Experience with Ultrasonic Flowmeters in Fiscal Applications for Oil (-products)

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Introduction

Last years the number of applications for fiscal metering of oil (-products) with a multi beam ultrasonic flowmeters has been increased significantly. The growing interest for this type of fiscal metering is mainly due to specific advantages.

Besides the high accuracy and complete independence of viscosity, the long-term stability is very good. These attractive properties are a result of an essentially different measuring principle. Multi beam ultrasonic flowmeters can be smoothly used in installations on the continent. In limited spaced offshore applications some specific features of an ultrasonic flowmeter must be taken into account, in the system design, to stay within the NPD repeatability requirements for turbine meters.

This article explains how to realise a successful application of a multi beam ultrasonic flowmeter in situations with a small prover volume. This is explained starting from the fundamental measuring principle of an ultrasonic flowmeter. The paper is finished with a consideration of the future developments and some conclusions.

Effects of velocity disturbances and changing viscosity on a multi beam ultrasonic flowmeter

Since several years a multi beam Ultrasonic Flowmeter (UFM) is available on the market which performs very well in custody transfer measurements on oil and oil-products (Figure 1and Figure 2).

Figure 1: A calibration of a 16” Altosonic V on oil at SPSE in France.

Figure 2: Application of an 8” Altosonic V on oil.

This meter has been made highly independent of disturbed velocity profile by the application of an integrated confusor in the meter body. This confusor homogenises the flow as illustrated in Figure 3.

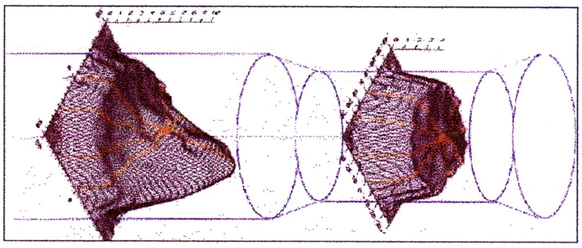


Figure 3: An illustrative example of the effect of a confusor on a disturbance in the velocity profile. The confusor stretches the flow and makes it more homogeneous. LaserDoppler Anemometry (LDA) has been used in this example to measure the velocity.

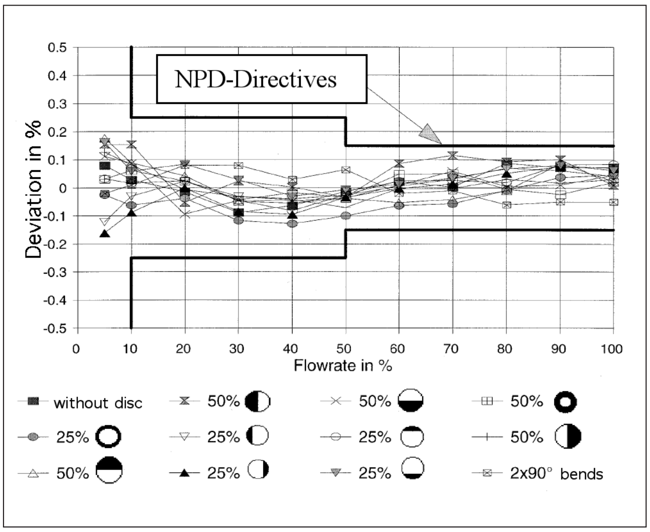
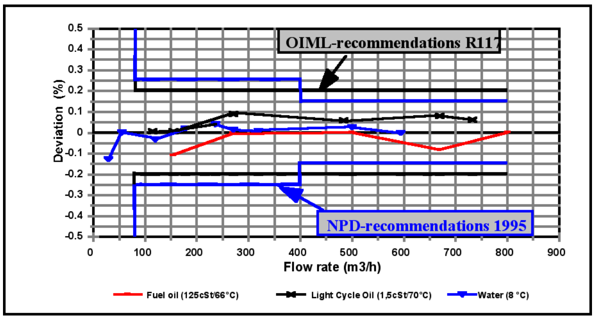


Figure 4: *Measurements at Krohne Altometer with a DN200 multi-channel ultrasonic custody transfer flowmeter with naphtha and gas oil. The deviation remains well within the NPD directives at the dynamic range of 1:10. The disturbance is generated 20D upstream.*

The effect is apparent from figure 4. This figure shows the sensitivity to different profile disturbances generated 20D upstream the UFM. The contraction stretches the flow and makes the velocity profile more uniform.

