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Field Experience and Performance of Wet Gas Meter

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ABSTRACT

A trial and comparison test was conducted for the wet gas meter with a separator at Qinghai Sebei gas field, located in the Northwest China in July 2008.

After the on-site calibration with well fluids, the wet gas meter provided continuous test data for three months. The comparison test result with the fixed separator showed that the wet gas meter gave an accuracy that was better than ±2% on the gas flow rate. This was an affirmation of the fact that wet gas meter measurements are increasingly gaining wide acceptance to replace expensive test separators and related infrastructure in gas/condensate field development.

Besides the significant cost savings, the availability of real time data for each well's production allowed for enhanced reservoir management and production optimization. The experience of the comparison test with separator showed that successful implementation of wet gas measurement technology requires adequate attention on each aspect of the metering process.

1 INTRODUCTION

There has been considerable focus in recent years on the development of new flow metering techniques for application in surface well testing and flow measurement allocation in multi-phase flow conditions, without separating the individual phases. Significant cost savings, related to production test of gas/condensate wells, can be realized if conventional test separators and related infrastructure are replaced by wet gas meters which are inline compact facilities that mainly consist of a venturi and a single gamma sensor.

Before this trial of the wet gas meter on gas wells in Sebei gas field in China, the vendor had conducted a successful validation on its multiphase flow meter performance at extreme high GVF (up to 99%) with high line pressure (around 3.5Mpa) condition on oil wells in Oman in early 2008 [1].

The wet gas meter is developed and designed according to the vendor's own technology and based on years of rich field experience in metering of three-phase fluids. In this sense, this trial meter was a custom-built meter for two phases (liquid/gas) testing, based on Sebei Gas-field current production and operation situation. This kind of wet gas meter has characteristics of small size, light weight and cost–effectiveness. As per different needs of end users, it can be installed at the wellhead or in the test line, monitoring the production of a single well, 24-hours in real time, without any disturbance or destruction to the pipeline's flow pattern. It also can allow the client to have remote control and data transfer through connection to the RTU.

Currently the conventional separators are deployed to measure the gas production in Sebei gas field. The configuration of the current metering is expensive, the size is big, and customer cannot achieve the on-line monitoring, because human intervention is required whenever the measurement is needed. To enter the "Digital Age" of the oil & gas fields, a better solution was needed to efficiently measure the field production in term of on-line monitoring, accuracy and cost-reduction. Based on its long established, international reputation of being a leader in the field of multiphase flow metering; the vendor was chosen to provide a customized wet gas meter for measurement in the field. Weeks long comparison tests were conducted in two wells from July to August 2008, to evaluate the performance of the wet gas meter. This paper describes the trial by introducing the customized wet gas solution first, followed by the field trials experience. The comparison test and analysis will be explained in detail as well.

2 SOLUTION FOR THE WET GAS MEASUREMENT

2.1 Metering Principle

The output of SeBai gas wells consists of mainly natural gas with tiny amount of water. It is considered as two phase flow. The customized wet gas flow meter for such type of flow is shown in Figure 1.

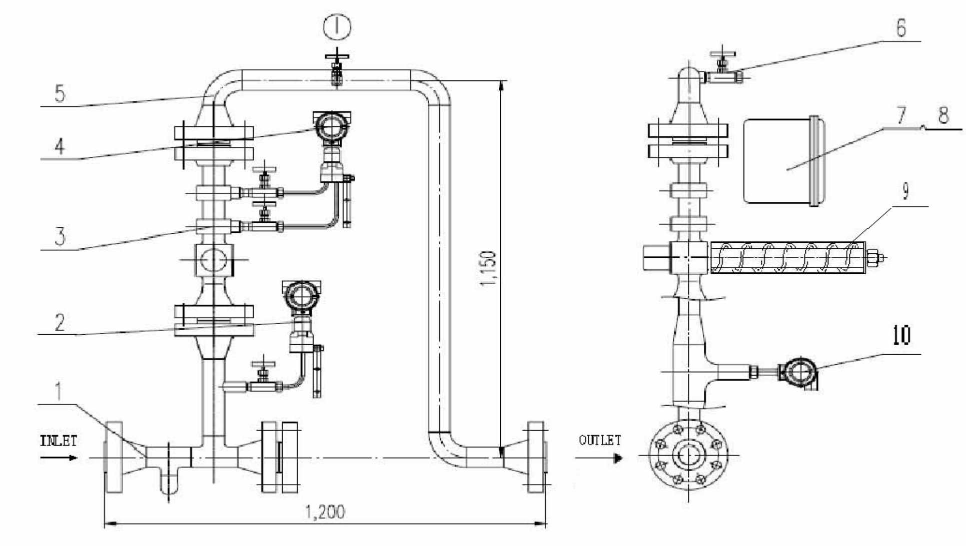

Figure 1 - Sketch of Wet Gas Meter

1: Inlet Blind Tee
2: Pressure Transmitter (PT)
3: Venturi + Single Gamma Sensor
4: DP Transmitter
5: Outlet pipe
6: Exhaust valve
7: Junction Box (power converter board)
8: Junction Box (DAU)
9: Temperature stabilization housing (TSH)
10: Temperature Transmitter (TT)

