Main Index

Field Testing Experience of Wet Gas and Multiphase Flow Meters Conducted in Saudi Arabian Wet Gas-Condensate Producers

Mohammed Asiri, Saudi Aramco
Ruben Villegas, Saudi Aramco
Shahid Hussain, Saudi Aramco
Ismail Buhidma , Saudi Aramco
Abdullah Subaii, Saudi Aramco

1 INTRODUCTION

The paper describes the challenges and uncertainties associate with the accurate flow measurement of gas, oil and water and the results of a trial test conducting using four multiphase flow meters in wet gas–condensate producers at a wide range of flowing conditions. The measurement of these three phase is very critical for reservoir monitoring and production diagnostic and obtaining the accurate three-phase data poses a significant challenge for the majority of conventional multi-phase flow meters, because of the high-gas volume fraction (95% and above) nature of the wells.

Multiphase flow meters technology has been successfully used around the world for over 10 years in oil and gas fields with low cost comparing with three phases test separator. This success encouraged the manufacturers to develop the current meters to satisfy and meet the production test requirements.

At the end of 2010, Saudi Aramco conducted a pilot test to evaluate four wet gas MPFMs from various leading manufacturers. The objective of this test was to confirm the accuracy and reliability of these meters for measuring gas, condensate and water flow rates in the wet gas stream. A high pressure test separator was the reference measurement and the test was repeated at several selected gas wells. After almost four months, the testing concluded that only a particular type of meter performed better than others and met the Saudi Aramco acceptance accuracy.

This paper also describes the Saudi Aramco's experience of field testing the latest MPFM's in real production condition, field test methodology, equipment setup and result analysis.

2 TECHNICAL SPECIFICATIONS AND PRINCIPLE OF OPERATION OF SELLECTED MPFM's

Following Wet Gas MPFM's were selected for trial testing:

- **MSI:** Internationally recognized high GOR meter. Having track record of more than 300 installations worldwide.
- **Roxar 2600 (Radioactive):** Roxar is an approved oil well MPFM vendor in Saudi Aramco having almost 150 units already installed and operational in the company. Roxar decided to try their wet gas model of the same meter.
- **Schlumberger Vx (Radioactive):** Largest oil MPFM supplier to Saudi Aramco. This meter has failed the previous trial test in 2006 and come back with improved version.
- **Weatherford:** Weatherford offered non-nuclear technology for wet gas metering. As a renounced service company the vendor already established in the KSA with appreciable technical and logistic strength.

2.1 MSI

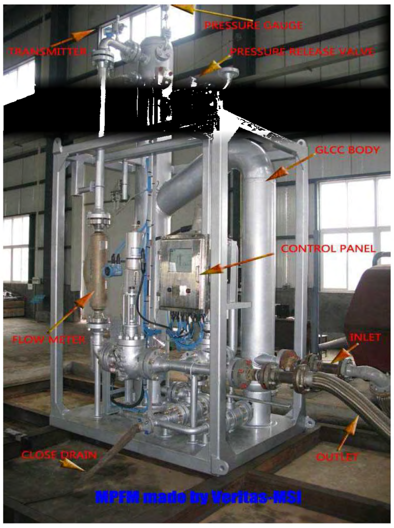

Fig. 1 – MSI Meter

This meter uses a Gas/Liquid Cylindrical Cyclone, GLCC. The gas-liquid mixture enters GLCC through an inclined inlet pipe and a tangential nozzle, sized to deliver a preconditioned flow into the body of the separator. The momentum of the gas-liquid mixture, combined with the tangential inlet, generates a liquid vortex with sufficient g-forces for bulk gas and liquid separation to occur rapidly. Finally, the gas exits through the top of the GLCC and the liquid exits through the bottom of the GLCC. Three control modes are used for different applications based on the operation requirements. After the separation, gas and liquid flow rates can be metered with a gas meter and liquid meter; water-cut value can be either obtained from density correlation or direct measurement using water-cut meter; flow computer will provide the accumulative gas, oil and water production rate and send the data to your existing data acquisition systems.

2.2 Roxar 2600 (Radioactive):

Roxar Multiphase flow meter 2600 is the third generation meter built on the ZectorTM Technology platform that includes upgraded non-gamma algorithms, advanced signal processing, compact sensor geometry and impedance field electronics. The Roxar MPFM 2600 is an inline, non-intrusive meter that measures multiphase flow without separation.

Fig. 2 – Roxar Meter

The new Zector technology covers three main components:

1. <u>Voxel-Based Signal Processing:</u>
Through its new Voxel-Based Signal Processing, the Zector technology defines the flow into separate volumes voxels or volumetric pixels. Near wall measurements and cross volume measurements also provide a comprehensive mapping of flow dynamics.
2. <u>DP26 Electrode, Geometry Sensor:</u>
DP26 Electrode Geometry Sensor allows for measurements in separate sectors in addition to the full cross sectional area.
3. <u>Field Electronics System:</u>
A New Field Electronics System, based around an Analog Devices Blackfin Processor with low energy requirements, allows for capacitance and conductance measurements to be combined using the same set of electrodes. Rather than switching between oil and water continuous mode in a matter of seconds, it now switches mode in milliseconds.

