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The performance of the Fluenta MPFM 900 phase fraction meter

by

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THE PERFORMANCE OF THE FLUENTA MPFM 900 PHASE FRACTION METER

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ABSTRACT

The purpose of the evaluation performed by NEL was to give Amerada Hess an independent and critical evaluation of the performance of the MPFM 900 prior to further investment in the MPFM 1900 multiphase flowmeter.

Whilst some of the early findings were unfavourable for totally unexpected reasons, the laboratory trials eventually proved to be highly successful. The instrument met the claimed uncertainty figures of 3 per cent on phase fraction over the entire test envelope.

A similar evaluation of the MPFM 1900 is presently in progress at NEL, prior to an offshore trial and then marinisation. The results of the NEL work will be presented in 1994.

1 INTRODUCTION

As part of the development of a multiphase flowmeter system for Amerada Hess's North Sea operations, the Fluenta multiphase fraction meter was evaluated at NEL in 1992. Since the phase fraction measurement is the most challenging part of multiphase metering, this work was seen as a necessary prelude to evaluating the MPFM 1900 multiphase flowmeter.

The MPFM 900 is a full-bore, non-invasive instrument which uses two fundamental measurements associated with the fluid properties: a measurement of the capacitance of the liquid to determine the water cut and a measurement of gamma ray absorption across the pipe diameter. In combination, these two measurements allow the phase fractions of oil, water and gas to be determined.

The purpose of the evaluation was to critically examine the claimed performance figures over a range of flow compositions, flow velocities and installation conditions. It will be seen that some important conclusions resulted.

2 THE TEST FACILITY

The instrument was installed in one of the multiphase flow facilities at NEL, see Figs 1 and 2. The water cut was set by adding the desired amount of water to the oil held in the main tank, and as such the nominal water content was fixed until the next addition or subtraction of water. Since the mixing within the tank was to some degree a function of the bypass flowrate, the test section water content was actually determined by abstracting a continuous sample from the liquid entering the test section. The sample flow passed through a Schlumberger densitometer and from the density readings the true water cut was obtained. During the test runs the density readings for a particular condition were stable to within a 5 kgm^{-3} range.

The liquid flowrate was determined by a turbine meter calibrated over a range of viscosities to allow for the viscosity variation as the water content changed. The gaseous phase was air, which was metered with a turbine meter of appropriate size from a set of three. From these measurements the <u>volumetric</u> phase fractions were determined. In addition, because the MPFM 900 measured the <u>area-based</u> phase fraction due to the operational characteristics of the gamma densitometer, a second gamma meter was installed to provide a reference <u>area-based</u> phase fraction measurement.

The initial test runs were performed using a refined oil, similar to kerosine, but with a viscosity of 7 cSt at 20°C. However, for reasons explained in Section 3 the oil was changed during the evaluation.

3 INITIAL RESULTS

The instrument was installed and commissioned using low water content mixtures and gave no indications of the rather unusual performance that was to follow.

On increasing the water cut to just over 20 per cent, the phase fraction measurements, notably the water and oil fractions, became highly dependent upon the liquid flowrate. Figs 3 and 4 illustrate the variation in phase fraction readings for an identical flow composition and installation, the only change between the graphs being an increase in liquid flowrate from 10 l/s to 20 l/s.

This problem was examined extensively using varying water cuts and flowrates and, for all instances were this increase in phase fraction was noted, the following were concluded:

a Liquid flowrate was the dominant parameter;

b On reducing the liquid flowrate below the apparent threshold value, the change in the MPFM 900 readings was sudden, usually taking no more than 5 seconds to move from the previous stable value to the new stable value.

There was much debate about mixing and whether the water was separating prior to reaching the instrument, and some tests were performed using jet mixing immediately upstream of the MPFM 900. The mixing had limited effects, and in view of (b) this was perhaps not unexpected: it would have been virtually impossible for the characteristics of the water droplet distribution to change so radically in 5 seconds.

Attention was therefore focused on the MPFM 900's capacitance sensor in relation to the characteristics of the oil/water mixture. Clearly the capacitance sensor was shorting out, hence the high water readings, and in view of the flowrate dependency it seemed feasible that water might be building up on the sensor walls. It was further believed that as the liquid flowrate increased, the water build-up was reduced until, at a critical flowrate, the sensor was no longer being shorted out. Beyond this critical liquid flowrate the MPFM 900 operated correctly.

After much analysis of oil/water samples, a very clear conclusion was drawn by the extremely simple method of shaking mixtures in bottles made from glass and polythene. Unlike virtually all the other oil/water combinations tested, the NEL refined oil and water promoted the adherence of water droplets on a surface similar in nature to the ceramic liner in the MPFM 900.