The wet gas meter can be installed either on the well head or any other connection on the production line. It is of a compact size, and light in weight. The test flow comes into the inlet blind Tee, where it will then be converted to vertical flow - the Venturi measures the total flow rate (Qtotal) and the single gamma sensor measures the Gas Void Fraction (GVF, or also known as gas holdup). The inline pressure transmitter (PT) and temperature transmitter (TT) are used to record the temperature / pressure data, which is needed to convert the flow rates from line conditions to standard conditions. The online Data Acquisition Unit (DAU) is used to access the measurement data and calculates the final results in real time. The DAU can be connected to a remote network so that the real time data monitoring can be achieved. After the original data Qtotal and GVF are measured from the meter, the final gas flow rate is obtained as:

$$Q_g = Q_{total} * GVF \quad (1)$$

Water flow rate is obtained as:

$$Q_w = Q_{total} * (1 - GVF) \quad (2)$$

The working principle for the meter is quite simple, and by using the wet gas meter, it can not only reduce the human error (that the conventional separator can't avoid), but also the accuracy and efficiency for measuring the gas well production can be improved dramatically.

2.2 Operating Envelope

Water flow range: 0 ~ 50 m3/d
Gas flow range: 2 ~ 14 x 10000 Nm3/d (different gas rate with different line pressure)
GVF range: 80 ~ 100%

2.3 Working Specifications

Skid size: 1.2 m x 0.9m x 1.5m
Weight: 200 kg
Design pressure: 20 Mpa; Operating pressure: 10 ~ 18 Mpa
Design temperature: -35 ~ 100 deg C; Operating temperature: 0 ~ 80 deg C

2.4 Uncertainties

Table 1 - Wet Gas Meter Measurement Uncertainties

Uncertainties	Liquid Rate	±10% @ GVF<99%
		±10m3/d @ GVF>99%
	Gas rate	5%
Repeatability	Total Flow	5%
	Gas rate	2%

3 FIELD INFORMATION AND TRIAL TEST SETUP

3.1 Field Information

SeBei gas wells of Qinghai oil field are located in the Qaidam Basin. The output of the wells is predominantly natural gas along with little bit of water and sand. The natural gas mainly consists of CH_4 at average 98.73% as listed in table 2. It's Specific Gravity (S.G) is around 0.56, and is pretty stable. The produced water is with type $CaCl_2$, and the average density is 1.134g/cm^3 as listed by table 3.

Below is some basic information for the wells:

* Operating pressure: 10~15 Mpa
* Operating temperature: around 30 deg C
* GVF level: up to 99.9%

Table 2 Properties and Components of Natural Gas

Gas layer	quantity of samples	S.G	Component analysis (%)				Pseudo critical temperature (K)	Pseudo critical Pressure (Mpa)	Pseudo Temperature ratio	Pseudo pressure ratio	Deviation factor
			CH_4	C_2H_6	C_3H_8	N_2					
0	1	0.56	98.53	0.04		1.43	192.40	4.42	1.62	2.38	0.87
1	6	0.56	98.37	0.05	0.01	1.57	192.52	4.41	1.66	2.84	0.86
2	7	0.56	98.73	0.07	0.02	1.18	191.60	4.51	1.72	3.55	0.86
3	8	0.56	98.91	0.09	0.02	0.98	191.12	4.58	1.75	3.88	0.87
4	5	0.55	98.85	0.05	0.04	1.06	190.78	4.58	1.78	4.40	0.89
Average	27	0.56	98.73	0.05	0.02	1.20	191.54	4.52	1.72	3.60	0.87

Table 3 Analysis of Produced Water

Gas layer	No. of samples	Produced Water Analysis										
		water type	PH	positive ion（mg/L ）			negative ion（mg/L）			total mineralized （mg/L ）		produced water density (g/cm3）
				K+Na	Mg	Ca	CL	SO4	HCO3	Before correction	After correction	
1	7	CaCl2	5.7	59064	1927	3623	224995	543	688	167747	165357	1.130
2	2	CaCl2	5.0	53231	1418	3692	92079	421	602	151441	150343	1.116
3	6	CaCl2	6.0	68515	2153	3987	108957	246	1449	198963	187893	1.144
Average	15	CaCl2	5.7	62066	1949	3778	160858	408	981	178059	172369	1.134

3.2 Test Setup

The wet gas meter was directly hooked up at the wellhead for the test purpose and its power supply was by a solar panel system, generating +36V DC, as shown in Figure 2.

