Index

Paper 5.3

Background and Operational Experience of Multiphase Metering in the Safaniya Field-Offshore Saudi Arabia

P. B. Warren, Saudi Aramco
S. Hussain, Saudi Aramco
S. Al-Ghamdi, Saudi Aramco

Background and Operational Experience of Multiphase Metering in the Safaniya Field-Offshore Saudi Arabia

P. B. Warren, Saudi Aramco
S. Hussain, Saudi Aramco
S. Al-Ghamdi, Saudi Aramco

1 INTRODUCTION

An automated and compact multiphase flow meter (MPFM) tested offshore Saudi Arabia has accurately measured three-phase flow rates under existing field operating flow conditions. An extensive eight-month field test in the Safaniya field was conducted from October 1999 to June 2000 utilizing over 350 well tests under varying operating conditions. A meter was installed on an offshore test barge, so that individual wells could be tested in series with traditional test barge methods. For these trial tests, the total liquid rate ranged from 1300 to 12000 barrels per day, the GOR ranged from 150 to 350 SCF/STB and the water cut ranged from 0 to 50%. The results indicate that over 90% of the wells tested were within +/- 10% of test barge results for both liquid and oil, and water cut (absolute) measurements. While gas measurements were determined to be within +/- 15% in 75% of the wells tested.

As a result of this favorable field test and other economic considerations, a multiphase flow meter is recommended for installation on all Safaniya Field existing offshore platforms. Project installation designs for the first five meters have been completed and plans are being made to install them beginning in late 2002.

2 BACKGROUND

The Safaniya Field, which is the largest offshore oil field in the world, has a wide variety of offshore platforms. These platforms differ in physical size and vary from single well to eight-well configurations. For accurate reservoir management, each well is individually rate tested to monitor well performance and to provide data for field allocation and planning purposes. The wells are presently being tested by two barges, which are equipped with testing facilities. These barges are approaching obsolescence and require extensive maintenance to maintain the current testing schedule. In addition, numerous offshore platforms are located in areas that are inaccessible to the barges and cannot be easily tested. The barges are also prevented from testing wells approximately one third (1/3) of the time each year due to adverse weather conditions. Furthermore, well testing requirements for the Safaniya field are increasing dramatically due to higher water cuts as the field matures, more wells being drilled, and fluctuations in the field production requirements.

As a result of the inefficiency and limitations of the test barges, a multi-phase flow meter was successfully field-tested as an alternative to the use of the test barges. Multiphase flow meters will provide the Safaniya field with more frequent tests and considerable economical savings in the long run.

3 METER DESCRIPTION

The Fluenta multiphase meter 1900VI trial tested in Safaniya field is the latest multiphase flow meter produced by Roxar in Norway. This meter measures oil, gas and water rates without separation of the production stream, and calculates flow rates for actual and standard conditions. The multiphase meter determines oil, gas and water fractions from the capacitance, inductance readings and gamma densitometer measurements. Each component's velocity, or mass flow rate, is determined from cross correlation or venturi measurements.

3.1 Components Of The MPFM

There are five main components of the multiphase flow meter as follows:

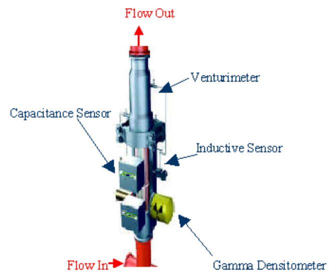

Fig. 1: Multiphase meter components

1) Capacitance sensor; 2) Inductance sensor; 3) Venturi; 4) Gamma densitometer; and 5) Pressure and temperature sensors (see Fig. 1).

A detailed discussion of each meter component and underlying operating principles can be obtained from the vendor, if interested.

3.2 Multiphase Meter Data Collection

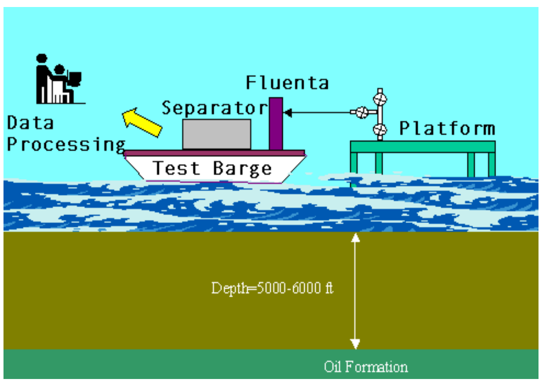

Fig. 2: Multiphase meter installation

Well production test data was simultaneously collected from the multiphase meter in series with the test barge separator (see Fig. 2). The meter was mounted on a blinded T-bend in a vertical position with upward flow, which provides for better mixing of the fluid. The test barge separator, which has gathered well tests in the field for many years, was used as the reference measurement for the MPFM. Only those tests that fell within the multiphase meter operating range and having valid test barge results were taken into account for the MPFM evaluation.