After a change of oil the instrument performed well, but this episode had created major doubts about the application of the meter for production well monitoring where the oil/water mixes would be of relatively unknown characteristics. These doubts were reinforced when offshore trials of the MPFM 900 in the Norwegian sector gave very similar results to the NEL findings. Fluenta therefore spent considerable time and effort investigating this problem further, taking advice from Bergen University, and it was eventually concluded that under certain conditions the ceramic liner was hydrophilic.

The liners are now made from borosilicate, and it should be made very clear that no such problems are now experienced, but for all would-be manufacturers of multiphase flowmeters, this is a very important example of how even simple design features can seriously influence performance.

4 EVALUATION WITH NEW OIL

The oil was changed to Shell Vitrea 9 and no trace of the difficulties described in Section 3 were evident. The evaluation therefore proceeded and a selection of the graphs produced are shown in Figs 5-9. Note that the Y-axis is given in absolute terms because the fraction measurements themselves were in percentage format.

In terms of phase fractions, Fig 5 and Fig 6 show the instrument to have been within 3 per cent of the reference measurement system which provided area-based data. As expected, the instrument gave incorrect readings at water cuts above 38 per cent, so the graphs of Fig 5 and Fig 6 represent the lower and upper bands of water content. The change to water continuous mixtures has been addressed in the most recent MPFM 1900 instruments which use both capacitance and inductance to cover the entire water content range.

It is interesting to compare Figs 5 and 6 with Figs 7 and 8 which were taken at identical flow conditions, in fact during the same test runs. Figs 7 and 8 used the reference flowmeters to derive the phase fractions, ie volume-based reference measurements. Agreement was reasonable at low gas fractions, but as the gas fraction increased the area-based measurements of gas fraction were significantly lower than the equivalent volume-based measurements. Gas-liquid slippage was therefore occurring, with the gas flowing faster than the liquid, but over a smaller area of the pipe cross-section (ie to maintain continuity). This is to be expected in vertical upward gas/liquid flow, but it ought to be noted that with the MPFM 900 installed 10D downstream of the blind 'Tee' rather than 5D downstream, the same slippage effects were not as prevalent. Installation position did therefore influence the area-based phase fraction measurements from the MPFM 900.

Other tests to determine instrument stability and repeatability were performed and both showed the instrument to be within the claimed specification. A temperature dependency was observed on this particular instrument, see Fig 9, which Fluenta have since corrected.

5 CONCLUSIONS

There were two major findings from the work. Firstly, the performance of the MPFM 900 with a ceramic liner was dependent upon the chemical characteristics of the oil/water mixture. A conclusion confirmed by subsequent independent trials in Norway. The liner has since been changed to borosilicate to eliminate this problem.

Secondly, after changing the oil to one that did not promote the hydrophilic nature of the ceramic, the (percentage) phase fraction measurements were always within 3 per cent of the reference (percentage) phase fractions. This was for gas fractions up to 70 per cent by volume, water cuts in the range 0-40 per cent, and for liquid flowrates in the range 5-25 l/s.

The instrument was considered to have passed the first stage evaluation, and work is now in progress at NEL on the MPFM 1900 multiphase flowmeter. The results will be reported in 1994.