Figure 2 - Wet Gas Meter Setup in the testing site

A separator is installed at the station, in series with wet gas meter at wellhead, and at some distance from wellhead. The comparison tests were conducted simultaneously to validate the performance of wet gas meter. As shown in Figure 3, the output flow from the well is sent to a big separator tank to separate gas from water (marked as 1), and then the separated gas rate is measured by either a orifice before 2008, or by a FL600-1P single ultrasonic from Germany after 2008 (marked as 3), the separated water with sand is measured by Magnetic Liquid Level meter (marked as 2).

The specifications of separator are:

* Design pressure: 6.8Mpa
* Working pressure：6.15Mpa
* Dimension：3.18m3

Figure 3 - Conventional Test Setup at the SeBai gas well

1. Separator 2. Liquid Level Reader 3. Ultrasonic flow meter

The specifications for the single ultrasonic meter are:

* Nominal pressure: 5.0-6.0 Mpa
* Flow range: 550-5000 Nm3/h
* Measurement uncertainties: ±0.5% to ±3%

4 KEY ASPECTS ON PERFORMANCE AND COMPARISON TEST

4.1 Analysis

Some potential aspects impact the performance of wet gas flow meter. These include fluid properties, natural gas compressibility factor, stabilization of single gamma ray counts and quality of the calibration of gas at line condition.

As the gas wells are predominated with gas under high GVF and high operating pressure conditions, the gas density is a key factor to the flow measurements [1]. Hence updtaed and correct gas densities must be available during the test.

High operating pressure makes natural gas compressibility factor very important to gas flow rate conversion from line condition to standard condition, hence in-line PVT models are embedded in the software of the wet gas meter. Online calibration of natural gas is also crucial to test performance under high GVF / high pressure conditions especially for liquid flow rate measurements.

4.2 Temperature Compensation Factor

Accurate GVF is crucial for the accuracy of flow rates measurement, especially for the liquid, and GVF is the direct outcome of single gamma ray count rates. At extremely high GVF situation, the measurements of flow rate are very sensitive to the GVF accuracy. For wet gas meter, gamma ray count rates are measured by a gamma detector whose performance may be affected by its working temperature.

The hardware solution was provided to use a TSH (temperature stabilization housing) to keep the detector away from the influence of working temperature. However the TSH of the Wet Gas Meter could not be applied unfortunately at site, due to solar power system supply available being +36V DC, which was too high as compared to the +24V required by TSH, and TSH had been auto self-protected. The wet gas meter however, had a backup software solution, and this was how the Na, temperature compensation factor, was used as a replacement of the function of TSH.

The basic theory of temperature compensation factor is to compensate the temperature effect on the detector then realize the stable gamma ray counts, away from the influence of the detector's working temperature.

Figure 4 shows the flow rates of the wet gas meter before and after this factor application. DP is differential pressure from Venturi.

