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MFI WATERCUT METER - A FISCAL METER

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SUMMARY

Two MFI WaterCut Meters have since January 1996 been under testing at the Tordis oil metering station at Statoil's Gullfaks C platform. As a result of these test the Norwegian Petroleum Directorate (NPD) has given temporarily approval for fiscal use on Tordis throughout 1997.

The WaterCut Meters (WCM) are being tested with reference to the automatic sampling system. Conversion factors from laboratory to line conditions have been developed. Important issues for these test are long term stability and minimum down-time.

1 INTRODUCTION

Tordis is a subsea oil field located 12 km north-west of Statoil's Gullfaks C platform. Saga Petroleum operates Tordis remotely from Gullfaks C where the processing is done. Both produced oil and gas are measured to fiscal standards according to the NPD regulation and used for allocation.

The Tordis oil metering station is located after the 1st. stage separator. The temperature is 63 ^{0}C and pressure 70 bar. The oil contains 16 % to 18 % gas, but is stable at line conditions. The water content has during the test period varied from 0,1 to 22 %. Sand is also periodically present. The samplers does not handle these conditions well.

Long term stability and trouble free operations at high pressure and temperature conditions, are issues to be considered thoroughly. The accuracy of the MFI WaterCut Meter has been thoroughly tested under controllable conditions at the Mongstad Terminal [1]. The accuracy has also been tested at the BP Forties Field [2], but at considerable lower pressure than for the Tordis metering station .

The sampling and analysis procedures [3] [4] and sampler maintenance are time consuming both for operators and lab technicians. Using on-line measurement reduces the total operating costs.

2 WATERCUT METER INSTALLATION

The Tordis production is separated in two trains, A and B, each train having dedicated metering runs, sampler and MFI WaterCut Meters. The WaterCut Meters are located on the outlet headers, immediately before the in-line samplers.

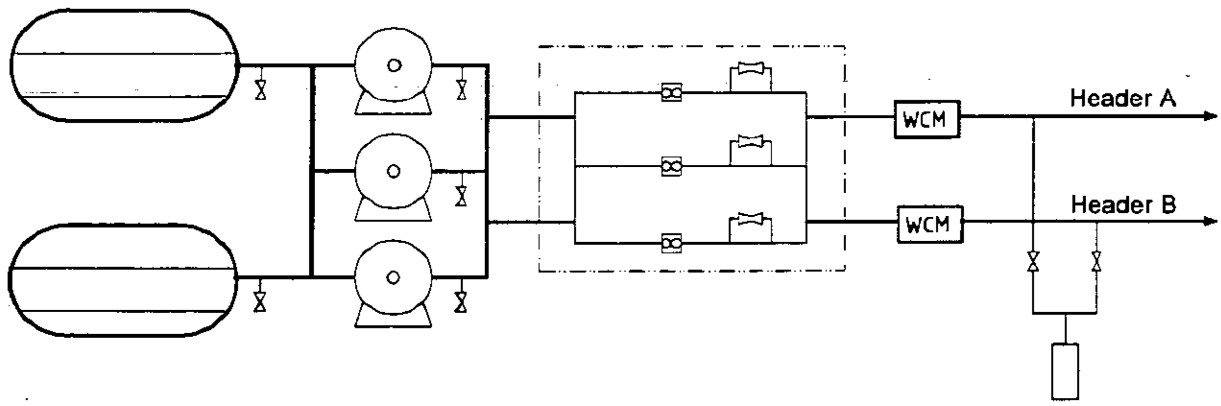

Figure 1. Installation

Both samplers are connected to the same sampling cylinder, sampling flow proportionally from separate production trains.

To get a representative sample from Tordis, both samplers must operate correctly. Tests at Tordis have shown high differences in grab samples. The volumes can vary from 0,8 ml to 1,2 ml. When two samplers with varying grab volumes, are sampling from different production train into one cylinder, the measurement uncertainty becomes high.

During 1996 the samplers were dismantled for repair 28 times, which gives us about 40 days without sampling. In agreement with the NPD the WaterCut Meters were used as back-up.