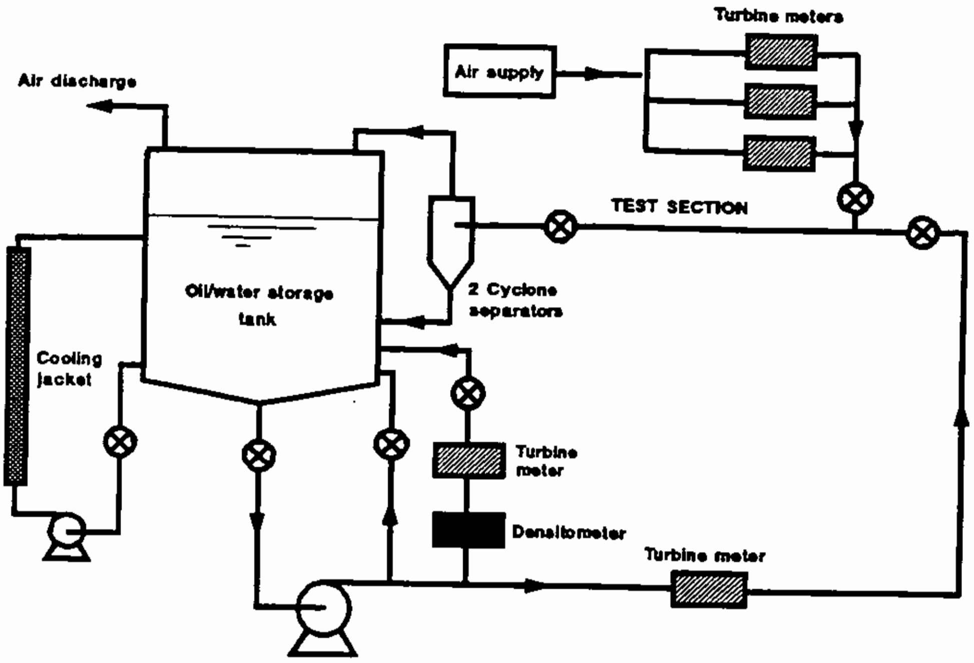

Fig 1 The test facility used for the evaluation

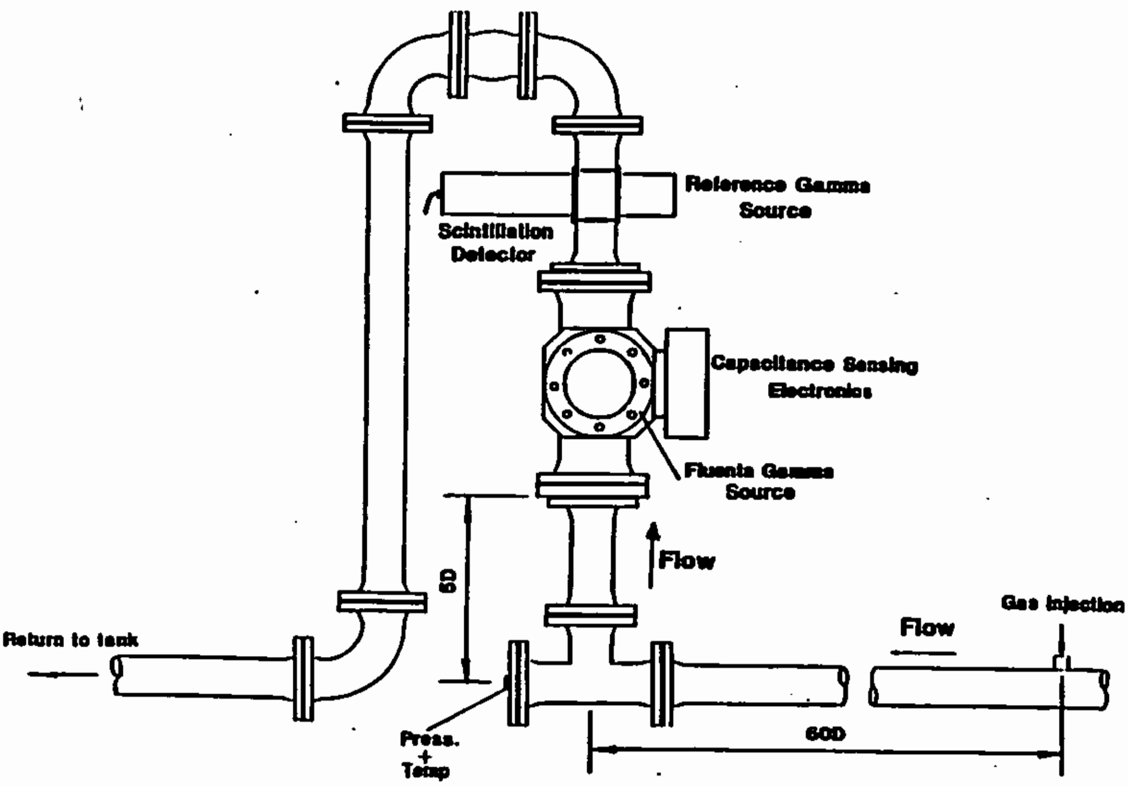