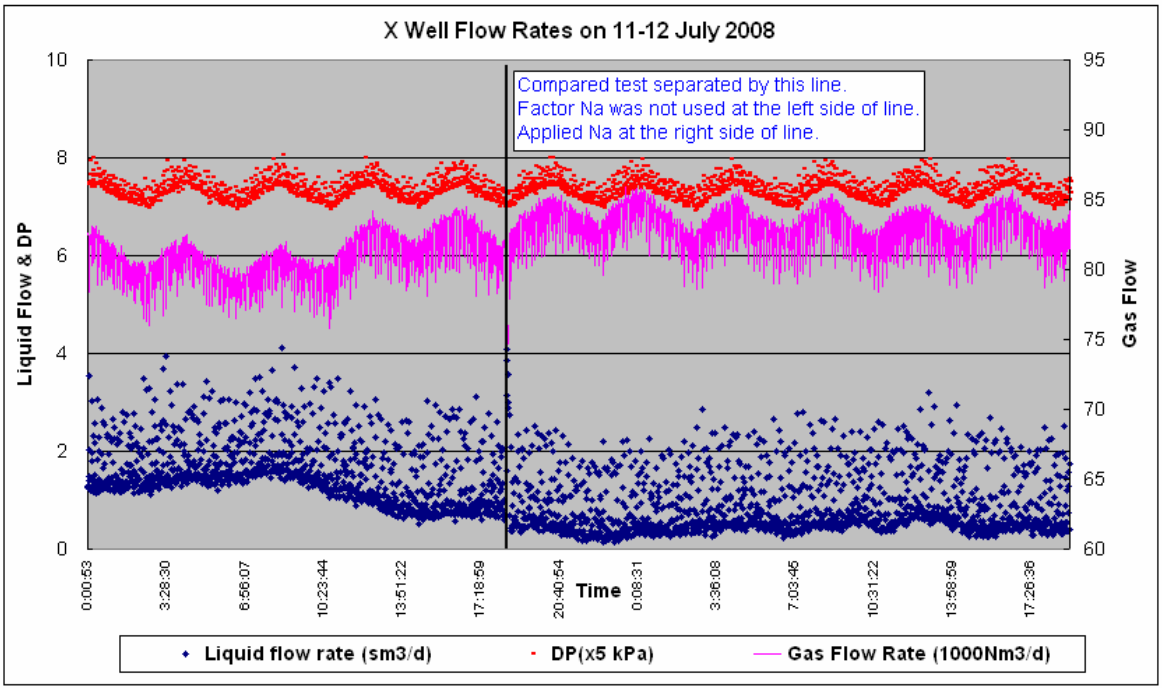

Figure 4 - X well flow rate on 11-12 July 2008

After the temperature compensation factor Na is applied to software the flow rates of liquid and gas become much more stable and exact, and the change of flow rates is an echo of change of DP readings.

4.3 Typical Minute Flow Rates Of Wet Gas Meter

Figure 5 shows the typical minute data of flow rates which was measured by the wet gas meter on well Y. It's very clear that the wet gas meter is a 24 hours real time testing facility. It can respond to any change of the well in one minute. In figure 4 and 5 the change of flow rates is an echo of change of DP readings.