Although the disturbances on the velocity profile are diminished the profile is still Reynolds or viscosity dependent. Therefore, the velocity is measured at five different heights in the tube. The shape of the velocity profile is directly related to the Reynolds number or viscosity. This information is taken into account in the measuring algorithm. In this way the linearity and meter factor of the multi beam UFM has been made completely independent of viscosity. The multi beam UFM of Krohne has been officially certified for the viscosity range from 0.1cSt to 150cSt. The linearity and repeatability for three different viscosities is shown in Figure 5 and Figure 6.



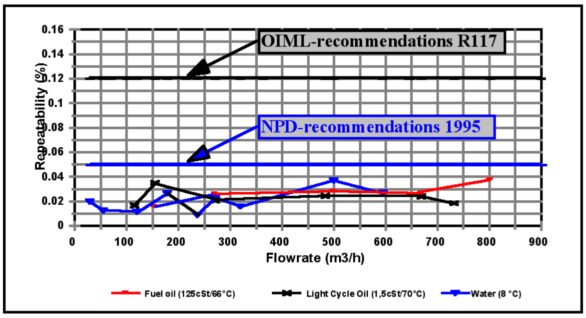


Figure 5: *Linearity of an UFM for three different viscosities. All the measurements stay within the NPD directives for turbine meters.*

Figure 6: *Repeatability of an UFM for three different viscosities. The blue lines indicate the NPD and OIML requirements for turbine meters. Prover volume 8 m3.*

A multi beam UFM can handle liquids with changing viscosity without loss of accuracy or need for intermediate calibration.

3. Ultrasonic flowmeter and repeatability

To guarantee a successful operating UFM, meeting the NPD repeatability requirements for turbine meters, the nature of the ultrasonic instrument must be taken into account in the early stage of system design. The physical principle demands some requirements with respect to the calibration system. It will be explained why.

The multi beam UFM uses the so-called run-time method. The difference in up and downstream sonic run time is a measure for the fluid velocity along the sonic beam. The method is very fast and doesn't affect the flow by the measurement itself. Furthermore, purely the velocity along the sound beam is measured. It is not a mixture between velocity and momentum as it is the case with a turbine meter. In addition, all the fluctuations in the flow are being measured without filtering by inertia due to moving parts.

The UFM measures the flow including turbulence and characteristics of the overall system. This is illustrated in the next figures. shows an on-line signal measured by a multi beam UFM during a steady flow in an offshore installation (not during a prover run). represents the frequency spectrum of obtained by means of a Fast Fourier Transformation.

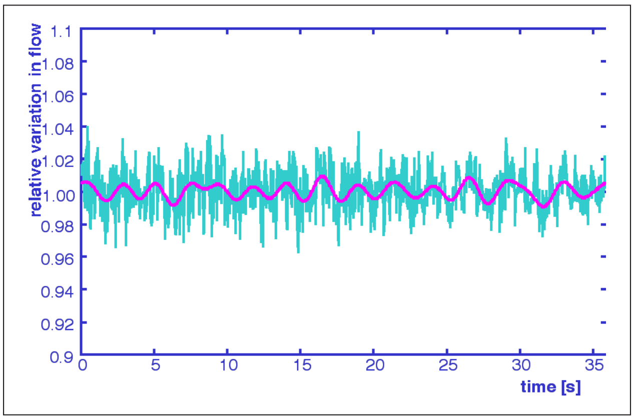


Figure 7: The steady real-time velocity signal measured by the multi beam UFM. The red line is the low frequency variation present in the flow.

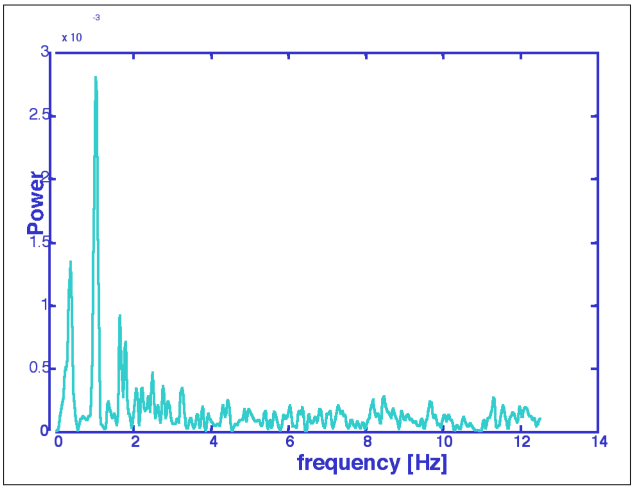


Figure 8: The Fast Fourier Transform of the signal in the left figure. Some strong low frequency components are present.

