Determination of Multiphase Flow Meter Reliability and Development of Correction Charts for the Prediction of Oilfield Fluid Flow Rates

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Abstract

The aim of field testing of Multiphase Flow Meter (MPFM) is to show whether its accuracy compares favourably with that of the Test Separator in accurately measuring the three production phases (oil, gas and water) as well as determining meter reliability in field environment. This study evaluates field test results of the MPFM as compared to reference conventional test separators. Generally, results show that MPFM compares favourably with Test Separator within the specified range of accuracy.

At the moment, there is no legislation for meter proving technique for MPFM. However, this study has developed calibration charts that can be used to correct and improve meter accuracy.

Keywords

Multiphase Flow Meter (MPFM); Test Separator (TS); Correction Charts; Accuracy; Water Liquid Ration (WLR); Oil; Gas.

Introduction

Until recently, large expensive test separators have been used to separate the oil, gas and water which are then measured using conventional technology [1, 2].

Multiphase meter is a device that can be used to measure individual fluid flow rates of oil and gas when more than one fluid is flowing through a pipeline. A multiphase meter provides accurate readings even when different flow regimes are present in the multiphase flow [3]. When using single-phase meters, the fluid mixture (oil and gas) coming from the wellbore must pass through a fluid-separation stage (separator) prior metering. Otherwise, the readings of the single-phase meters will be inaccurate. Separators are not necessary for multiphase metering, and the meters can support different proportions of gas and oil. Multiphase meters provide the advantage of continuous well monitoring, which is not possible using single-phase meters. Additionally, multiphase meters cost less, weigh less and require less space. Multiphase meters are more common in deepwater operations, where well-intervention operations are often prohibitively expensive.

The problem now arises as to whether the accuracy of multiphase meter (MPFM) compare well with that of test separator. How can the MPFM accuracy be improved? This paper proposes solutions to these probes.

MPFM Test Reference Loop

The test reference loop consists of a three-phase separator. Gas and liquid are separated in the test separator. In order to achieve the desired steady water cut concentration, the oil/water volume in the separator and different draw points are adjusted. On separation, the liquid is pumped through a liquid measurement line. In this line, volumetric measurement is performed with PD meters and water cut measurement is performed with the oil/water meter. A vortex meter and rotameters are used to measure gas after compression.

Following the separation is a recombination of gas and liquid phases. On recombination, the combined stream then passes through the multiphase meter and measurement taken accordingly. Figure 1 shows the diagram of the test reference loop [4].

Test Procedure

Below is a list of the procedure for the main testing of MPFM [5]. Test separator is

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p. 165-174

validated as a reference to the multiphase flow meter.