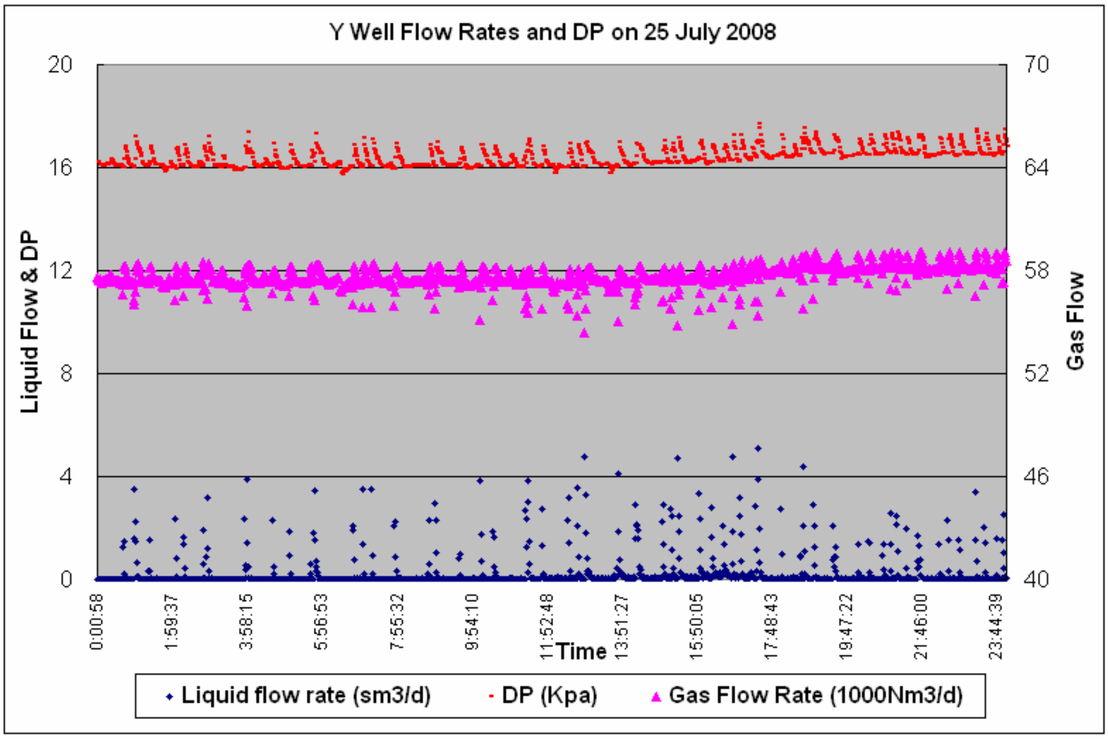

Figure 5 - Y well minute data of flow rates and DP

4.4 Comparison Test

Comparison Test of well X

Two gas wells X and Y were chosen for the trial tests. The trial for well X was three days period from 17th July to 19th July, 2008. The tests were started simultaneously at wet gas meter and separator when the flow was stable from the well head. The data was recorded in both test units every hour, totally 24 sets of data were recorded every day, the total production of every day was summed up from both the wet gas meter and separator, and the results are as summarized in table 4 below.

Table 4 Comparison test results of well X

Test Date	Temperature	Pressure	Wet Gas Meter		Separator		Gas Error	Water Error
	(ºC)	(MPa)	Gas Rate	Water Rate	Gas Rate	Water Rate	Err(%)	Err(%)
			(Nm3/d)					
2008-7-17	28.07	13.87	78977	1.04	78954	---	0.03	---
2008-7-18	28.27	13.87	80210	1.07	79203	---	1.27	---
2008-7-19	28.51	13.87	81574	1.08	81591	---	-0.02	---
Remarks	No water flow rates of separator were recorded by separator operator, so error of water rate cannot be given in the table.							

For each day, the hourly gas rate were also recorded and compared between wet gas meter and the separator as shown in Fig 6~8.

