SPE 84506

High-Water Cut: Experience and Assessment in PDO

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This paper was prepared for presentation at the SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A, 5-8 October 2003.

Abstract

A study from PDO indicated that the allocation and reconciliation factors of Nimr field had shown a deterioration trend since 1999. The suggested possible cause of this deterioration was the increase of net oil calculation uncertainty as water cuts approaches 80% and above. On the individual well basis, about 20% of all the wells produce at greater than 95% water cut but contribute to about 8% of production. The overall water cut of the Nimr asset is currently 87% and is forecast to increase to 90% over the next ten years causing further deterioration of the reconciliation factor.

Inaccurate water cut measurements causes failure to optimize wells production within the capacity constrains of production facilities. As such, PDO has been on the lookout for a solution for high accuracy water cut meter for the high water cut wells.

A market search was done in 2001 as the first phase of identifying the water cut meters that could be considered for Nimr application. The main criterion used in the market search was to list down those meters with quoted absolute error lower than +/- 0.5% as the water cut approaches 80% and above. Four meters were proposed for loop test i.e., Red Eye from Premier Instruments (USA), Phase Dynamics (USA), H2Oil from Honeywell (USA) and Haimo (China).

All the four vendors were invited to participate in the accuracy test. Phase Dynamics declined to participate, while the other three vendors accepted to participate in the proposed test.

The objective of the test was to evaluate the consistency of the quoted specifications and performance of the proposed water cut meters under a simulated field conditions with live crude, gas and water.

The test was carried out at the DOD Multiphase Flow Facility in Daqing Oilfield, Daqing City, China (DOD). The facility uses live crude coming directly from the Daqing oil wells. The test was carried out during the period of 22nd January to 26th January 2002. During the test, the Honeywell meter could not be operated due to problems with the hardware of the meter. Another test was then arranged to test the Honeywell meter separately during the period of 11th March to 13th March 2002 in the same facility.

During the test, the accuracy of the three meters were assessed for different water cut. The Red Eye meter proved to work with an accuracy of within +/- 1% absolute for water cut higher than 85% in oil/water flow. The meter exhibited large error (+/-2% absolute to +/-6% absolute) for water cut lower than 85% in oil/water flow. For three phase flow (GVF < 25%), the accuracy of the meter was +/-2% absolute for water cut higher than 85% and +/-8% absolute for water cut lower than 85%.

The Haimo meter has proved to work well within full operating range 0 to 100% water cut with an accuracy within +/-1.5% absolute for oil/water flow. For three phase flow (GVF < 25%), the accuracy of the meter was found to be within +/- 2% absolute.

The Honeywell meter has proved to work within accuracy of +/- 1.5% absolute for water cut higher than 70% and +/- 0.5% absolute for water cut less than 30%. In the transition region (WC from 30% to 70%), the accuracy of the meter was +/- 5% absolute. The test has also shown that the accuracy of the meter deteriorates when gas is applied to the flow.

Definitions

PDO: Petroleum Development Oman

DOD: Daqing Oilfield Construction in Daqing, China

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.

GVF: Gas Volume Fraction. It is defined as the ratio of gas volume flow rate and the total fluid (oil, water and gas) flow rate, both volume flow rates should be converted to the same pressure and temperature. It can be expressed as a fraction or 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 downstream the two-phase separator in the case of three-phase oil / water / gas flow or at 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 level for high water cut range.

Further inaccurate water cut measurements on wells will not help in optimizing production facilities within the capacity constrains. Thus the drive in PDO for a solution for water cut measurement which has a higher accuracy (+/- 0.5% absolute) at high water cut (above 85%). This would also give added benefits in terms of potential savings in capital expenditure.

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 (see figure 1) which the liquid stream flows, a compound radioactive 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 communication.

3. Honeywell Water Cut (H_2Oil Analyzer System)

The H_2Oil analyzer consists of three (3) components (see figure 2) that are integrated into a complete measurement solution.

