

THE DEVELOPMENT OF A NEW WATER/OIL MIXTURE FACILITY FOR TESTING SAMPLING TECHNIQUES AND FLOW METERS

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Abstract

From a recent investigation by CEESI, it is clear that the independent data available on the performance of custody transfer metering systems to operate with high water content, 5-90%, is both scattered and sparse. As a result of the investigation, CEESI were commissioned to produce a water in oil test facility, aimed at carrying out experimental work on both the direct metering and sampling of high water cuts. It is designed to be able to change the oil viscosity, to look at the effect of viscosity variation on the performance of the measuring instruments. The paper describes the design of the flow facility, which has individually measured oil and water inputs, pipe sizes from 2" up to 8" capability, clear viewing sections in horizontal and vertical piping, a flexible working section for testing the instruments in different orientations, and sampling section to determine the distribution of mixing across the pipe cross sections.

Introduction

It may sound like bad measurement practice to try to measure oil that is mixed with greater than 5% of water by volume. Unfortunately life is making it essential to do such measurements:

- The price of oil, \$100/ barrel, makes it viable to produce oil with high water cuts.
- Oil fields are running low on oil, water is pumped in to pressurise the well, and water comes out as part of the drilling.
- Low quality oil wells are being developed which naturally have high water content.
- The measurement of oil without separation is becoming more common to reduce cost of drilling and oil collection.
- Some wells now produce over 50% water content, and even as high as 90%.

The problem is, how do such mixtures effect the performance of the different measurement components in a custody/ allocation metering system?

Measurement Philosophy

It would appear that this is a classic "multi-phase meter" problem, and that multiphase meters with uncertainties in

the region of 5-15% would be acceptable. Although the fluid dynamic problem is similar, the oil and water flow measurement philosophy is very different. The assumption is that meters are required to read the combined volume of the two fluids to "custody transfer" levels of measurement. Further, the sampling needs a good enough measurement of the oil content to fall within an acceptable uncertainty for the overall measurement. In general we are talking of uncertainties in the region of 0.2-0.4% maximum. This is very different to the currently recognised multi-phase measurement uncertainties. As soon as CEESI started investigations it became clear that:

- The area of sampling is neglected by most users of metering systems, and has little independent data.
- The area of high water cuts is becoming more important as the years progress.
- There is not good data on the effect on the performance of samplers, meters etc,

CEESI decided to build a facility to allow the testing of all of the components from meters, to samplers, to complete systems, to test the effect of water content from less than 1% to greater than 90%.

What is a "High Water Cut"?

What is the definition of water cut? It is the ratio of water produced compared to the volume of total liquids produced. In other words it is the water content contained in produced oil. It is interesting to note that most standards concentrate on measuring of the water content, whereas, what is of real interest is the oil content. This produces, interestingly, a situation in sampling where the testing for water content in terms of percentage errors becomes more critical in regard to the performance than effect it has on the oil quantity.

So how do we define high water cut? For custody transfer levels of oil measurement, in general, the oil should contain no water—at the measurement point. However, all oil from production wells contains some water content (as well as sediment), even after separation and refining.

A general definition of high water cut, therefore, might be a level outside of the accepted industry standards for water content, taking the overall measurement of oil outside of an acceptable uncertainty and quality, in the US often taken as above 0.5% water cut.

In sampling it would perhaps be above 5% by volume of water in oil, this is the generally accepted limit in API 8.2 [2], for acceptable sampling and mixing operation.

The situation in practice is that a growing number of metering stations have to cope with water well outside of this limit, and there is not a clear guidance as to how to approach the metering, and what uncertainties will be achieved.

Measurement Components Affected

The following components will be affected by the presence of water in oil:

- Flow meter performance.
- Calculation of Correction factors.
- Sampling performance with increased water in oil content.
- Determination of the water content after sampling.

Flow Metering

There is very little independent data with regard to the performance of meters with high water content. The performance will certainly depend on the meter type, and design. It certainly depends on the state of mixing. For Reynolds number and viscosity dependent meters the combined and relative viscosities will affect the performance. A flow meters performance may depend on how the fluids flow. For example do Coriolis meters tend to separate out the water? How do turbine meters cope with unmixed flow? Finally for custody transfer systems, do provers retain their performance with high water content?

The major meters involved with custody transfer of oil are the Turbine, positive displacement, Coriolis and ultrasonic meter. There is very little independent data on the performance of Turbine meters, the workhorse of oil measurement, in high water cuts. Certainly one of the perceived advantages is that they keep giving an answer, however, what this answer represents may be in question.

There is some data on USMs, but there is very little independent data, and data on the varying designs. The chordal meters certainly need low frequency transducers, and have issues when the water is not well mixed. It is claimed because they are mass meters Coriolis meters give the best performance. But there is evidence that the high water cut can cause variations in operation, and certainly a noisy output.

Almost certainly a PD meter would have reliability issues.