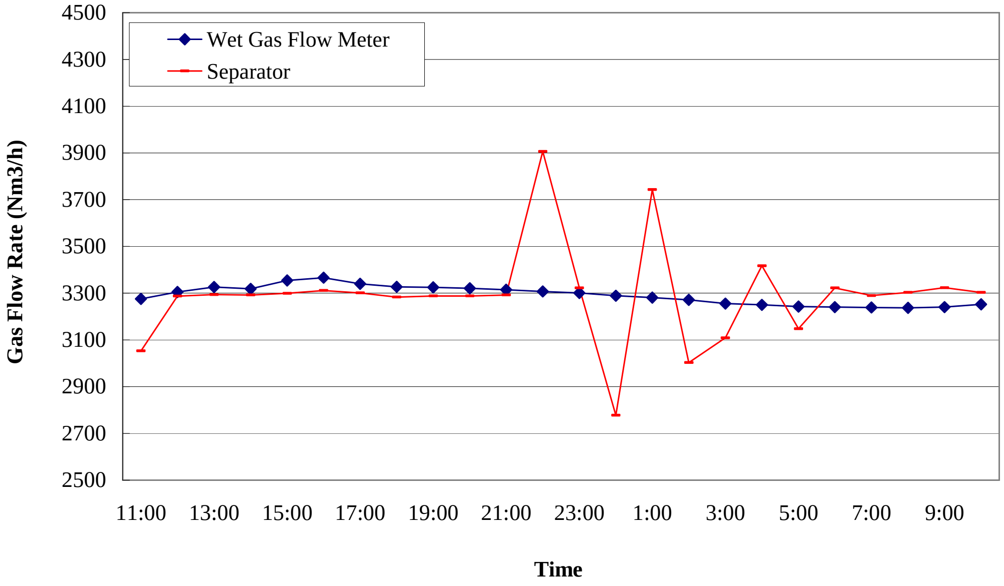

Figure 6. Hourly gas rate comparison on 17th July, 2008 for Well X

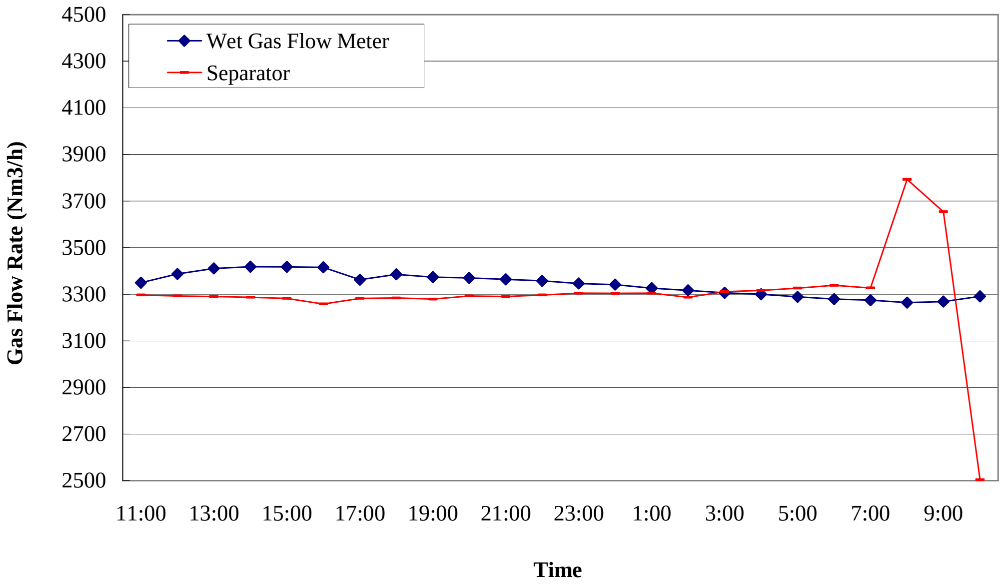

Figure 7. Hourly gas rate comparison on 18th July, 2008 for Well X

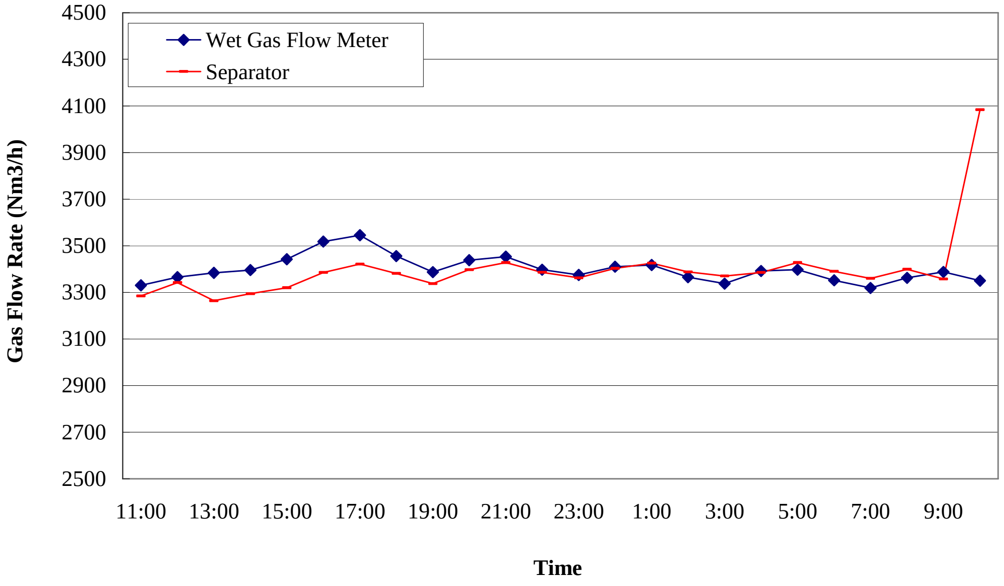

Figure 8. Hourly gas rate comparison on 19th July,2008 for Well X

From data comparison, either hourly or daily (figure 9), it can be concluded that the wet gas meter data matched very well with the data from separator. The performance is well beyond acceptance. In the mean time, from the hourly data diagram, it can be seen that the meter has more stability than the separator. The accumulated 24 hours production error of the gas rate from meter is 0.03%, 1.27%, and -0.02% compared to the reference values from the separator.