2.3 Schlumberger Vx (Radioactive)

Fig. 3 – Schlumberger Vx Meter

Vx multiphase measurement technology combines an instrumented venturi with a dual-energy fraction meter. This combination measures the total mass flow rate and the fractions of gas, oil, and water, which in turn determine the oil, water, and gas flow rates. Vx technology functions without the need for separation or an upstream mixing device, which minimizes the size and weight of the equipment. The technology has no moving parts and is essentially maintenance-free. The PhaseWatcher permanent multiphase flowmeter uses Vx technology to continuously measure flow rates in wells exhibiting one, two, or three-phase flow for production monitoring on land, platform, and subsea wells.

2.4 Weatherford

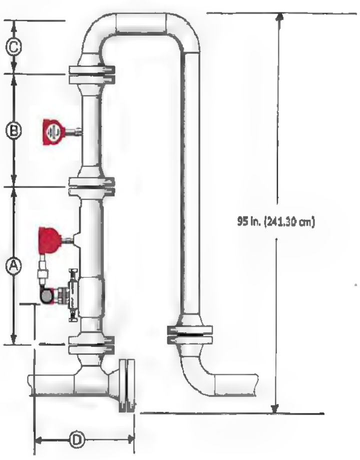

Fig.4 – Weatherford Meter

Alpha VS/R is based on an extended-throat Venturi (V), a Sonar (S) flow meter and an optional Red Eye (R) multiphase water-cut meter. The sonar flow meter measures the convection of turbulent vortices using an array of dynamic strain sensors. Sonar has the unique ability to measure total flow rate accurately over an extremely wide range of Reynolds numbers (flow rate, fluid types) with a negligible over-reading in wet-gas flows. (Over-reading is the ratio of apparent flow rate to the actual flow rate). The Venturi flow meter is based on the measurement of static pressure drop across a converging pipe section. The combination of Sonar and Venturi in the Alpha VS flow meter yields total gas and liquid flow rates in real time. The optional Red Eye multiphase water-cut meter is a filter spectrometer that employs the principle of near-infrared absorption to measure the water content in a liquid or multiphase stream. The Red Eye multiphase meter reports water cut independent of flow regime, flow rates, water salinity and hydrate inhibitors. The Sonar-Venturi flow meter comprises a Sonar sensor array located in the extended throat section of a Venturi-Nozzle. In essence, the total flow rate is derived from the bulk velocity measured by the Sonar device, while the liquid loading is resolved by the Venturi DP over-reading. In practice, the sonar device also has minor over-reading that needs to be accounted for in an iterative solution that converges on a total rate and liquid loading that matches the readings of both instruments.

3 FIELD TRIAL TEST METHOLOGY

The trial test was successfully conducted while the deliverability test program was developed for 5 Saudi Aramco gas wells. The Wet Gas MPFMs test results were directly compared with the measurements from the conventional high pressure test separator results (2K psi separator), which was considered as the reference measurement for this project.

Table below shows important information for the trial test:

Table 1 – General Information for the Selected Wells

Well No.	CGR (BC/MMSCFD)	Water Injection required	Choke Size (/64")	Test Rate (MMSCFD)	Test Duration
1	20-30	NO	22/36/40	7, 15 & 20	24/24/24
2	30-50	NO	36/48/70	12, 20 & 30	24/24/24
3	70-90	YES	26/38/38*	10, 22 & 20*	24/24/24*
4	310-350	YES	34/48/34*	10, 20 & 10*	24/24/24*
5	90-110	NO	44/70	20 & 40	24/24

* Water injection was performed at this choke/ rate.

4 TRIAL TEST PROCEDURE

The well tests were performed according with the program established for normal deliverability tests, but also some tests were carried out by pumping some water into the system in two wells C and D to simulate the water production at one of the same choke sizes.

The test procedure was as follow:

1. The four wet gas MPFM's were installed in a parallel arrangement downstream the choke manifold and upstream of the 2K Psi test separator, the reference equipment for comparing the tests results.

