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Field Validation and Long-term Performance Monitoring of MPFM at Very High GVF and High Pressure Conditions

Junjie Ye, Qianhui Li and Charles J. Chen, Haimo Technologies Inc.
Abdullah Al Obaidani and Ibrahim Mahrooqi, Petroleum Development Oman (PDO)

1 INTRODUCTION

Ever since the application of MPFM in petroleum industry, efficient field validation and long-term performance monitoring of MPFM are seldom reported, which is also true for reports at challenging conditions such as very high GVF and high pressure are scarce.

In early 2008, with joint efforts between PDO and the MPFM vendor, a two month field validation was conducted on MPFMs with a high performance tester (HPT) in one very high GVF (up to 99%) and high pressure field of PDO, followed by a two-year performance monitoring which is still continuing. Satisfactory outcome has resulted from the project. The validation and monitoring prove that MPFM is an effective well testing tool with excellent stability.

This paper describes the process for validation and monitoring. Basic field information will be introduced first in section 2, MPFM and validation unit HPT will be described in section 3 and 4, the validation procedure will be briefed in section 5, then some validation results will be discussed in section 6, the long-term monitoring results will be illustrated in section 7, and finally, the conclusion will be drawn in section 8.

The oil field discussed in this paper will be referred to as Field-A.

2 FIELD-A DESCRIPTION

Field-A is one of the many promising fields of PDO where the process conditions are at pressures higher than 30 bar and GVFs generally as high as 99%. The oil productions from these wells vary from 20 to 300m^3/d. Gas production varies from well to well, with most wells produce gas at a rate of 100,000 to 350,000 Sm^3/d. Most wells have less water cut except in few cases (highest WC is above 40%). Oil densities of field-A wells vary from one to another. Most wells have oil with densities (at 15 degC) between 750 and 820 Kg/m^3.Gas specific gravity is typically around 0.67 (air=1).

3 DESCRIPTION OF FIELD-A MPFM

The basic configuration of the MPFM at field-A is a combination of a liquid / gas two phase measurement module, a full range three phase water in liquid ratio (WLR) measurement module, and a flow computer unit as shown in Fig. 1. The WLR measurements are carried out independent of the liquid / gas flow rate measurement.