1. **Sensor Assembly** that includes the measurement spool with electrodes and electronics enclosure

2. **Analyzer** that calculates the % water from the output signals of the sensor assembly, enables local operation and control functions, and provides output to SCADA systems.

3. **Calibration Chamber** and **Toolkit Software** – Consists of hardware and Windows-based software application for the H_2Oil Analyzer system calibration and configuration.

The **sensor assembly** consists of a **measurement spool** with electrodes and an integrated **electronics enclosure**. **Measurement spool** is an in-line flanged pipe section with electrodes embedded in the pipe which act as sensors to detect the fluid content passing through the spool. The measurement spool is available in 2, 3, 4, 6, and 8-inch line sizes equipped with ANSI flanges. A 3-wire RTD integrated in the spool provides temperature compensation for fluid measurement. A sampling port on the measurement spool provides access to the process fluid for calibration and lab verification purposes.

4. Premier (Red Eye) Water Cut

The Red Eye Water Cut Meter employs a technology based on the bulk transmission of infrared radiation through an oil-water mixture.

The Red Eye sensor interfaces with a microprocessor-based flow computer, which processes analog signals from the sensor. The computer can take pulse input from a flow meter to provide net oil and water volumes in a stand-alone operation. The computer also provides pulse output for oil and water, a 4-20 mA output for water cut, modbus communications, and two discrete outputs for alarm relays. The analog, discrete, and serial outputs give the user the flexibility of interfacing the Red Eye meter to network systems including remote terminal units (RTU) and supervisory control and data acquisition (SCADA) for remote operation.

The Red Eye Water Cut Meter uses the basic principle of spectroscopy, relying on the large difference in the absorption of near infra red radiation between crude oil and water. Differentiation is achieved by operating over a very narrow band of radiation with maximum intensity occurring at a wavelength where crude oil and water exhibit large differences in opacities. While this approach forfeits the ability to perform detailed compositional analysis, a water cut sensor need only distinguish between relative volumes of oil and water.

5. Description of the DOD Test facility

The DOD Multiphase Flow Facility is located in Daqing Oilfield, Daqing City, China. The facility was conceptually designed by *National Engineering laboratory*, Glasgow, UK and was approved by *China National Measurement Institute* and *China National Petroleum Corporation*.

The multiphase pipeline size is DN50, DN80 and DN100. The operating pressure is 200 – 500kPa. The Maximum fluid temperature is 80 degree C.

The test fluids used in DOD are as follows:

Oil phase - Crude oil from Daqing Oilfield. Water in oil less than 0.5%.
Gas phase - Natural gas from Daqing Oilfield. Liquid in gas less than 0.5%.
Water phase - Produced water from Daqing Oilfield. Oil in water less than 0.5%.

Crude Properties

Property	Unit	Value
Crude density	kg/m3 @ 15degree C	862.5
Dispersed water content	wt %	0.4
Viscosity	cSt at 45 degree C	25.34

Water Properties

Density of Water	kg/m3 @ 15degree C	1000
pH of Water	pH	7.88
OIW	ppm	167
Salinity	ppm	2192
Resistivity	mS.cm-1 25 degree	2.901

The capacity of the DOD facility is given below: -

Max. Liquid flow rates:	1200 m3/d
Max. Oil flow rates:	1200 m3/d
Max. Water flow rates:	1200 m3/d
Max. Gas flow rates:	28080 Sm3/d

The accuracy and repeatability of the DOD facility is given below: -

Description	Accuracy	Remarks
Oil phase:	+/- 1.0 % relative	PD meter
Gas phase:	+/- 1.5 % relative	Turbine meter
Water phase:	+/- 0.2 % relative	Electro Magnetic meter

The range-ability of the DOD facility is given below: -

GVF:	0 - 100 %
Water cut:	0 - 100 %

6. Testing Results

The test has focused on studying the absolute error of watercut measurement as the watercut approaches 80% and above. The expected absolute error was less than +/-0.5%. Accuracy of watercut measurement at watercut lower than 80% was also studied as supplement to this experiment.

