Main Index

North Sea FLOW Measurement Workshop 1995

Paper 8:

ENHANCED SYSTEM FOR CRUDE OIL MASS FLOW MEASUREMENT

2·2

Author:
A. Boe
Multi-Fluid International, Norway

Organiser:
Norwegian Society of Chartered Engineers
Norwegian Society for Oil and Gas Measurement
Co-organiser:
National Engineering Laboratory, UK

5

ENHANCED SYSTEM FOR CRUDE OIL MASS FLOW MEASUREMENTS

Arnstein Bø	Multi - Fluid International AS
Scott Gaisford	Multi - Fluid Inc.
Rune Sørhus	Multi - Fluid International AS

SUMMARY

A new system is proposed for enhancing and simplifying the metering of oil and water flow rates in liquid lines containing mixtures of water and crude oil, including liquid lines from two and three phase separators. By combining a Coriolis and a MFI WaterCut Meter, one achieves a measurement system capable of more accurate measurements of oil and water flow rates than is possible with either device alone, while at the same time reducing maintenance and calibration requirements.

1. INTRODUCTION

It is of great interest for Measurement Engineers to simplify the systems for metering oil mass-flow and the watercontent in the oil with high accuracy. During the last few years, several new technologies and products have been introduced, making a simplification possible. The system proposed in this paper is thoroughly tested and verified in a series of successful tests and installations, and is expected to help operators reduce operating expenditures and improve their profit. The system consists of a Coriolis Meter and a MFI WaterCut Meter linked together in such a way that the two instruments together provide better results then they would separately. Coriolis Meters have demonstrated the ability to accurately measure mass flow rates, even to fiscal specifications. The MFI WaterCut Meter is also used for fiscal metering and in custody transfer applications.

A Coriolis Meter can be used to determine the water cut of oil. The water cut is determined by comparing the mixture density to reference densities of free oil and water. However, significant errors can be encountered if the densities of the oil or water should vary from the calibrated reference values. The errors are magnified as the density difference between the oil and the water decreases.

Water cut meters, based on electrical measurements of oil/water mixtures, are in general much more accurate than the method described above, but tend to behave similarly. Their readings shift according to changes in the dielectric properties of the pure oil and the water. The dielectric variations are in turn related to oil and water density variations.

This paper outlines how the AutoZero function of the MFI WaterCut Meter overcomes this problem and enables a measurement system based on a Coriolis meter

and a MFI WaterCut meter to measure correct water and oil flow rates, even if the density of oil and water changes over time.

2. TRADITIONAL MASS FLOW MEASUREMENT SYSTEM

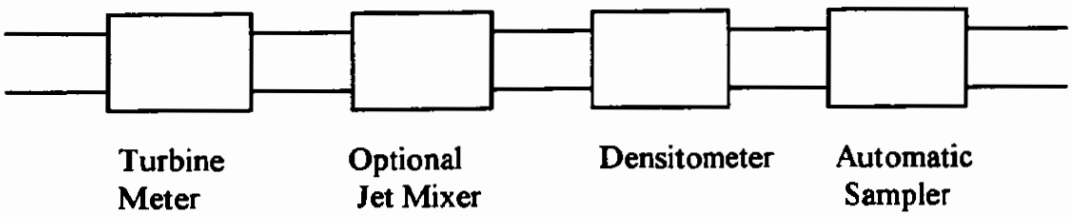

Figure 1

A traditional mass flow measurement system may consist of a flowmeter such as a turbine meter, a mixer, a densitometer and an automatic sampler. The turbine meter measures the total volumetric flow rate. This result, when combined with the mixture density from the densitometer and the water cut from the automatic sampler, gives the mass flow rates of water and oil.

There are several weaknesses of this system. The automatic sampler, turbine meter and the Jet Mixer have moving parts which require regular maintenance in order to obtain the desired accuracy. Secondly, the automatic sampler requires a technician on site in order to collect and analyse the daily, weekly and monthly samples. Finally, the only on-line information the system supplies is total volume flow and mixture density. Oil density, oil mass-flow rate and water mass-flow rate must be calculated off-line.

