FOCUS DISCUSSION GROUP D

Practical Considerations Related to Multiphase Flowmetering of a Well Stream.

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PRACTICAL CONSIDERATIONS RELATED TO MULTIPHASE METERING OF A WELL STREAM

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ABSTRACT

Multiphase Flow Meters have in recent years become a fully accepted tool for well testing, management and allocation metering. Metering of an unprocessed well stream does, however, involve conditions which are not straight forward to deal with, and which can not easily be simulated in a test laboratory. The FRAMO Multiphase Flow Meter concept has been designed particularly for such conditions, and its performance has been demonstrated in field installations on land, offshore and subsea.

This paper describes some of the design and operation particulars of the FRAMO Multiphase Flow Meter which make this flow meter concept suitable for the demanding task of accurate and reliable metering of an unprocessed well stream.

1. INTRODUCTION

The FRAMO Multiphase Flow Meter has for several years been marketed and sold to various commercial applications on land, offshore and subsea (Martin, Woiceshyn, Torkildsen, 1992 /2/ and Olsen, Hanssen 1994 /6/), and is today installed at several fields where it is used for well testing, management and allocation metering.

The FRAMO Multiphase Flow Meter has been received by the market as robust, simple and versatile, features which are of great importance to the environments where it is to be used. It has - as the only one in the market - been conceptually unchanged throughout all the development stages, a fact which has largely contributed to the relatively high degree of technical maturity even for this new technology.

Through several test installations, the FRAMO Multiphase Flow Meter has proved its capability to consistently measure multiphase flow, fully independent of upstream flow regimes, gas volume fractions and water in liquid ratios. The meter is also characterised by the extended use of standard off-the-shelf instrumentation, standard commercial programming tools and standard computers, all contributing to the robustness and high reliability of the concept.

Standardised methods and protocols have also been developed and verified for communication between the FRAMO flow computer and platform or process facility supervisory control systems as well as between the subsea version of the FRAMO Multiphase Flow Meter and all major subsea control systems.

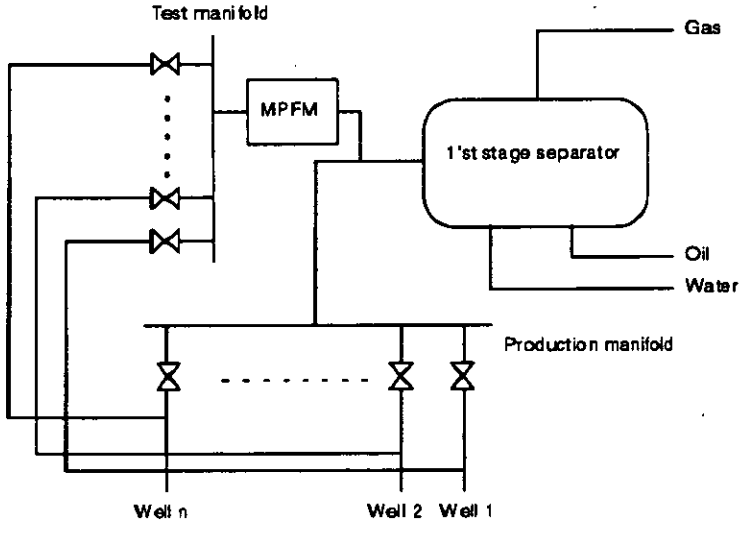

Figure 1: Typical application of the Framo Multiphase Flow Meter

2. THE FRAMO MULTIPHASE FLOW METER

The FRAMO Multiphase Flow Meter is designed for measuring the individual flow rates of oil, water and gas as well as the pressure and temperature of a well stream.

The meter consists of the following main elements:

- Static Flow Mixer for homogenisation of the multiphase flow
- Multi Energy Gamma Meter for measurement of the oil, water and gas fractions
- Venturi Meter for measurement of the total flow momentum flux

The Venturi Meter includes a standard differential pressure transmitter, a pressure transmitter and a temperature transmitter which together with the gamma detector are wired to a Data Acquisition Unit which transmits raw data and/or processed data to a PC based Flow Computer.