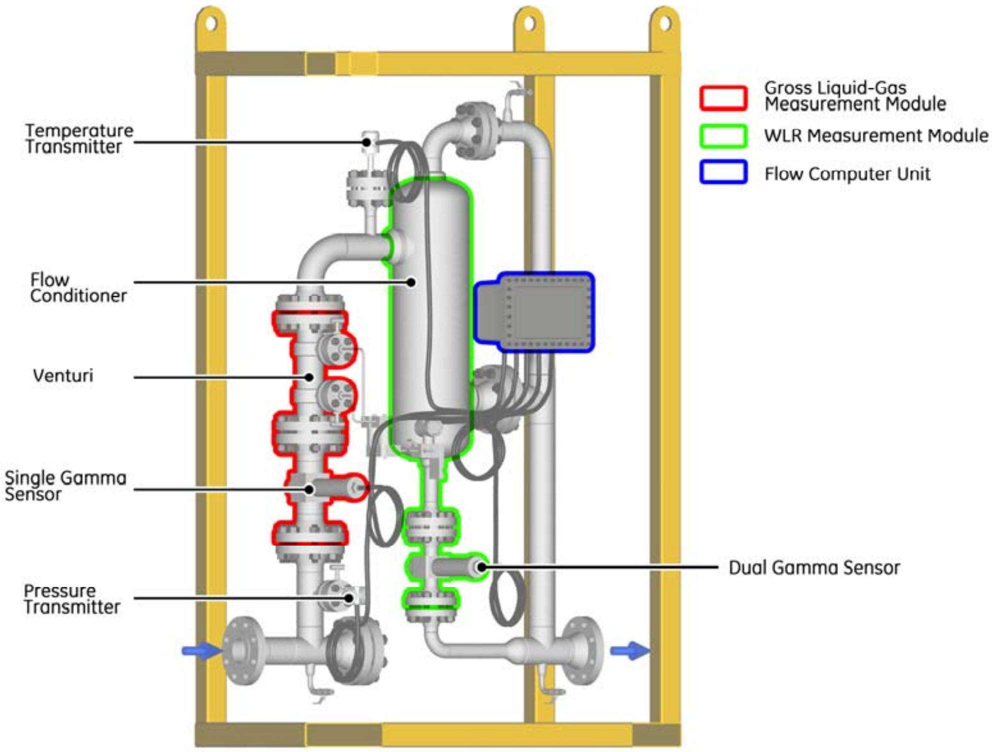

Fig. 1 - Multiphase Flow Meter (MPFM) Diagram

The liquid / gas two phase module consists of a Venturi and one single gamma (59.5 keV) sensor. The WLR measurement module comprises a dual energy gamma (22 and 59.5 keV) sensor and a flow conditioner located upstream. Measurement of the gas and liquid streams is carried out upstream of the flow conditioner by the two-phase measurement module.

The Dual gamma sensor measures the WLR under a stable flow regime, which is critical for the accuracy of the WLR measurements. Net oil flow rate is finally calculated based on the gross liquid and WLR measurements. The combination of the flow conditioner and the dual energy gamma sensor helps to achieve the +/-2% abs. error on WLR over 0-99.5% GVF range with a 90% confidence level.

A microprocessor based flow computer unit installed in the junction box (Eexd enclosure) is mounted on the skid to collect, process and archive signals and data from all instruments and sensors of the field, and to carry out the flow metering calculations based on the following measurements:

a. Total flow rate of the multiphase fluids (TFR) measured by the Venturi.

b. The gas-liquid phase fraction (GVF) measured by a single gamma sensor.

c. Pressure and temperature transmitters are mounted in appropriate locations in the skid for correction of measured values to standard conditions.

d. WLR measured by the dual gamma sensor, and can be corrected for pressure and temperature for representation to standard conditions as water cut (WC).

e. The gas flow rate calculated as a product of TFR x GVF, and is corrected for pressure and temperature for representation to standard conditions.

f. The gross liquid flow rate (GLR) calculated as a product of TFR x (1-GVF).

g. The water flow rate calculated as a product of GLR x WLR, and corrected for pressure and temperature for representation to standard conditions.

h. The oil flow rate calculated as a product of GLR x (1- WLR), and corrected for pressure and temperature for representation to standard conditions.

Uncertainties for field-A MPFMs

Liquid flow rate	± 10% relative
Gas flow rate	± 10% relative
WLR	± 2% absolute

4 VALIDATION UNIT — HPT DESCRIPTION

The HPT is characterized by its high efficiency in separation and good measurement accuracy. It was delivered by the MPFM vendor to PDO in 2007 and has been proven to be an accurate and appropriate tool for both verification and well testing purpose.

In the operation of the HPT, the multiphase flow enters a vertical separator to separate gas from liquid and then through two horizontal separators gas is further separated. HPT is equipped with a mist extractor to drop any remain droplets of liquid in the gas. The separation is controlled via level control scheme ensuring no liquid carry over or gas carry under. Then gas flow rate is measured by vortex meter in the gas leg, gross liquid flow rate and WLR are measured by coriolis mass meter simultaneously in the liquid leg and water or oil flow rate are derived from gross liquid and WLR by simple calculations. The attached P&ID diagram (Fig.2) shows the design detail and operation principle of HPT.

Performance Specification for HPT

Design Pressure:	ANSI 600#
Liquid Flow rate:	20 – 2,000 m^3/d
Gas Flow rate:	0 – 25,000 am^3/d
GVF:	0 – 100%
WLR:	0 – 100%
Liquid Uncertainty:	+/-5% (relative)
Gas Uncertainty:	+/-5-10% (relative)
Water cut uncertainty:	+/-1- 2% (absolute)

The HPT has wide operating envelope covering all wells in Field-A and others in other fields. The operating envelope of the HPT is shown in Fig.3.