Corrections for Meter Compensation

The meters have to be corrected for temperature and pressure, Ctl and Cpl, to obtain standard flow. This begs the questions, what is the correct value for thermal expansion of the combined fluid? What is the average density of the fluid? Does a densitometer give good answers under such conditions, and finally what is the compressibility of the combined fluid?

There is some data, mainly theoretical produced in Norway by CMI[4].

Sampling

The area of sampling in general is not well researched independently, even at low water cuts. At high water cuts there is certainly very little independent verification.

We know that water and oil do not mix so how do we mix water in oil to ensure that the sample point represents the quantity of water in the overall cross-section of the pipe. Do static mixers really mix well, particularly at high water cuts? What are the limitations? What is the effect of the orientation, mixing in horizontal compared to vertical lines? Should dynamic mixers be used instead of static mixers for high water cuts? These are all questions that need answers, particularly for high water cut meters.

The standards API 8.2 [2] and ISO 3171[1] describe the mixing properties of different fittings in theoretical terms: API 8.2 sets a limit to be 5% of water.

ISO 3171 discusses higher volumes of water but does not give any real solutions.

Neither gives any method for calculating the ability of a proprietary mixer to mix the fluid, leaving it to the discretion of the supplier. API 8.2 shows a rough guideline table to indicate the performance of different mixing configurations, but it is very general in nature.

Determination of Water Cut

The standard methods of water cut determination are not feasible for high water cuts, and combined methods have to be tried. Removing the majority of water in a sample and then using the oil water residue with standard methods such as distillation have to be carried out. Measuring cylinders appear to also give good results. A good description is given in the API test document on high water cuts [3].

The CEESI Water in Oil Facility

Due to the CEESI expertise with wet gas mixtures, they were asked to adjudicate in an issue where there is a dispute over the performance of static mixers with high water cuts, in the range of 5-50% water. As soon as the investigation started it became clear that:

- The area of sampling is neglected by most users of metering systems, and has little independent data.
- The area of high water cuts is becoming more important as the years progress.
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Flow Facility Design

The system, shown in Figure 1, is comprised of two centrifugal pumps, supplied from individual tanks, used to produce the flow for the water and oil. The pumps have controllers, but for lower flows, control valves are required. The flow from each passes through a Coriolis meter to allow the water/oil proportions to be set up, and also to give the actual water cut being pumped into the line. Both pumps go into a phase stabilizer to reduce the effect of turbulence caused by the pumps, meter and control valve. It is essentially a header, Figure 2 & 3, divided into two sections that allow the water and the oil to travel along to the inlet pipe separately. The cross sectional area/volume compared to the inlet pipe is large enough to ensure that the flow from the pumps is relatively isolated. The reducer cone has an included angle of less than 7deg, to ensure that there is minimal turbulence to affect the mixing at the entrance of the inlet pipe. The mixing will largely be the result of the inlet pipe to the working sections. This is at least 60 diameters long, depending on the pipe size. The majority of the pipe length is clear plastic, allowing a view of the mixing as the flow moves along the pipe. The inlet pipe then goes into the working section, described in detail in the next section. Finally the mixture moves into a separator, where the separated constituents return to the oil and water supply tanks.

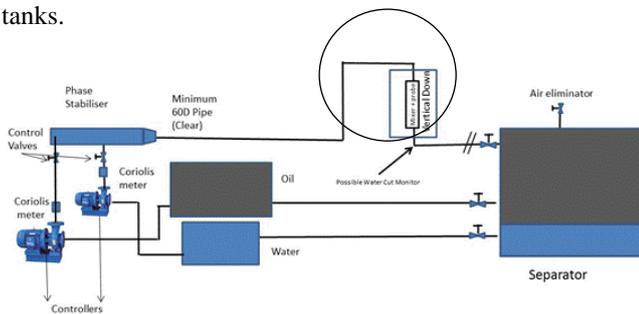


Figure 1. Schematic of Flow Line

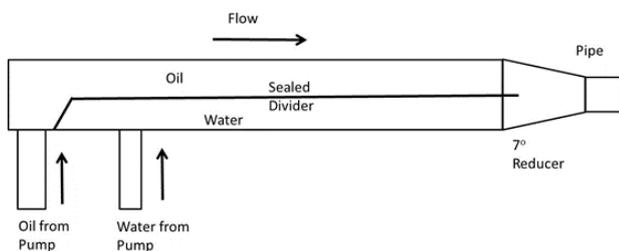


Figure 2. Schematic of the Phase Stabilizer



Figure 3. Inlet to the Phase Stabilizer

Working Section

Within the design there are a number of possibilities for placing a test section, depending on the instrument under test, the installation being modelled and orientation. In Figure 1, the objective was to model an actual sampler installation. In this case the sampler section was mounted in a particular configuration, shown in the circular bubble. The actual sampling took place in the downward leg, after a static mixer. This section can be replaced by any configuration for testing, including a complete system if required. Flowmeters can be tested in both the long horizontal pipe or in the vertical direction. Figures 4 & 5 show sample photographs of test run set ups.