The multiphase meter data logger has a large data storage capacity that is capable of receiving sensor signals every second and storing running averages. During the multiphase meter trial test the data logger was set to record test data every 15 minutes. Afterwards, data logger information was downloaded to a PC and analyzed. Recorded data parameters consisted of operating pressure, temperature, oil, water, and gas rates in actual and standard conditions.

3.3 Test Barge Separator Data Collection

The test barge comparison data for total liquid and gas rates were automatically fed into a computer located in the test barge control room. However, the test barge water cut comparison data had to be gathered and measured manually by taking samples every half hour.

3.4 Multiphase Meter Operating Range

The 3-inch, 316L stainless steel multiphase meter's specified operating ranges are:

0-100%, water-cut
0-90%, gas volume fraction
2,000-15,000 bpd liquid rate

Typical fluid velocity: Min.1.5 m/s (5 ft/sec)
Max. 25.0 m/s (81 ft/s)
Max. fluid temperature: 177° C (350° F)
Max. operating pressure: 2,000 psi
Meter length: Approx. 625mm (24.6 in)
Meter weight: 250 kg (551 lbs)

3.5 Trial Testing Production Range And Performance

The production range for wells covered in this trial test:

Total Liquid Rate:	1300 to 12000 BPD
Gas Oil Ratio:	150-350 SCF/ STB
Watercut:	0 to 50%

3.6 Multiphase Meter Performance Results For 351 Valid Tests

Total liquid rates within ±10%: 330 tests, (94%)
Oil rates within ±10%: 323 tests, (92%)
Water-cut within ±10% "window": 325 tests, (99%)
Gas oil ratio (GOR) within ±15%: 39 tests, (75%)

3.7 Test Performance Summary

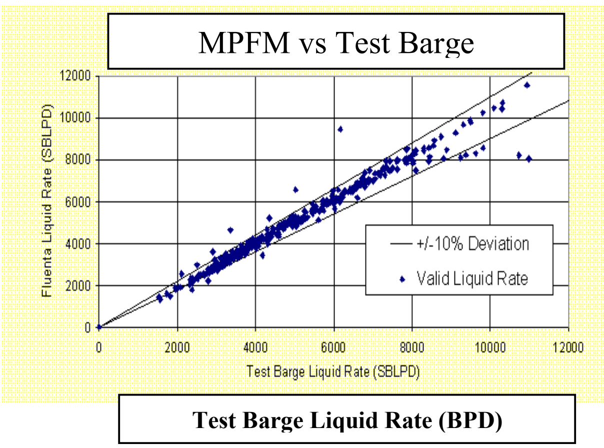

Fig. 3: Liquid rate comparison plot

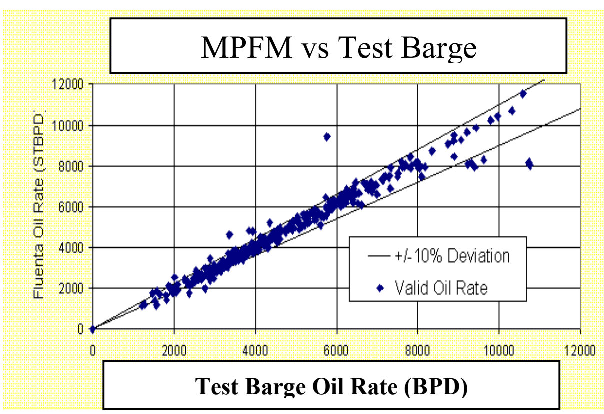

Fig. 4: Oil rate comparison plot

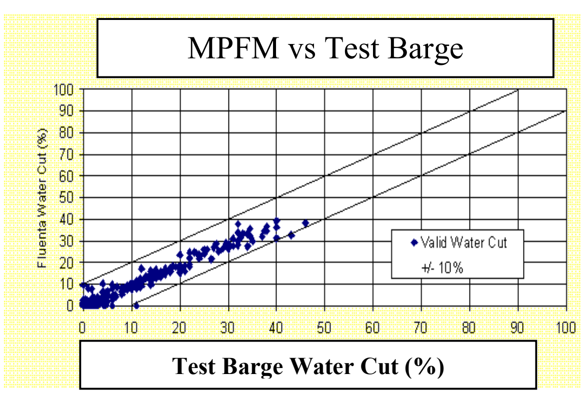

Fig. 5: Water cut comparison plot

For 351 valid tests, 94% of the liquid rate measurements and 92% of the oil rate measurements were within acceptable limits, as shown in Fig. 3 and Fig. 4. And for watercut measurements, 99% of the MPFM results fell within +/-10% (absolute) water cut fractions when compared against all manually gathered water cut data (see Fig. 5).