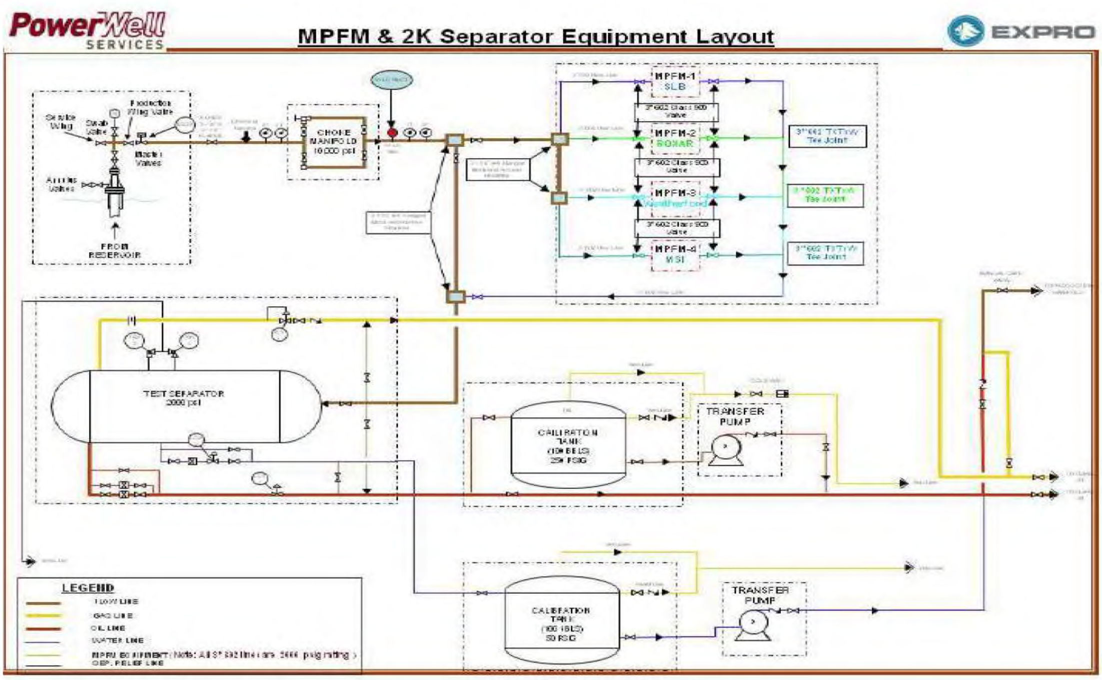

Fig.5 – MPFM & 2 K Separator Layouts

2. The WG MPFM vendor personnel were on location while rigging up, pressure testing and during the trial test of their meters.
3. The trial test was executed following the steps for the deliverability test as per the program.
4. During each test, following data was recorded by the conventional well testing company at the test separator: Test separator pressure and temperature, gas, condensate and water rates,
5. The identical test data was recorded continuously by every Wet Gas MPFM.
6. The gas, condensate and water flow rates were generated at standard conditions.
7. Water injection was pumped into the system to simulate higher liquid yield situation and also in order to monitor the meter performance while measuring higher water cuts.
8. The required operating standards were followed during all operations.

5 MPFM ACCEPTANCE CRITERIA

In 85% of the total tests conducted, a meter should stay within the following allowable error band for each phase as compared to the test separator (reference measurement) in order to be considered acceptable for Saudi Aramco application.

Table 2 – MPFM Acceptance Criteria

Gas Rate	10%	Relative
Condensate Rate	15%	Absolute
Water Rate	20%	Absolute

6 TEST RESULTS

The flow rates measurement of Gas, Oil/Condensate, and Water from each meter and test separator were collected and tabulated as follows:

Table 3 – MPFM Trial Test Results

SUMMARY TABLE

	NUMBER OF FAILED TESTS													
					WATER						All Fluids			
	GAS		CONDENSATE		Rel		Abs		TOTAL LIQUID		w/Rel		w/Abs	
MPFM	#	%	#	%	#	%	#	%	#	%	#	%	#	%
A	6	43%	10	71%	11	79%	0	0%	8	57%	14	100%	14	100%
B	1	7%	8	57%	13	93%	4	29%	10	71%	14	100%	11	79%
C	1	7%	6	43%	12	86%	1	7%	8	57%	13	93%	7	50%
D	2	15%	1	8%	7	54%	0	0%	1	8%	9	56%	3	23%
	10	18%	25	45%	43	78%	5	9%	27	49%	50	91%	35	64%

	NUMBER OF SUCCESSFUL TESTS													
					WATER						All Fluids			
	GAS		CONDENSATE		Rel		Abs		TOTAL LIQUID		w/Rel		w/Abs	
MPFM	#	%	#	%	#	%	#	%	#	%	#	%	#	%
A	8	57%	4	29%	3	21%	14	100%	6	43%	0	0%	0	0%
B	13	93%	6	43%	1	7%	10	71%	4	29%	0	0%	3	21%
C	13	93%	8	57%	2	14%	13	93%	6	43%	1	7%	7	50%
D	11	85%	12	92%	6	46%	13	100%	12	92%	4	31%	10	77%
	45	82%	30	55%	12	22%	50	91%	28	51%	5	9%	20	36%

Cross plots were obtained to observe the meters performance when comparing their results with the test separator.