Some strong peaks are observed in the lower frequency range, whereas this is not obvious from the signal in the time domain. In fact, low frequency peaks are always present as a result of turbulence. However, in a poor system design some dominating low frequency oscillations can be generated additionally.

Precisely the presence of low frequency peaks has an important impact on the calibration of the UFM. Due to the fast response of the UFM these frequencies are fully measured. In order to obtain a good repeatability, a number of periods of these low frequency components must be acquired to eliminate its effect on the mean value. Up to certain limits can be stated that the smaller the oscillations are, the smaller the required prover volume is. The lower natural limit is generated by the turbulence present in the flow.

In several systems the flow conditions change when the ball prover is placed on-line. The flow significantly decreases and becomes unstable as a result of transients in the prover behaviour. These phenomena are accurately measured by the UFM. Because a turbine meter has some inertia, this has a positive consequence for the repeatability but may have a negative effect on the meter factor.

As a matter of fact, the repeatability proof is an excellent way of proving the mechanical condition of a turbine meter. The final goal is to control the overall uncertainty of the meter.

From the ultrasonic point of view, the mechanical proof is not concentrated in the repeatability because it has no moving parts. The less accurate short-term repeatability does not mean that the meter is not in order, but reflects the quality of the measuring principle. Therefore, the UFM is better characterised by the overall uncertainty. Of course, the repeatability should stay within certain limits.

4. Recommended calibration procedure

4.1 Larger prover volumes

Excellent linearities and repeatabilities have been obtained with larger prover volumes (e.g. in France with 8 and 10m3 and in the USA with 5.4m3. In these applications the UFM can be applied smoothly even with the presence of strongly dominating low frequency components in the flow.

4.2 Small volume provers

In the situation that a compact prover is the one and only solution, another calibration procedure is required to satisfy the NPD requirements for turbine meters. A successful working calibration system in this case is a combination of a small volume ball prover, a turbine meter and a multi beam UFM. One of the features of a turbine meter is that it has a good repeatability even when a small prover volume is available. This feature is used. This leads to a three-step method:

- The turbine meter is calibrated with the small volume prover.
- Then the turbine meter is placed in series with the UFM. With a calibration time of e.g. 2 minutes per point the UFM is calibrated.
- After the calibration of the UFM the turbine is put out of operation.

Next, the UFM is being used as the duty meter, which is very stable, constant and independent on viscosity. The turbine meter that is sensitive to wearing and viscosity effects is secluded.

This method has been successfully applied by Saga Petroleum ASA for already two years. They will use the same method for Snorre B platform. Statoil has utilised this approach for Vslefrikk too. The intention is to save calibration costs by reducing the frequency of calibration. The extension of calibration interval will be discussed in chapter 6 too.

A combination of a small prover volume and an UFM may be possible with a well-designed prover (generating a stable flow) using several added runs. Furthermore, a shift towards the accent on uncertainty instead of repeatability may lead to a better characterising treatment of the UFM. This leads to a decrease in required prover volume.

5. Advantages of an instrument without moving parts

With the application of a multi beam UFM, the measuring system has become independent of viscosity effects caused by temperature variations or changes in composition of the oil. A recalibration after the velocity has been changed is not necessary. These are important aspects. Another important point is the long-term stability.

Experiments have been performed to investigate the stability of the multi beam UFM on the longer term. shows the stability over a period of 2½ years. This multi beam UFM has been externally used and two times recalibrated.