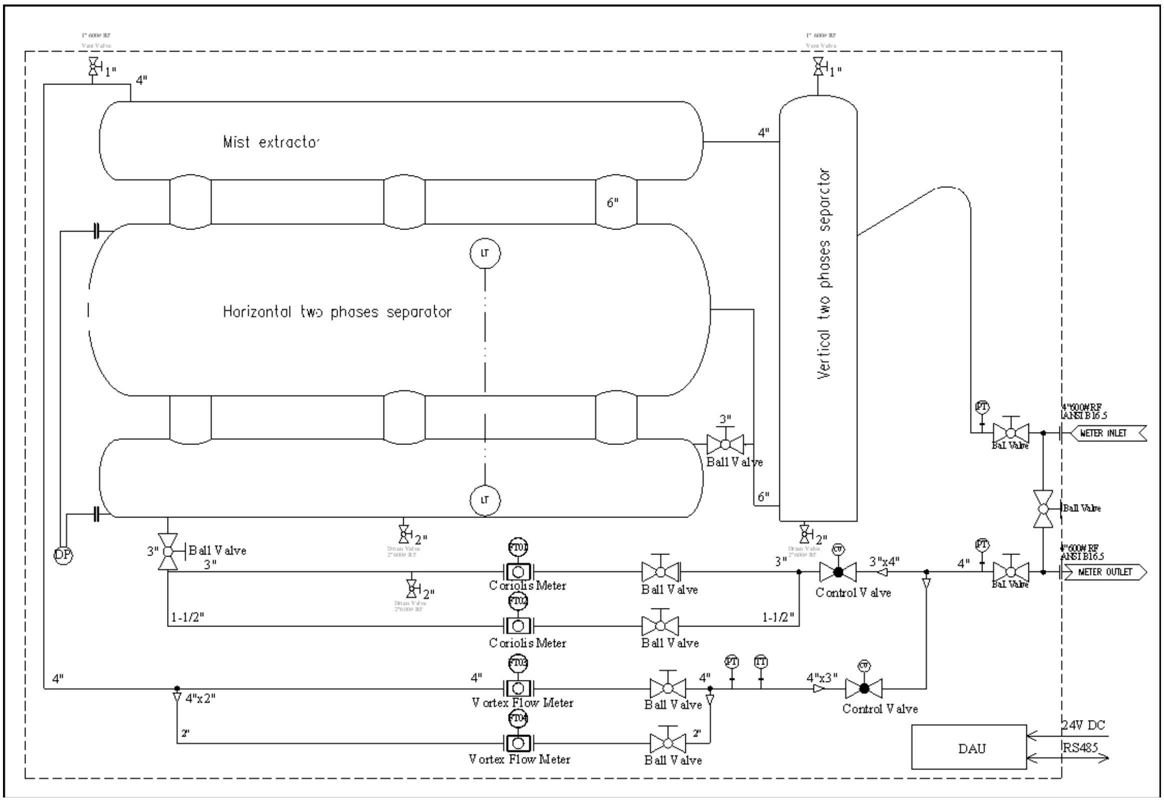

Fig. 2 - P&ID of High Performance Tester (HPT)