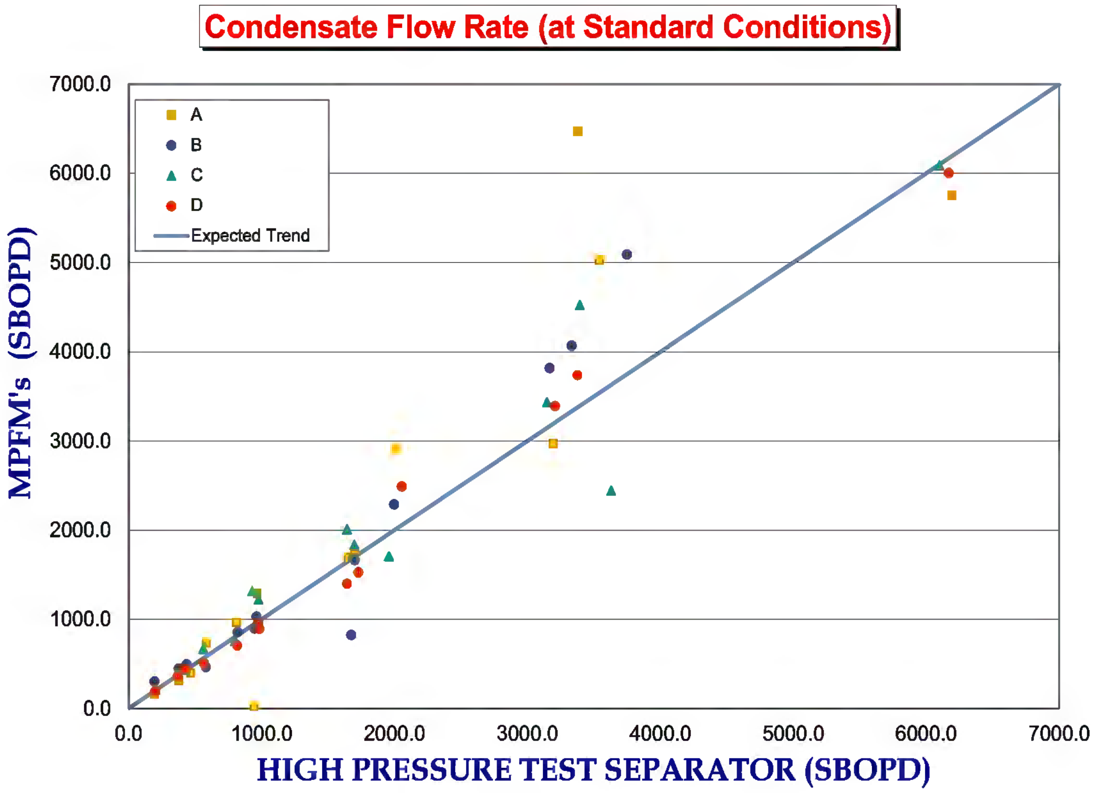

Fig.6 – Condensate Flow Rate at Standard Condition

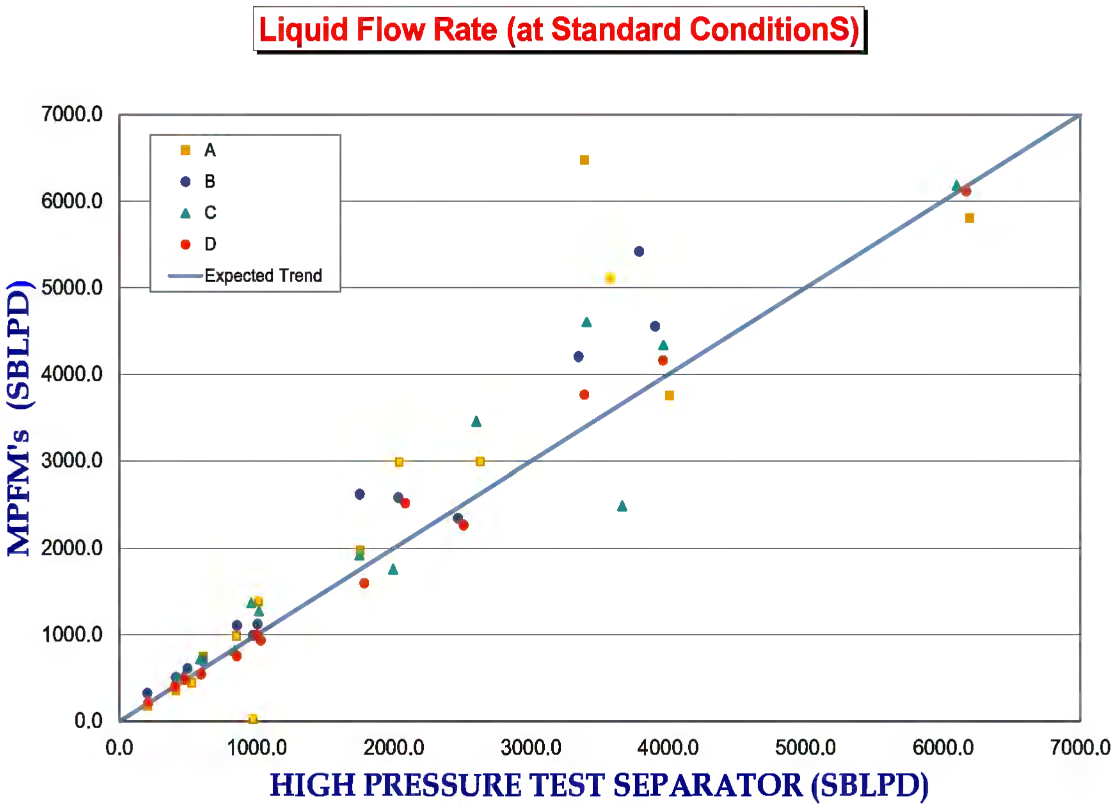

Fig.7 – Liquid Flow Rate at Standard Condition

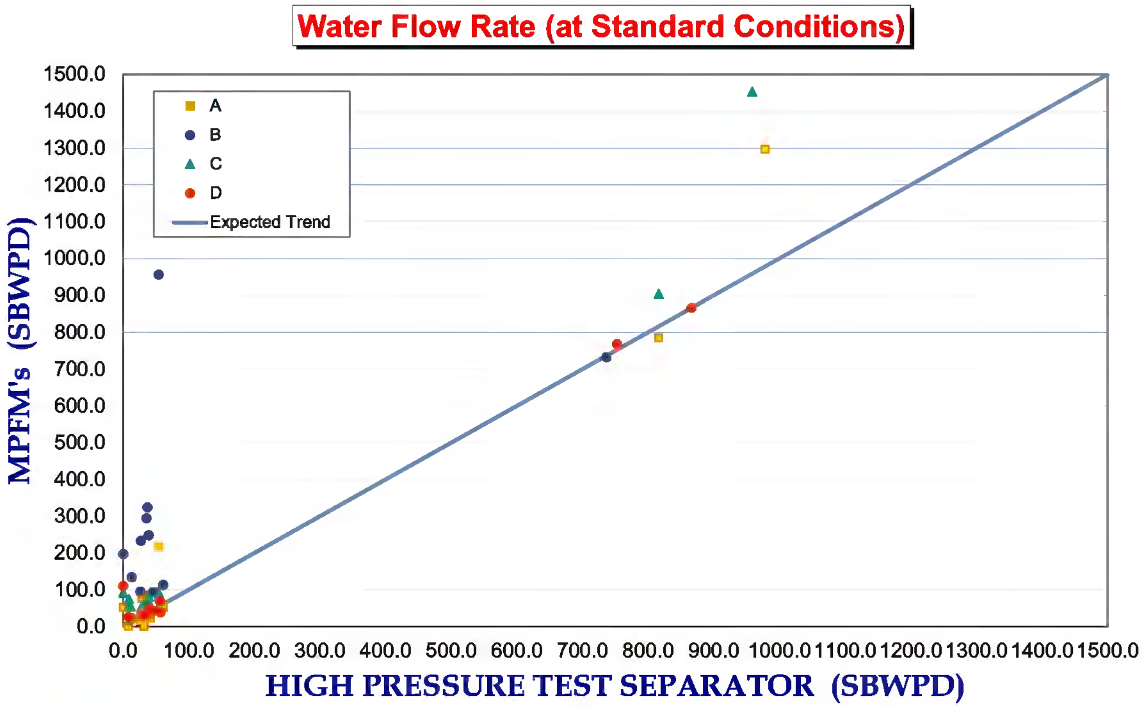

Fig.8 – Water Flow Rate at Standard Condition

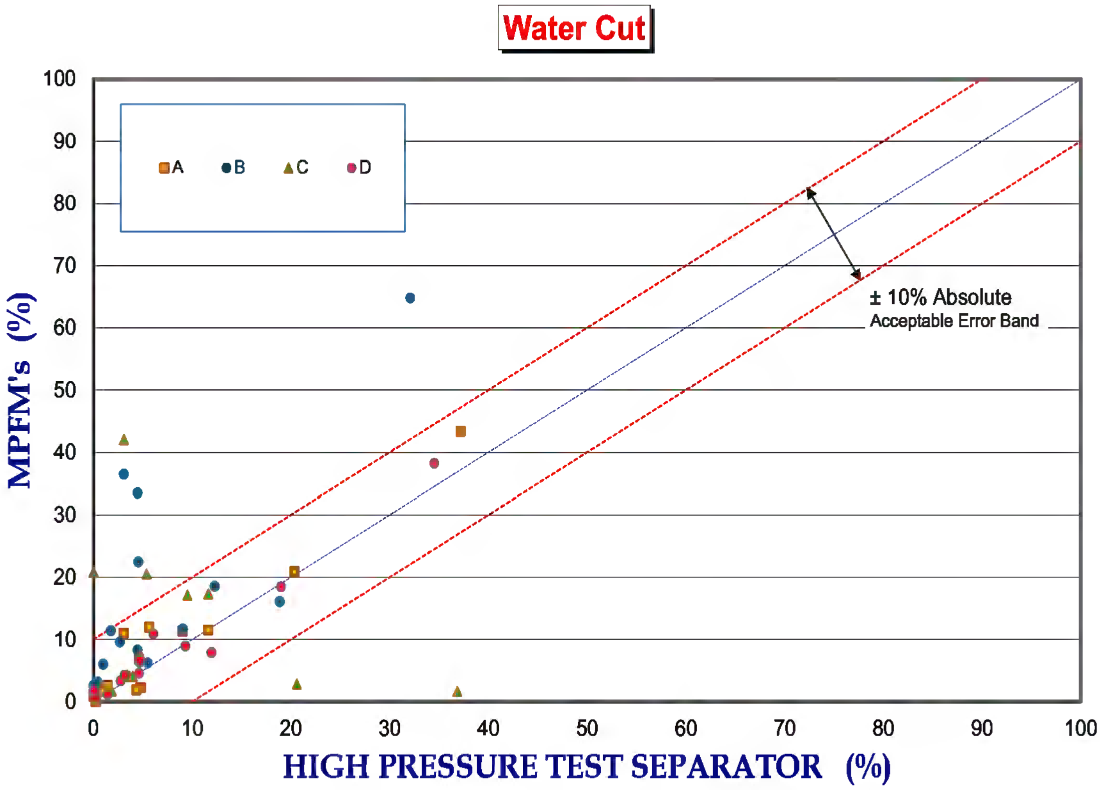

Fig.9 – Water Cut

