogly we may look at the watercut calculated by the meters. Figure no.12 and no. 13 show watercut as presented by the meters versus reference watercut. Once again we observe the influence of water on the composition measurements of the cross-correlation based meter. The meter readings show a much wider distribution at watercuts of 60 % and higher.

For the venturi based meter the picture is not that clear; we find distribution in the watercut area of 40 - 75 %, however, at the 90 % level the readings are well located in a narrow distribution.

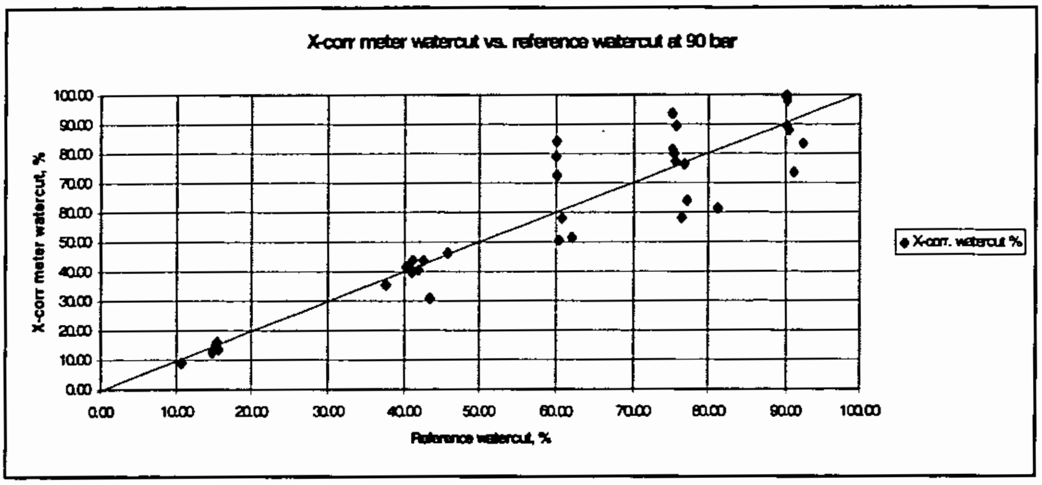


Fig. 12 Watercut presented by cross-correlation based meter vs. reference watercut

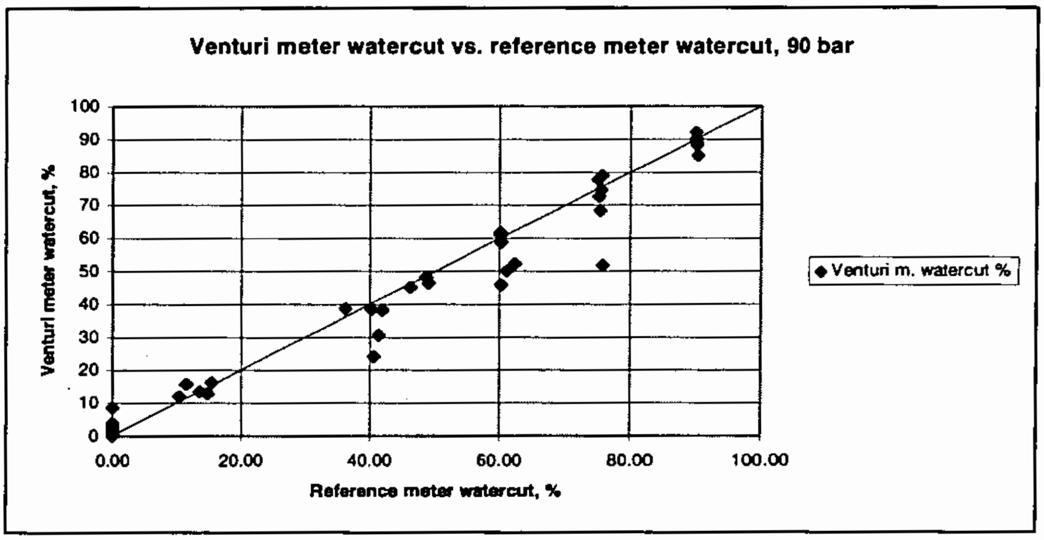


Fig. 13 Watercut presented by "Venturi meter" vs. reference watercut

7.3 Reproducibility

In cases when having a good reference system the possible offset of a multiphase meter could be compensated by making meter adjustments. Consequently it wil be most important to have a meter reproducing the readings at equal operating conditions with a high degree of accuracy.