Figure 4. Meter Sections for 4 and 6" Lines



Figure 5. Sampler Section

Specification

The main pipe sizes will be 2-8"
 Up to 12" test lines will be feasible.
 Oil can be varying viscosities, at present it is Shellsol D80, which is approximately 2cS at room temperature.

Maximum combined flow velocity 14ft/s (Depending on the pipe size)
 Water cut, 0.2-90%
 Water can have added salt to simulate Brine
 Uncertainty of Oil measurement 0.2%
 Uncertainty of water measurement 0.2%
 Combined Uncertainty at 50% Water Cut 0.28%

Flow Visualisation

The flow visualisation from the first commissioning can be seen in Figures 6-8. In the horizontal plane the water separated out very clearly at the low velocities of 0.6 m/s, Figure 6. In Figure 7 the start of some mixing at the boundary can be seen at 0.9m/s. In Figure 8 the effect of the combination of a bend and a vertical section can be seen. The mixing effect is clearly visible, and unlike the horizontal pipe continues for some time.



Figure 6. Horizontal flow with 50, 30, 5% Water Cut 0.6m/s



Figure 7. 50% Water Cut at 0.6 and 0.9 m/s



Figure 8. Effects on Mixing of a Bend and Vertical Flow 0.6 m/s

Initial Testing

The specific results of the first tests on the effect of large water cuts on static mixers for sampling systems are confidential, but one general point could be made from the testing. The design of the mixer is critical. If the mixing is carried out by using swirl, obviously a very large upheaval of the flow, with the obvious expectation of good mixing, the opposite happens. This was visually clear very early on. For a particular design that produced a swirl mixing action, the water appeared to be moved towards the outside of the pipe. This was confirmed by testing the profile of water across the pipe using a multi-point sampler, which showed more oil at the centre of the pipe

than the outsides. Essentially the mixer was acting as a vortex separator.

Further confirmation of this came from CFD simulations carried out by CPA [7], where the water, blue at the sampler cross-section can be seen to be moving towards the outside of the pipe, Figures 9 and 10.

Testing has now begun on the performance and operation of a number of flowmeters at high water cuts.

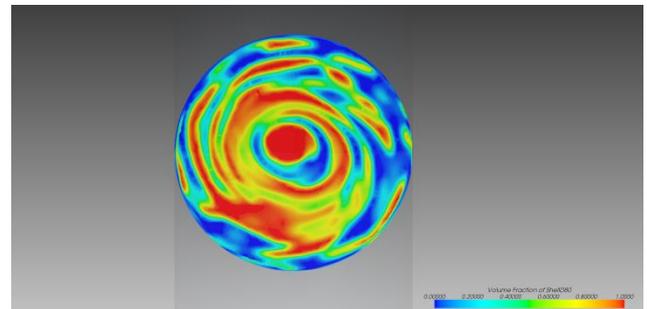


Figure 9. 50% Water CFD Simulation of Mixing After a Swirl Type Mixer

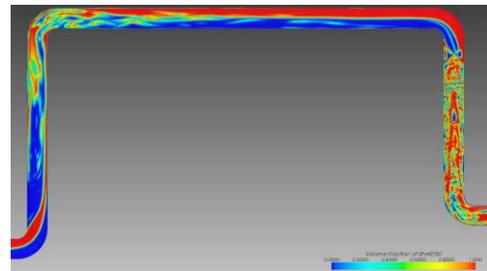


Figure 10. CFD Visualisation of the Complete Mixer Station

Conclusions

- There is an increasing commercial need for good measurement of higher water cut oil mixtures.
- The standards and literature are not extensive on the subject and a great deal of testing is required to improve the knowledge of the operation and performance of meters and sampling systems at high water cuts.
- CEESI have developed a new facility designed specifically to carry out testing at high water cuts with a good uncertainty of measurement.
- The flow line has been commissioned and used for testing of static mixers successfully.

References

- [1] ISO 3171 (1988) "Petroleum liquids - Automatic Pipeline sampling"
- [2] API MPSM Chapter 8 "Sampling"
- [3] "API HIGH WATER CONTENT PHASE II - ANALYTICAL TEST METHODS" Final Report 5/05/05
- [4] "Fiscal measurement of oil with high water fraction: Phase 1: Sensitivity study for a turbine meter based fiscal metering station" CMI 2007

[5] “Fundamentals of Liquid Measurement – Part 1”

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[6] “HANDBOOK of Water Fraction Metering” Revision 2, December 2004, Coordinated by Eivind Dahl, Christian Michelsen Research AS, Norwegian Society for Oil and Gas Measurement

[7] D. Sawchuck, Raphael Selirio CPA Computational Solutions Ltd. Private Communication.