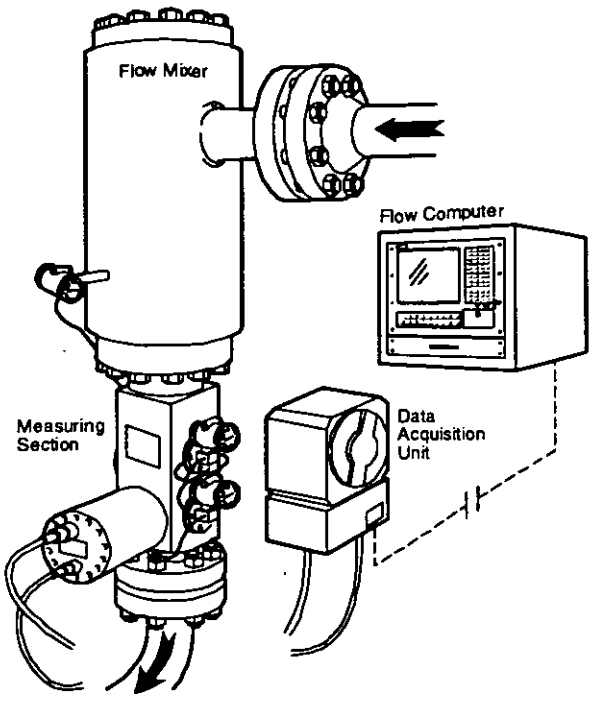

Figure 2: FRAMO Topside Multiphase Flow Meter

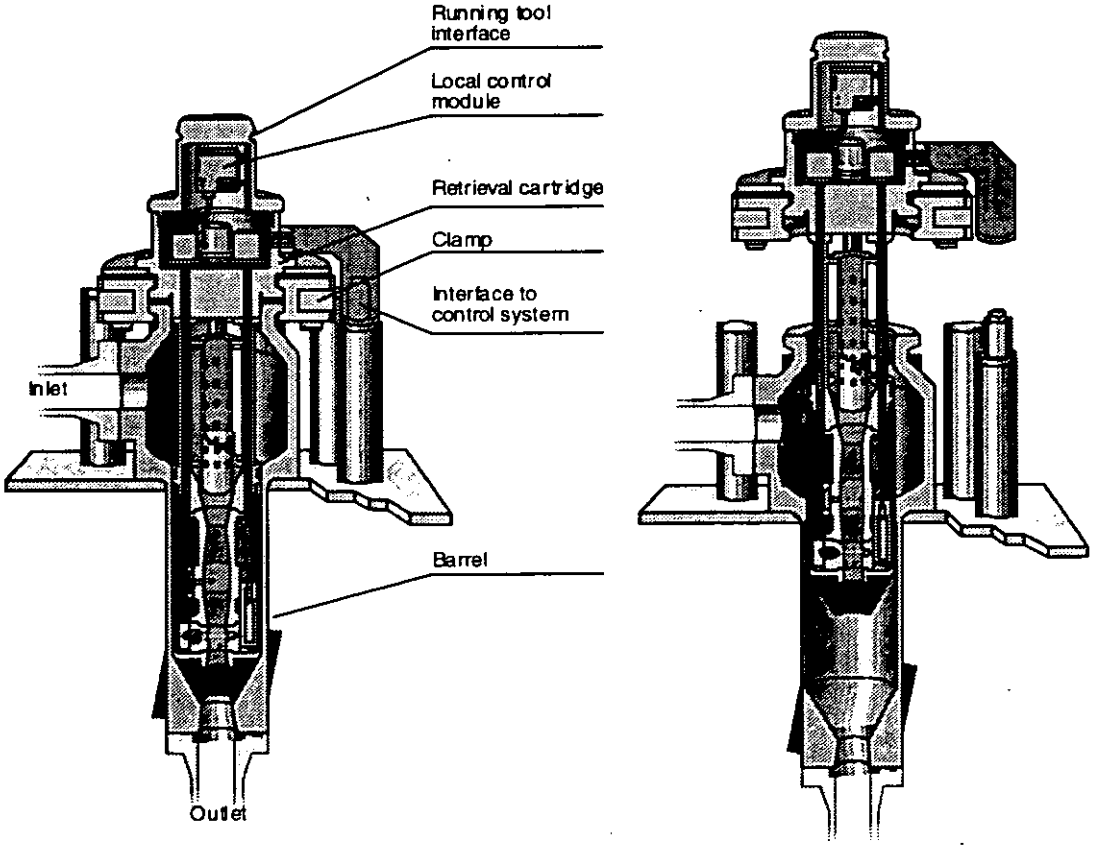

Figure 3: FRAMO Subsea Multiphase Flow Meter

3. WELL STREAM CONDITIONS

Characteristic for well streams is that fluid and flow parameters are continuously changing. In this section the different conditions which are encountered in a well stream will be addressed, and the relevant design and operating particulars of the FRAMO Multiphase Flow Meter will be described.