The sensitivity test was limited to GVF and fluid flow rates. The rest of the sensitivity tests i.e. droplet size, salinity and pulsation flow could not be assessed because of limitations in the test facility.

All watercut meters proposed for the test were installed in series. This arrangement was to ensure that all the watercut meters are subjected to the same testing conditions. The Honeywell meter could not be assessed in the 1st test because of problems in the hardware, and thus it was tested separately.. The results of the test are shown in figures 5, 6 and 7. The duration for each test point was from 5 to 10 mins. The water cut (WC) measurements determined by the Haimo, Red Eye and Honeywell water cut meters were compared against the reference WC measurements. Note that the reference water cut measurement is calculated using the reference oil and water volumetric flow rates. (Water Cut is equal to water flow rate divided by the sum of the water flow rate and oil flow rate). The repeatability of the WC meters were also assessed.

7. Conclusions and Summary of Findings

Below is a summary of the findings of the water cut at DOD Multiphase flow facility in Daging, China

- The accuracy of Haimo meter was within +/- 1.5% absolute in oil/water flow for water cut 0 to 100% with a confidence level better than 90%. In oil/water/gas flow (GVF =< 25%), the accuracy was within +/- 2% absolute with a confidence level better than 90%.

- The accuracy of Red Eye meter was within +/- 1% absolute in oil/water flow for water cut 85 to 100% with a confidence level better than 90%. In oil/ water/gas flow (GVF =< 25%, the accuracy was within +/- 2% absolute with a confidence level better than 90%. The Red Eye meter exhibited large error (up to 20% absolute) at lower water cut. The Red Eye meter also exhibited large error at low flow rate (gross of 200m3/d). This was due to the flow not being properly mixed. It is therefore strongly recommended that this meter is always installed with a mixer upstream.

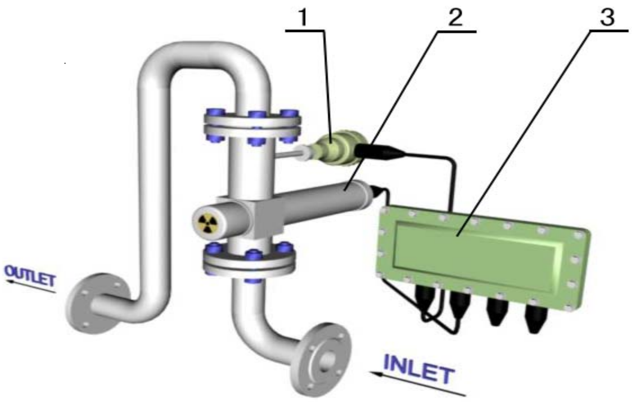
  The repeatability of the Red Eye and the Haimo meters was found to be within +/-2% absolute.

- The accuracy of Honeywell meter was within +/- 0.5% absolute in oil/water flow for water cut lower than 30% with a confidence level better than 90%. For water cut above 70%, the accuracy was within +/- 1.5% absolute with a confidence level better than 90%. During the transition region (WC from 30% to 70%), the error was within +/- 4% absolute. In oil/ water/gas flow (GVF =< 25%, the accuracy was within +/- 5% absolute with a confidence level better than 90%.

- The repeatability of the Honeywell meter was found to be within +/-0.5% absolute.