3. ENHANCED MASS FLOW MEASUREMENT SYSTEM

3.1 Basic Principles of the Coriolis Meter

A Coriolis meter measures the total mass flow rate and the mixture density. The Coriolis meter sensor is a vibrating, twisting tube. When liquid is flowing through a tube which is forced to resonate at it's natural frequency, it causes the tube to twist. This twisting effect characteristics is called the Coriolis effect. According to Newton's Second Law of Motion, the amount of tube twist is directly proportional to the mass flow rate of the liquid flowing through the tube. The density measurement is obtained by mounting the tube such that it is fixed at one end and free at the other end. This configuration can be envisioned as a spring and mass assembly. Once placed in motion, a spring and mass assembly will vibrate at its resonant frequency. The resonant frequency is a function of the mass of the assembly, and since the volume of the tube is known, the density of the liquid flowing through the tube can be determined.

3.2 Basic Principles of the MFI WaterCut Meter

The MFI WaterCut Meter uses a unique, patented microwave technology that measures the dielectric constant of oil/water mixtures with an extremely high degree of accuracy and resolution. From this measurement, together with the measured temperature, the meter can determine the volume fractions of water and oil in a mixture. The meter is calibrated by entering data which enables the meter to determine the respective dielectric constants of the oil and water.

The Meter uses the resonant cavity method to measure the mixtures dielectric constant. A resonant cavity is a closed structure from which electromagnetic energy cannot escape. Instead it reflects back and fourth until it is dissipated. At characteristic frequencies, the electromagnetic waves constructively interfere with one another (or resonate) and produce a very narrow, high output power peak. By measuring the frequency of the resonance, one can derive the dielectric constant of the material in the pipe. The WaterCut sensor is constructed in such a way that the oil/water mixture may easily flow through the sensor, whereas the electromagnetic energy cannot escape.

3.3 The AutoZero setting function.

The MFI Meter must be field configured with the density of the dry oil and the conductivity of the water. The oil density is used to determine the dielectric constant of oil, which defines the zero point. The conductivity of water is used to calculate the dielectric constant of water, which defines the span of the measurement. As a result of extensive research and testing, Multi - Fluid has determined that the high frequency dielectric constant of a dry hydrocarbon liquid is closely correlated to its density as shown in figure 2.