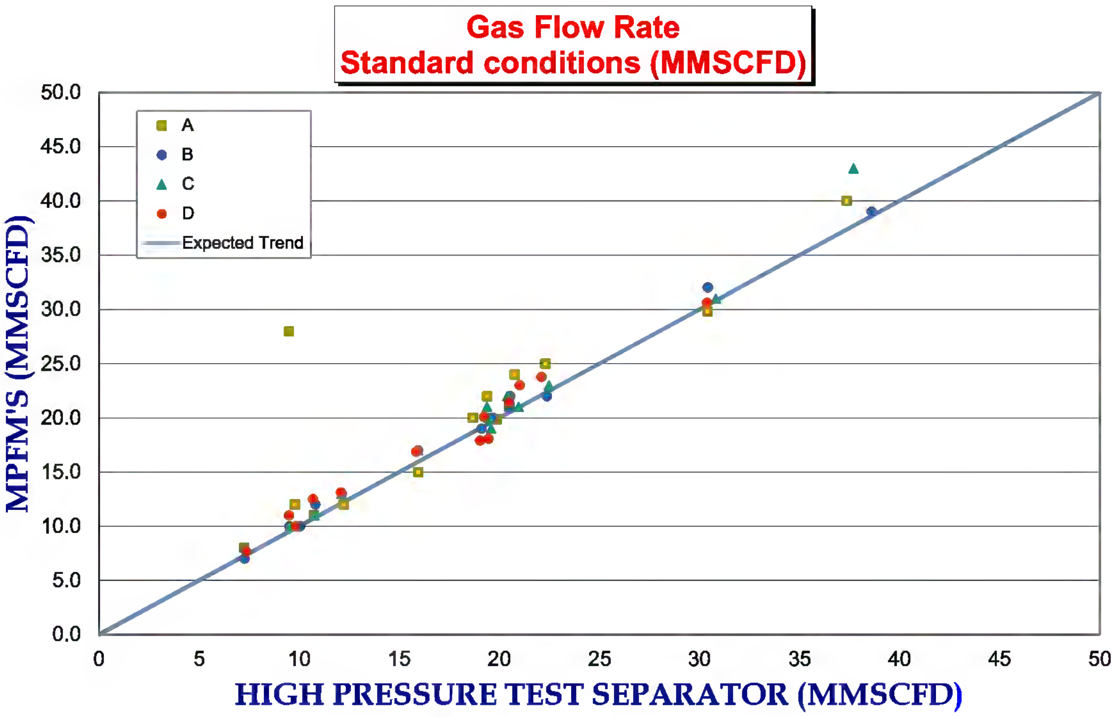

Fig.10 – Gas Flow Rate at Standard Condition

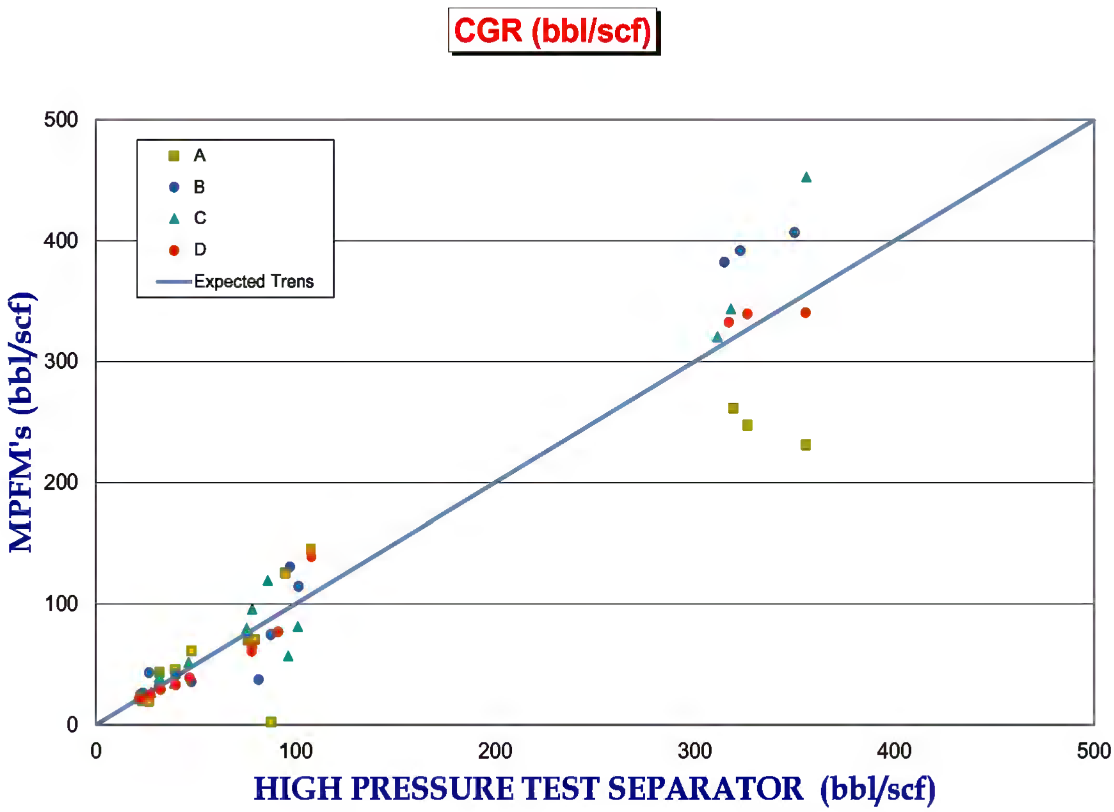

Fig.11 – Condensate gas ratio

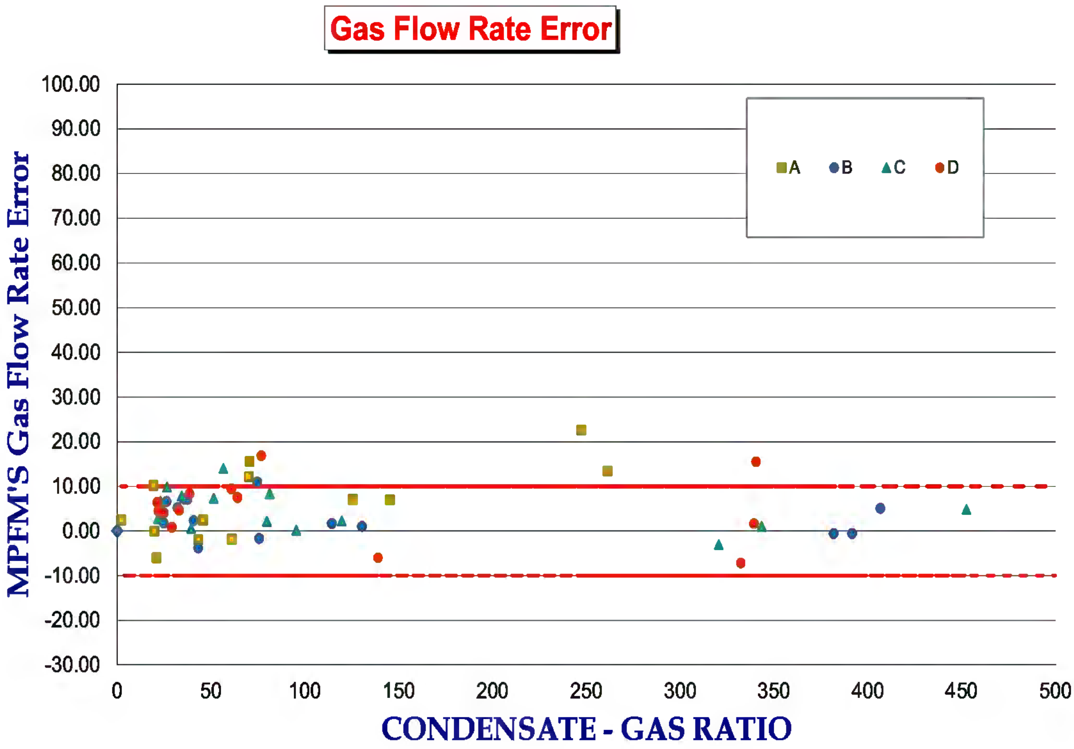

Fig.12 – Gas flow rate error

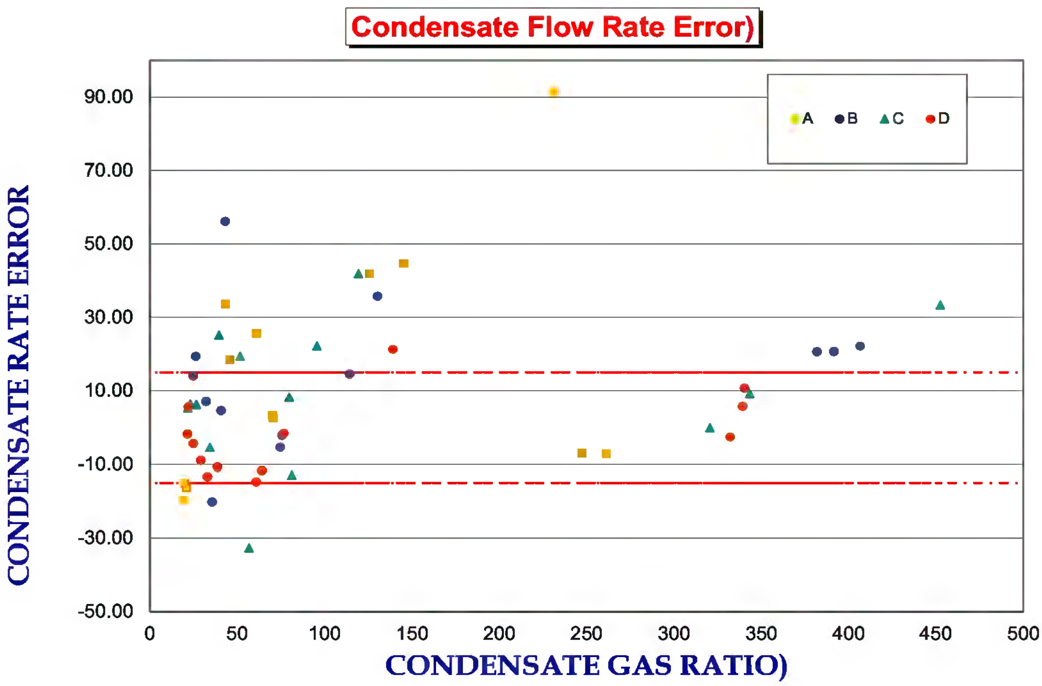

Fig.13 – Condensate flow rate error

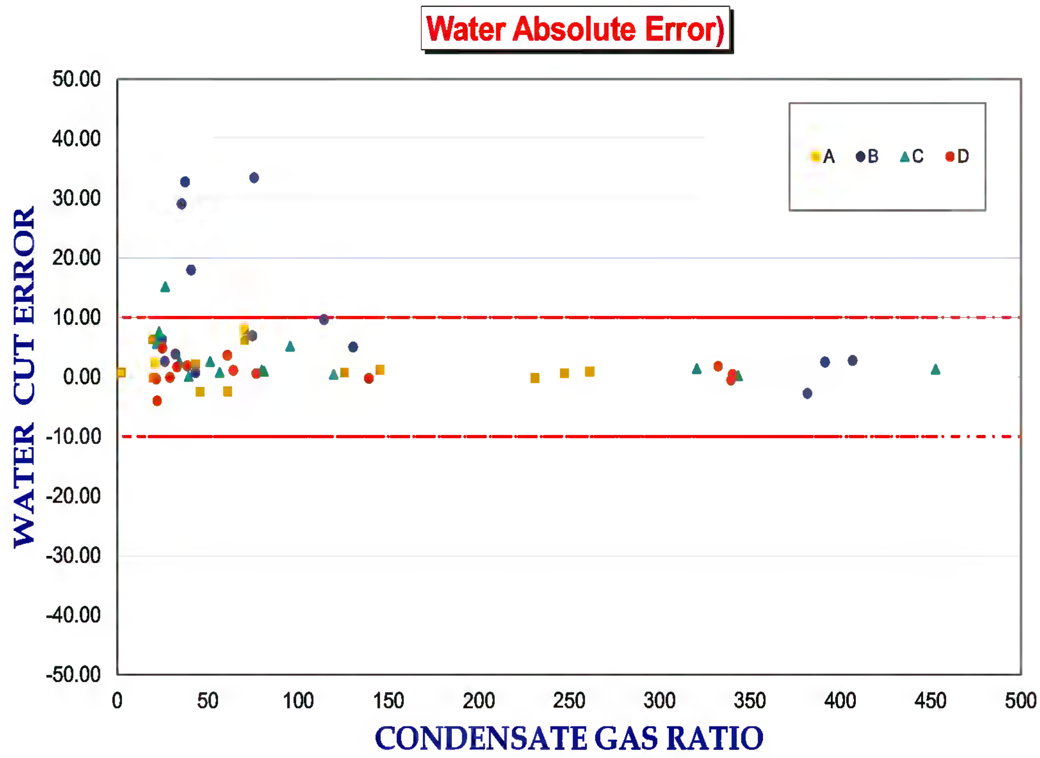