Fig 2 The test section configuration

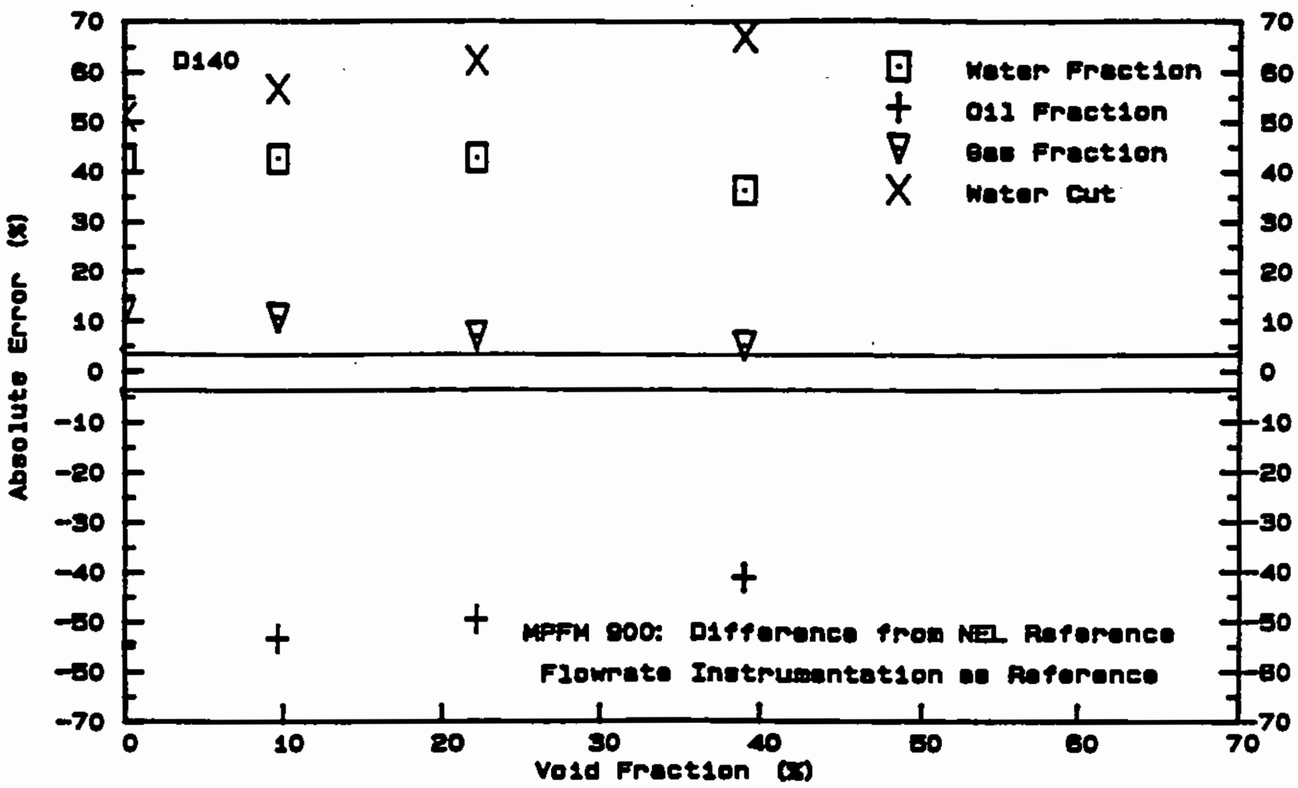

Fig 3 Initial testing with 23 per cent water at 10 l/s
(NB oil subsequently changed)