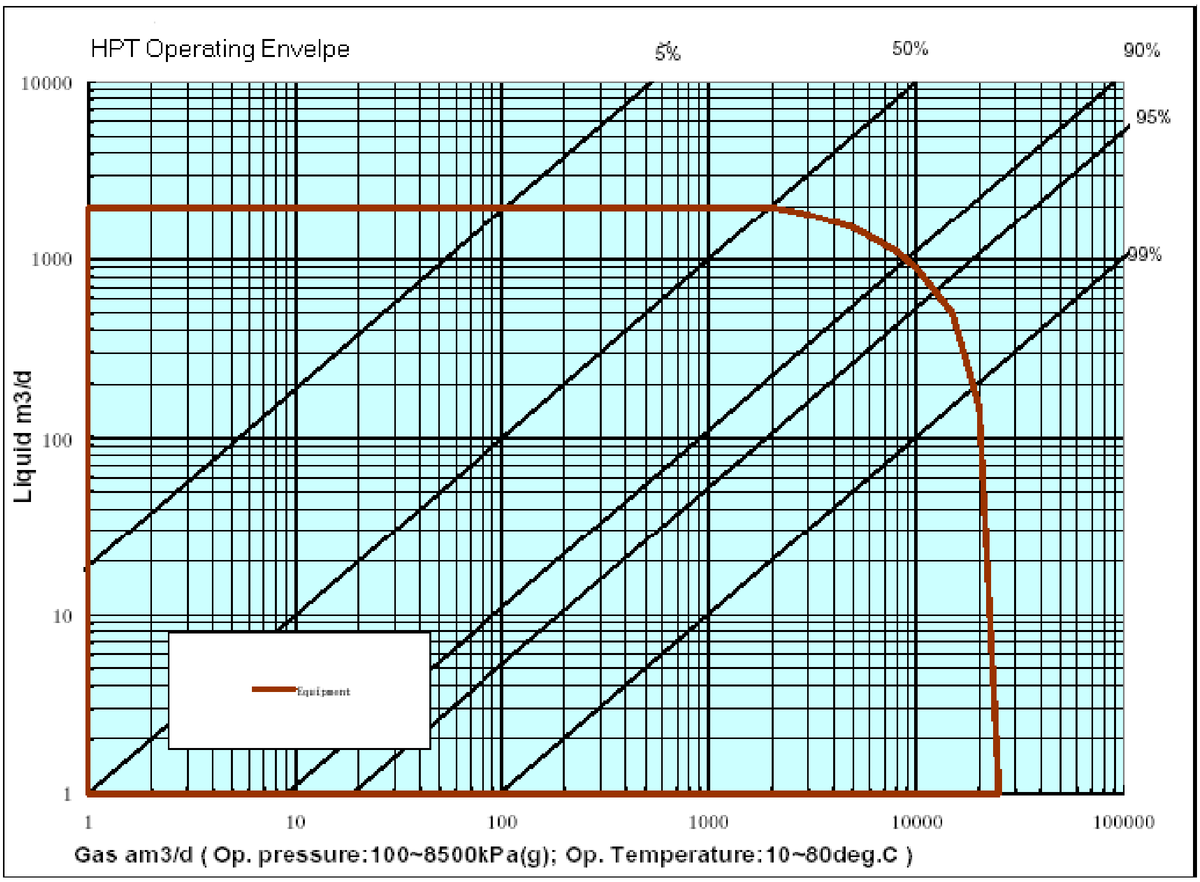

Fig. 3 - HPT Operating Envelope

5 VALIDATION PROCEDURE

The verification of the MPFMs was carried out by connecting the MPFM and HPT in series (Fig. 4) and comparing the individual well test results from the MPFM against those from the HPT. The total volumes of each phase from all the wells measured by using both units at same time were also compared.

Fig. 4 - HPT & MPFM Setup for Validation Test

Additionally, before the validation, wells for validation test were carefully chosen according to the MPFM operating envelope, oil and water samples calibrations of the wells were carried out, pressurized gas samples from different wells were taken and then analyzed at the field laboratory to obtain compositions and specific gravity values, gas on-line calibrations were done on to obtain the attenuation coefficient of the gas. During the validation test, adequate purging time for each well was set properly to avoid affections from previous well test due to the long process line from wellhead to the station on which the validation was carried out. Manual water cut samples were taken from the right sampling point to crosscheck against the instantaneous results from MPFM and HPT. And same PVT parameters were applied to convert test results of MPFM and HPT at line conditions to standard conditions.

6 VALIDATION RESULTS AND ANALYSIS

Table 1 illustrates the comparison test results of MPFM against HPT on each well. The total oil and gas rates are also compared at the end of the table. It can be clearly seen that the total flow ratio of the two units are very close to 1.

Table 1 Comparison Test Results of HPT & MPFM

Well No.	MPMF					HPT				Error	
	Liquid Rate	Oil Rate	Gas Rate	GVF	WC	Liquid Rate	Oil Rate	Gas Rate	WC	Gas	Liquid
	m3/d	m3/d	m3/d	%	%	m3/d	m3/d	m3/d	%	%	%
1	237	237	134,975	94	0.0	254	254	126,161	0.0	7.0	-6.9
2	223	192	15,125	60	14.0	208	173	13,282	16.4	13.9	7.4
3	135	80	247,446	98	40.6	132	77	243,123	41.7	1.8	1.6
4	120	120	387,836	97	0.2	121	121	369,441	0.2	5.0	-0.3
5	95	95	230,556	98	0.0	96	96	220,293	0.2	4.7	-0.7
6	94	94	202,992	98	0.0	88	87	199,748	1.0	1.6	7.2
7	86	86	208,545	98	0.2	87	86	193,068	0.3	8.0	-0.9
8	76	76	90,794	96	0.5	70	70	90,610	0.4	0.2	8.3
9	76	76	149,500	98	0.3	75	74	151,511	0.4	-1.3	1.6
10	74	74	150,365	97	0.0	82	80	140,121	2.4	7.3	-9.4
11	72	72	75,697	98	0.0	68	68	80,420	0.0	-5.9	5.0
12	57	57	104,455	98	0.0	53	53	115,504	0.5	-9.6	6.5
13	47	47	118,977	99	0.0	44	43	100,350	2.0	18.6	6.5
14	29	29	109,494	99	0.0	21	21	112,999	0.4	-3.1	39.0
Total	1,421	1,334	2,226,756	95	6.1	1,399	1,304	2,156,630	6.8	3.3	1.6

