Global Flow Measurement Workshop
22 - 24 October 2024

Extended Abstract

Field testing and verification of Xsens flow and water cut Meter with PDO

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1 INTRODUCTION

Petroleum Development Oman (PDO) and Xsens Flow Solutions have carried out an extensive field test program with the aim of qualifying this new innovative clamp-on flow and water cut measurement technology for use in PDO`s operation in Oman. The technology tested is Ultrasonic measurement from the outside of the pipe, enabling both flow rate measurement and continuous water cut measurement (0-100% abs.).

The aim of the project was to field test and qualify the Xsens meter to measure each individual well stream for flow rate and water cut in applications with very low flowrates and high water cut.

This paper will present in detail how the Meter was installed, which references used and performance from such. Finally, the test meter was sent to TUV National Engineering Laboratory (NEL) in Scotland for verification of accuracy by testing at similar operational conditions as the PDO wells in Oman, with very low flow rate and high water cuts. This test was conducted as a blind test performed by PDO and was concluded in December 2023.

The paper will also discuss potential savings this technology can bring to fields similar to the one tested in Oman.

2 Introduction to flow and water cut meter under testing

The flow and water cut meter under testing was a multipath ultrasonic clamp on transit time flowmeter. The flowmeter was set up with 3 axial and 2 helical transducer pairs.

The setup of the flowmeter is showed in the figure below.

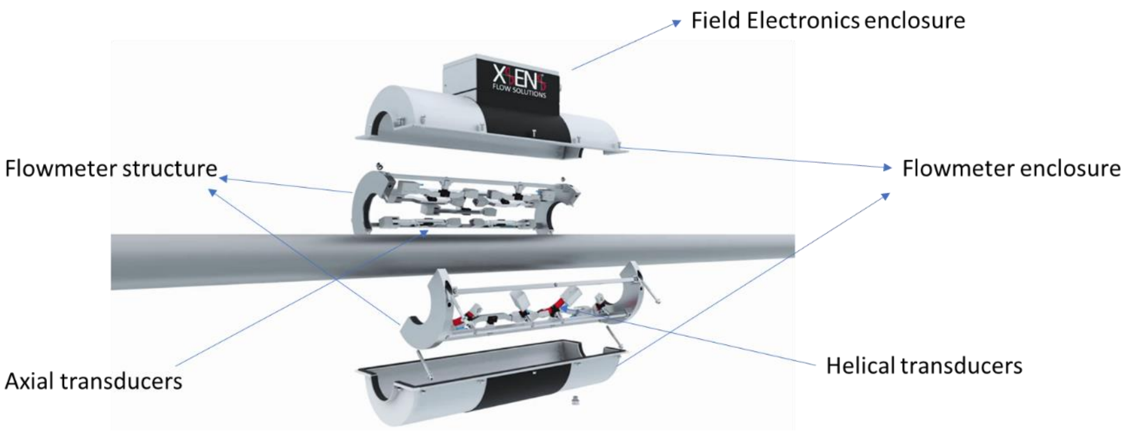


Fig. 1 – Mechanically assembly of Flowmeter under testing

Extended Abstract

By using a transducer configuration with 3 axial and 2 helical transducer pairs, the sound paths generated is illustrated in the figure below. Difference in measured transit time of the acoustic signal upstream and downstream is used to measure the flow rate while the measured transit time, together with an advanced acoustic two phase model is used to measure the water in oil concentration.

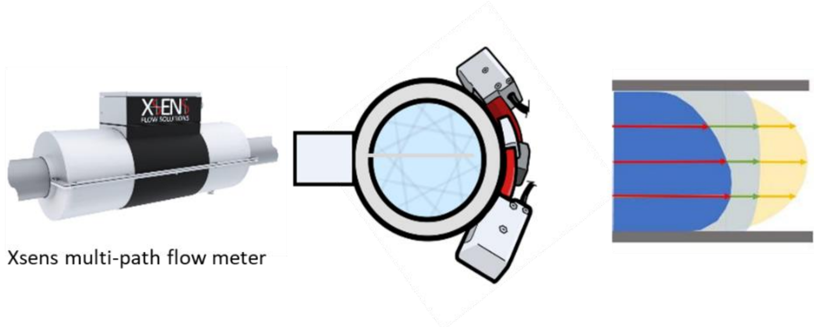


Fig. 2 – Example of acoustic paths and flow profile

3 Field layout

The typical field layout in the region is several ESP operated wells with individual flowlines to a collection point with a multiport selector valve arrangement (MSV). The MSV is usually equipmed with a coriolis flowmeteter and a infrared absorption water cut unit. The flow from each well can have water cut up to 98% water with rapid changes in water cut and can contain some gas combined with a low flow rate. The lengt of the flow lines are typically 2-5km. The figure below illustrate such a typical field layout.

