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New Development in Water Cut Meter with Salinity Compensation

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Abstract

Salinity variation partly causes the inaccuracy of water cut measurement that leads failure to optimize wells production within the capacity constrains of production facilities. In this paper, salinity compensation method is introduced using Gamma-ray absorption technology, as well as Haimo FM2000SC Water Cut meter, which have the built-in Gamma-Ray salinity compensation capability. Test has been conducted on Haimo FM2000SC to determine salinity contents. The compensation is realized by analysis the received radiation count with the different saline water, and obtaining the coefficient value between these two factors. Testing shows that Haimo water cut meter can achieve accuracy of water cut measurement ± 2.0% absolute with 85% confidence factor.

Definitions

PDO: Petroleum Development Oman

WC: Water Cut. This is defined as ratio of the volume flow rate of water and the total liquid volume flow rate, both volume flow rates should be converted to the same pressure and temperature (generally at the standard conditions). It is generally expressed in a percentage.

1. Introduction

During the late 80's the oil and gas industry started to realize that the availability of accurate well testing meters could have a larger economic impact on the infrastructure of oil and gas developments. This has driven the development of high accuracy high water cut in oil industry. Various research projects has been initiated sine the late 80's and the early 90's, both in-house with the oil companies and through Joint Industry Programs (JIP's).

Worldwide the application of high accuracy high water cut meters is growing. The water cut meters are being applied in two-phase oil / water flow in combination with flow meter to measure the individual oil and water flow rate. They can be installed either as downstream the two-phase separator in the case of three-phase oil / water / gas flow or in the well head in the case of two-phase oil / water flow.

In the last ten years a lot of development has taken place, and at present a degree of maturity is emerging in applied techniques and fabrication of water cut meters by a variety of manufacturers. Still a substantial amount of development and improvement is required, especially in the field of improving accuracy levels over the high water cut range.

A study from PDO has showed that the reconciliation factor of some of its fields was deteriorating since 1999 and at the end of year 2000 the asset reconciliation factor had dropped to 0.775. The suggested possible cause of this deterioration was the increase of uncertainty in net oil calculation as a result of inaccuracy in water cut measurement. This has been identified partly due to salinity variation.

Inaccurate water cut measurements fails to optimize wells production within the capacity constrains of production facilities. As such, PDO has been on the lookout for a solution for water cut meter which has salinity compensation in-built, considering the high number of wells with high salinity variations. Salinity in water increases the density proportionally. Gamma-Ray absorption technology can be used to obtain the water density. In the Gamma absorption method, the absorption varies proportional to the density. The count rate of radiation received after absorption keeps decreasing with salinity increasing in the solution. When salinity effect is ignored, the instrument is calibrated based on densities of oil and produced water and assume that the densities do not vary. There are only two phases in such a case. The calibration curve in the water cut meter is fixed based on the count rates received for the extremes of pure oil and produced water. However if the produced water density changes due to salinity, and if it is not compensated for, then the meter will show an output of more water than actually present, which causes additional errors in the net oil measurement. The salt or salinity effect hence should be considered as the third component.

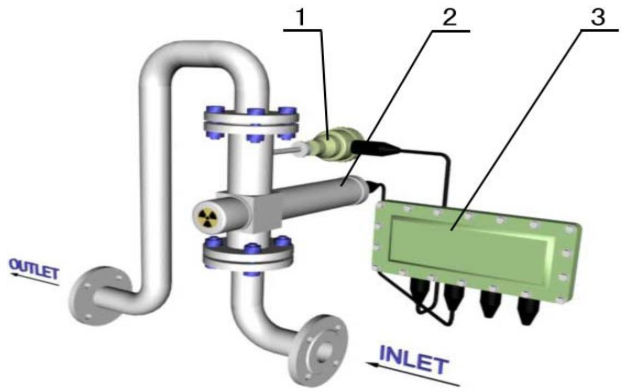
In order to compensate for the varying contents of salt in produced water, it is necessary to nullify the effects of salt in the solution. The tests are needed to establish the same and the accuracy results attainable with the compensation mechanism so that the salinity compensation can be derived.

Haimo FM2000SC water cut meter is the meter that does have the built-in salinity compensation functionality. It is based on the Gamma-Ray absorption principle. A test was conducted using the Haimo FM2000SC Water Cut Meter to evaluate the Gamma-Ray salinity compensation mechanism, and water cut measurement accuracy with the salinity compensation method ready. The test was performed using the dual energy gamma ray principle at Haimo Water Cut testing loop in Lanzhou, China from December 6^{th} to 13^{th}, 2001.