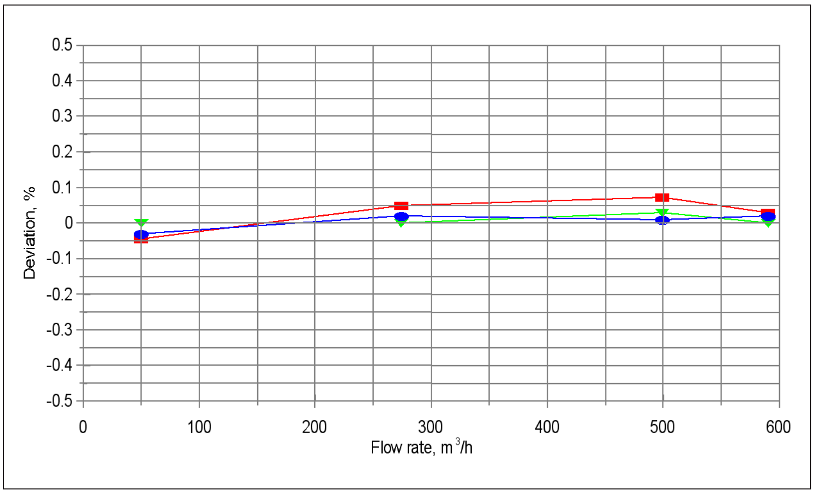


Figure 9: Long-term stability of a multi beam UFM (Altosonic V). Uncertainty of the calibration rig is (0.03%. The results include installation effects. The recalibration is performed on water.

The differences displayed include the uncertainty of the calibration rig (0.03% and installation effects. The shift in meter factor is in the order of a few hundredth of a percent. Similar results have been obtained in offshore applications. There has been no measurable effect of scaling. This shows that the stability on longer term is very good.

6. Perception of future developments

With growing confidence in the long term stability of the multi beam UFM the calibration interval of this type of meter may be extended. It is no longer necessary to perform a calibration at each separate viscosity or velocity. This leads to another view on the calibration procedure.

With a move from frequent calibration nowadays towards a calibration e.g. each year in the future, a fixed prover system may be no longer the best solution. It may be replaced by a mobile prover system. The duty UFM may generate a kind of health or confidence factor, which is a measure for the quality of the measurement. A second UFM duty meter eventually checks the first one. This system is sketched in .

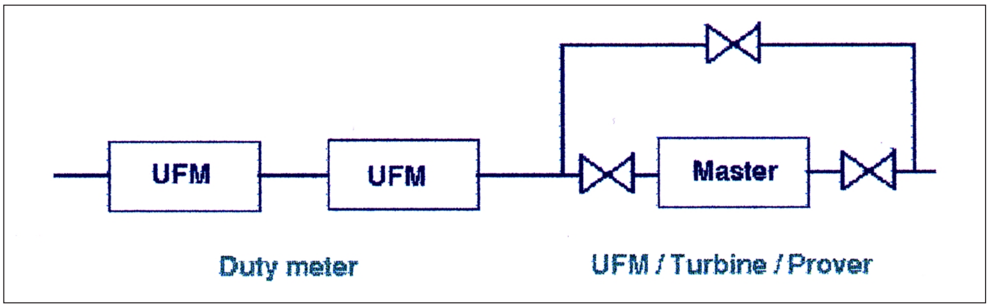


Figure 10: An offshore measuring system as it may be become in future. One or two multi beam UFM's run as the duty meter. The master meter can either be an UFM, a turbine or a (mobile) prover. The UFM duty meter generates a kind of quality factor to indicate it's health or reliability.

7. Conclusions

A multi beam UFM has many advantages when compared to a turbine meter. Since the measuring principle is basically different from the principle of a turbine meter, the nature of an UFM has to be taken into account in the system design. The UFM must be applied as an UFM. This requires a somewhat longer period of a stable flow during calibration to meet the current NPD requirements with respect to the repeatability. In continental applications the prover volume is sufficiently large. A prover volume of about 6 m3 has been demonstrated to be sufficient.

In some situations the space of a larger prover volume is not available. In these cases a very practical and guaranteed successful method to meet the current NPD requirements is the application of a turbine meter, calibrated with a compact prover, that serves as an intermediate reference. The turbine meter is taken out of service after calibration.

This does not mean that a multi beam UFM can not be combined with a small prover volume. Special attention and ongoing developments makes it presumably possible to meet the NPD requirements in the next future.

A multi beam UFM can be applied as the duty meter. This instrument is completely independent of viscosity and has a proven high long-term stability in the field. The results of the current development show the potential to change the vision on the system design with respect to calibration.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.