8. References

1. Albusaidi K. H and Bhaskaran H. 2002. New Development in Water Cut Meter with Salinity Compensation. SPE Asia Pacific Oil & Gas Conference and Exhibition (APOGCE), 2002, Melbourne, Australia



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

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

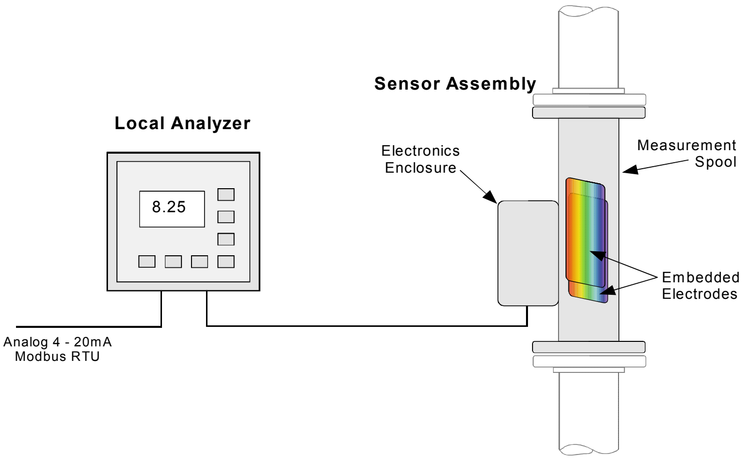


Fig. 2 Schematic of the Honeywell H2O Analyser

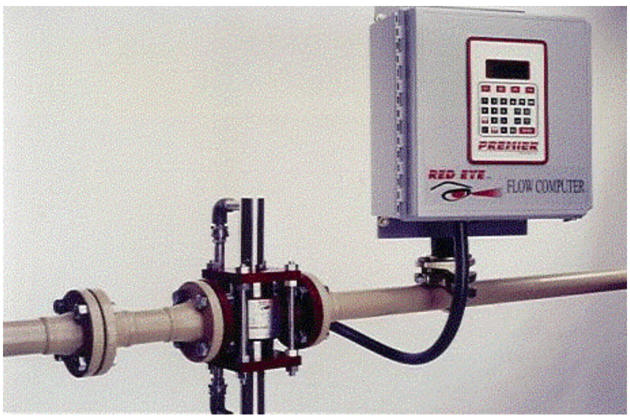


Fig. 3 Red Eye meter

Figure 4. Picture showing the three meters connected in series during the test (Date on the picture is incorrect because of wrong date setup in the camera)