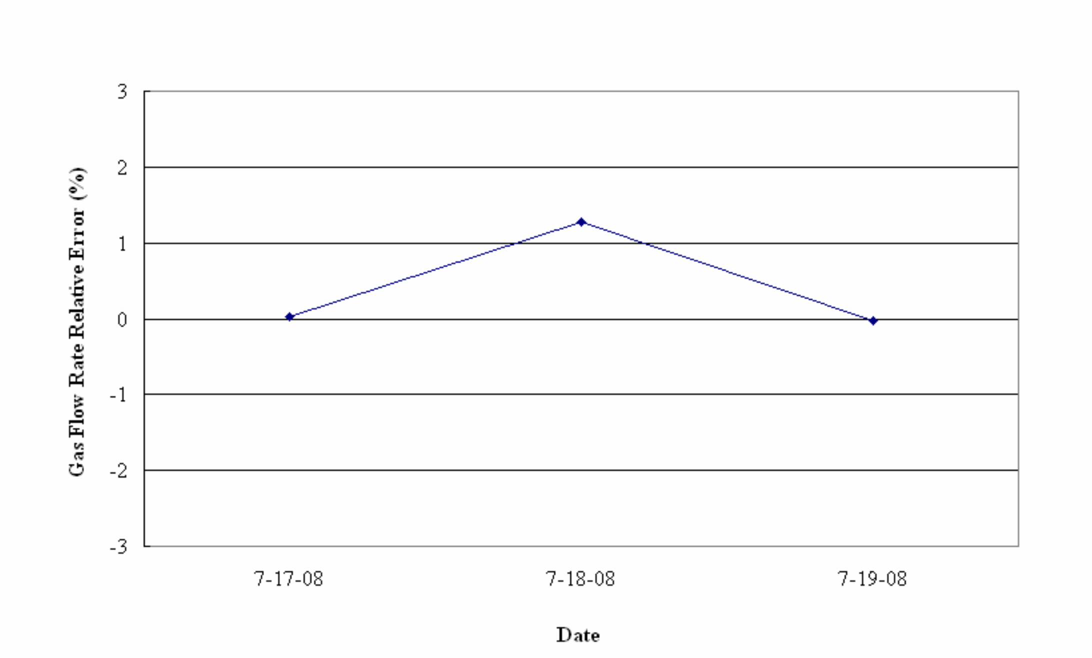

Figure 9 - Daily Tested Gas Rate Error between Meter and Separator for Well X

Comparison Test of well Y

After the three days testing on well X, the trial testing is moved to well Y for another five days. The same test strategy was used, the 24 hours tests at both wet gas meter and separator were conducted simultaneously; the test data was recorded every hour. Table 3 lists the 24 hours total production comparison between the meter and separator in five days.

Table 5 Comparison test results of well Y

Test Date	Temp	Pressure	Wet Gas Meter		Separator		Gas Error	Water Error
	(ºC)	(MPa)	Gas rate	Water rate	Gas rate	Water rate	Err	Err
			(Nm3/d)	(m3/d)	(Nm3/d)	(m3/d)	(%)	(%)
2008-7-27	24.42	14.32	57746	0.29	58841	---	-1.86	---
2008-7-28	24.22	14.32	57430	0.30	58081	---	-1.12	---
2008-7-29	24.30	14.32	57476	0.31	58364	---	-1.52	---
2008-7-30	23.67	14.32	57388	0.19	58634	---	-2.13	---
2008-7-31	23.79	14.31	57823	0.23	58407	0.64	-1.00	---
2008-8-1	24.17	14.40	58192	0.26	57408	---	1.37	---
Remarks	The Water rate was only recorded once, it was at 09:00 on 31st of Jul, water rate was 0.64m3/d, but it was not known from which day the water rate was counted, so error of water cannot be calculated							

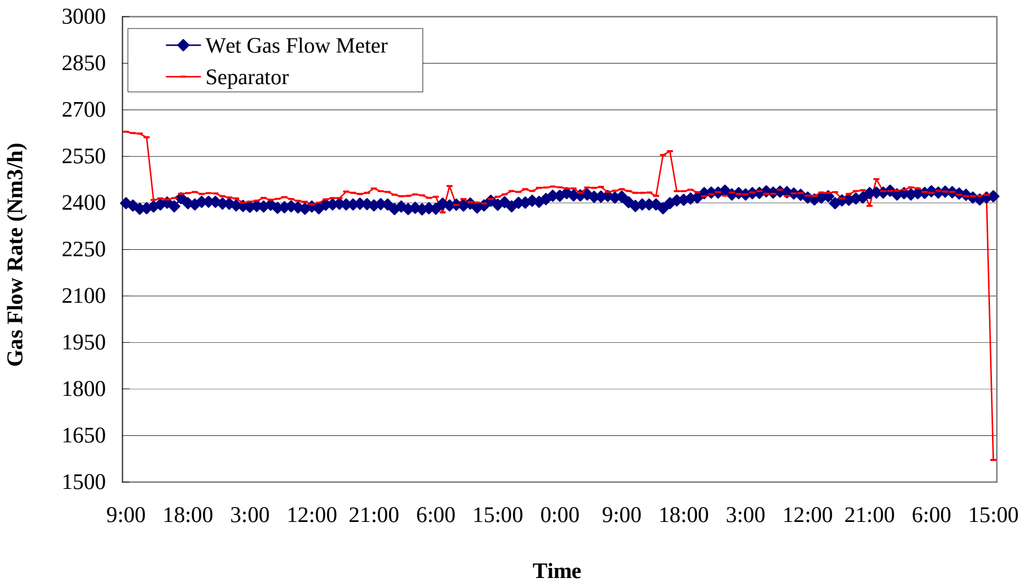

Figure 10 - The hourly gas rate comparison for well Y for 5 days.