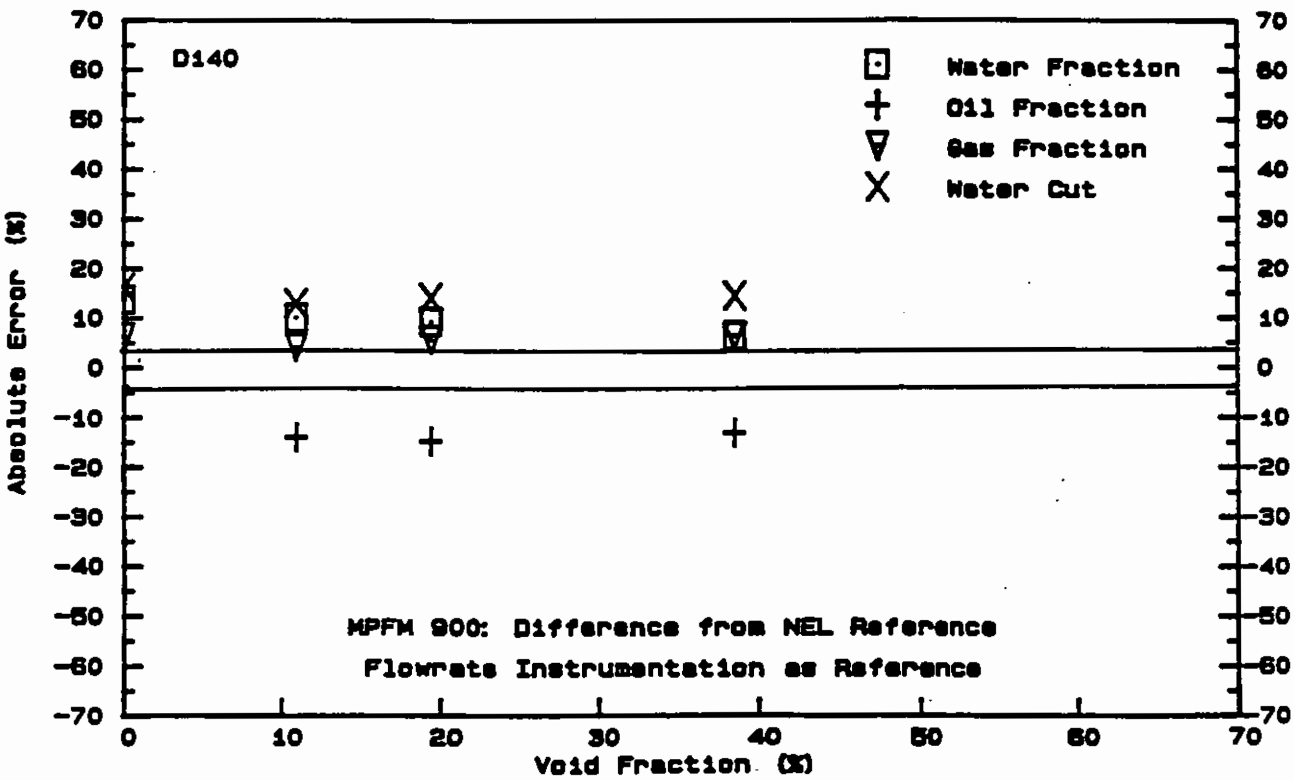

Fig 4 Initial testing at 23 per cent water at 20 l/s
(NB oil subsequently changed)

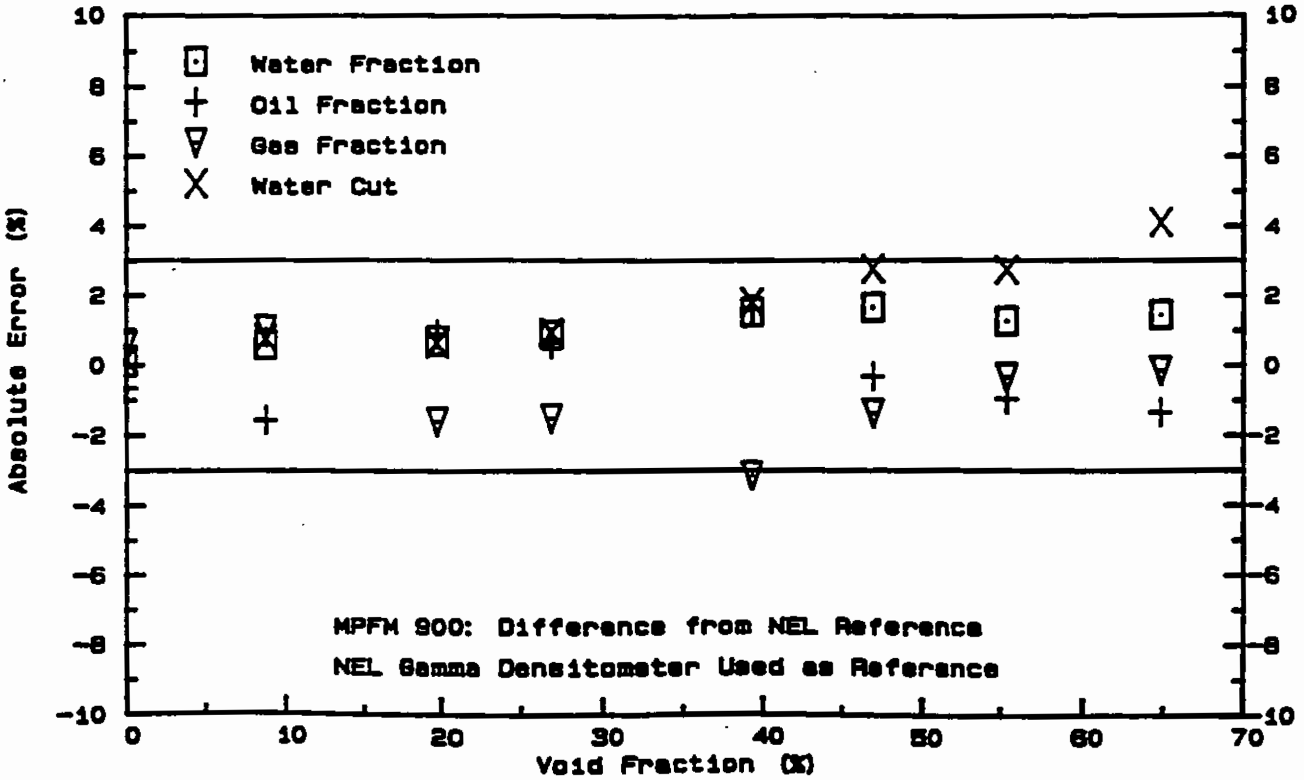

Fig 5 Performance with 10 per cent water at 10 l/s
(Area-based reference measurements)

