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QUALITY ASSESSMENT OF GAS METERING STATIONS BY MEANS OF A PORTABLE AND RETRACHTABLE INSPECTION PROBE

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Quality assessment of gas metering stations by means of a portable and retractable inspection probe

by

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ABSTRACT

The compliance of gas metering stations to design specifications has in general been limited to the comparison of as-built with the recommendations provided by accepted international standards, national regulations or recognised databases. A major objective of the design specifications is to ensure that the flow profile is fully developed at the location of the flow element (FE). Verification of the quality of a metering station can be conducted using provers or master meters for on site calibrations. A cheaper and more efficient method could be to perform measurement of the flow conditions in the metering stations by using an retractable inspection probe which could depict the flow inside the meter tube such as velocity profile and swirl angle.

K-Lab has over years contemplated such technology and has used and tested retractable inspection probes of different types. All of them use general Pitot measurement principles. The latest version of K-Lab's retractable inspection probe has been tested in different baseline configurations and Reynolds number at K-Lab. Reference configurations have been tubes with very long straight upstream lengths, immediately downstream of 90 degree bends in the same plane or in different planes. The test results show that the velocity profiles departing from fully developed flow and the presence of swirls are easily detectable.

The retractable inspection probe, described in this paper, has been built to be mounted in the meter tube through a conventional threaded pressure tapping through a 1" ball valve without depressurising the line. It can be mounted in pipes of different diameters and operated at pressures up to 150 bar, and is therefore a very flexible tool.

The paper presents the results obtained during tests at K-Lab and in a gas metering station at the Kårstø gas treatment plant.

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Background

Quality assurance has become a key consideration in gas metering systems. Achieving continuous quality improvement in these systems calls for a comprehensive process of the kind depicted in figure 1. At any step in this process, the experience from the previous step is fed in with the aim of making an optimal choice. But those directly involved in or responsible for one of the phases must not forget that the activity they are pursuing is merely one link in a chain (ref.1).

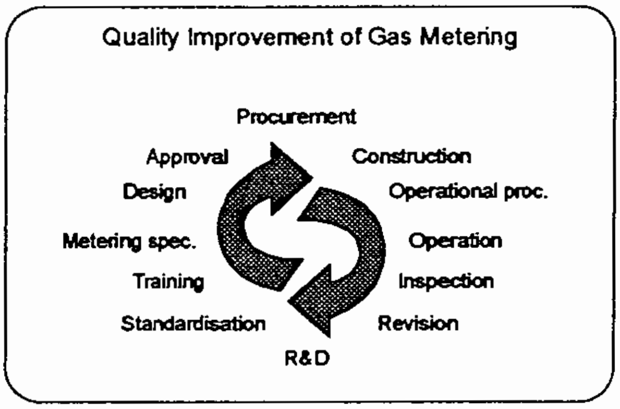

Figure 1

In the above process (fi.1) one of the key issues is *inspection*. Depending on the type of flowmeter which is used, different methods and procedures are recommended by the manufacturers or by the operational staff based upon their experience. This type of inspection generally addresses the instrument itself and its local environment, such as the secondary instrumentation, the pipe wall characteristics and the fluid properties. Except for laboratory applications, no practical devices have been developed to look inside the pipe and "watch" how the flowing fluid behave.

The test results and preliminary experience obtained by Statoil with its K-Lab probe are reported in the present paper.

Requirements of an inspection probe

Previous studies (ref.2) have shown that the departure from fully developed velocity profiles generates substantial errors in the discharge coefficient for orifice meters, as shown in figure 2.