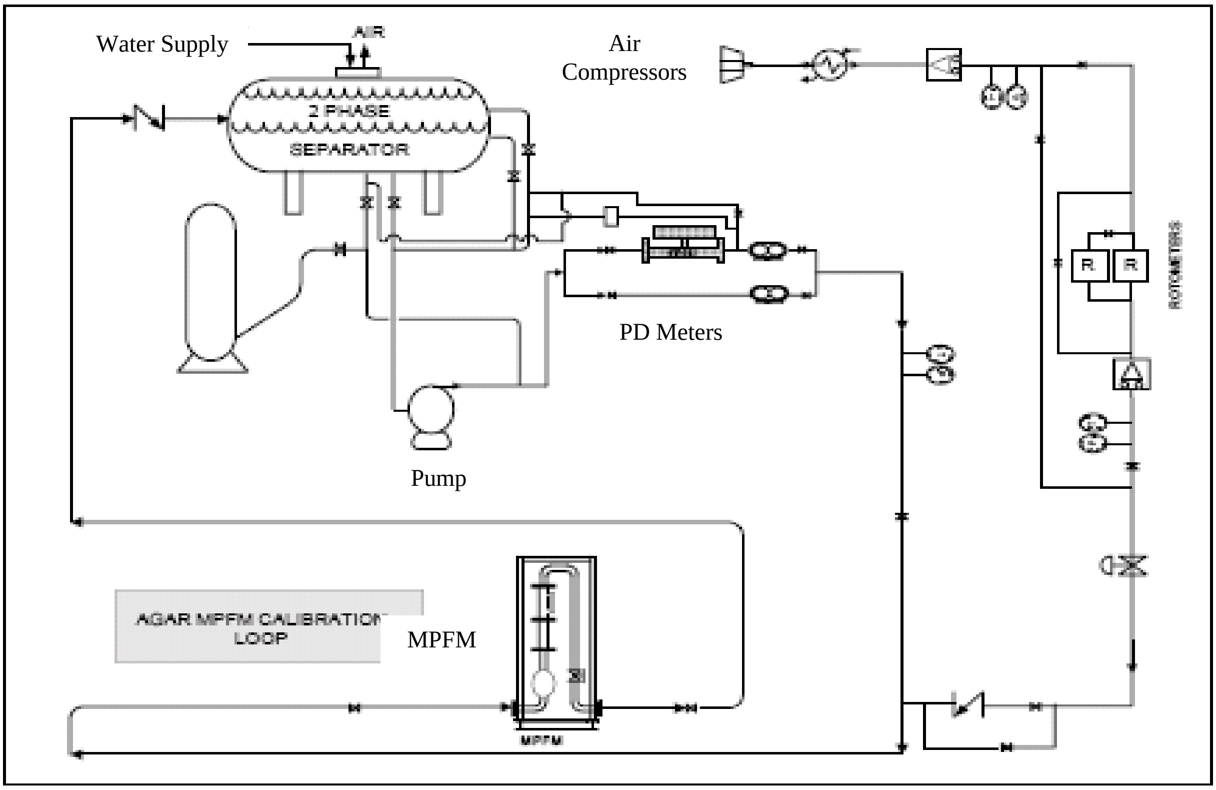

Figure 1. Schematic of test reference loop. Adapted from Tests at Agar Corporation (1999)

1. A purge is time is assigned to each well to be tested.
2. Data review from test separator to ensure that a steady production condition is attained before starting test.
3. Data collection from the MPFM and test separator at the same time when test starts.
4. Initial test result is reviewed.
5. Enquiry from vendor for any modification for improvement of meter performance was made
6. Validity of all data collected with a test separator. This involves comparing test results with historical data.
7. Test is invalidated if major discrepancies are observed.
8. MPFM inputs were reviewed.
9. A final list of valid comparison tests was prepared.
10. Cross-plots of MPFM against test separator were produced.

Process and Performance Conditions

Process and performance specifications are given in Tables 1 and 2, respectively.

Table 1. Process Conditions

Description	Process Conditions
Watercut	10 – 90%
GVF	24 – 85%
Liquid flow rate	1,000 – 5,000 BPD
Salinity of water	1.5% by weight
Oil viscosity	360cp
Temperature	40^{o}C

Table 2. Performance Specification (accuracy)

Description	Specification
Liquid (oil and water)	± 5%
Crude Oil	± 5%
Water	± 5%
Gas	± 5%

The formula below was then used to compute accuracies in each case from the total flow rate and total deviations.

$$\%\text{Accuracy} = \left[\frac{\text{Deviation}}{\text{referenceMeasurement}} \times 100 \right] \quad (1)$$

Test Result Summary

The test result summary is presented in Table 3 for clarity.

Table 3. Test results summary

No.	Reference Measurements (BPD)					Test Measurement (BPD)					Deviations				
	Oil	Water	Gas (ACFD)	Liquid	WLR	Oil	Water	Gas (ACFD)	Liquid	WLR	Oil	Water	Gas	Liquid	WLR
1	1054	129	40229	1183	0.109	1128	84	39954	1212	0.069	74	-45	-275	29	-0.04
2	2701	363	20080	3064	0.118	2819	305	19026	3124	0.098	118	-58	-1054	60	-0.02
3	3276	433	6835	3709	0.117	3382	363	5427	3745	0.097	106	-70	-1408	36	-0.02
4	786	701	47241	1487	0.471	730	729	47376	1459	0.5	-56	28	135	-28	0.029
5	2373	2575	30098	4948	0.521	2480	2488	28839	4968	0.501	107	-87	-1259	20	-0.019
6	180	1319	48773	1498	0.881	218	1204	50196	1423	0.846	38	-115	1423	-75	-0.035
7	487	4504	29236	4991	0.902	661	4493	27048	5154	0.872	174	-11	-2188	168	-0.03
Total	**10857**	**10024**	**222492**	**20880**	**3.119**	**11418**	**9666**	**217866**	**21805**	**2.983**	**561**	**-358**	**-4626**	**205**	**-0.135**

The following results in Table 4 were obtained using equation 1 above.