Since many of the test barge separator gas rates proved unreliable, the MPFM gas measurements were verified by using Safaniya field lab PVT data. The Safaniya field is an under saturated reservoir with no free gas, so the produced gas is equal to the solution gas. The amount of solution gas in Safaniya crude is readily available from lab PVT data. As shown in Fig. 6, the MPFM recorded acceptable gas measurements. The GOR could also be evaluated against valid historical field data for comparison purposes. However, in the Safaniya field, the gas measurements are not critical and thus do not require highly accurate gas measurements. Seldom are important decisions made from the gas measurement information for this particular field.

It is worth noting that the MPFM was essentially maintenance free for over 2 years. The meter was installed on the test barge from October 1999 to December 2001 without any maintenance issues. This is understandable when considering that there are no moving parts.

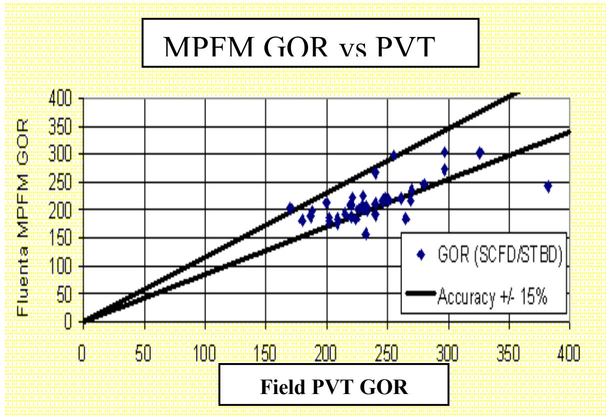

Fig. 6: GOR comparison plot

3.8 Installation Considerations

After the successful field test of the meter, a decision was made to utilize this MPFM technology. However, many technical issues still had to be addressed, especially since the MPFM installations were recommended for the offshore platform environment. For the first five Safaniya field installations, three different platform styles were selected to obtain the experience and costs associated with designing and installing these meters. Future MPFM installations will greatly benefit from the knowledge acquired from these first five installations. The first five platforms include 2 six-well universal modular platforms, 2 two-well platforms, and 1 single-well platform.

3.9 Meter Sizing

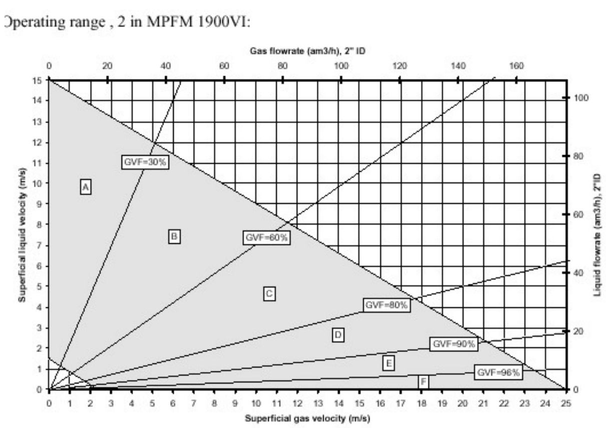

Fig. 7: Meter sizing manufacturer's plot

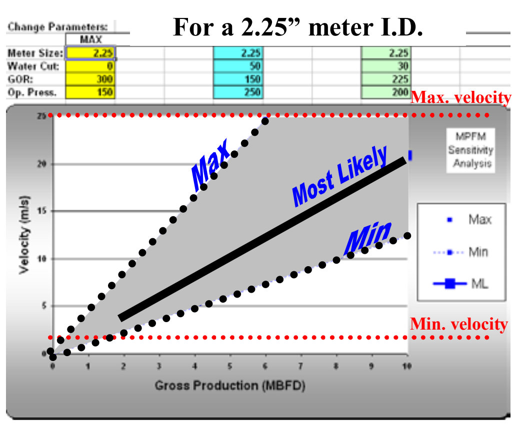

Fig. 8: Meter sizing sensitivity analysis

A new technique was developed to assist in properly sizing the I.D. of the MPFM's using fluid velocity versus gross production. Uncertanties in the production rates, for each of the wells on a given platform, had to be accounted for and evaluated to come up with the optimal meter I.D. that is capable of accurately testing all wells.

Rather than attempt to size the platform meter I.D. utilizing the manufacturer's method of crossplotting superficial liquid velocity versus superficial gas velocity, an alternative method was developed which uses gross production as the main uncertainty variable (see Fig. 7 & 8). Analyzing the variations of gross production from several different wells could quickly be reviewed and a proper meter I.D. selected.