The reproducibility of the cross-correlation based multiphase meter was evaluated. Since the concentration of water has been found to have influence on the meter accuracy the same parameter is used as a basis for reproducibility evaluation. The following figure shows reproducibility versus watercut.

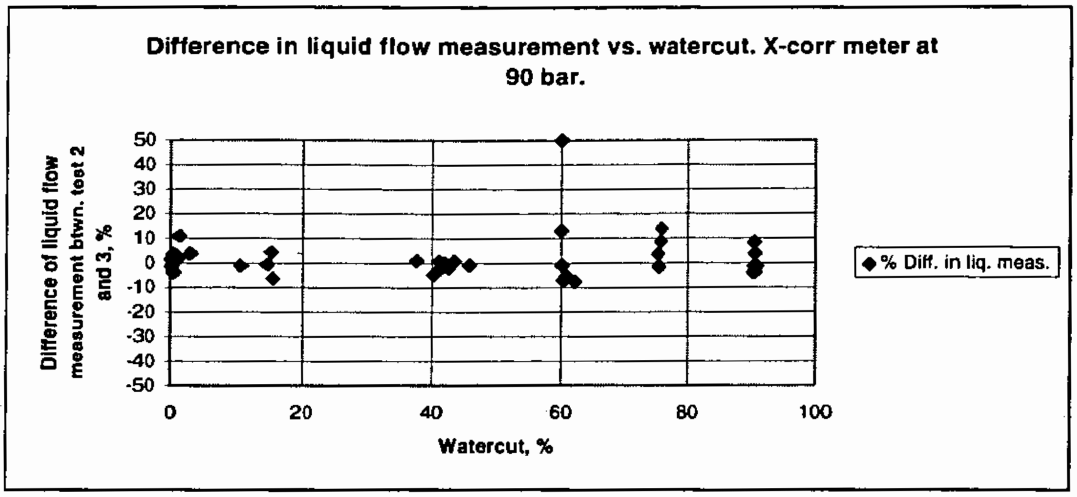
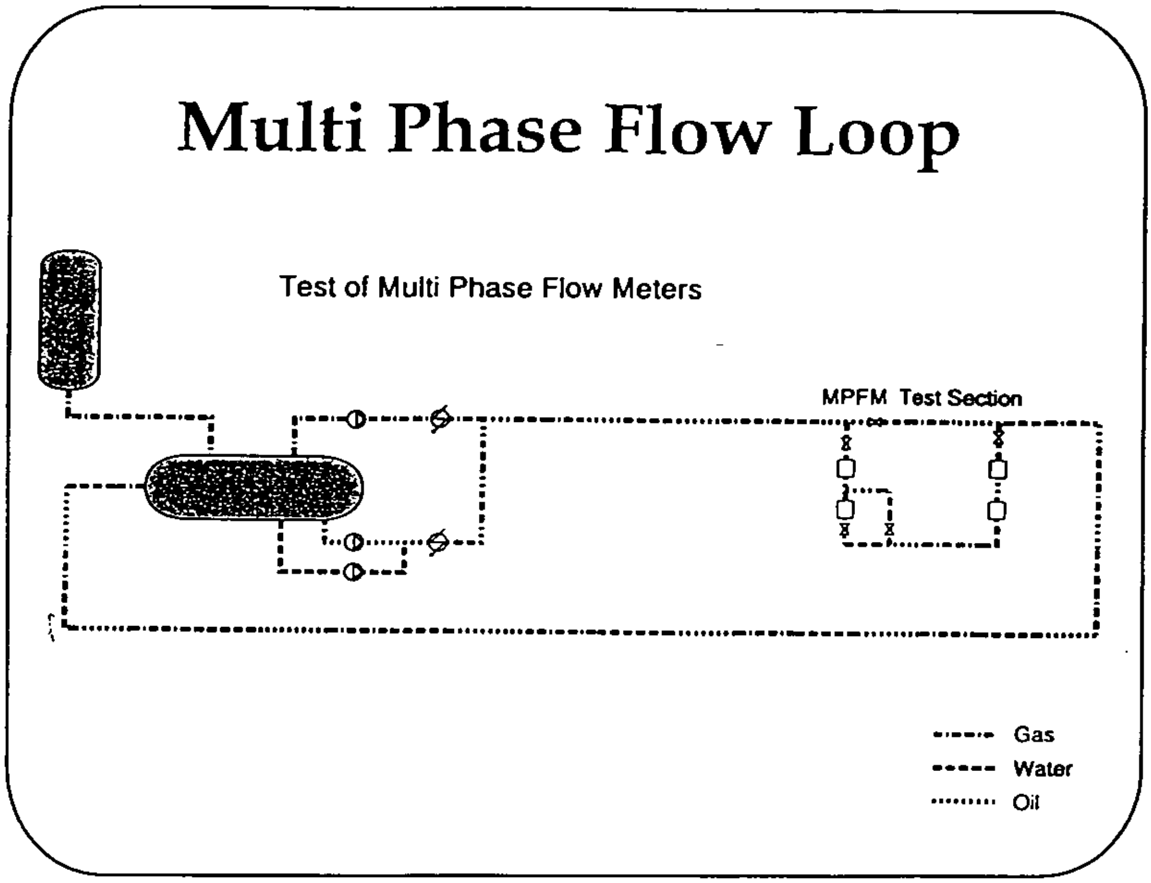