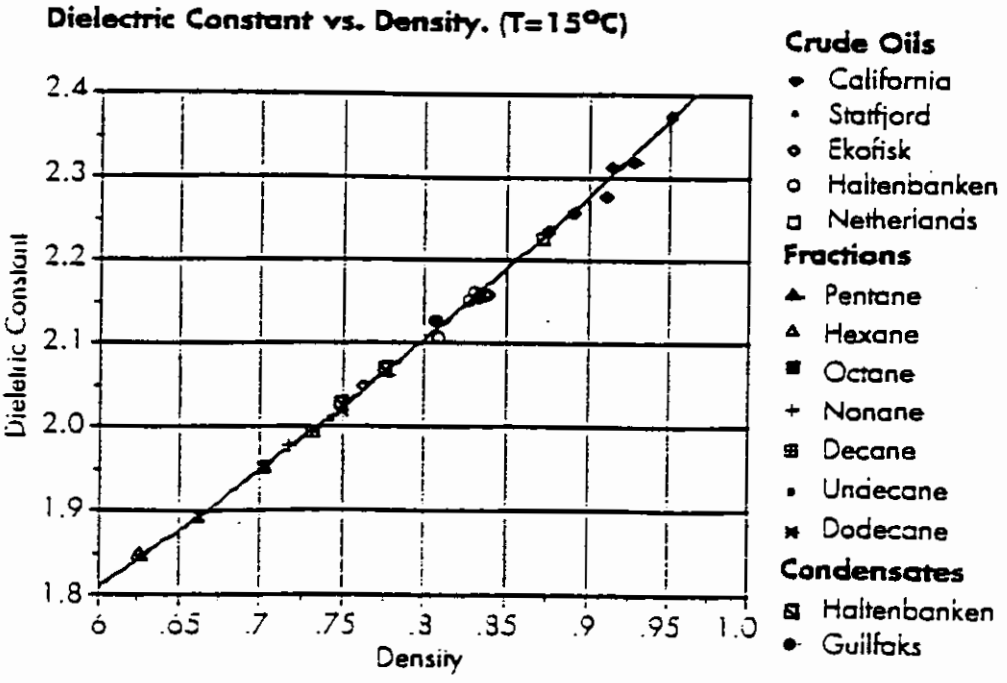

Figure 2

As implied by Figure 2, the MFI WaterCut meter is in principle sensitive to the variations in dry oil density, though the sensitivity is far less than the sensitivity of a density based watercut measurement. However, the patented AutoZero function of the MFI Meter overcomes this problem. By using the relationship in figure 2 and linking the WaterCut Meter with a densitometer, the MFI Meter can dynamically adjust its zero setting, defined by the dry oil density, according to the measured density of the process stream, and thereby leaving the operation of the Meter fully automatic. In operation the AutoZero function works as follows :

1) The MFI Meter reads the mixture (oil + water) density from the densitometer.
2) It measures the raw dielectric constant of the mixture using the microwave sensor.
3) It measures temperature of the mixture.
3) Finally, it solves a complex set of simultaneous equations to determine the correct dry oil density and the watercontent of the particular mixture.

Thus, the MFI WaterCut Meter with AutoZero dynamically measures the correct watercontent and the dry oil density of a mixture when the dry oil density and the watercontent is changing over time, or more correctly, the Meter measures the density of the *non-water* phase. Consequently, the Meter may measure the watercontent and either a) the dry oil density *or* b) the amount of free gas in the pipe if the dry oil density is constant.

3.4 Enhanced Crude Oil Mass Flow Measurement system.

By combining a Coriolis Meter with a WaterCut meter with AutoZero, one obtain a very compact oil mass-flow measurement system as shown in figure 3.

Figure 3

The combined system measures the following parameters, assuming that the mixture density and dielectric constant are measured at the same temperature and pressure :

Coriolis Meter :	Total Mass Flow Rate Mixture Density
WaterCut Meter :	%Water by volume Dry oil density Temperature

Hence the following parameters can be calculated assuming a constant water density :

Oil Volume Flow
Oil Mass Flow.
Water Volume Flow
Water Mass Flow

The combined system has several advantages :

1. There are no moving parts. This eliminates most maintenance and reduces cost.
2. The WaterCut Meter is able to perform all the necessary calculations and transmit the results on either analogue 4-20 mA outputs, frequency outputs, or a digital RS422 serial communication port. Hence a minimum of additional instrumentation and software is required to install and use the system.
3. The measurement system gives in-line, real time information of all the above mentioned values making it possible to improve process efficiency.
4. The system can be completely field mounted, with no need for dedicated control room equipment.

4. APPLICATIONS

Custody Transfer

Coriolis Meters have shown that they are capable to measure mass flow to fiscal standards, and meters are already in use on such applications. However, in order to determine the watercut, an automatic sampler is required. Consequently the system requires a technician on site in order to collect and analyse the daily, weekly and monthly samples, and furthermore, the system only gives in-line information about the total mass flow. The MFI WaterCut Meter with AutoZero is in the process of being approved for custody transfer in UK and Norway. Next, a complete fully automatic field mounted , in-line Mass Flow Measurement System based on a Coriolis Meter and a WaterCut Meter could be used for custody transfer.

Separator Liquid Outlets.

The amount of water in the oil-leg at test and production separators may vary over time due to water "carry-over" or depending on how strong the binding is between water and oil. Furthermore, there may be some free gas in the oil-leg, particular in low pressure systems. A traditional system for measuring the flow rate from an oil-leg on a test or production separator may be by using a turbinemeter or a ultra-sound based meter to measure the total volume flow, and perhaps an in-line densitometer to measure the density in order to obtain the mass flow rate. Alternatively a Coriolis Meter may be used to fulfill both these requirements.