The two WaterCut Meters installed at the Tordis tie-in at the Gullfaks C platform are 6" full-bore monitors. The WaterCut Meters installed are LowCut models (0-20 % water range) and the AutoZero function is implemented.

The mixture density is measured by a Solatron densitometer interfaced to an Entelec main computer in a safe area. The mixture density from header A and B is transmitted to the WaterCut Meters on a RS422 link. As a result, all measurements and calculations performed in the WaterCut Meter are available and returned via the link to the Entelec main computer.

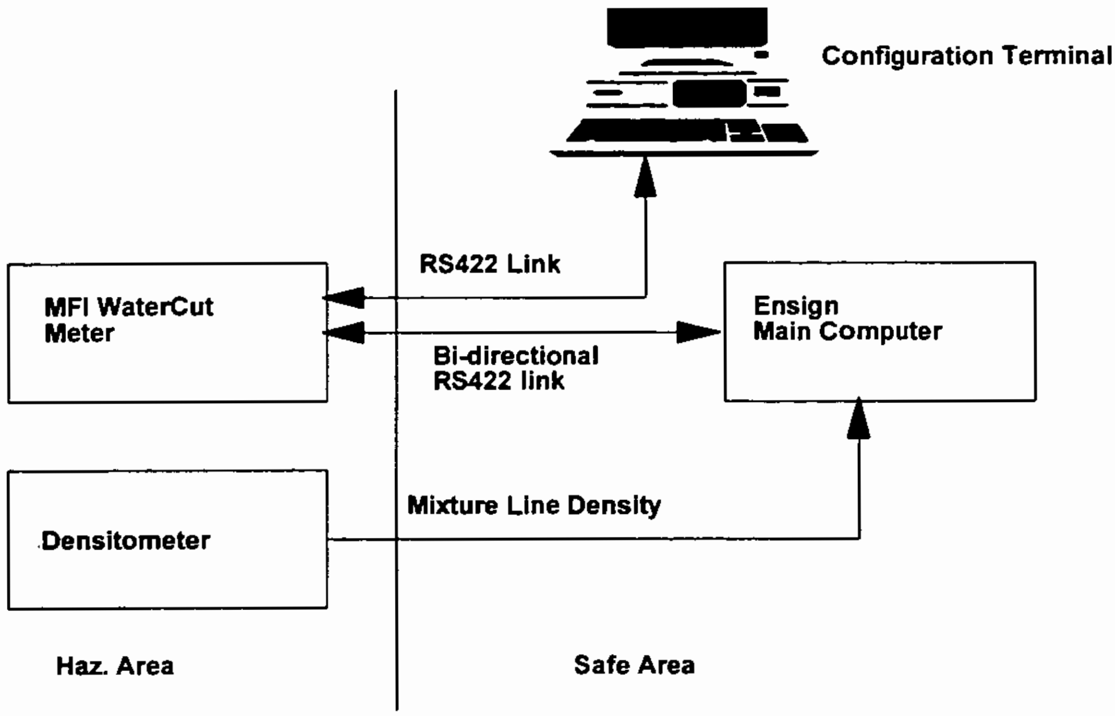

Figure 2. Block functional diagram

3 MEASUREMENT PRINCIPLE

3.1 MFI WaterCut Meter description

The MFI WaterCut Meter is a field instrument which determines the water content of mixtures of water and hydrocarbons by measuring the dielectric constants of the mixture. This basic method takes advantage of the large difference in the dielectric constants of hydrocarbon liquids and water respectively. The dielectric constant of water is far higher than that of oil. Thus, as the water content in a mixture increases, so does the mixture dielectric constant.

The WaterCut Meter uses the resonant cavity method to measure the mixture dielectric constant. A resonant cavity is a closed metal structure from which electromagnetic energy cannot escape. The WaterCut Meters are constructed such that the electromagnetic waves transmitted into a particular flowing mixture will, at a characteristic frequency (wavelength), resonate to produce a distinct peak amplitude. This peak corresponds directly to the water content of the mixture in that the characteristic resonant frequency is inversely proportional to the square root of the mixture's dielectric constants.