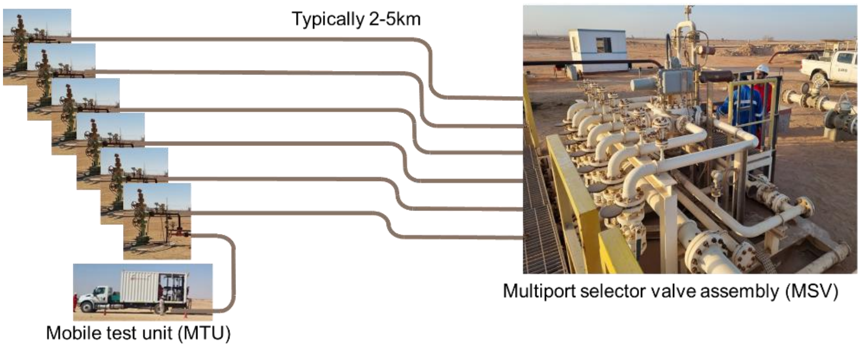


Fig. 3 – Typical field layout

Such a field layout gives several operational and financial challenges, such as:

- High water fraction wells.
- Large differences in Water-in-Oil (WIO) between wells coming into one MSV
- Long distance between wellheads and measurement point on MSV
- Low flow rate (0.08-0.4m/s) resulting in separation in flow line prior to MSV
- Difficult to take accurate WIO samples due to separation and rapid variations in WIO
- Flow rate combined with separated flow results in inaccurate measurements from meters installed on MSV
- Large ammount of wells and long time (months) between mobile tests per well.

There is a need for a suitable and accurate WIO measurement at individual wells to overcome these challenges.

3 Qualification program

The Qualification program for the Xsens Flow and water cut meter qualification was performed over a period of 2 years, from February 2022 to December 2023. It consisted of verification of both measurement accuracy, measurement robustness, ease of installation and reliability.

The Qualification program consisted of

- Long term installation
- Flow measurement: Well test campaigns on different locations
- Extended Water-in-Oil (WIO) testing
- Blind testing at 3rd party flowloop (NEL TüvSüd)

3.1 Long term installation

The flowmeter was put in operation for almost 2 years. This was to verify reliability and how the flowmeter would work under real world installations. The flowmeter was installed on one well close to the wellhead, commissioned and hooked up to the clients IO system (PI) where measurement was recorded over time. Measurements were compared towards manual WIO sampling, Coriolis meter on MSV and mobile test units (MTU).

3.2 Flow measurement: Well test campaigns

Well testing performed on 3 separate locations. The well testing was conducted as blind tests, where the XACT flowmeter was compared towards mobile test units (MTU) with auto sampler and Coriolis meter. Each well test was performed as a regular 24hr well test. A picture of one of these well tests is given in the figure below.

Fig. 4 – Picture from well test

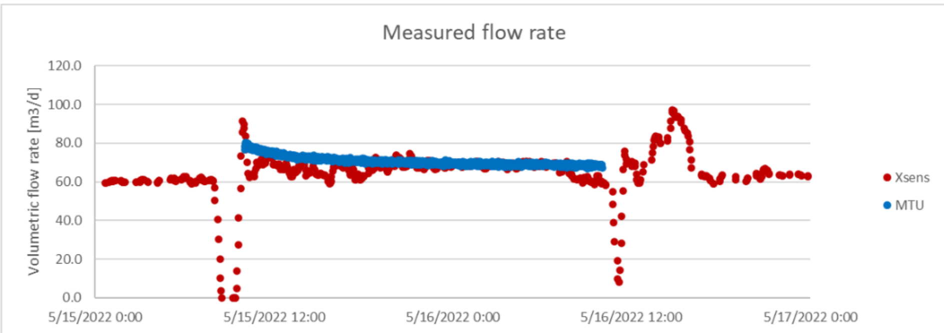
3.3 Extended WIO testing

Due to the high focus on WIO performance, extended testing was performed with a WIO sampling campaign for one well which was performed in addition to the well tests. For this extended WIO test, a total of 30 WIO sampled were taken at regular intervals from both wellhead and MSV, and the results were compared to the measurement from the Xsens flowmeter. The figure below shows the sampling points and the installation location of the Xsens flowmeter.

Fig. 5 – WIO sampling points and meter installation location

3 Field trial and well test results

The field trial resulted in flow rate performance validated successfully with good performance, even at low velocities and within PDO acceptance criteria. In the figure below, results from one such well test is given.