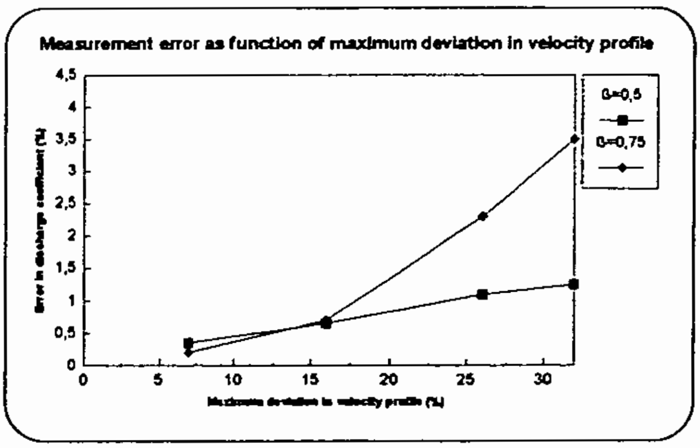

Figure 2

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The inspection probe was therefore designed to meet the following requirements:

- portable
- sustain pressure up to 150 bar
- measure velocity profiles and swirl angles
- user friendly
- safe

Design of the inspection probe

The probe is a Cylinder Pitot (CP) originally designed and tested at Institute for Energy Technology and K-Lab from 1987 (ref.3). A new design based on the same principle, making the probe portable, was developed by Read Matre Instruments for K-Lab in 1996. The probe is shown in figure 3.

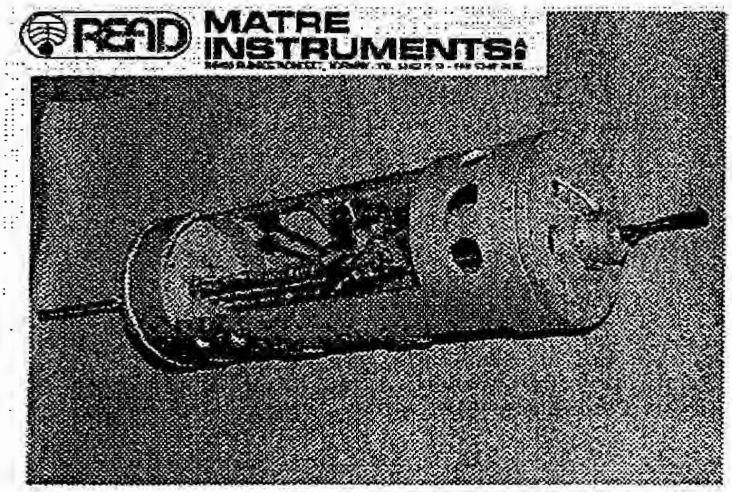

Figure 3

The CP probe is an aerodynamic sensor which is described in the literature to some extent (ref. 4 and 5). Its applications in fluid flow measurement in general, are only briefly described (ref.6). Recently such probes have been used in field tests (ref.7). The design used in the K-Lab probe applies specifications from reference 4.

The CP can be rotated and translated radially. The readings of the rotation angle and the radial position (on two separate rules), give the (ϕ, r) position of the CP inside the pipe.

To sustain the operating conditions which could be encountered in the field, the probe stem had an outer diameter of 12 mm to support flow induced vibrations. In practice, this means that the recommendations in ISO Standard 3977 was exceeded and a correction factor as recommended by the standard was applied (ref.8) for the flow calculations, taking into account the blockage of flow around the stem which influences the measurement of the static pressure.

How to use the probe

The K-Lab probe is built to be mounted in the meter tube through a conventional threaded pressure tapping and a 1" ball valve without depressurising the line. The tapping point has an inner diameter of approximately 12 mm. The probe is designed to be electrically connected to a computer which gives the (ϕ, r) position of the CP inside the pipe and the differential pressure between probe tip and the pipeline wall and also the differential pressure to calculate swirl angle.

The local mean velocity (U,r) is calculated from the differential pressure measured by the CP. The swirl angle is measured by rotating the probe until zero differential pressure is observed on the same differential pressure transmitters. The reading of the angle on the rule gives the degree of swirl.