Total oil flow rate ratio 1,334/1,304 = 1.023; Total gas flow rate ratio 2,226,756/2,156,630 = 1.033

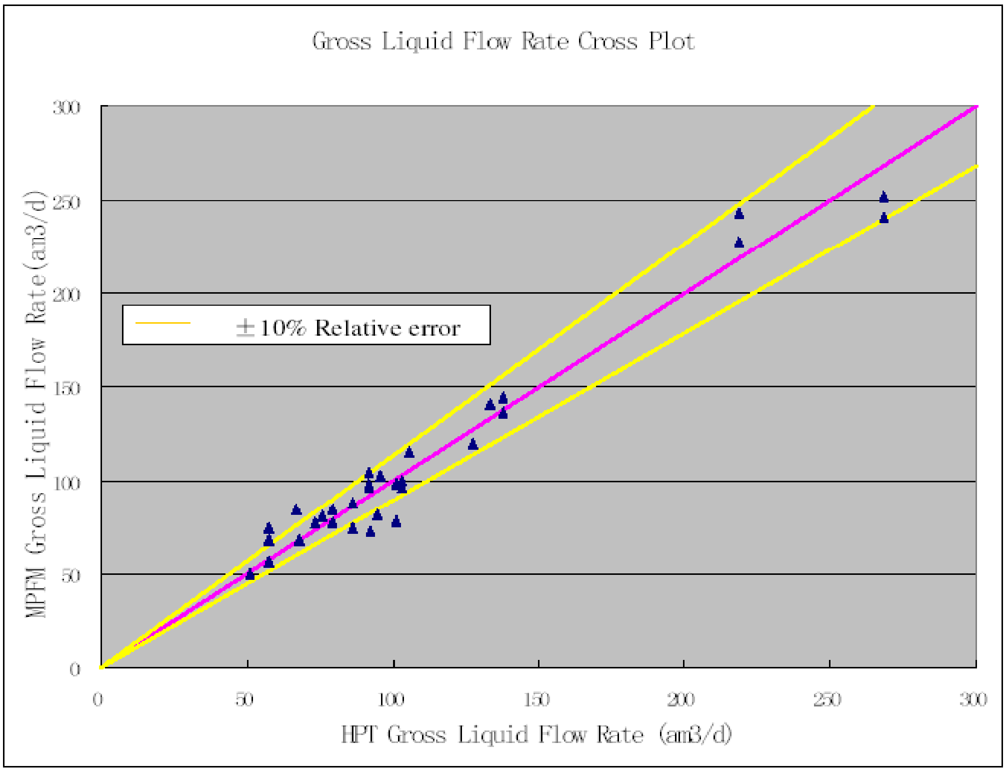

Fig. 5 - Cross Plot of Gross Liquid

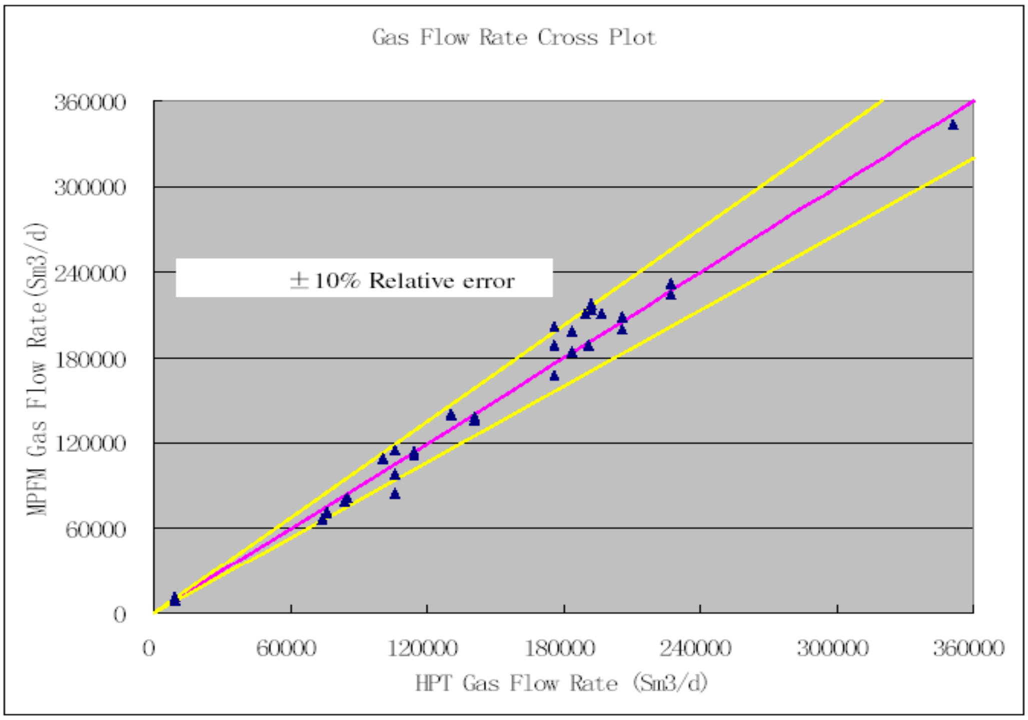

Fig. 6 - Cross Plot of Gas

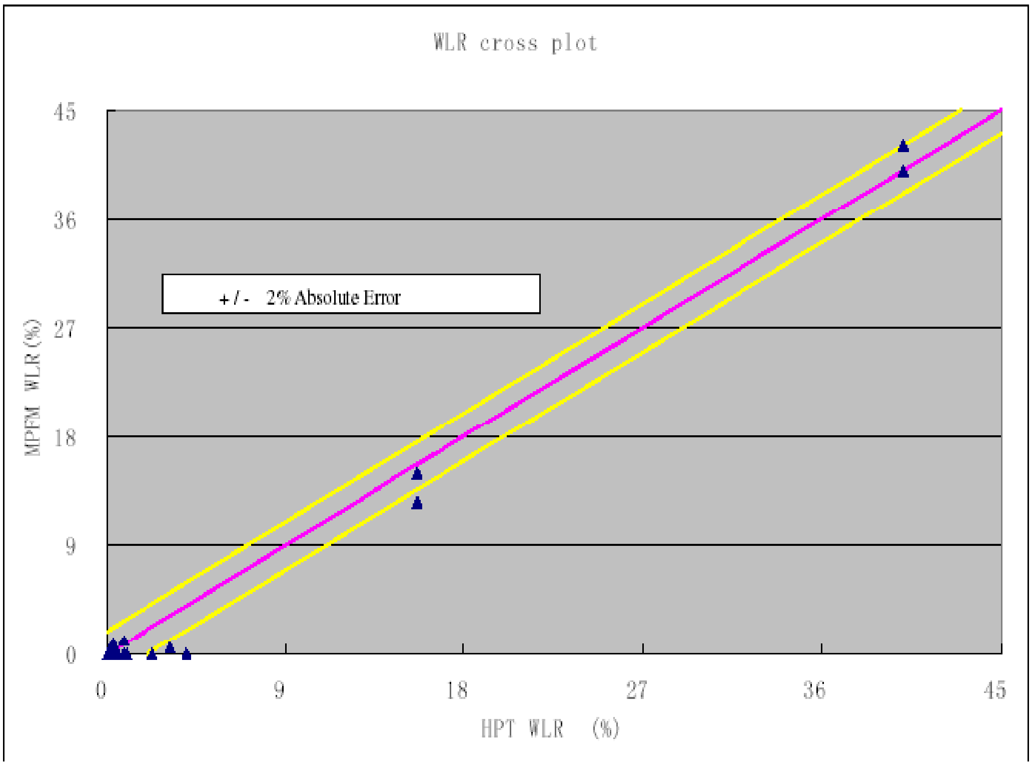

Fig. 7 - Cross Plot of WLR

Figures 5, 6 and 7 show the cross plots for gross liquid, gas and WLR for Field-A wells tested by the MPFM and the HPT and met client's accuracy requirement. For the gross liquid and gas, most results are within the accepted +/-10% uncertainty band. Most WLR results are also inside the acceptable +/-2% reference band at 90% confidence level.