MTU	Xsens
Gross Volume (Sm3/d)	Gross Volume (Sm3/d)
76.73	58.64
74.62	61.33
73.03	65.57
71.71	68.69
71.22	68.65
70.72	69.13
70.27	68.55
69.99	68.35
69.55	68.63
69.37	68.60
69.16	69.18
68.94	68.68
68.78	69.78
68.58	70.12
68.38	68.28
68.48	68.66
68.20	64.01
67.95	68.16
67.98	63.90
67.95	64.79
67.94	66.34
67.64	67.78
67.57	70.88
67.43	66.41
69.67	**67.21**

Fig. 6 – Results from well test

For the water in oil measurements performance, the results looked very promising, but it was not possible to quantify performance due to not being able to have accurate enough reference measurement. This was due to

- Large and rapid changes in WIO inside pipe making accurate enough sampling not possible.
- Low flow rate (0.1 m/s) and large distances bwtween sampling points resulting in difficult to synchronize samples with measurements.

These challenges can easily be seen in the figure below, where the samples from each location together with the measured WIO from the Xsens meter is given.

Type	Avg. WRL %	Pulsation	% +/-	spread
Wellhead	61	47-77	16/-14	30
MSV	89	81-94	5/-8	13
Xsens	78	68-95	17/-10	27
Avg Sampling	75	NA	NA	

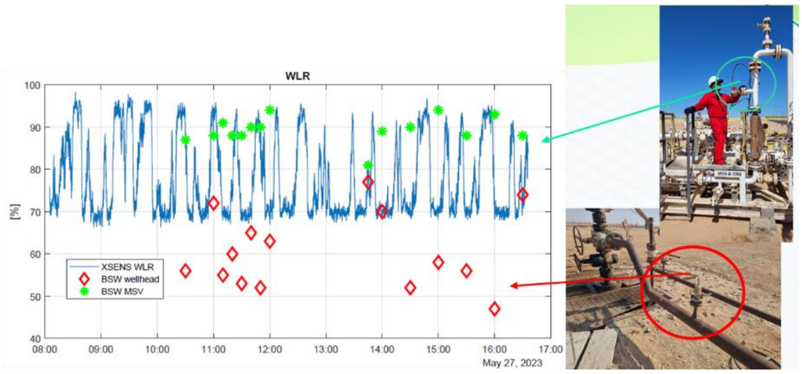


Fig. 7 – Results from extended WIO test

The overall result from the field trial was that the flow rate measurements performance was qualified, but final WIO performance required to be qualified in a multiphase flowloop.

3 Multiphase flow loop blind test results

Blind testing of WIO performance was performed at a 3rd party multiphase flowloop (TüvSüd NEL)

The goal of the test was to verify accuracy in WIO measurement under similar operational conditions as in the field.

A 3'' flowmeter was tested with WIO fractions from 50% to 95% at a flow rate of 0.3 m/s. Testing was performed with the flowmeter installed vertically in the same configuration as intended to be installed in the field on a MSV. The Xsens flowmeter was connected to the NEL IO system through a modbus RTU interface and all data was collected and reported by NEL.

The figure below shows the meter installed at TüVSüd NEL.

Fig. 8 – Flowmeter under test at TüVSüd NEL.

The test was run as a blind test consisting of 16 test points with increasing ad decreasing water in oil fractions. The test points and results are given in table 1 while the measured WIO vs the reference WIO are given in figure 9.

Table 1 – Test matrix with test results

Test Point	Reference Oil Volumentric Flowrate	Ref Oil Std Dev	Reference Water Volumetric Flowrate	Ref Water Std Dev	Reference WC	Reference WC Std Dev	Xens WC	Xsens DUT Std Dev	WC Difference
-	m^3/h	%	m^3/h	%	%	%	%	%	%
TP 1	4.962	0.0443	0.000	0.0000	0.00	0.0443	0.00	0.0000	0.00
TP 2	0.000	0.0000	5.039	0.0460	100.00	0.0460	100.00	0.0023	0.00
TP 3	2.582	0.0417	2.561	0.0251	49.80	0.0486	49.07	0.8872	-0.73
TP 4	2.263	0.0351	2.761	0.0357	54.95	0.0501	54.05	0.6098	-0.90
TP 5	1.980	0.0643	2.993	0.0281	60.18	0.0701	59.11	0.5212	-1.07
TP 6	1.731	0.1319	3.255	0.0351	65.28	0.1365	63.58	1.1275	-1.70
TP 6 - repeat	1.729	0.1506	3.255	0.0280	65.31	0.1531	63.91	1.0242	-1.40
TP 7	1.499	0.0610	3.506	0.0249	70.05	0.0659	69.66	0.8341	-0.39
TP 8	1.246	0.0728	3.764	0.0135	75.13	0.0740	75.39	0.3653	0.26
TP 9	0.974	0.1423	3.997	0.0144	80.41	0.1430	80.76	0.3552	0.34
TP 10	0.720	0.1119	4.251	0.0254	85.51	0.1148	86.26	0.1836	0.75
TP 11	0.442	0.1752	4.533	0.0188	91.12	0.1763	91.92	0.0573	0.80
TP 12	0.234	0.4571	4.741	0.0095	95.30	0.4572	95.90	0.3529	0.60
TP 13	0.486	0.2697	4.508	0.0155	90.26	0.2701	91.54	0.0837	1.28
TP 14	0.730	0.2996	4.265	0.0319	85.39	0.3013	86.06	0.1736	0.67
TP 15	1.000	0.0875	3.991	0.0177	79.97	0.0893	80.11	0.3386	0.15
TP 16	1.245	0.0896	3.750	0.0186	75.08	0.0915	75.26	0.5223	0.18