It can be inferred from the results in Table 4 that the MPFM compare well with test separator. The percent accuracy falls within the specifications in Table 2. This means that the overall performance of the meter was excellent.

Table 4. Percent accuracy of Oil, Water, Gas, Liquid and Watercut

Description	Oil	Water	Gas	Liquid	Watercut
Accuracy	5.17%	3.57%	2.08%	0.98%	4.34%

Development of Correction Charts and Descriptive Statistics

The correction charts below are developed from the test result summary (Table 4). They are to be used for improving meter accuracy. These charts are developed by selecting the best trend line for oil, gas water, liquid and water liquid ration (WLR) separately. They are presented in Figures 2 – 6. Descriptive statistics are also presented.

Correction Charts for Oil Rate

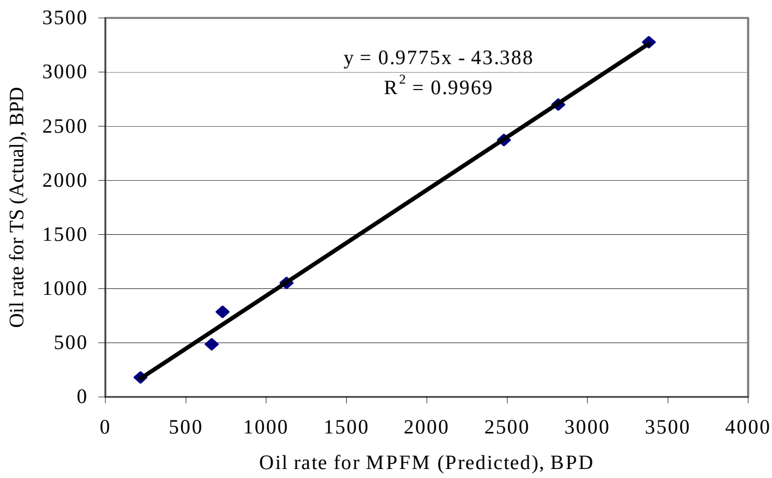

Figure 2. Cross plot for oil rate for test separator versus oil rate for MPFM

Descriptive Statistics for Oil Rate

Table 5a. Descriptive Statistics

Regression Statistics	
R Square	0.9969
Standard Errors	73.90
Observations	7

Table 5b. Descriptive Statistics

	Coefficients	Standard Error	t Stat	P-Value	Lower 95%	Upper 95%
Intercept	-43.39	48.58	-0.89	0.41	-163.26	81.48
X Variable	0.98	0.02	40.12	1.81E-07	0.91	1.04

Correction Charts for Water Rate

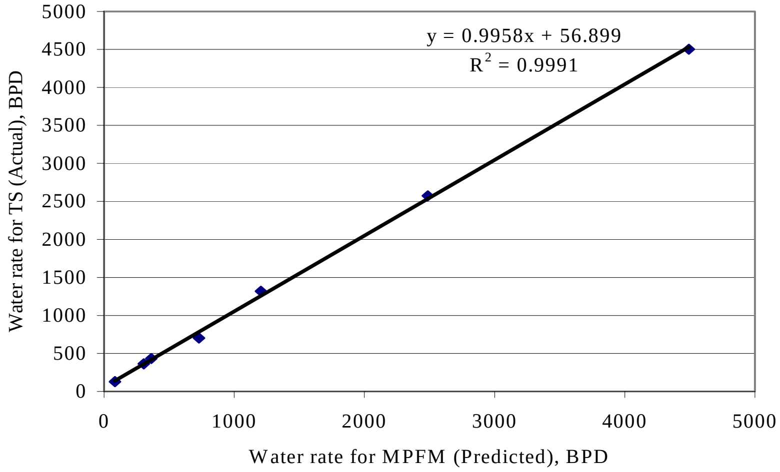

Figure 3. Cross plot for water rate for test separator versus water rate for MPFM