Preferably, the correct meter I.D. selected would allow for the full range of gross production found on each platform while staying between velocity ranges of 1.5 m/s to 25 m/s. In reality, meter velocities above 25 m/s will still give valid measurement readings in most cases, but could cause a backpressure on the well and restrict production.

The other important input parameters besides gross production for analyzing meter I.D. include: 1) water cut, 2) GOR and 3) operating pressure, defined for a maximum, minimum and a most likely scenario. By inputting several different meter I.D. sizes and comparing meter velocity versus anticipated gross production on the platform allows for much easier sizing evaluations.

3.10 Power Requirements

The platforms are not electrified, and therefore require solar power energy to obtain approximately 30 watts of power for the MPFM equipment (*note: newer versions of the same equipment now utilize less than 8 watts of power, a substantial improvement for those installations requiring solar panels and batteries*). For offshore platforms, the amount of space is limited, and therefore, a critical variable when defining the solar panel dimensions required to run the MPFM. For the six-well platforms, there is enough space to handle the large solar panels required for 24 hours of meter operation. However, to handle the meter power requirements on the single well platform, a small platform extension is required to allow enough space for the solar panels and batteries to operate the equipment. In addition, the single well platforms are designed to operate just 12 hours per day in order to minimize the solar panel dimension requirements. Reducing the number of solar panels will help avoid extensive platform modifications and excessive project installation costs. The MPFM located on the single well platform will automatically power itself on and off every 12 hours in order to conserve energy.

3.11 Radioactive Sources

Numerous issues came up regarding the transportation and installation associated with handling radioactive sources. Although the radioactive source used in this MPFM is only 30 mC, regulations exist within Saudi Arabia, and most areas around the world, that need to be followed closely. In addition, the project team decided to arrange for a training session for field personnel to avoid misperceptions, with this low radiation source, regarding radiation exposure and risks.

3.12 Communication Issues

The MPFM will be hooked into an existing SCADA system that will allow engineering personnel onshore to access well test information and meter functionality. This will substantially improve the well testing system by providing real time well data for better well surveillance and production allocation techniques. For our newer six-well universal modular platforms, existing diversion valves may be automated in the future to allow remote switching of wells from the production header to the test header for testing. If the diversion valves are automated, then additional RTU I/O expansion modules will be required for remote operability utilizing our existing SCADA system.

3.13 Other Installation Issues

Meter flange-to-flange distance was designed to be the same for all meters regardless of meter I.D. size. This was established to allow for interchangeability of the meters at some future date, if required. The first set of 30 platforms reviewed for varying production rates will have just 4 different size meter I.D.'s (1.75", 2.25", 2.75", 3.25"). It is anticipated that perhaps 10% of the meters will need to be swapped to optimize well testing during the first 5 years. Having the same flange-to-flange distance for all meters will allow for simple and inexpensive meter exchanges that do not require welding or xraying of reconfigured piping modifications. Possibilities for meters having to be swapped could result from production rate changes due to: 1) new wells being drilled and coming online at much higher or lower production rates than estimated; 2) worked over wells responding much differently than anticipated, and 3) wells or platforms being shut in and no longer need testing. On multiwell platforms the meter needs to be designed for numerous wells. Substantial production changes in any one well (in a multiwell platform) may result in another meter I.D. being more capable of testing all production ranges on a platform.

4 SUMMARY

The MPFM proved reliable for Safaniya field installation purposes and acceptable as an alternative to conventional test barge separator testing. In addition, the MPFM was maintenance free for over 2 years, before being removed from the test barge.

After properly field-testing and analyzing MPFM results, there are still numerous technical issues that have to be addressed. For example, proper meter I.D. sizing requires a comparison of current and projected individual well production forecasts. In addition, the power requirements and platform space availability are important considerations prior to installing a MPFM.

Additional meters are being evaluated and tested for field operations to ensure that the best technology and most economical meters are being utilized.

5 NOMENCLATURE

BPD	= Barrels per day
GOR	= Gas oil ratio
I.D.	= Inner diameter
MPFM	= Multiphase flow meter
M/S	= Meter per sec
RTU	= Remote terminal unit
SCADA	= Supervisory control and data acquisition
SCF	= Standard cubic feet
STB	= Stock tank barrel

6 ACKNOWLEDGEMENT

We would like to thank all those people associated with this project that have made it a success. In addition, we would like to thank the Saudi Aramco management for their support and permission to publish this paper.

7 REFERENCES

1. Al-Taweel A.B., Barlow S.G., “Field Testing of Multiphase Meters”, SPE 56583, SPE ATC&E, Houston, Texas, October 1999.

2. Hussain S., Al-Ghamdi S., “Fluenta MPFM Trial Test Completion Report”, July 2000, Saudi Aramco Report.

3. Fluenta Multiphase Metering Department, “Fluenta Multiphase Flowmeters”, Product Information