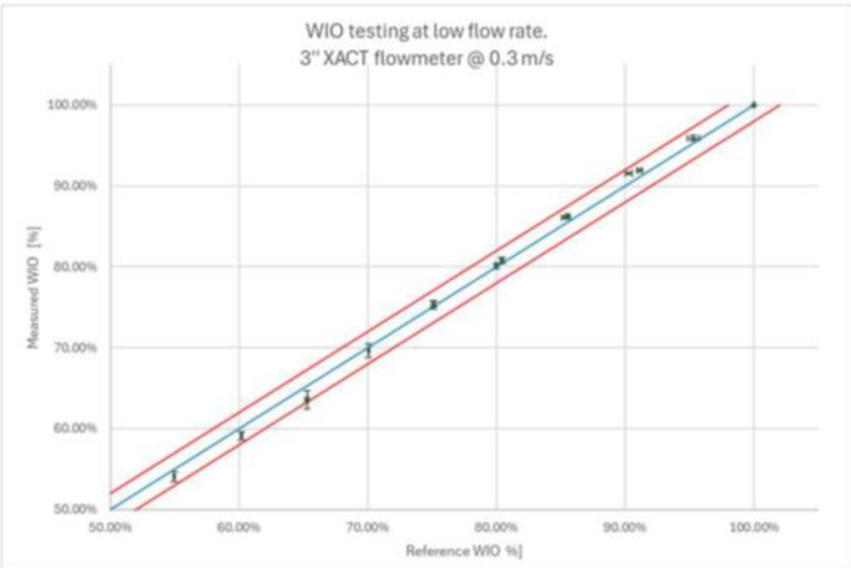


Fig. 9 – Measured WIO vs Reference WIO. Red lines are +/-2%

The results from the WIO blind test was successful, with WIO measurement performance verified successfully within PDO requirements. 82% of all test points were within +/- 0.9%, 90% test points within +/- 1.07% and 100% test points within +/- 1.4%.

An example of the stability in measurement from the Xsens flowmeter and the reference is given infigure 10 below, where the standard deviation in Xsens measurements and reference are given.

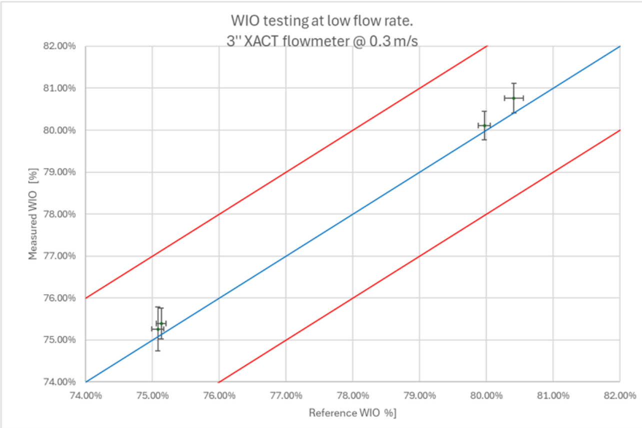


Fig. 10 – Measured WIO vs Reference WIO, zoomed in. Horizontal error bars are standard deviations in reference measurements while vertical error bars are standard deviation in Xsens meter readings logged in NEL IO system

As can be seen from figure 10 above, the standard deviation in the measurements from the Xsens meter is comparable with the standard deviation in reference metering.

3 Summary from qualification program

- Flow rate performance validated successfully in the field
- The Meter`s required WIO accuracy could not be confirmed in the field due to site challenges in trusting the reference measurements.
- Observations from field trial is that live temperature input is required for accurate WIO measurement when there are large differences in temperatures during day and night combined with low flow rate.
- The WIO measurement performance verified successfully within PDO requirements in TUV SUD (NEL) multiphase flow loop under similar conditions as in the field.