2. Haimo Water Cut

The Haimo FM 2000 Water Cut Meter utilizes dual energy gamma ray technology to determine the phase fractions such as water content and GVF in an oil/gas/water three phase mixture.

The meter consists of a Spool Piece through which the stream is conducted, a compound source, ^{241}Am+Ag, which generates 22 and 59.5 keV dual gamma rays and is directed through the spool piece, a NaI (Tl) Detector disposed for receiving the gamma rays after they pass through the spool piece, a built-in Temperature Sensor for real time temperature compensation, and a Data Acquisition Unit for collecting signals, computing and data communicating.



1. Integrated Temperature Transmitter
2. Dual Energy Gamma Sensor
3. Data Acquisition Unit

Fig. 1 Schematic of FM 2000 Three-phase Water Cut Meter

3. Gamma-Ray Salinity Compensation Method

Salinity in water increases the density proportionally. In the Gamma absorption method, the absorption varies proportional to the density. Bigger the water density, more absorption of Gamma-Ray which travels through the water, therefore less count rate of radiation received afterwards. By setting up the relationship between the salinity and radiation count, the density of the water can be identified, and thus the salinity contents in the water as well. The compensation factor can then be obtained and applied to the meter to correct the water/oil production measurement.

In order to compensate for the varying contents of salt in produced water, the accurate calibration is very important. Below is the calibration procedure that would be followed in the field while setting up the water cut meter. In the real calibration in the field, the following is done:

(Below figures in bold are count rates measured from the 2 sources or those that become known after calculations. Figures in italic are unknown that are calculated)

Fill up meter with oil to derive at oil coefficient

u_oil = ln(**n0/n_oil**)
U_oil = ln(**N0/N_oil**)

Fill up meter with dematerialized Water to derive at pure water coefficient

u_water = ln(**n0/n_water**)
U_water = ln(**N0/N_water**)

Fill up with produced water of known salt concentration / density

u_salty_water = ln(**n0/n_salty_water**)
U_salty_water = ln(**N0/N_salty_water**)

To derive the salt coefficient correction factor, subtract (2 from 3) and divide by the actual salt in the solution.

u_salt = (**u_salty_water - u_water**) / **Salinity**
U_salt = (**U_salty_water - U_water**) / **Salinity**

where,
n0: count rate of gamma ray before absorption, measured with the empty pipe
n: count rate of gamma ray after absorption, measured during the flow
u_oil: absorption coefficient of oil, derived by filling with 100% oil
u_water: absorption coefficient of water, derived by filling with 100% water
u_salt: absorption coefficient of salt; to be calculated based on results from the absorption rates for known salinity levels in dematerialized water

(......N & U for high energy)

Taking the salinity into account, there will be two variables - water cut and salinity, therefore two different gamma ray energy levels are used, something like "three phase" condition. The formula used is as follows, similar to that used for three-phase water cut meter.

Low energy equation: ln(**n0/n**) = **u_oil** x (1-*WC*) + **u_water** x *WC* + **u_salt** x *Salinity* x *WC*
High energy equation: ln(**N0/N**) = **U_oil** x (1-*WC*) + **U_water** x *WC* + **U_salt** x *Salinity* x *WC*

There are two unknowns in the above two equations namely Salinity and WC, which can be solved. In the above procedure, the Absorption coefficient of Salt will be worked out using one saline water reference solution, apart from dematerialized water.

The chosen points really cover most of the salinity cases that happen in PDO. For example, the salinity in the Saih Rawl and Musallim fields are about 150 -200 kg/m3 approx. 100,000 ppm is 10%, which is 10% salt in 100% water => about 100 kg/m3 salt in water. The salinity is varied up to 200 kg/m3.

4. Test Description

4.1 Description of the Haimo Test facility

Name: Haimo Water Cut Testing Loop
Location: Haimo Technologies Co. Ltd., Lanzhou, China

Pipeline size: DN50
Operating pressure: 200 - 500 KPa
Max. fluid temperature: 80 °C
Volume: 8700ml
Test Fluids:
Oil phase - Diesel oil
Water phase – Water with salinity variation
Accuracy: Water cut : ± 0.5% abs.
Range ability: Water cut: 0 – 100%

4.2 Haimo water cut meter used in the testing

The Haimo FM2000SC Water Cut Meter utilizes dual energy gamma ray technology to determine the phase fractions such as water content with salinity variation.