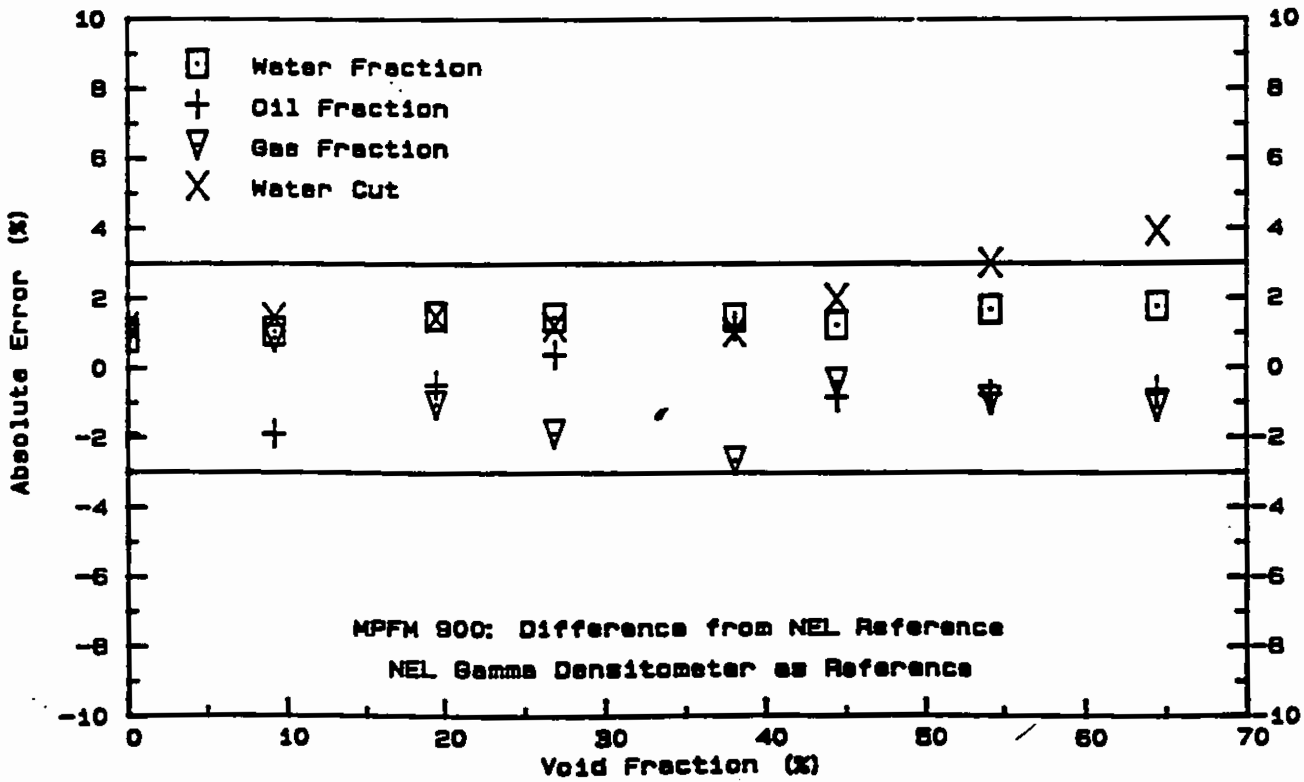

Fig 6 Performance with 30 per cent water at 10 l/s
(Area-based reference measurements)