Fig.14 – Water absolute error

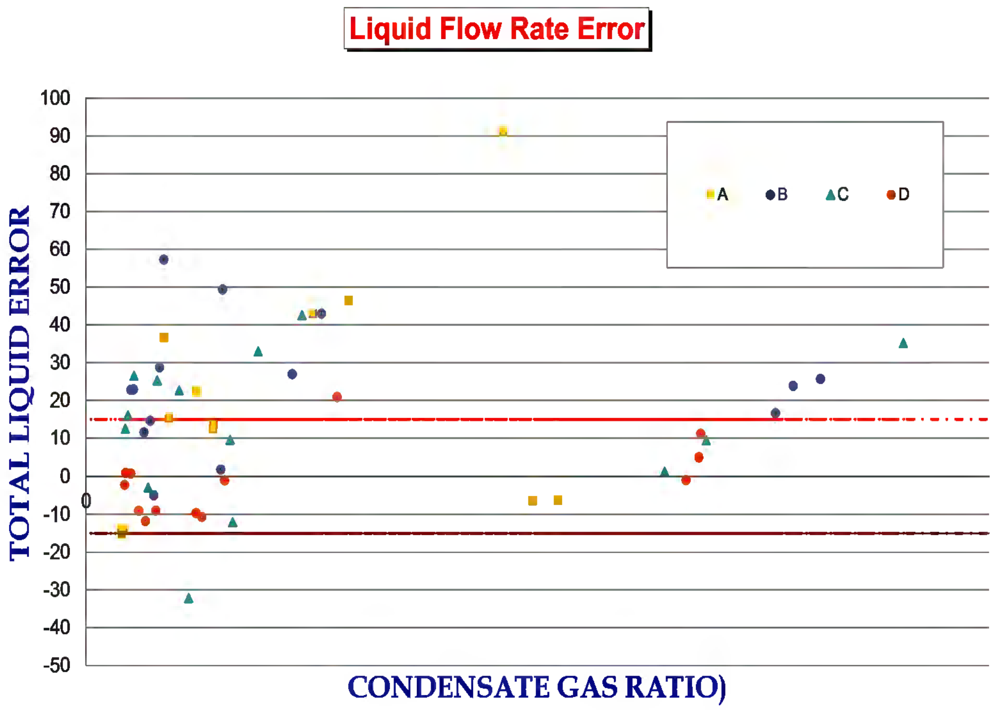

Fig.15 – Liquid flow rate error

For the final results, table below show the performance of the 4 meter in terms of gas, condensate and water measurements.

Table 4 – Results

	Gas Rate	Conden. Rate	Water Rate	**Overall**
A			✓	
B	✓			
C	✓		✓	
D	✓	✓	✓	✓

In summary, plots and table indicated that only one mater **(D)** has met the minimum required acceptance criteria in measuring accurately the gas, condensate and water cut.

7 RECOMMENDATION

- Meter **(D)** should be brought in for an extended reliability test before it can be fully approved to be applied in Saudi Aramco gas fields.
- The other meters should further upgrade their WGMPFM technologies to be able to meet Saudi Aramco acceptance criteria.
- A new WGMPFM trial test campaign should be arranged shortly to retest the upgraded versions of **A**, **B** and **C** meters and to trial test other WGMPFMs.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.