The resonant cavity method has long been a standard laboratory technique for measuring the dielectric constants of material samples.

3.2 Automatic Calibration (AutoZero)

The MFI WaterCut Meter uses an automatic calibration feature called the AutoZero function. With this feature the WaterCut Meter can continuously adjust its baseline calibration to minimise errors associated with changes in types of crude oil. Automatic calibration, therefore, significantly increases the accuracy of the Meter and reduces maintenance.

In operation the AutoZero function works as follows. First the WaterCut Meter determines the mixture density from the density input signal. Then it measures the raw dielectric constant of the mixture using the microwave sensor. Finally it shows a complex set of simultaneous equations to determine the correct Dry Oil Density and water content for the particular mixture.

4 CONVERSION FROM LAB TO LINE CONDITIONS

As the WaterCut meters are installed right after the 1st. stage separator, where the mixture has a high temperature and pressure, and a high gas content, conversion factors between lab and line conditions had to be developed for calibration purposes.

For Tordis oil which is stable at high line pressure, some of the oil will evaporate when a sample is taken for laboratory analysis. There is also volume change due to pressure and temperature changes. The shrinking factor, which is given as the volume ratio between the dry oil at line conditions and standard conditions, will include the evaporation as well as the PT corrections.

The water content found from the Karl Fisher titration method is given in weight percent pure water in relation to the weight of the sample mixture. This sample weight also includes the weight of salt.

In order to convert the Karl Fisher value to the corresponding volume percent water at line conditions, a determination of the evaporation is required.

Figure 3. Oil components

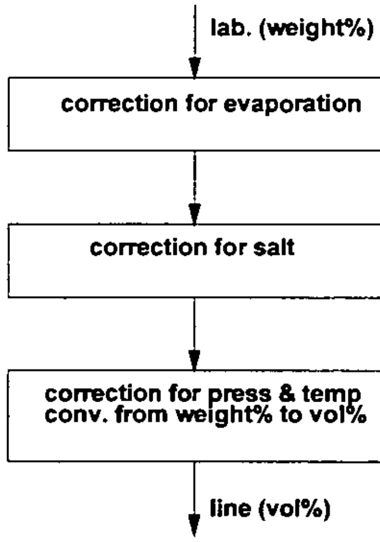

Figure 4. Conversion from lab to line conditions.

A simplified version of the upgraded Gullfaks C WaterCut Meters calibration calculations are shown below. New requirements are pressure, density of shrinked oil and shrinking factor as input parameters.

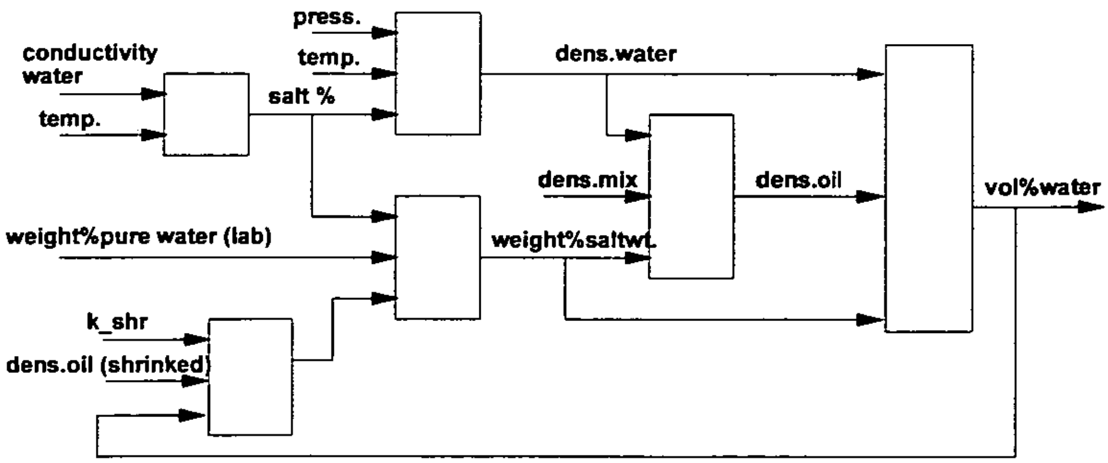

Figure 5. Simplified block diagram for calibration calculation.