Descriptive Statistics for Water Rate

Table 6a. Descriptive Statistics

Regression Statistics	
R Square	0.9996
Standard Errors	51.8
Observations	7

Table 6b. Descriptive Statistics

	Coefficients	Standard Error	t Stat	P-Value	Lower 95%	Upper 95%
Intercept	56.90	26.81	2.12	0.087	-12.02	125.82
X Variable	1.00	0.013	75.06	7.95E-09	0.96	1.02

Correction Charts for Liquid Rate

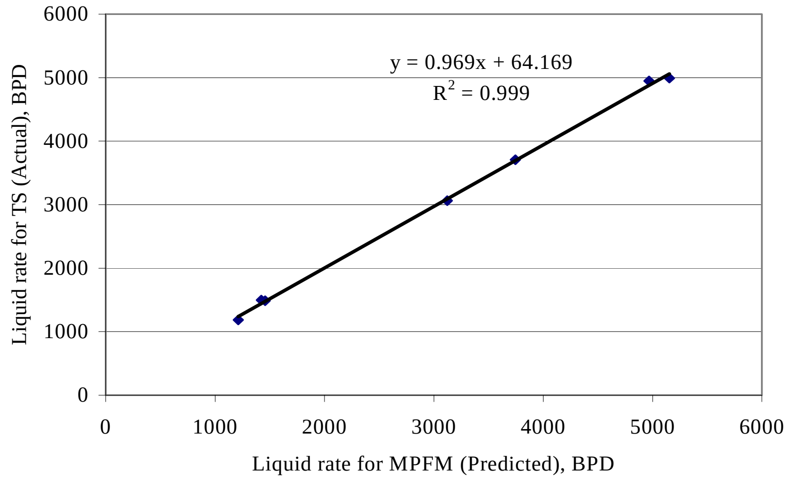

Figure 4. Cross plot for liquid rate for test separator versus liquid rate for MPFM

Descriptive Statistics for Liquid Rate

Table 7a. Descriptive Statistics

Regression Statistics	
R Square	0.999
Standard Errors	57.6
Observations	7

Table 7b. Descriptive Statistics

	Coefficients	Standard Error	t Stat	P-Value	Lower 95%	Upper 95%
Intercept	64.17	47.26	1.36	0.23	-57.31	185.65
X Variable	0.97	0.014	69.6	1.16E-08	0.93	1.00

Correction Charts for Gas Rate

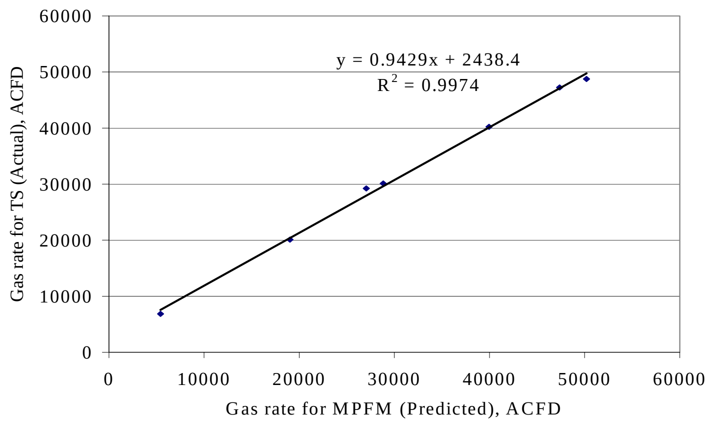

Figure 5. Cross plot for gas rate for test separator versus gas rate for MPFM

Descriptive Statistics for Gas Rate

Table 8a. Descriptive Statistics

Regression Statistics	
R Square	0.997
Standard Errors	839.36
Observations	7

Table 8b. Descriptive Statistics

	Coefficients	Standard Error	t Stat	P-Value	Lower 95%	Upper 95%
Intercept	2438.41	738.53	3.30	0.021	539.96	4336.86
X Variable	0.94	0.021	44.00	1.14E-07	0.89	1.00