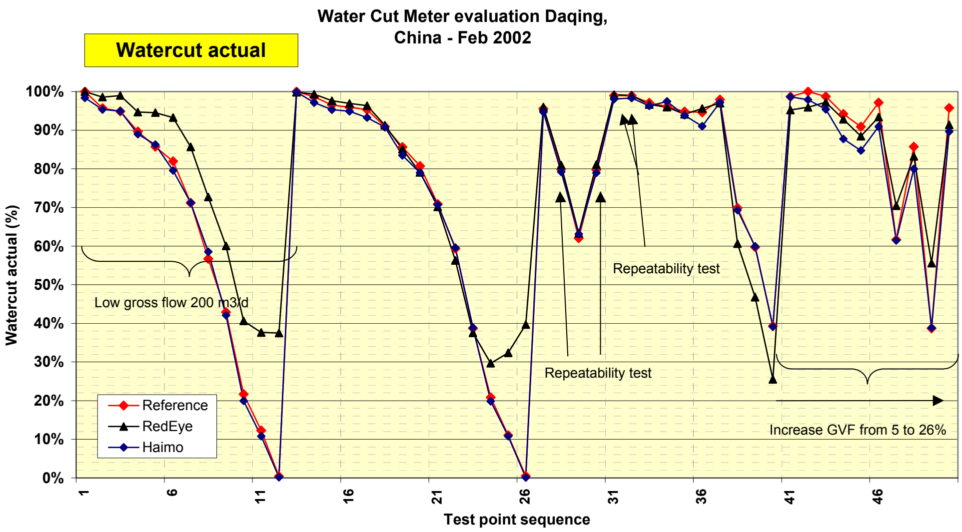


Figure 5. Test result

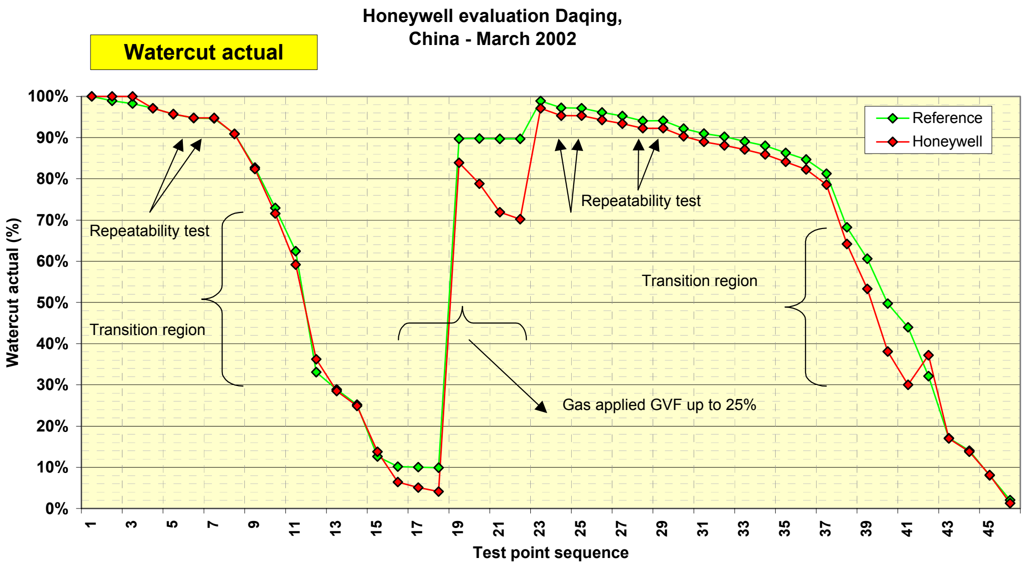


Figure 6. Test result

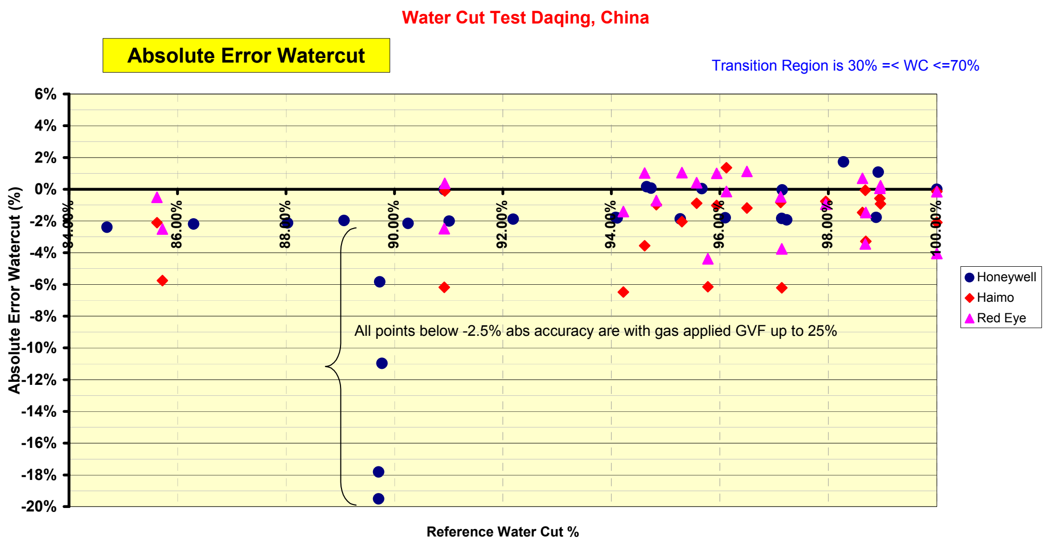


Figure 7. Test result