5 TEST PROGRAM

A test program was started in January 1996. The initial idea was to compare spot samples with automatic measurements taken simultaneously at the WaterCut meter. However, as the spot samples were taken a considerable distance from the WaterCut meter, and the water content changed rapidly, it was not possible to get representative samples.

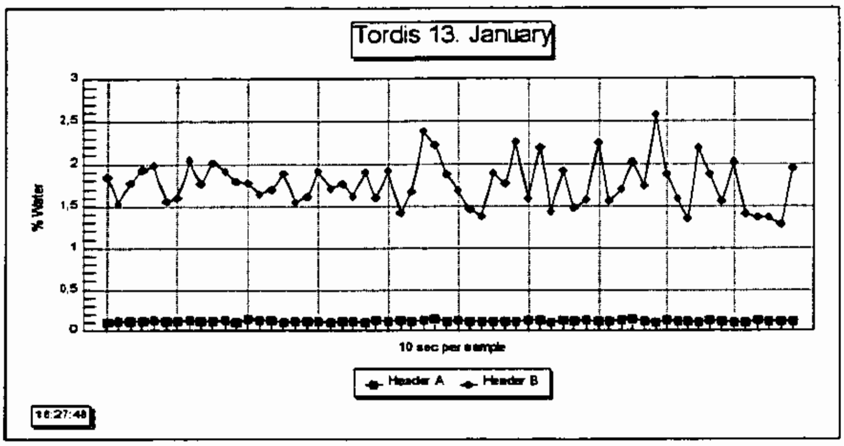

Figure 6. Changes in water fraction over a 10 minute period.

Figure 6 shows the water content on the B header varying from 1,3 % to 2,6 % through a 10 minutes period. Fig. 7 and 8 show a considerable difference between lab and on-line meter for water content above 1 %.

The WaterCut Meters were therefore tested separately with corresponding daily sampler as reference. An average of 24 hours from the WaterCut Meter was compared with the daily sample analysis.

6 TEST RESULTS

Results from January and February 1996 are presented below.

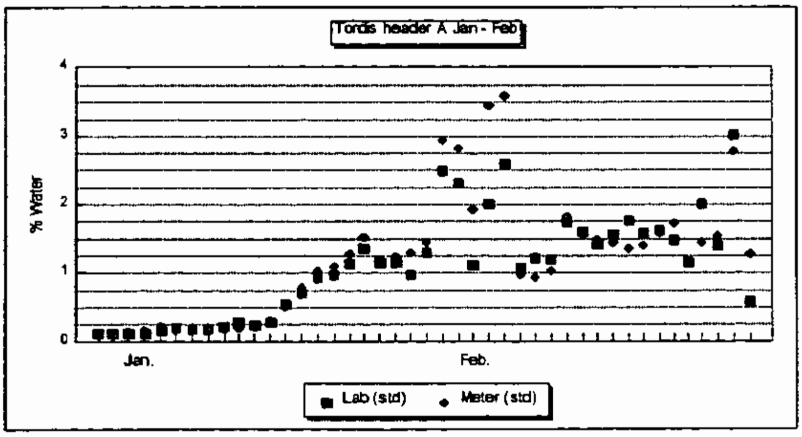

Figure 7. Spot samples compared to simultaneous readings from the WaterCut Meter

Both lab and meter values are converted to standard conditions. For water fractions below 1 % the sampling conditions were stable and the test show good agreement between spot samples and in-line meter. For water fractions above 1 % the deviation between reference and WaterCut Meter is explained by non-ideal reference conditions.