K-Lab tests

The tests of the probe at K-Lab were carried out in the 6" test line, with more than 60D straight upstream pipe length and a K-Lab flow conditioner mounted at the upstream inlet of the straight pipe. The probe was installed vertically in the pipe.
The test conditions were as follow:

- *Pressure: 32bar - Average flowrate: 616 and 880 act.m^3/h. - Re: respectively 3.48x10^6 and 5.17x10^6 - Results in figure 4 & 5*
- *Pressure: 72 bar - Average flowrate: 350 and 616 act.m^3/h. - Re: respectively 4.5x10^6 and 7.8x10^6 - Results in figures 6 & 7*

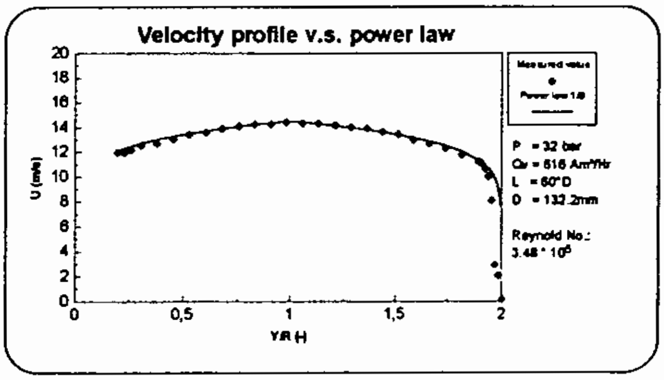

Figure 4

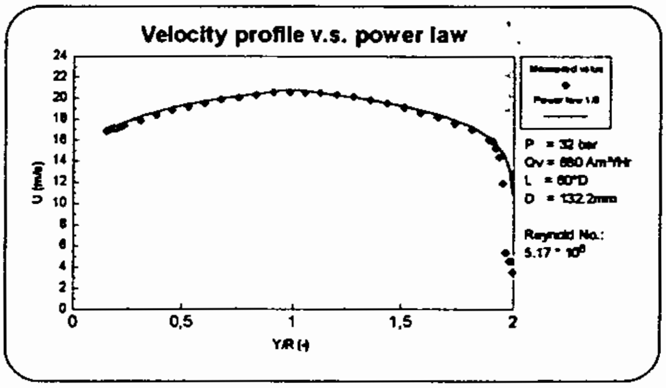

Figure 5

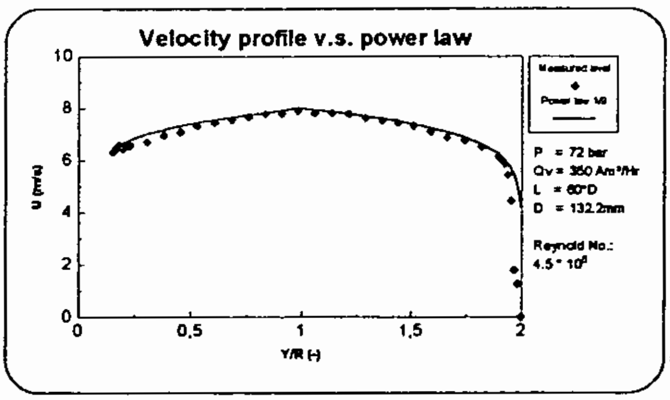

Figure 6

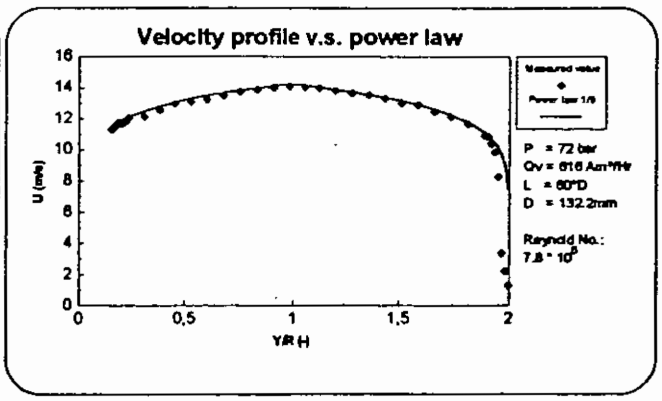

Figure 7

The results show that measured velocity profiles fit the 9th power law curve very closely, confirming fully developed flow (the 9th power law function has been chosen as reference (ref.2) as it produces representative velocity profiles for the Reynolds number range which is considered).

It was observed that the velocity measurements close to the walls were perturbed by the shape of the probe and by the tapping point used for insertion of the probe.