3.1 Multiphase flow regimes

Multiphase flow regimes are not only dependent on the individual phase flow rates or velocities, but also on pressure, temperature and fluid properties such as interfacial tension and densities as well as upstream pipe configuration. Consequently, reproducibility or the ability to measure with the same accuracy at changed inlet conditions is an essential feature of a multiphase flow meter.

Framo has therefore designed a multiphase flow meter based on flow mixing rather than flow modelling. An integrated static Flow Mixer of FRAMO design (patented) enables accurate and repeatable measurements independent of the upstream flow regime. Whether the multiphase flow regime is dispersed, separated or intermittent flows, or any combinations or transitions between these, the Flow Mixer provides homogeneous flow conditions to the downstream metering section allowing straight forward application of a Multi Energy Gamma Meter and a Venturi Meter.

3.2 Fluid composition

The fluid composition or fractions of oil, water and gas in the well stream will always change over time and large changes are normally encountered as a result of pressure decline and / or water break-through. The liquid phases will form various types of emulsions, and dependent on the actual water in liquid ratio, the liquid can be oil continuous, water continuous or even a combination of the two. At some conditions, even foaming occurs.

The Multi Energy Gamma Meter features the ability to measure all combinations of oil, water and gas fractions, including 0 - 100% water in liquid ratio independent of the liquid being oil continuous or water continuous (Rafa, Tomoda, Ridley 1989 /1/). This is possible since the Gamma Meter measurements are independent of electrical properties of the fluid. Whether the liquid is an oil external or water external emulsion, or the flow is foaming, has no effect on measurement accuracy, while such conditions can dramatically influence the performance of a separation based metering systems, including conventional test separator systems.

3.3 Turn-down in flow rate

Metering of an unprocessed well stream does normally involve measurements with large turn-down in flow rates. The venturi meter is ideally suitable for this application as the differential pressure across the venturi is proportional to the momentum flux of the total flow. The turn-down in total flow rate which can be achieved in a multiphase flow, is therefore 3 to 4 times larger than what can be achieved at single-phase conditions, since high flow velocity normally is associated with low multiphase density.

During life time of a well, flow rates may sometime change so much that even a venturi meter can not cover the required range. Very large turn-down is in some cases also required when a single multiphase flow meter is installed in a test manifold for several wells.

Framo has therefore developed and patented a venturi arrangement which allows in-line altering of the physical venturi size. The mechanical arrangement is simple and robust and can be remotely operated by means of hydraulic or electrical functions. This way it is possible to obtain a turn-down in total flow rate at multiphase conditions of more than 1000:1. It can easily be shown that from only two

different positions of the venturi arrangement, the turn-down ratio which can be achieved, is equal to the square of the turn-down ratio for a single venturi meter.

The physical venturi size can be altered when the multiphase flow meter is on-stream, and it can be done without affecting calibration of the meter. This allows continuous operation with one single meter on a range of flow rates or a range of different wells which otherwise would have required two or more meters. In remote area, offshore and particular subsea where changeout of a meter is critical, this option provides a large cost saving potential, both regarding investment and operating cost.

4. FLUID CHARACTERISATION

In order to make accurate and reliable measurements of both mass and volumetric flow rates, the Multiphase Flow Meter needs information about the oil and gas densities and the water salinity. However, since the composition measurement in the FRAMO Multiphase Flow Meter is based on gamma attenuation only, the sensitivity to varying salinity is relative low and far less than for those meters which primarily measure electrical fluid properties (Slijkerman W.F.J., Jamieson A.W., Priddy W.J., Økland O., Moestue H. 1995 /8/).

Information about the individual fluid phase properties is required for other purposes as well, such as converting the measured flow rates to stock tank conditions. The water salinity can also provide information to the reservoir engineer about the water source and possible scaling problems.

The FRAMO Multiphase Flow Meter can be utilised in several ways in order to obtain this information, and this will be discussed below.

4.1 Direct single-phase measurements

For some applications, the multiphase flow meter can relatively easily be filled with the fluid phase of interest at static conditions. This can be done simply by closing an upstream or downstream valve and let the fluid inside the multiphase flow meter settle. Alternatively if a test separator is available, any fluid phase can easily be back routed to the multiphase flow meter.

In these cases the FRAMO Multiphase Flow Meter can by itself measure the required fluid properties.