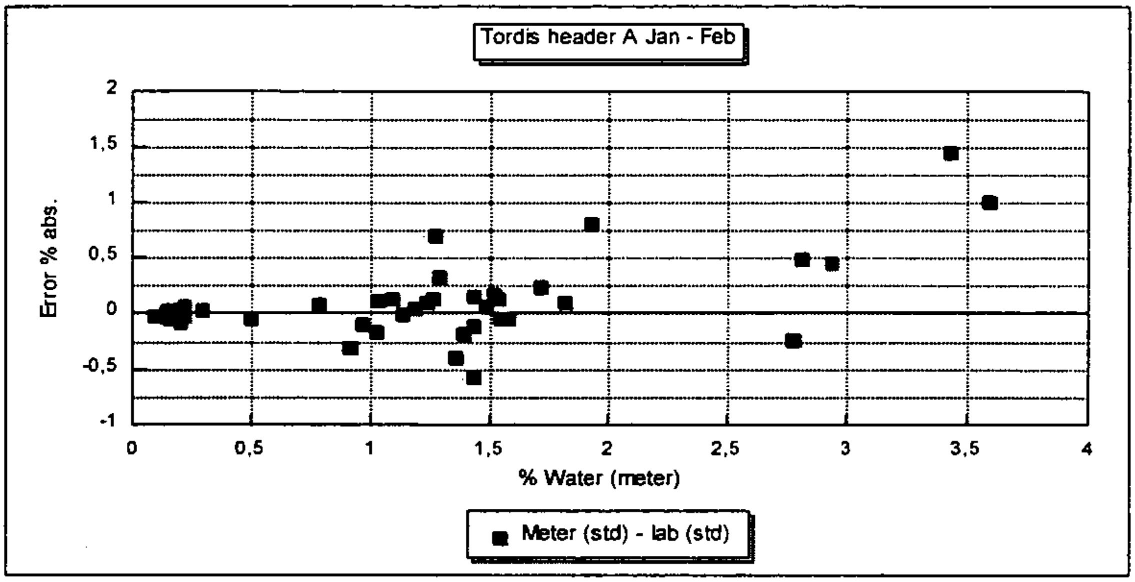

Figure 8, Deviation between spot samples and WaterCut Meter values in January and February.

Tests were done in May, September and November 1996 using the daily sampler as reference. During this period the water content varied from 0,5 % to 22 %. According to IP386, the Karl Fisher method can be used from 0,02 % to 5 %. For high water contents both Karl Fisher and centrifugal analysis were used. For high water contents the difference between lab and on-line values can be explained by the negative effect of emulsion breaker on the laboratory analysis.

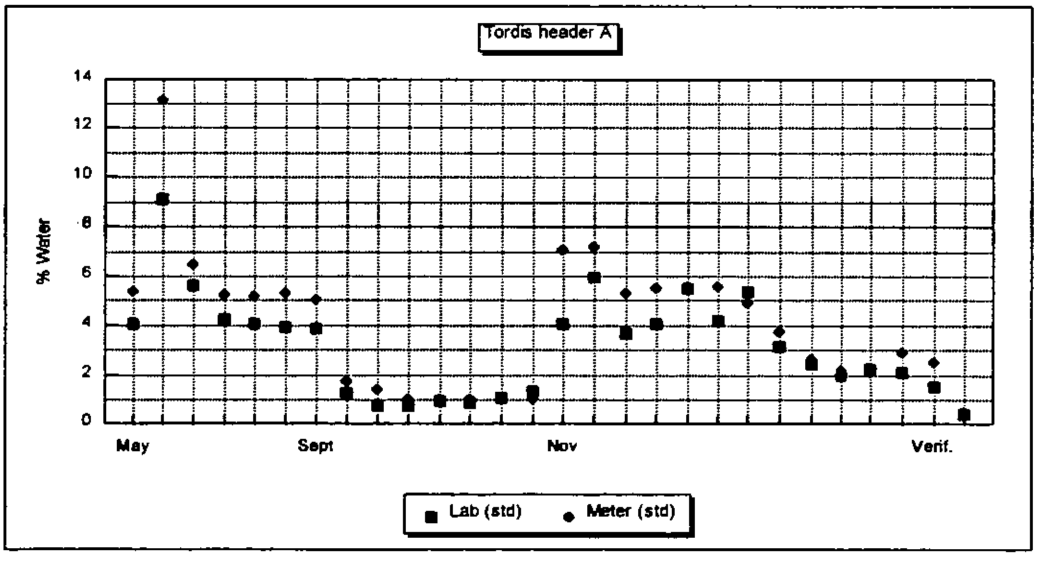

Figure 9. Daily samples and 24 hours flow weighted WaterCut Meter values, header A, included the following verification tests in -97.