A 2" new Haimo FM2000SC Water Cut Meter was installed for performance testing at the above mentioned Haimo Water Cut Testing Loop

The specifications of the Haimo Water Cut Meter used during the test was as follow:

Measurement range: 0 ~ 100% water cut
Salinity variation: 0 ~ 200,000ppm
Accuracy: ±2.0% abs (85 % confidence level)

4.3 Test Matrix

Range:
Water cut: 25 ~ 100%
Salinity variation: 0 ~ 200,000ppm

The test matrix was as follow (table 1):

Salinity Water cut	0 ppm	30,000 ppm	50,000 ppm	100,000 ppm	150,000 ppm	200,000 ppm
100%	×	×	×	×	×	×
~75%	×	×	×	×	×	×
~50%	×	×	×	×	×	×
~25%	×	×	×	×	×	×

Table 1. Test matrix followed during the test

Total test points: 24
Test duration for each point: 30 min.

4.4 Test method

The Haimo Water Cut Meter was mounted on water cut testing section the Testing Loop downstream. Before the testing, the Haimo Water Cut Meter was calibrated and configured with the three individual fluid phases, which are fresh water, diesel oil and salty water (salinity is

200,000ppm). The procedure for calibration is used to measure the count rate from the gamma ray sources with the gamma meter empty before any fluid is passed through them. All the internal surfaces were kept clean before the test, then the count rates were measured while the meter was filled with fresh water, diesel oil and salty water separately. This calibration has to be conducted at the beginning of the tests, and once for all.

Then the actual testing was carried out with varying levels of water cut and salinity in the testing loop. The testes were carried out with 5 kinds of salty water with different salinity levels, one after the other. The levels were 30,000ppm, 50,000ppm, 100,000ppm, 150,000ppm and 200,000ppm. More than 13-kg salt was used in testing. For each test point, one of salty water above mentioned and diesel oil as testing liquids are selected, which first measured by the reference liquid measurements respectively, then filled into the test loop for the testing.

Each test point was measured for 20 minutes. There is a stability time for about 10 minutes after each test point so that the flow condition could reach a new level.

5. Test Results

5.1 Results of salinity Compensation

The results of the salinity compensation is shown on table 2.

5.2 Summary of results

- 13 out of the tested 23 points were within ± 1.0% accuracy
- 15 out of the tested 23 points were within ± 1.5% accuracy
- 20 out of the tested 23 points were within± 2.0% accuracy
- All 23 points were within ±2.5% accuracy

6. Conclusions

The test was conducted from 25 to 100% water cut and the salinity was varied from 0 to 200,000ppm. 13 out of the tested 23 points were within ± 1.0% accuracy. 15 out of the tested 23 points were within ±1.5% accuracy. 20 out of the tested 23 points were within ± 2.0% accuracy. All 23 points were within ± 2.5% accuracy. The tests have proved the applicability and accuracy of Gamma-Ray salinity compensation method deployed in water cut measurement. The Haimo water cut meter using this method of compensation can achieve accuracy of water cut measurement as ±2.0% absolute with 85% confidence factor.

Test points		Results of Test			
Water cut	Salinity (ppm)	Reference	Result	Density	Error
100	0	100	99.783	1.001	-0.217
	50,000	100	99.94	1.0495	-0.06
	100,000	100	101	1.098	1
	150,000	100	101.97	1.147	1.97
	200,000	100	99.65	1.196	-0.35
75	0	75	75.91	0.99	0.91
	30,000	75	74.26	1.02	-0.74
	50,000	75	74.7	1.045	-0.3
	100,000	74.86	74.26	1.103	-0.6
	150,000	74.78	73.37	1.149	-1.41
	200,000	75.42	73.49	1.196	-1.93
50	0	50	51.17	0.997	1.17
	30,000	50	49.71	1.029	-0.29
	50,000	50.3	49.72	1.05	-0.58
	100,000	51.21	49.71	1.103	-0.29
	150,000	49.79	49.18	1.149	-0.61
	200,000	49.67	47.16	1.196	-2.51
25	0	25.92	26.3	0.998	0.28
	30,000	25.5	23.27	1.029	-2.23
	50,000	25.44	26.9	1.036	1.54
	100,000	25	23.27	1.1	-1.73
	150,000	25.13	23.46	1.149	-1.67
	200,000	25.06	22.81	1.198	-2.25

Table 2. Results the salinity compensation test