4.2 Multiphase sampling

The FRAMO Multiphase Flow Meter can also be used to take fluid samples by utilising the flow mixer arrangement. This sampling system provides an excellent basis for dedicated liquid and gas sampling which otherwise will be extremely difficult and unreliable due to the presence of multiphase flow regimes.

From the FRAMO Flow Mixer the liquid phases can be effectively drained for the low part of the compartment, and gas phases from the upper part. An arrangement and procedure for subsea sampling performed by an ROV have been developed and qualified.

4.3 Determination of water salinity by gamma spectrometry

The gamma meter, which is part of the FRAMO Multiphase Flow Meter, makes use of two distinct gamma energy levels in order to determine the oil, water and gas composition in the multiphase fluid flow. The gamma meter does, however, also measure attenuation of a third gamma energy level, and this measurement provides information about the water salinity.

Framo has developed and patented a unique method for on-line measurement of the water salinity in a multiphase stream, based on gamma spectrometry.

This measurement does not require any additional instrumentation, as it makes use of the same gamma spectre as is used for the composition measurement. The method provides an independent means of measuring the water salinity. This means that the measurement is not influenced by the other measurements of oil, water and gas nor by the density information required by the Multiphase Flow Meter.

The independent measurement of water salinity can therefore be made to automatically update the water property required by the Multiphase Flow Meter at any desired interval, and thereby ensure that maximum accuracy of the Multiphase Flow Meter is achieved.

5. CALIBRATION

The calibration of a multiphase flow meter is different from that of a single-phase flow meter. In a single-phase stream the flow parameters can be specified and controlled. Flowing calibration of a single-phase flow meter can therefor be performed in any appropriate flow laboratory with reference to a common standard, and the calibration will be valid as long as there are no changes in the meter itself. Accurate references for flow rates can easily be achieved since the changes in flow parameters between a reference and the meter are well understood.

None of these conditions are true for the calibration of a multiphase flow meter. In particular will flow parameters such as multiphase flow regimes not be known for the operator, and even if they were known, it would not be possible to reproduce or simulate the same conditions in a flow laboratory or in any other installation. No standards exist relevant for multiphase flow conditions, nor is it likely to be developed in the near future.

Even in-situ flowing calibration of a multiphase flow meter would have only very limited value, as fluid properties, composition and flow rates in a well stream normally are changing continuously and cause changes in the multiphase flow regime which are difficult or impossible to predict and which in general will invalidate a flowing calibration performed at other conditions.

Accurate references for flow rates are also very difficult to obtain as the thermodynamics governing the fluid phase and flow changes between a reference and the multiphase flow meter is complex and can not easily be modelled.

It is also for these reasons that Framo has developed a multiphase flow meter based on flow mixing rather than flow modelling, and which does not require any flowing calibration. The FRAMO Multiphase Flow Meter does only require individual static single-point calibration of the gamma detector and the venturi differential pressure transmitter.

This calibration is normally performed on air at atmospheric conditions prior to installation, however, it can as well be performed on any other fluid as long as its properties are known. This way a remotely operated multiphase flow meter, such as one subsea, can be calibrated simply on the fluid which may settle out inside the multiphase flow meter after closing of an upstream or downstream valve. Even without being properly calibrated, the gamma meter will identify whether the fluid is oil, water or gas, and the appropriate static single-point calibration can be performed.

6. CONCLUSIONS

The FRAMO Multiphase Flow Meter has been designed particularly for the severe and unpredictable flow conditions which are typical for unprocessed well streams. The meter which has been received by the market as robust, simple and versatile, consists of the following main elements:

- Static Flow Mixer
- Multi Energy Gamma Meter
- Venturi Meter

Through field installations on land, offshore and subsea the FRAMO Multiphase Flow Meter has proved its ability to cope with the extremes in:

- Multiphase flow regimes
- Fluid compositions
- Turn-down in flow rates

A mechanism for altering the venturi size is available for the FRAMO Multiphase Flow Meter.

The meter features methods for fluid characterisation including:

- Direct single-phase measurements
- Multiphase sampling
- Determination of water salinity by gamma spectrometry

Calibration of the FRAMO Multiphase Flow Meter is simple and involves only:

- Static single-point calibration of the gamma detector
- Static single-point calibration of the venturi differential pressure transmitter

ACKNOWLEDGEMENTS

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Also all the users have through their early commitment to the FRAMO Multiphase Flow Meters on a commercial basis, enabled Framo to continue the development of the product. Through a continued commitment to the technology and a good and open dialogue with the users, we are convinced that the product also in the future will continue to be refined.

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