For low water fractions the daily samples and the WaterCut Meter values correspond. The deviation increases with increasing water fraction. So does the uncertainty in the Karl Fisher analysis.

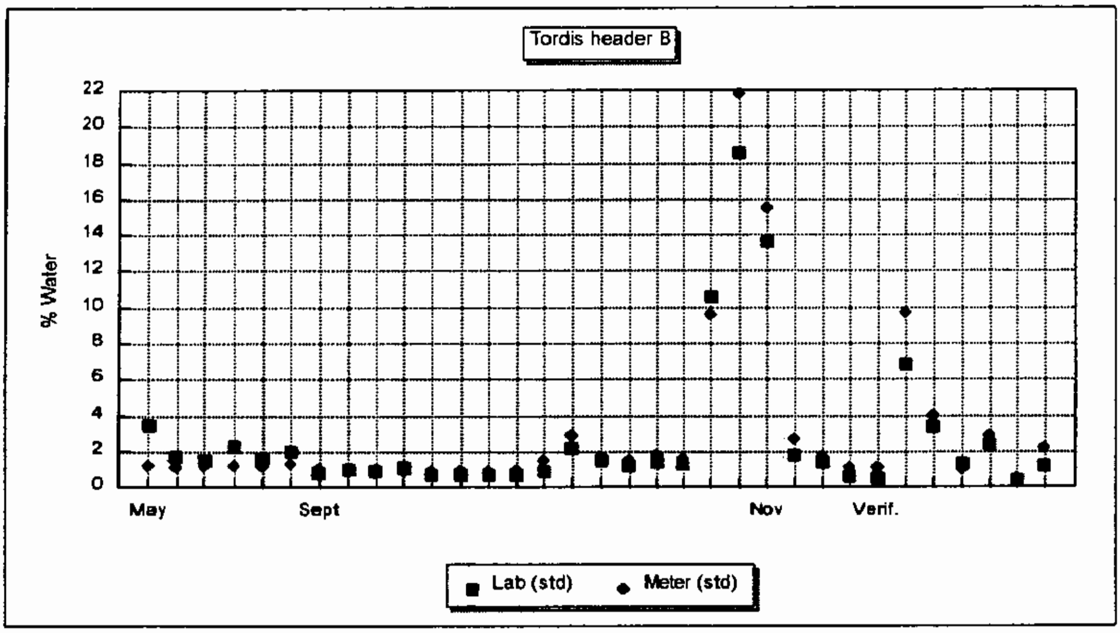

Figure 10, Daily samples and 24 hours flow weighted WaterCut Meter values, header B, included verification tests in -97.

The exceptionally high water contents at the end of September were due to separator problems. It gave us an unique opportunity to test the WaterCut Meter at the limit of its operational range. The WaterCut Meters measured the rapidly changing water contents without any difficulty.

7 CONCLUSION

The MFI WaterCut Meter has been successfully tested at the Tordis oil metering station. This has been a test site with highly non-ideal conditions. The WaterCut Meters have shown a significantly higher reliability and far less malfunctions than the automatic samplers. Long term stability and trouble free operation have been major issues in this test program. During the last one and a half years, the down-time of the WaterCut Meters has been neglibile.

Initial statistical work indicate good correlation between the MFI WaterCut Meter and traditional sampling also at Tordis operational conditions. The accuracy itself can not be fully verified under these conditions. However, the accuracy of the WaterCut Meters is previously tested under more ideal test conditions [1].

The NPD has temporarily approved the MFI WaterCut Meter as a fiscal water in oil monitor for use on Tordis. An application for permanent fiscal approval will be forwarded together with the results from the ongoing verification tests ultimo this year.

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