Fig. 14 Reproducibility presented as difference between the readings of two equal test points in two differents test series.

The data points do not show any significant watercut influence on the reproducibility. Consequently systematic errors caused by weakness in the liquid composition measurement can be corrected.

8. The conclusions

The results from testing of a multiphase flow meter having velocity calculations based on cross-correlation only show that the accuracy and distribution of the liquid and gas flowrates are well up to the level of the venturi based meter tested. Studying flow regimes and fluid continuity as possible factors for making influence on multiphase meter performance we found that even if the test programme covered several flow regimes, non of these were found to have any significant influence on the accuracy of the two specific multiphase meters. However, we found watercut to be a parameter that made significant influence on the composision measurement of one of the two meters.



Simplified flow diagram of the Multiphase Flow Loop

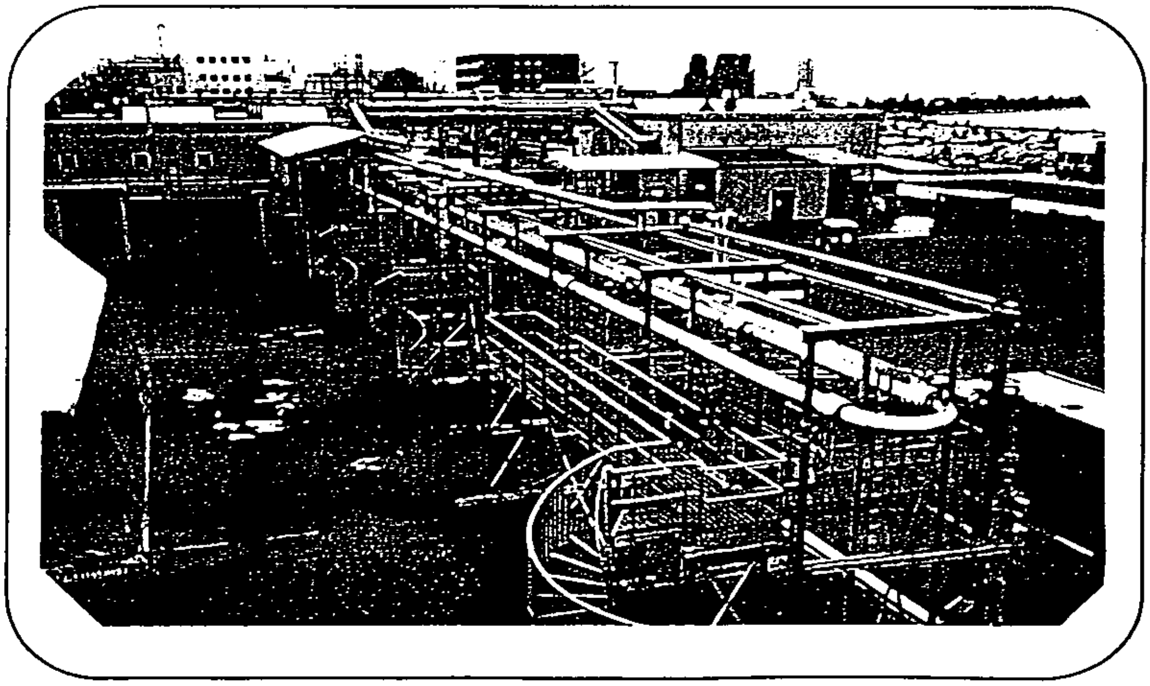


Photo of the loop including test section

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.