7 LONG-TERM PERFORMANCE MONITORING OF MPFM

Followed by the individual well validation test, the MPFM performance has undergone a long-term monitoring since March of 2008 up to date from the oil reconciliation factor (RF) perspective.

Since there is no reference in the field to cross-check the performance of the MPFM after the validation test, the export flow meter from the gathering station was used as a validation tool. The oil rate ratio between the export flow meter and the sum reading of the MPFMs is defined here as RF. The acceptable RF by PDO is generally within 0.9 to 1.1. Even though the export flow meter may only indicate that the field potential is determined accurately but does not indicate if wells' potential is also determined accurately by the MPFM because one well may be over measured and the other well is under measured, it is still a useful way to monitor the performance of MPFM. The monthly node oil RF of field-A is recorded in Figure 8. from March 2008 to December 2010. It can be seen that all the RF values are within the acceptable RF limits of 0.9 and 1.1.

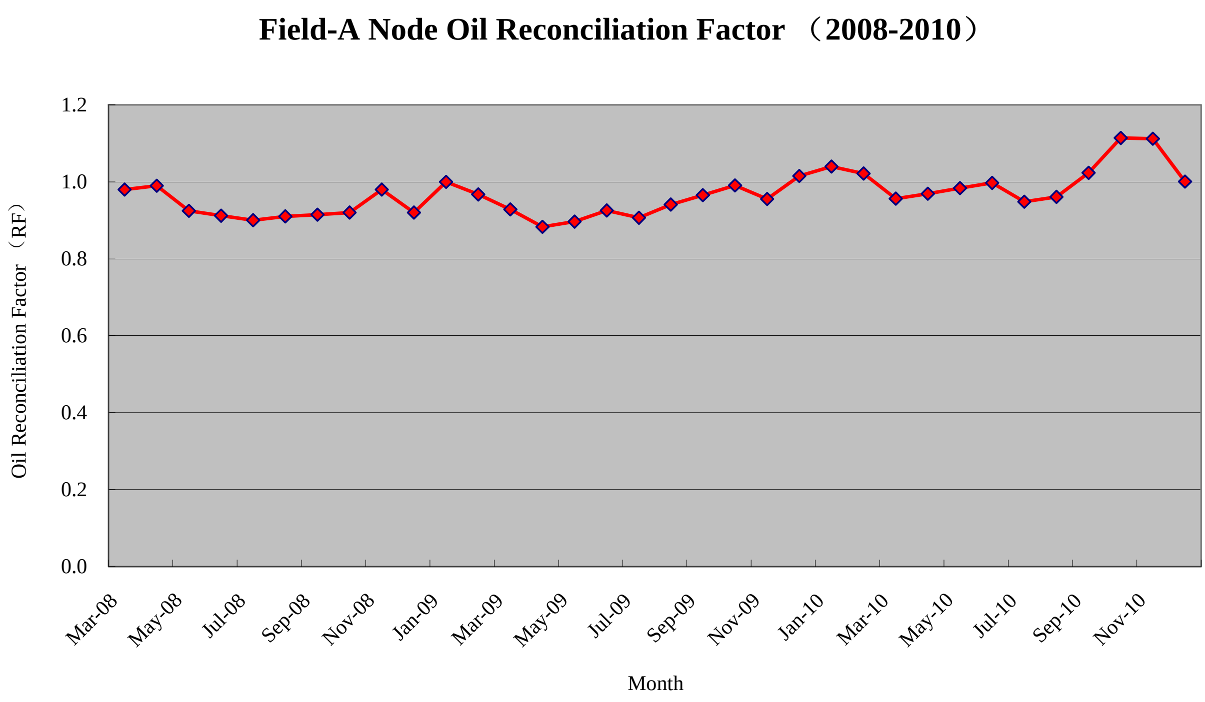

Fig. 8 - Field-A Node Oil Reconciliation Factor (Mar 2008 – Dec 2010)

Note: Field-A is sharing the RF with some other fields. Generally the RF structure will cause the RF trend to shift should the well testing performance of those fields change.