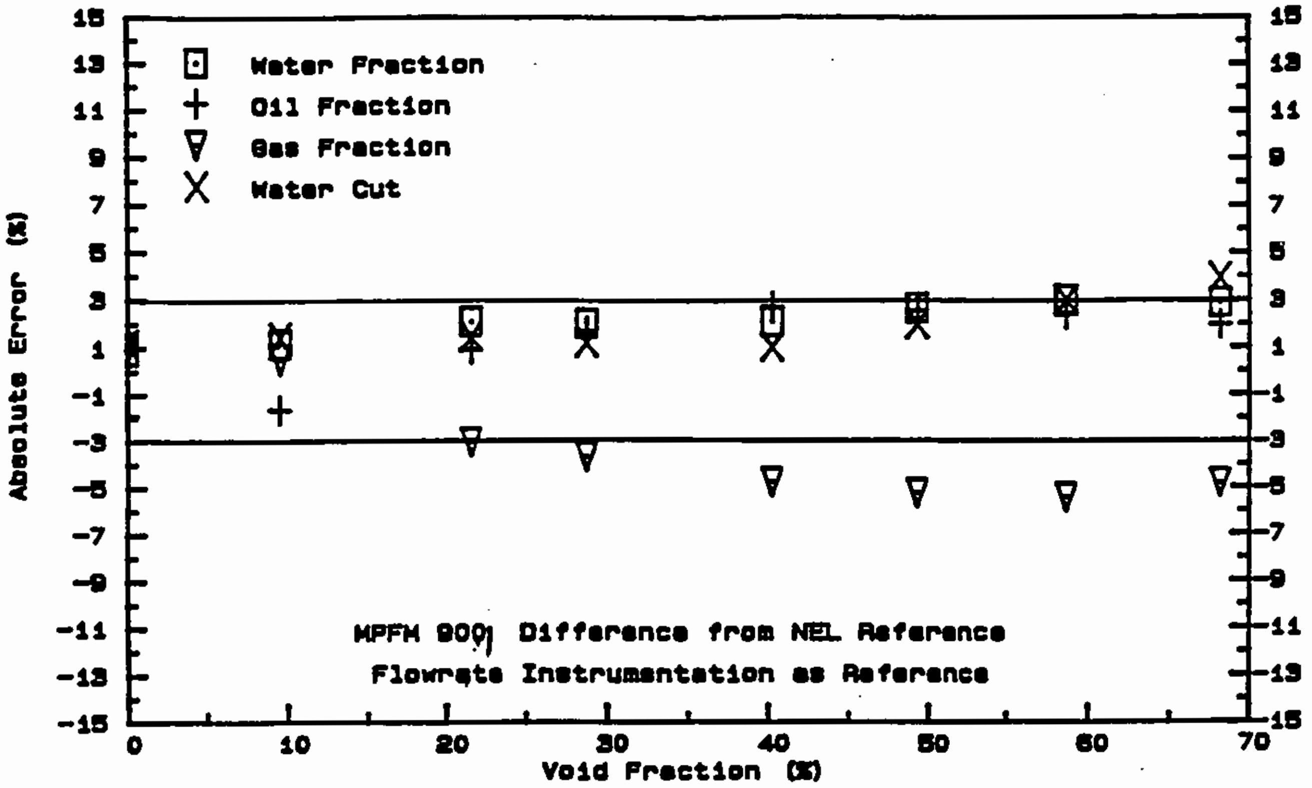

Fig 7 Performance with 10 per cent water at 10 l/s
(Volume-based reference measurements)