At the wall, opposite to the tapping point, the velocity measurements are stopped 10-15 mm from the wall due to flow induced perturbations occurring between the probe tip and the wall. On the other wall, at the tapping point, similar flow induced perturbations occur, much closer to the wall, due to the recirculation of flow in the annular space between the probe and the tapping.

Due to these wall effects, the comparison between the calculated flowrate, based on the integration of the measured velocity profiles and K-Lab reference flowmeters (sonic nozzles) was not representative. As an example, the accuracy claimed by industrial Pitot probes, not perturbed by such type of wall effects, is normally close to +\-5%.

Field tests

The field tests were performed in a 6" fuel gas metering station at the Kårstø gas treatment plant where the probe was installed horizontally, 8D downstreams of a senior orifice meter, the only position available for the test. The pipe inner diameter was 154.6 mm.

During the test, the plate was removed from the stream (senior fitting) and the straight pipe length upstream of the probe became 37D. Besides, opposite to the port where the probe was inserted, there was a tapping point for a densitometer. This allowed the probe to come much closer to the wall than in the K-Lab tests. However, coming close to the wall at both ends, the CP experienced similar type of flow induced disturbances as in the lab tests. No swirl was observed, except very close to the aperture of the tapping point of the densitometer.

The operating conditions during the field tests were as follow:

- *Pressure: 30 bar - Flowrate: 648 act.m^3/h. - Re : 2.86 x10^6 - Results in figure 8.*

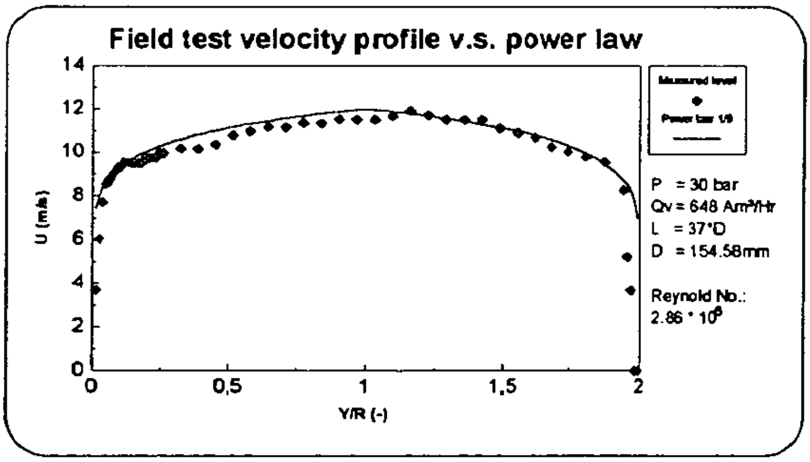

Figure 8

The results from these preliminary field tests show that the measured velocity profile fits the 9th power law curve in a fairly god manner.

How to use the information from the inspection probe

The probe has been designed to give a realistic picture of the flow profile and the degree of swirl in the meter tube, preferably at the position of the FE. However, in combination with available 3-dimensional CFD-calculations, the probe offers an efficient tool for the evaluation of the quality of metering stations in operation. Such analysis could tell the operator whether the meter run is within the required specifications or whether it needs to be improved, for instance by installing a flow conditioning device. The quality of the analysis depends on the position of insertion ports for the probe. When designing new metering stations it would be worthwhile to consider, from the beginning, tapping points for the insertion of an inspection probe at appropriate positions along the meter tube.

Conclusions

The preliminary results from the qualification tests conducted with the K-Lab inspection probe has documented:

- the velocity profiles and swirl angle measurements can be performed with the K-Lab probe. The probe ensures a good qualitative description of the existing profiles and swirls.
- that the probe is effectively portable. The probe can be lifted by one person. Two persons are required to conduct a field test which last approximately 2 to 3 hours, installation and dismounting included.
- the probe, in combination with CFD-simulations and flow conditoners, offers a performant package for the improvement of the quality of a gas metering station.
- additional tests are planned to confirm the preliminary results from the field tests. Special attention will be paid to improve the measurements close to the walls.

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