The MFI WaterCut Meter with AutoZero in combination with a Coriolis Meter measures the correct water and oil mass flow rates even if the dry oil density is changing. Moreover, the WaterCut meter functions with free gas present. Depending on the mixing, the meter may work with 3 - 5 % of free gas, or even higher, this mainly being limited by the Coriolis Meter. Based on the measured density from the Coriolis meter, the WaterCut meter is able to measure the correct watercut in addition to the density of the non-water phase. This information could be used to calculate the amount of free gas if the dry oil density is known, hence more accurate measurements of the oil and water mass flow rates could be obtained.

Multi - Phase Metering

A simple Multiphase metering system could be built by separating the gas from the liquid. The gas could be measured separately and the oil and water rates could then be measured by a Coriolis/WaterCut Meter configuration as shown in figure 4 below.

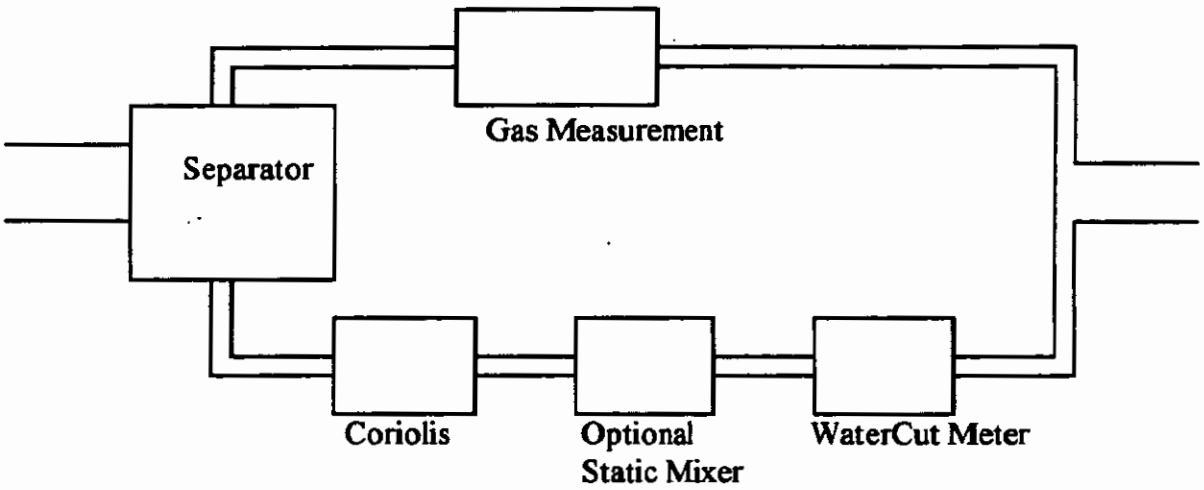

Figure 4

Because the Coriolis / WaterCut combination is able to function properly with some free gas in the liquid, the separator does not need to separate out all the gas from the liquid line, hence the separator could be a simple cyclone separator. The water and oil rates together with the remaining gas in the liquid leg are measured by the Coriolis / WaterCut Meter. The MFI WaterCut Meter has the capability of performing all the necessary calculations for the whole system.

5. LITERATURE

1. R. Purvey : Evaluation of an On - Line Water Content Analyzer for Low Water-cut Crude Oil's. The Institute of Petroleum, Measurement of Water in Oil Workshop, June 1995.

2. O. Økland, H. Berentsen and O. Olsen. Testing Water in Oil Monitors at the Mongstad Terminal. North Sea Flow Measurement Workshop 1994

3. S. Gaisford : MFI WaterCut Meter Field Adaptation Phase 1 Phillips Petroleum Company Norway R&D Contract nb. 03 - 005 - 0098

4. S. Gaisford and A.Bø : MFI WaterCut Meter Field Adaptation Phase 2. Phillips Petroleum Company Norway R&D Contract nb. 03 - 005 - 0147

5. Gray E. Pawlas and Tony Pankratz : Fluid Mechanics Effects in Coriolis Massflow Meters. North Sea Flow Measurement Workshop 1994

6. Various Coriolis Vendor Product Catalogues.