Correction Charts for WLR Rate

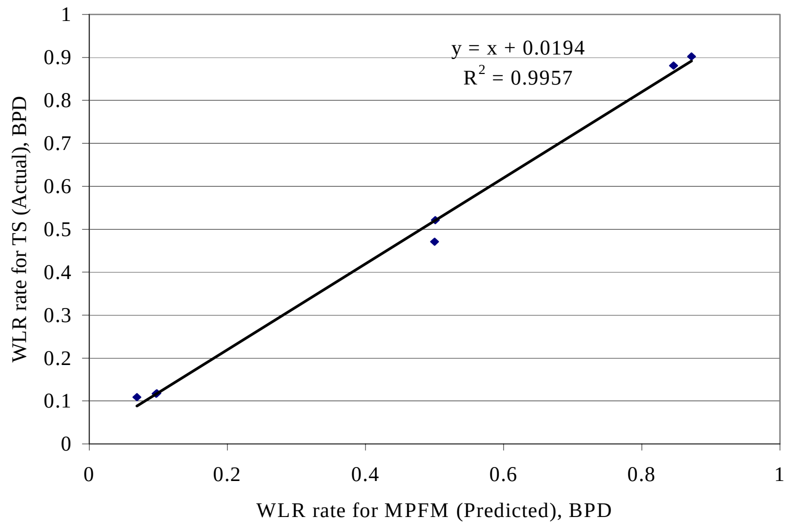

Figure 6. Cross plot of WLR for test separator versus WLR rate for MPFM

Descriptive Statistics for Gas Rate

Table 9a. Descriptive Statistics

Regression Statistics	
R Square	0.996
Standard Errors	0.025
Observations	7

Table 9b. Descriptive Statistics

	Coefficients	Standard Error	t Stat	P-Value	Lower 95%	Upper 95%
Intercept	0.019	0.016	1.24	0.27	-0.021	0.06
X Variable	1.00	0.029	34.18	4.03E-07	0.92	1.07

Interpretation of Charts

The plots in Figures 2 – 6 can be used to predict what the rate (oil, gas, water, liquid or WLR) of a MPFM will be if that of test separator is known.

For example, if the oil rate for test separator is 2000BPD, then the predicted value of MPFM will 2200BPD. Also, if the gas rate for test separator is 1000ACFD, the predicted MPFM rate will be 800ACFD. The closer the value of R^2 is to unity (1), the better. For rates that fall outside those presented in the charts above, the corresponding correlations can be used to determine the predicted values. That is if the value of test separator is know, make substitution into the appropriate equation to get the corresponding value of MPFM. For example, if the test separator rate for liquid is 10,000BPD, it will be better to substitue into the liquid rate equation to obtain the value for MPFM. Doing this, we will get 10254BPD.

The equations, R^2 and P values are summarised below:

Table 10. Equations and R^2 values for different rates

S/No.	Description	Equation	R^2 Value	P-Value
1	Oil rate	y = 0.9775x – 43.388	0.9969	0.412
2	Water rate	y = 0.9958x + 56.899	0.9991	0.087
3	Liquid rate	y = 0.969x + 64.169	0.999	0.233
4	Gas rate	y = 0.9429x + 2438.4	0.9974	0.0214
5	WLR rate	y = x + 0.0194	0.9957	0.269

Conclusions

This study has been able to show that the MPFM accuracy compare favourable with that of test separators. Hence, due to the economic benefits and the dependability of its accuracy, it is important to spread the expertise in MPFM through the oil industry. Both field and laboratory testing should be conducted to determine meter accuracy for added confidence.

Also, the correction charts developed in this study are useful tools for predicting the values of MPFM fluid flow rates when the flow rates of test separators are known. However, the charts are limited to the ranges shown on them. For fluid flow rates outside those obtainable on the charts, the equations developed are recommended for use.

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