The hourly data comparison between wet gas meter and separator for five days is also plotted in figure 10. The wet gas meter hourly test data matches the data from separator quite well, except for a few hours.

The daily measured gas flow error between the meter and separator for the 5 day period is also as shown in figure 11. The error is within +-2% tolerance band.

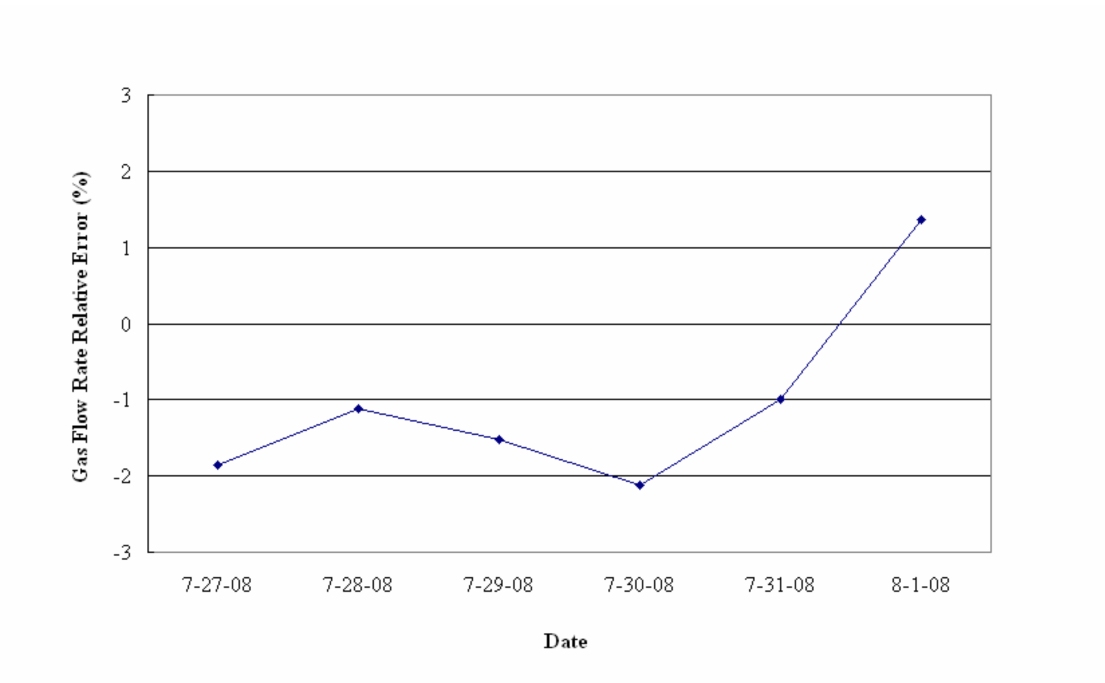

Figure 11 Well Y Daily Tested Gas Rate Error between Meter and Separator

5 Conclusion

Total eight days comparison test was conducted in the Sebei gas field, over 2 well sites, to evaluate the wet gas meter performance for the gas wells. The test strategy was designed jointly by the vendor and field experts to collect hourly data simultaneously with wet gas meter and validation reference tool – separator, under the similar working condition.

Single gamma ray counts stability has an impact on MPFM measurement especially with extreme high GVF and high pressure condition. Temperature compensation factor Na also proved to be an effective solution, when Temperature Stabilization Housing application is not available.

The test configuration guarantees the validity for hourly compared data set. Hourly data for each tested gas well was collected and they matched well between the wet gas meter and separator, and accumulated 24 hour data was also summed up and error was calculated between them. It was within the desired uncertainty range, and better than ±2%. The trial convinced the end users of the wet gas meter performance and that it is an accurate, new generation measurement tool for gas fields.

Compared to the conventional separator, the meter also has a lighter weight, smaller size, and more importantly less cost. It has thus obvious advantages over the conventional separator. By connecting to the remote site; the meter can achieve monitoring of the well production round the clock without human intervention. It will dramatically improve the production efficiency in the gas fields, once deployed in more numbers.

6 NOTATIONS

Notation has been used in the paper as follows:

PT	Pressure Transmitter	DAU	Data Acquisition Unit
TT	Temperature Transmitter	Qtotal	Total flow rate
DP	Differential Pressure Transmitter	Qg	Gas flow rate

Qw	Water flow rate
S.G	Specific Gravity
GVF	Gas Void Fraction
Na	Temperature Compensation Factor
TSH	Temperature Stabilization Housing
RTU	Remote Terminal Unit

7 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