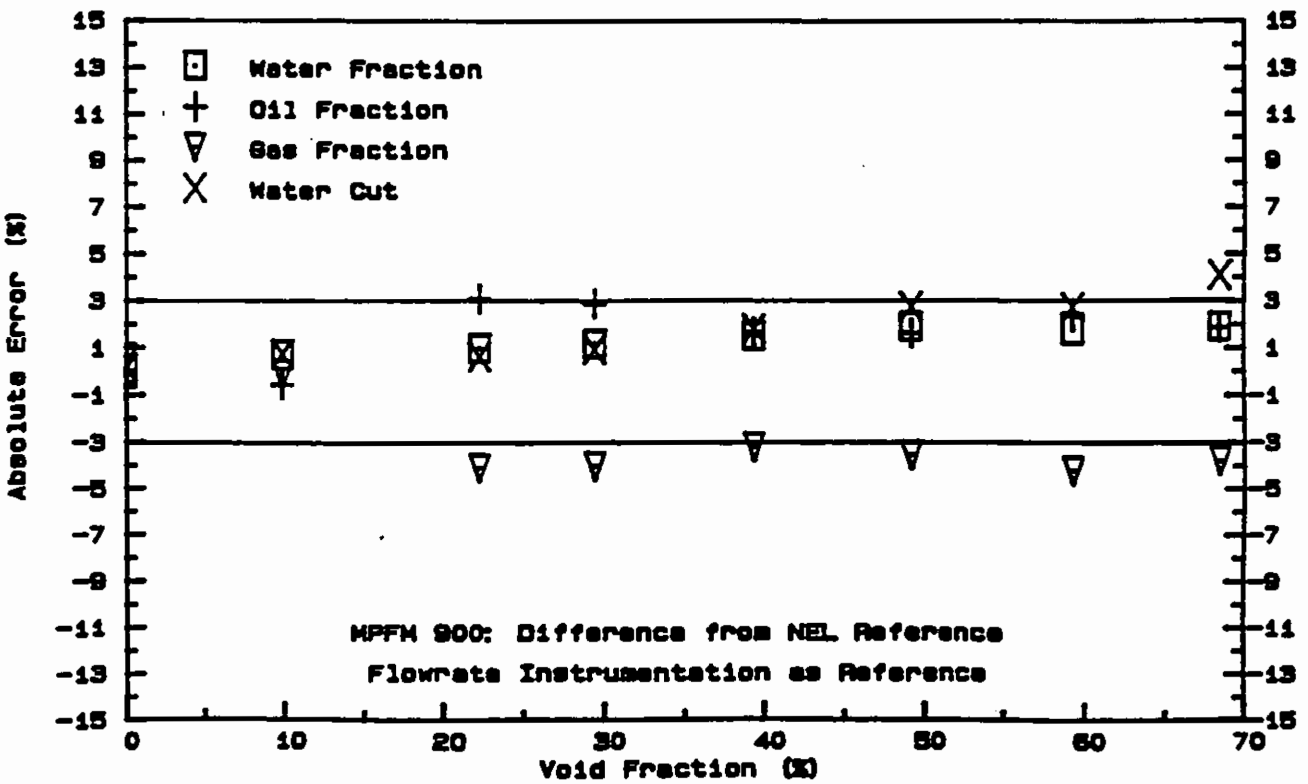

Fig 8 Performance with 10 per cent water at 10 l/s
(Volume-based reference measurements)

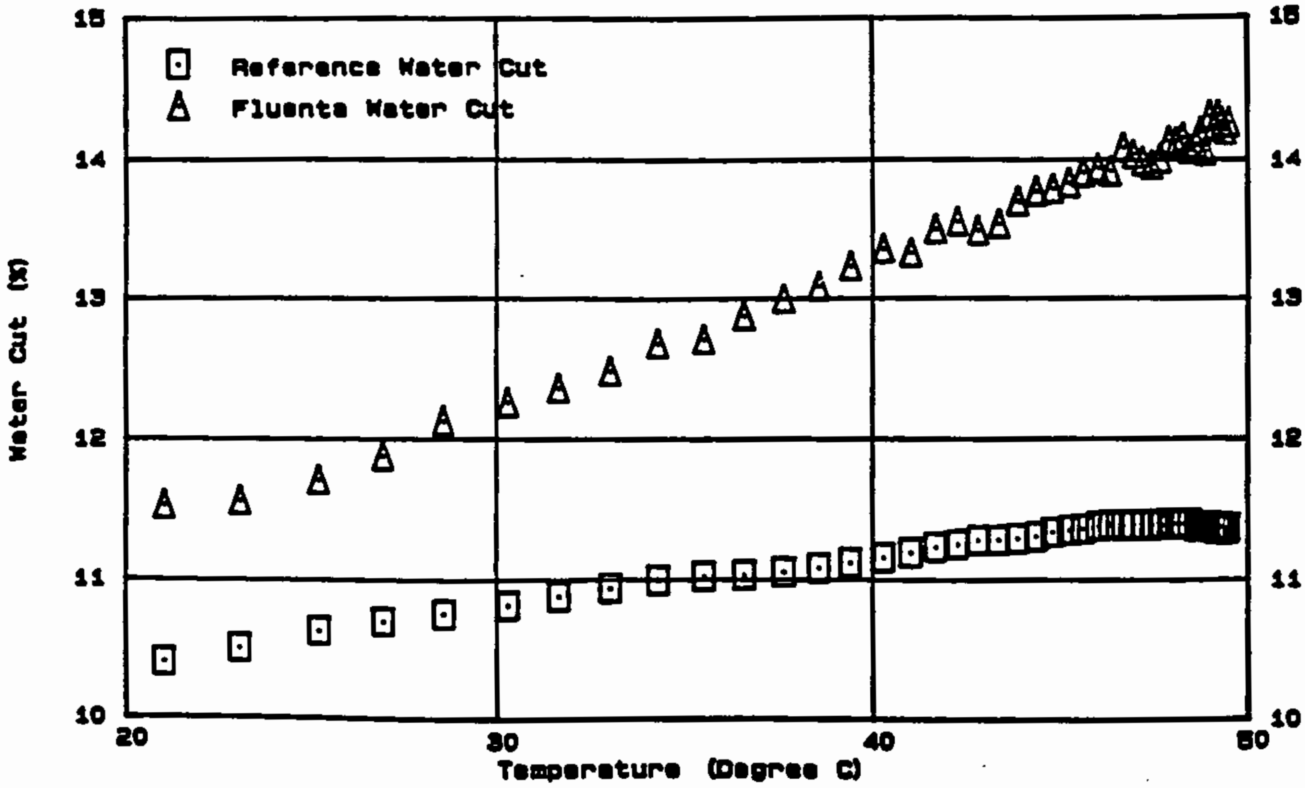

Fig 9 The effect of temperature on water cut measurements

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.