Field-A is basically a stable production field at current stage and there is no significant production deviations observed from the export flow meters or other facilities. The monthly total gross liquid rate, gas rate and average WC measured by MPFM are tracked from May 2008 to February 2011 as shown in figure 9. The MPFM has shown the similar stability with the field production profile.

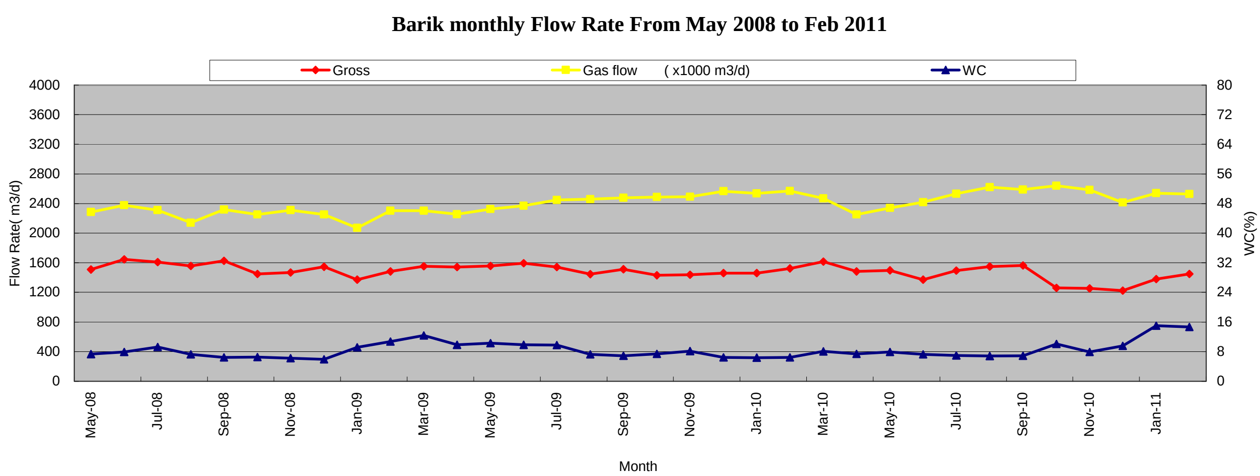

Fig. 9 - Monthly total rates and average WC measured by MPFM

8 CONCLUSIONS

A specific case of field validation and long-term performance monitoring of the MPFM was presented in detail. Different methodologies to validate and monitor MPFMs performance were discussed including individual well test comparison with an efficient validation unit, RF analysis, and meter self stability tracking.

Well testing at very high GVF and high pressure condition gives additional challenges to MPFM measurements. The validation test has proved that the MPFM is an effective tool to accurately measure the wells under these conditions when it is used in the correct applications and focused efforts in maintencane, calibration and monitoring is in place. Through the field validation, the MPFM was able to achieve the measurement accuracy with liquid flow rate at ±10% relative error, gas flow rate at ±10% relative error, and WLR at ±2% absolute error at 90% confidence level meeting the client's well testing accuracy requirement. The reliable well testing data provided by MPFM is critical for helping the well & reservoir management (WRM) in PDO.

The RF factor for field-A has been tracked stably in the 0.9 to 1.1 level. These behaviors have increased end user confidence in the MPFM application to determine the well and field potential.

9 NOTATIONS

MPFM	Multiphase Flow Meter
PDO	Petroleum Development Oman
GVF	Gas Volume Fraction
HPT	High Performance Tester
WC	Water Cut (standard condition)
WLR	Water in Liquid Ratio (line condition)
TFR	Total Flow Rate
GLR	Gross Liquid Flow Rate
P&ID	Process and Instrument Diagram
RF	Reconciliation Factor

10 REFERENCES

[1] Abdullah Al-Obaidani, Salim Al-Sibani. Petroleum Development Oman (PDO) experience in well Testing at High GVF and High Pressure conditions. 8th South East Asia Hydrocarbon Flow Measurement Workshop 4th – 6th March 2009